MOHAMED SATHAK A J COLLEGE OF ENGINEEERING

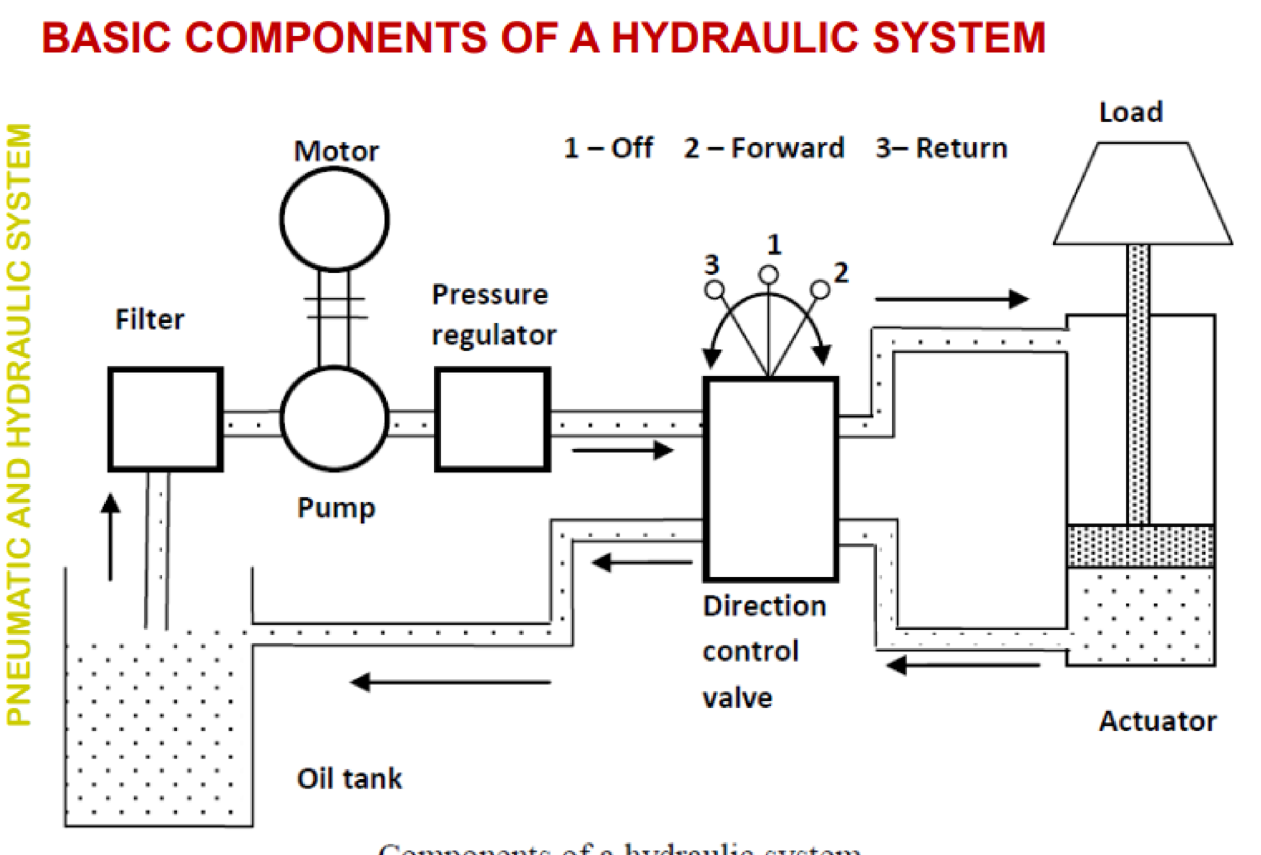
DEPARTMENT OF MECHANICAL ENGINEERING

ME8694-HYDRAULICS AND PNEMATICS

UNIT – I FLUID POWER PRINCIPLES AND HYDRAULIC PUMPS

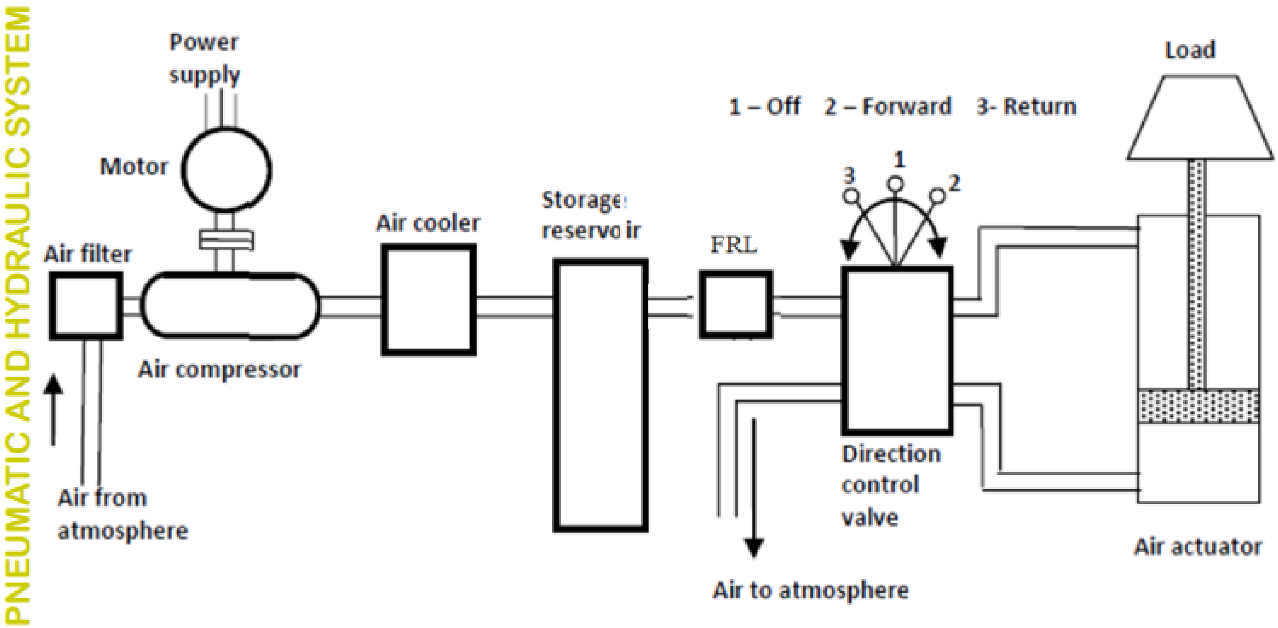
Functions of the components are as follows: 1. the hydraulic actuator is a device used to convert fluid power into mechanical power to do useful work. The actuator may be of the linear type (cylinder) or rotary type (motor) to provide linear or rotary motion. 2. The hydraulic pump is used to force the fluid from the reservoir to rest of the hydraulic circuit by converting mechanical energy into hydraulic energy. 3. Valves are used to control the direction, pressure and flow rate of a fluid flowing through the circuit.

4. External power supply (motor) is required to drive the pump. B 5. Reservoir is used to hold the hydraulic oil. 6. Piping system carries the hydraulic oil from one place to another. 7. Filters are used to remove any foreign particles so as keep the fluid system clean and efficient, as well as avoid damage to the actuator and valves. 8. Pressure regulator regulates the required level of pressure in the hydraulic fluid.



Components of a hydraulic system

Basic Components of Pneumatic System



Components of a pneumatic system.

Air filters: These are used to filter out the contaminants from the air. Compressor: Compressed air is generated by using air compressors. Air cooler: During compression operation, air temperature increases. Therefore coolers are used to reduce the temperature of the compressed air. B Control Valves: Control valves are used to regulate, control and monitor for control of direction flow, pressure etc. Air Actuator: Cylinders and motors are used to obtain the required movements of mechanical elements of pneumatic system. Electric Motor: Transforms electrical energy into mechanical energy. It is used to drive the compressor. Receiver tank: The compressed air coming from the compressor is stored in the air receiver.

The functions of various components shown in Fig. are as follows: 1. The pneumatic actuator converts the fluid power into mechanical power to perform useful work. 2. The compressor is used to compress the fresh air drawn from the atmosphere. 3. The storage reservoir is used to store a given volume of compressed air. 4. The valves are used to control the direction, flow rate and pressure of compressed air 5. External power supply (motor) is used to drive the compressor. 6. The piping system carries the pressurized air from one location to another.

Hydraulic system can be classified in five categories:

Industrial: Plastic processing machineries, steel making and primary metal extraction applications, automated production lines, machine tool industries, paper industries, loaders, crushes, textile machineries,R & D equipment and robotic systems etc.

Advantages of Hydraulic systems:

High power to weight ratio compared to electrical systems

Allows easy control of speed and position, and direction

Facilitates step less power control

Allows combination with electric controls

Delivers consistent power output which is difficult in pneumatic or mechanical drive systems

Performs well in hot environment conditions

Compared to Pneumatics:

Much stiffer (or rigid) due to incompressible fluid

Better speed of response

Better lubricity (less friction) and rust resistance

Low maintenance cost.

Disadvantages:

Material of storage tank, piping, cylinder and piston can be corroded with the hydraulic fluid. Thereforeone must be careful while selecting materials and hydraulic fluid.

Structural weight and size of the system is more which makes it unsuitable for the smaller instruments. Small impurities in the hydraulic fluid can permanently damage the complete system. Therefore suitable filter must be installed.

Leakage of hydraulic fluid is also a critical issue and suitable prevention method and seals must beadopted. Hydraulic fluids, if not disposed properly, can be harmful to the environment.

Relative advantages of different power transmission systems:

Each type of power transmission and control system has specifically suitable application areas. However,we can make some general comparisons between them.

Fluid power and Electrical are good at transmitting power over long distances, and also better controllable Compared to mechanical devices. Electrical devices are the cheapest. Hydraulic systems have better Power/weight ratio. In terms of cost, electrical would be the cheapest.

Following table gives a relative comparison of Hydraulic, pneumatic and Mech / EM systems.H – Hydraulic; P – Pneumatic M – Mechanical/Electromechanical; E – Electrical

Hydraulic fluids: The general requirements of fluids in power transmission are:

Low cost

Non-corrosive

Have infinite stiffness

Good lubrication properties

Store well without degradation
Non-toxic
Non-inflammable

Properties remain stable over wide range of temperatures.

Many types of fluids are used ranging from water, mineral oils, vegetable oils, synthetic and organic liquids. Water was the first liquid used and is very cheap. But its disadvantages are – freezes easily, rusts metal parts, boils and relatively poor lubricant. Mineral oils are far superior in these properties. Its success also lies in – the ease with which their properties can be changed with additives.

Additives used are - various chemicals like phenols and amines, chlorine and lead compounds, esters, organo-metallic compounds, for change in properties such as:

- Antioxidants
- Corrosion inhibitor
- Rust inhibitor
- Anti-foam
- Lubrication improver
- Pour point depressant
- Viscosity index improver.

FILTERS:

When hydraulic fluids are contaminated, hydraulic systems may get damaged and malfunction due to clogging and internal wear. They require filtration to remove contaminants.

Filters are classified as

- Line filters
- Off-line filters

- Other cleaning equipment

Reservoir filters: These may be installed in the reservoir at the pump suction port or in the return line cleaning the liquid returning to the port.

Suction type filter: consists of a core rolled up with a filter paper and submerged in working fluid.Typically they use 100 micron filter papers.

Return filters or either mounted on the reservoir or in the lines.

Filtration ratings in return lines vary from 10 micron to 35 micron, lower micron rating being used for higher pressures.

Line filters: These are installed when high filtration is required and are used to avoid high suction at the reservoir filters. These are used with a separate line connection. Filter selection depends upon pressure,flow rate and filtration rating.

Off-line filters: These filter clean fluids in a reservoir using a dedicated pump and filter separate from theline. These are used when higher cleaning level is required.

Other equipment include air breather (filtering out dust in the air), oil filling port or magnetic separator toabsorb iron powders in reservoir.

ACCUMULATORS:

These are used to supply additional fluid when main line fluid pump is inadequate to perform the actuation. Usually gas filled bladders at high pressure act on the reservoir of fluid in the accumulator to make up for the required line flow.

- Accumulators are used to accommodate large flow rates or to compensate leakages.
- Absorb pulsations and reducing noise
- To absorb shocks.

HEAT EXCHANGERS:

Energy generated by prime movers transforms to thermal energy which increases the temperature of the working fluid. High temperatures deteriorate the fluid properties and result in shorter fluid life. Hence it is required to cool the oil to certain level for smooth operation.

Typical heat exchangers used are:

Tubular heat exchangers: This delivers cooling fluid through copper tubes to accomplish heat exchange between fluid and cooling water.

Plate heat exchanger: This consists of many thin cooling plates which exchange heat with cooling water.Air cooing radiator: Forced air flows through tubes and cools the fluid

Refrigerant exchanger: This is like a domestic refrigerator and dissipates heat from fluid. It consists of a hydraulic pump, a motor and thermos stat . It is used when accurate temperature control is needed.

Heaters: In cold regions, viscosity becomes high causing high pressure loss in the system. Hence electronic heater or steam heaters are used for heating the oil to the desired temperature.

2 Pumps:

Pumps used in hydraulic systems are Positive displacement pumps. (Rotodynamic pumps like centrifugal pump are not used)

Most commonly used pumps are

- Gear Pump (External or Internal),
- Vane Pump
- Piston pump (Axial – Regular or Bent Axis type).

Points to Note about Pumps:

- Positive displacement pumps
- generate high pressures,
- high volumetric efficiency,
- high power to weight ratio,
- have little change in efficiency throughout the pressure range
- have wide operating range pressure and speed.

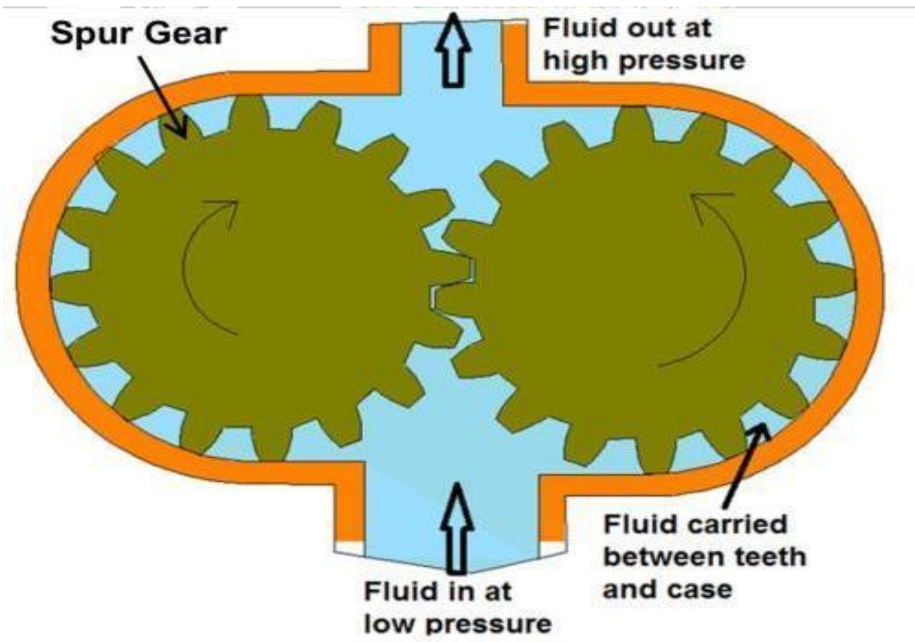
Gear Pumps:

Gear pump is a robust and simple positive displacement pump. It has two meshed gears revolving about their respective axes. These gears are the only moving parts in the pump. They are compact, relatively inexpensive and have few moving parts.

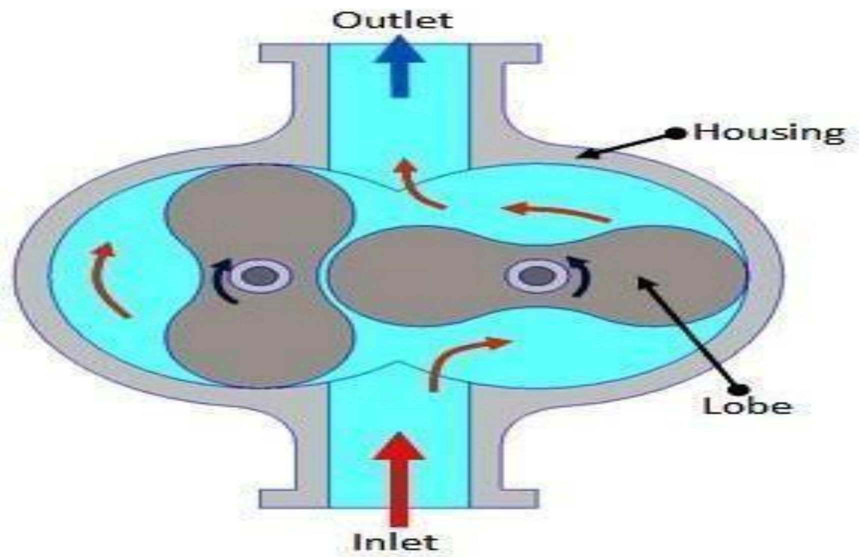
Gear pumps are most commonly used for the hydraulic fluid power applications and are also widely used in chemical industries.Based upon the design, the gear pumps are classified as:

- Lobe pumps
- Internal gear pumps
- Gerotor pumps

External gear pump:



Lobe Pump:

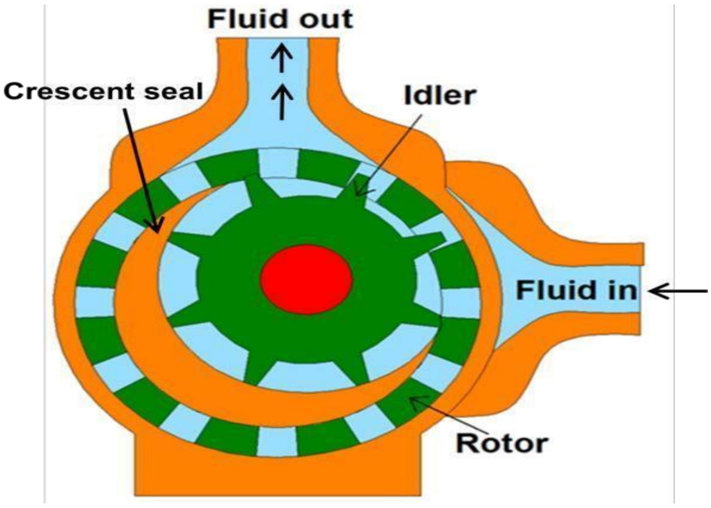


Working: One of the two gears / lobes is connected to a motor and causes rotation of the other. As they rotate in the direction shown, vacuum is created on the inlet side, liquid is trapped between the gear teath / lobe and the motor casing. On further rotation liquid is forced to the outlet side. The gear teeth or lobes at the centre provide a seal between the inlet and outlet.

The volume displaced (dp) is product of the area entrapped and width of tooth per each revolution and is constant. Flow rate is N x dp, where is the speed of motor. (use appropriate units).

Internal Gear Pump:

Working: The internal gear is eccentric to the outer gear. Rotation of the internal gear causes suction on inlet side, liquid is trapped between internal gear teeth and the crescent seal, and is forced out to outlet port.

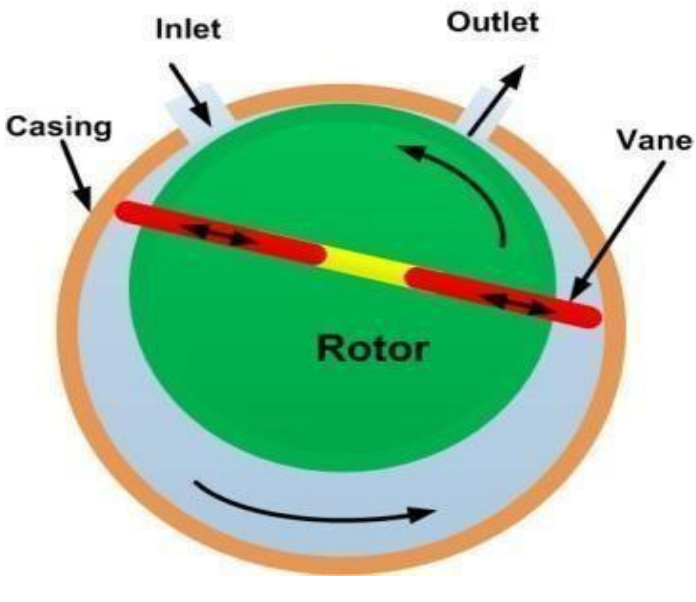


Internal gear pumps are exceptionally versatile. They are often used for low or medium viscosity fluids such as solvents and fuel oil and wide range of temperature. This is non- pulsing, self-priming and can run dry for short periods. It is a variation of the basic gear pump.

Vane Pumps:

Gear pumps have a disadvantage of small leakage due to gap between gear teeth and the pump housing. This limitation is overcome in vane pumps.

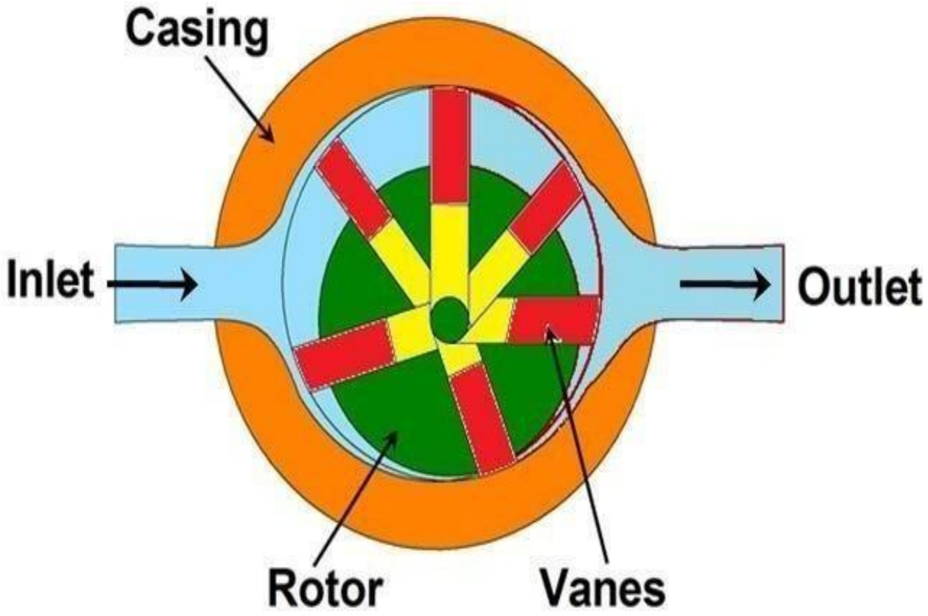
Working principle: The schematic of vane pump working principle is shown in figure. Vane pumps generate a pumping action by tracking of vanes along the casing wall.



The vane pumps generally consist of a rotor, vanes, ring and a port plate with inlet and outlet ports. The rotor in a vane pump is connected to the prime mover through a shaft. The vanes are located on the slotted rotor. The rotor is eccentrically placed inside a cam ring as shown in the figure. The rotor is sealed into the cam by two side plates. When the prime mover rotates the rotor, the vanes are thrown outward due to centrifugal force. The vanes track along the ring. It provides a tight hydraulic seal to the fluid which is more at the higher rotation speed due to higher centrifugal force.

Unbalanced Vane pump:

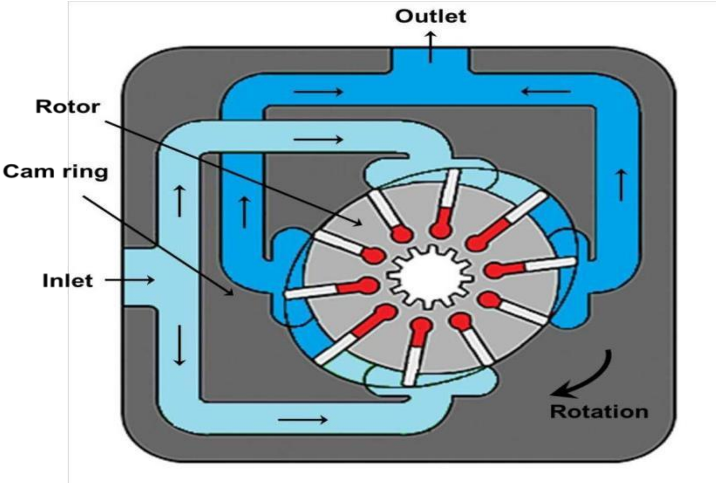
In practice, the vane pumps have more than one vane as shown in figure



The rotor is offset within the housing, and the vanes are constrained by a cam ring as they cross inlet and outlet ports. Although the vane tips are held against the housing, still a small amount of leakage exists between rotor faces and body sides. This type of pump is called as unbalanced vane pump.

Balanced vane pump:

This pump has an elliptical cam ring with two inlet and two outlet ports. Pressure loading still occurs in the vanes but the two identical pump halves create equal but opposite forces on the rotor. It leads to the zero net force on the shaft and bearings. Thus life of pump and bearing increase significantly. Also the sound andvibration are less.



Balanced Vane Pump

Axial Piston Pump:

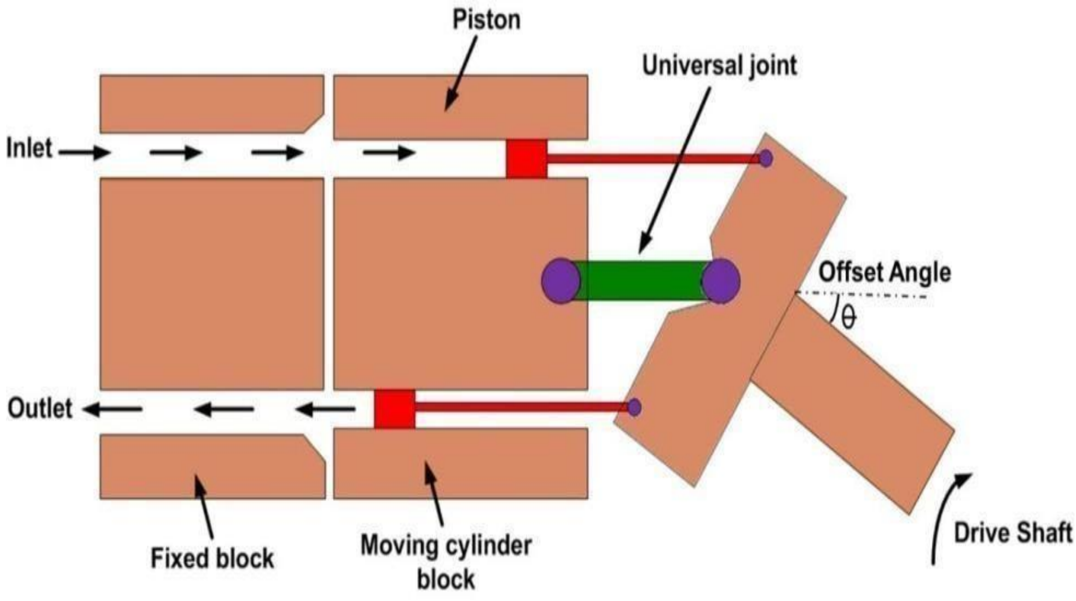
Axial piston pumps are positive displacement pumps which converts rotary motion of the input shaft into an axial reciprocating motion of the pistons. These pumps have a number of pistons (usually an odd number) in a circular array within a housing which is commonly referred to as a cylinder block, rotor or barrel. In general, these systems have a maximum operating temperature of about 120 °C. Therefore, the leakage between cylinder housing and body block is used for cooling and lubrication of the rotating parts. This cylinder block rotates by an integral shaft aligned with the pistons.

There are two types of axial piston pumps.

- Bent axis piston pumps.
- Swash plate axial piston pump

1. Bent-Axis Piston Pump:

In these pumps, the reciprocating action of the pistons is obtained by bending the axis of the cylinder block. The cylinder block rotates at an angle which is inclined to the drive shaft. The cylinder block is turned by the drive shaft through a universal link. The cylinder block is set at an offset angle with the drive shaft. The cylinder block contains a number of pistons along its periphery. These piston rods are connected with the drive shaft flange by ball-and- socket joints. These pistons are forced in and out of their bores as the distance between the drive shaft flange and the cylinder block changes.



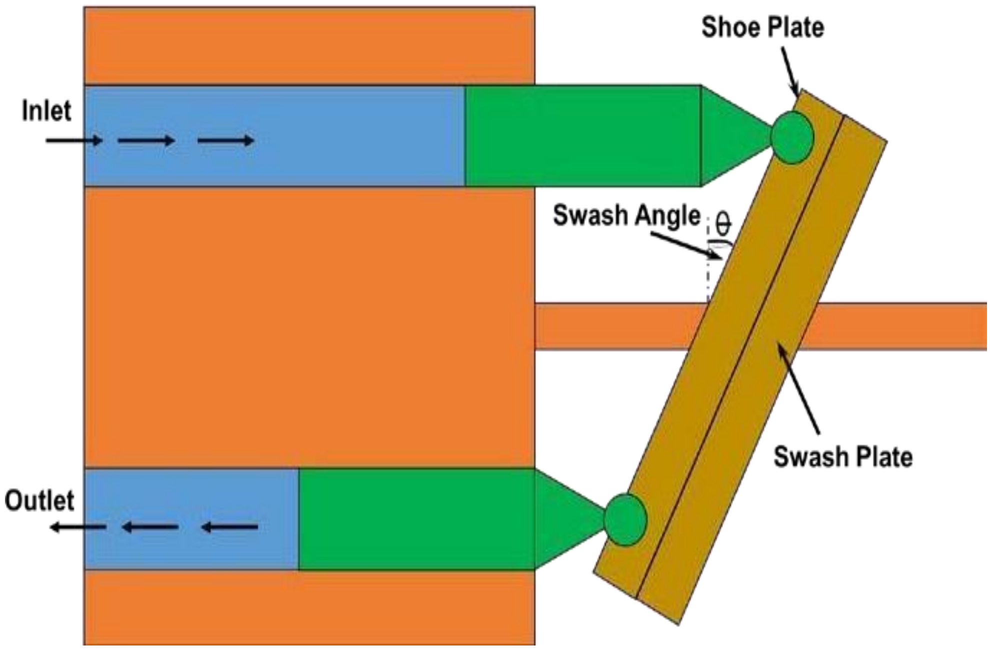
Bent Axis Piston pump

The volumetric displacement (discharge) of the pump is controlled by changing the offset angle.

Swash Plate Axial Piston Pump:

A swash plate is a device that translates the rotary motion of a shaft into the reciprocating motion. It consists of a disk attached to a shaft as shown in Figure If the disk is aligned perpendicular to the shaft; the disk will turn along with the rotating shaft without any reciprocating effect. Similarly, the edge of the inclined shaft will appear to oscillate along the shaft's length. This apparent linear motion increases with increase in the angle between disk and the shaft (offset angle).

The apparent linear motion can be converted into an actual reciprocating motion by means of a follower that does not turn with the swash plate.



Swash plate piston pump:

In swash plate axial piston pump a series of pistons are aligned coaxially with a shaft through a swash plate to pump a fluid. The axial reciprocating motion of pistons is obtained by a swash plate that is either fixed or has variable degree of angle. As the piston barrel assembly rotates, the piston rotates around the shaft with the piston shoes in contact with the swash plate. The piston shoes follow the angled surface of the swash plate and the rotational motion of the shaft is converted into the reciprocating motion of the pistons. Pump capacity can be controlled by varying the swash plate angle with the help of a separate hydraulic cylinder.

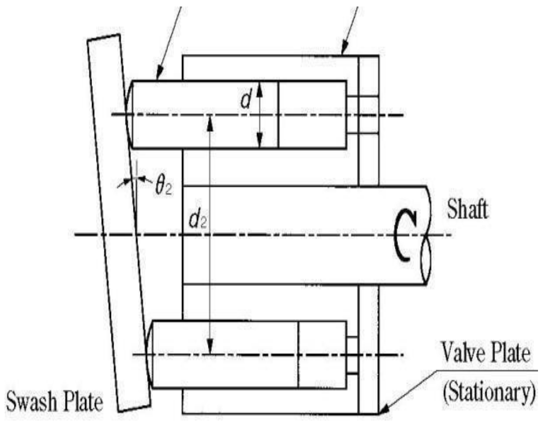
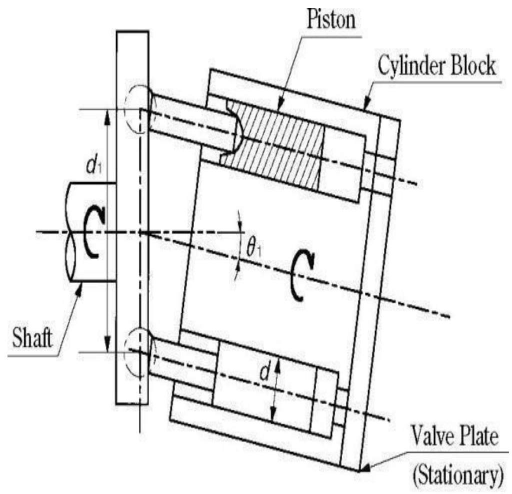
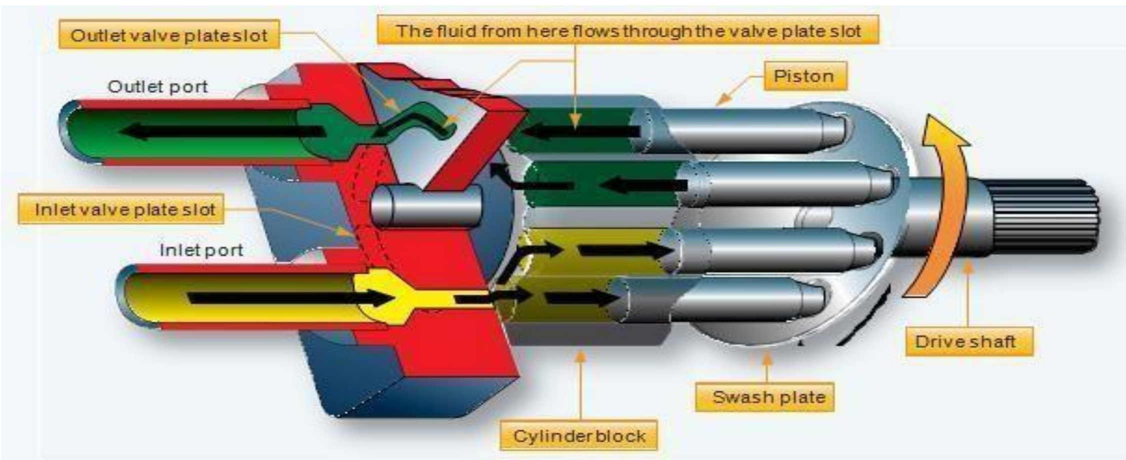


Fig. 2.1 Swash Plate Type





PUMP

Introduction:

The function of a pump is to convert mechanical energy into hydraulic energy. It is the heart of any hydraulic system because it generates the force necessary to move the load. Mechanical energy is delivered to the pump using a prime mover such as an electric motor. Partial vacuum is created at theinlet due to the mechanical rotation of pump shaft. Vacuum permits atmospheric pressure to force the fluid through the inlet line and into the pump. The pump then pushes the fluid mechanically into the fluid power actuated devices such as a motor or a cylinder.

Pumps are classified into three different ways and must be considered in any discussion of fluid power equipment.

Classification based on displacement:

- Non-positive displacement pumps (hydrodynamic pumps).
- Positive displacement pumps (hydrostatic pumps).
- Classification based on delivery:
- Constant delivery pumps.
- Variable delivery pumps.
- Classification based on motion:
- Rotary pump.
- Reciprocating pump.

Classification of Pumps:

Classification Based on Displacement;

Non-Positive Displacement Pumps:

Non-positive displacement pumps are primarily velocity-type units that have a great deal of clearance between rotating and stationary parts. Non-displacement pumps are characterized by a high slip that increases as the back pressure increases, so that the outlet may be completely closed without damage to the pump or system. Non-positive pumps do not develop a high pressure but move a large volume of fluid at low pressures. They have essentially no suction lift. Because of large clearance space, these pumps are not self-priming. In other words, the pumping action has too much clearance space to seal against atmospheric pressure. The displacement between the inlet and the outlet is not positive. Therefore, the volume of fluid delivered by a pump depends on the speed at which the pump is operated and the resistance at the discharge side. As the resistance builds up at the discharge side, the fluid slips back into the clearance spaces, or in other words, follows the path of least resistance. When the resistance gets to a certain value, no fluid gets delivered to the system and the volumetric efficiency of the pump drops to zero for a given speed. These pumps are not used in fluid power industry as they are not capable of withstanding high pressure. Their maximum capacity is limitedto 17–20 bar. These types of pumps are primarily used for transporting fluids such as water, Petroleum, etc., from one location to another considerable apart

The advantages are as follows:

- Non-displacement pumps have fewer moving parts,
- Initial and maintenance cost is low,
- They give smooth continuous flow,
- They are suitable for handling almost all types of fluids including slurries and sledges,
- Their operation is simple and reliable.

The disadvantages are as follows:

- Non-displacement pumps are not self-priming and hence they must be positioned below thefluid level,
- Discharge is a function of output resistance,
- Low volumetric efficiency

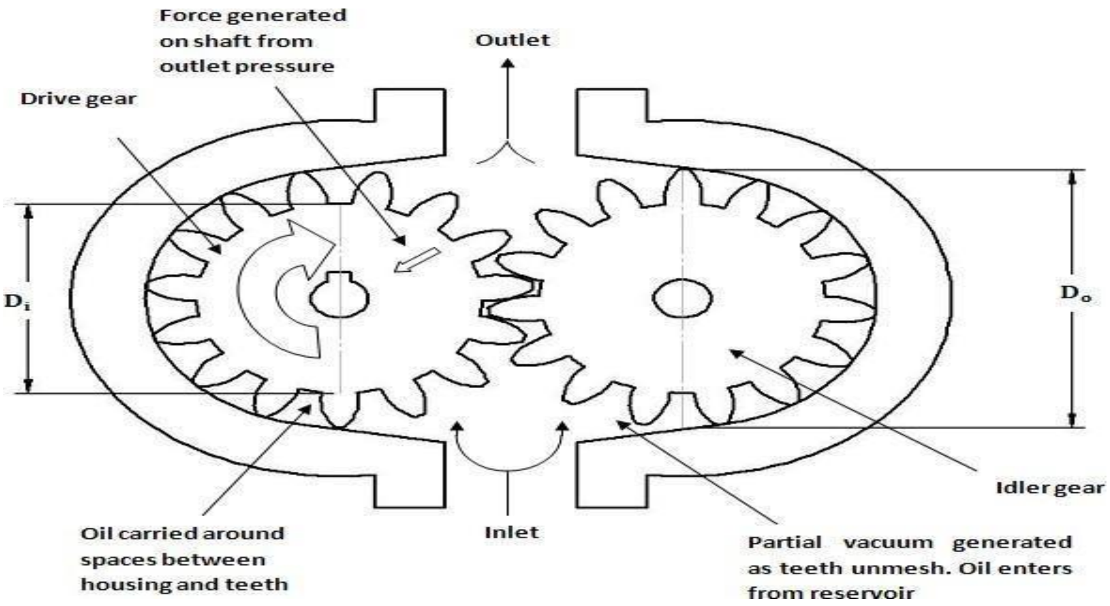
Positive Displacement Pump:

Positive displacement pumps in contrast have very little slips, are self-priming and pump against very high pressures, but their volumetric capacity is low. Positive displacement pumps have a very close clearance

between rotating and stationary parts and hence are self- priming. Positive displacement pumps eject a fixed amount of fluid into the hydraulic system per revolution of the pump shaft. Such pumps are capable of overcoming the pressure resulting from mechanical loads on the system as well as the resistance of flow due to friction. This equipment must always be protected by relief valves to prevent damage to the pump or system. By far, a majority of fluid power pumps fall in this category, including gear, vane and piston pumps. Performance curves for positive and non-positive displacement pumps.

Positive displacement pumps are classified based on the following characteristics:

Type of motion of pumping element: Based on the type of motion of pumping element, positive fixed displacement pumps.



Operation of an external gear pump

Internal Gear Pumps:

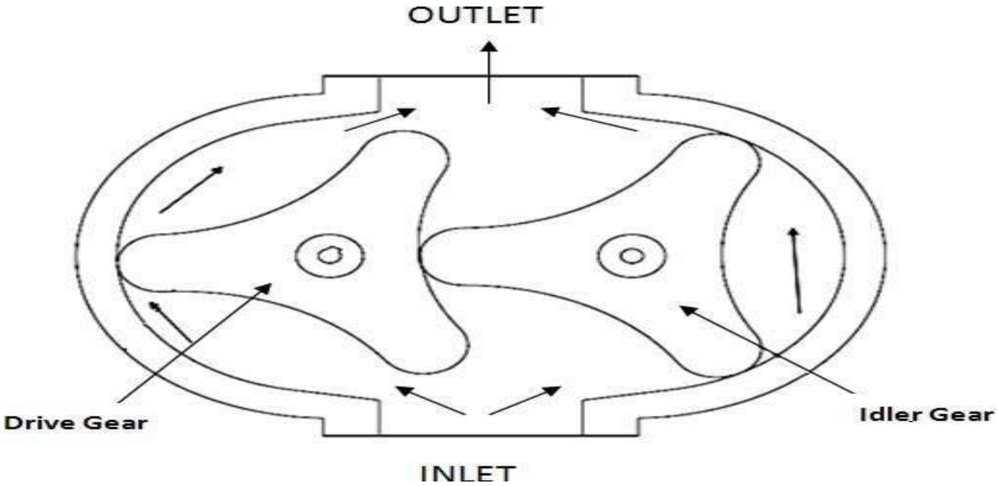
Another form of gear pump is the internal gear pump. They consist of two gears. An external gear and an internal gear. The crescent placed in between these acts as a seal between the suction and discharge. When a pump operates, the external gear drives the internal gear and both gears rotate in the same 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. The fluid volume is directly proportional to the degree of separation and these units may be reversed without difficulty. The major use for this type of pump occurs when a throughshaft is necessary, as in an automatic transmission. These pumps have a higher pressure capability than external gear pumps.

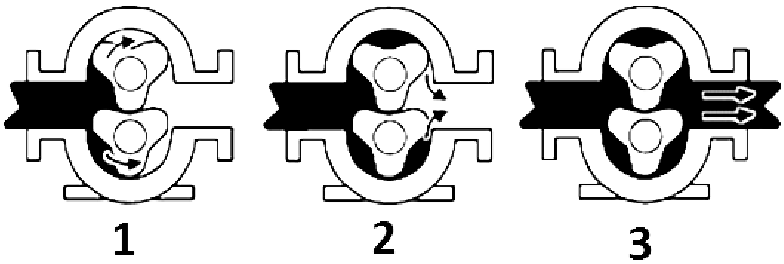
Lobe Pumps:

The operation of lobe pump shown is similar to that of external gear pump, but they generally have a higher volumetric capacity per revolution. The output may be slightly greater pulsation because of the smaller number of meshing elements.

Lobe pumps, unlike external gear pumps,have both elements externally driven and neither element has any contact with the other.For this reason, they are quieter when compared to other types of gear pumps. Lobe contact is prevented by external timing gears located in the gearbox. Pump shaft support bearings are located in the gearbox, and because the bearings are out of the pumped liquid, pressure is limited by bearing locationand shaft deflection. They do not lose efficiency with use. They are similar to external gear pumps with respect to the feature of reversibility



Stages of operation of Lobe pump:



As the lobes come out of mesh, they create expanding volume on the inlet side of the pump. Liquid flows into the cavity and is trapped by the lobes as they rotate. Liquid travels around the interior of the casing in pockets between the lobes and the casing (it does not pass between the lobes). Finally, the meshing of the lobes forces the liquid through the outlet port under pressure. Lobe pumps are frequently used in food applications because they are good at handling solids without inflicting damage to the product. Solid particlesize can be much larger in lobe pumps than in other positive displacement types. Because lobes do not make contact, and clearances are not as close as in other positive displacement pumps, this design handles low- viscosity liquids with diminished performance. Loading characteristics are not as good as other designs and suction ability is low. High-viscosity liquids require reduced speeds to achieve satisfactoryperformance. Reductions of 25% of rated speed.

Advantages:

The advantages of lobe pumps are as follows:

- Lobe pumps can handle solids, slurries, pastes and many liquid.
- No metal-to-metal contact.

- Superior CIP (Cleaning in Place) /SIP (Sterilization in Place) capabilities.
- Long-term dry run (with lubrication to seals).
- Non-pulsating discharge.

Disadvantages:

The disadvantages of lobe pumps are as follows:

- Require timing gears.
- Require two seals.
- Reduced lift with thin liquids.

Applications:

Common rotary lobe pump applications include, but are not limited to the following:

- Polymers,
- Paper coatings,
- Soaps and surfactants,
- Paints and dyes,
- Rubber and adhesives,
- Pharmaceuticals,
- Food applications.

Screw Pumps:

These pumps have two or more gear-driven helical meshing screws in a closefitting case to develop the desired pressure. These screws mesh to form a fluid-type seal between the screws and casing. A schematic diagram of a screw pump. A two-screw pump consists of two parallel rotors with inter-meshing threads rotating in a closely machined casing. The driving screw and driven screw are connected by means of timing gears. When the screws turn, the space between the threads is divided into compartments. As the screws rotate, the inlet side of the pump is flooded with hydraulic fluid because of partial vacuum. When the screws turn in normal rotation, the fluid contained in these compartments is pushed uniformly along the axis toward the center of the pump, where the compartments discharge the fluid. Here the fluid does not rotate but moves linearly as a nut on threads. Thus, there are no pulsations at a higher speed; it is a very quiet operating pump .Ina screw pump, a chamber is formed between thread and housing.

Principle Used in Hydraulic Actuator System:

Pascal's Law:

Pressure applied to a confined fluid at any point is transmitted undiminished and equally throughout the fluid in all directions and acts upon every part of the confining vessel at right angles to its interior surfaces.

Amplification of Force:

Since pressure P applied on an area A gives rise to a force F, given as, F = P×A Thus, if a force is applied over a small area to cause a pressure P in a confined fluid, the force generated on a larger area can be made many times larger than the applied force that crated the pressure.

Conservation of Energy:

Since energy or power is always conserved, amplification in force must result in reduction of the fluid velocity. Indeed if the resultant force is applied over a larger area then a unit displacement of the area would cause a larger volumetric displacement than a unit displacement of the small area through which the generating force is applied. Thus, what is gained in force must be sacrificed in distance or speed and powerwould be conserved.

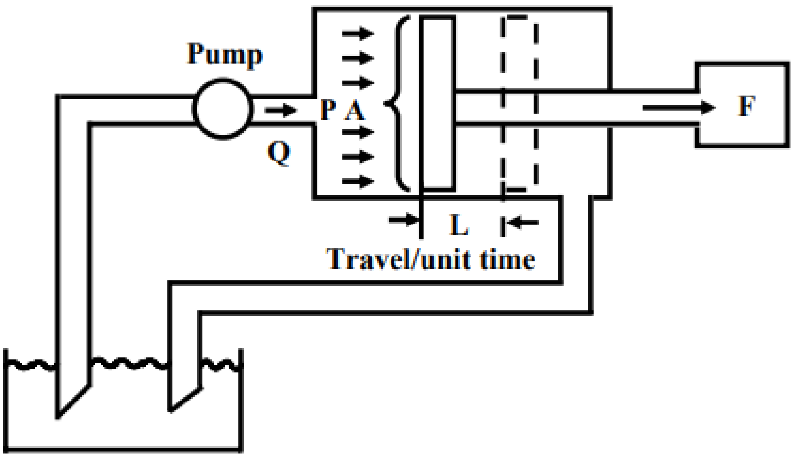


Fig. 26.1 Major hydraulic and mechanical variables

pump. However, the mechanical equipment cannot be coupled directly to the prime mover because the required control over the motion, necessary for industrial operations cannot be achieved. In terms of these Hydraulic Actuation Systems offer unique advantages, as given below.

Variable Speed and Direction:

Most large electric motors run at adjustable, but constant speeds. It is also the case for engines. The

Actuator (linear or rotary) of a hydraulic system, however, can be driven at speeds that vary by large amounts and fast, by varying the pump delivery or using a flow control valve. In addition, a hydraulic Prime movers.

Power-to-weight ratio:

Hydraulic components, because of their high speed and pressure capabilities, can provide high power output with vary small weight and size, say, in comparison to electric system components. Note that in electric components, the size of equipment is mostly limited by the magnetic saturation limit of the iron.Itis one of the reasons that hydraulic equipment finds wide usage in aircrafts, where dead-weight must be reduced to a minimum.

Stall Condition and Overload Protection:

A hydraulic actuator can be stalled without damage when overloaded, and will start up immediately when the load is reduced. The pressure relief valve in a hydraulic system protects it from overload damage.

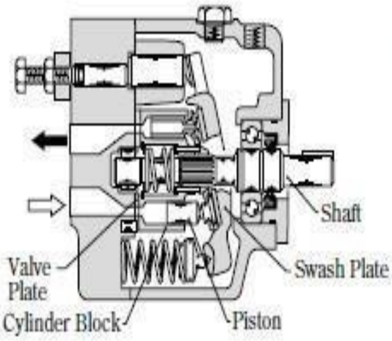
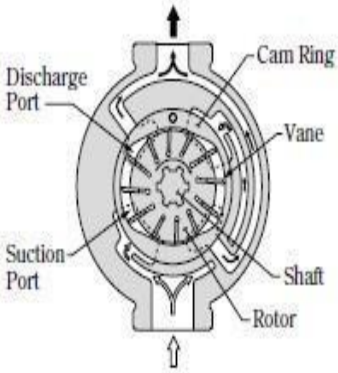
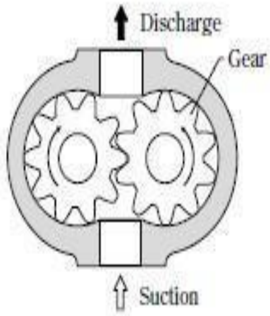
During stall, or when the load pressure exceeds the valve setting, pump delivery is directed to tank with definite limits to torque or force output. The only loss encountered is in terms of pump energy. On the contrary, stalling an electric motor is likely to cause damage. Likewise, engines cannot be stalled without the necessity for restarting.

Point to Ponder: 2

Consider two types of variable speed drives:

In the first one an electric motor with a power electronic servo drive is directly coupled to the load through a mechanism. In the second one an electric motor with a constant speed drive drives the pump in ahydraulic system which provides the variable speed drive to the load. Which one of these two is more energy efficient?

Table 2.1 Characteristics of the Pumps

Type	Piston Pumps	Vane Pumps	Gear Pumps
Structure			
Operation Principle	Expansion and compression of a volume in a cylinder block with the piston stroke	Expansion and compression of volumes between the vanes and the cam ring	Movement of volumes between tooth spaces and the casing (the external gear pump is shown.)
Efficiency	· Generally the highest. · The valve plate is easily damaged and efficiency drops as the plate wears out.	· Generally low. · Can be compensated when the vane wears out.	· Generally low. · Drops as the gear wears out.
Contamination Resistance	Highly susceptible to foreign substances in oil.	Susceptible to foreign substances in oil, but less so than piston pumps.	Susceptible to foreign substances in oil, but hardly susceptible when the pumps are low pressure types.
Suction Ability	Low.	Middle.	High.
Variable Displacement Type	Easy to convert by changing the angle of the swash plate or bent axis.	Can be converted by changing the eccentricity of the cam ring for the unbalanced type.	Difficult.
Size and price	Generally large, heavy, and expensive.	Smallest and relatively inexpensive.	Small, light, and inexpensive.

UNIT -II HYDRAULIC ACTUATORS AND CONTROL COMPONENTS

DIRECTIONAL CONTROL VALVES (DCV):

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

According to type of construction:

- Poppet valves
- Spool valves

According to number of working ports:

- Two- way valves
- Three – way valves
- Four- way valves.

According to number of switching position:

- Two – position
- Three - position

According to Actuating mechanism:

- Manual actuation
- Mechanical actuation
- Solenoid (Electrical) actuation
- Hydraulic (Pilot) actuation
- Pneumatic actuation
- Indirect actuation

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

How to read the valve schematic:

Symbols: P – Pressure port (high pressure oil inlet from pump) T – Tank or return port connected to tank A,B – Ports connected to actuator (eg., piston side and rod side of cylinder) The figure below represents a2 position, 4-way (or 4- port) valve .

The two rectangular blocks represent two positions of possible actuation of valve. A,B,P and T are the 4 ports of the valve connected to different components. Hence it is called a 2/4 valve.

The construction or design of the valve is such that when valve is actuated to left side, as shown by arrows,pressure line from pump is connected to A side of actuator, and B side is connected to the tank. Similarly when valve is switched to second position, the right side is effective. (Now read the four symbols A,B,P,T on the four ports in right rectangle, which is effective). From the arrows it means P is connected to B and A is connected to T).

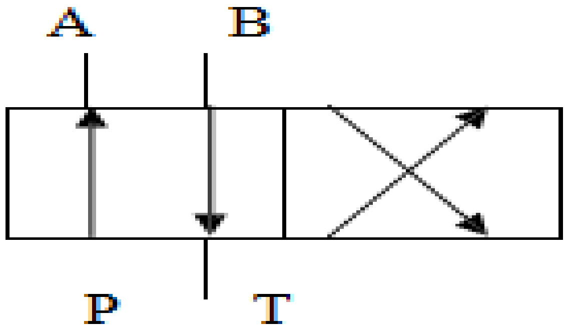
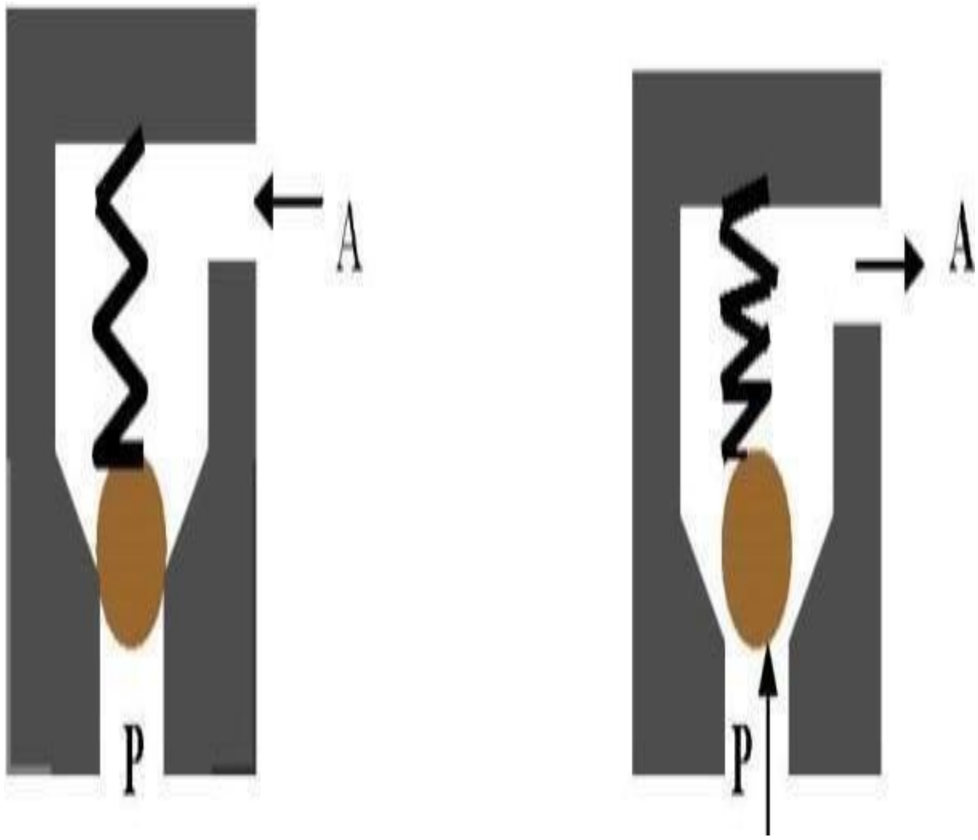


Fig 4.3. 2 / 4 valve symbol

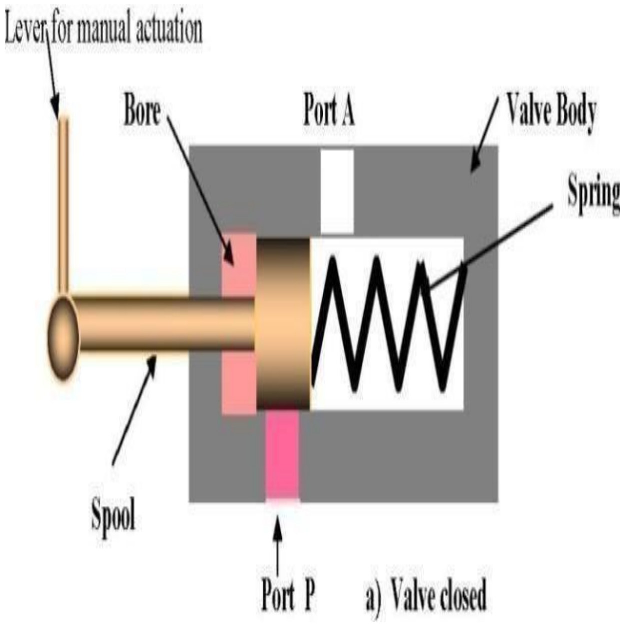
Check Valve: This valve allows flow from P to A., when pressure is enough to overcome the spring force acting on the ball, which is quite small. It does not allow flow in the other direction ie from A to P.

The symbol for check valve is as shown. It is also called On-off or Non-return valve.



The simplest type of directional control valve is a check valve which is a two way valve because it contains two ports. These valves are also called as on-off valves because they allow the fluid flow in only in one direction and the valve is normally closed. Two– way valves is usually the spool or poppet design with the poppet.

Spool type on/ off valve:



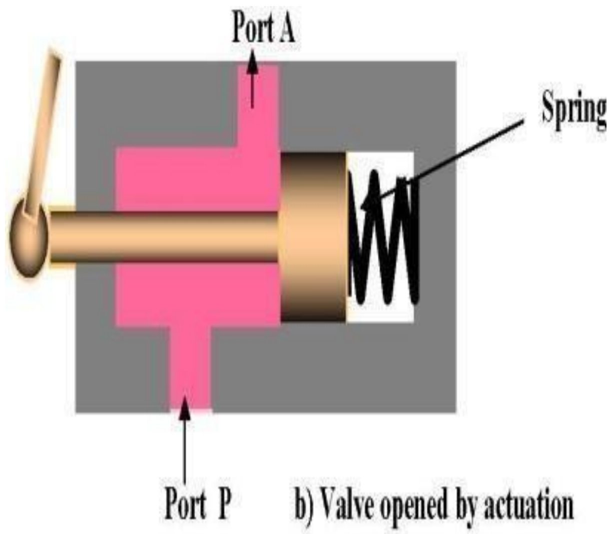


Fig 4.7 Spool type 2 / 2 DCV

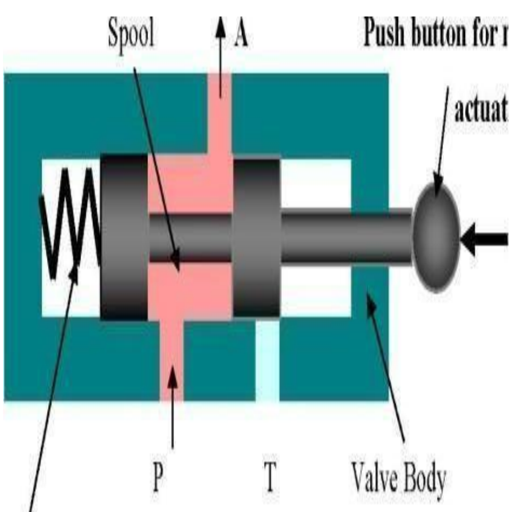
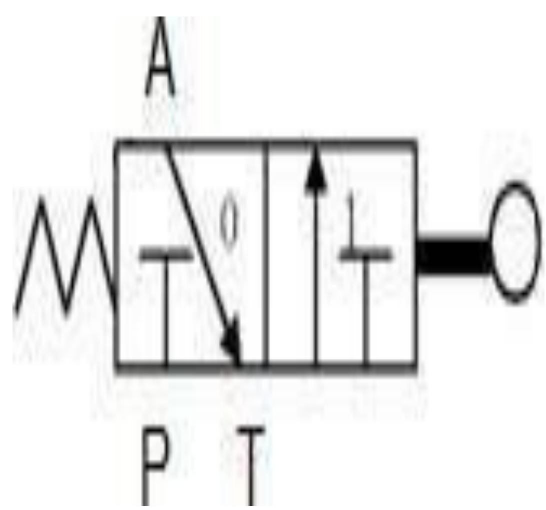


Fig a. 1 position: P to A , T blocked



3- position, 3-way valve:

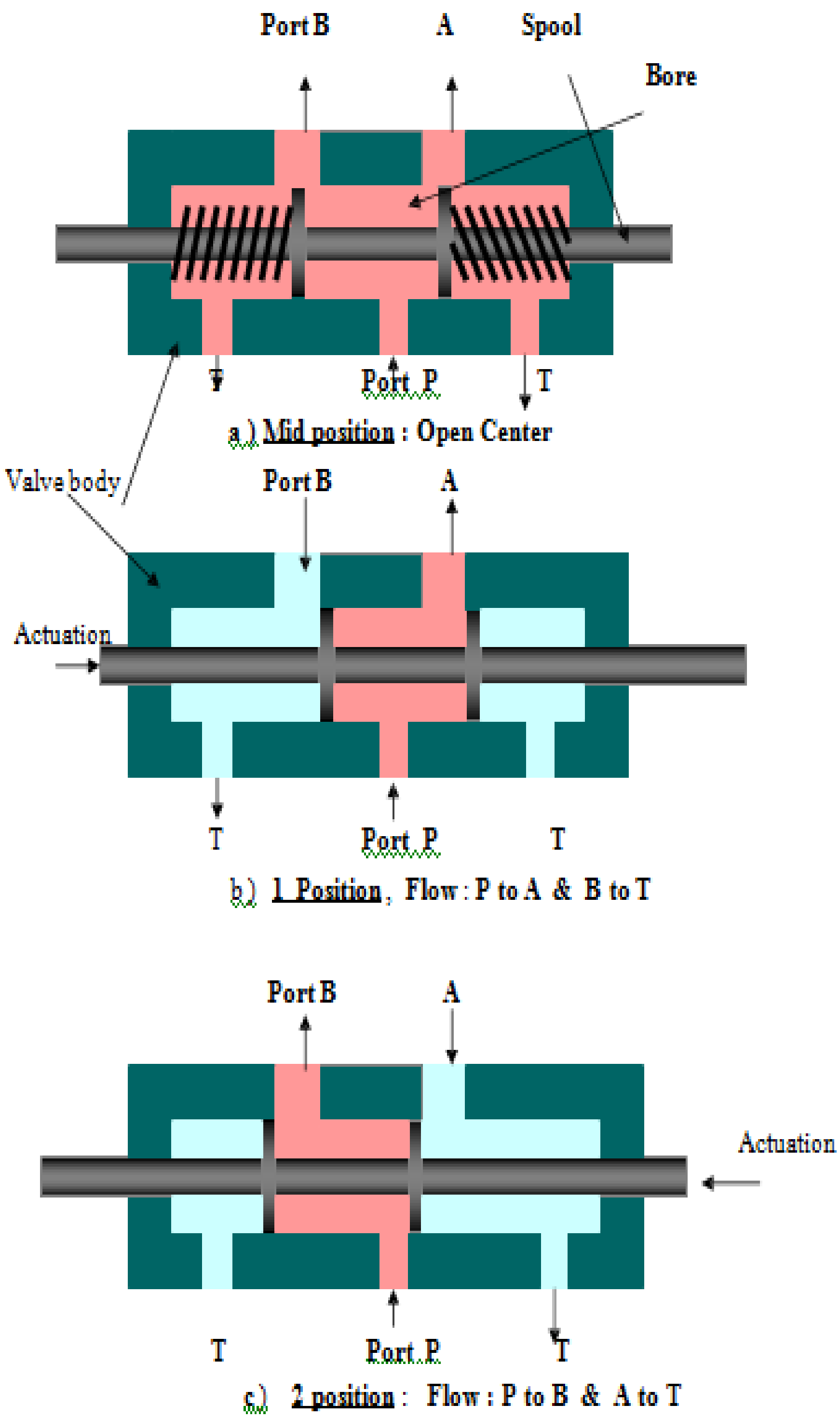
Symbol of 2/3 valve

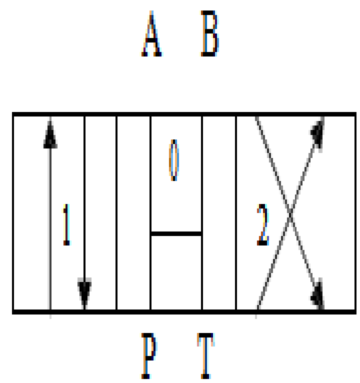
Pos

ition 0: A to TPosition 1: P to

A

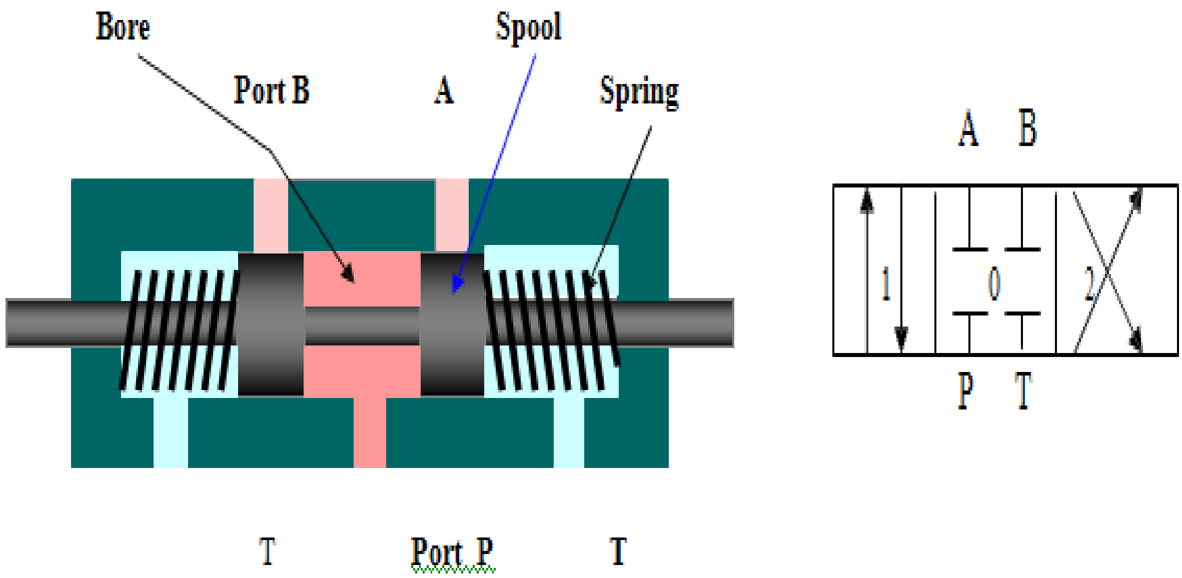
Open center 3/4 DCV:





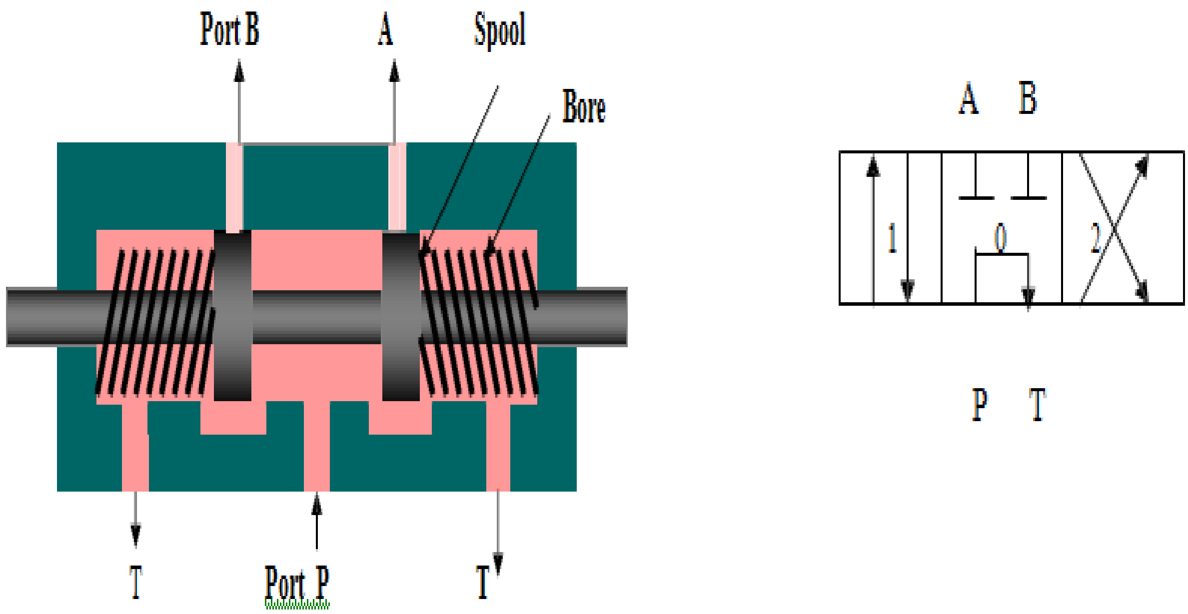
Symbol: Open Center 3 / 4 DCV

Closed Center 3 / 4 DCV:



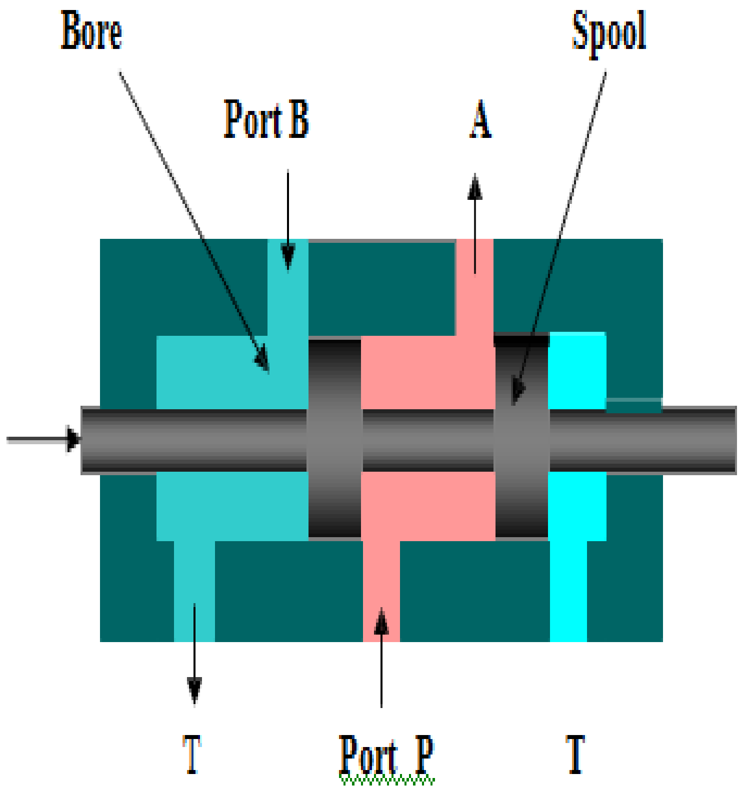
Mid Position: Closed Center3 / 4 DCV

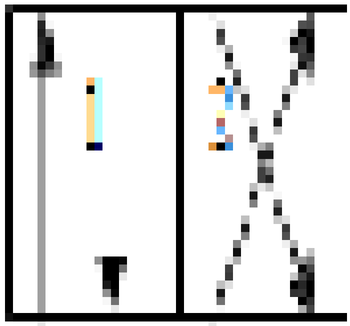
Tandem centered 3 /4 DCV:



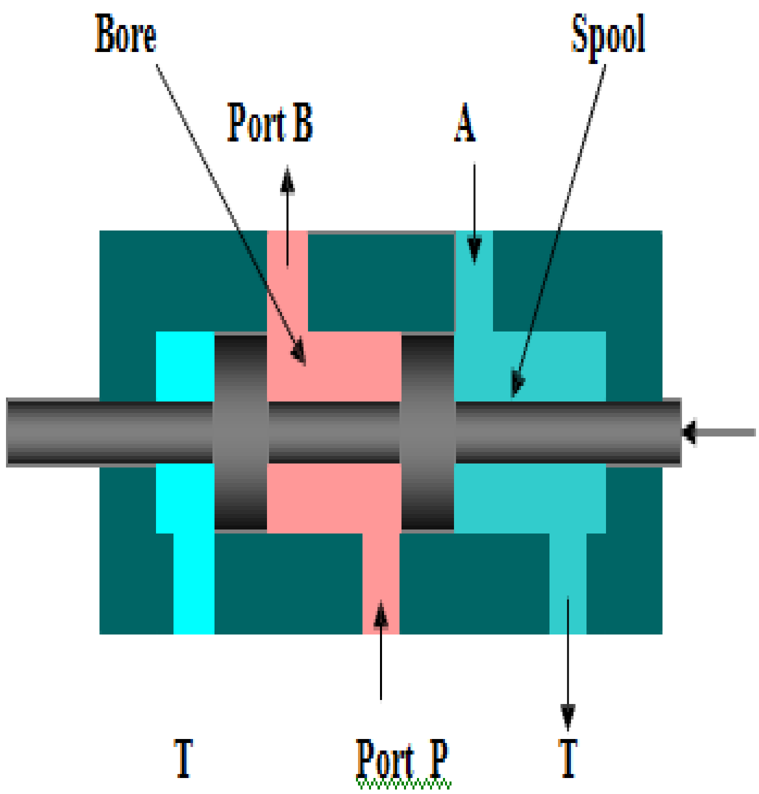
Tandem Center 3 / 4 DCV : Mid position

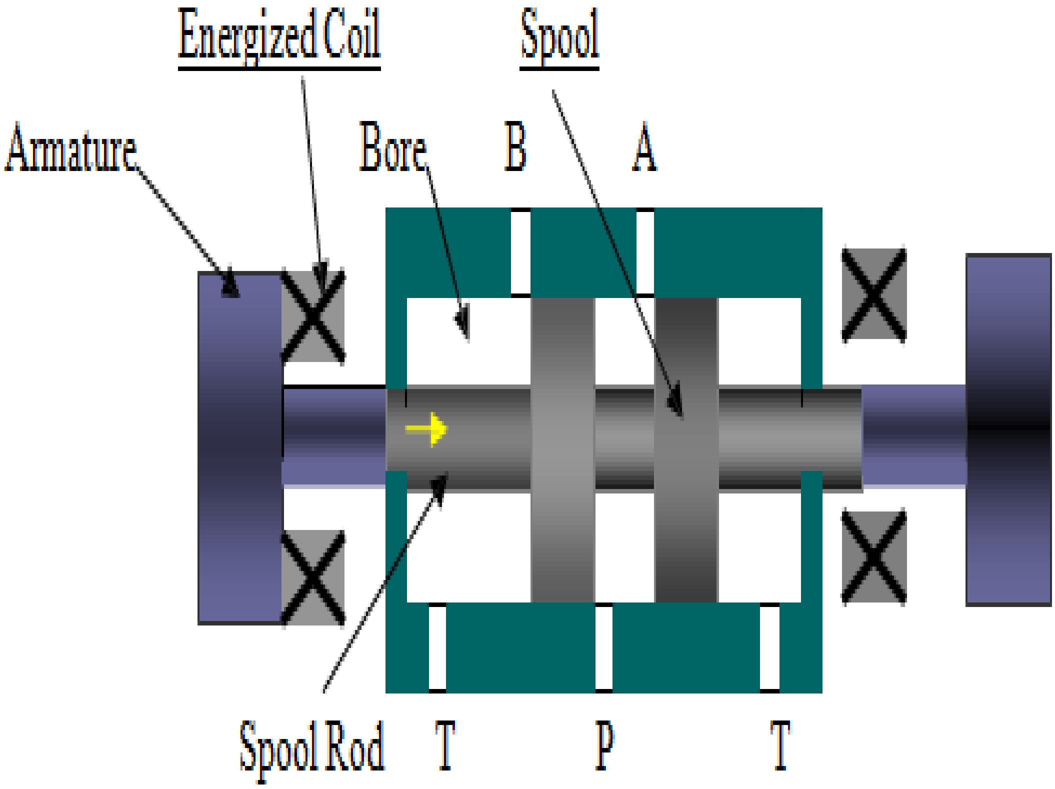
Two position, Four – way DCV:



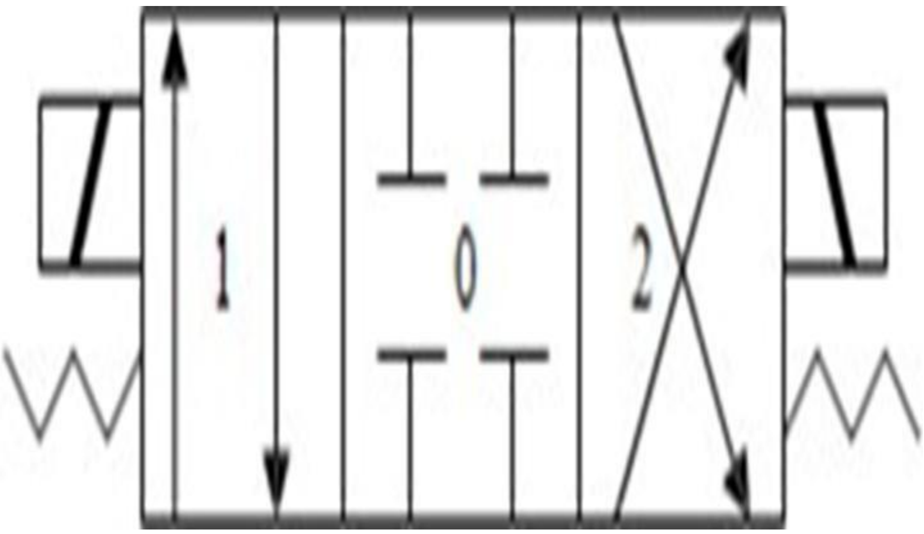


a. 1 Position : P to A and B to T



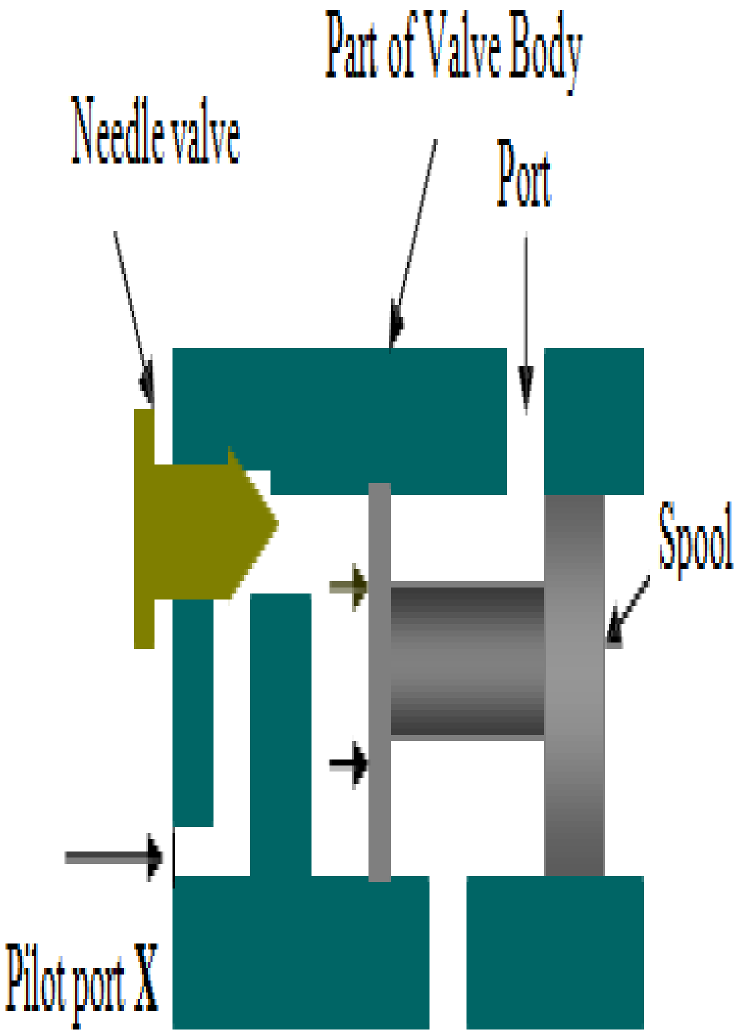


Working of solenoid to shift spool of valve.



Solenoid Actuated DCV

Hydraulic actuation: This type actuation is usually known as pilot-actuated valve. The hydraulic pressure may be directly used on the end face of the spool . The pilot ports are located on the valve ends.

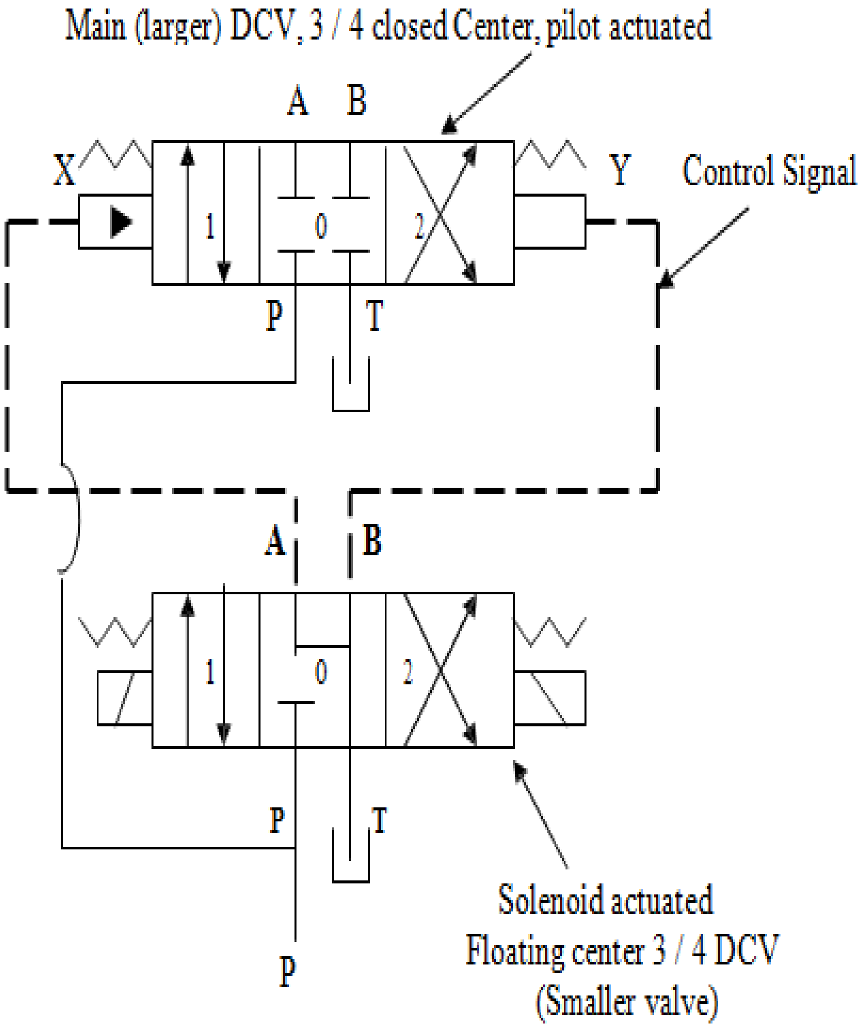


Pilot actuated DCV

Hydraulic actuation

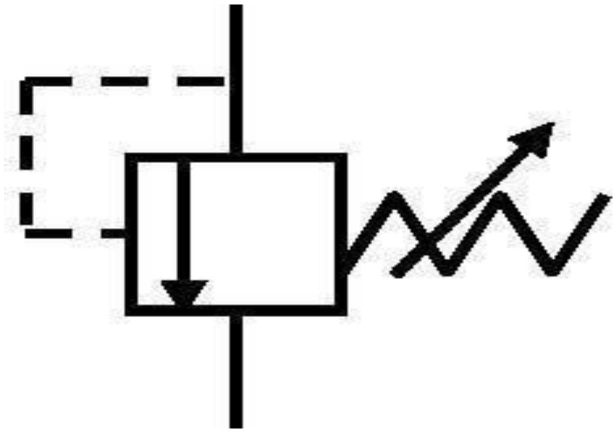
Figure shows a DCV where the rate of shifting the spool from one side to another can be controlled by a needle valve. Fluid entering the pilot pressure port on the X end flows through the check valve and operates against the piston. This forces the spool to move towards the opposite position. Fluid in the Y end (right end, not shown in the figure) is passed through the adjustable needle valve and exhausted back to tank. The amount of fluid bled through the needle valve controls how fast the valve will shift.

Indirect actuation of directional control valve:



Pressure Relief Valves: The pressure relief valve is used to protect the hydraulic components from excessive pressure. It is one of the most important components of a hydraulic system and is essentially required for safe operation of the system. Its primary function is to limit the system pressure within a specified range. It is normally a closed type and it opens when the pressure exceeds a specified maximum value by diverting pump flow back to the tank. The simplest type valve contains a poppet held in a seat against the spring force as shown in the figure. The fluid enters from the opposite side of the poppet. Whenthe system pressure exceeds the present value, the poppet lifts and the fluid is escaped through the orifice to the storage tank directly.

It reduces the system pressure and as the pressure reduces to the set limit again the valve closes. This valve does not provide a flat cut-off pressure limit with flow rate because the spring must be deflected more when

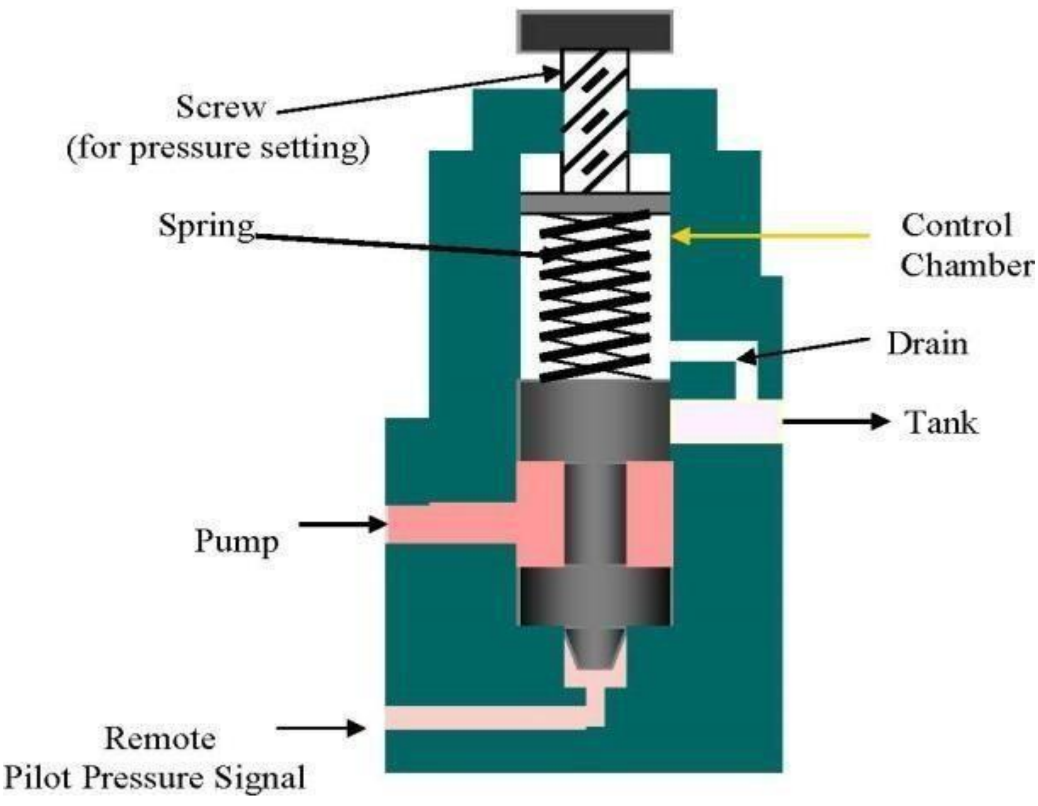


the flow rate is higher. Various types of pressure control valves are discussed in the following sections. When the system pressure exceeds a set value, the poppet raises up and allows fluid.

Pressure Relief Valve:

Unloading Valve:

Unloading valve is used to permit a pump to operate at minimum load. The unloading valve is normally closed valve with the spool closing the tank port. When a pilot pressure is enough to overcome the spring force, spool moves up and flow is diverted to tank. When the pilot pressure is relaxed, spool moves down and lets the flow to the circuit for operation.



Unloading Valve

The unloading valve is used in system having one or more fixed delivery pump to control the amount of flow at any given time. A well designed hydraulic circuit uses the correct amount of fluid for each phase of a given cycle of machine operations. When pressure builds up during the feed phase of the cycle, the pilot pressure opens the unloading valve, causing the large discharge pump to bypass its flow back to the tank.

Sequence valve: A sequence valve's primary function is to divert flow in a predetermined sequence. It is a pressure-actuated valve similar in construction to a relief valve and normally a closed valve. When the main system pressure overcomes the spring setting, the valve spool moves up allowing flow from the secondary port.

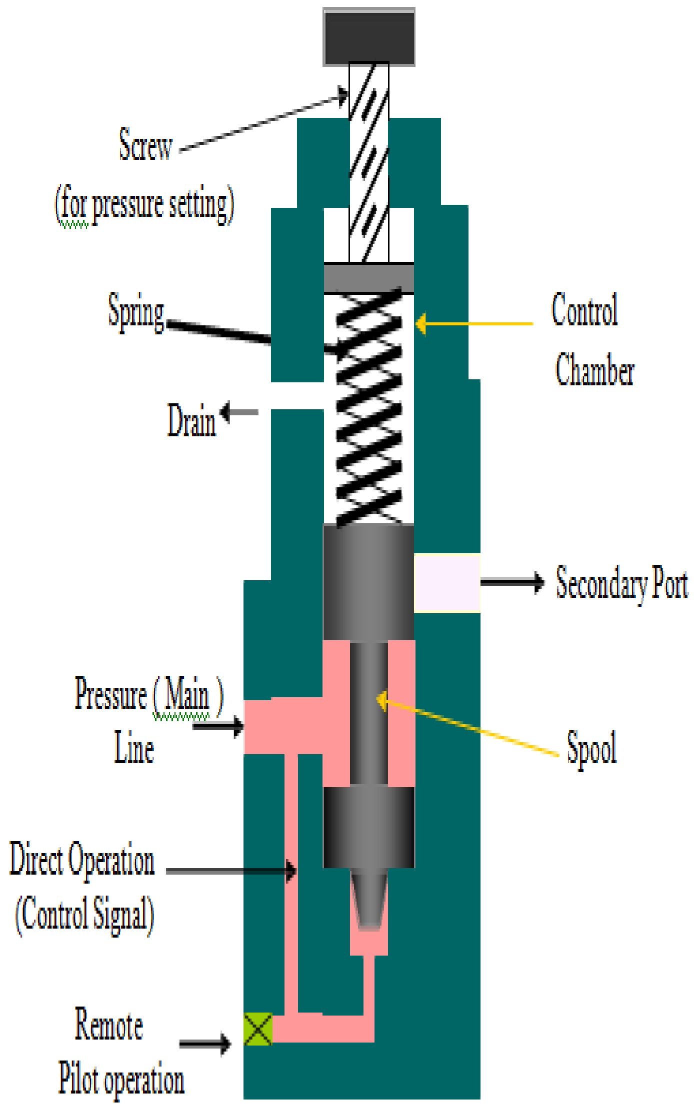
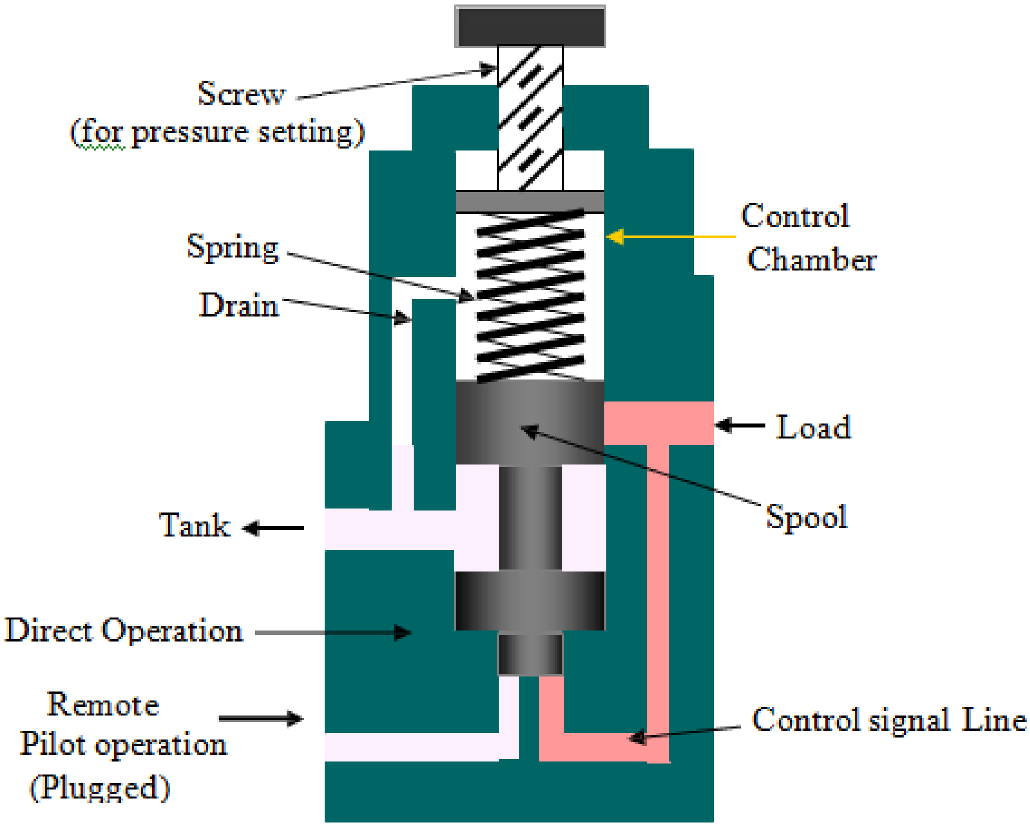
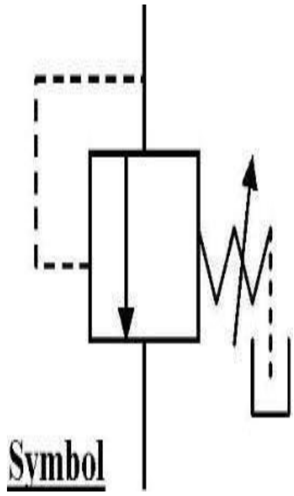


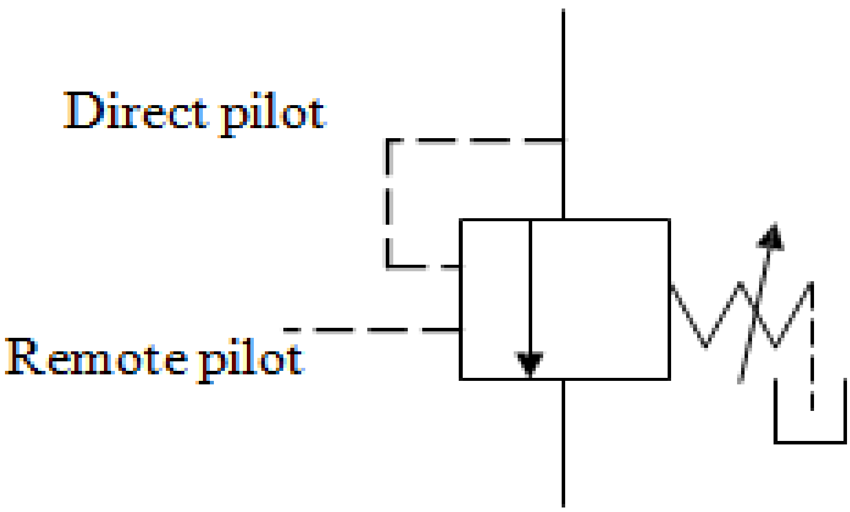
Fig 4.29b. Sequence valve

Counter balance Valve: A Counter balance valve is used to maintain back pressure to prevent a load from failing. One can find application in vertical presses, lift trucks, loaders and other machine tool that must position or hold suspended loads.

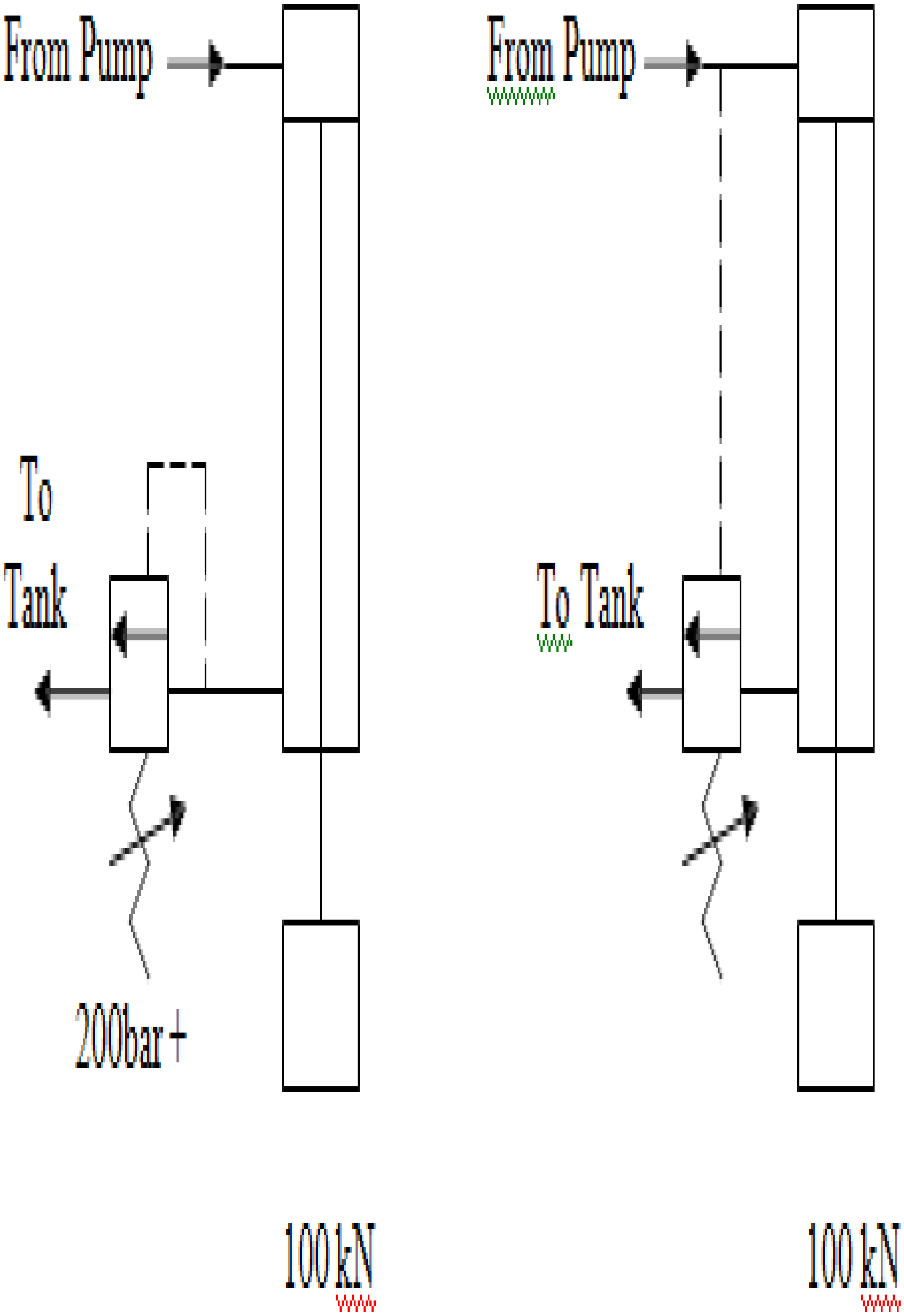


Counter Balance Valve



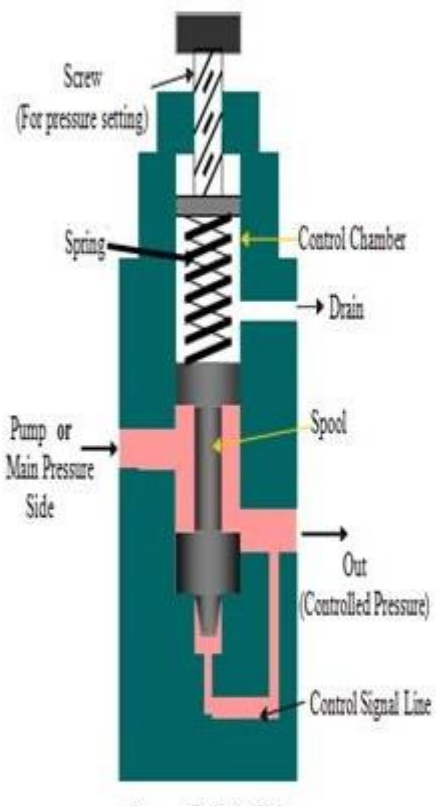


When a counterbalance valve is used on large vertical presses, it may important to analyze the source of pilot pressure. Figures illustrate the comparison between direct and remote pilot signal.



Pressure Reducing Valve: Pressure reducing valve is used to limit its outlet pressure. Reducing valves are used for the operation of branch circuits, where pressure may be less than the main systempressure.

The pressure reducing valve is normally an open type valve. When the secondary pressure is high, it lifts the spool against the spring force and throttles the flow till such extent that the secondary pressure reaches the value as set by spring.



Pressure Reducing Valve

A hydraulic pump unit (HPUs) is an arrangement of interconnected components that control hydraulic energy. It is an integral component in most hydraulic systems.

- A hydraulic system is any component that uses a fluid to generate and transmit energy from one point to another within the enclosed system. This force can be in the form of linear motion, force or rotary motion.This is based on the Pascal's Laws: Therefore, whenever you refer to hydraulic power units, it is basically a system that generates pressure or force based on the above fundamental aspects. You can use them in applications that require heavy and systematic lifting.

At times, the hydraulic pump units may also be referred to as the hydraulic power packs, hydraulic Power pack units or hydraulic power units. They all refer to the same component. To generate, transmit, distribute and control this energy, HPU uses different components.

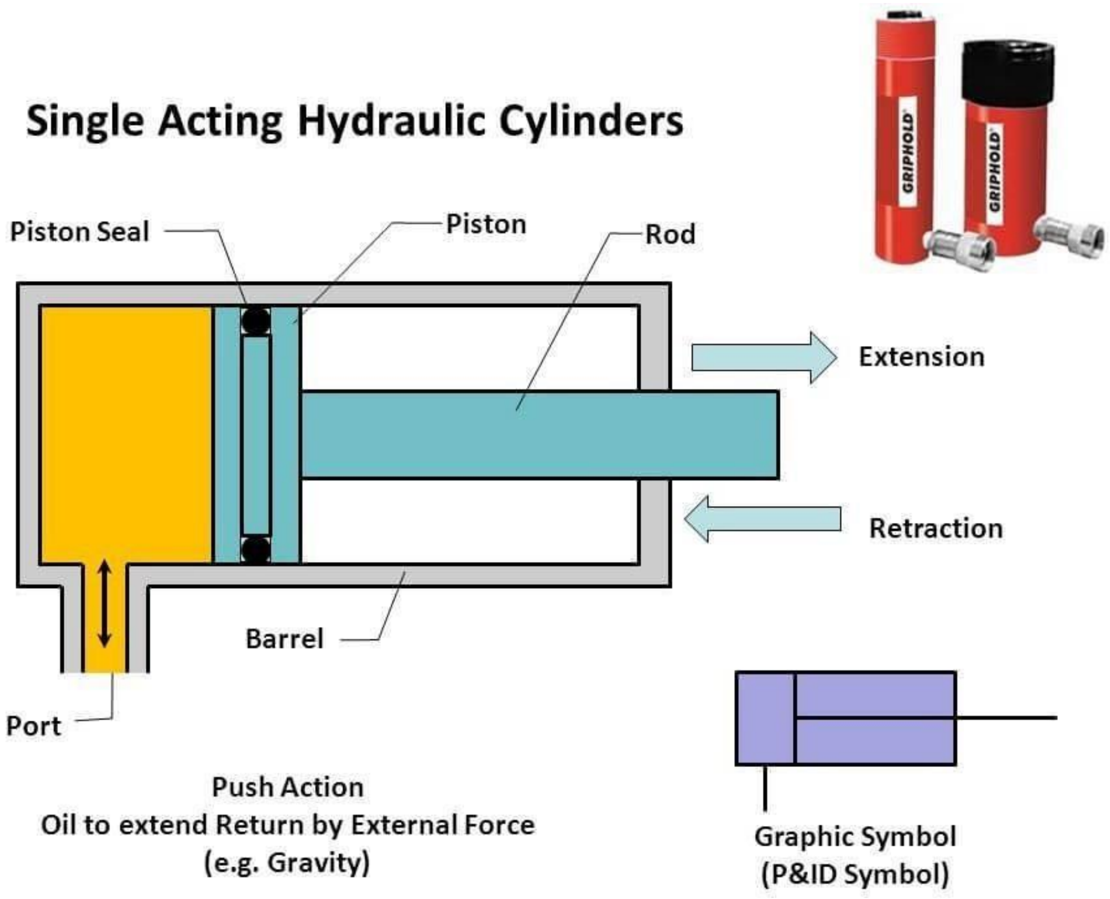
- Reliability and safety
- Flexibility in design.

There are many types of hydraulic power packs in the market. As you will realize later in this hydraulic power pack eBook, the classification may depend on the construction, function and size of the power pack. Let's begin with:

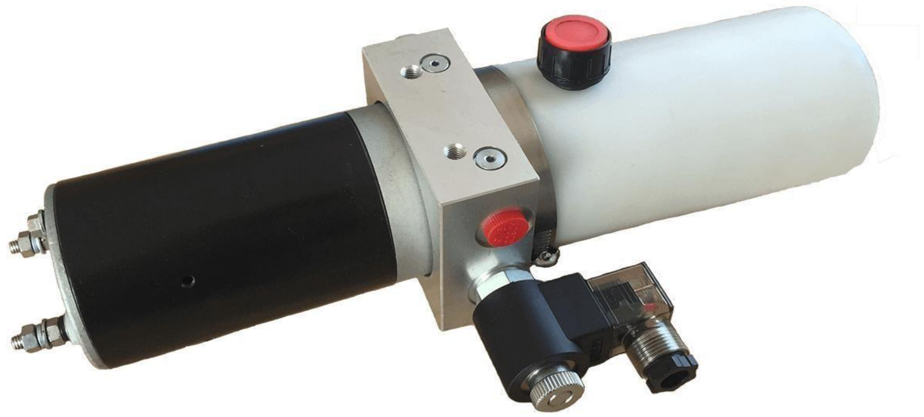
- Single acting hydraulic power pack
- Double acting hydraulic power pack

Single acting hydraulic cylinders:

In single acting hydraulic cylinders, the hydraulic fluid acts on only one end of the piston. Therefore, to push the piston back to its original position (retraction), the cylinder uses a compressed air, mechanical spring, a flying wheel or gravity load.



Single acting hydraulic cylinders



Micro Power Pack Units

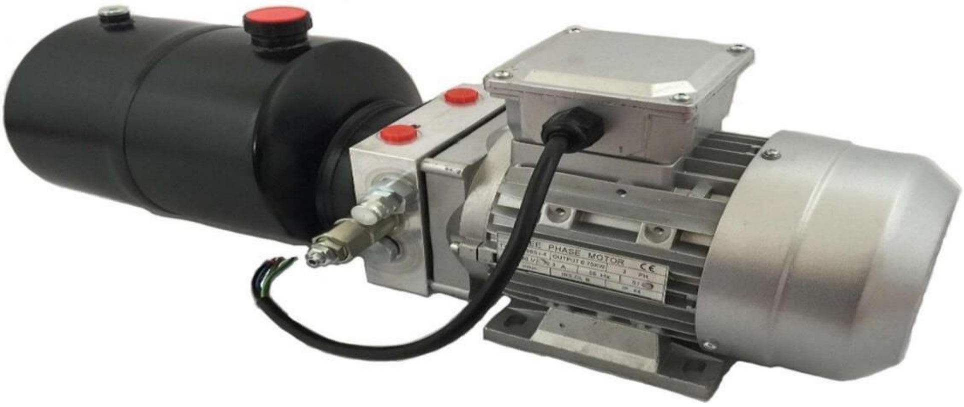
They are compact in size and available as either single or double acting. Due to their flexibility, you can operate them in either single or double acting without necessarily having a solenoid control valve.

All you need to do is reverse the motor movement. Such micro power packs have dual pressure relief valves, giving separate control options. Also, a dual check valve reduces the effects of noise and induced pressure. Their tank capacity may range between 0.1 to 3 liters. To drive the hydraulic pumps, the micro hydraulic power pack uses either 150 to 800 watt DC motors. Remember, all these specifications may vary depending on the manufacturer.

2) Mini Power Pack Units:

The mini hydraulic power packs are suitable for mobility applications. They are slightly larger than the micro power pack units.

For these hydraulic power packs, space is never an issue.



Mini Power Pack Units

They are available in different configurations such as horizontal or vertical mounting with a reservoir tank capacity ranging between 0.8 and 30liters. It uses a DC 0.8kW to 4.0kW motor, or AC 0.75kW to 7.5kW motor. The voltage of DC motors is DC 12V/24V or DC36v/48v, and the voltage of AC motors is AC 110V/220V/230V/380V/415V.With the advancement in technology, there are portable hydraulic power units that come with remote control options.

3) Standard Hydraulic Power Pack Units:

The standard hydraulic power pack units are designed for in-plant operations. They are mainly used for industrial applications. Such hydraulic power packs create huge power and high flow rates. They can handle heavy loads for a long period of time.

Their tank capacity is about 180 liters, with a flow rate of about 100 liters/minute. In most cases, you'llfind that most standard hydraulic power packs have a motor rating of about 30kW.

4) Hydraulic Power Unit Stations:

The Hydraulic power unit stations are designed for specific applications. These may include sewage treatment, construction and mining applications, just to mention a few.

Hydraulic Power Unit Stations

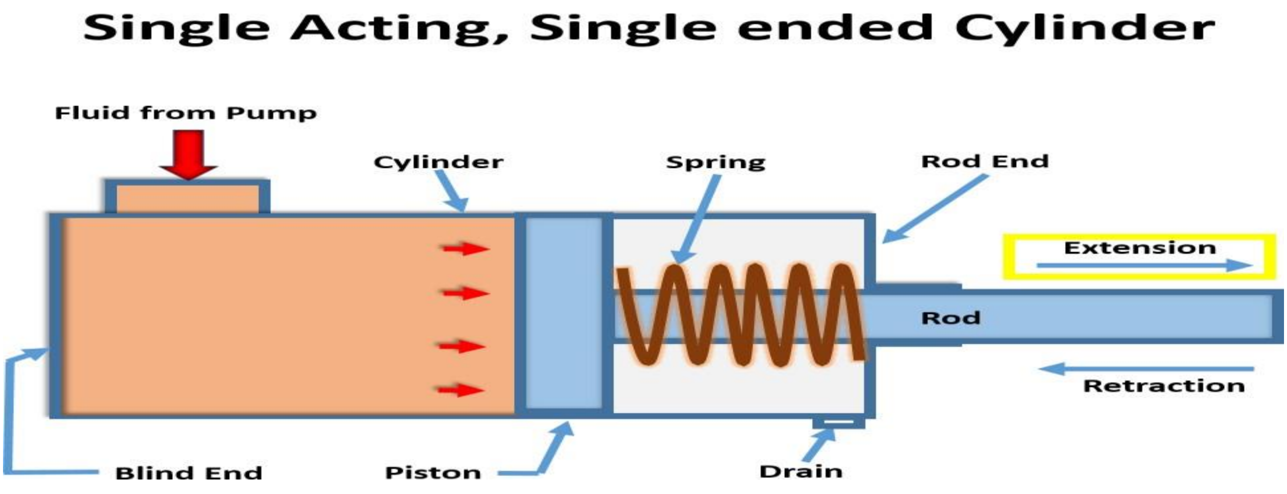
Mostly, they are available in custom designs to meet the specific requirement of any unique application. Broadly, these are the main types of hydraulic power packs available in the market. As you can see, as the sizes increase, their capacity and power also increases.

Function of Hydraulic Power Pack:

a single acting and double acting hydraulic power packs work. Generally, the main difference between the two is the force that moves the piston from one end of the cylinder to the other.

Single Acting Hydraulic Power Pack:

In a single acting hydraulic cylinder, the hydraulic fluid enters the cylinder only in one direction. As aresult, it pushes the piston to the opposite side of the hydraulic cylinder.

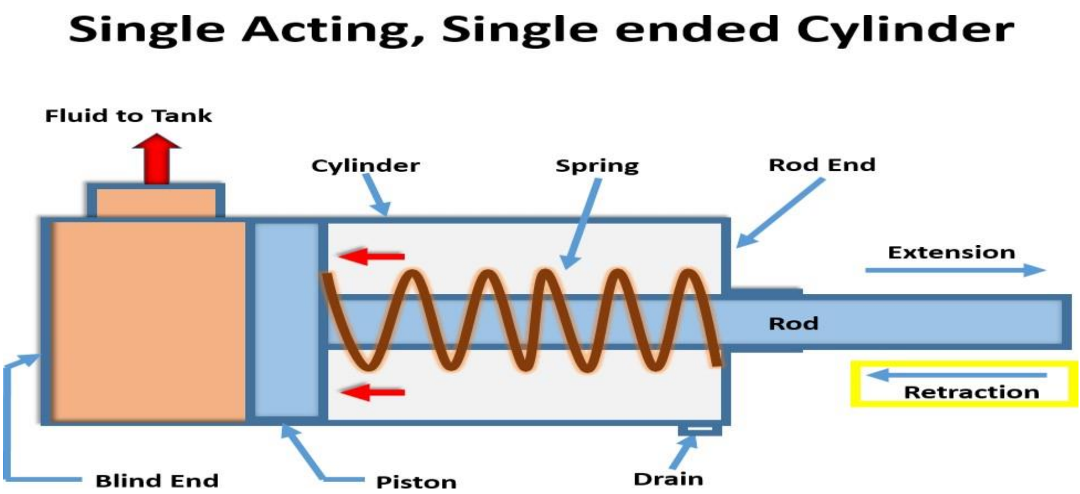


Single Acting Hydraulic Power Pack

To return the piston to its original position, there must be an external intervention, i.e., a force that will push the piston to its initial position. This force can be in the form of spring tension, gravity or compressed air.

So, assuming your single acting cylinder has a spring on one side, then you should expect; When the hydraulic fluid enters the cylinder, it will exert pressure on the piston head, pushing it in the opposite direction. As a result, the spring will be compressed between the opposite side of the piston and the cylinder.

During the retraction process, the cylinder weight holding valve (solenoid release valve) is opened, releasing pressure due to the hydraulic fluid. As a result, the spring tension (due to the compression) will force the piston back to its original position, pushing the hydraulic fluid back to the reservoir.



Single Acting Hydraulic Power Pack

Normally, you will find that this single acting hydraulic actuator system is fitted with only one hydraulic hose

They are common in applications where either weight, gravity or other external force is available to push thecylinder in the direction opposite to that of the hydraulic fluid.

Therefore, it is only a single acting power unit that can operate these systems. The single acting power packs area perfect choice for dump trailers, tipper applications, hydraulic lifts, etc.

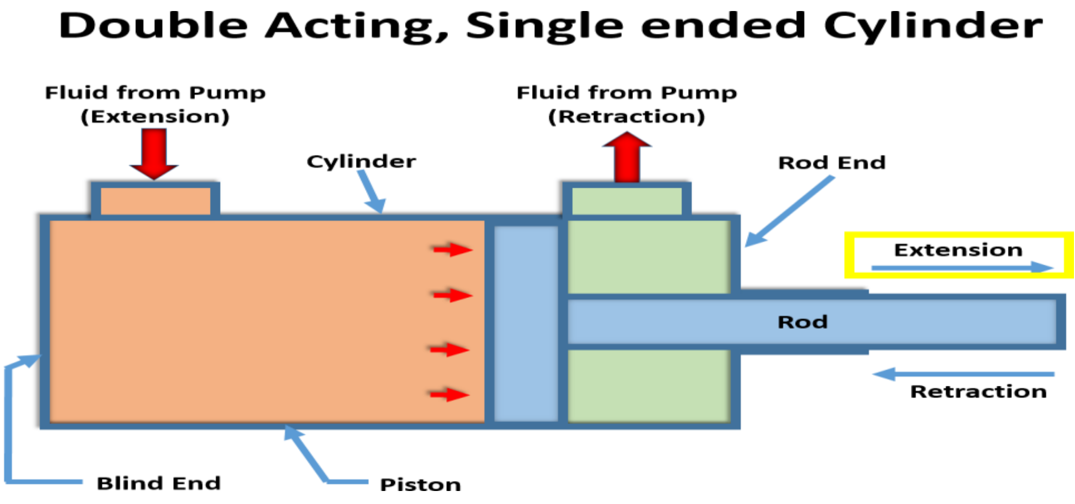
Single Acting Hydraulic Power Pack

A single acting hydraulic power pack can, thus, achieve the ―power up, gravity down‖ required to operate anysingle acting cylinder.

These accessories are popular since they can be mounted in any direction, besides being cheap compared to thedouble acting cylinders.

Double Acting Hydraulic Power Pack:

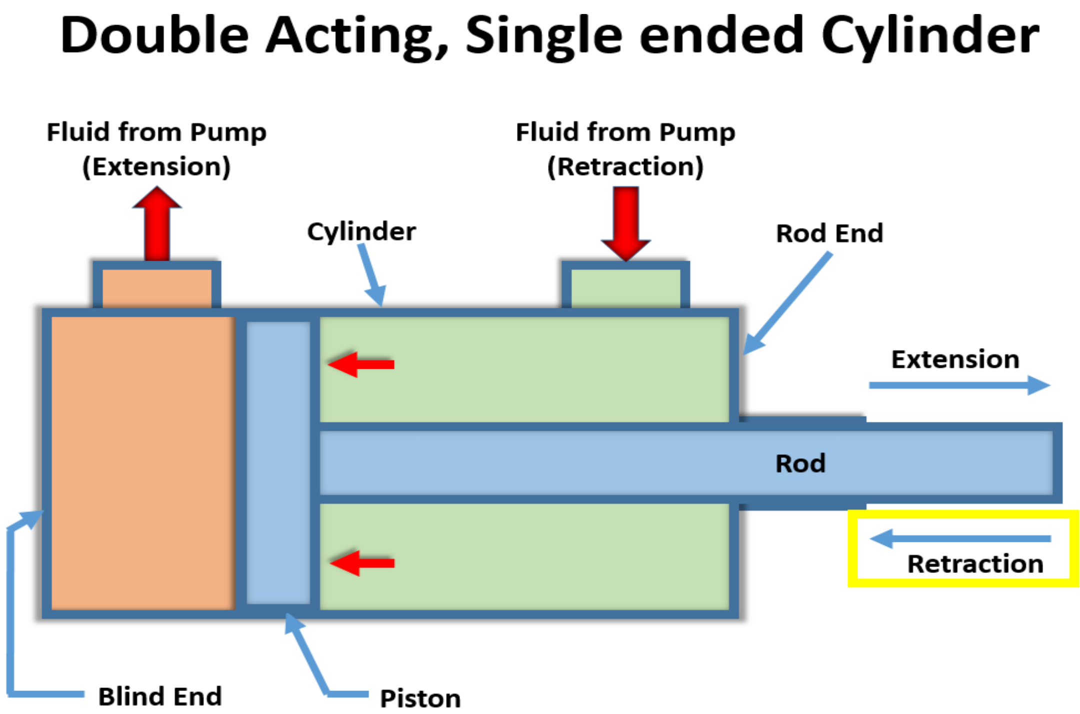
These are systems where the hydraulic fluids act interchangeably on both ends of the piston.



Double Acting Hydraulic Power Pack

Unlike the single acting hydraulic cylinders, that achieve ―power up, gravity down‖, a double acting hydrauliccylinder achieves a ‐power up, power down‖.

These systems are designed with two hydraulic fluid hose pipes, taking fluid into and out of the extreme ends ofthe hydraulic cylinder.



Double Acting Hydraulic Power Pack

In some applications such as snow-plows and hydraulic presses, double acting hydraulic systems are a perfect choice due to the following reasons. The existence of enough force to return the piston to its original position. The pressure hydraulic fluid will automatically do this for you. Secondly, they have a small hydraulic reservoir.

Therefore, they are a perfect choice where the space available is limited.

Thirdly, corrosion is reduced since the rod is lubricated by the fluid that flows in both ends of the hydraulic cylinder. This reduces the possibility of wear and tear.

Apart from these, the double acting cylinders are readily available. So, even getting the spare parts is easier compared to the single acting. Therefore, such a hydraulic system, your only option is to choose a double acting hydraulic power pack. They are the only accessories that can drive a double acting cylinder system.

Double Acting Hydraulic Power Pack

Depending on the specifications of your systems, you can choose from a wide range of double acting hydraulicpower units with the right specifications.

Other than the double acting power units and single acting power units, there are certain complex applicationsthat may require advanced systems.

Application of Hydraulic Power Pack:

- Lifting heavy motors, Hay or offloading trucks.
- Hydraulic systems provide a perfect solution to this problem.
- The transportation, lifting and distributing heavy equipment with the help of a hydraulic system.
- Hydraulic technology in very many industries such as agriculture, automotive, manufacturing industries,garbage collection, mobile hydraulics, etc.
- Plastic tube thermal melting welders
- Steering gears
- Transmission systems
- Hydraulic motor
- Hydraulic wrench
- Hydraulic road blocker
-

Hydraulic Power Unit Design and Operation:

A hydraulic system employs enclosed fluid to transfer energy from one source to another, and subsequently

Hydraulic Power Unit

Hydraulic power units apply the pressure that drives motors, cylinders, and other complementary parts of a hydraulic system. Unlike standard pumps, these power units use multi-stage pressurization networks to move fluid, and they often incorporate temperature control devices. The mechanical characteristics and specificationsof a hydraulic power unit dictate the type of projects for which it can be effective.

Some of the important factors that influence a hydraulic power unit's performance are pressure limits.

UNIT-III HYDRAULIC CIRCUITS AND SYSTEMS

SOME TYPICAL HYDRAULIC CIRCUITS:

In this part we will look at some of the simple and commonly encountered hydraulic circuits. The circuits are drawn using the standard graphical symbols.

Control of a Single- Acting Hydraulic Cylinder:

In single acting cylinder hydraulic force is exerted on the piston for forward movement (to right in the figure shown). For retraction, no hydraulic force is applied and the rod moves (to left) due to a spring force or weight of the piston and rod

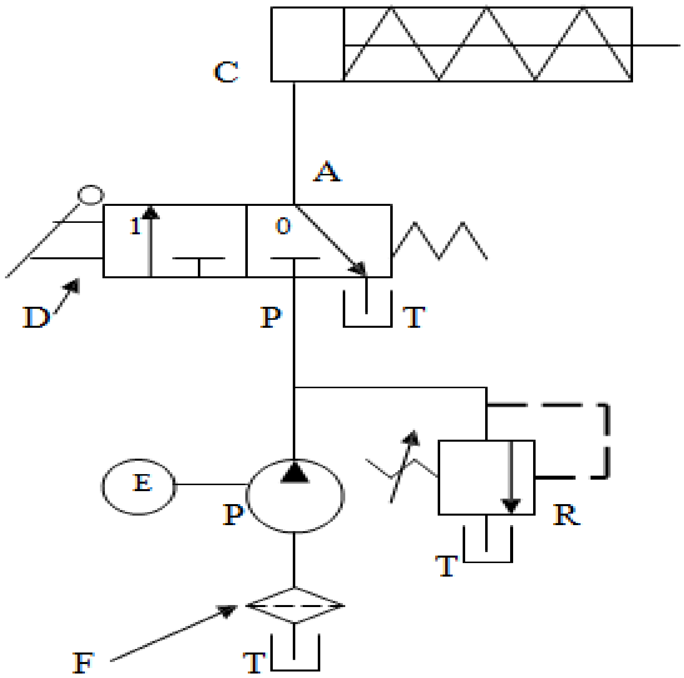


Figure shows a two-position, three way, manually operated, spring offset directional control valve (DCV) used to control the operation of a single – acting cylinder.

Single- Acting Hydraulic Cylinder

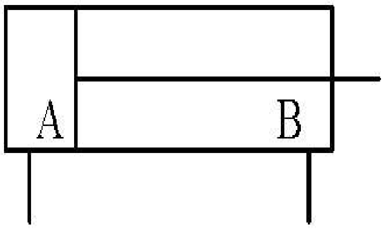
As valve is moved to occupy position 1 (left) flow goes to rod end and rod is pushed to right.

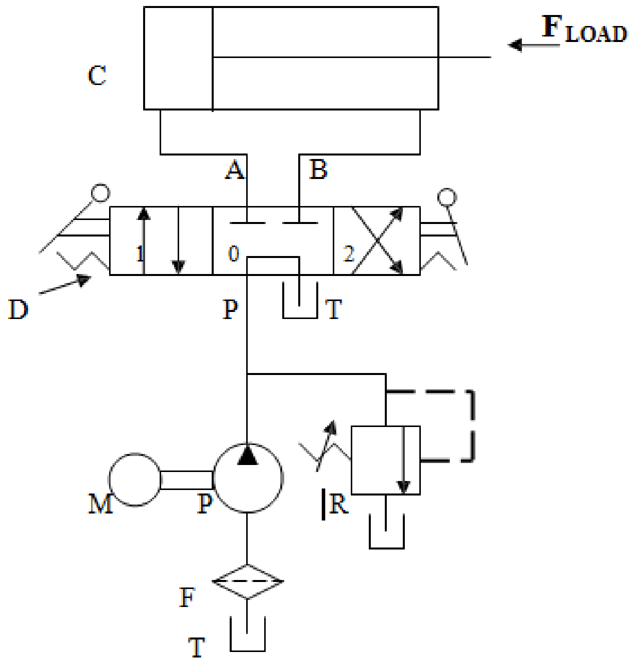
When valve is moved to position 0, i.e. shifted to right indicate position, flow from pump is blocked in the valve. There is no hydraulic pressure on the piston side. The flow goes to tank via relief valve at the set pressure. The actuator moves to left due to spring force acting on the rod end of piston.

Control of Double Acting Hydraulic Cylinder:

Double –Acting cylinders can be extended and retracted hydraulically. Thus, an output force can be applied intwo directions.

Double acting cylinder:





Double Acting Hydraulic Cylinder

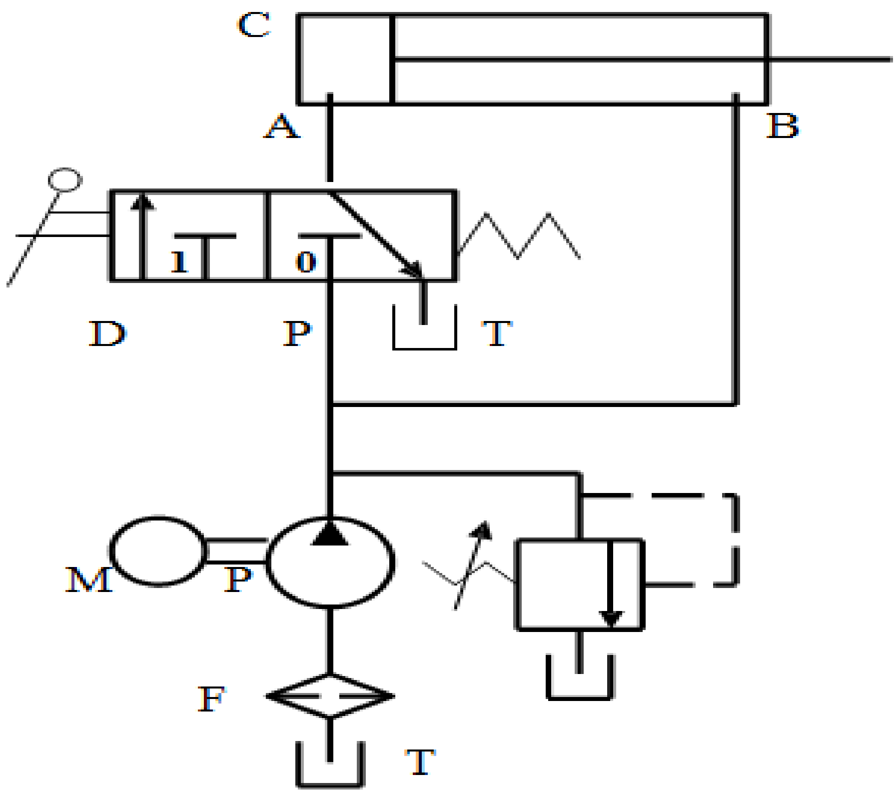
The valve is manual 3postion /4-way valve. In the neutral or valve central (0) position, oil from pump goes to tank, and no action on actuator. Note that the valve does not go through relief valve to tank, thereby saving power (Pressure set in relief valve x pump flow rate). There is minor power loss due to drop in valve orifices, and piping.

In position 1 of valve, oil flow is P to A. ie. from pump to piston side and rod moves to right acting on the load. Oil from rod side chamber of cylinder goes to tank (B to T).

In position 2, Oil from pump goes to rod end (P to B) and Oil from piston end goes to tank. (A to T) thereby pushing the rod (load) to left.

Regenerative circuit:

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



Regenerative circuit

It can be seen that in position 1 when pump is connected to piston side chamber ,ie., when main load is operated, fluid from piston side also flows into it. Thereby the flow rate is more thanpump flow. Thus the velocity of actuation on piston side is increased by the ratio (Ap / Ar), where Ap is the piston area and Ar is the rod area. .However, the net force due to the piston rod is reduced to Ar x Pressure.

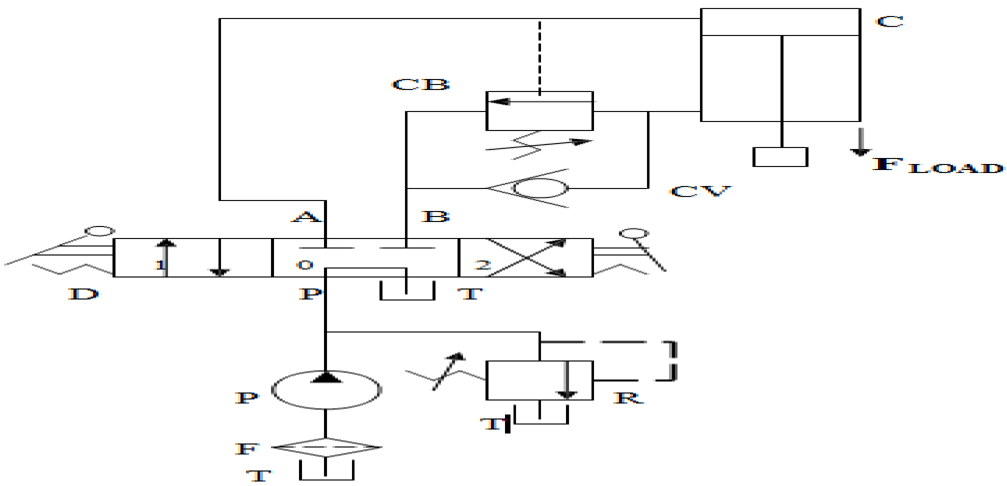
In position 2, when flow is directed to rod side, oil from the piston side flows to tank directly.

Pump Unloading Circuit:

The figure shows a circuit using an unloading valve to unload a pump. 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. Thus, the unloading valve unloads the pump at the ends of the extending and retraction strokes as well as in the spring-centered position of the DCV.

Pump Unloading Circuit Counter Balance Valve Application:

Counter balance valve is used to hold loads in vertical position without descending while idling in neutral position. Rod side fluid cannot flow unless a pilot pressure acts on the valve and permits flow to tank.



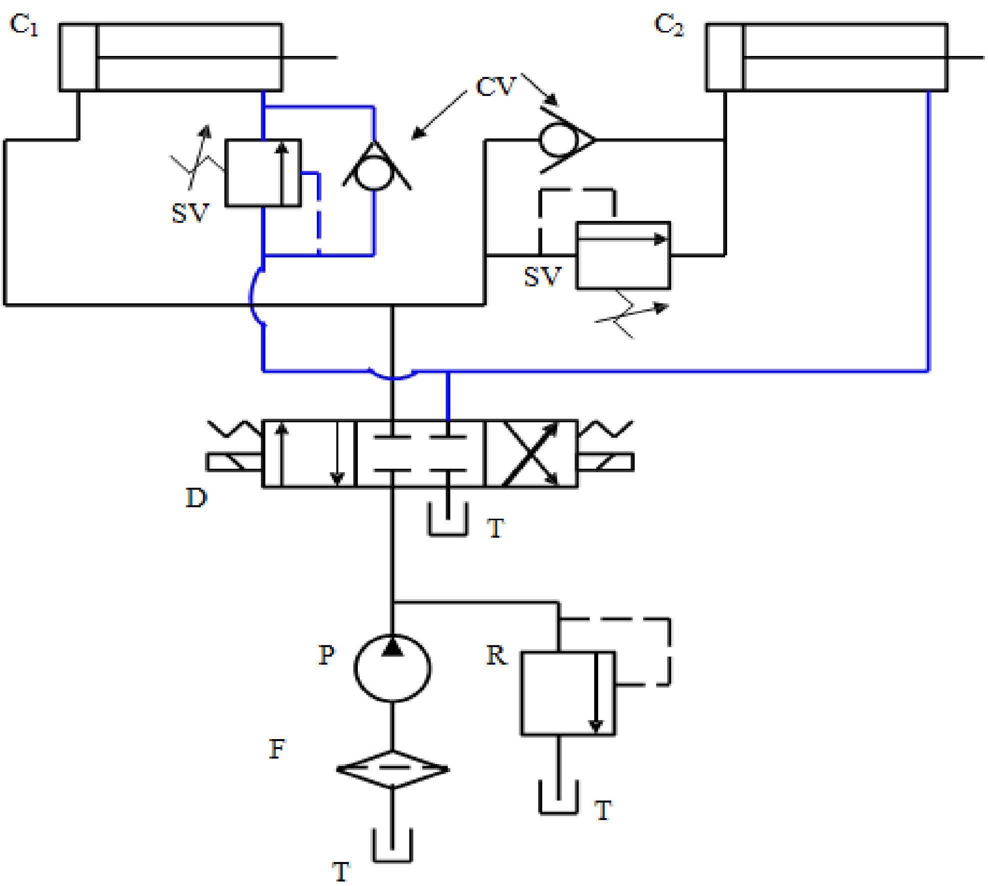
Hydraulic Cylinder Sequencing Circuits:

Figure shows an example where two sequence valves are used to control the sequence of operations of two double-acting cylinders C1 and C2 . When the DCV is shifted into its left position, the left cylinder extends completely, and pressure builds up and only when the left cylinder pressure reaches the pressure setting of sequence valve, the sequence valve connected to the right cylinder opens and permits flow to rod end of C2, and extends it.

If the DCV is then shifted to right position, flow to rod end of C1 is blocked, but flows freely to rod end of C2. After C2 retracts fully, pressure builds up till the valve connected to C1 opens.

Thus the sequence is C1Ext - C2Ext - C2Retr – C1.

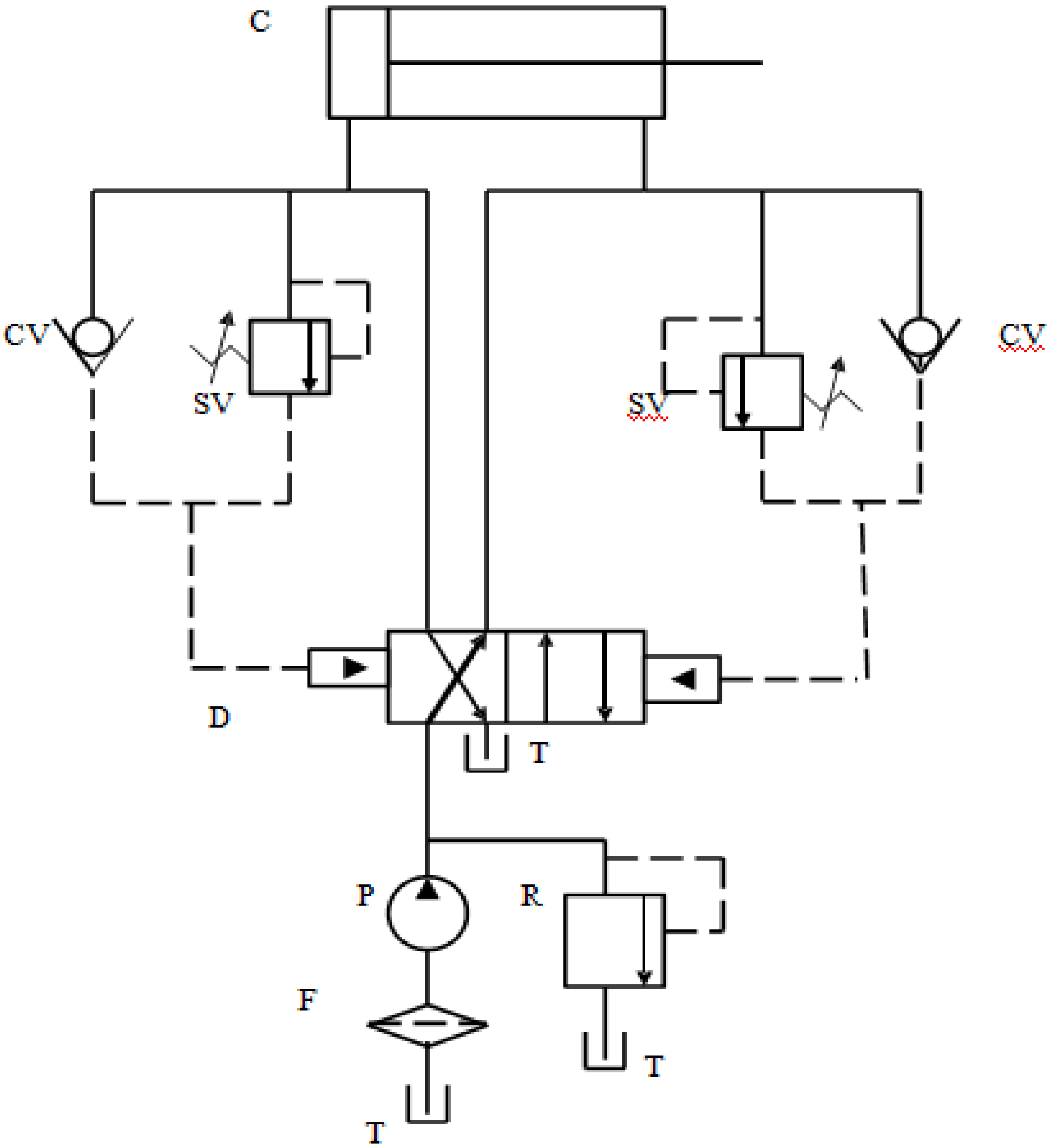
One can find the application of this circuit in press circuit. For example, the left cylinder the clamping cylinder C1 could extend and clamp a work piece. Then the right cylinder C2, the punching cylinder extends to punch a hole in the work piece. The right cylinder then retracts the punch , and then the left cylinder retracts to declamp the work piece for removal.



Cylinder Sequencing circuit

Automatic Cylinder Reciprocating System:

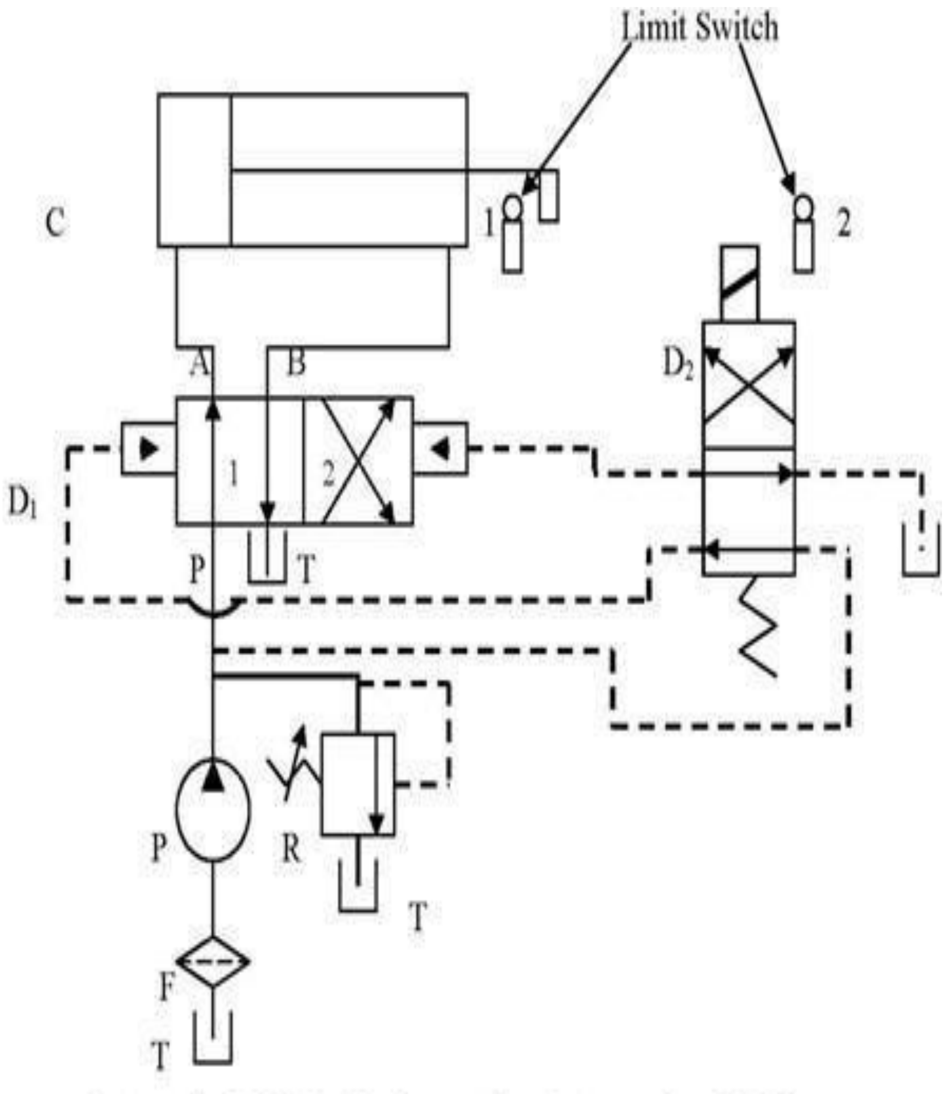
Using Sequence Valves Operation: In the left position of valve shown, P is connected to rod-side, and the rod retracts. After piston reaches the left end, pressure builds up on rod side which opens the sequence valve on the right and permits pilot hydraulic line to act on the main DCV to switch to right position. Check valves allow pilot oil to leave either end of the DCV while pilot pressure is applied to the opposite end.



Automatic Cylinder Reciprocating System using Sequence valves

An alternative circuit is shown using limit switches and solenoid valve, and a pilot operated DCV. . Operation: Suppose the left position of the main DCV is on. Then the piston rod moves to right > It hits the limit switch 2 > which energies solenoid valve D2 > which shifts the solenoid operated DCV (D2) to position (top as shown) > which now permits pilot oil from D2 to right end of DCV D1 > changes D1 position 2 > flow is now to rod end > rod moves to left till it hits limit switch 1.

Now the reverse of the above sequence is repeated so that Position 1 of the main DCV becomes operative. Thus it leads to automatic reciprocation of the actuator between the limit switch positions.Circuits are shown for synchronizing the operation of two cylinders (i.e., simultaneous equal movement).

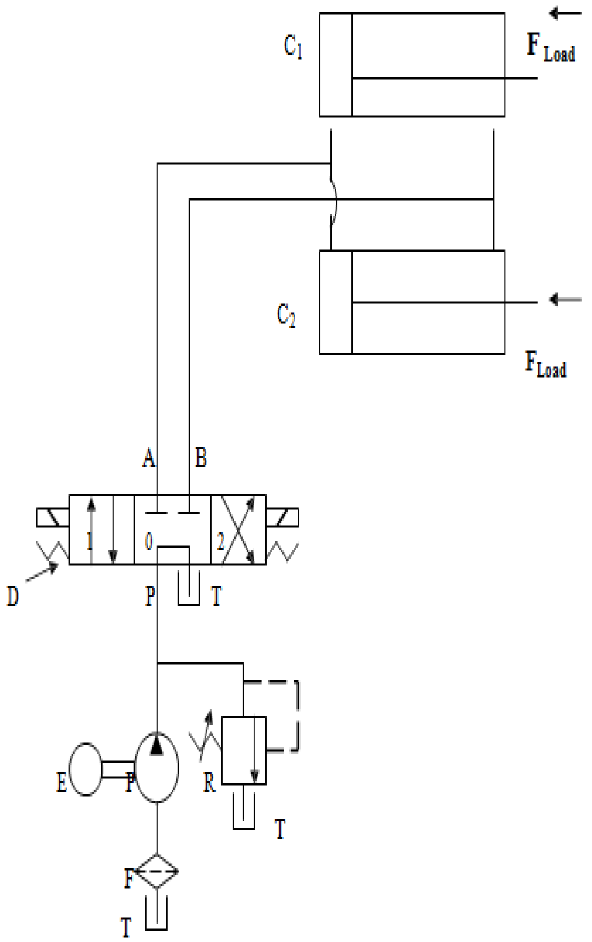


Automatic Cylinder Reciprocating System using DCV's.

Cylinder connected in Parallel:

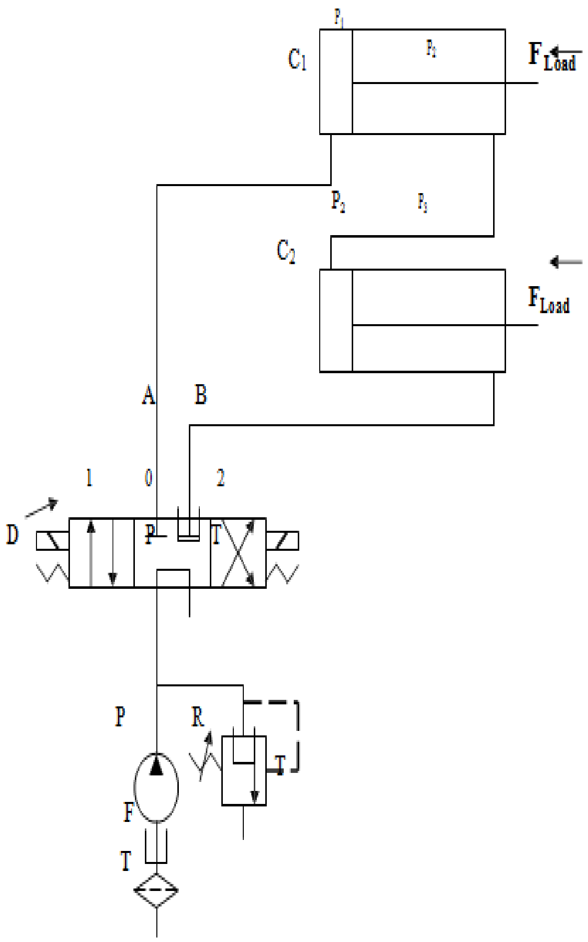
In the circuit shown, piston or rod ends of both cylinders are connected to one line. Thus oil flows simultaneously. However, if load on one cylinder is more, the other cylinder needing less pressure operates first, and after completion of stroke, pressure builds up to operate the second cylinder. This operation is not synchronized. The problem may arise with slight differences in the size of cylinders as well.

Cylinders connected in Series: The rod end of C1 is connected to piston end of C2. Thus C1 and C2 have to move together. However, for to have equal stroke, rod end area of C1 should be equal to piston area of C1. Also, rod end of C2 has to have high pressure to do work by C2. Hence piston side pressure would be that much higher.



Cylinder hooked in parallel for synchronizing

(will not operate)



Cylinder hooked in Series for synchronizing

(Will Operate)

Cylinder connected in Parallel

Speed Control:

Speed control of Hydraulic Cylinder: Speed control of a hydraulic cylinder is accomplished using a flow control valve. A flow control valve regulates the speed of the cylinder by controlling the flow rate to and of the actuator.

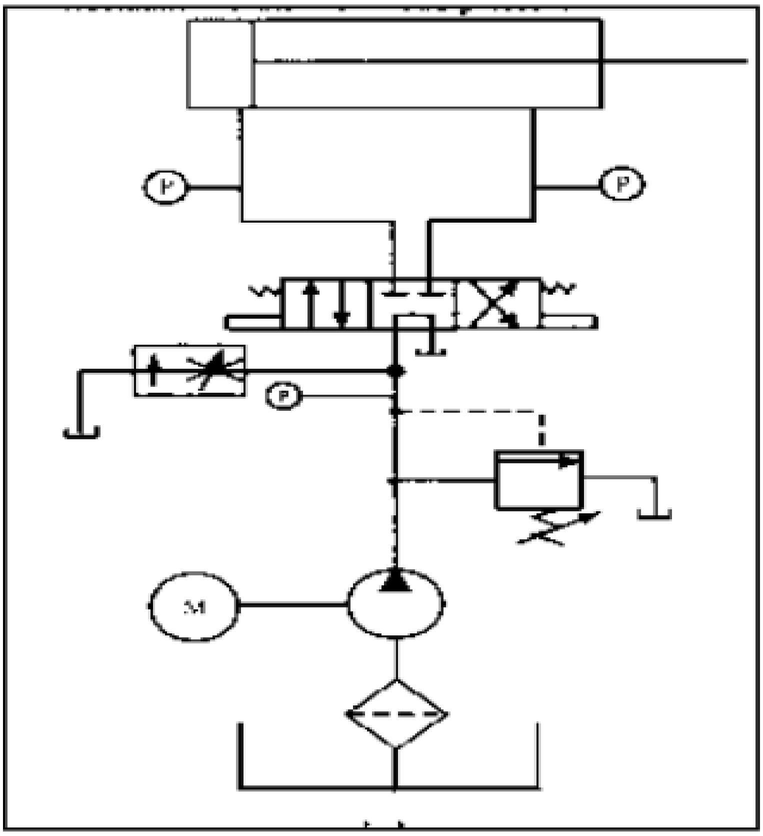
There are 3 types of speed control:

- Meter-in circuit (Primary control)
- Meter-out circuit (Secondary control)
- Bleed -off circuit (By pass control)

Meter – in Circuit: In this type of speed control, the flow control valve is placed between the pump andthe actuator. Thereby, it controls the amount of fluid going into the actuator. Figure below shows meter-in circuit.When the direction is reversed, oil from piston side flows to tank via check valve as well as FC valve freely. The excess flow is dumped to tank via relief valve.

Meter – out Circuit: In this type of speed control, the flow control valve is placed between the actuator and the tank. Thereby it controls the amount of fluid going out of the actuator and thereby the speed of retraction. Meter out circuits are useful to control free fall of loads due to gravity etc. connected to the load. Oil is dumped at load pressure but not at relief valve set pressure. However, meter –out can lead to high pressure intensification sometimes twice supply pressure, leading to damage of seals etc. Still it is favored in drilling, reaming and milling when it is required to control the tool feed rate.

Bleed off circuit: This circuit is used to overcome the disadvantages of meter-in and meter- out circuits. Here, a flow control valve is kept between either ends. Flow is controlled in each direction, and excess flow to tank is not through relief valve.



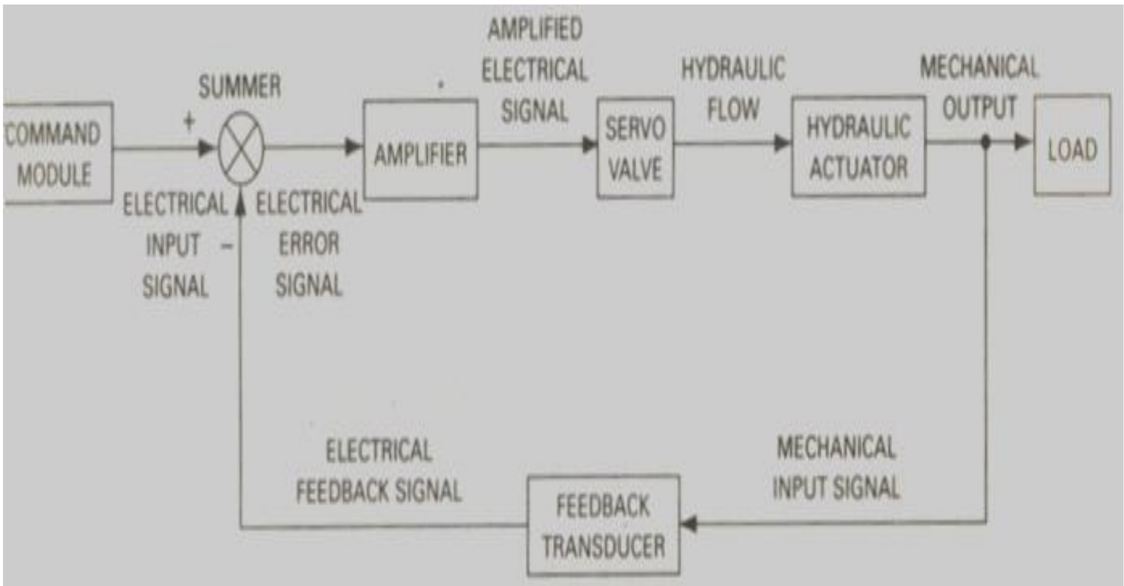
Hydraulic Servo Systems:

Servo systems refer to systems where automatic control of actuator movements is required. These movements should be as per a predetermined rate and deviations should be reduced to a minimum.

A servomechanism is an automatic control system designed to operate in accordance with input control parameters. The mechanism continuously compares the input signal to the feedback signal to adjust the operating conditions to correct error.

Applications: Hydraulic servo systems are widely used in the airline, maritime, and military applications. Servo systems capable of automatic position, speed, force control with high accuracy are used in high- speed injection molding, die casting, rolling mills, presses, industrial robots, flight simulators testing machinery and table feeders.

For achieving automation, a feedback signal, using a sensor, from the actuator or any variable to be controlled such as actuator force or velocity or displacement or angle of rotation of a rotary actuator is required. This feedback signal is compared with the reference input and a suitably modified signal is sent to the flow control valve to thereby control the required variable. A block diagram representation of a hydraulic servo system is shown below.



Block diagram of an electrohydraulic servo system
(closed-loop system).

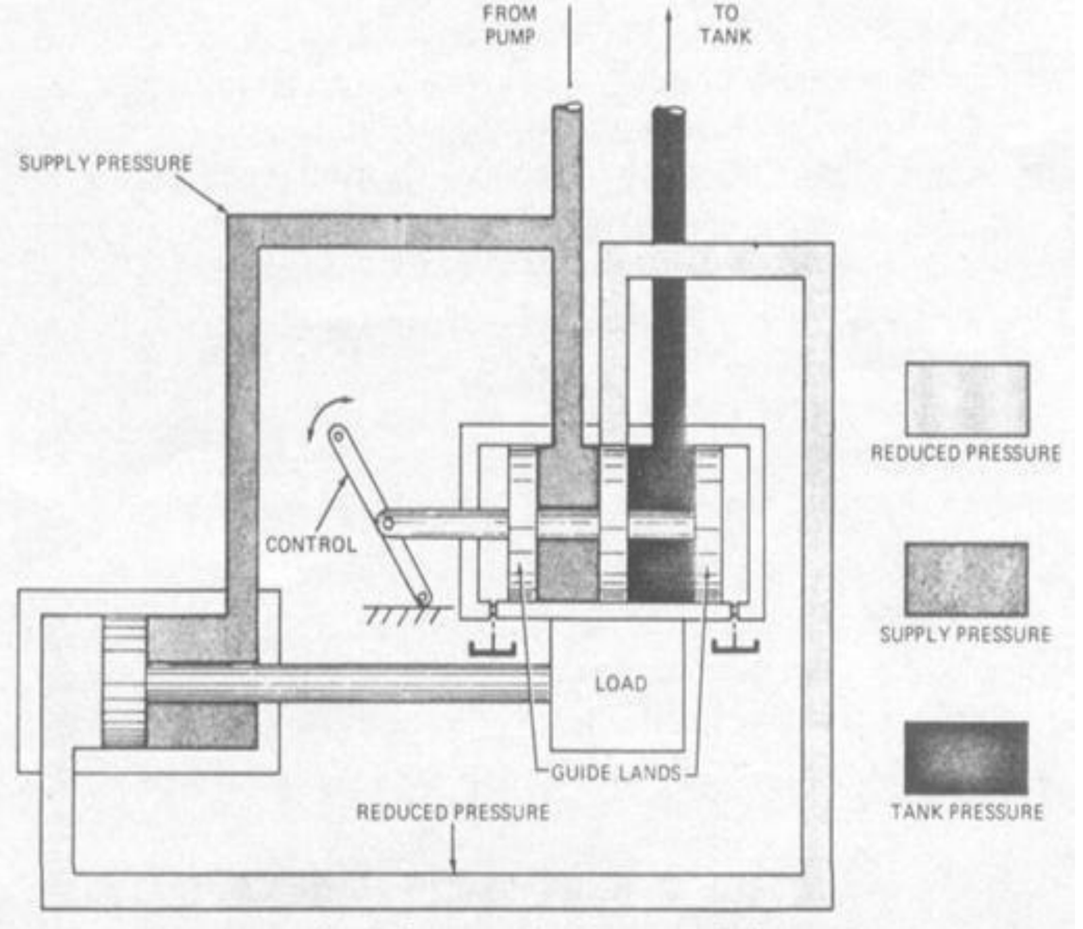
A Mechanical servo system:

In this system shown in the figure, load is connected to the valve spool, and special sensors and electrical components are not required.

Operation:

Input movement to the valve opens the spool (to left) for certain flow rate.The flow actuates the piston and the load to left.

The load, being connected to the valve body, also moves to left, while the spool is in the same position. Thus the opening of spool is gradually reduced as the piston moves. When the piston moves by the distance of initial spool movement, spool close the port opening and flow becomes zero. Thus Input movement of spool is related to the load movement. Thus this arrangement provides a feedback signal. A separate link can be connected to valve spool, cylinder rod and the input, to achieve a ratio of output/input other than 1.



Elec'ro-mechanical servo, also known as follow valve.

Proportional type valves:

Valves explained so far are on-off type, i.e., they take distinctly one of the two or three positions letting full flow in either direction or stop the flow. However for servo systems valves which operate in an analog fashion, ie continuously variable control are required.

Special valves:

In view of the continuous control, special proportional control valves are used which produce movement of the spool proportional to an electrical signal. The signal given to the valve is the error signal (difference between the reference input and that sensed by the actuator), so that the system corrects to make the error zero, or actuator achieves the desired parameter.

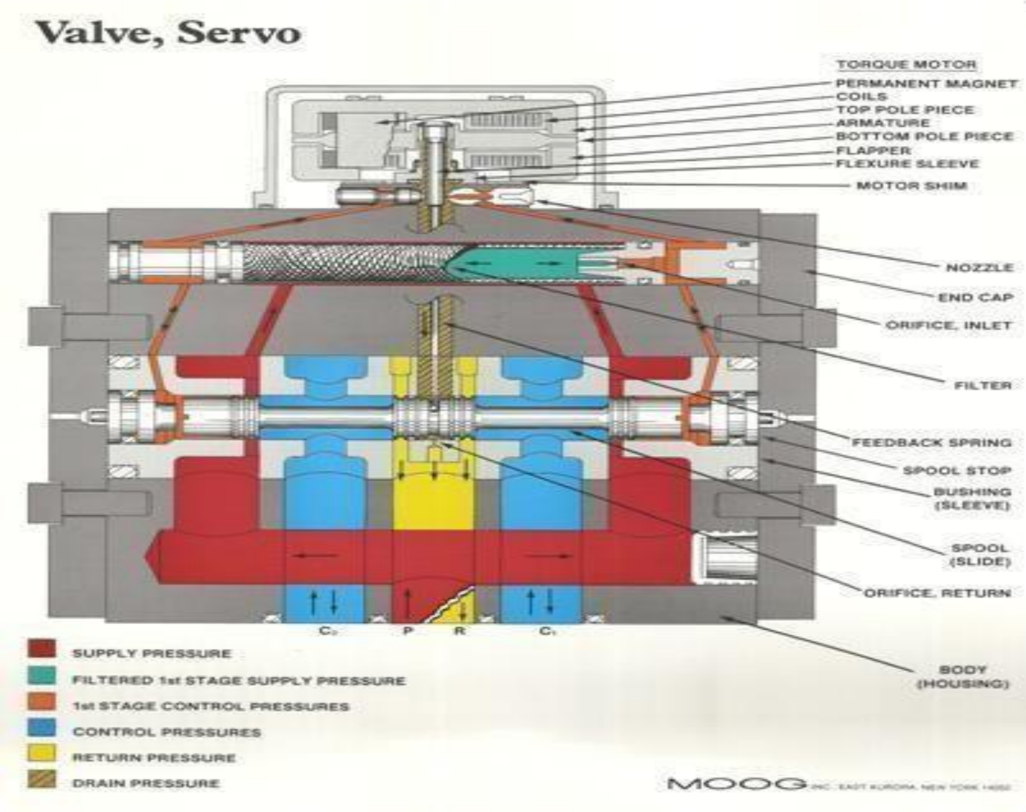
Electrohydraulic Servo System:

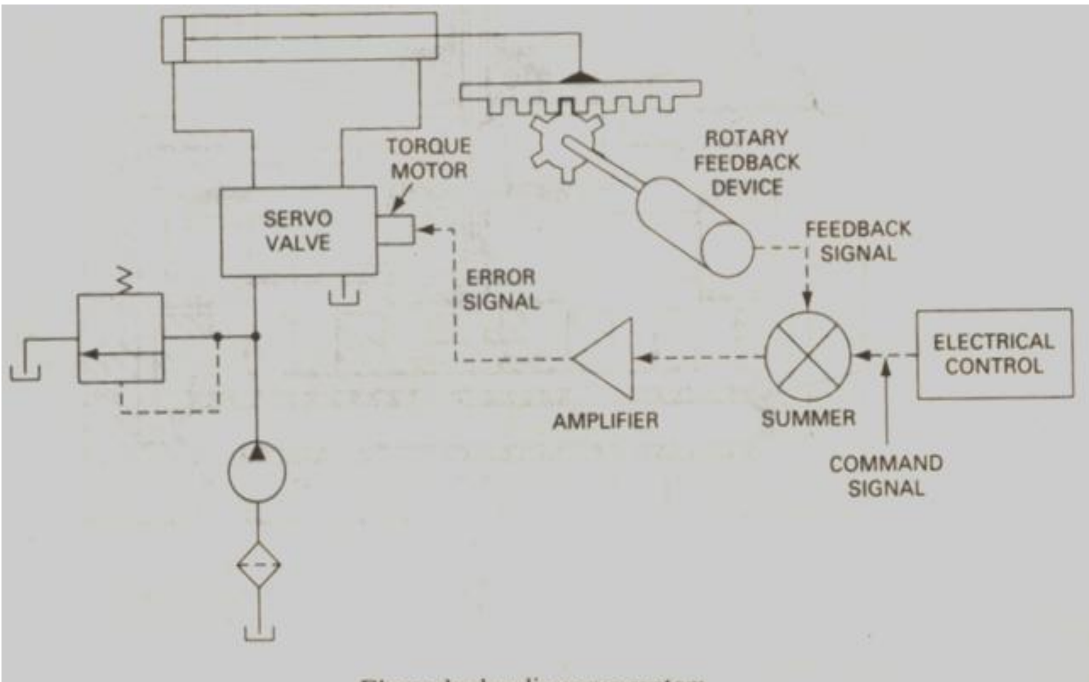
For highly accurate control as in aerospace systems and some machine tools, a two- stage electro hydraulic servo valve is used.

In this valve, an electrical input signal operates a torque motor , which turns a flapper which runs between two nozzles > which varies the back pressures at two nozzles > backpressures act at either end of the main spool > which moves the spool and lets certain flow > which in turn moves the flapper at the nozzles in opposite direction to that produced by torque motor > which in turn changes the feedback pressures acting on spool > spool keeps on moving this way till flapper comes to the middle of nozzles, when the back pressures acting on spool are equal> spool movement stops.

With the above sequence of operations, it can be seen that magnitude of spool movement or of the corresponding flow is related to the input current or voltage signal to the servo valve.

These valves are highly accurate but cost can be very high ranging from Rs. 3 to Rs. 10 lakhs and higher.





Electrohydraulic servo system.

9-3 Electro-Hydraulic Two-Stage Servo Valves

Nearly all types of servo valves are based on common principles. Electro-hydraulic two-stage servo valves generally operate with force feedback. Given that valve pressure drop is constant, the valves control the output flow in proportion to the input signal. Therefore, they can be used to drive a hydraulic cylinder or motor at a speed proportional to the input current.

Figure 9.5 provides illustrations of an electro-hydraulic servo valve. The valve contains identical torque motors in parallel, which serve as a nozzle flapper amplifier with movable coils and nozzles. Coil displacement always determines the spool position. To ensure reliable pilot operation, the valve is provided with a filter prior to the pilot line, as well as a high-performance line filter prior to the valve inlet. Table 9.1 shows valve specifications, and Fig. 9.6 provides frequency response variations.

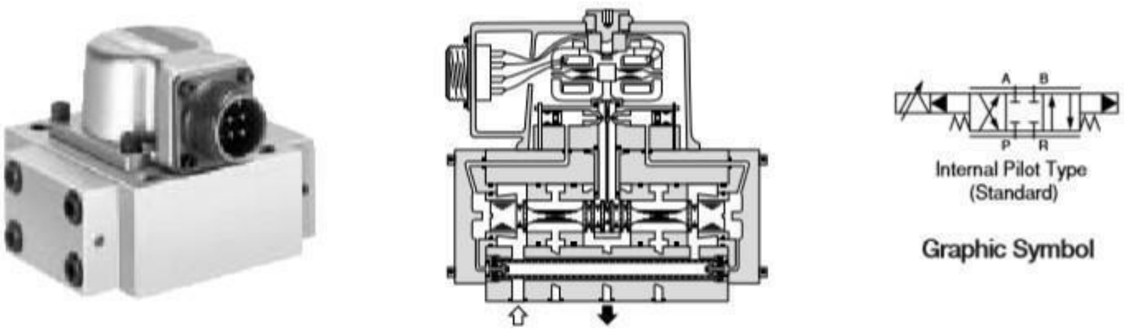


Fig. 9.5 Electro-Hydraulic Servo Valve

9-1 Servomechanism (Tracking Mechanism)

A servomechanism is an automatic control system designed to operate in accordance with input control parameters. The mechanism continuously compares the input signal to the feedback signal to adjust the operating conditions for error correction. Commercially available servo systems vary according to their methods for error detection, amplification, communication, and output.

Hydraulic servo systems have been widely applied in general industrial areas, as well as in the airline, maritime, and military industries. Servo systems, capable of automatic position, speed, and force (load) control with high accuracy and quick response, are used for high-speed injection molding, die-casting, rolling mill, press machines, industrial robots, simulators, testing machinery, and table feeders.

A hydraulic servo system consists of an actuator (hydraulic motor/cylinder), servo valves, sensors, and a servo amplifier, as shown in Fig. 9.1. Figure 9.2 shows a servo system applied to a high-speed vibration test machine.

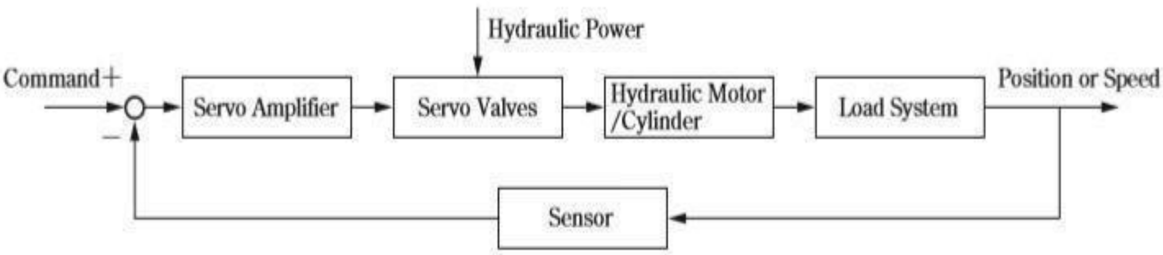
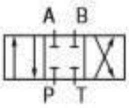
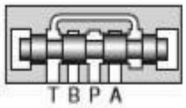
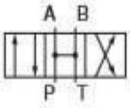
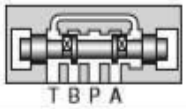
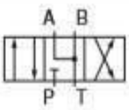
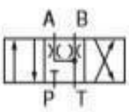
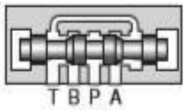
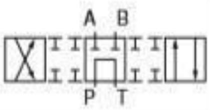
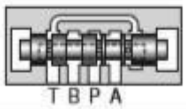
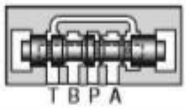
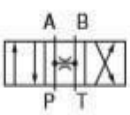
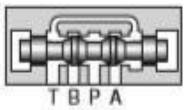
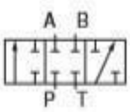
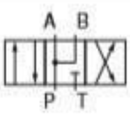
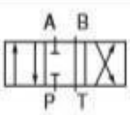
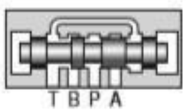
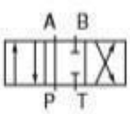
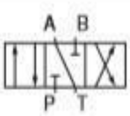
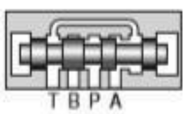


Fig. 9.1 Servo System Configuration

Table 4.2 Spool Types

Spool Type		Graphic Symbol	Valve and Spool (Neutral Position)	Function and Usage
"2"	Closed-Center			Maintains the pump pressure and cylinder position in the neutral position. For the two-position type, each port is blocked during the spool transition, causing shock to the system line. This type requires due caution.
"3"	Open-Center			Unloads the pump and floats the actuators in the neutral position. For the two-position type, each port is connected to the tank during the spool transition; thus, shock can be reduced.
"4"	ABT Connected			Maintains the pump pressure and floats the actuator in the neutral position. The two-position type is used to maintain the system pressure during the spool transition. Shock is reduced compared to the type "2."
"40"	ABT Connected, with Throttle			A variation of the type "4," having throttles between A to T and B to T. It can quickly stop the actuator.
"5"	PAT Connected			Used to unload the pump in the neutral position and stop the actuator by feeding flow in one way.
"6"	PT Connected (Closed during Transition)			Unloads the pump and maintains the actuator in the neutral position. It allows valves to be connected in serial.
"60"	PT Connected (Opened during Transition)			A variation of the type "6." Each port is connected to the tank during the spool transition; thus, shock can be reduced.
"7"	Center Opened, with Throttle			Mainly used for the two-position type; shock can be reduced during the spool transition.
"8"	Two-Way			Maintains the pump pressure and cylinder position in the neutral position, similar to the type "2." Used as a two-way directional control valve.
"9"	PAB Connected			Forms a differential circuit in the neutral position.
"10"	BT Connected			Prevents one-way minor sliding of the actuator due to leak at the port P in the neutral position.
"11"	PA Connected			Blocks one end and feeds flow from the other end to completely stop the actuator in the neutral position.
"12"	AT Connected			Able to prevent the actuator from minor one-way sliding due to leak at the port P in the neutral position.

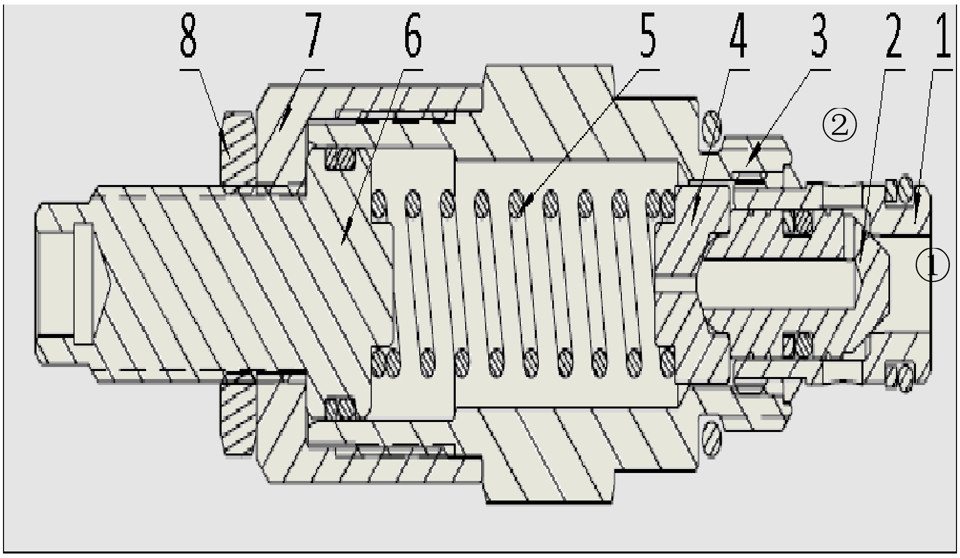
Pressure Control Valve:

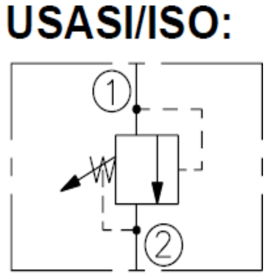
Pressure control valve on the hydraulic power unit with pressure relief valve, sequence valve, relief valve, pressure relay-based. Almost each hydraulic power unit complete with a relief valve. Sequence valve, relief valve and pressure switch on some special hydraulic power unit having a sequence of actions and the same system have different working pressures used, such as Dock leveler hydraulic power units for logistics equipment and Paper Cutter production line hydraulic power units.

Relief Valve: Umbrella of hydraulic power unit:

Pressure relief valve on the hydraulic power unit primarily as a security role, limit the maximum pressureto avoid other hydraulic components, pipe damage. As part of a back pressure relief valve in the hydraulic power unit, causing back pressure to increase the stability of motion.

Hydraulic-Symbol





valve body 2—valve spool 3—valve body 4—spring seat 5—spring 6—adjusting lever 7—screw-in body 8—Locking nut

How Relief valve works:

Under normal ①chamber to chamber ②closed until the liquid pressure chamber ①sufficient to overcome the spring force of the valve body from the valve seat, ① communicating with the chamber ②, the flow of oil from the chamber

Directional Control Valve:

Hydraulic power units varied different types of directional control valve, check valve, P-O-check valve, shuttle valve, solenoid valve, hydraulic control valve, electric proportional valve and so on.

a Check valve –(one-way valve) oil traffic in one-way.

One-way valveis also known as a check valve, which allows fluid only in one direction through the reversing valve closing direction.

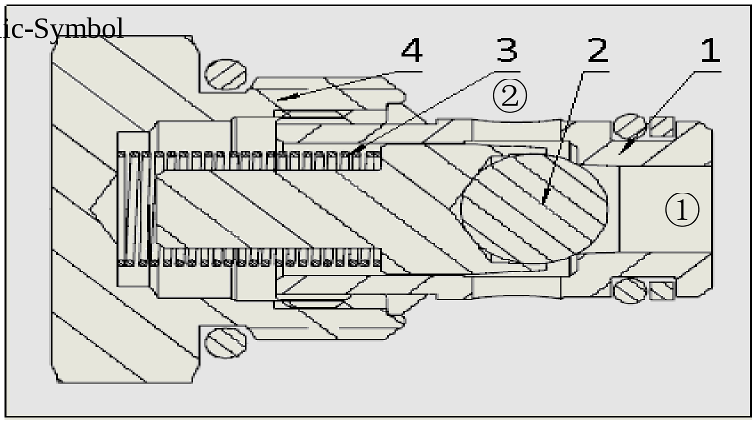
The main role of the check valve in the hydraulic power unit are:

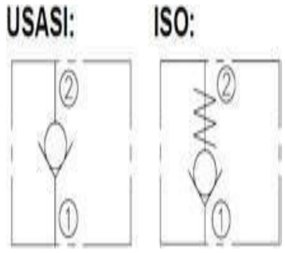
To keep the system pressure constant period of time and other pressure retaining components, installation preventing normal operation of the hydraulic pump hydraulic shocks in pump outlet position, the check valve installed in the back part oil used as a back-pressure valve.

According to the role of one-way valve in the hydraulic power unit, his performance was mainly:

- Oil pressure loss circulation of small forward,
- Reverse seal better performance,
- Quick action,
- Low noise.

draulic-Symbol





2- Valveseat 2-Checkvalvespool 3-Spring

4-Screw PlugHow Check valve works

The pressure port ① is higher than the pressure port ② plus spring force, the spool is pushed, the channel is open, fluid forward through the check valve (①flow to ②).When the port ② pressure plus the spring force is higher than the port ① pressure spool is pressed against the spring force and fluid pressure on the valve seat, the flow is turned off. b directional valve - oil traffic red and green lights. Directional valve is the largest amount components of Hydraulic power unit request.

Directional valve use of different relative positions in hydraulic power pack. Hydraulic power unit requirements: the oil through a less pressure loss, less amounts of the oil leakage gap between the mouth commutation reliable, sensitive, reversing smoothly without impact.

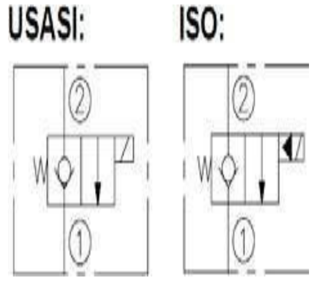
According manipulation way valve used in the hydraulic power unit valve can be divided into:

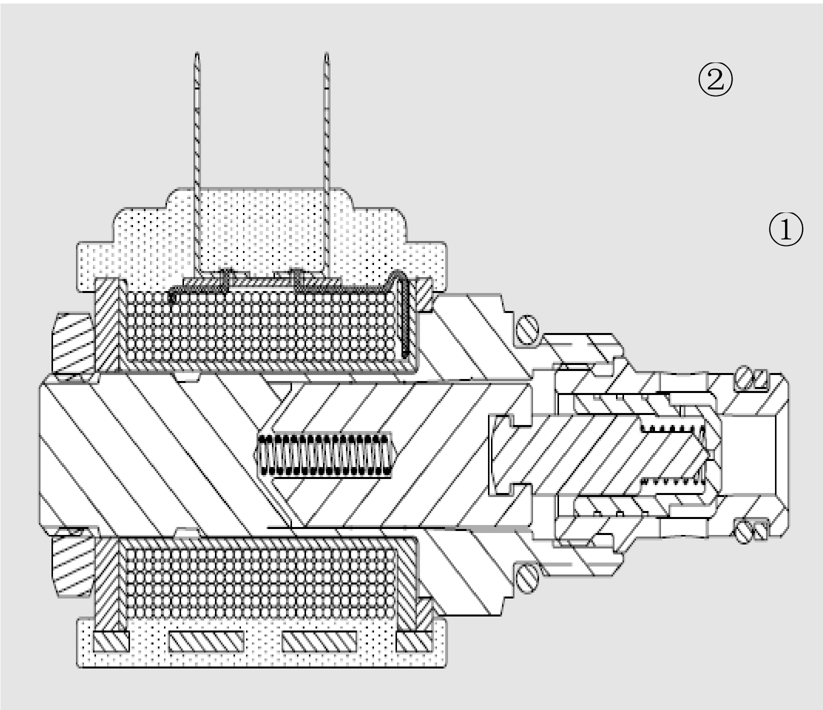
Manual Valve,

Solenoid Valve,

Motorized Valve.

For example, in the automotive lift hydraulic power unit, electric pallet truck hydraulic power unit, electric car pushing hydraulic power unit, hydraulic power units and other Tipper trailers on two two-way solenoid valves with the most.



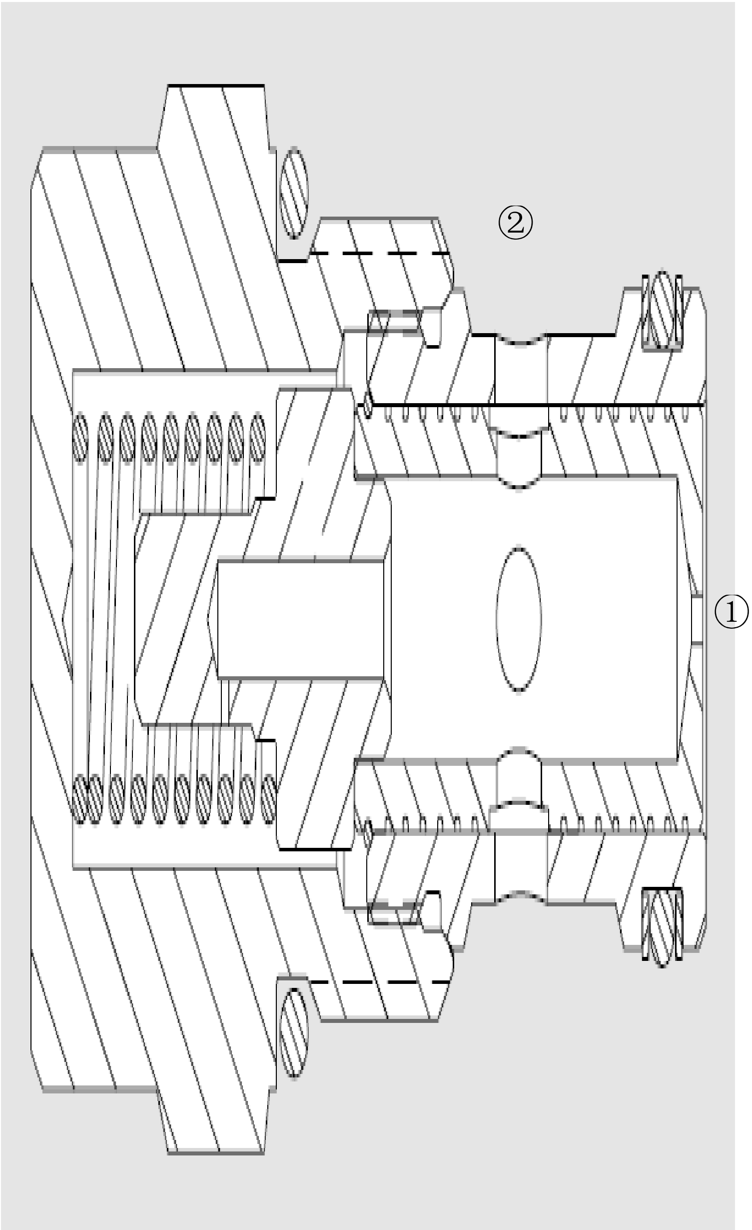


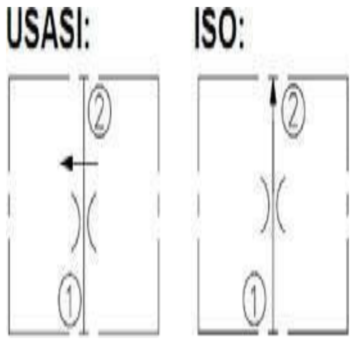
Hydraulic power unit valve : Hydra force SV type two two-way solenoid valve works

When the solenoid valve coil power, the two two-way solenoid valve can do a one-way valve to allow flow from ①to ②chamber cavity, and the cavity reverse blocking oil from ②to ①,Solenoid valve coil is energized, the lifting force generated by the coil, valve open, fluid chamber from ②to ①, ②and ① chamber to the fluid chamber due to structural reasons strong resistance.

Flow Control Valve:

Flow control valve referred to the flow valve, is by changing the orifice flow area to achieve flow control.It is a control valve components to control the speed of movement of the element. Flow valve can be opened as a small mark of "taps." Flow valve can generally be divided into: a throttle valve, 2-way flow control valve (also known as pressure-compensated flow valve), the three-way flow control valve. Currently on the hydraulic power unit is mainly used Hydraforcecompany NV Throttle and Comatrol's SC13 type 2-way flow valve.





Hydra force FR-type pressure compensated flow control valve works:

FR-type pressure compensated flow control valve ②from holding chamber effluent flow rate constant and is not affected by the load pressure changes in the circuit downstream of the chamber ②, when the flow through the valve in the control orifice pressure differential created more than 5.5bar, valve beginsresponse to load changes within a pressure range of 7.6 ~ 240bar can maintain accurate flow, reverse flow (chamber ②to chamber①) through the control orifice, no pressure compensation, and orifice same.

Third, the auxiliary section:

Hydraulic auxiliary components of the hydraulic power unit are a "supporting role", but it is also an important part of the hydraulic power unit. Types of hydraulic auxiliary element are varied, including: tank, filter, and suction pipe, return pipe, an intermediate manifold, control switches, pressure gauge, accumulator, and so on. The right choice and ensure the rational use of the hydraulic power unit is reliable, stable and has a very important auxiliary hydraulic components.

Tank - the hydraulic medium required for storage of the hydraulic system, as a heat sink, the role of the liquid medium in air separation and precipitation of impurities.

Filter - filtration of impurities mixed in with the oil, foreign particles in a controlled hydraulic power unit normal operating range, the protection of hydraulic components.

Central manifold - Installation Connecting the motor and gear pump, simplifying the piping, integrated control valve of the hydraulic power unit compact and convenient.

Replace with a different intermediate manifold control valve can be achieved on different principles of hydraulic power unit, which makes the intermediate manifold high versatility.

Cooling Hydraulic Oil: Two types of heat exchanger are used to cool hydraulic oil:

- shell-and-tube and
- Finned tube.

The shell-and-tube has a series of tubes inside a closed cylinder. The oil flows through the small tubes, and the fluid receiving the heat (typically water) flows around the small tubes. Routing of the oil can be done to produce a single pass (oil enters one end and exits the other end) or a double pass (oil enters one end, makes a u-turn at the other end, and travels back to exit at the same end it entered).

The finned tube exchanger is used for oil-to-air exchange. The air may be forced through the exchanger with a fan or may flow naturally. If an oil cooler is used on a mobile machine, it is the finned tube type.

Oil coolers are not built to withstand pressure; they are mounted in the return line in an off-line loop. The two options used are the system pump flows oil through the heat exchanger in the return line. This arrangement works well for many circuits. The exchanger is sized to give only a small pressure drop at rated flow. The circuit has a separate low-pressure pump to flow oil through the heat exchanger.

More complex circuits can have significant pressure pulses in the return line. These pulses hammer the heat exchanger and, over time, the joints fracture and begin to leak. If significant (greater than 10 psi) pulses are measured in the return line, the circuit should be used. Here, a separate pump is used to circulate oil from the reservoir through the heat exchanger and back to the reservoir. This circulating pump does not have to build pressure (only the 15 psi or so is required to flow fluid through the exchanger); therefore, it can be an inexpensive design. Any kind of pump is satisfactory if it is rated for the needed flow rate and has seals that are compatible with the fluid properties.

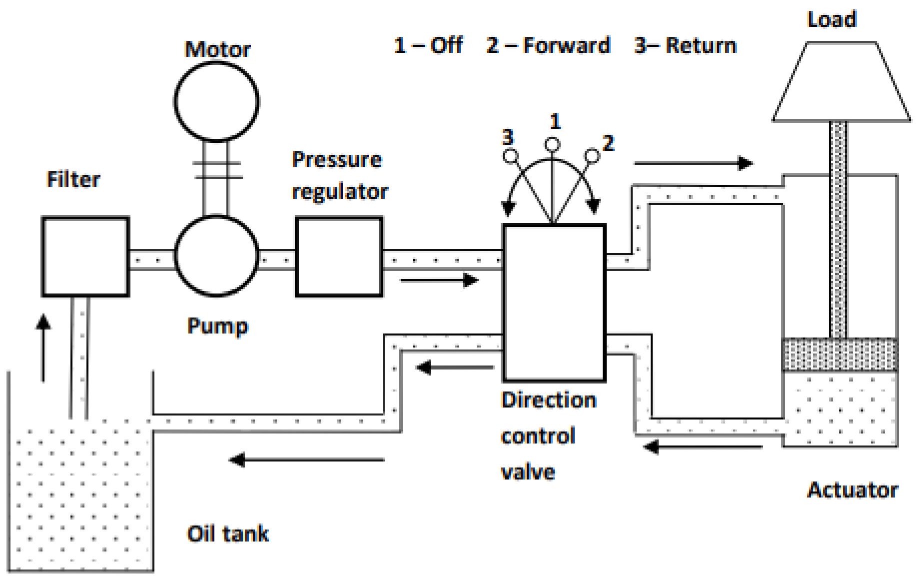
UNIT IV PNEUMATIC AND ELECTRO PNEUMATIC SYSTEMS

Introduction:

Typical hydraulic circuits for control of industrial machinery are described in this lesson. Graphical hydraulic circuit diagrams incorporating component symbols are used to explain the operation of the circuits.

Basic Components of a Hydraulic System:

Hydraulic systems are power-transmitting assemblies employing pressurized liquid as a fluid for transmitting energy from an energy-generating source to an energy-using point to accomplish useful work. Figure 1.1 shows a simple circuit of a hydraulic system with basic components.



Hydraulic System

Functions of the components shown are as follows:

- The hydraulic actuator is a device used to convert the fluid power into mechanical power to douseful work.
- The actuator may be of the linear type (e.g., hydraulic cylinder) or rotary type(e.g., hydraulicmotor) to provide linear or rotary motion, respectively.
- The hydraulic pump is used to force the fluid from the reservoir to rest of the hydraulic circuit byconverting mechanical energy into hydraulic energy.

Valves are used to Pressure regulator

External power supply (motor) is required to drive the pump.

Reservoir is used to hold the hydraulic liquid, usually hydraulic oil.

Piping system carries the hydraulic oil from one place to another.

Filters are used to remove any foreign particles so as keep the fluid system clean and efficient, as well as avoid damage to the actuator and valves.

Pressure regulator regulates (i.e., maintains) the required level of pressure in the hydraulic fluid.

The piping is of closed-loop type with fluid transferred from the storage tank to one side of the piston and returned back from the other side of the piston to the tank.

Fluid is drawn from the tank by a pump that produces fluid flow at the required level of pressure. If the fluid pressure exceeds the required level, then the excess fluid returns back to the reservoir and remains there until the pressure acquires the required level. Control the direction, pressure and flow rate of a fluid flowing through the circuit. Motor 1 – Off 2 – Forward 3– Return 3 2 1 Load Direction control valve Pump Oil tank Filter Actuator.

Cylinder movement is controlled by a three-position change over a control valve:

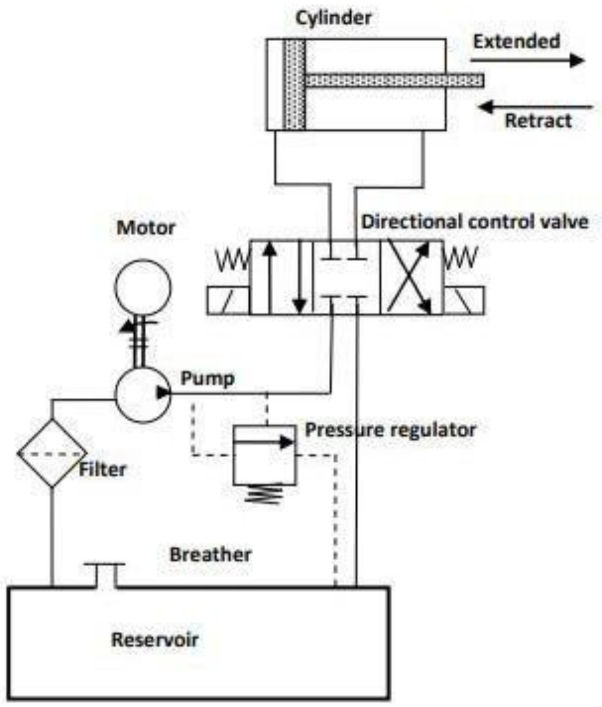
When the piston of the valve is changed to upper position, the pipe pressure line is connected to port A and thus the load is raised.

When the position of the valve is changed to lower position, the pipe pressure line is connected to port B and thus the load is lowered.

When the valve is at center position, it locks the fluid into the cylinder(thereby holding it in position) and dead-ends the fluid line (causing all the pump output fluid to return to tank via the pressure relief).

In industry, a machine designer conveys the design of hydraulic systems using a circuit diagram.

The components of the hydraulic system using symbols. The working fluid, which is the hydraulic oil, is stored in a reservoir. When the electric motor is switched ON, it runs a positive displacement pump that draws hydraulic oil through a filter and delivers at high pressure. The pressurized oil passes through the regulating valve and does work on actuator. Oil from the other end of the actuator goes back to the tank via return line. To and fro motion of the cylinder is controlled using directional control valve.



Control Valve

The hydraulic system discussed above can be broken down into four main divisions that are analogous to the four main divisions in an electrical system.

- The power device parallels the electrical generating station.
- The control valves parallel the switches, resistors, timers, pressure switches, relays, etc.
- The lines in which the fluid power flows parallel the electrical lines.
- The fluid power motor (whether it is a rotating or a non-rotating cylinder or a fluid power motor) parallels the solenoids and electrical motors.

Case Study I: Unloading System for Energy Saving

An ―unloading‖ system is used to divert pump flow to a tank during part of the operational cycle to reduce power demand. This is done to avoid wasting power idle periods. For example, it is often desirable to combine the delivery of two pumps to achieve higher flow rates for higher speed while a cylinder is advancing at low pressure. However, there may be considerable portions of the cycle, such as when the cylinder is moving a heavy load, when the high speed is no longer required, or cannot be sustained by the prime mover. Therefore, one of the two pumps is to be unloaded resulting in a reduction of speed and consequently, power.

The components of this system are:

A, B: Hydraulic pumps,

C, E: Pilot operated spring loaded Relief valves,D: Check valve.

The hydraulic system discussed above can be broken down into four main divisions that are analogous to the four main divisions in an electrical system.

- The power device parallels the electrical generating station.
- The control valves parallel the switches, resistors, timers, pressure switches, relays, etc.
- The lines in which the fluid power flows parallel the electrical lines.
- The fluid power motor (whether it is a rotating or a non-rotating cylinder or a fluid power motor)parallels the solenoids and electrical motors.

Mode 1: Both Pumps Loaded:

When both pumps are delivering, oil from the pump A passes through the unloading valve C and the check valve D to combine with the pump B output. This continues so long as system pressure is lower than the setting of the unloading valve C.

Mode 2: One pump unloaded:

When system pressure exceeds the setting of the unloading valve C, it makes pump A to discharge to the tank at little pressure. Although the system pressure, supplied by pump B, is high, the check valve prevents flow from B through the unloading valve. Thus only pump B now drives the load at its own delivery rate. Thus the load motion becomes slower but the power demand on the motor M also reduces. If the system pressure goes higher, say because load motion stops, pump B discharges when its relief valve settings would be exceeded.

Points to Ponder: 1

Can you imagine what would happen, if the check valve was not present?

How would you modify the system if you wanted to unload pump B instead of pump A?

Case Study II: Selection of System Operating Pressure

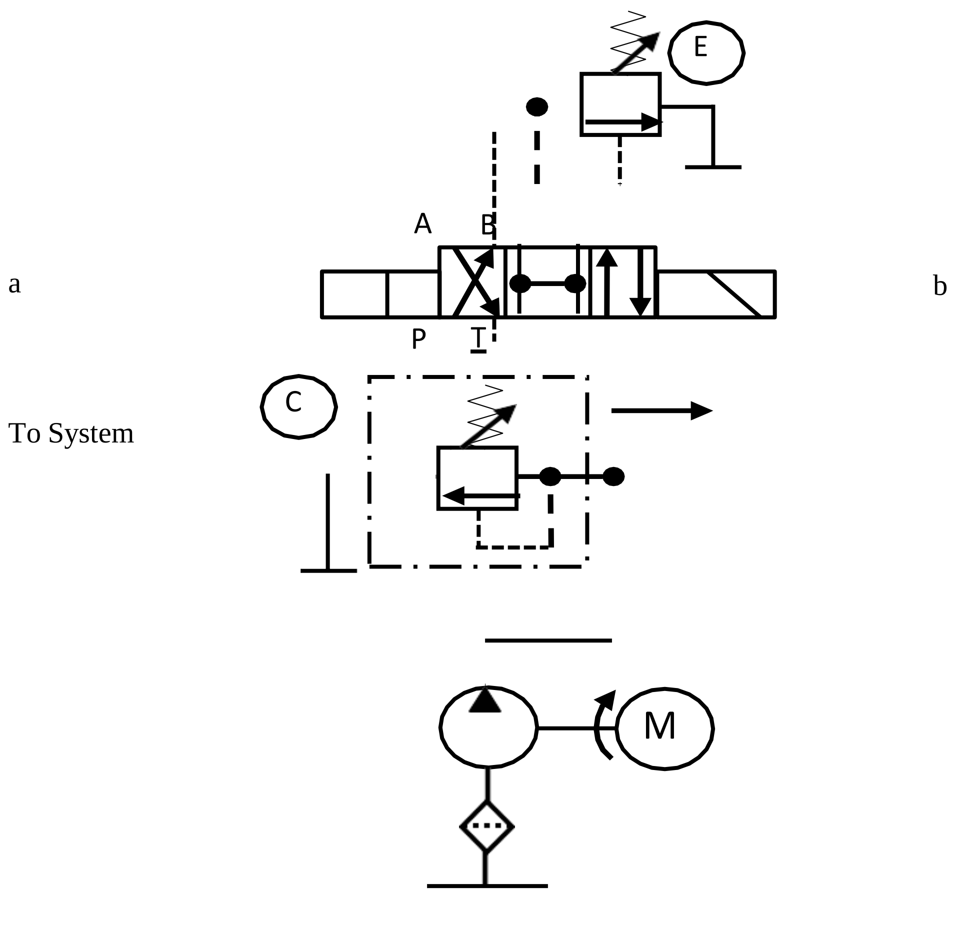
The circuit allow selection of operating pressure limits in a hydraulic system from three options, namely, two maximum pressures, plus venting. First note the components, namely, A: Reservoir with Filter, B: Hydraulic Pump, C, E: Pilot Relief Valve, D: Solenoid activated Four-way Directional valve.

Venting Mode:

Both solenoids a and b of the directional valve D are de-energized. The open- center spool is centered by the valve springs, and the vent port on the relief valve is opened to tank. Therefore, the pump flow opens to tank at a very low pressure.

Intermediate Maximum Operating Pressure:

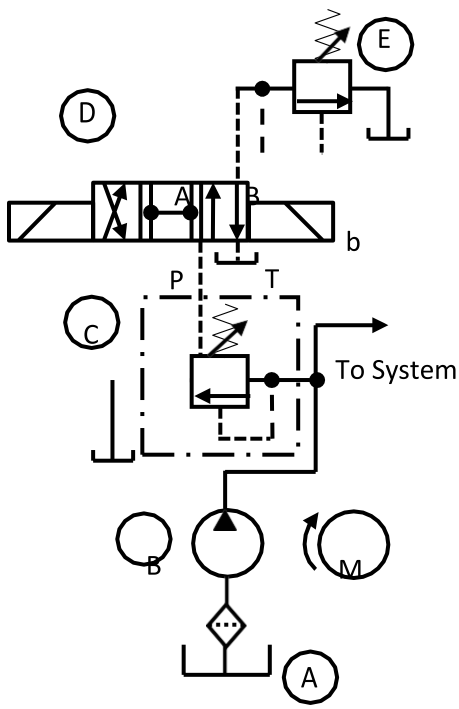
The left-hand solenoid a of the directional valve is energized. The valve spool is shifted to the leftmost position and connects the relief valve vent port to the remote control valve. Pump flow is now diverted to tank when the pressure setting of the remote valve E is reached.



Operating Mode with Intermediate Maximum Operating Pressure

High Maximum Pressure:

The right solenoid b of the directional valve is energized. The spool now shifts right to connect the relief valve vent port to a plugged port in the directional valve. The relief valve C now functions at the setting of its integral pilot stage.



Operating Mode with High Maximum Operating Pressure

Points to Ponder: 2

Why are lines connecting C to D and D to E marked in dashed lines?

Can you briefly describe a scheme to automate the above system such that whenever, in the intermediate pressure mode, pressure setting is exceeded, the system would automatically switch to the low pressure mode?

Case Study III: Reciprocating Cylinder with Automatic Venting at End of Cycle

A reciprocating cylinder drive is a very common hydraulic system. In systems where it is not necessary to hold pressure at the end of a cycle, it is desirable to unload the pump by automatically venting the relief valve, to save energy. Figures 28.5-28.8 show such a system. The system components are : A : Reservoir with Filter, B : Hydraulic pump, C, E : Check valve, D : Pilot operated relief valve, F : Two-position electro-hydraulic pilot operated Four-way Directional valve, G : Cam operated pilot valve, H : Double acting Single rod Cylinder, I : Limit Switch.

Retraction Stroke:

At the extreme end of the extension stroke, the limit switch is made on by the cylinder rod to break the solenoid circuit for the directional valve F. The directional valve now shifts to its right position and the pump gets connected to the rod end of the cylinder which now retracts. Note that the relief valve vent connection is still blocked.

Automatic Venting at End of Retraction Stroke:

At the extreme end of the retraction stroke, the cam on the cylinder separated by the rod to shift valve G. The relief valve vent port is thus connected, through E and G, to the line from the cap end of the cylinder, and to tank through the F and the inline check valve C. This vents the relief valve D and unloads the pump.

Push Button Start of Cycle:

If another cycle of reciprocating motion is desired, a start button connected to the solenoid circuit is depressed to energize the solenoid, and, in turn, the directional valve shifts to direct pump output into the cap end of the cylinder. This causes the check valve in the vent line to close. Pressure again builds up and the cylinder starts extending. This releases the cam, which, under spring action, shifts and the vent port of E is again blocked at G. Thus the cycle repeats.

Points to Ponder: 3

How does the solenoid get energized if the limit switch is made?

Is the speed of the cylinder going to be equal during extension and retraction? If not, then what decides the speeds?

Case Study IV: Regenerative Reciprocating Circuit

Conventional reciprocating circuits use a four-way directional valve connected directly to a cylinder. In a regenerative reciprocating circuit, oil from the rod end of the cylinder is directed into the cap end to increase speed, without requiring increasing pump flow. The circuit components are:

A : Hydraulic Pump,

B : Relief valve,

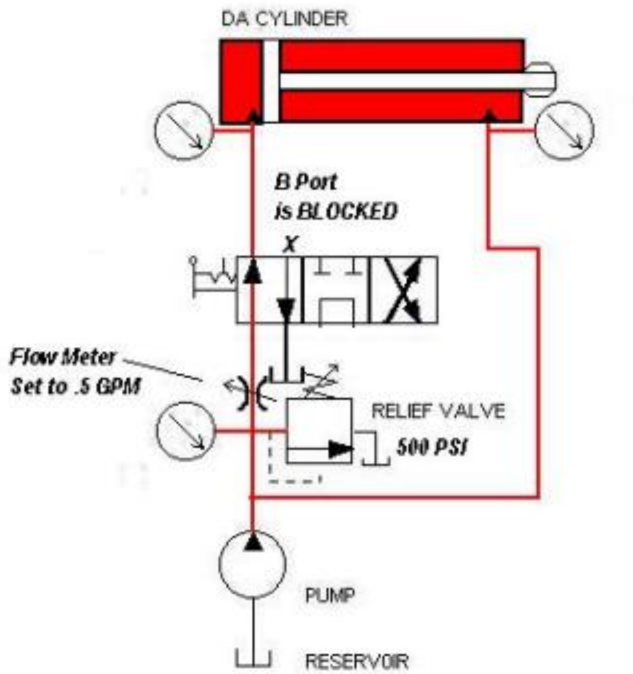
C : Four-way two position solenoid operated valve,

D : Double-acting Single-rod Cylinder.

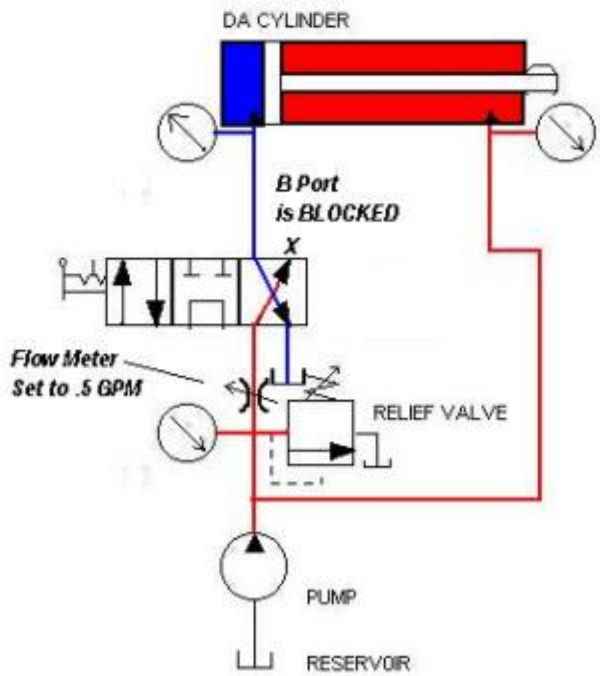
The operation of the regenerative circuit. Case, the force on the cylinder as well as the pump flow remains unchanged during extension and retraction. Thus, the speed of the piston during both advancement and retraction remain same.

Regenerative circuits are used when it is desirable to rapidly advance an actuator into position to reduce cycle time. When configured as a regenerative system, cylinders can be advanced more rapidly than in normal operation with the pump flow rate alone. In order to accomplish regeneration, the fluid leaving the rod end of the cylinder is routed back to the cap side of the cylinder to combine with the pump flow rate from the pump as shown in Figure.

Regenerative circuit (during extension)



Regenerative circuit (during retraction)



Case Study V: Sequencing Circuits

In many applications, it is necessary to perform operations in a definite order. Following is one of several such circuits.

The components of the system are as follows:

A : Reservoir and Filter ;

B : Hydraulic Pump ;

C : ; Relief valve : D ;

F1, F2, G : Relief valve with integral check valve ;H,

J : Cylinders ;

I : Check Valve

The sequence of operation realized by the circuit:

Step A – Extend Cylinder H

Step B – Extend Cylinder J while holding pressure on Cylinder HStep

C – Retract Cylinder J

Step D – Retract Cylinder H

Pressing a pushbutton would start the cycle and shift the directional valve E to the position. At first the fluid flows through the integral check valve in G into the cap end of H and returns freely through the check valve in F2. The pump pressure is low during this period, only to the extent of pushing the load on H.Once H reaches its rod end, the pressure builds up and now the flow develops through F1 into the cap end of J and out through the rod end to go back directly to tank through F2, E and C. Note that a pressure equal to the setting of the valve F1 is maintained on H. When J is fully extended, pressure increases further and is limitedby the setting of D, providing overload protection to B. Similarly, when the other solenoid of E is energized, the directional valve shifts to the other position. Now, pump delivery is directed through D, E and F2, into the rod end of J. As before, the flow out of the cap end of J flows to tank through F1, E and C. **Accumulators:**

A hydraulic accumulator is a device that stores the potential energy of an incompressible fluid held under pressure by an external source against some dynamic force. This dynamic force can come from different

Sources. The stored potential energy in the accumulator is a quick secondary source of fluid power capable of doing useful work. There are three basic types of accumulators. The main task of the hydraulic accumulator is to accumulate fluid under pressure and return it when necessary. Since the accumulator contains a fluid under pressure, it is treated as a pressure tank and must therefore be sized for the maximum operating pressure according to test regulations in force in the country where it is installed. To achieve the volume compensation and get the accumulation of energy, the fluid is pre-loaded by a weight, a spring or a compressed gas. Between the pressure of fluid and the counter-pressure exerted by the weight, the spring or the compressed gas must be in a constant state of equilibrium. Weight and spring accumulators are used in industry only in special cases and thus have a relative importance. Gas accumulators without a separating element are rarely used in hydraulics due to the absorption of gas by the fluid. In most of the hydraulic systems are then used the gas accumulators provided with a separating element between gas and fluid. Depending on the type of separating element, we can distinguish bladder, piston and diaphragm accumulators.

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.

Types of Accumulators with Separating Element:

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. Furthermore, the pressure exerted on the oil is not constant as in the dead-weight-type accumulator. As the springs are compressed, the accumulator pressure reaches its peak, and as the springs approaches their free lengths, the accumulator pressure drops to a minimum.

Gas-loaded accumulator:

A gas-loaded accumulator is popularly used in industries. Here the force is applied to the oil using compressed air. Schematic diagram of a gas loaded accumulator. A gas accumulator can be very large and is often used with water or high water-based fluids using air as a gas charge. Typical application is on water turbines to absorb pressure surges owing to valve closure and on ram pumps to smooth out the delivery flow. The exact shape of the accumulator characteristic curve depends on pressure–volume relations.

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. Because the piston is free sliding, the pressure on the gas and that on the hydraulic fluid are always equal.

Diaphragm 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.

Bladder accumulator:

It functions in the same way as the other two accumulators.. Here the gas and the hydraulic fluid are separated by a synthetic rubber bladder. The bladder is filled with nitrogen until the designed precharge pressure is achieved. The hydraulic fluid is then pumped into the accumulator, thereby compressing the gas and increasing the pressure in the accumulator. The port cover is a small piece of metal that protects the bladder from damage as it expands and contacts the fluid port.

These accumulators consist of a fluid zone, a gas zone and a separating gas-tight element. The fluid area is in contact with the circuit. With the pressure increases, a certain volume of fluid enters into the accumulator and compresses the gases.

In the hydraulic systems, are used with the following accumulators with a separating element:

- bladder accumulators
- piston accumulators

Bladder Accumulators:

In the bladder accumulators, the fluid area is separated from the gas area by a flexible bladder. The fluid around the bladder is in contact with the circuit, so any increase in pressure causes the entry of the fluid into the accumulator and thereby compresses the gas. Vice versa, every drop of pressure in the circuit causes the expansion of the gas, resulting in delivery of the fluid from the accumulator to the circuit. Bladder accumulators can be installed in vertical position (preferable), in horizontal one and, under certain operating conditions, also in an inclined one. In the inclined and vertical positions, the valve on the fluid side should face down. The bladder accumulators include a pressure welded or forged vessel, a flexible bladder and the fittings for gas and oil.

Piston Accumulators:

In the piston accumulators, the fluid area is separated from the gas area from a metal piston fitted with gas tight seals. The gas area is filled with nitrogen. The fluid zone is connected to the hydraulic system, so any increase in pressure in the circuit causes the entry of fluid in the accumulator resulting in compression of the gas. Vice versa, at every drop of pressure in the circuit, the compressed gas contained in the accumulator expands and the accumulator delivers the fluid to circuit. The piston accumulators can operate in any position, but it is preferable to mount them with the gas area upwards in order to prevent that solid contaminants contained in the fluid settle by gravity on the piston seals. The typical structure of the piston accumulator includes a cylindrical pipe, a piston with seals, end caps in which there are the fluid side and gas side connections. The pipe serves to resist to the internal pressure and to drive the piston. To ensure that the pressures of the two chambers are as balanced as possible, during the movement, it's necessary that the friction between the piston and the pipe is minimized. For this reason, the inner surface of the pipe must be

Honed. In practice, however, the friction between the piston seals and the pipe creates, between gas area and fluid one, a pressure difference that, however, can be limited to 1 bar with appropriate selection of seals. The position of the piston can be shown continuously through a passing rod. By fixing a cam to the rod, you can also take advantage of the movement of the piston in order to control through limit switches the switching on or switching off of the pump.

Accumulator Selections:

When selecting an accumulator for a particular application, both system and performance criteria should be taken into account. To ensure long and satisfactory service life, the following factors should be taken into account.

- failure modes
- flow rate
- response time
- high frequency cycling
- external forces
- output volume

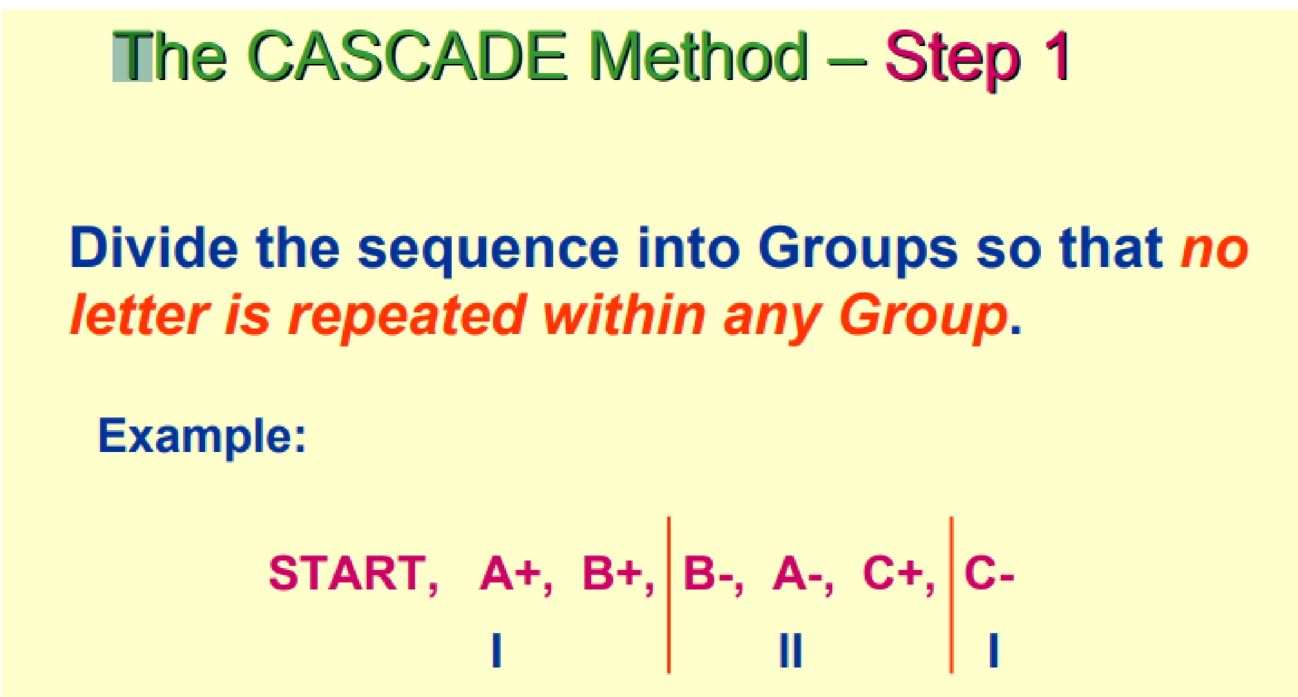
- fluid type
- shock suppression
- sizing information
- temperature effect
- safety
- certification.

Failure Prevention:

Accumulator failure is generally defined as inability to accept and exhaust a specified amount of fluid when operating over a specific system pressure range. Failure often results from an unwanted loss or gain of pre-charge pressure. It cannot be too highly stressed that the correct pre-charge pressure is the most important factor in prolonging accumulator life. If maintenance of the pre-charge pressure and relief valve settings are neglected and if system pressures are adjusted without making corresponding adjustments to pre-charge.

CASCADE Method:

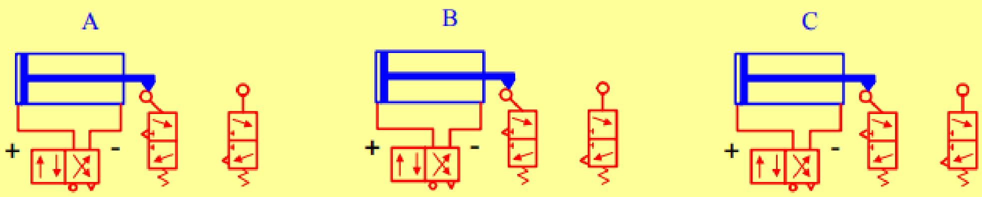
Involves dividing the sequence into groups with each group's manifold (power or main pressure line) being supplied with pneumatic power (pressure) one at a time and in sequence. • Motion within each group is powered by its own group manifold.



Step 2: For each cylinder, assign a 4/2(or 5/2) control valve with double pilot lines (i.e., without spring return) and two spring-return 3/2 limit valves to indicate end of strokes.

START, A+, B+, | B-, A-, C+, | C-

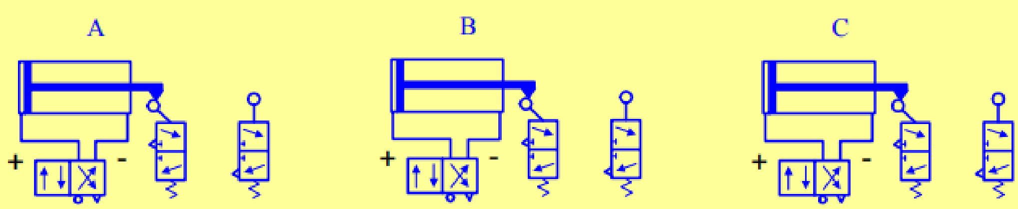
I II I

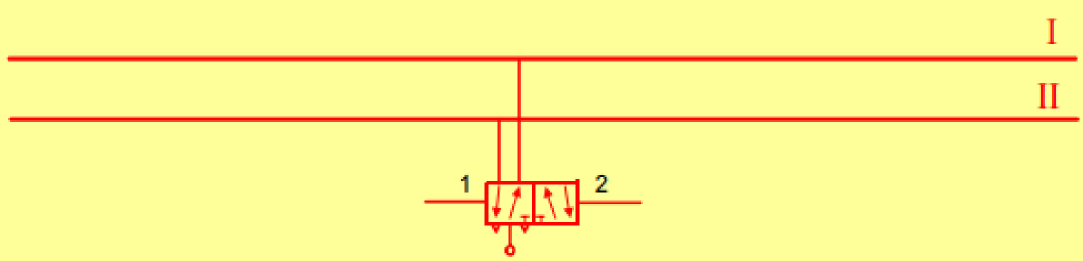


Step 3: Assign one or more *Group Valves* or *Cascade Valves* to control air pressure to the Group manifold lines so that only one Group manifold line is pressurised at any one time and in sequence.

START, A+ B+ | B- A- C+ | C-

I II I





Step 4 There are two approaches.

Approach 1: Design according to the sequence and using your understanding of how the Cascade Method is intended to work. The principal basis is the switching of the Group manifolds.

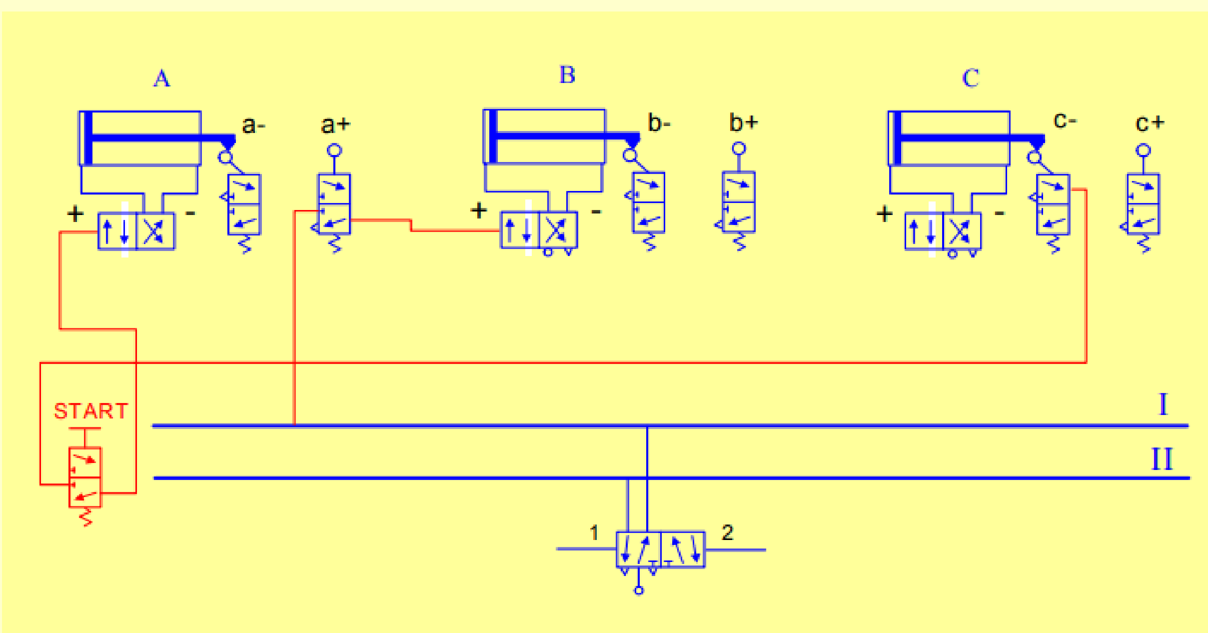
Approach 2: Design according to a set of rules worked out according to the principles of the Cascade Method.

Approach 1

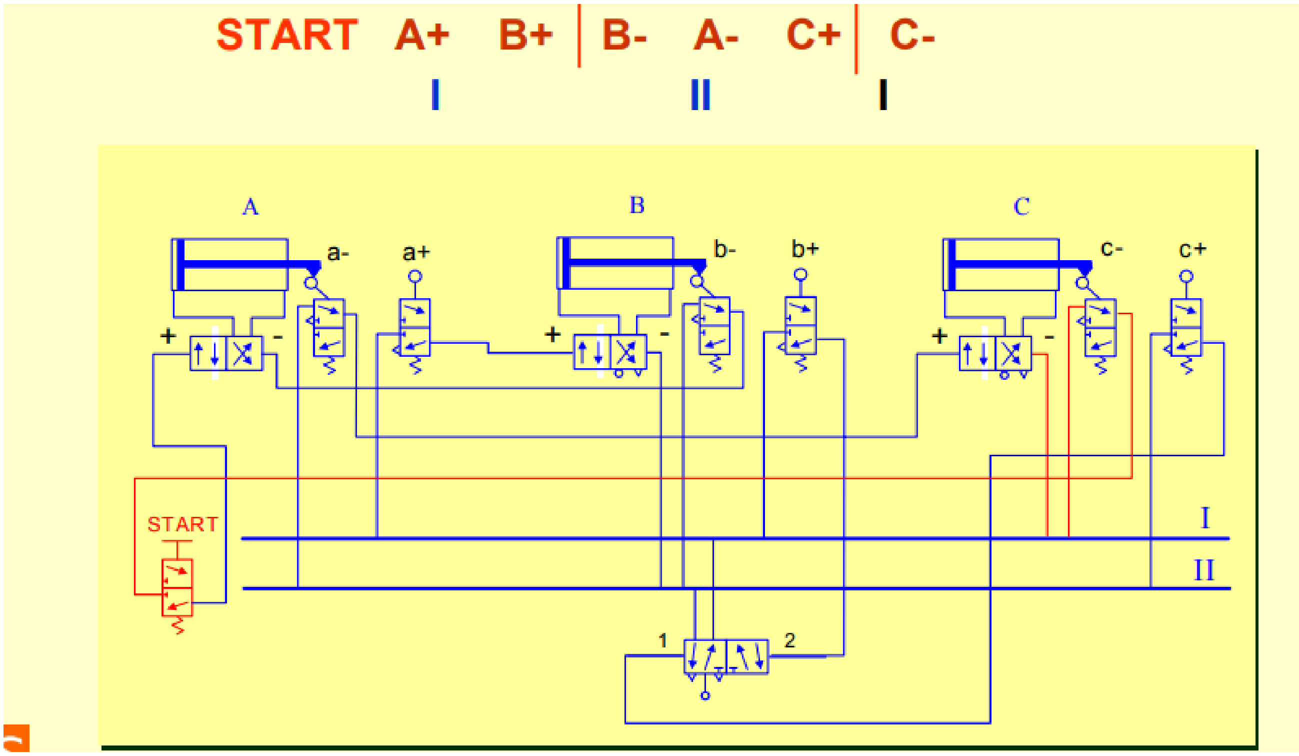
- Begin with START. Input to START comes from c- limit valve and output goes to initiate A+ motion.
- After A+ motion, take input to a+ from its own Group I manifold and output to initiate B+ motion.

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

I II I



IA – Cascade Method



What is mean by Ladder Programming ?

- ✓ The basic form of programming commonly used with PLCs is ***ladder programming***.
- ✓ PLC programming based on the use of ladder diagrams involves writing a program in a similar manner to drawing a switching circuit.
- ✓ The ladder diagram consists of two vertical lines representing the power lines. Circuits are connected as horizontal lines. *i.e.*, the rungs of the ladder, between these two verticals.

PLC Ladder Symbols

- ✓ Fig.15.18 shows the basic standard symbols that are used.
- ✓ Fig.15.19 shows an example of rungs in a ladder diagram.

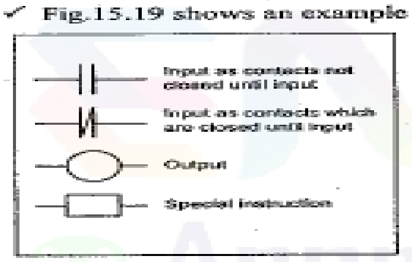


Fig. 15.18. Symbol

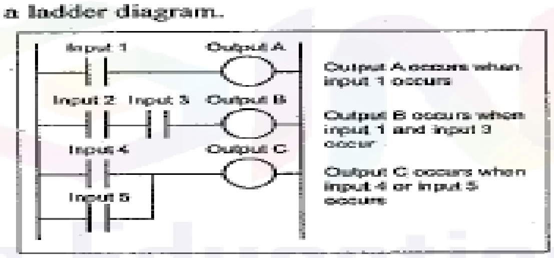


Fig. 15.19. Example of rungs in a ladder diagram

Construction

In drawing the circuit line for a rung, inputs must always precede outputs and there must be at least one output on each line. Each rung start with an input or a series of inputs and end with an output.

The inputs and outputs are numbered, the notation used depending on the manufacturer. For example, the Mitsubishi F series of PLCs precedes input elements by an X and output elements by a Y and uses the following numbers :

Inputs	X400–407, 410–413
	X500–507, 510–513
	(24 possible inputs)
Outputs	Y430–437
	Y530–537
	(16 possible outputs)

Illustration of Drawing a PLC Ladder Diagram

Consider an example of a solenoid valve which opens to allow water to enter a vessel. This situation, where the output from the PLC is to energise a solenoid when a normally open start switch connected to the input is being closed, is shown in Fig.15.20(*a*). The PLC ladder diagram for the situation is shown in Fig.15.20(*b*).

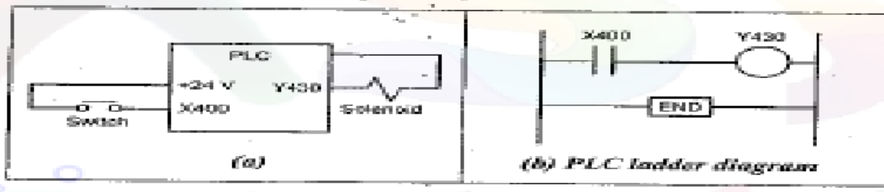


Fig. 15.20. Illustration of drawing a PLC ladder diagram

Starting with the input, we have the normally open symbol | |. This might have an input address X400. The line terminates with the output, the solenoid, with the symbol O. This might have the output address Y430. To indicate the end of the program the end rung is marked. When the switch is closed the solenoid is activated.

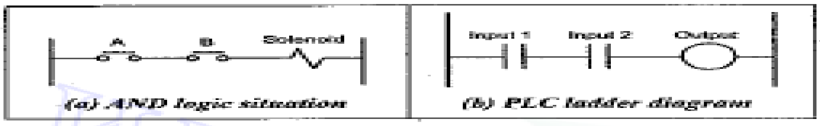
PLC LADDER PROGRAMS FOR LOGIC FUNCTIONS

The logic functions (such as AND, OR, NOR, *etc.*) can be obtained by combinations of switches (such as limit switches, solenoid coils, *etc.*). The following sections show how we can write PLC ladder programs for such combinations.

15.11.1. AND Logic Function

Fig.15.21(*a*) shows a situation where a coil is not energized unless two, normally open, switches are both closed. Switch A and switch B have both to be closed, which thus gives an AND logic situation.

Fig.15.21(*b*) shows the PLC ladder diagram for the AND logic function shown in Fig.15.21(*a*). In Fig.15.21(*b*), the ladder diagram starts with | |, labelled Input 1, to represent switch A and in series with it | |, labelled Input 2, to represent switch B. The line then terminates with O to represent the output.

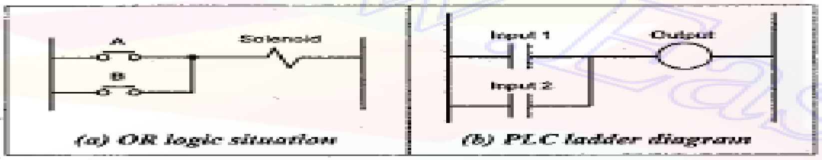


(a) AND logic situation *(b) PLC ladder diagram*

Fig. 15.21. An AND system

15.11.2. OR Logic Function

Fig.15.22(*a*) shows a situation where a coil is not energized until either, normally open, switch A or B is closed. This situation is an OR logic gate.



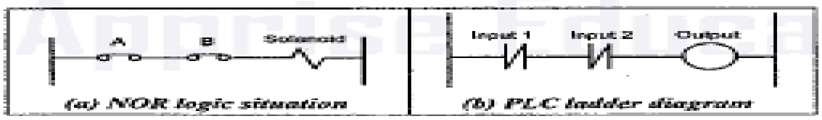
(a) OR logic situation *(b) PLC ladder diagram*

Fig. 15.22. An OR system

Fig.15.22(*b*) shows the PLC ladder diagram for the OR logic gate shown in Fig.15.22(*a*). In Fig.15.22(*b*), the ladder diagram starts with | |, labelled Input 1, to represent A and in parallel with it | |, labelled Input 2, to represent switch B. The line then terminates with O to represent the output.

15.11.3. NOR Logic Function

Fig.15.23(*a*) shows a NOR logic gate situation. Fig.15.23(*b*) shows the PLC ladder program for the NOR gate shown in Fig.15.23(*a*). Since there has to be an output when neither A nor B have an input and when there is an input to A or B the output stops, the ladder program shows Input 1 in parallel with Input 2, with both being represented by normally closed contacts.

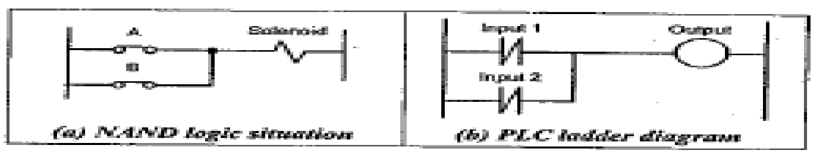


(a) NOR logic situation *(b) PLC ladder diagram*

Fig. 15.23. A NOR system

15.11.4. NAND Logic Function

Fig.15.24(*a*) shows a NAND logic gate situation. Fig.15.24(*b*) shows the PLC ladder program for the NAND gate shown in Fig.15.24(*a*). There is no output when both A and B have an input. Thus for the ladder program line to obtain we require no inputs to Input 1 and to Input 2.



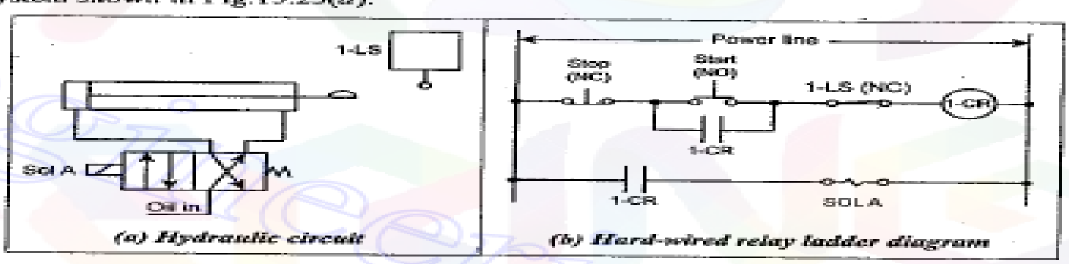
(a) NAND logic situation *(b) PLC ladder diagram*

Fig. 15.24. A NAND system

15.12. PLC CONTROL OF A HYDRAULIC CYLINDER

15.12.1. Circuit and Relay Ladder Diagram

Consider a system, shown in Fig.15.25, which is used to control a double-acting hydraulic cylinder using a single limit switch. Fig.15.25(*b*) shows the hard-wired relay ladder diagram for system shown in Fig.15.25(*a*).



(a) Hydraulic circuit *(b) Hard-wired relay ladder diagram*

Fig. 15.25. Control of a hydraulic cylinder using a single limit switch

15.12.2. PLC Ladder Logic Diagram

Fig.15.26 shows a PLC ladder logic diagram for the equivalent hard-wired relay ladder diagram shown in Fig.15.25(*b*). It may be noted that the layout of both diagrams are similar. The two rungs of the relay ladder diagram are converted to two rungs of the PLC ladder logic diagram.

Since the input modules act like relays, the relay contacts are substituted for original switch contacts (with the prefix X followed by a number) and output modules are substituted by relay coils (with the prefix Y followed by a number).

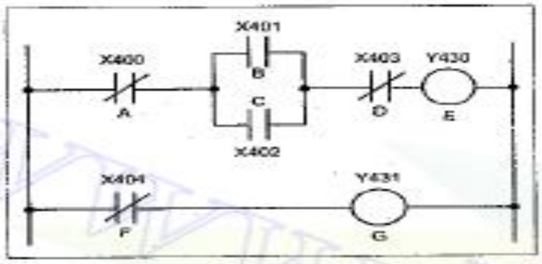


Fig. 15.26. PLC ladder logic diagrams

15.12.3. Boolean Equations

We know that the PLC performs operations based on logic functions. Each rung of a ladder diagram be represented by a Boolean equation. For this purpose, the capital letters A, B, C, *etc.* are used to represent each electrical component in the Fig.15.36. Now the Boolean equations can be written for each rung as follows :

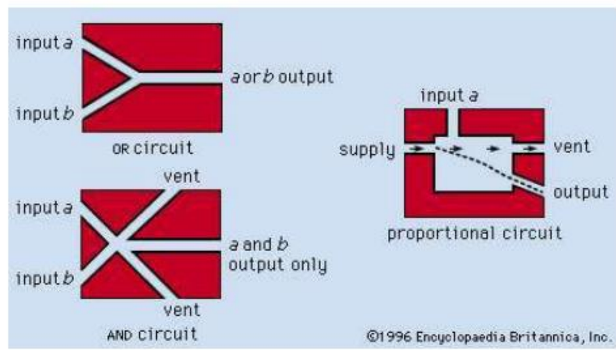
Top Rung : $\bar{A} \cdot (B + C) \cdot \bar{D} = E$

This equation can be read as : NOT A AND (B OR C) AND NOT D EQUALS E. We know that OFF state can be represented by 0 and ON state by 1. This equation means that E is energized when A is NOT actuated AND B OR C is actuated AND D is NOT actuated.

Bottom rung : $F = G$

Introduction to Fluidics Pneumatic logic circuits

Fluidics. **Fluidics**, or **fluidic logic**, is the use of a fluid to perform analog or digital operations similar to those performed with electronics. The physical basis of **fluidics** is pneumatics and hydraulics, based on the theoretical foundation of fluid dynamics.



UNIT -V TROUBLE SHOOTING AND APPLICATIONS

Troubleshooting and remedies in hydraulic systems:

Gradual or sudden loss of pressure or flow resulting in a loss of power is common in hydraulic system failure.

Any one of the system's components may be at fault. These step-by-step procedures should help you locate and remedy the problem quickly.

1. **SYSTEM INOPERATIVE**

- No oil in system, insufficient oil in system. Fill system. Check for leaks.
- Wrong oil in system. Refer to specifications. Change oil.
- Filter dirty or clogged. Drain oil and replace filter or filter element.
- Oil line restriction. Oil lines dirty or collapsed. Clean or replace.
- Air leaks in pump suction line. Repair or replace as necessary.
- Worn or dirty pump. Clean, repair or replace. Check alignment. Check for contaminated oil. Drain and flush system.
- Badly worn components (valves, cylinders, etc.) Examine and test for internal or external leakage. Replace faulty components. Check for cause of wear.
- Leakage. Check all components, particularly the relief valve for proper settings. Refer to technical manuals.
- Excessive load. Check unit specifications for load limits.
- Slipping or broken pump drive. Repair or replace belts, couplings, etc. Check for proper alignment or tension.

2. **SYSTEM OPERATES ERRATICALLY**

- Air in system. Check suction side of system for leaks. Repair.
- Cold oil. Allow ample warm-up period.
- Dirty or damaged components. Clear or repair as necessary.
- Restrictions in filters or lines. Clean and/or replace elements or lines.

3. **SYSTEM OPERATES SLOWLY**

- Oil viscosity too high, cold oil. Allow oil to warm up before operating machine.
- Low pump drive speed. Increase engine speed (check manual for recommendations.)
- Air in system. Check suction side for leaks. Repair.
- Badly worn pump, valves, cylinders, etc. Repair or replace as needed.
- Restrictions in filters or lines. Clean and/or replace elements or lines.
- Improper adjustments. Check orifices, relief valves, etc. Adjust per manual.
- Oil leaks. Tighten fittings. Replace seals or damaged lines.

4. **SYSTEM OPERATES TOO FAST**

- Wrong size or incorrectly adjusted restrictor. Replace or adjust as necessary.
- Engine running too fast.
- Reduce engine speed.

5. **OVERHEATING OF OIL IN SYSTEM**

- Oil passing thru relief valve for excessive time. Return control valve to neutral when not in use.
- Incorrect oil, low oil, dirty oil. Use recommended oil, fill reservoir, clean oil, replace filter elements.
- Engine running too fast. Reduce engine speed.
- Excessive component internal leakage. Repair or replace component as necessary.
- Restriction in filters or lines. Clean and/or replace elements or lines.
- Malfunctioning oil cooler. Clean or repair.
- Insufficient heat radiation. Clean dirt and mud from reservoir and components.

- Malfunctioning component. Repair or replace.
- Reservoir too small. Recommended size is 1 1/2 times pump gpm.

6. **FOAMING OF OIL**

- Incorrect, low or dirty oil. Replace, clean or add oil as needed.
- Air leaks. Check suction line and component seals for suction leaks. Replace.

7. **NOISY PUMP**

- Low oil level, incorrect oil, foamy oil. Replace, clean or add oil as needed.
- Suction line plugged or too small, inlet screen plugged. Clean or replace. Follow instructions packed with unit.
- Use of pipe fitting in inlet. Replace with correct fitting.

8. **BLOWN SHAFT SEAL**

- Pump: wrong pump shaft rotation. Replace seal. Refer to installation instructions.
- Motor: failure to hook up drain line. Replace seal. Refer to installation instructions.

9. **LEAKY PUMP OR MOTOR**

- Damaged or worn shaft seal. Replace seal. Check for misalignment.
- Loose or broken parts. Tighten or replace.

10. **LOAD DROPS WITH CONTROL VALVE IN NEUTRAL**

- Leaking cylinder seals or fittings. Replace worn parts.
- Control valve not cantering when released. Check linkage. Check for spool binding. Repair.

11. **CONTROL VALVE DOES NOT CENTER (Binding)**

- See Hydraulic Product Safety sheet.
- Valve linkage misaligned. Repair.
- Tie-bolts too tight (stack valves). Loosen as necessary.
- Valve damaged. Repair or replace.
- Handle bracket screws loose. Tighten.

12. **CONTROL VALVE LEAKS EXTERNALLY**

- Tie-bolts too loose (stack valves). Tighten as necessary.
- Seals damaged or worn. Replace.
- Back pressure or restriction in tank line. Check quick couplers. Use power beyond when necessary.
- Cracked port or body. Replace. (see Hyd. Prod. Safety)

13. **CYLINDER LEAKS EXTERNALLY**

- Seals damaged or worn. Replace.
- Rod damaged. Replace.

14. **CYLINDER LOWERS WITH VALVE IN "METER UP" POSITION**

- Damaged or leaky load check. Replace check.
- Leaking cylinder seal. Replace seal.

<u>Troubleshooting and remedies in pneumatic system:</u>

Pneumatic systems comprise a number of complex and interlinked components, which need comprehensive and careful tuning to run at their optimal performance. Needless to say, optimal performance is not always the norm. Frequent adjustments need to be made to achieve it, as well as regular checks for leakage, faulty connections and other contributory problems. It's also not infrequent that your system just isn't working properly and you don't know why – and that's where troubleshooting comes in.

The following is a list of 11 steps for troubleshooting pneumatic systems which should get you up and running:

Safety first

- What, when & where

- Understand your system
- Visual inspection
- Run the system
- Another visual inspection
- Isolate sub-systems
- List & test possibilities in sub-system
- Repair or replace
- Test
- Conclude troubleshooting
- Safety first

Before beginning any troubleshooting procedures, you should first take care to secure the system so it's completely safe. Compressed air can be very dangerous, and an exploding air tank could inflict severe personal injuries, as well as damage to equipment and property. It is therefore imperative before undertaking any repairs to relieve the pressure in the storage tank. Any loads that are not mechanically locked down should also be secured before servicing, so they don't fall on people or drift.

Make sure the power supply is disconnected so that there's no danger of electrical activity that might cause injury. In the case of solenoid valves that require electricity to operate, such as directional control valves, these very often have a manual override that you can use to operate the system during troubleshooting. Your pneumatic system should also be fitted with lockout valves that prevent any accidental operation of the system.

2. What, when & where

Whenever your system suffers a breakdown, the first step in troubleshooting is to ask yourself the following three 'W' questions.

- What is or isn't happening in the functions of the system?
- When did this start? Was the failure sudden or gradual?
- Where is the problem happening in the machine cycle? Is it on first starting up or somewhere mid-cycle?

The system operator is the best person to identify what is or isn't happening. The most common problems are likely to be a slow-moving or drifting actuator, insufficient pressure, issues with valves or the filtration unit. You can learn more about pneumatic systems and some of the most common issues here.

Finding out when the problem started, and how suddenly, can determine what troubleshooting steps to take. Sudden malfunctions or breakdowns are likely to indicate catastrophic failures, such as ruptures in lines, broken components and possible mechanical issues. Gradual failures are more likely to suggest leaks or worn components such as seals, or contaminants in the system.

Determining where the problem occurs in the machine cycle can also help distinguish between a one-off breakdown or a recurring condition. Check your maintenance records to see whether any recurrent problem is listed, to give you a starting point. It should also give you food for thought as to why the problem keeps recurring, and what to do about it.

3. Understand Your System

Before trying to run a pneumatic system or effect repairs, it's essential to understand how all the components and subsystems on the machine interrelate. All pneumatic systems when supplied by the manufacturer should come with two types of documentation: the schematic drawings and the service manual. Study of these diagnostic tools will greatly assist you in the troubleshooting process.

The schematic drawing is a road map of the pneumatic circuit which explains how its various components function. It contains a lot of useful information, including:

- cylinder stroke lengths;
- flow rates;
- pressure test points;
- pressure settings for regulators and valves;
- air motor speeds;
- a bill of materials or product structure.

Studying this kind of information can help you determine whether the system is functioning within its design parameters. The service manual and any update bulletins may also contain information about potential issues – this will help you to diagnose problems and effect repairs. You should also consult with machine operators, who may be more familiar with the system's functions and components.

4. Visual Inspection

Having familiarised yourself with the schematics, you should also take time to locate and identify them visually. Walking around the equipment will often identify basic problems like frayed, leaking or burst hoses, worn or extruded seals, and loose or broken components.

Check the pressure regulator valve to make sure there's sufficient pressure, and the flow control valve in case you've got too much choke. You might need to replace the filter if it's clogged up, and clean out contaminants. You should also look for pinches in the hoses, and check for air or fluid leaks.

5. Run The System

Once you've read the documentation and looked the machine over, start it up (if you can) and run it so you can watch the system working and see the malfunction at first hand. Is the reported malfunction still happening? Seeing the machine in action may make the problem obvious and greatly reduce your troubleshooting time.

Look out for:

excessive air leakage;

system pressures not matching the levels specified in the documentation;

manual controls (if any) that are too stiff or too loose;

moving components which are moving erratically.

6. Another Visual Inspection

Once you've run the machine you'll have to go through all your safety checks again (see 1 above), to make sure power is disconnected and stored pressure vented.

7. Isolate subsystems

All parts of the machine are interrelated, so a malfunction in one subsystem, e.g. the air preparation subsystem, can lead to a related malfunction in a different subsystem. It helps if you isolate the subsystems so as to focus on them one at a time. This will reduce the diagnostic area, but extra precautions should be taken while operating the machine. Caution and safety are paramount in this diagnostic step.

Any disconnected lines and any ports opened in the isolation of a subsystem should be properly plugged to prevent contamination and unnecessary air leakage. Pressures within the system should also be closely monitored while it's running, so as not to exceed maximum allowable pressures.

8. List & Test Possibilities In Subsystem

The immediate problem may make itself apparent in the preceding step, but in troubleshooting, the root cause may not always be the obvious one. You may have a problem that manifests as a slow actuator, for example, but this could be caused by an underlying problem such as a faulty lubricator or valve seals. Having a thorough understanding of the operating principles of the system, and all its components, is essential if you’re going to match the problem accurately to its root cause.

Make a list of potential underlying causes, then check each one and eliminate it, without returning to previously covered ground. This will also reduce your troubleshooting time, and can avoid the trial and error method of exchanging parts.

9. Test

After narrowing down the possible causes of the malfunction, you now have to decide which one of those remaining is the most probable. The conclusion may seem difficult at first, but this step is effectively your starting point for getting to the actual repair. So far in the troubleshooting process, you've evaluated the system. Now you have to test your conclusions. This might merely mean adding lubricant or adjusting its drip rate. Other tests can help eliminate the items on your list until you've accurately identified the cause:

- check actuator alignment;
- check pressures with an accurate gauge;
- check flow rates with a flow meter;
- check air system temperature.

10. Repair Or Replace

Testing your conclusions should find the fault, and then you must decide whether to repair or replace. If you choose to repair parts for immediate reinstallation, your downtime and consequent costs will increase. If you choose to replace them with new or refurbished parts, your downtime will be less but your inventory cost will be greater. Your decision will also depend on whether replacement parts are readily available, and/or whether you can effect repairs in-house.

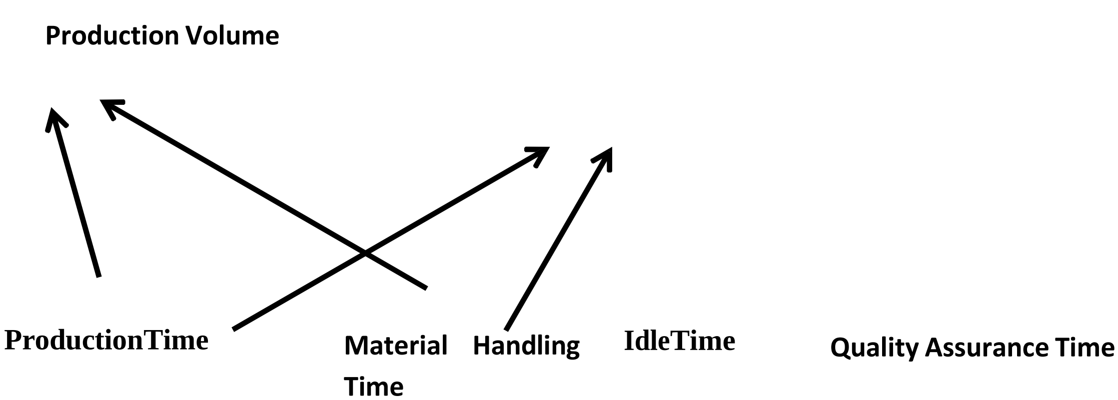
11. Conclude Troubleshooting

The last step in troubleshooting pneumatic systems is reporting your findings. Paperwork is a tiresome but vital element of the procedure, but maintaining a record of problems, solutions, and changes to individual machines is helpful for future troubleshooting. Schematics should also be regularly updated to keep them accurate.

Test, Deduce, Act

Asking the first three 'W' questions takes some of the guesswork out of troubleshooting, and can significantly reduce costs and downtime. The mechanics of the process are clarified by studying the schematics, and conducting a visual inspection of the machine. Testing and logical deduction should eliminate the factors that aren’t contributing to your problem, until you are left with the unavoidable truth. Then it's up to you to determine the best course of remedial action.

A CNC Machine with an Automated Tool Changer and the Operator Console with Display for Programming and Control of the Machine

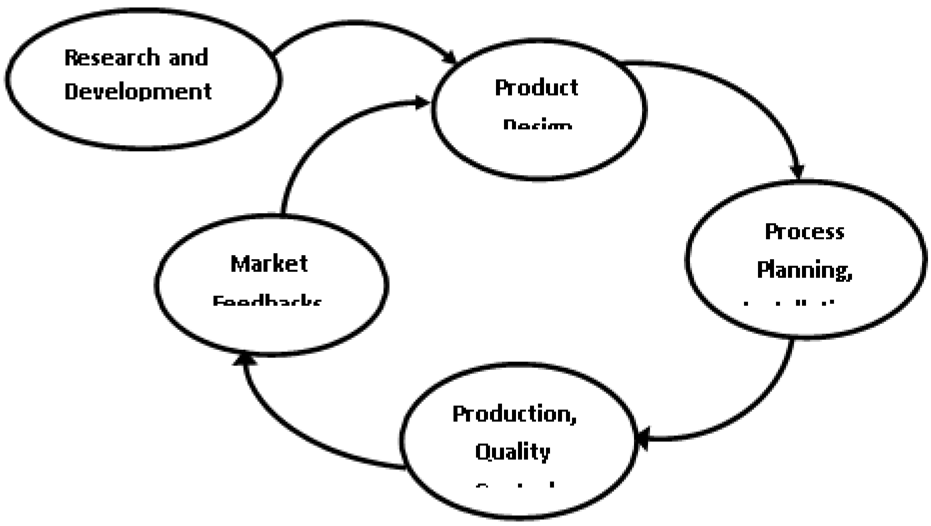


The product quality that can be achieved with automated precision machines and processes cannot be achieved with manual operations. Moreover, since operation is automated, the same quality would be achieved for thousands of parts with little variation. Industrial Products go through their life cycles, which consists of various stages. At first, a product is conceived based on Market feedbacks, as well as Research and Development Activities. Once conceived the product is designed. Prototype Manufacturing is generally needed to prove the design. Once the design is proved, Production Planning and Installation must be carried out to ensure that the necessary resources and strategies for mass manufacturing are in place.

This is followed by the actual manufacture and quality control activities through which the product is mass-produced. This is followed by a number of commercial activities through which the product is actually sold in the market.

Automation also reduces the overall product life cycle i.e., the time required to complete

- Product conception and design
- Process planning and installation
- Various stages of the product life cycle



A Typical Industrial Product Life Cycle

Economy of Scale and Economy of Scope:

In the context of Industrial Manufacturing Automation, Economy of Scale is defined as follows.

Economy of Scale Definition: Reduction in cost per unit resulting from increased production, realized through operational efficiencies. Economies of scale can be accomplished because as production increases, the cost of producing each additional unit falls.

Obviously, Automation facilitates economy of scale, since, as explained above, it enables efficient large-scale production. In the modern industrial scenario however, another kind of economy, called the economy of scope assumes significance.

Economy of Scope Definition : The situation that arises when the cost of being able manufacture multiple products simultaneously proves more efficient than that of being able manufacture single product at a time.

Economy of scope arises in several sectors of manufacturing, but perhaps the most predominantly in electronic product manufacturing where complete product life cycle, from conception to market, are executed in a matter of months, if not weeks. Therefore, to shrink the time to market drastically use of automated tools is mandated in all phases of the product life cycle. Additionally, since a wide variety of products need to be manufactured within the life period of a factory, rapid programmability and reconfigurability of machines and processes becomes a key requirement for commercial success. Such an automated production system also enables the industry to exploit a much larger market and also protects itself against fluctuations in demand for a given class of products. Indeed it is being driven by the economy of scope, andenabled by Industrial Automation Technology that Flexible Manufacturing (i.e. producing various products with the same machine) has been conceived to increase the scope of manufacturing. Next let us see the various major kinds of production systems, or factories, exist. This would be followed by a discussion on the various types of automation systems that are appropriate for each of thesecategories.

Point to Ponder: 7

Types of production systems:

Major industrial processes can be categorized as follows based on their scale and scope of production.

Continuous flow process: Manufactured product is in continuous quantities i.e., the product is not a discrete object. Moreover, for such processes, the volume of production is generally very high, while the product variation is relatively low. Typical examples of such processes include Oil Refineries, Iron and Steel Plants, Cement and Chemical Plants.

Mass Manufacturing of Discrete Products: Products are discrete objects and manufactured in large volumes. Product variation is very limited. Typical examples are Appliances, Automobiles etc.

Batch Production: In a batch production process the product is either discrete or continuous. However, the variation in product types is larger than in continuous-flow processes. The same set of equipment is used to manufacture all the product types. However for each batch of a given product type a distinct set of operating parameters must be established. This set is often referred to as the ―recipe‖ for the batch. Typicalexamples here would be Pharmaceuticals, Casting Foundries, Plastic moulding , Printing etc.

Job shop Production: Typically designed for manufacturing small quantities of discrete products, which arecustom built, generally according to drawings supplied by customers. Any variation in the product can be made. Examples include Machine Shops, Prototyping facilities etc.

The above types of production systems are shown in Figure 1.6 categorized according to volumes of production and variability in product types. In general, if the quantity of product is more there is little variation in the product and more varieties of product is manufactured if the quantity of product is lesser.

Types of Automation Systems:

Automation systems can be categorized based on the flexibility and level of integration in manufacturing process operations. Various automation systems can be classified as follows

Fixed Automation: It is used in high volume production with dedicated equipment, which has a fixed set of operation and designed to be efficient for this set. Continuous flow and Discrete Mass Production systems use this automation. e.g. Distillation Process, Conveyors, Paint Shops, Transfer lines etc.

A process using mechanized machinery to perform fixed and repetitive operations in order to produce a high volume of similar parts.

Programmable Automation:

It is used for a changeable sequence of operation and configuration of the machines using electronic controls. However, non-trivial programming effort may be needed to reprogram the machine or sequence of operations. Investment on programmable equipment is less, as production process is not changed frequently. It is typically used in Batch process where job variety is low and product volume is medium to high, and sometimes in mass production also. e.g. in Steel Rolling Mills, Paper Mills etc.

Flexible Automation:

It is used in Flexible Manufacturing Systems (FMS) which is invariably computer controlled. Human operators give high-level commands in the form of codes entered into computer identifying product and its location in the sequence and the lower level changes are done automatically. Each production machine receives settings/instructions from computer. These automatically loads/unloads required tools and carries out their processing instructions. After processing, products are automatically transferred to next machine. It is typically used in job shops and batch processes where product varieties are high and job volumes are medium to low. Such systems typically use Multipurpose CNC machines, Automated Guided Vehicles (AGV) etc.

Integrated Automation:

It denotes complete automation of a manufacturing plant, with all processes functioning under computer control and under coordination through digital information processing. It includes technologies such as computer-aided design and manufacturing, computer-aided process planning, computer numerical control machine tools, flexible machining systems, automated storage and retrieval systems, automated material handling systems such as robots and automated cranes and conveyors, computerized scheduling and production control. It may also integrate a business system through a common database. In other words, it symbolizes full integration of process and management operations using information and communication technologies. Typical examples of such technologies are seen in Advanced Process Automation Systems and Computer Integrated Manufacturing (CIM). As can be seen from above, from Fixed Automation to CIM the scope and complexity of automation systems are increasing. Degree of automation necessary for an individual manufacturing facility depends on manufacturing and assembly specifications, labor conditions and competitive pressure, labor cost and work requirements. One must remember that the

Investment on automation must be justified by the consequent increase in profitability. To exemplify, the appropriate contexts for Fixed and Flexible Automation are compared and contrasted. Fixed automation is appropriate in the following circumstances. Low variability in product type as also in size, shape, part count and material. Predictable and stable demand for 2- to 5-year time period, so that manufacturing capacity requirement is also stable. High production volume desired per unit time Significant cost pressures due to competitive market conditions. So automation systems should be tuned to perform optimally for the particular product. Flexible automation, on the other hand is used in the following situations. Significant variability in product type. Product mix requires a combination of different parts andproducts to be manufactured from the same production system. Product life cycles are short. Frequent up gradation and design modifications alter production requirements. Production volumes are moderate, and demand is not as predictable.

Point to Ponder: 8

- Light bulbs
- Garments
- Textile
- Cement
- Printing
- Pharmaceuticals
- Toys

Pressure-control valves:

A pressure-relief valve at the pumps automatically protects the system from overpressure. An unloading valve dumps the high-volume pump to tank after reaching a preset pressure. A kick-down sequence pressure-control valve forces all oil to the cylinder until it reaches a preset pressure. After reaching this pressure, the valve opens and sends all pump flow to the hydraulic motor first. A sequence valve upstream from the rotary actuator keeps it from moving until the hydraulic motor stalls against its load. A pressure-reducing valve ahead of the hydraulic motor allows the operator to set maximum torque by adjusting pressure to the motor inlet. Another pressure-control valve -called a counterbalance valve - located in the rod end line of the main cylinder keeps it from running away when the directional control valve shifts. The Counterbalance valve is adjusted to a pressure that keeps the cylinder from extending, even when weight onits rod could cause this to happen.

Parallel and series circuits:

There are parallel and series type circuits in fluid power systems. Pneumatic and hydraulic circuits may be parallel type, while only hydraulic circuits are series type. However, in industrial applications, more than 95% of hydraulic circuits are the parallel type. All pneumatic circuits are parallel design because air is compressible it is not practical to use it in series circuits. In parallel circuits, fluid can be directed to all actuators simultaneously. Hydraulic parallel circuits usually consist of one pump feeding multiple directional valves that operate actuators one at a time or several in unison. Hydraulics and pneumatics will be a familiar topic for you. Both work using the same principle, Pascal's law to generate force or motion. The major difference between these two power transferring technique is the medium used. For hydraulics, incompressible fluids are used and for pneumatics, compressed gases are used. The article Hydraulics and Pneumatics will be one useful article if you want to study the difference between these. In general, hydraulic systems are used for precise controlling of large force applications and pneumatic systems for lightweight and speedy applications. Hydraulic-based components are made using steel and pneumatic components are made using plastics and non-ferrous materials. Hydraulics and pneumatics have similar functions and working principle. The points provide Hydraulics and pneumatics have similar functions and working principle. The points provided here will help you to choose the right technique for your application.

- Consider the environment of your application(temperature, pressure, etc..)
- Hydraulics is more expensive.
- Hydraulics utilize less energy than pneumatics
- Hydraulic equipment requires a power pack for installation and pneumatic equipment can beplugged into a ring main.
- Hydraulics is suitable for high-pressure applications
- Hydraulics requires more complicated assemblies and repairing process.

Now, in this article, we can discuss applications of hydraulics and pneumatics. Most of the stationary or mobile equipment you use in your daily life is an application of hydraulics and pneumatics. It is impossible

To mention each and every example. Some of the daily used hydraulics and pneumatics applications are Listed below.

Hydraulics Applications:

Industrial:

Electrohydraulic is the mechanism used for controlling the industrial applications of hydraulics. Precise and fast response is an advantage of this. Plastic processing machinery, steel making and primary metal extraction applications, automated production lines, machine tool industry, paper industries, loaders, crushers, presses, textile industry machinery, etc. are some of the examples of industrial hydraulics.

Mobile Hydraulics:

In mobile hydraulics, the hydraulic system is controlled manually. Building and construction equipment like cranes, excavators, backhoe, earth moving equipment, etc., tractors, irrigation system, material handling equipment, tunnel boring equipment, rail equipment, etc. are some examples of mobile hydraulics.

Automobiles:

Hydraulics have many interesting applications in the automobile industry. Most of the important work using the principle of hydraulics. Power steering, shock absorbers, windshields, and brake are the common applications of hydraulics in vehicles. Two-post lifts and four-post lifts are used in the automobile industry to lift vehicles for servicing and inspecting.

Marine Applications:

Hydraulics plays an important role in maintaining the stability and control of ships. Steering gears, bow and stern thrusters, engine room maintenance systems including pumps and jacks, deck machineries like cranes, winches, hatch covers, mooring drums and others are examples of hydraulics in the marine industry.

Aerospace Applications:

Airplanes, rockets, spaceships, etc. Use hydraulic systems for various applications. Aerospace industryuses hydraulics for adjusting wings, retraction and extension of landing gears, opening/closing of doors, brakes, steering, etc.

Mining:

Hydraulic fracturing is one of the advanced mining technology used for extracting unused gases/oils beneath the earth surface. In this approach, a high-pressure mixture of water, sand and other chemical additives are passed into the cracks.

- Fundamentals of hydraulics: Basics of water and oil hydraulics
- Hydraulic system accessories: Reservoirs, filters, coolers, Instrumentation and accumulators
- Principle construction and working of components
- Hydraulic pumps: Pump basics positive & non-positive displacement pumps
- Pressure control: relief, reducing, regulating valves
- Flow control: FCV, non-return valves
- Actuators: Linear actuators, hydraulic motors, Hydraulic drives.
- Direction control valves: Direct operated, pilot operated
- ISO symbol and hydraulic circuit reading
- Performance evaluation and testing of Hydraulic pumps, Relief & DC valves
- Principle of solenoid valves
- Working principles of proportional valves and servo valves
- Interpretation and discussions of electro-hydraulic circuits in plant machinery
- Material handling system
- Proportional variable pump control system
- General troubleshooting and maintenance

Pneumatics Applications:

Automobile:

Automobile industry use pneumatic systems for dismantling vehicle tire, filling compressed air in the tire,vehicle painting, opening and closing of doors, air brakes on heavy vehicles, etc.

Transporting Goods:

Pneumatics is used to transport goods from shelf to other location inside the company. The cylinder will push the item on the shelf into the moving belt if the button is pushed.

Industrial Applications:

Material handling, drilling, sawing, filling, packaging, clamping, shifting, etc. are some of the general applications of the pneumatic system.

Theories of compressed air:

- Operation & function of Pneumatic system components
- Design & drawing of air symbols
- Simulation of movement phases & function phases
- Drawing air circuits according to standards
- Dryers, air receivers
- Compressors
- Pneumatic actuators
- Air distribution systems
- Directional valves
- Flow valves
- Fault-finding & trouble shooting of compressed air control circuits
- Guidelines for industrial safety

Hydraulic and pneumatic circuit:

Design Considerations:

Safety of Operation:

1. Pressure and Temperature ratings.
2. Interlocks for sequential operations
3. Emergency shutdown features.
4. Power failure locks.
5. Operation speed.
6. Environment conditions.

Meet functional requirements:

1. Meet required performance specification.
2. Life expectancy same as machine.
3. Facilitate good maintenance practice.
4. Compatibility with electrical and mechanical components.
5. Withstand operational hazards.

Efficiency of Operation:

1. Keep system Simple, Safe and Functional.
2. Access to parts needs repair or adjustment.
3. Design to keep min operational cost.
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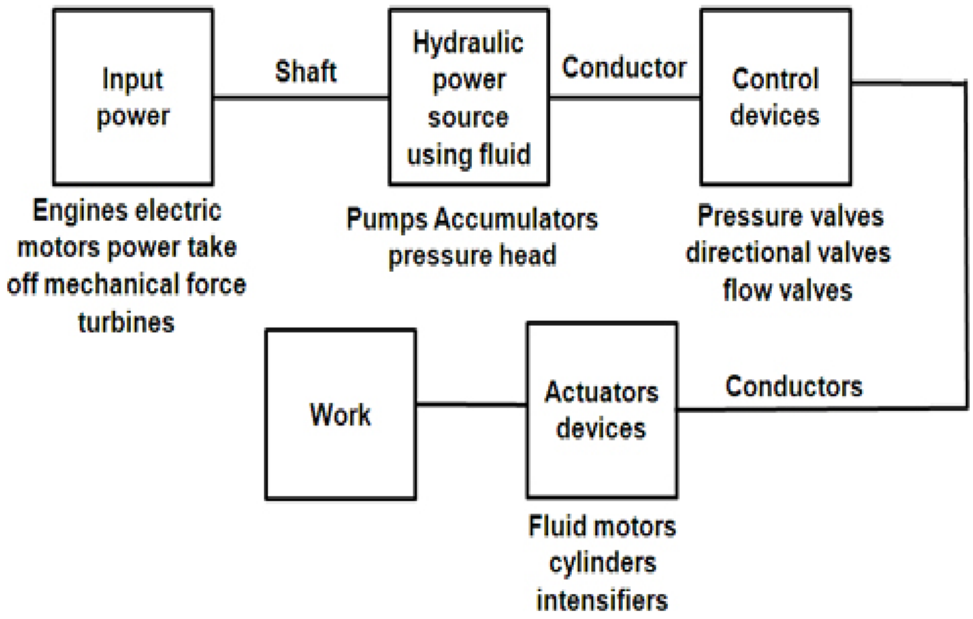
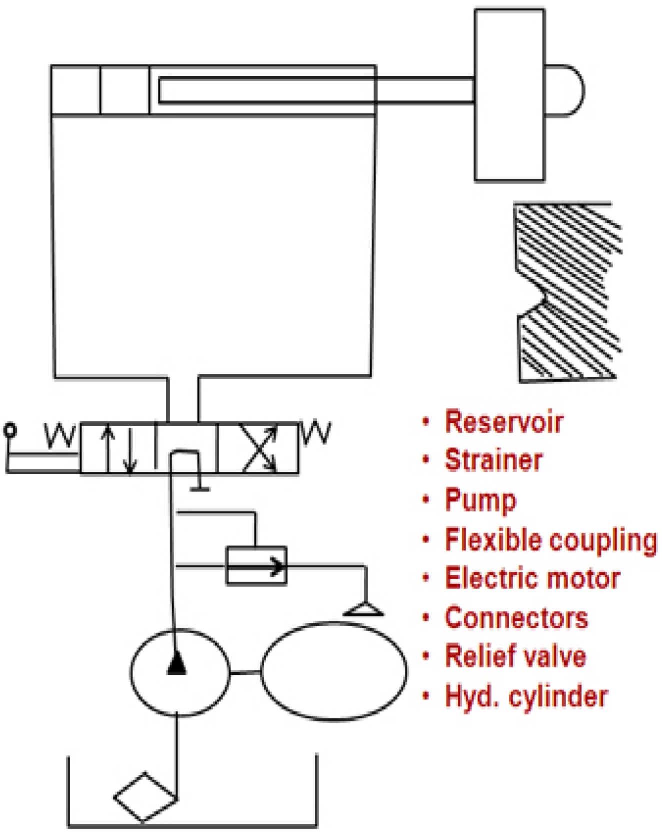
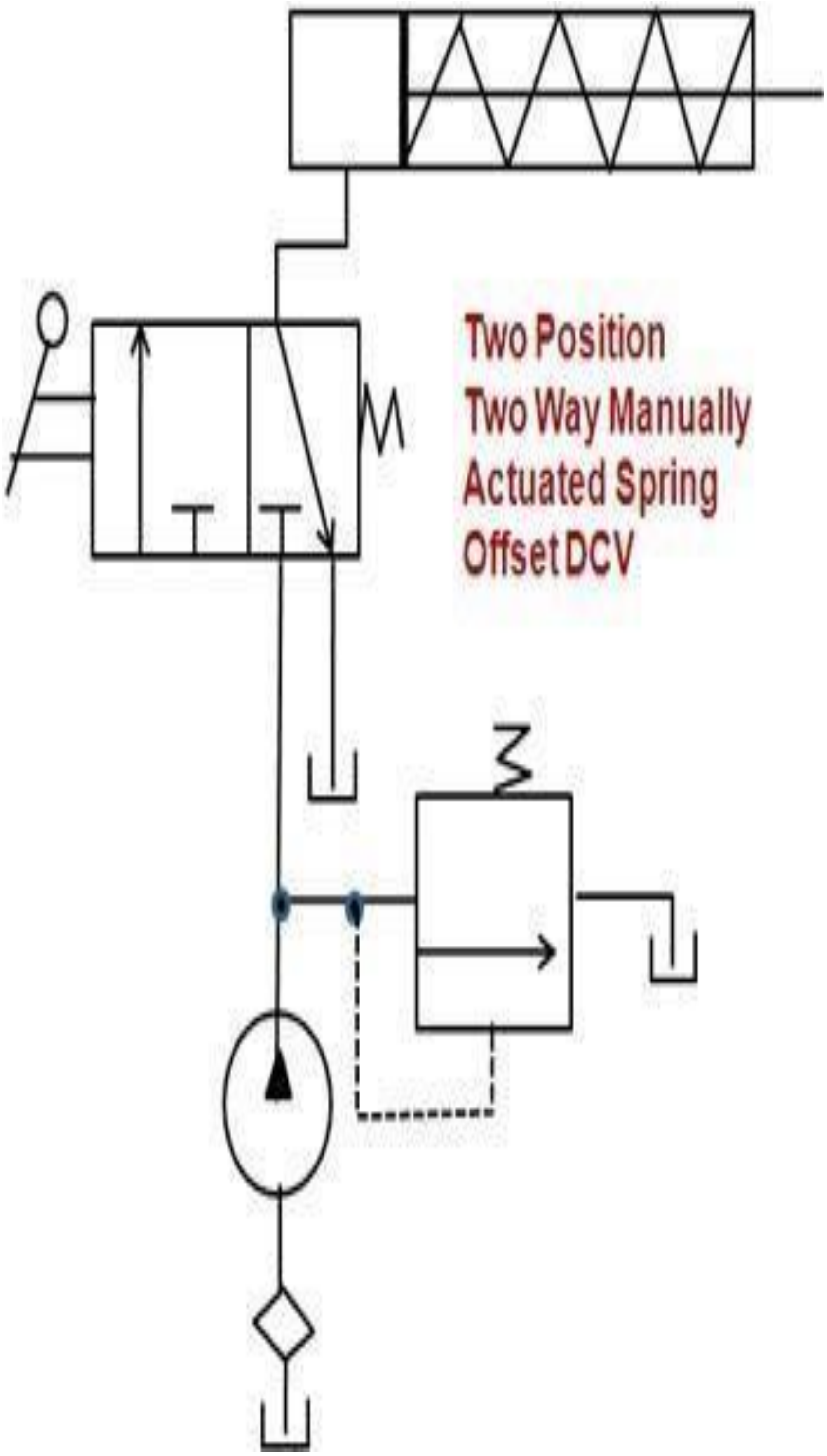
Linear Circuits:





Control of a Single Acting Hydraulic Cylinder:



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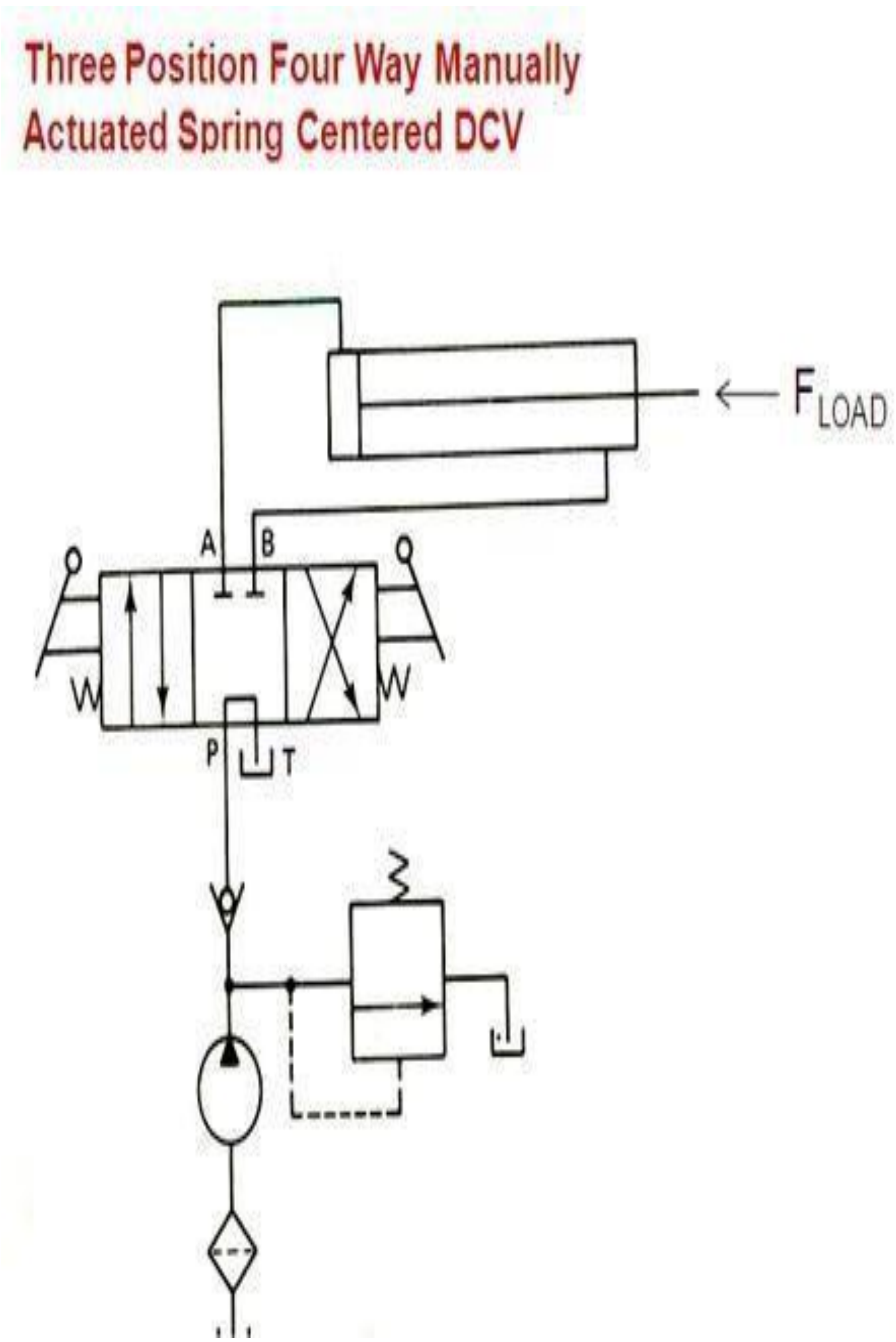
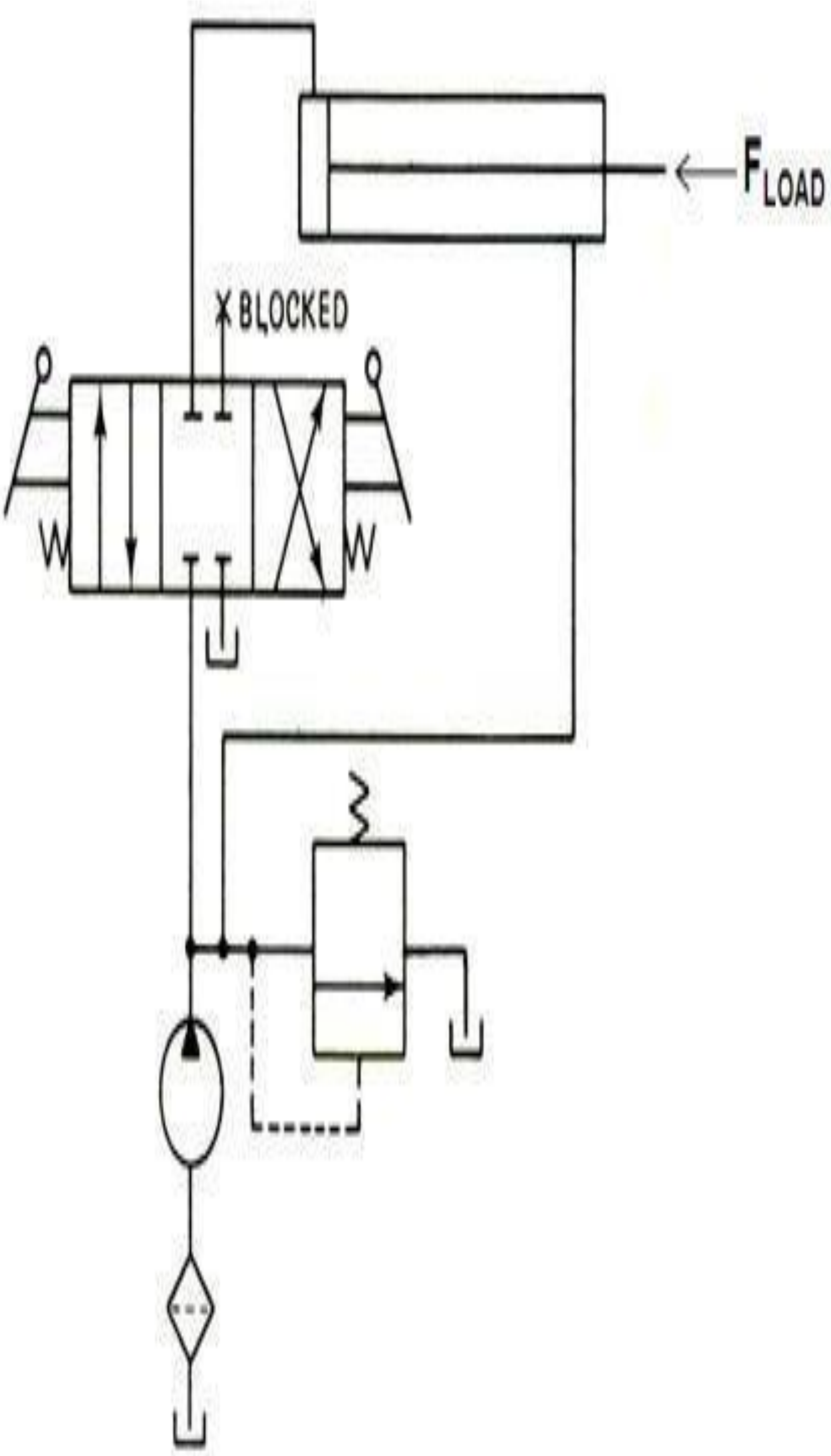


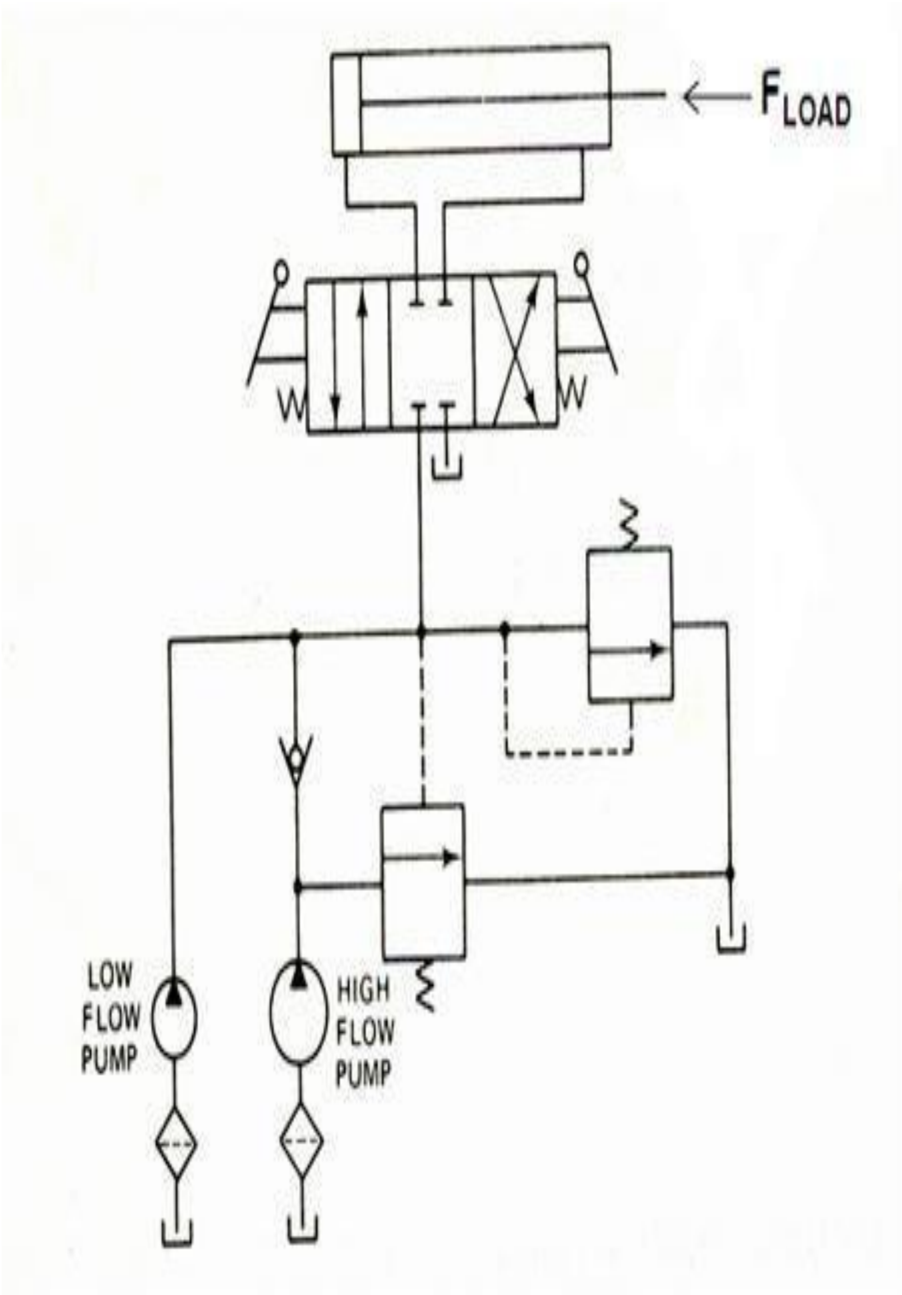
Regenerative Circuit



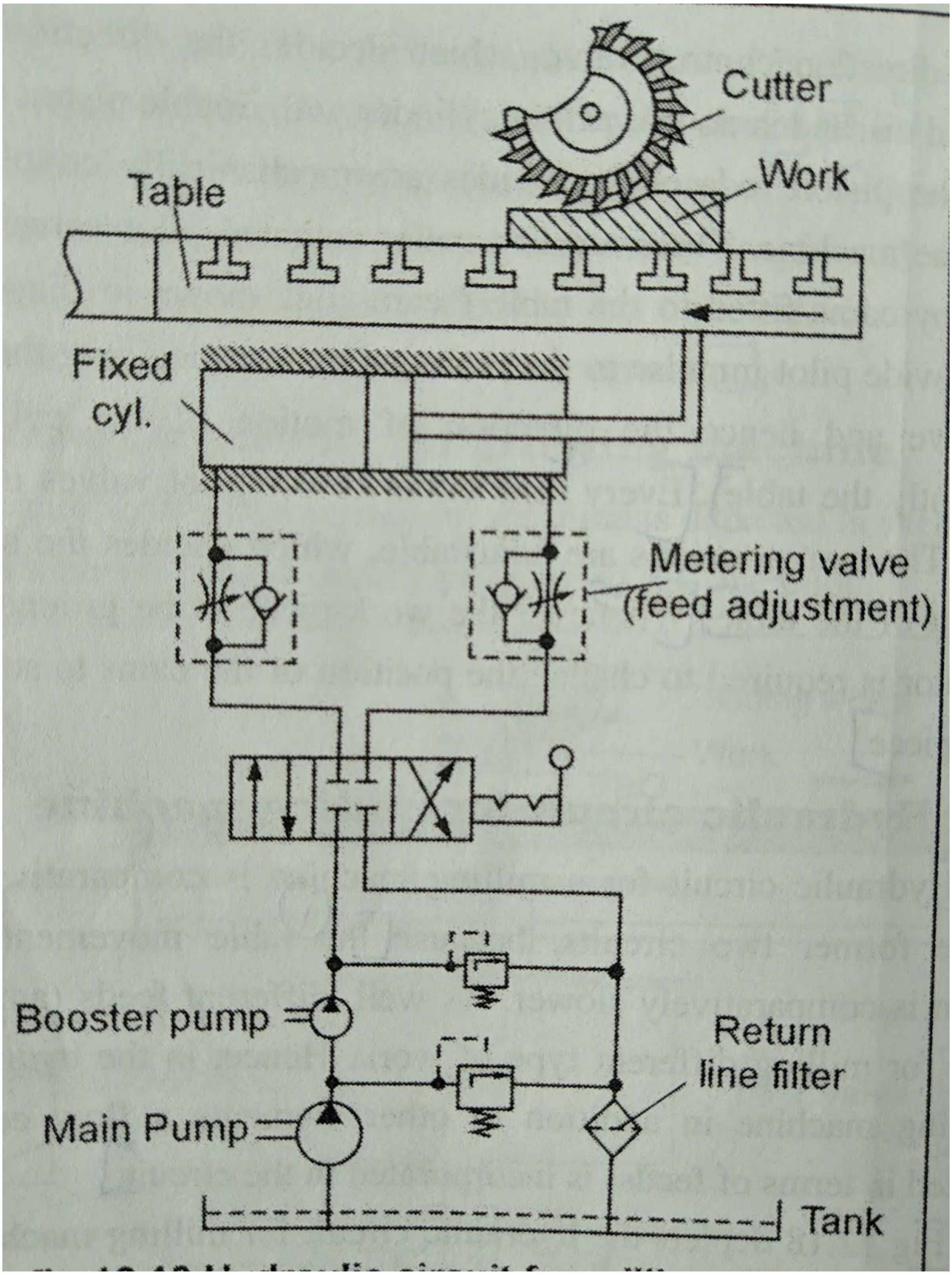
PUMP Unloading circuit

Double Pump Hydraulic System :

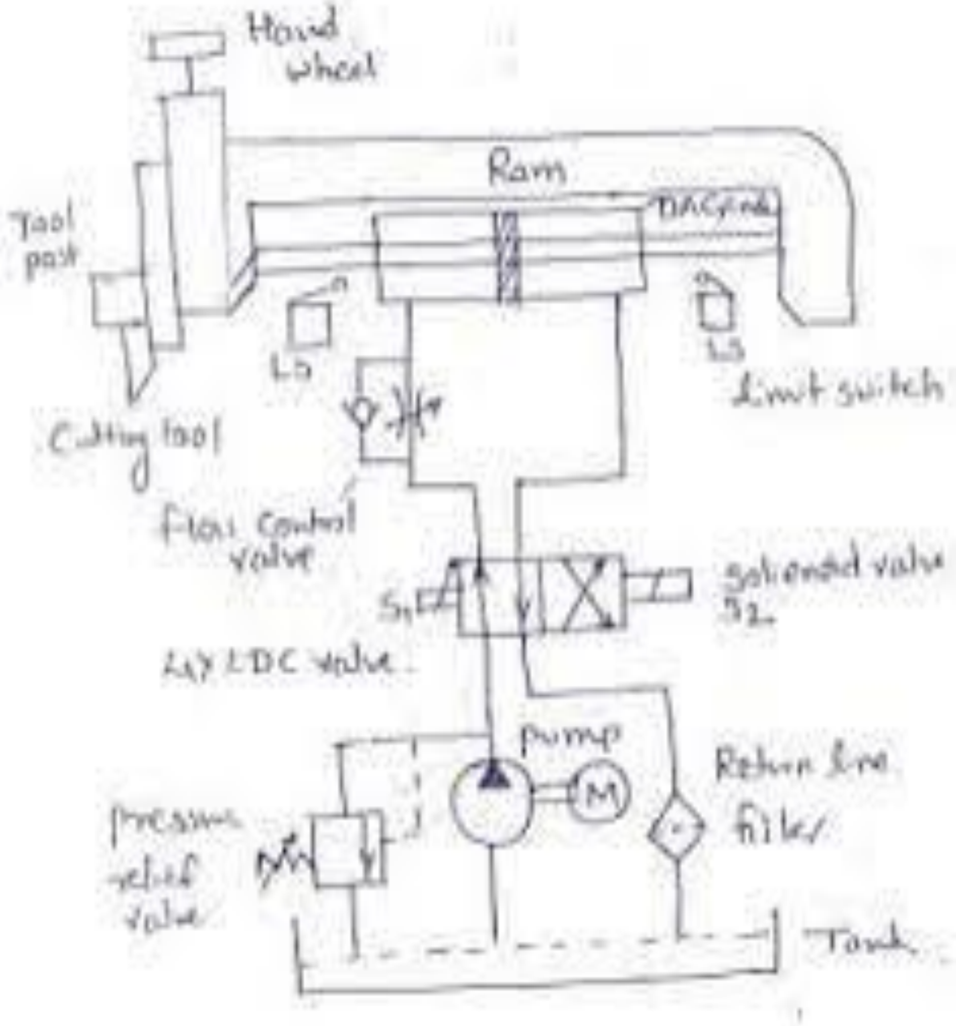
- Punch Press.
- Initial Low Pressure high flow rate req.
- When punching operation begins, increased pressure opens unloading valve tounload low pressure pump.
- To keep vertically mounted cylinder in upward position while pump is idling.
- Counterbalance valve is set to open at slightly above the pressure required to holdthe piston up.



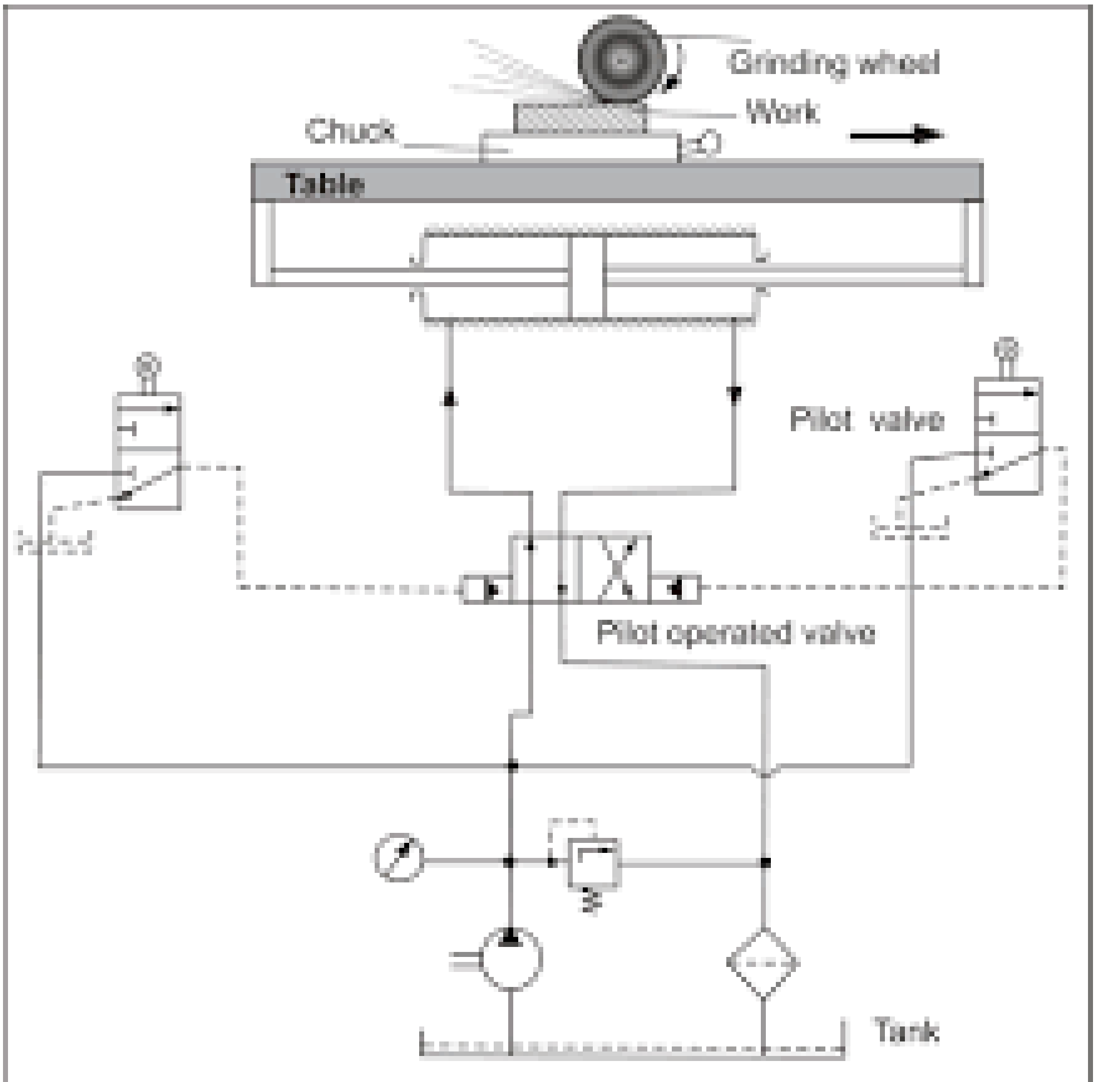
Double Pump Hydraulic System



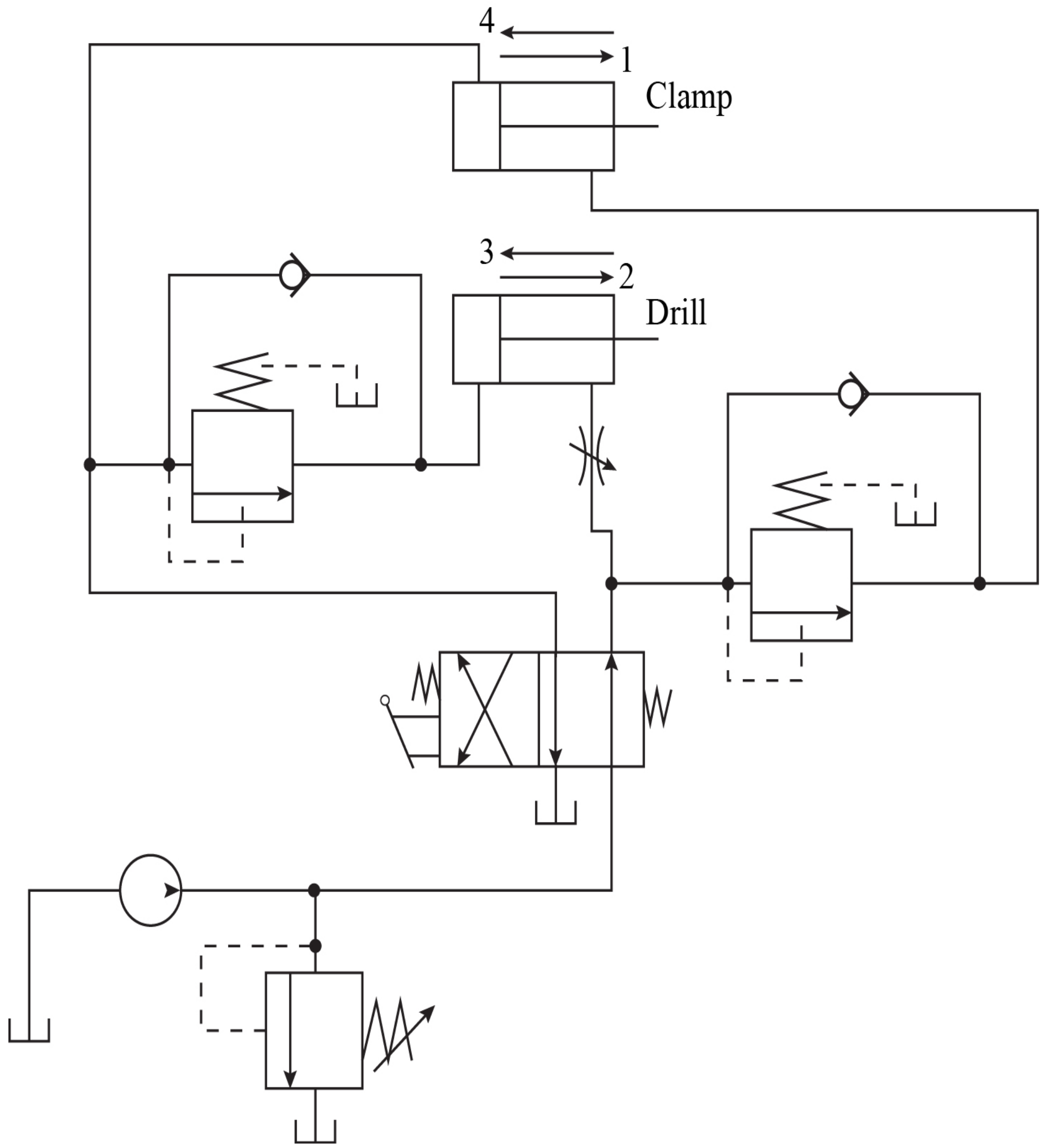
Hydraulic circuit for milling machine



Hydraulic circuit for Shaping machine



Hydraulic circuit for surface grinder



Hydraulic Drilling Machine

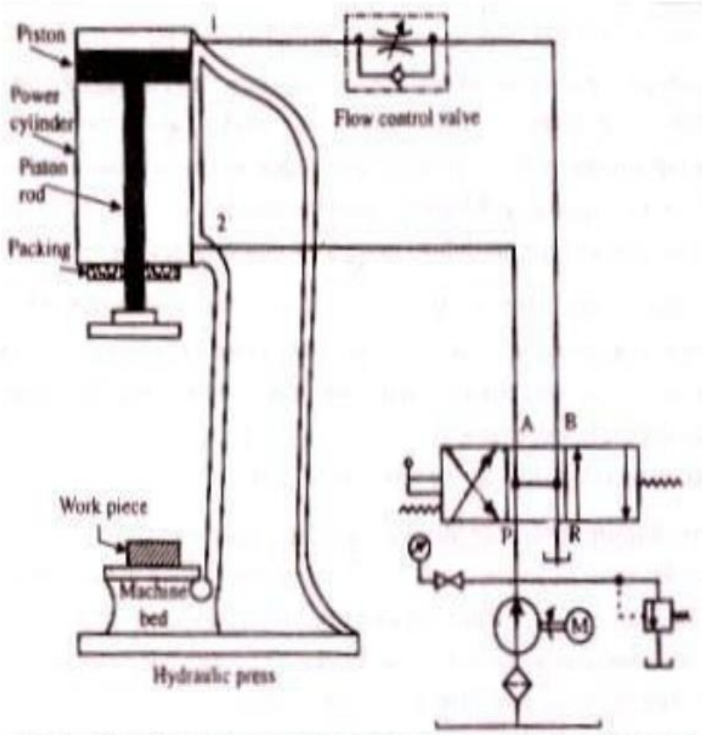


Fig. 7.16 : Hydraulic circuit for the operation of hydraulic press

LOW COST AUTOMATION — A CASE STUDY

Presently, manufacturing industries are constantly facing the challenge to reduce cost through productivity improvement. Considering the uncertain volumes, increasing labour cost, fluctuating demands and changes in customer needs, the challenge is not to merely level up one time but also to sustain the trend continuously.

Fluctuation in customer demand & increase in labour cost year on year leads to product cost increase. To overcome this and remain competitive, Productivity Improvement (PI) activities are a must. For Indian manufacturing industries, adopting conventional automation is still impractical in terms of return on investment (ROI usually requires 10 ~ 15 years). Toyota Kirloskar Auto Parts (TKAP) develops & encourages ‘Low Cost Automation (LCA)’ through innovative and breakthrough ideas to achieve automation in our manufacturing lines at affordable cost, ensuring flexibility to change.

Definition of LCA

Generally, when we discuss Low Cost Automation, we assume it is to implement an automation solution at the lowest cost. We define LCA as ‘a system where man & machine collaborate & work together, meeting expectations of the Toyota way’.

IMAGE GALLERY

SI No	CRITERIA	CONVENTIONAL AUTOMATION		TKAP LCA (Karakuri)	
		Idea	Demerit	Idea	Merit (Unique)
1	Part Movement	Power, Roller, Conveyor, etc.	Use Power High Power High Maintenance More space Less Flexible High Cost... Supplier Dependency	Free roller Gravity Chute	No Power Low Power Low Maintenance More Compact More Flexible Low Cost In-house Design, Development & Installation
2	Part Lifting	Pneumatic/ Hydraulic/ Electric Actuator		a). No Power: - Counter weight Karakuri lifter b). Low Power: - Karakuri with rope, pulley & DC motor	
3	Part Pushing/ Pulling	Power Roller, Conveyor, Actuator drive etc.		a). No Power: - Power sharing - Energy storage b). Low Power: - Karakuri with rope, pulley & DC motor	
4	Part Rotation	Actuator drive		a). No Power: - Power sharing - Energy storage - Cam & Follower mechanism	

Table 1

An automation, which consumes zero or very little power (eco-friendly), with zero or minimum actuators (safety), highly flexible & reliable in nature, which occupies less space (lean concept), that needs zero or minimum maintenance (high efficiency), with minimum investment and running cost, is termed as LCA.

TKAP Tool for LCA

Our tool for achieving all the above objectives of Low Cost Automation is termed as ‘Karakuri’— a Japanese word, which means achieving motion with no power or low power. It’s an ancient Japanese technique to move dolls without actuators or power. In Karakuri technique, we use different mechanisms like rope & pulley mechanism, counter weight mechanisms, cam & follower mechanisms, etc, to achieve unique motion or to convert one form of motion into another like vertical to horizontal and linear to rotary. Combining these motions together to form an automation solution requires an engineering approach. Using innovation and creativity, we develop unique solutions of Karakuri automation.

Karakuri versus conventional automation

Unlike conventional automation, Karakuri LCA provides safer, cost-effective, lean & maintenance-free flexible solutions with a target ROI of less than 2 years. Different tools and techniques used in Karakuri automation compared to conventional automation & their advantages are charted in the table. With increase in demand for energy efficient Kaizens to reduce CO2 emission and move towards a green plant, these Karakuri devices promote eco-friendly solutions by utilising no power or low power in the field of automation.

Need for LCA

The need for LCA development was identified during a cross functional group activity – 'Jishuken', which means "Time & Motion study". This activity covers a detailed study of each and every element of work to identify Muda (waste or unwanted work), Muri (burden) and Mura (fluctuation) involved in them. At the end of this activity, Kaizens were carried out to reduce Muda, Muri and Mura thereby increasing the value added work. The Kaizens that require major investments were identified for Low Cost Automation solutions.

The idea for LCA was generated by shopfloor personnel (operator or supervisor) who in turn pitched the idea on to our engineering team to build a concept. Then the concept was converted into design & development by our in-house engineering team. A prototype was developed for unique ideas before actual implementation to check its effectiveness. A 100% in-house solution starting from idea generation till execution & implementation in line makes this truly low cost and appropriate.

As a collaborative effort of Jishuken & LCA, the results were achieved in the form of manual time/effort reduction, consequently achieving productivity improvement. The combined efforts fetched positive results in all the 3 plants of TKAP, not only in terms of man hour reduction and productivity, but also motivating and improving morale of all employees.

Next action

As a part of Human Resource Development (HRD) for worklife improvement, we are now setting up a 'Karakuri Dojo', a training house for all TKAP employees to learn and implement Karakuri at their work place on their own, to build a safe and lively work environment. The training module covers basics of Karakuri including practical demo of various Karakuri mechanisms & models like:

- No power Karakuri
- Low power Karakuri
- Energy sharing Karakuri
- Energy storage Karakuri

Covering both theory and practice along with shopfloor experience will enhance knowledge and skill of our team members to overcome their work place concerns by themselves.

Continuous Improvement (PDCA)

As a part of continuous improvement, we are also developing Low Cost Automatic Guided Vehicles (AGV's) as a tool of LCA to better utilise our in-house engineering capabilities.

The journey started with development of a simple battery operated manual dolly and now, the in-house made AGV's can automatically transfer parts from one location to another, thereby, eliminating the Muda of manual conveyance of parts.

The different types of in-house AGV's at TKAP are:

- Modular AGV
- Steering AGV
- Towing AGV

Our vision is to develop an integrated logistic solution within the plant for all material movement using intelligent AGVs.

To conclude, Low Cost Automation is an effort to develop effective engineering solutions that eliminate wasteful manual effort on the shopfloor and address several aspects of performance such as safety, quality, productivity, environment, morale and cost, a panacea for manufacturing managers.

Hydraulic Cylinder Sequence Circuit:

- **Left Env :** Left Cyl extends completely and then Right Cyl extend.

Right Env : Right Cyl retracts fully and then Le