ME 407 – MECHATRONICS

MODULE II

- Actuators: Hydraulic and Pneumatic actuators.
- Directional control valves, pressure control valves, process control valves.
- Rotary actuators.
- Development of simple hydraulic and pneumatic circuits using standard Symbols.

INTRODUCTION

Both **pneumatics and hydraulics** are applications of fluid power. **Pneumatics** uses an easily compressible gas such as air or suitable pure gas while **hydraulics** uses relatively incompressible liquid media such as oil. A hydraulic system is used to amplify force. Generally they are slower than pneumatic ones but much greater force can be achieved.

Examples for pneumatic systems:- Air brakes on buses and trucks, Air brakes on trains, Air compressors, Air engines for pneumatically powered vehicles, Compressed-air engine and compressed-air vehicles, HVAC control systems, Pneumatic air guns, Pneumatic cylinder, Vacuum pump.

Examples for hydraulic systems:- Earth moving machines - TLB, Excavator, Dump Truck, Automotive-Power steering, Brakes, Cam phasing valves, suspension., Heavy duty robot arms, Aircraft landing gear.

BASIC COMPONENTS OF HYDRAULIC SYSTEM

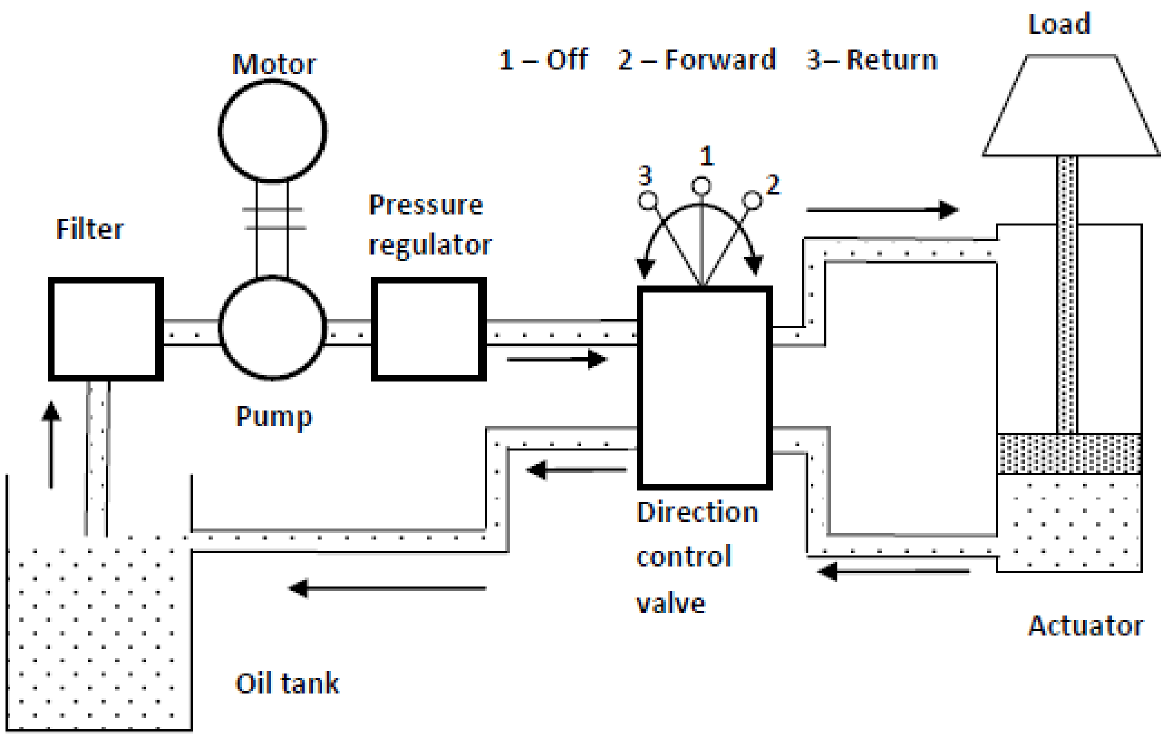


Fig 2.1 Components of a Hydraulic System

- The hydraulic actuator is a device used to convert the fluid power into mechanical power to do useful work. The actuator may be of the linear type (e.g., hydraulic cylinder) or rotary type(e.g., hydraulic motor) 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 by converting mechanical energy into hydraulic energy.
- Valves are used to control the direction, pressure and flow rate of a fluid flowing through the circuit.
- 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 shown in figure 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.

BASIC COMPONENTS OF A PNEUMATIC SYSTEM

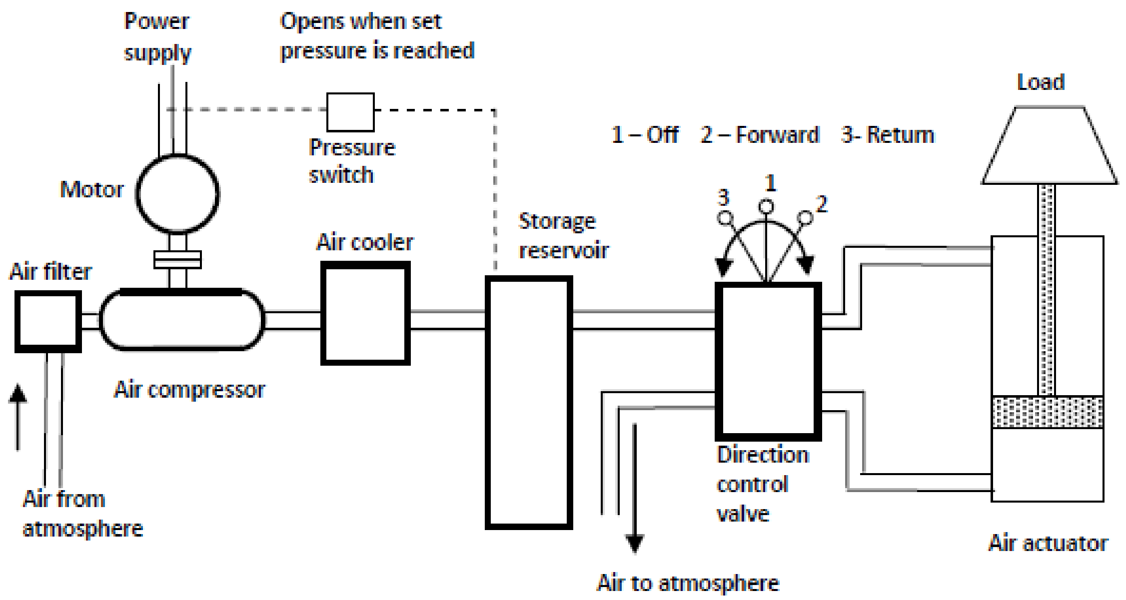


Fig 2.2 Components of Pneumatic System

- The pneumatic actuator converts the fluid power into mechanical power to perform useful work.
- The compressor is used to compress the fresh air drawn from the atmosphere.
- The storage reservoir is used to store a given volume of compressed air.
- The valves are used to control the direction, flow rate and pressure of compressed air.
- External power supply (motor) is used to drive the compressor.
- The piping system carries the pressurized air from one location to another.

- Air is drawn from the atmosphere through an air filter and raised to required pressure by an air compressor. As the pressure rises, the temperature also rises; hence, an air cooler is provided to cool the air with some preliminary treatment to remove the moisture.
- The treated pressurized air then needs to get stored to maintain the pressure. With the storage reservoir, a pressure switch is fitted to start and stop the electric motor when pressure falls and reaches the required level, respectively.
- The three-position change over the valve delivering air to the cylinder operates in a way similar to its hydraulic circuit

COMPARISON BETWEEN HYDRAULIC AND PNEUMATIC SYSTEMS

S. No.	Hydraulic System	Pneumatic System
1.	It employs a pressurized liquid as a fluid	It employs a compressed gas, usually air, as a fluid
2.	An oil hydraulic system operates at pressures up to 700 bar	A pneumatic system usually operates at 5–10 bar
3.	Generally designed as closed system	Usually designed as open system
4.	The system slows down when leakage occurs	Leakage does not affect the system much
5.	Valve operations are difficult	Valve operations are easy
6.	Heavier in weight	Lighter in weight
7.	Pumps are used to provide pressurized liquids	Compressors are used to provide compressed gases
8.	The system is unsafe to fire hazards	The system is free from fire hazards
9.	Automatic lubrication is provided	Special arrangements for lubrication are needed

HYDRAULIC & PNEUMATIC ACTUATORS

Actuators are output devices which convert energy from pressurized hydraulic oil or compressed air into the required type of action or motion. In general, hydraulic or pneumatic systems are used for gripping and/or moving operations in industry. These operations are carried out by using actuators. Actuators can be classified into three types.

- Linear actuators: These devices convert hydraulic/pneumatic energy into linear motion.
- Rotary actuators: These devices convert hydraulic/pneumatic energy into rotary motion.
- Actuators to operate flow control valves: these are used to control the flow and pressure of fluids such as gases, steam or liquid.

SINGLE ACTING HYDRAULIC & PNEUMATIC CYLINDERS

- These cylinders produce work in one direction of motion hence they are named as single acting cylinders.
- The compressed air pushes the piston located in the cylindrical barrel causing the desired motion.
- The return stroke takes place by the action of a spring.
- Generally the spring is provided on the rod side of the cylinder.

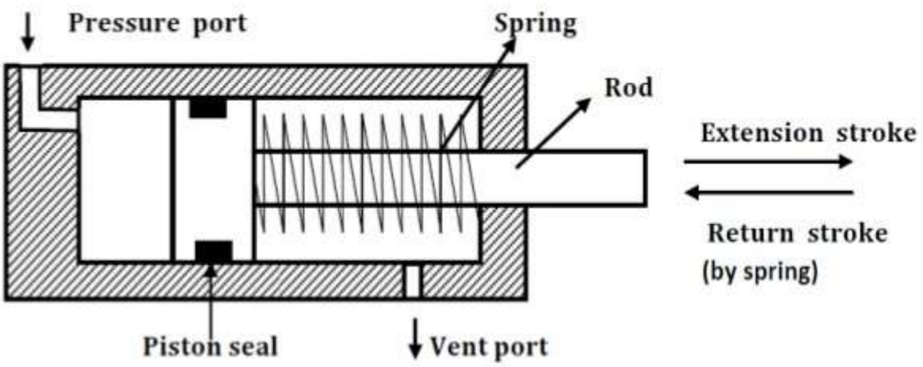


Fig 2.3 Single Acting Cylinder

DOUBLE ACTING HYDRAULIC & PNEUMATIC CYLINDERS

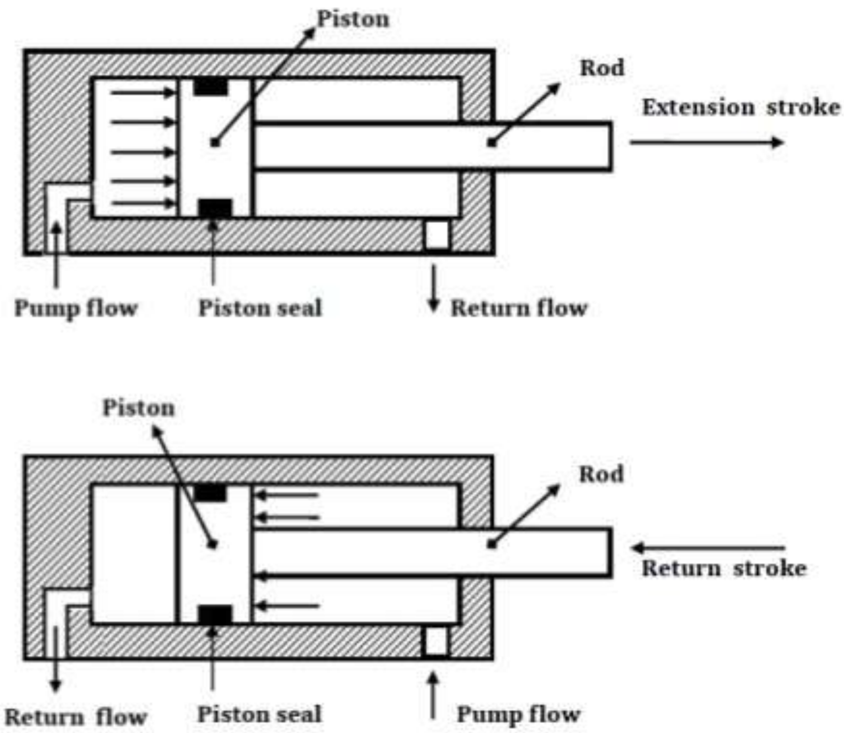


Fig 2.4 Double Acting Cylinder

- The main parts of a hydraulic double acting cylinder are: piston, piston rod, cylinder tube, and end caps.
- The piston rod is connected to piston head and the other end extends out of the cylinder. The piston divides the cylinder into two chambers namely the rod end side and piston end side.
- The seals prevent the leakage of oil between these two chambers.
- The cylindrical tube is fitted with end caps. The pressurized oil, air enters the cylinder chamber through the ports provided.
- In the rod end cover plate, a wiper seal is provided to prevent the leakage of oil and entry of the contaminants into the cylinder.
- The combination of wiper seal, bearing and sealing ring is called as cartridge assembly.

- The end caps may be attached to the tube by threaded connection, welded connection or tie rod connection.
- The piston seal prevents metal to metal contact and wear of piston head and the tube. These seals are replaceable. End cushioning is also provided to prevent the impact with end caps.

Cylinder end cushions

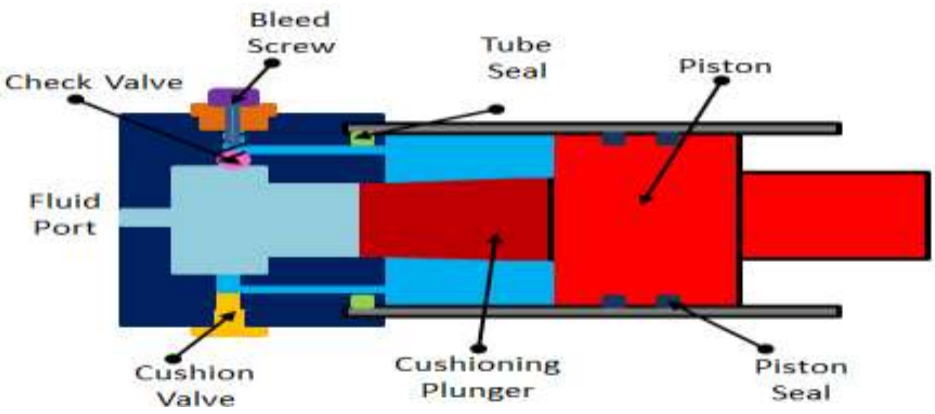


Fig 2.5 Cylinder End Cushion

- Double acting cylinders generally contain cylinder cushions at the end of the cylinder to slow down the movement of the piston near the end of the stroke.
- Cushioning arrangement avoids the damage due to the impact occurred when a fast moving piston is stopped by the end caps.
- Deceleration of the piston starts when the tapered plunger enters the opening in the cap and closes the main fluid exit. This restricts the exhaust flow from the barrel to the port. This throttling causes the initial speed reduction.
- During the last portion of the stroke the oil has to exhaust through an adjustable opening since main fluid exit closes. Thus the remaining fluid exists through the cushioning valve. Amount of cushioning can be adjusted by means of cushion screw.
- A check valve is provided to achieve fast break away from the end position during retraction motion. A bleed screw is built into the check valve to remove the air bubbles present in a hydraulic type system.

TANDEM CYLINDER

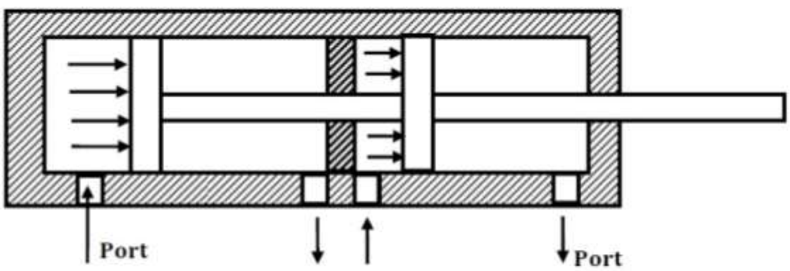


Fig 2.6 Tandem Cylinder

- In tandem two cylinders are arranged in series and the force obtained from the cylinder will be almost double.

TELESCOPIC CYLINDER

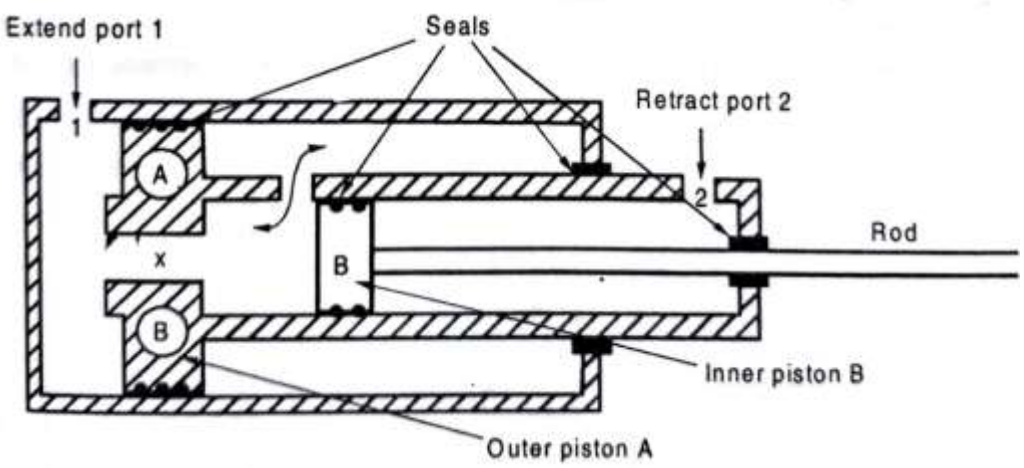


Fig 2.7 Telescopic Cylinder

- Telescopic cylinders are used where limited space is available.
- Fluid is applied through 'extend port 1' during extension. Fluid is applied to both sides of the outer piston A through the ports X and Y and the piston is moving right side due to the difference in areas between sides of piston A
- Fluid applied through 'retract port 2' during retraction. The port 2 is connected with the flexible hose so that movement can be obtained without disturbance.
- When the piston B is driven fully to the left, then the port Y will be connected to the port 2, applying force on the right hand side of the piston A during retraction.

TURN CYLINDER

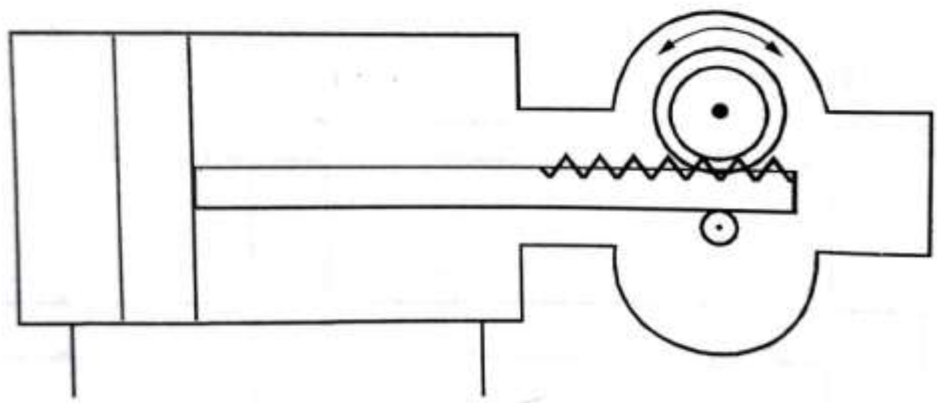


Fig 2.8 Turn Cylinder

- Rack and pinion arrangement is made in this type. One end of the piston rod is made as rack to mesh with a pinion.
- Here linear movement of the piston rod is converted to rotary motion by the pinion. The pinion can be rotated through any angle by movement of piston rod.

THROUGH ROD CYLINDER

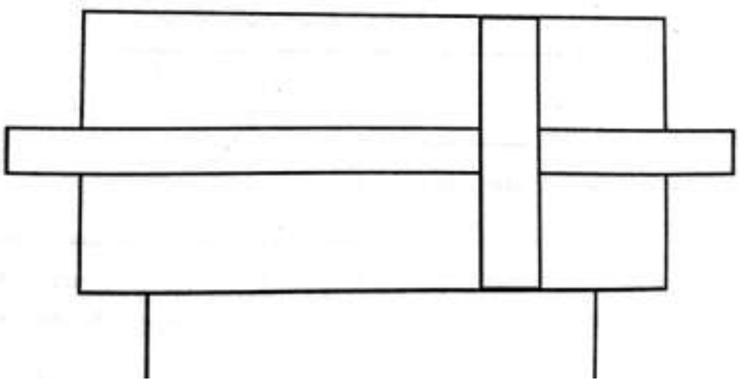


Fig 2.9 Through Rod Cylinder

- Through rod cylinder has piston rods on both sides of the plunger. This type assures equal force and speed on both sides of the cylinder.

AXIALPISTON 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.
- These pumps have sub-types as:
    - Bent axis piston pumps
    - Swash plate axial piston pump

BENT-AXIS PISTON PUMPS

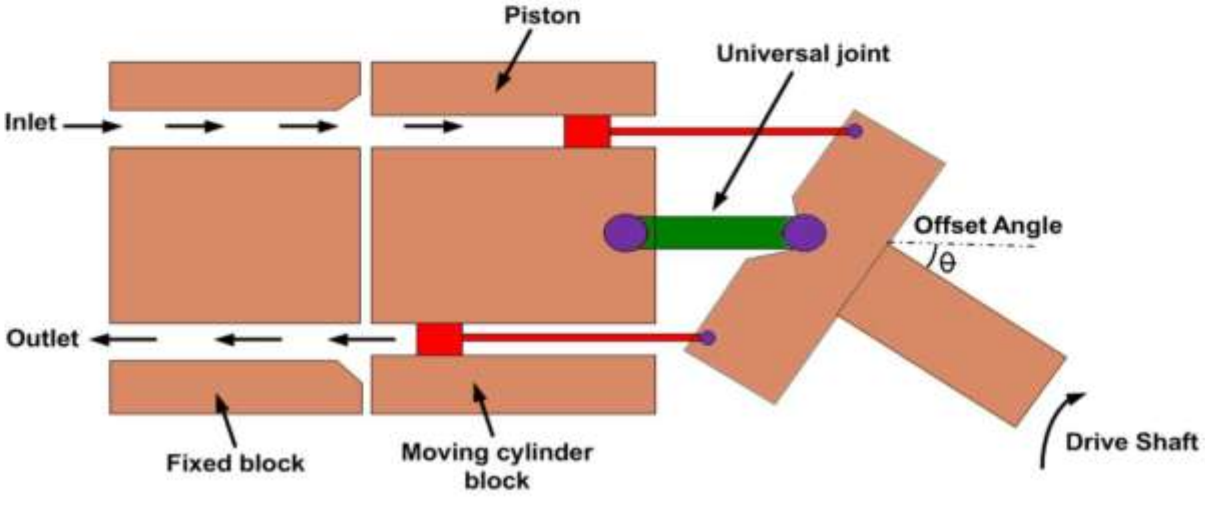


Fig 2.10 Bend Axis Piston Pump

- 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.
- A universal link connects the block to the drive shaft, to provide alignment and a positive drive.
- The volumetric displacement (discharge) of the pump is controlled by changing the offset angle. It makes the system simple and inexpensive.
- The discharge does not occur when the cylinder block is parallel to the drive shaft. The offset angle can vary from 0° to 40°.
- The fixed displacement units are usually provided with 23° or 30° offset angles while the variable displacement units are provided with a yoke and an external control mechanism to change the offset angle.
- Some designs have arrangement of moving the yoke over the center position to reverse the fluid flow direction. The flow rate of the pump varies with the offset angle θ.

<u>SWASH PLATE AXIAL PISTON PUMP</u>

- 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. 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.

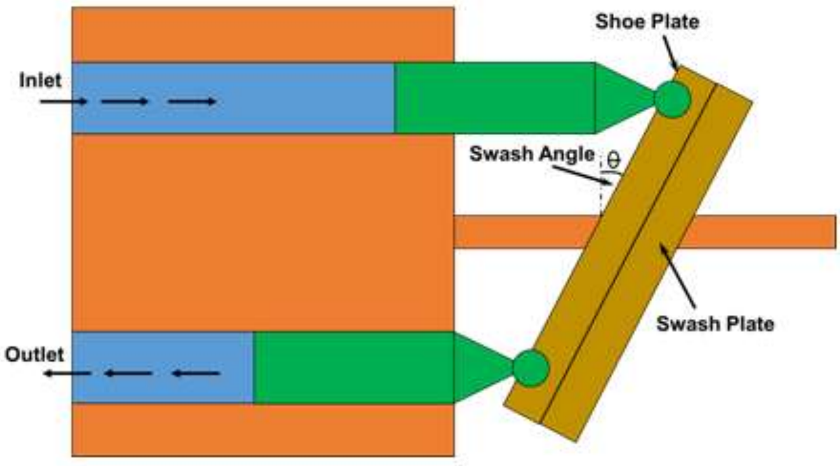


Fig 2.11 Swash Plate Axial Piston Pump

- 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.

- When the swash plate is perpendicular to the shaft; the reciprocating motion to the piston does not occur. As the swash plate angle increases, the piston follows the angle of the swash plate surface and hence it moves in and out of the barrel.
- The piston moves out of the cylinder barrel during one half of the cycle of rotation thereby generating an increasing volume, while during other half of the rotating cycle, the pistons move into the cylinder barrel generating a decreasing volume. This reciprocating motion of the piston results in the drawing in and pumping out of the fluid.
- Pump capacity can be controlled by varying the swash plate angle with the help of a separate hydraulic cylinder. The pump capacity (discharge) increases with increase in the swash plate angle and vice-versa.
- The cylinder block and the drive shaft in this pump are located on the same centerline. The pistons are connected through shoes and a shoe plate that bears against the swash plate. These pumps can be designed to have a variable displacement capability. It can be done by mounting the swash plate in a movable yoke.

ROTARY ACTUATORS

GEAR MOTOR

- Rotary actuators convert energy of pressurized fluid into rotary motion. Rotary actuators are similar to electric motors but are run on hydraulic or pneumatic power.
- It consists of two inter meshing gears inside a housing with one gear attached to the drive shaft.
- The air enters from the inlet, causes the rotation of the meshing gear due to difference in the pressure and produces the torque. The air exists from the exhaust port.
- Gear motors tend to leak at low speed, hence are generally used for medium speed applications.

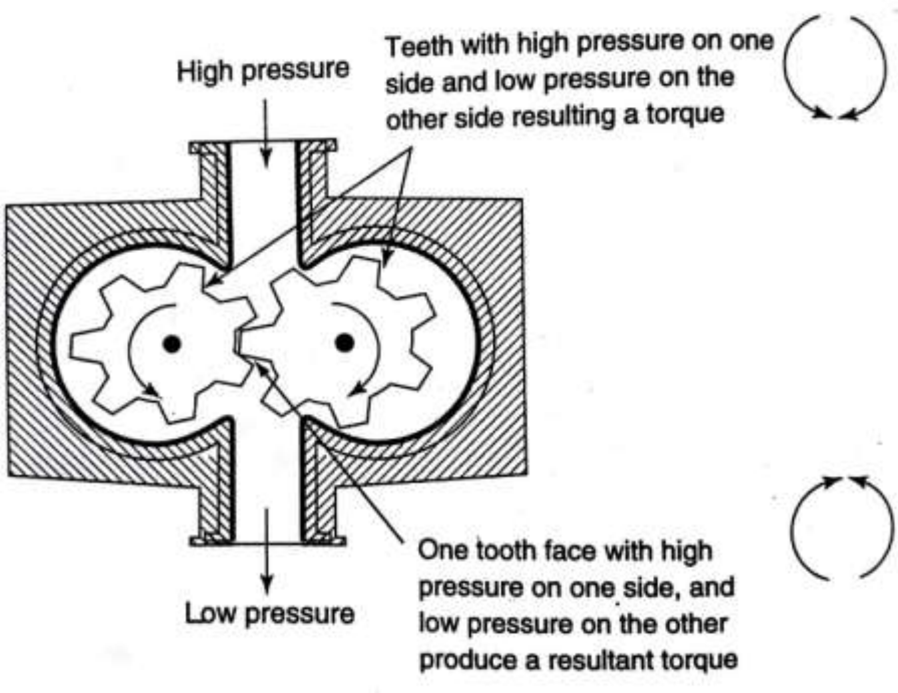


Fig 2.12 Gear Motor

VANE MOTOR

- A rotary vane motor consists of a rotor with sliding vanes in the slots provided on the rotor.
- The rotor is placed eccentrically with the housing. Air enters from the inlet port, rotates the rotor and thus torque is produced.
- Air is then released from the exhaust port (outlet).

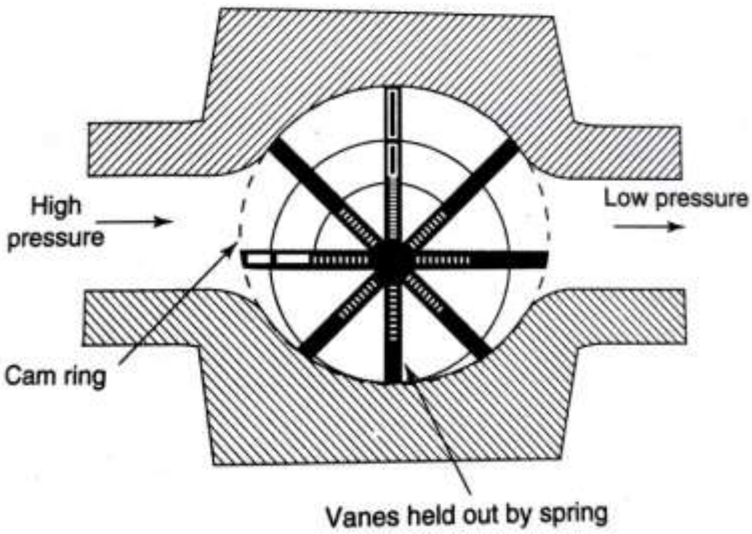


Fig 2.13 Vane Motor

LIMITED ROTATION ACTUATORS

- It consists of a single rotating vane connected to output shaft.
- It is used for double acting operation and has a maximum angle of rotation of about 270°.
- These are generally used to actuate dampers in robotics and material handling applications.
- Other type of limited rotation actuator is a rack and pinion type actuator.

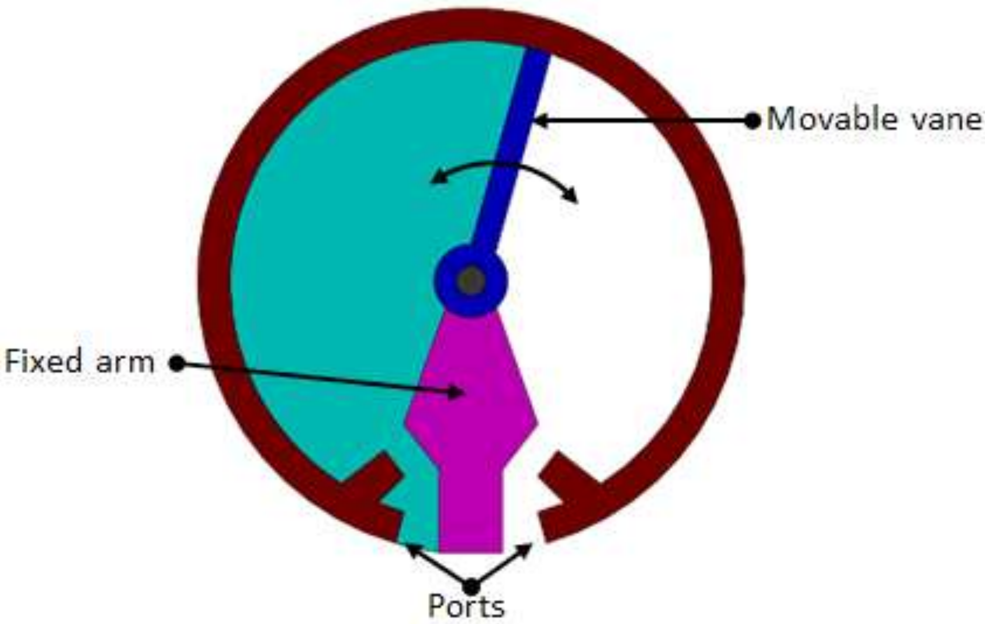


Fig 2.14 Limited Rotation Actuators

RACK AND PINION ROTARY ACTUATORS

- Figure shows a double-rack design that has fluid in the area where the pinion runs.
- This configuration requires a high-pressure shaft seal but assures that the rack and pinion is well lubricated.
- With fluid piped to the *CW* port, the output shaft turns clockwise.
- With fluid piped to the *CCW* port, the output shaft turns counter clockwise.
- This design works best in pneumatic or low-pressure hydraulic applications.

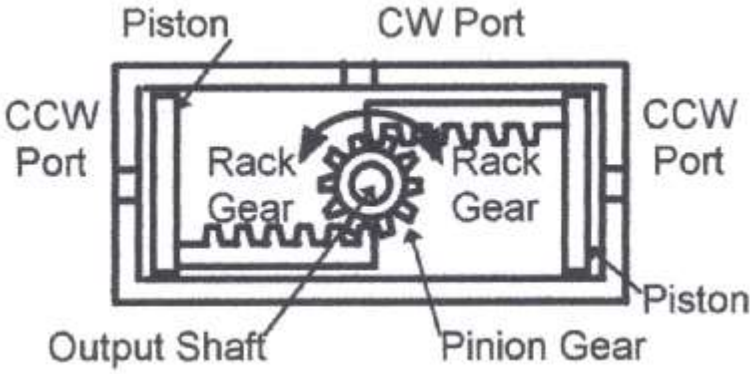


Fig 2.15 Rack and Pinion Rotary Actuator

VALVES

DIRECTION CONTROL VALVES

- Directional control valves are used to control the distribution of energy in a fluid power system.
- They provide the direction to the fluid and allow the flow in a particular direction.
- These valves are used to control the start, stop and change in direction of the fluid flow. These valves regulate the flow direction in the hydraulic circuit.
- These control valves contain ports that are external openings for the fluid to enter and leave. The number of ports is usually identified by the term ‘way’.

Directional control valves can be classified in the following manner:

According to type of construction:

1. Poppet valves 2. Spool valves

According to number of ports:

1. Two- way valves 2. Three – way valves 3. Four- way valves.

According to number of switching position:

1. Two – position 2. Three - position

According to actuating mechanism:

1. Manual actuation 2. Mechanical actuation 3. Solenoid actuation

4. Hydraulic actuation 5. Pneumatic actuation 6. Indirect actuation

ACCORDING TO TYPE OF CONSTRUCTION

1. CHECK VALVES

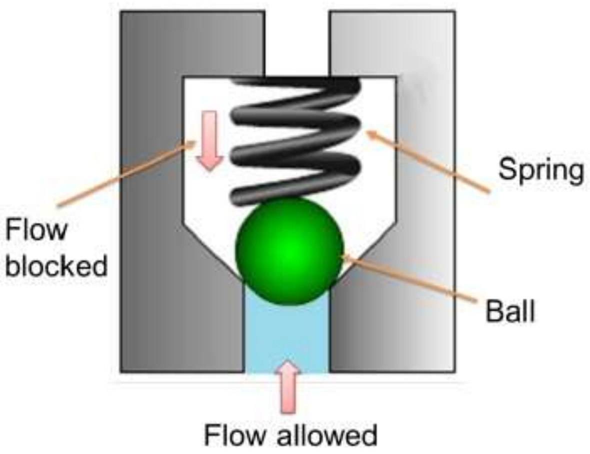


Fig 2.16 Inline Check Valve

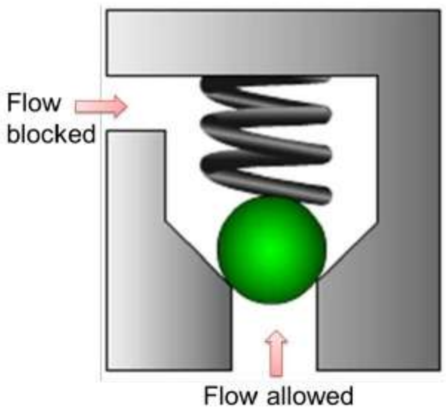


Fig 2.17 Right Angle Check Valve

- These are unidirectional valves and permit the free flow in one direction only.
- These valves have two ports: one for the entry of fluid and the other for the discharge.
- They are consists of a housing bore in which ball or poppet is held by a small spring force.
- The valve having ball as a closing member is known as ball check valve. The various types of check valves are available for a range of applications.
- These valves are generally small sized, simple in construction and inexpensive.
- Generally, the check valves are automatically operated. Human intervention or any external control system is not required.
- These valves can wear out or can generate the cracks after prolonged usage and therefore they are mostly made of plastics for easy repair and replacements. An important concept in check valves is the cracking pressure.
- The check valve is designed for a specific cracking pressure which is the minimum upstream pressure at which the valve operates.
- The simplest check valve is an inline check valve. The ball is held against the valve seat by a spring force. Fluid flow is not possible from the spring side but the fluid from opposite side can pass by lifting the ball against. However, there is some pressure drop across the valve due to restriction by the spring force. Therefore these valves are not suitable for the application of high flow rate. When the operating pressure increases the valve becomes more tightly seated in this design.
- The advantages of the poppet valves include no leakage, long life and suitability with high pressure applications.
- Sometimes, the right angle check valve is used for the high flow rate applications. The pressure drop is comparatively less in right angle check valve.

2. POPPET VALVES

- When the closing member is not a ball but a poppet energized by a spring is known as poppet valve.

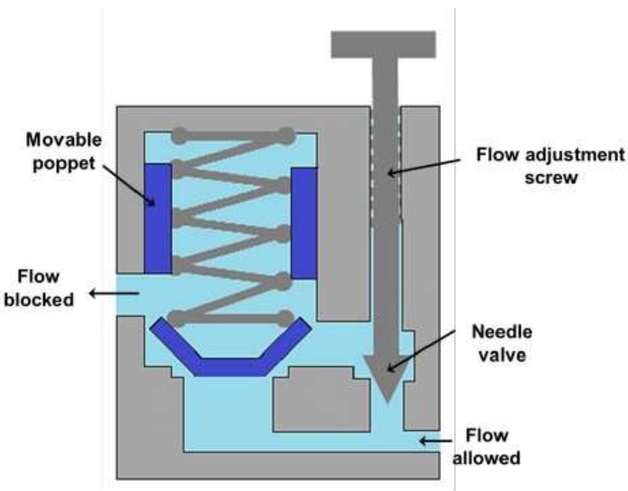


Fig 2.18 Restriction Check Valve

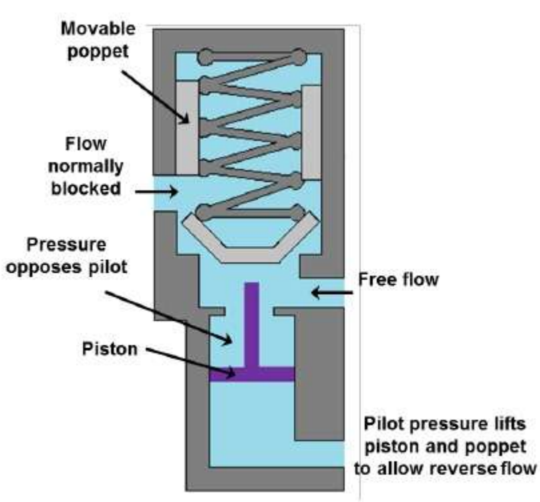


Fig 2.19 Pilot Operated Check Valve

- Some valves are meant for an application where free flow is required in one direction and restricted flow required in another direction. These types of valves are called as restriction check valve. These valves are used when a direction sensitive flow rate is required
- Another important type of check valve known as pilot operated check valve. The function of the pilot operated check valve is similar to a normal check valve unless it gets an extra pressure signal through a pilot line. Pilot allows free flow in one direction and prevents the flow in another direction until the pilot pressure is applied. But when pilot pressure acts, the poppet opens and the flow is blocked from both the sides. These valves are used to stop the fluid suddenly.

3. SPOOL VALVE

- The spool valves derive their name from their appearance. It consists of a shaft sliding in a bore which has large groove around the circumference. This type of construction makes it look like a spool. The spool is sealed along the clearance between moving spool and housing (valve body).
- The quality of seal or the amount of leakage depends on the amount of clearance, viscosity of fluid and the level of the pressure. The grooves guide the fluid flow by interconnecting or blocking the holes (ports).
- The standard terms are referred as Port ‘P’ is pressure port, Port ‘T’ is tank port and Port ‘A’ and Port ‘B’ are the actuator (or working) ports.
- The actuators can move in forward or backward direction depending on the connectivity of the pressure and tank port with the actuators port.

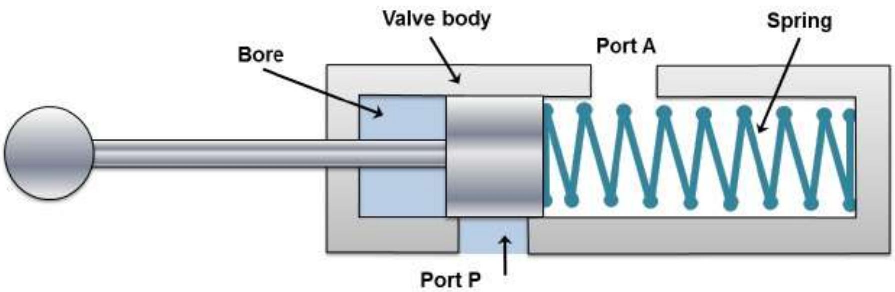


Fig 2.20 Spool Valve

ACCORDING TO NUMBER OF PORTS

1. TWO WAY VALVES

- Two way valves have only two ports. These valves are also known as on-off valves because they allow the fluid flow only in direction.
- Normally, the valve is closed. These valves are available as normally open and normally closed function. These are the simplest type of spool valves.
- When actuating force is not applied to the right, the port P is not connected with port A as shown in figure. Therefore, the actuation does not take place. Similarly, in the open condition the pressure port P is connected with the actuator port A

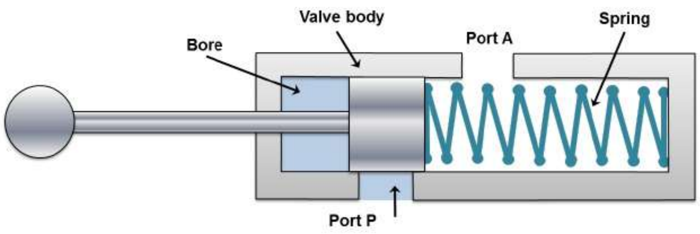


Fig 2.21 Valve Closed

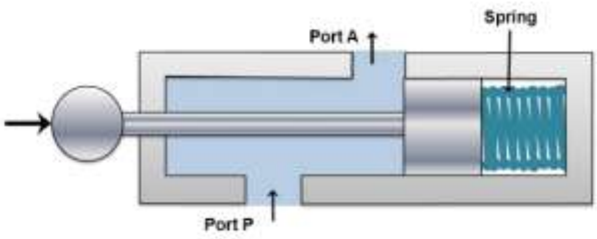


Fig 2.22 Valve Opened

2. THREE WAY VALVES

- When a valve has one pressure port, one tank port and one actuating port, it is known as three way valve.
- In this valve, the pressure port pressurizes one port and exhausts another one.
- As shown in figures, only one actuator port is opened at a time. In some cases a neutral position is also available when both the ports are blocked.
- Generally, these valves are used to operate single acting cylinders.

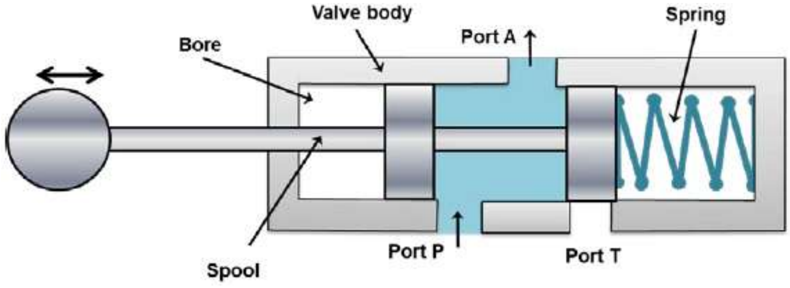


Fig 2.23 Three Way Valve: Position 1

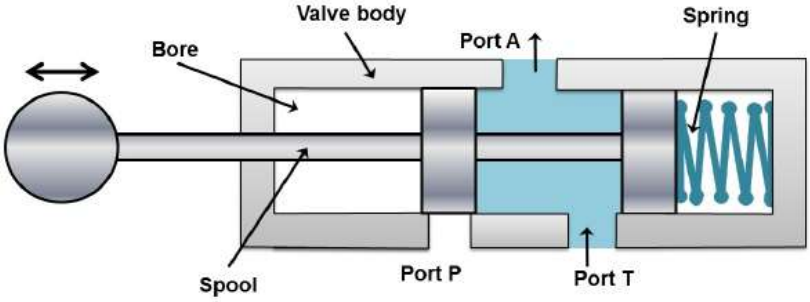


Fig 2.24 Three Way Valve: Position 2

3. FOUR WAY VALVES

- It is generally used to operate the cylinders and fluid motors in both the directions. The four ways are: pump port P, tank port T, and two working ports A and B connected to the actuator.
- The primary function of a four way valve is to pressurize and exhaust two working ports A and B alternatively.

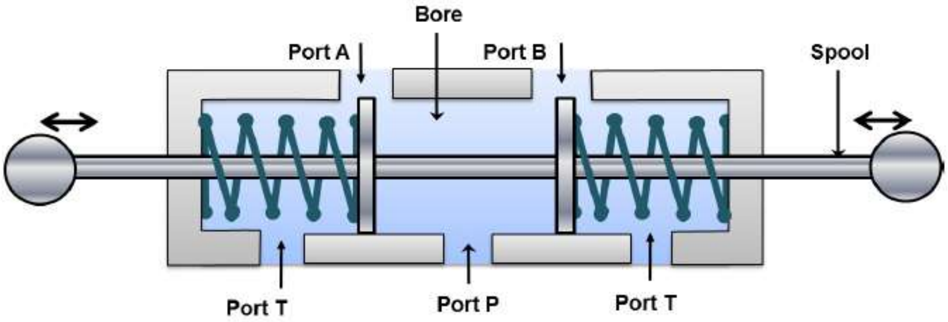


Fig 2.25 Four Way Valve

ACCORDING TO NUMBER/WAYS OF SWITCHING POSITION

1. THREE POSITION FOUR WAY (3/4) VALVES

- Three position four way (3/4) valves are used in double-acting cylinders to perform advance, hold and return operation to the piston.
- These types of valves have three switching positions. They have a variety of possible flow path configurations but have identical flow path configuration.
- When the centered path is actuated, port A and B are connected with both the ports P and T respectively. In this case, valve is not active because all the ports are open to each other. The fluid flows to the tank at atmospheric pressure. In this position work cannot be done by any part of the system. This configuration helps to prevent heat buildup.
- When left end (port B) is actuated, the port P is connected with ports B and T is connected with port. Similarly, when the right end is actuated the port P is connected to A and working port B is connected to port T.
- The three position valves are used when the actuator is needed to stop or hold at some intermediate position. It can also be used when the multiple circuits or functions are accomplished from one hydraulic power source.

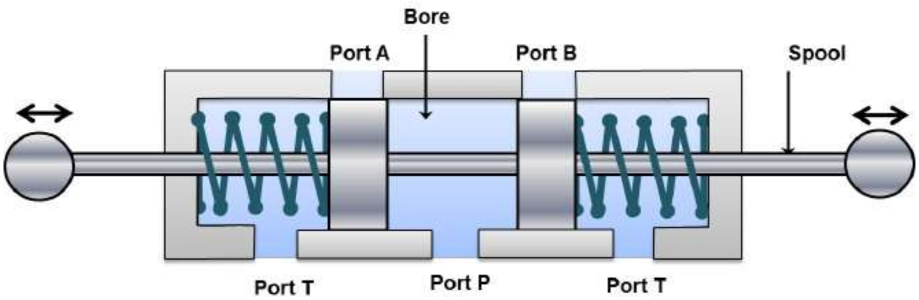


Fig 2.26 Three Position Four Way Valve: Closed Center

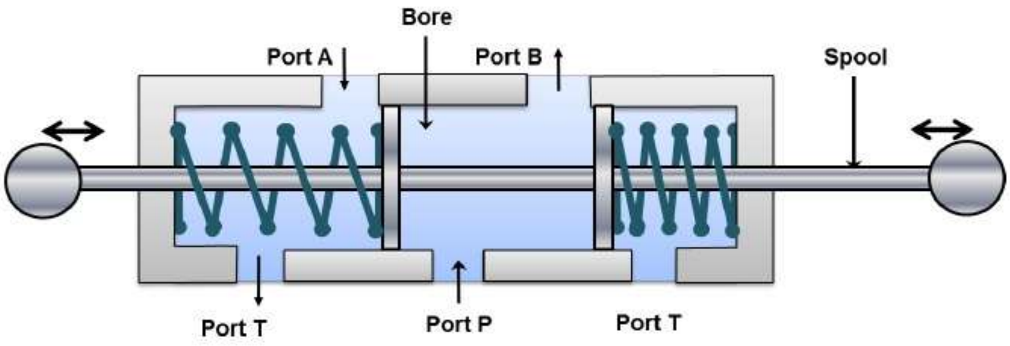


Fig 2.27 Three Position Four Way Valve: P to B and A to T

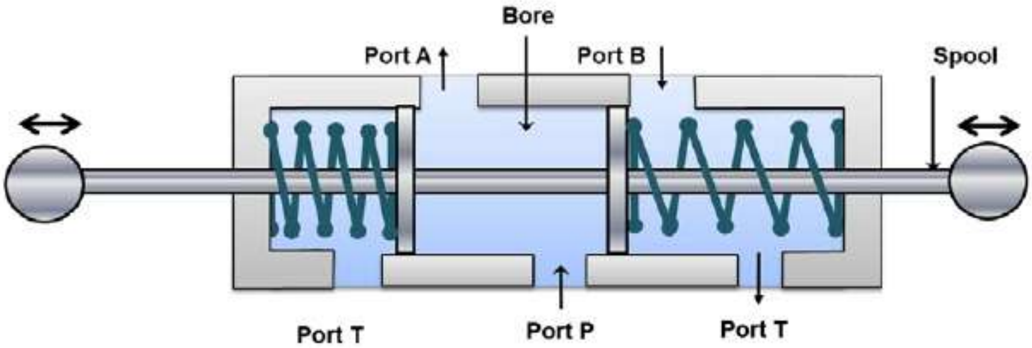


Fig 2.28 Three Position Four Way Valve: P to A and B to T

2. TWO POSITION FOUR WAY (2/4) VALVES

- The two position four way valves have only two switching positions and do not have any mid position. Therefore, they are also known as impulse valves.
- These valves can be used to operate double acting cylinders. These are also used to reciprocate or hold an actuator.
- The operation is faster because the distance between ports of these valves is smaller. Hence these valves are used on machines where fast reciprocation cycles are needed such as punching and stamping etc.

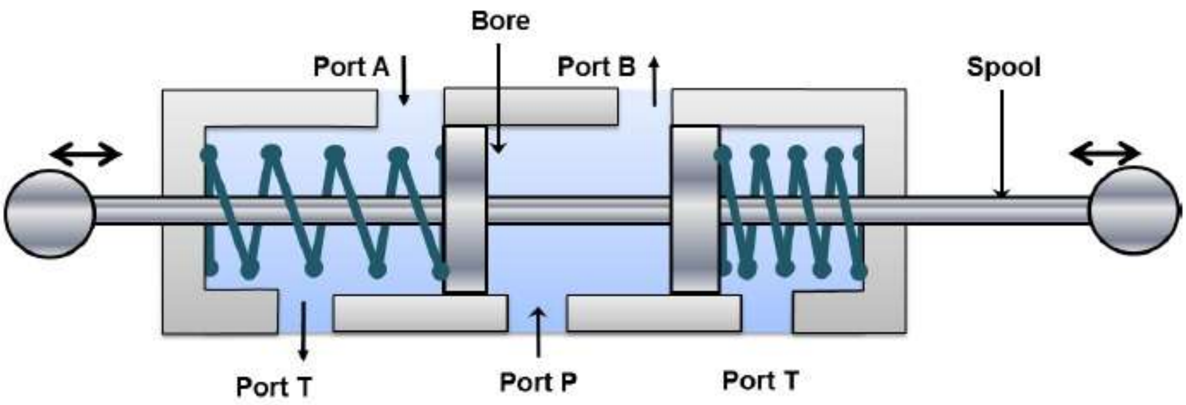


Fig 2.29 Two Position Four Way DCV: P to B and A to T

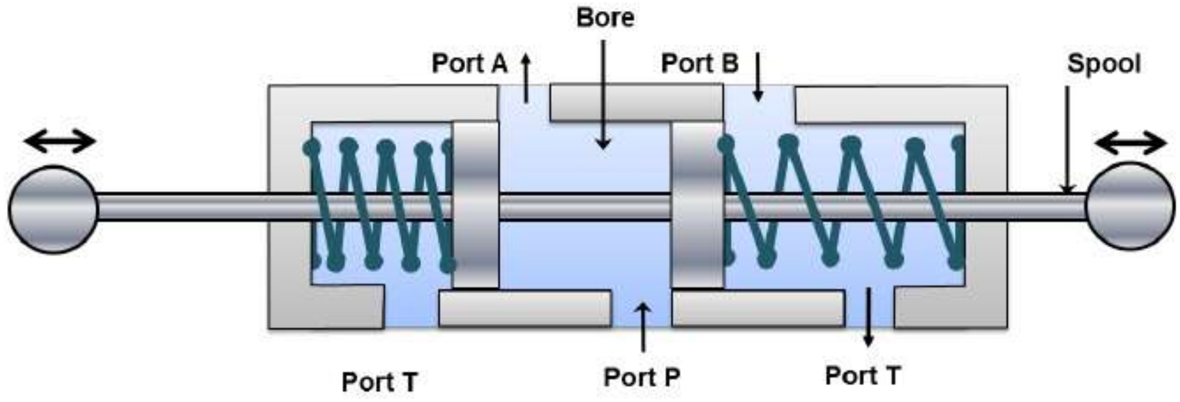


Fig 2.30 Two Position Four Way DCV: P to A and B to T

ACCORDING TO ACTUATION MECHANISM

1. MANUAL ACTUATION

- In this type, the spool is operated manually. Manual actuators are hand lever, push button and pedals etc.

2. MECHANICAL ACTUATION

- The DCV spool can be operated by using mechanical elements such as roller and cam, roller and plunger and rack and pinion etc.
- In these arrangements, the spool end is of roller or a pinion gear type. The plunger or cam or rack gear is attached to the actuator.
- Thus, the mechanical elements gain some motion relative to the actuator (cylinder piston) which can be used for the actuation.

3. SOLENOID ACTUATION

- The solenoid actuation is also known as electrical actuation.
- The energized solenoid coil creates a magnetic force which pulls the armature into the coil. This movement of armature controls the spool position.
- The main advantage of solenoid actuation is its less switching time.

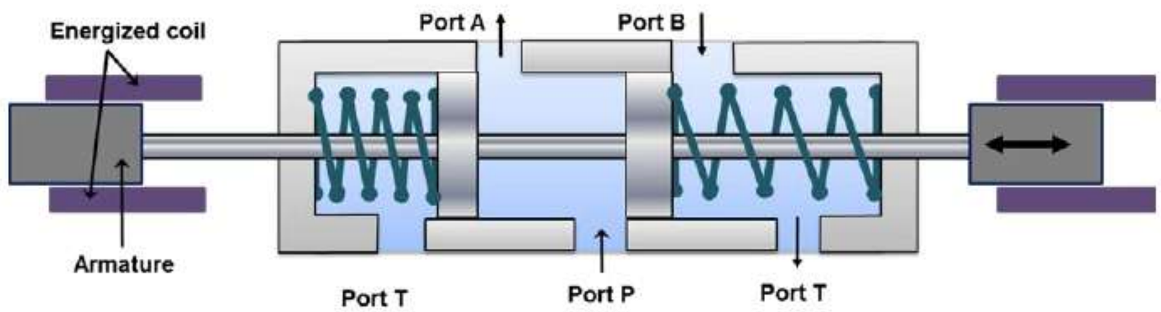


Fig 2.31 Working of Solenoid to Shift Spool of Valve

4. HYDRAULIC ACTUATION

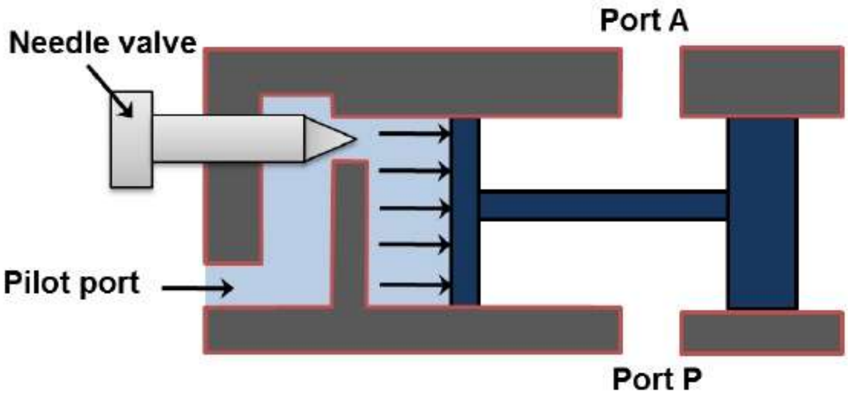


Fig 2.32 Pilot Actuated DCV

- This type actuation is usually known as pilot-actuated valve.
- In this type of actuation, the hydraulic pressure is directly applied on the spool. The pilot port is located on one end of the valve. Fluid entering from pilot port operates against the piston and forces the spool to move forward.
- The needle valve is used to control the speed of the actuation.

5. PNEUMATIC ACTUATION

- DCV can also be operated by applying compressed air against a piston at either end of the valve spool.
- The construction of the system is similar to the hydraulic actuation.
- The only difference would be the actuation medium. The actuation medium is the compressed air in pneumatic actuation system.

6. INDIRECT ACTUATION OF DIRECTIONAL CONTROL VALVE

- The direction control valve can be operated by manual, mechanical, solenoidal (electrical), hydraulic (pilot) and pneumatic actuations. The mode of actuation does not have any influence on the basic operation of the hydraulic circuits.
- Mostly, the direct actuation is restricted to use with smaller valves only because usually lot of force is not available. The availability of limited force is the greatest disadvantage of the direct actuation systems.
- In practice, the force required to shift the spool is quiet higher. Therefore, the larger valves are often indirectly actuated in sequence.
- First, the smaller valve is actuated directly and the flow from the smaller valve is directed to either side of the larger valve. The control fluid can be supplied by the same circuit or by a separate circuit.
- The pilot valve pressure is usually supplied internally. These two valves are often incorporated as a single unit.
- These valves are also called as Electro-hydraulic operated DCV.

FLOW CONTROL VALVES

- In practice, the speed of actuator is very important in terms of the desired output and needs to be controlled. The speed of actuator can be controlled by regulating the fluid flow. A flow control valve can regulate the flow or pressure of the fluid.
- The fluid flow is controlled by varying area of the valve opening through which fluid passes. The fluid flow can be decreased by reducing the area of the valve opening and it can be increased by increasing the area of the valve opening. A very common example to the fluid flow control valve is the household tap.
- The pressure adjustment screw varies the fluid flow area in the pipe to control the discharge rate. The pressure drop across the valve may keep on fluctuating.
- In general, the hydraulic systems have a pressure compensating pump. The inlet pressure remains almost constant but the outlet pressure keeps on fluctuating depending on the external load. It creates fluctuating pressure drop. Thus, the ordinary flow control valve will not be able to maintain a constant fluid flow.

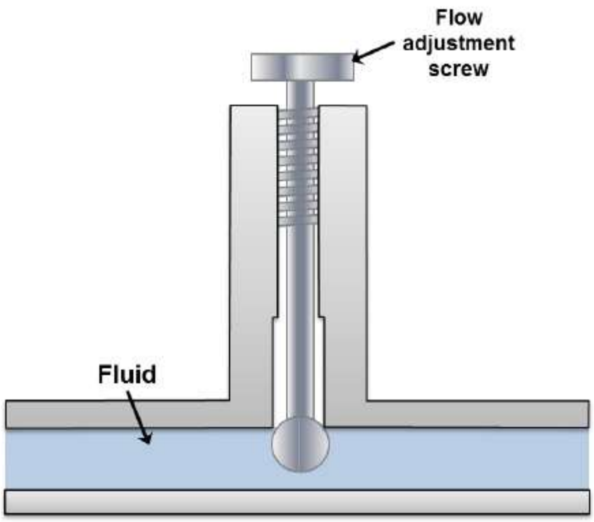


Fig 2.33 Flow Control Valve

- A pressure compensated flow control valve maintains the constant flow throughout the movement of a spool, which shifts its position depending on the pressure.
- Flow control valves can also be affected by temperature changes. It is because the viscosity of the fluid changes with temperature. Therefore, the advanced flow control valves often have the temperature compensation.
- The temperature compensation is achieved by the thermal expansion of a rod, which compensates for the increased coefficient of discharge due to decreasing viscosity with temperature.

TYPES OF FLOW CONTROL VALVES

1. PLUG OR GLOVE VALVE

- The plug valve is quite commonly used valve. It is also termed as glove valve.
- This valve has a plug which can be adjusted in vertical direction by setting flow adjustment screw.

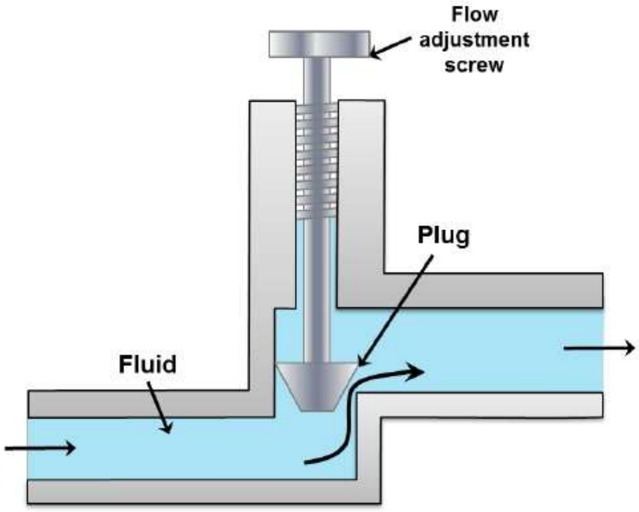


Fig 2.34 Plug or Glove Valve

- The adjustment of plug alters the orifice size between plug and valve seat. Thus the adjustment of plug controls the fluid flow in the pipeline.
- The characteristics of these valves can be accurately predetermined by machining the taper of the plug.
- The typical example of plug valve is stopcock that is used in laboratory glassware.
- The valve body is made of glass or teflon. The plug can be made of plastic or glass.
- Special glass stopcocks are made for vacuum applications. Stopcock grease is used in high vacuum applications to make the stopcock air-tight.

2. BUTTERFLY VALVE

- It consists of a disc which can rotate inside the pipe. The angle of disc determines the restriction.
- Butterfly valve can be made to any size and is widely used to control the flow of gas.
- The resilient butterfly valve uses the flexibility of rubber and has the lowest pressure rating.
- The high performance butterfly valves have a slight offset in the way the disc is positioned. It increases its sealing ability and decreases the wear.
- For high-pressure systems, the triple offset butterfly valve is suitable which makes use of a metal seat and is therefore able to withstand high pressure. It has higher risk of leakage on the shut-off position and suffer from the dynamic torque effect.
- Butterfly valves are favored because of their lower cost and lighter weight. The disc is always present in the flow therefore a pressure drop is induced regardless of the valve position.

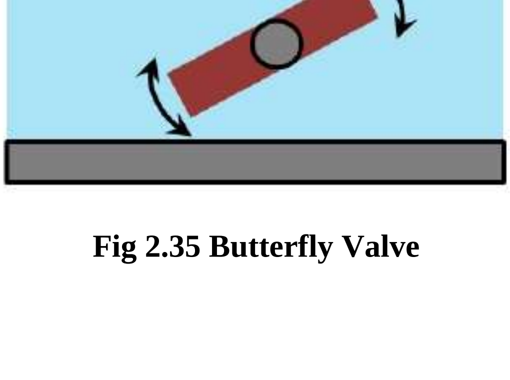


Fig 2.35 Butterfly Valve

3. BALL VALVE

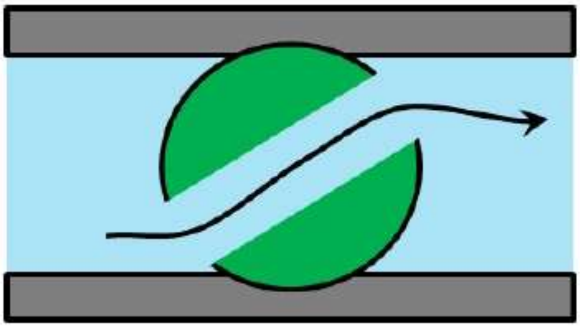


Fig 2.36 Ball Valve

- This type of flow control valve uses a ball rotated inside a machined seat. The ball has a through hole as shown in figure. It has very less leakage in its shut-off condition.
- These valves are durable and usually work perfectly for many years. They are excellent choice for shutoff applications.
- They do not offer fine control which may be necessary in throttling applications.
- These valves are widely used in industries because of their versatility, high supporting pressures (up to 1000 bar) and temperatures (up to 250°C).
- They are easy to repair and operate.

4. BALANCED VALVE

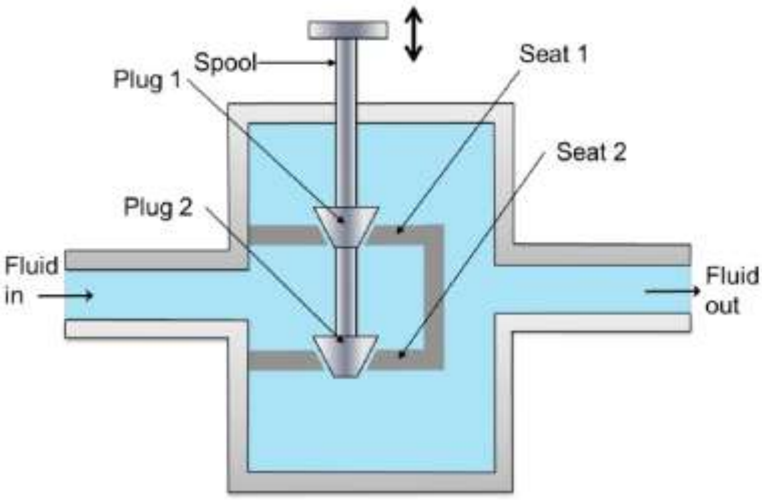


Fig 2.37 Balanced Valve

- It comprises of two plugs and two seats.
- The opposite flow gives little dynamic reaction onto the actuator shaft. It results in the negligible dynamic torque effect.
- However, the leakage is more in these kind of valves because the manufacturing tolerance can cause one plug to seat before the other.
- The pressure-balanced valves are used in the houses. They provide water at nearly constant temperature to a shower or bathtub despite of pressure fluctuations in either the hot or cold supply lines.

5. GATE VALVE

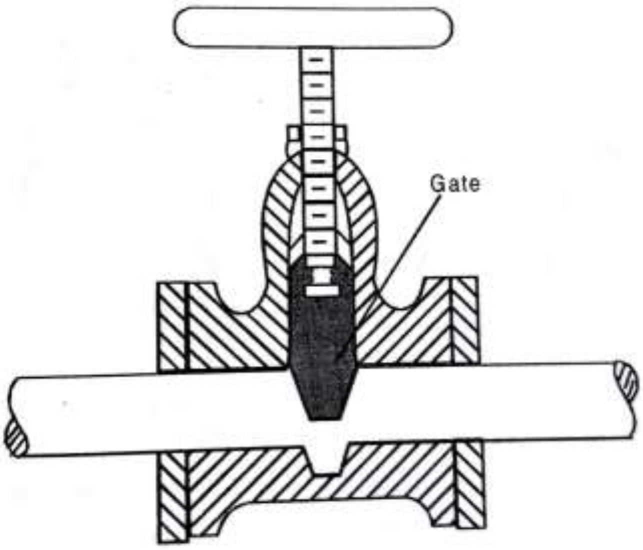


Fig 2.38 Gate Valve

- Gate valves are used as 'stops' to shut off fluid flow or to open the line to full flow.
- Gate valves provide an opening with minimum pressure drop.
- Basic gate valves are no compensated type i.e. they are not compensated for changes in fluid pressure or temperature.

6. NEEDLE VALVE

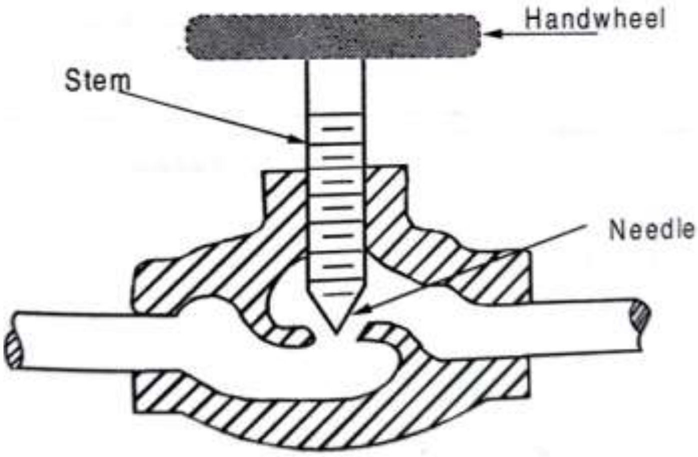


Fig 2.39 Needle Valve

- Needles valves provide finer control of flow in small diameter pipes.
- They have sharp pointed conical disc and matching seat.
- Needle valves are normally made up of steel bar.
- Needle valves are also used as stop valves in hydraulic circuit to shut off the flow of fluid from one part of a circuit to another part.
- Needle valves are suitable for throttling i.e. the flow area is slowly reduced as the valve is closed, gradually reducing the quantity of fluid passing through the valve.

7. GLOBE VALVE

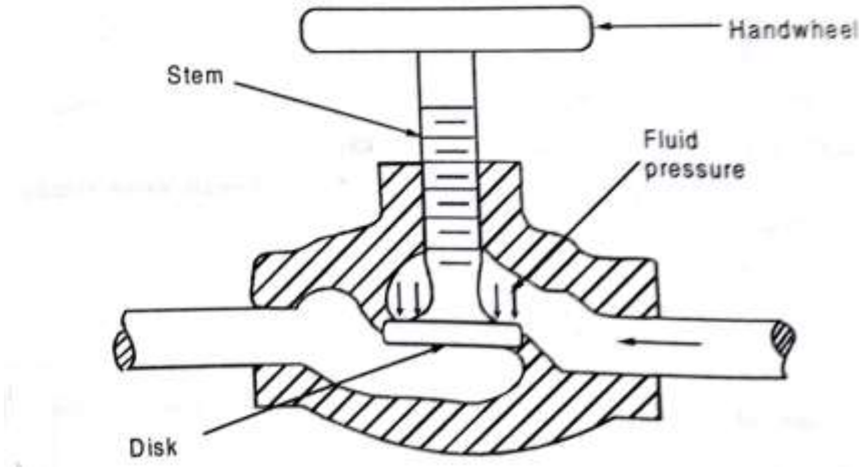


Fig 2.40 Globe Valve

- Globe valves have a round disk to control or stop the fluid flow.
- The flow area of the globe valve is more than that of the needle valve. Hence, globe valve will have a larger flow capacity at a lower pressure drop than a needle valve of the same size.

PRESSURE CONTROL VALVES

- The pressure relief valves are used to protect the hydraulic components from excessive pressure.
- This 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

1. DIRECT TYPE OF RELIEF VALVE

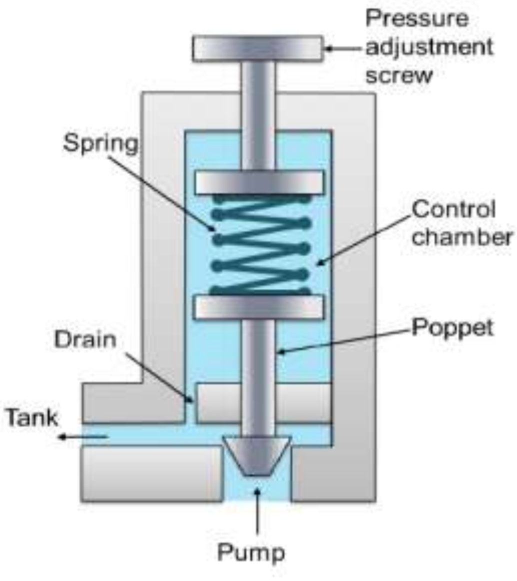


Fig 2.41 Direct type pressure relief valve

- This type of valves has two ports; one of which is connected to the pump and another is connected to the tank.
- It consists of a spring chamber where poppet is placed with a spring force. Generally, the spring is adjustable to set the maximum pressure limit of the system. The poppet is held in position by combined effect of spring force and dead weight of spool.
- As the pressure exceeds this combined force, the poppet raises and excess fluid bypassed to the reservoir (tank). The poppet again reseats as the pressure drops below the pre-set value.
- A drain is also provided in the control chamber. It sends the fluid collected due to small leakage to the tank and thereby prevents the failure of the valve.

2. UNLOADING VALVE

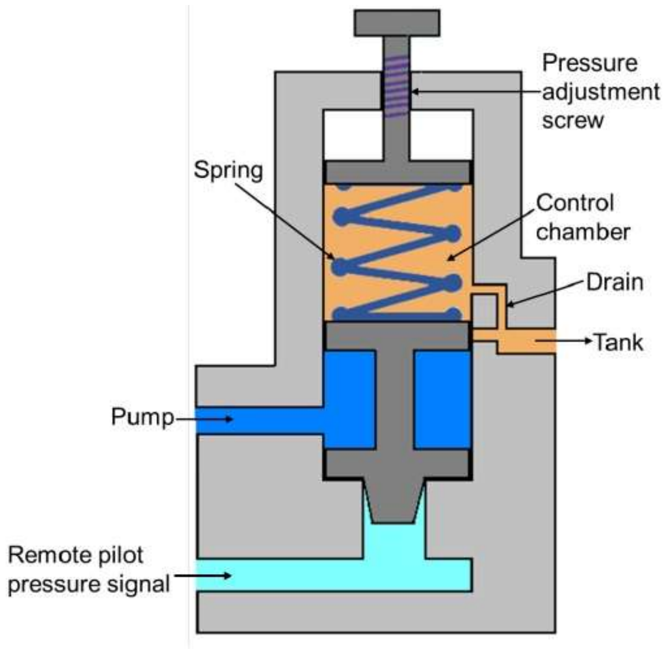


Fig 2.42 Unloading Valve

- This valve consists of a control chamber with an adjustable spring which pushes the spool down.
- The valve has two ports: one is connected to the tank and another is connected to the pump. The valve is operated by movement of the spool.
- Normally, the valve is closed and the tank port is also closed. These valves are used to permit a pump to operate at the minimum load.
- It works on the same principle as direct control valve that the pump delivery is diverted to the tank when sufficient pilot pressure is applied to move the spool. The pilot pressure maintains a static pressure to hold the valve opened. The pilot pressure holds the valve until the pump delivery is needed in the system.
- As the pressure is needed in the hydraulic circuit; the pilot pressure is relaxed and the spool moves down due to the self-weight and the spring force. Now, the flow is diverted to the hydraulic circuit.
- The drain is provided to remove the leaked oil collected in the control chamber to prevent the valve failure.
- The unloading valve reduces the heat build-up due to fluid discharge at a pre-set pressure value.

3. SEQUENCE VALVE

- The primary function of this type of valve is to divert flow in a predetermined sequence. It is used to operate the cycle of a machine automatically.
- A sequence valve may be of direct-pilot or remote-pilot operated type.
- Its construction is similar to the direct relief valve. It consists of the two ports; one main port connecting the main pressure line and another port (secondary port) is connected to the secondary circuit. The secondary port is usually closed by the spool. The pressure on the spool works against the spring force.
- When the pressure exceeds the pre-set value of the spring; the spool lifts and the fluid flows from the primary port to the secondary port.
- For remote operation; the passage used for the direct operation is closed and a separate pressure source for the spool operation is provided in the remote operation mode.

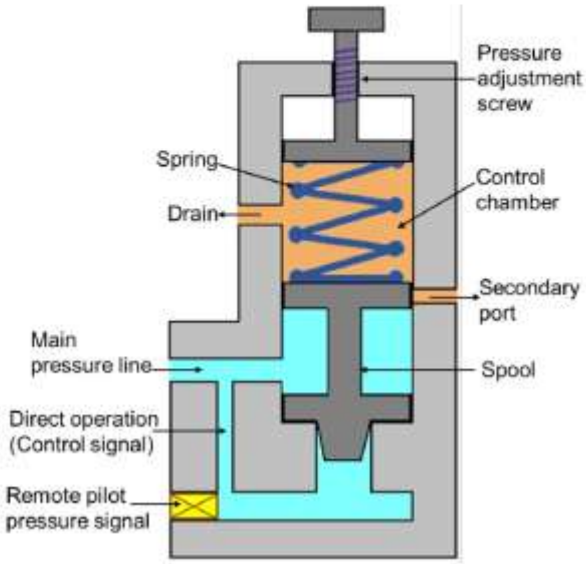


Fig 2.43 Sequence Valve

4. COUNTERBALANCE VALVE

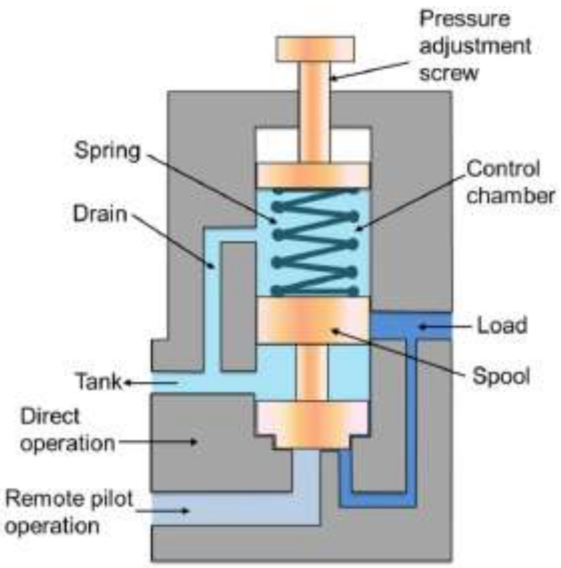


Fig 2.44 Counterbalance Valve

- It is used to maintain the back pressure and to prevent a load from failing. The counterbalance valves can be used as breaking valves for decelerating heavy loads.
- These valves are used in vertical presses, lift trucks, loaders and other machine tools where position or hold suspended loads are important.
- Counterbalance valves work on the principle that the fluid is trapped under pressure until pilot pressure overcomes the pre-set value of spring force. Fluid is then allowed to escape, letting the load to descend under control.
- This valve is normally closed until it is acted upon by a remote pilot pressure source. Therefore, a lower spring force is sufficient.
- It leads to the valve operation at the lower pilot pressure and hence the power consumption reduces, pump life increases and the fluid temperature decreases.

5. PRESSURE REDUCING VALVE

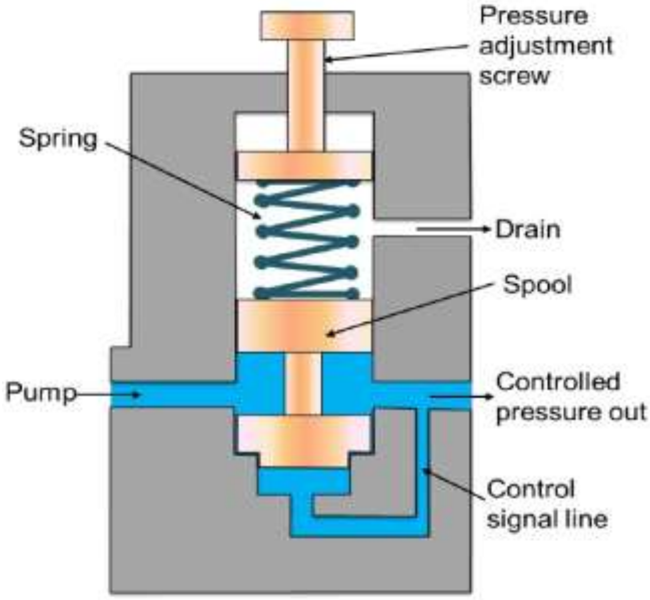


Fig 2.45 Pressure Reducing Valve

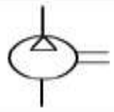
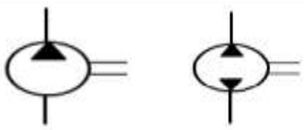
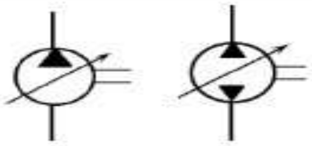
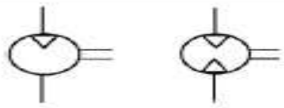
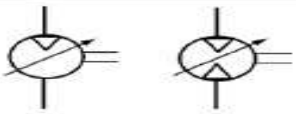
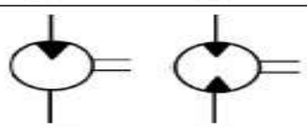
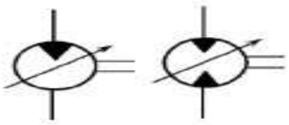
- Sometimes a part of the system may need a lower pressure. This can be made possible by using pressure reducing valve. These valves are used to limit the outlet pressure. Generally, they are used for the operation of branch circuits where the pressure may vary from the main hydraulic pressure lines.
- These are open type valve and have a spring chamber with an adjustable spring, a movable spool. A drain is provided to return the leaked fluid in the spring (control) chamber.
- A free flow passage is provided from inlet port to the outlet port until a signal from the outlet port tends to throttle the passage through the valve.
- The pilot pressure opposes the spring force and when both are balanced, the downstream is controlled at the pressure setting.
- When the pressure in the reduced pressure line exceeds the valve setting, the spool moves to reduce the flow passage area by compressing the spring.
- It can be seen from the figure that if the spring force is more, the valve opens wider and if the controlled pressure has greater force, the valves moves towards the spring and throttles the flow.

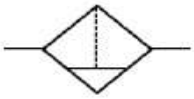
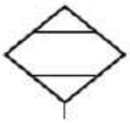
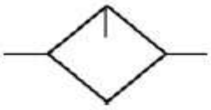
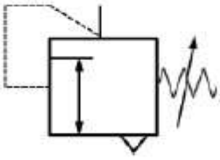
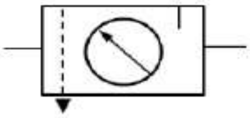
DEVELOPMENT OF SIMPLE HYDRAULIC AND PNEUMATIC CIRCUITS USING STANDARD SYMBOLS

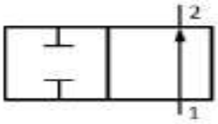
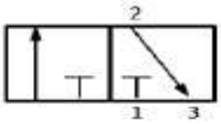
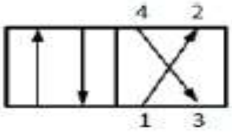
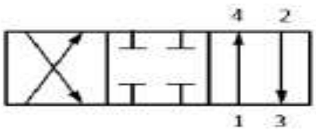
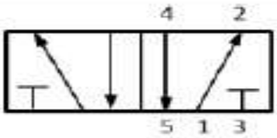
Port	Letter system	Number system
Pressure port	P	1
Working port	A	4
Working port	B	2
Exhaust port	R	5
Exhaust port	S	3
Pilot port	Z	14
Pilot port	Y	12

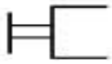
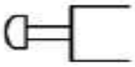
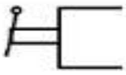
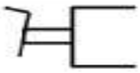
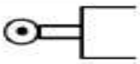
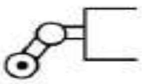
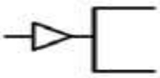
Fig 2.46 Symbols for Ports

GRAPHICAL SYMBOLS OF HYDRAULIC / PNEUMATIC EQUIPMENTS

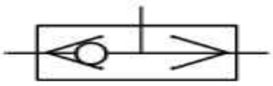
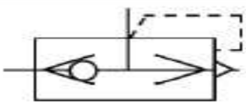
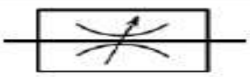
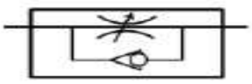
SYMBOL	DESIGNATION	EXPLANATION
Energy supply		
	Air compressor	One direction of rotation only with constant displacement volume
	Air receiver	Compressed air from the compressor is stored and diverted to the system when required
		One direction and two direction of rotation with constant displacement volume
	Hydraulic pump	One direction and two direction of rotation with variable displacement
Rotary actuators		
	Pneumatic motor	One direction and two direction of rotation with constant displacement volume
		One direction and two direction of rotation with variable displacement
	Hydraulic motor	One direction and two direction of rotation with constant displacement volume
		One direction and two direction of rotation with variable displacement

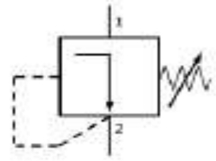
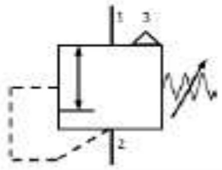
Service units		
	Air filter	This device is a combination of filter and water separator
	Dryer	For drying the air
	Lubricator	For lubrication of connected devices, small amount of oil is added to the air flowing through this device
	Regulator	To regulate the air pressure
	FRL unit	Combined filter, regulator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

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

Direction control valve actuation methods		
	General manual actuation	Manual operation of DCV
	Push button actuation	
	Lever actuation	
	Detent lever actuation	
	Foot pedal actuation	Mechanical actuation of DCV
	Roller lever actuation	
	Idle return roller actuation	
	Spring actuation	
	Direct pneumatic actuation	Pneumatic actuation of DCV

Non return valves		
	Check valve	Allows flow in one direction and blocks flow in other direction
	Spring loaded check valve	

	Shuttle/ OR valve	When any one of the input is given the output is produced
	AND valve	Only when both the inputs are given output is produced
	Quick exhaust valve	For quick exhaust of air to cause rapid extension/ retraction of cylinder
Flow control valves		
	Flow control valve	To allow controlled flow
	Flow control valve with one way adjustment	To allow controlled flow in one direction and free flow in other

Pressure control valves		
	Pressure relieving valve	Non relieving type
		Relieving type with overload being vented out

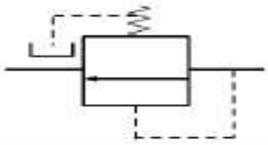
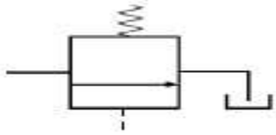
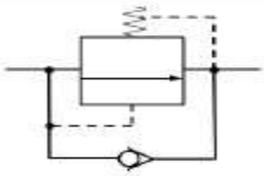
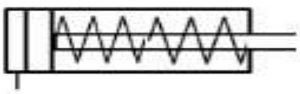
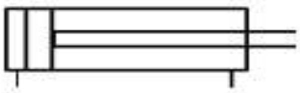
	Pressure reducing valve	Maintains the reduced pressure at specified location in hydraulic system
	Unloading valve	Allows pump to build pressure to an adjustable pressure setting and then allow it to be discharged to tank
	Counter balance valve	Controls the movement of vertical hydraulic cylinder and prevents its descend due to external load weight
Actuators		
	Single acting cylinder	Spring loaded cylinder with retraction taking place by spring force
	Double acting cylinder	Both extension and retraction by pneumatic/hydraulic force

Fig 2.47 Symbols for Hydraulic and Pneumatic Elements

<u>EXAMPLE 1</u>

<u>Control of a single acting cylinder</u>

C = Single acting cylinder P = Pump, E = Electric Motor, T = Tank, F = Filter, R = Relief Valve, D =2-position, 3 way DCV Manually operated and spring return

- Figure below shows a two- postion, three way, manually operated, spring offset directional control valve (DCV) used to control the operation of a single – acting cylinder.
- In the spring offset mode, full pump flow goes the tank via the pressure relief valve. The spring in the rod end of the cylinder retracts the piston as oil from the blank end ‘A’ drains back to the rank.
- When the valve is manually actuated the pump flow goes to the cylinder blank end ‘A’ via DCV 1 position. This extends the cylinder. At full extension, pump flow goes through the relief

valve. Deactivation of the DCV allows the cylinder to retract as the DCV shift into its spring – offset mode.

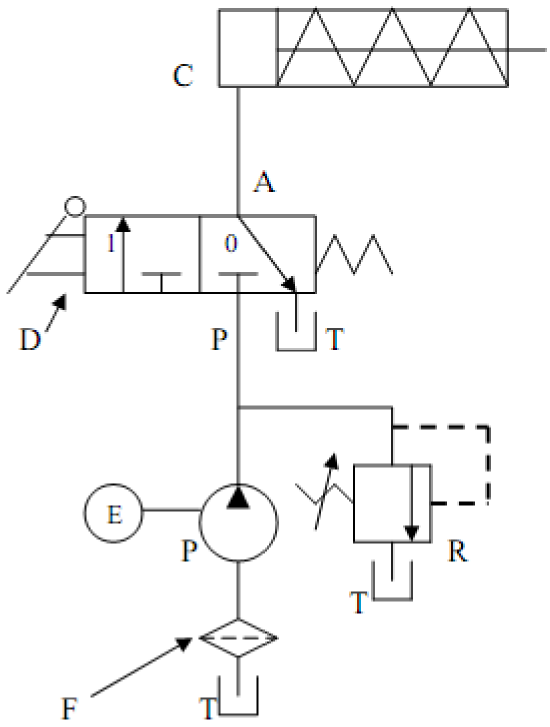


Fig 2.48 Control of Single Acting Cylinder

EXAMPLE 2

Control of a Double acting cylinder

C = Double acting cylinder, P = Pump, E = Electric Motor, T = Tank, F = Filter, R = Relief Valve, D =3 position 4 way Tandem center Manually operated and Spring Centered DCV

- Figure shows a circuit used to control a double – acting hydraulic cylinder. When the four way valve is in centered configuration, the cylinder is hydraulically locked as the ports A and B is blocked.
- The pump flow is unloaded back to the tank at essentially atmospheric pressure. When the four way valve is actuated into the 1st position, the cylinder is extended against its load force F load as oil flows to the blank end of the cylinder from port P through port A .
- Also, oil in the rod end of the cylinder is free to flow back to the tank via the four way valve from port B through port T. Note that the cylinder would not extend if this oil were not allowed to leave the rod end of the cylinder.
- When the four way valve is actuated into the 2st position , the cylinder is retracts against as oil flows to the rod end of the cylinder from port P through port B. Oil in the blank end of the cylinder is returned to the tank from port A to port T.
- At the end of the stroke, there is no system demand for oil. Thus, the pump flow goes through the relief valve at its pressure- level setting unless the four- way valve is deactivated. In any event the system is protected from any cylinder overloads.

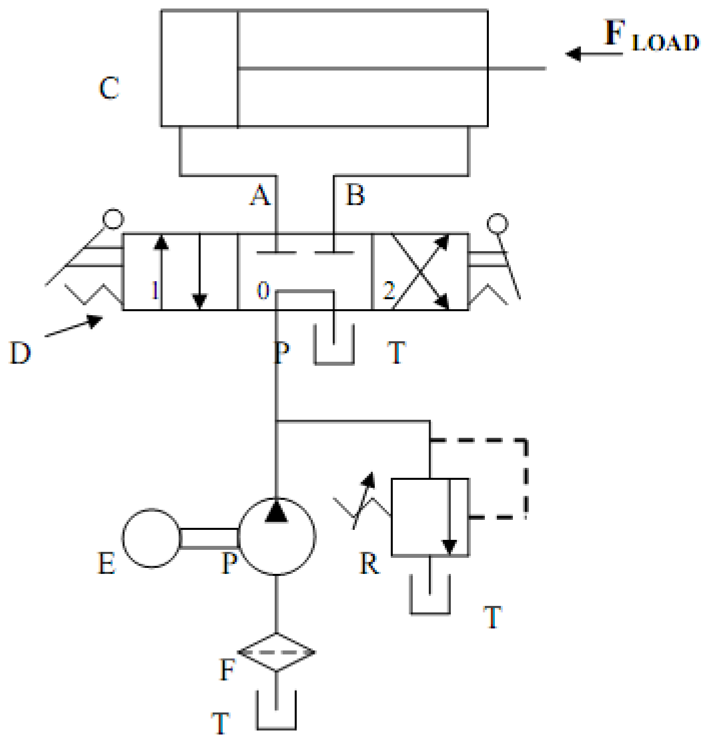


Fig 2.49 Control of Double Acting Cylinder

EXAMPLE 3

A double acting cylinder guides machined axles to an assembly unit. The axle is guided when the operator presses a pushbutton and an axle is sensed by using a 3/2 way limit switch. Upon release of the push button, the cylinder is retracted automatically. Design the pneumatic circuit for the given application.

Step 1 Initial position:- The piston rod of the cylinder (1.0) assumes the retracted end position. The final control valve (1.1) generates the signal through the right – hand air route to supply air to the piston rod side of the cylinder as a result of the spring returns

Step 2 Push button operation:- The 3/2 roller operated valve (1.4) generates signal output when it senses the axle. If the 3/2 push button valve (1.2) is also pressed, the pressure is applied on both input sides of the dual pressure valve (1.6), and satisfies the requirement of AND condition for the valve 1.6 to produce the output. As a result of the pilot signal, the final control valve actuates to reverse the switching to the left hand air route of the cylinder. Now the cylinder moves to its forward end position. If both 3/2 valves 1.2 and 1.4 are actuated, the cylinder remains in the forward position.

Step 3 Retraction of cylinder:- If at least one of the 3/2 valves 1.2 or 1.4 is released, then pilot air supply is ceased and spring return of the final control valve reverses the switching to its original position. Therefore the piston travels to its initial position.

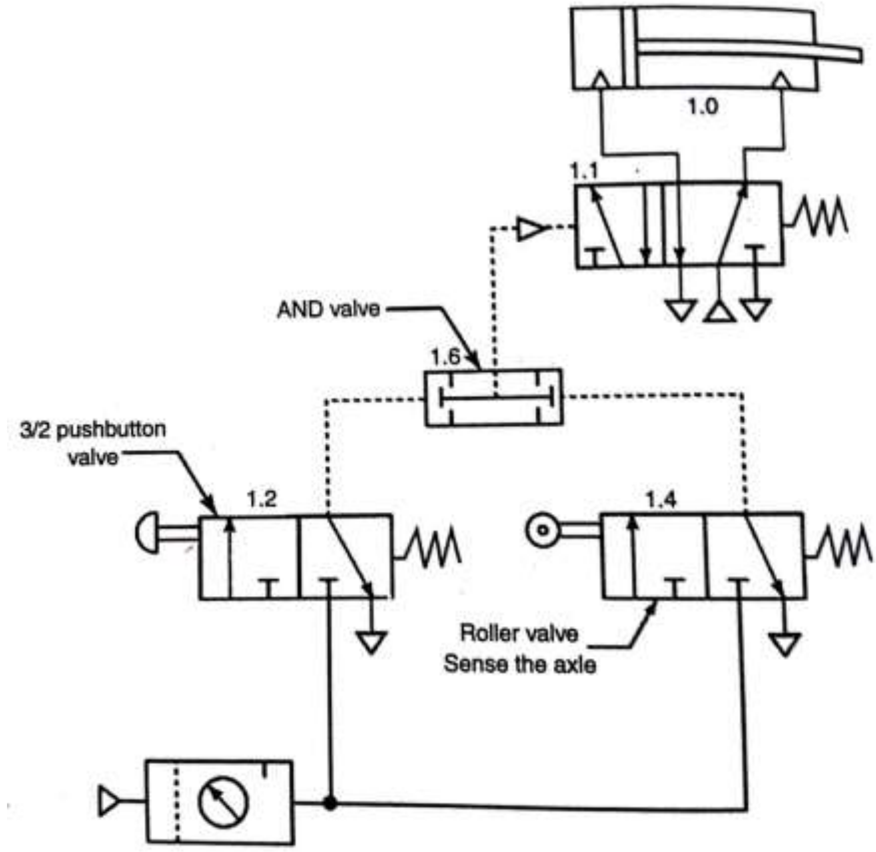


Fig 2.50 Proposed Circuit