CBCS SCHEME

USN 18ME55

Fifth Semester B.E. Degree Examination, Feb./Mar. 2022
Fluid Power Engineering

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. Define fluid power system. Sketch and explain the structure of a hydraulic control system. **(08 Marks)**

b. State Pascal's law and explain its applications. **(06 Marks)**

c. A force of 500 N is applied on a plunger of 5 cm diameter of a hydraulic press that moves the piston through a distance of 20 cm. What is the maximum weight of the load that can be placed on the ram and what will be the displacement of the ram, if the diameter of the ram is 40 cm. **(06 Marks)**

OR

2 a. What are the desirable properties of hydraulic fluids? Explain them. **(08 Marks)**

b. Define a seal. Explain in brief, how hydraulic seals are classified. **(08 Marks)**

c. What are the methods to control contamination in a system? **(04 Marks)**

Module-2

3 a. Explain the working principle of an external gear pump. **(05 Marks)**

b. What are the factors considered for selecting a hydraulic pump and explain the pumping theory of positive displacement pumps? **(09 Marks)**

c. A vane pump has its rotor and cam ring diameters of 60 mm and 80 mm respectively. If the volumetric displacement is 90 cm^3/rev and the width of the vane is 3 cm, what is eccentricity? What is the maximum displacement possible? **(06 Marks)**

OR

4 a. Explain the following with neat sketches:
(i) Single-acting cylinder
(ii) Telescopic cylinder **(08 Marks)**

b. What is a hydraulic motor? What are the four broad basis of classification of hydraulic motors? **(05 Marks)**

c. A hydraulic motor has a volumetric displacement of 123 cm^3 operating at a pressure of 60 bar and speed 180 rpm. If the actual flow rate consumed by the motor is 0.004 m^3/sec and actual torque delivered by motor is 100 Nm, find:
(i) Volumetric efficiency (ii) Mechanical efficiency (iii) Overall efficiency. **(07 Marks)**

Module-3

5 a. Explain with a neat sketch, the principle of working of a pilot operated pressure relief valve. Draw the graphical symbol of the valve. **(07 Marks)**

b. With a neat sketch, explain the working of a check valve. **(06 Marks)**

c. Define control valves. Explain the classification of control valves. **(07 Marks)**

OR

6 a. Explain the following with neat sketches:
(i) Sliding spool flow control valve
(ii) Needle flow control valve (04 Marks)
b. Explain the concept of meter-in and meter-out circuits. List the advantages and limitations of each of the circuit. (10 Marks)
c. What is a regenerative circuit? Sketch schematically regenerative circuit to increase the regenerative speed of the cylinder. (06 Marks)

Module-4

7 a. What are the advantages, disadvantages and applications of pneumatic system? (07 Marks)
b. Explain the characteristics of compressed air. (04 Marks)
c. Explain the construction and working of single and double acting cylinder. (09 Marks)

OR

8 a. Briefly explain cylinder cushioning. (08 Marks)
b. Explain with a suitable circuit diagram, Quick Exhaust Valve. (06 Marks)
c. Explain with a neat sketch, the construction of poppet valves. (06 Marks)

Module-5

9 a. Explain the following functions generated in pneumatic systems:
(i) OR gate
(ii) AND gate
(iii) NOT gate (12 Marks)
b. Explain direct and indirect actuation of pneumatic cylinders. (08 Marks)

OR

10 a. Write short notes on the following:
(i) Solenoid
(ii) Electromagnetic Relay (08 Marks)
b. What are the advantages of cascade design? (03 Marks)
c. Explain with a neat sketch, coordinated sequence motion of two cylinders. (09 Marks)

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Fluid Power Engineering

Time: 3 hrs. Max. Marks: 100

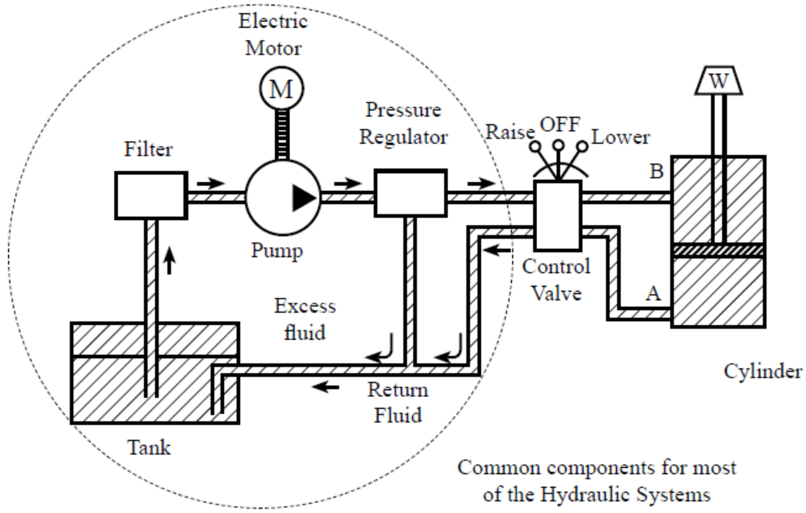
Solution

1 a. Fluid power is the technology that deals with the generation, control, and transmission of power, using pressurized fluids. It can be said that fluid power is the muscle that moves industry. This is because fluid power is used to push, pull, regulate, or drive virtually all the machines of modern industry.

A hydraulic control system is a group of hydraulic components arranged in an order to transmit hydraulic power using oil to perform useful work.

There are eight basic components required in a hydraulic system.

1. A reservoir is used to hold the hydraulic oil.
2. An actuator to convert the fluid power into mechanical power to perform useful work.
3. A pump is used to force the fluid from the reservoir.
4. An electric motor is required to drive the pump.
5. Valves are used to control the direction, pressure and flow rate of a fluid.
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.
8. Pressure regulator regulates (i.e. maintains) the required level of pressure in the hydraulic fluid

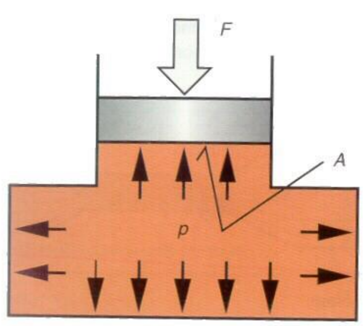


The hydraulic system requires a liquid fluid to operate; this is expensive and messy. The piping must act as a closed loop, with fluid transferred from a storage tank to one side of the cylinder, and returned from the other side of the cylinder to the tank.

Fluid is drawn from the tank by a pump which produces fluid flow at the required pressure. A prime move generally an electric motor is required to run the pump. Cylinder movement is controlled by a three-position direction control valve (DCV). To extend the cylinder, port A is connected to the pressure line and port B to the tank. To reverse the motion, port B is connected to the pressure line and port A to the tank. In its centre position the valve locks the fluid into the cylinder.

b. Pascal's Law is the most fundamental principle in fluid power. It deals with hydrostatics, the transmission of force through a confined fluid under pressure.

Pascal's law reveals the basic principle of how fluid power systems perform useful work. This law can be stated as follows: "Pressure applied to a confined fluid is transmitted undiminished in all directions throughout the fluid and acts perpendicular to the surfaces in contact with the fluid".



Pressure in an enclosed fluid can be considered uniform throughout a practical system. There may be small differences arising from head pressures at different heights, but these will generally be negligible compared with the system operating pressure. This equality of pressure is known as *Pascal's law,* and is illustrated in figure above.

The applied force develops a pressure, given by the expression:

$p = f/a$

The force on the base is:

$F = p \times A$

from which F can be derived as:

$F = f \times A/a$

The above expression shows an enclosed fluid may be used to magnify a force.

c. Numerical : Refer last section

2 a. The desirable properties of a hydraulic fluids are listed below:

1. Ideal viscosity.
2. Variation of viscosity with temperature (viscosity Index); must be minimal viscosity change with temperature change.
3. Good lubrication capability.
4. Good chemical stability.
5. High specific heat and thermal conductivity to dissipate heat.
6. Low compressibility.
7. Fire resistance property.
8. System compatibility.
9. Foam resistant properties.
10. Environmental Compatibility.

Explanation of any five:

1. Viscosity is the measure of a fluid's resistance to flow and shear. A fluid of higher viscosity will flow with higher resistance compared to a fluid with a low viscosity.
2. Viscosity Index is how the viscosity of a fluid changes with a change in temperature. A high VI fluid will maintain its viscosity over a broader temperature range than a low VI fluid of the same weight.
3. Oxidation Stability is the fluid's resistance to heat-induced degradation caused by a chemical reaction with oxygen. Oxidation greatly reduces the life of a fluid, leaving by-products such as sludge and varnish.
4. Wear Resistance: It is the lubricant's ability to reduce the wear rate in frictional boundary contacts.

5. Incompressibility: Liquids are of very low compressibility, while gases are highly compressible. Therefore, liquids are usually assumed incompressible.

b. Leakage from a hydraulic or pneumatic system can be a major problem, leading to loss of efficiency, increased power usage, temperature rise, environmental damage and safety hazards. Minor internal leakage (Example: Round the piston in a double-acting cylinder) can be of little consequence and may even be deliberately introduced to provide lubrication of the moving parts. External leakage, on the other hand, is always serious. In pneumatic systems, external leakage is noisy; with hydraulic systems, external loss of oil is expensive as lost oil has to be replaced, and the resulting pools of oil are dangerous and unsightly.

Functions of Seals

Seals are used in hydraulic systems to prevent excessive internal and external leakage and to keep out contamination. Various functions of seals include the following:

1. They prevent leakage – both internal and external.

2. They prevent dust and other particles from entering into the system.

3. They maintain pressure.

4. They enhance the service life and reliability of the hydraulic system.

The following represents the most widely used types of seal configurations.

1. O-rings
2. Compression packings (V- and U- shapes)
3. Piston cup packings
4. Piston rings
5. Wiper rings

c. According to the filtering methods:

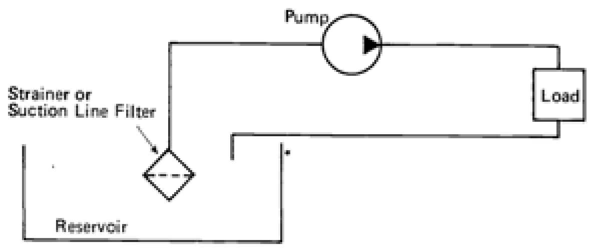
Mechanical filters: This type normally contains a metal or cloth screen or a series of metal disks separated by thin spacers. Mechanical filters are capable of removing only relatively coarse particles from the fluid.

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

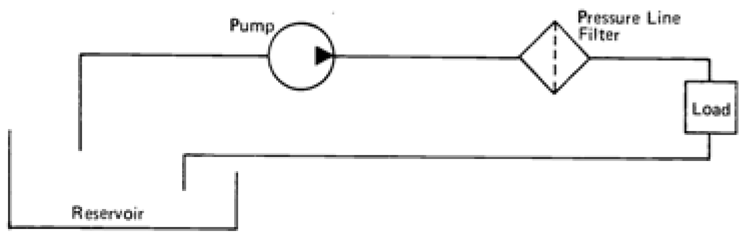
Adsorbent filters: Adsorption is a surface phenomenon and refers to the tendency of particles to cling to the surface of the filters. Thus, the capacity of such a filter depends on the amount of surface area available. Adsorbent materials used include activated clay and chemically treated paper.

According to the location of filters:

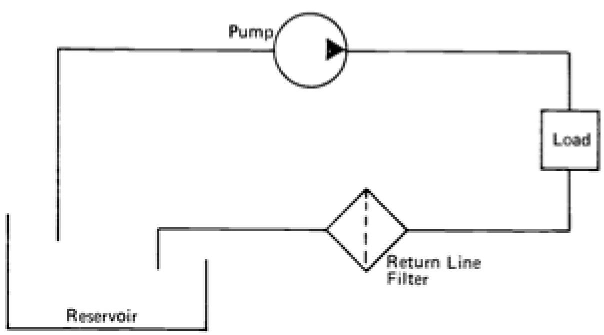
Intake or inline filters (suction strainers): These are provided first before the pump to protect the pump against contaminations in the oil as shown in Fig. These filters are designed to give a low pressure drop, otherwise the pump will not be able to draw the fluid from the tank. To achieve low pressure drop across the filters, a coarse mesh is used. These filters cannot filter out small particles.



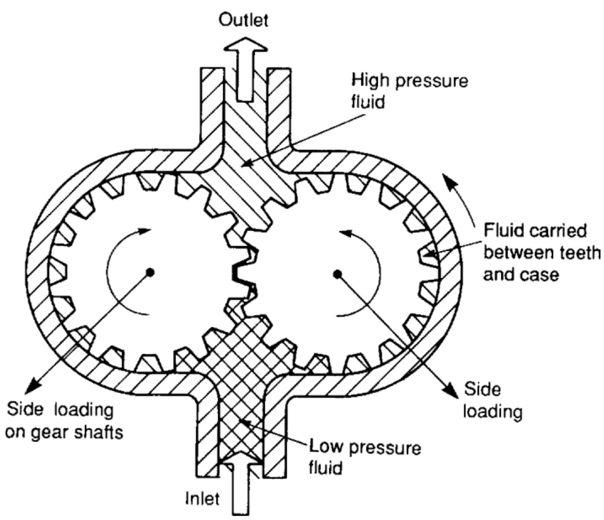
Pressure line filters (high-pressure filters): These are placed immediately after the pump to protect valves and actuators and can be a finer and smaller mesh. They should be able to withstand the full system pressure. Most filters are pressure line filters.



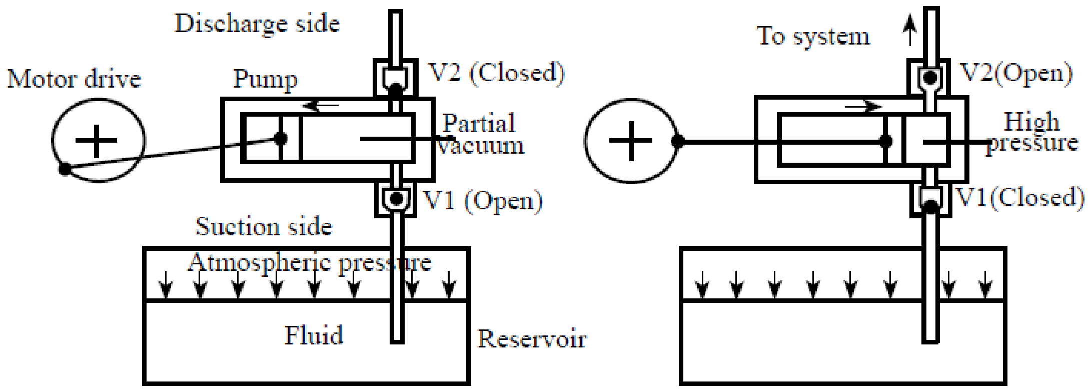
Return line filters (low-pressure filters): These filters filter the oil returning from the pressure-relief valve or from the system, that is, the actuator to the tank. They are generally placed just before the tank. They may have a relatively high pressure drop and hence can be a fine mesh. These filters have to withstand low pressure only and also protect the tank and pump from contamination.



3a. External gear pumps are the most popular hydraulic pumps in low-pressure ranges due to their long operating life, high efficiency and low cost. These are simplest and most robust positive displacement pump, having just two moving parts, is the gear pump. Its parts are non-reciprocating, move at constant speed and experience a uniform force. Internal construction, shown in Figure, It consist of a pump housing in which a pair of precisely machined meshing gears runs with minimal radial and axial clearance. One of the gears, called a driver, is driven by a prime mover. The driver drives another gear called a follower. As the teeth of the two gears separate, the fluid from the pump inlet gets trapped between the rotating gear cavities and pump housing. The trapped fluid is then carried around the periphery of the pump casing delivered to outlet port. The teeth of precisely meshed gears provide almost a perfect seal between the pump inlet and the pump outlet. When the outlet flow is resisted, pressure in the pump outlet chamber builds up rapidly and forces the gear diagonally outward against the pump inlet. When the system pressure increases, imbalance occurs. This imbalance increases mechanical friction and the bearing load of the two gears. Hence, the gear pumps are operated to the maximum pressure rating stated by the manufacturer. The direction of rotation of the gears should be carefully noted; it is the opposite of that intuitively expected by most people.



b. A positive displacement hydraulic pump is a device used for converting mechanical energy into hydraulic energy. It is driven by a prime mover such as an electric motor. It basically performs two functions. First, it creates a partial vacuum at the pump inlet port. This vacuum enables atmospheric pressure to force the fluid from the reservoir into the pump. Second, the mechanical action of the pump traps this fluid within the pumping cavities transports it through the pump and forces it into the hydraulic system. It is important to note that pumps create flow not pressure. Pressure is created by the resistance to flow.



(a) Suction stroke (b) Return stroke

All pumps operate by creating a partial vacuum at the intake, and a mechanical force at the outlet that induces flow. This action can be best described by reference to a simple piston pump shown in Fig.

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

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

Pumps are selected by taking into account a number of considerations for a complete hydraulic system involving a particular application. The main parameters affecting the selection of a particular type of pump are as follows:

1. Maximum operating pressure.
2. Maximum delivery.
3. Type of control.
4. Pump drive speed.
5. Type of fluid.
6. Pump contamination tolerance.
7. Pump noise.
8. Size and weight of a pump.

9. Pump efficiency.

10. Cost.

11. Availability and interchangeability.

12. Maintenance and spares.

c. Numerical

4 a. i) Single acting cylinders produce work in one direction of motion hence they are named as single acting cylinders. Figure below shows the construction of a single acting cylinder. 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.

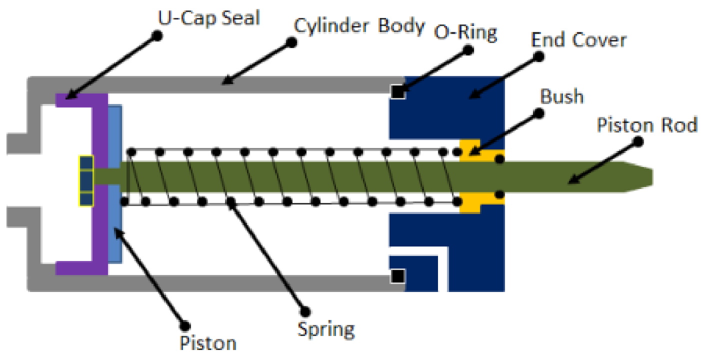


Fig. Single acting cylinder

ii. telescopic cylinder

b. Hydraulic motors extract energy from a fluid and convert it to mechanical energy to perform useful work. Hydraulic motors can be of the limited rotation or the continuous rotation type. A limited rotation motor, which is also called a *rotary actuator* or an *oscillating motor*, can rotate clockwise and counterclockwise but through less than one complete revolution.

A continuous rotation hydraulic motor, which is simply called a *hydraulic motor*, can rotate continuously at an rpm that is determined by the motor's input flow rate. In reality, hydraulic motors are pumps that have been redesigned to withstand the different forces that are involved in motor applications.

As a result, hydraulic motors can be classified into three types:

1. Gear motors
2. Vane motors and
3. Piston motors.

c. Numerical

Solution:

i) To find the volumetric efficiency, we first calculate flow rate:

$$Q_T = V_D \times N$$

$$= 0.000130 \ m^3/rev \times \frac{2000}{60} \ rev/s = 0.00433 \ m^3/s$$

$$\eta_v = \frac{Q_T}{Q_A} = \frac{0.00433}{0.005} = 0.866 \Rightarrow \eta_v = 86.7\%$$

ii) To find η_m, we need to calculate the theoretical torque

$$T_T = \frac{V_D \, p}{2\pi} = \frac{0.000130 \times 105 \times 10^5}{2\pi} = 217.15 \ N \cdot m$$

$$\eta_m = \frac{T_A}{T_T} = \frac{200}{217.15} = 0.9210 \Rightarrow \eta_m = 92.1\%$$

iii) $\eta_o = \eta_v \times \eta_m = 0.866 \times 0.9210 = 0.7975$

$\therefore \ \eta_o = 79.75\%$

iv) Actual power $= T_A \times \omega$

$$= 200 \times 2000 \times \frac{2\pi}{60}$$

$$= 41.9 \ kW$$

5 a.

b. The simplest type of direction control valve is a check valve (see Figure), which is a two-way valve because it contains two ports. The purpose of a check valve is to permit free flow in one direction and prevent any flow in the opposite direction.

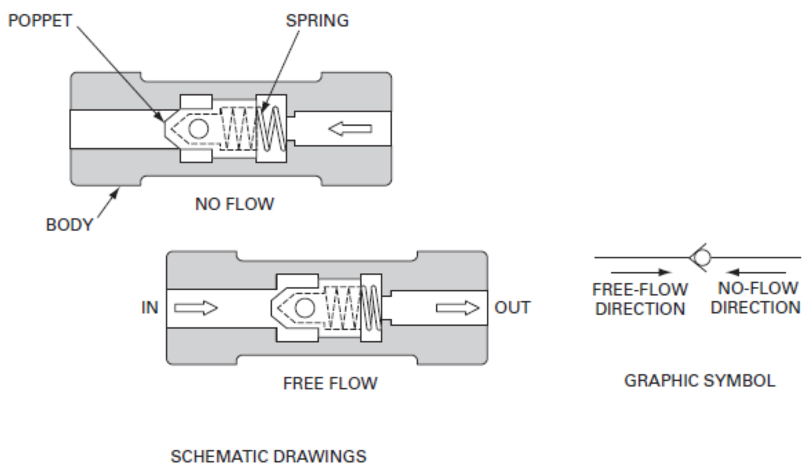


Figure provides two schematic drawings (one for the no-flow condition and one for the free-flow condition) showing the internal operation of a poppet check valve. A poppet is a specially shaped plug element held onto a seat (a surface surrounding the flow path opening inside the valve body) by a spring. Fluid flows through the valve in the space between the seat and poppet. As shown, a light spring holds the poppet in the closed position. In the free-flow direction, the fluid pressure overcomes the spring force at about 5 psi. If flow is attempted in the opposite direction, the fluid pressure pushes the poppet (along with the spring force) in the closed position. Therefore, no flow is permitted. The higher the pressure, the greater will be the force pushing the poppet against its seat. Thus, increased pressure will not result in any tendency to allow flow in the no-flow direction.

c. With a neat chart give detailed classification of control valves used in hydraulic system.

Fluid power is controlled primarily through the use of control devices called *valves*. The selection of these valves involves not only the type but also the size, actuating technique, and remote-control capability. There are three basic types of valves:

(1) directional control valves,

(2) pressure control valves, and

(3) flow control valves.

Directional control valves determine the path through which a fluid traverses a given circuit. For example, they establish the direction of motion of a hydraulic cylinder or motor. This control of the fluid path is accomplished primarily by

1. Check valves
2. Shuttle valves
3. Two-way
4. Three-way, and
5. Four-way directional control valves.

Pressure control valves protect the system against overpressure, which may occur due to excessive actuator loads or due to the closing of a valve. In general pressure control is accomplished by

1. Pressure relief valves
2. Pressure reducing valves
3. Sequence valves
4. Unloading, and
5. Counterbalance valves.

In addition, fluid flow rate must be controlled in various lines of a hydraulic circuit. For example, the control of actuator speeds depends on flow rates. This type of control is accomplished through the use of flow control valves. Non-compensated flow control valves are used where precise speed control is not required since flow rate varies with pressure drop across a flow control valve. Pressure-compensated flow control valves automatically adjust to changes in pressure drop to produce a constant flow rate.

Flow control valves can be classifies as:

1. Needle valve
2. Plug or globe valve
3. Butterfly valve
4. Gate valve

6 a. The needle valve is quite commonly used valve. It is also termed as plug valve. Schematic of Needle or plug valve is shown in Figure. This valve has a conical disc which can be adjusted in vertical direction by setting flow adjustment screw. The adjustment of needle 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 needle 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.

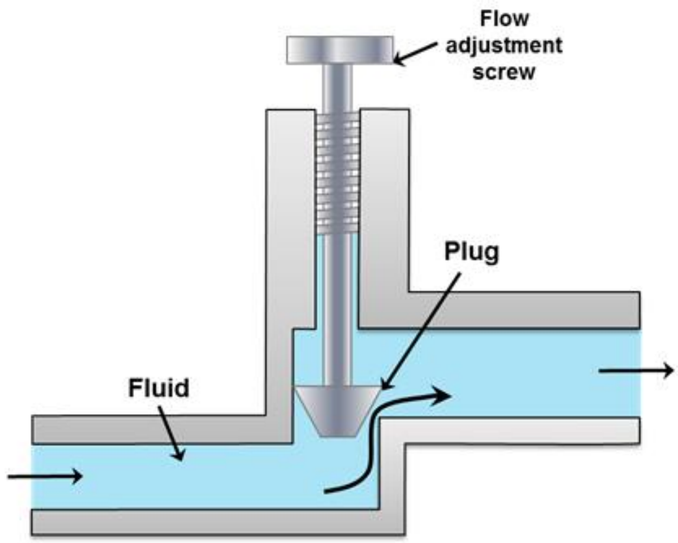


Fig: Needle or plug valve

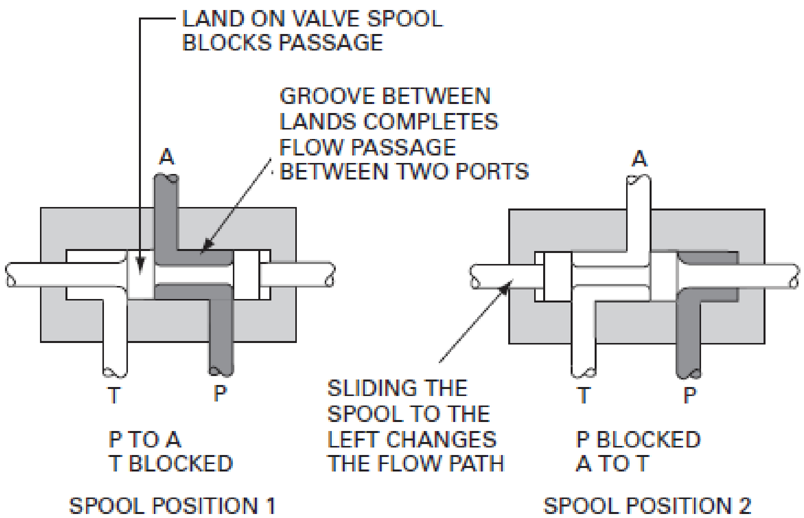
b. Spool (Slide valve)

Three-way directional control valves, which contain three ports, are typically of the spool design rather than poppet design. A spool is a circular shaft containing lands that are large diameter sections machined to slide in a very close fitting bore of the valve body. The radial clearance between the land and bore is usually less than 0.001 in. The grooves between the lands provide the flow paths between ports. These valves are designed to operate with two or three unique positions of the spool. The spool can be positioned manually, mechanically, by using pilot pressure, or by using electrical solenoids.

Figure shows the flow paths through a three-way valve that uses two positions of the spool. Such a valve is called a three-way, two-position directional control valve. The flow paths are shown by two schematic drawings (one for each spool position) as well as by a graphic symbol (containing two side-by-side rectangles). In discussing the operation of these valves, the rectangles are commonly called “envelopes.”
The following is a description of the flow paths through the three-way valve of Figure:

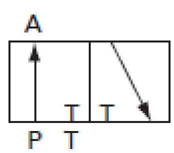
Spool Position 1: Flow can go from pump port P (the port connected to the pump discharge pipe) to outlet port A as shown by the straight line and arrow in the left envelope. In this spool position, tank port T (the port connected to the pipe leading to the oil tank) is blocked.

Spool Position 2: Flow can go from port A to port T. Port P is blocked by the spool. Note that the three ports are labeled for only one of the two envelopes of the graphic symbol. Thus the reader must mentally identify the ports on the second envelope.



SCHEMATIC DRAWINGS

Three-way valves are typically used to control the flow directions to and from single-acting cylinders, as illustrated in Figure 8-7. As shown, the cylinder extends under hydraulic pressure (left envelope) and retracts under spring force as oil flows to the oil tank (right envelope). Observe that fluid entering the pump port of a three way valve can be directed to only a single outlet port (in this case port A).



GRAPHIC SYMBOL

c.

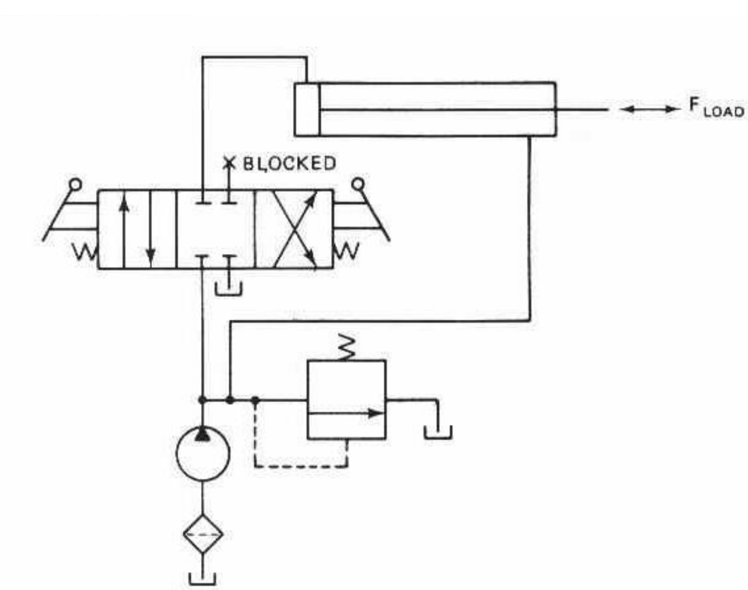


Figure shows a regenerative circuit that is used to speed up the extending speed of a double-acting cylinder. The pipelines to both ends of the hydraulic cylinder are connected in parallel and one of the ports of the 4/3 valve is blocked by simply screwing a thread plug into the port opening. During retraction stroke, the 4/3 valve is configured to the right envelope. During this stroke, the pump flow bypasses the DCV and enters the rod end of the cylinder. Oil from the blank end then drains back to the tank through the DCV.

When the DCV is shifted in to its left-envelope configuration, the cylinder extends as shown in Figure the speed of extension is greater than that for a regular double-acting cylinder because the flow from the rod end regenerates with the pump flow Q_P to provide a total flow rate Q_T.

Expression for the Cylinder Extending Speed

The total flow rate Q_T entering the blank end of the cylinder is given by

$$Q_T = Q_P + Q_r$$

Where Q_P is the pump flow rate and is Q_r the regenerative flow or flow from the rod end.

Hence, Pump flow rate,

$$= Q_P = Q_T - Q_r$$

But the total flow rate acting on the blank rod end is given by

$$Q_P = A_P V_{ext}$$

Similarly, the flow rate from the rod end is given by

$$Q_r = (A_P - A_r) V_{ext}$$

So pump flow rate is

$$Q_P = A_P V_{ext} - (A_P - A_r) V_{ext}$$

$$Q_P = A_r V_{ext}$$

The extending speed of the piston is given as

$$V_{ext} = Q_P / A_r$$

Thus, a small area provides a large extending speed. The extending speed can be greater than the retracting speed if the rod area is made smaller.

7 a The main advantages of pneumatic systems are

1. **High effectiveness**

Many factories have equipped their production lines with compressed air supplies and movable compressors. There is an unlimited supply of air in our atmosphere to produce compressed air. Moreover, the use of compressed air is not restricted by distance, as it can easily be transported through pipes. After use, compressed air can be released directly into the atmosphere without the need of processing.

2. **High durability and reliability**

Pneumatic components are extremely durable and cannot be damaged easily. Compared to electromotive components, pneumatic components are more durable and reliable.

3. **Simple design**

The designs of pneumatic components are relatively simple. They are thus more suitable for use in simple automatic control systems.

4. **High adaptability to harsh environment**

Compared to the elements of other systems, compressed air is less affected by high temperature, dust, corrosion, etc.

5. **Safety**

Pneumatic systems are safer than electromotive systems because they can work in inflammable environment without causing fire or explosion.

6. **Easy selection of speed and pressure**

The speeds of rectilinear and oscillating movement of pneumatic systems are easy to adjust and subject to few limitations. The pressure and the volume of air can easily be adjusted by a pressure regulator.

7. **Environmental friendly**

The operation of pneumatic systems does not produce pollution. The air released is also processed in special ways. Therefore, pneumatic systems can work in environments that demand high level of cleanliness. One example is the production lines of integrated circuits.

8. **Economical**

As pneumatic components are not expensive, the costs of pneumatic systems are quite low. Moreover, as pneumatic systems are very durable, the cost of repair is significantly lower than that of other systems.

b

Availability	Air is available practically everywhere in unlimited quantities.
Transport	Air can be easily transported in pipelines, even over large distances.
Storage	Compressed air can be stored in a reservoir and removed as required. In addition, the reservoir can be transportable.

Temperature	Compressed air is relatively insensitive to temperature fluctuations. This ensures reliable operation, even under extreme conditions.
Explosion proof	Compressed air offers no risk of explosion or fire.
Cleanliness	Unlubricated exhaust air is clean. Any unlubricated air which escapes through leaking pipes or components does not cause contamination.
Components	The operating components are of simple construction and therefore relatively inexpensive.
Speed	Compressed air is a very fast working medium. This enables high working speeds to be attained.
Overload safe	Pneumatic tools and operating components can be loaded to the point of stopping and are therefore overload safe.

c. Single acting cylinders produce work in one direction of motion hence they are named as single acting cylinders. Figure below shows the construction of a single acting cylinder. 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.

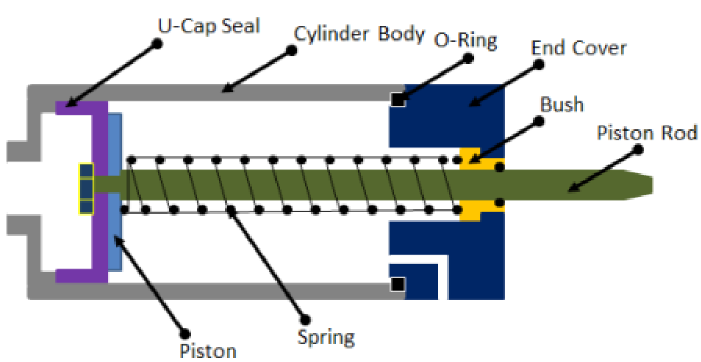


Fig. Single acting cylinder

The main parts of a hydraulic double acting cylinder are: piston, piston rod, cylinder tube, and end caps. These are shown in Figure 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.

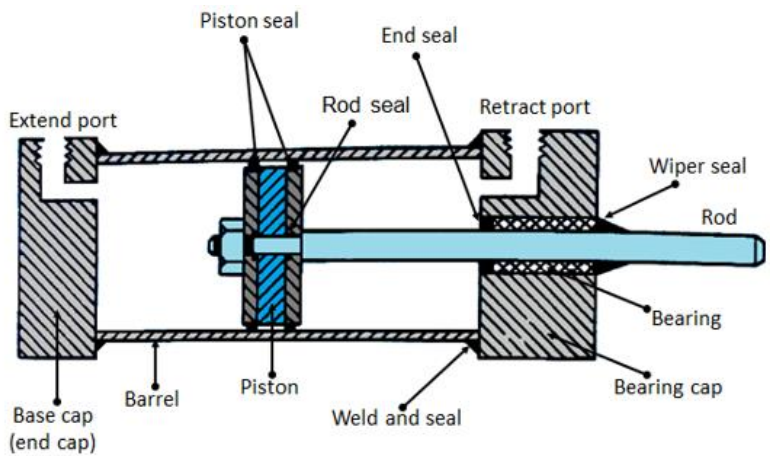
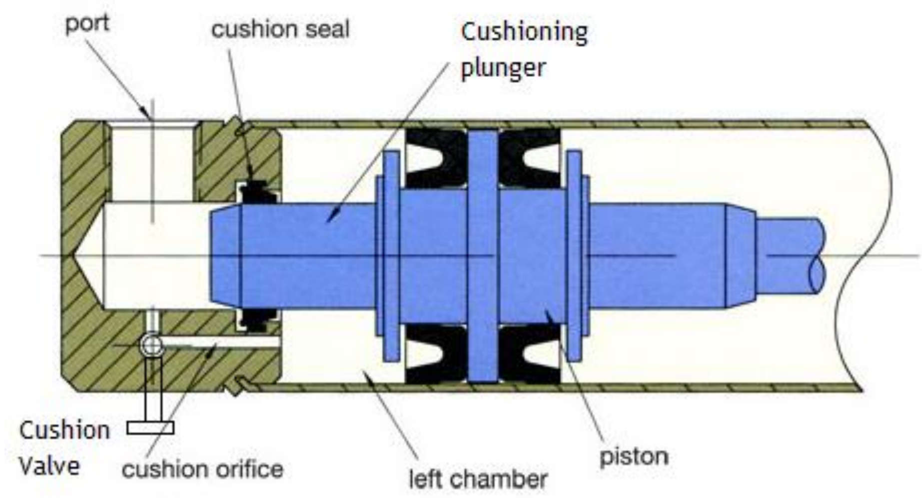


Fig. Double acting cylinder

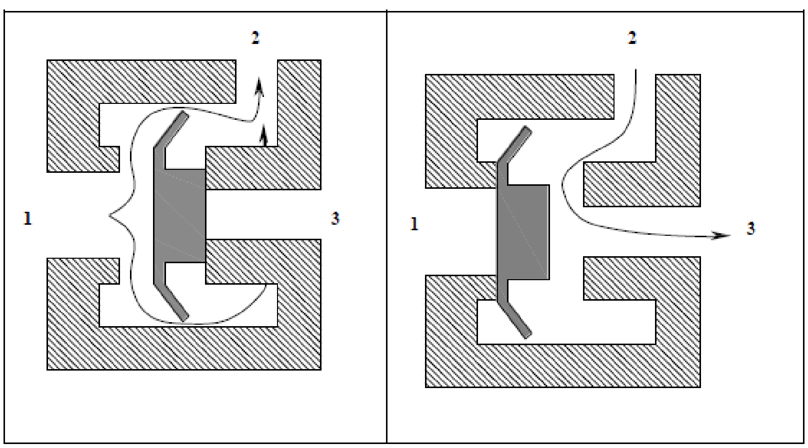
The pressurized oil, air enters the cylinder chamber through the ports provided. In the rod end cover plate, a wiper seal is provided to prevent the leakage of oil and entry of the contaminants into the cylinder. The combination of wiper seal, bearing and sealing ring is called as cartridge assembly. 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.

8 a



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. Figure shows the construction of actuating cylinder with end cushions. 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 can be 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.

b A quick exhaust valve is a typical shuttle valve. The quick exhaust valve is used to exhaust the cylinder air quickly to atmosphere. Schematic diagram of quick exhaust valve is shown in Figure 4.38(a). In many applications especially with single acting cylinders, it is a common practice to increase the piston speed during retraction of the cylinder to save the cycle time. The higher speed of the piston is possible by reducing the resistance to flow of the exhausting air during the motion of cylinder. The resistance can be reduced by expelling the exhausting air to the atmosphere quickly by using Quick exhaust valve.



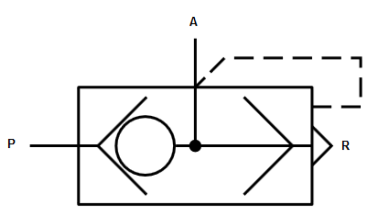


Figure Working of quick exhaust valve and graphical symbol

The construction and operation of a quick exhaust valve is shown in Figure 4.39. It consists of a movable disc (also called flexible ring) and three ports namely, Supply port 1, which is connected to the output of the directional control valve. The Output port, 2 of this valve is directly fitted on to the working port of cylinder. The exhaust port, 3 is left open to the atmosphere.

Forward Motion: During forward movement of piston, compressed air is directly admitted to cylinder inlet through ports 1 and 2. Port 3 is closed due to the supply pressure acting on the diaphragm. Port 3 is usually provided with a silencer to minimize the noise due to exhaust.

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

c. Poppet valves

In a poppet valve, simple discs, cones or balls are used in conjunction with simple valve seats to control flow. Figure shows the construction and symbol of a simple 2/2 normally closed valve, where depression of the pushbutton lifts the ball off its seat and allows fluid to flow from port P to port A. When the button is released, spring and fluid pressure force the ball up again, closing the valve.

Figure shows the construction and symbol of a disc seal 3/2 poppet. With the pushbutton released, ports A and R are linked via the hollow pushbutton stem. If the pushbutton is pressed, port R is first sealed, then the valve disc pushed down to open the valve and connect ports P and A. As before, spring and fluid pressure from port P closes the valve. The valve construction and symbol shown in Figure is a poppet changeover 4/2 valve using two stems and disc valves. With the pushbutton released, ports A and R are linked via the hollow left-hand stem and ports P and B linked via the normally open right-hand disc valve. When the pushbutton is pressed,

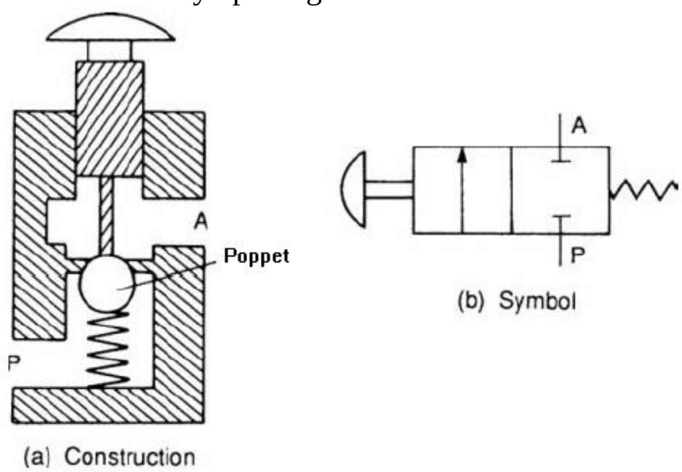


FIGURE Simple 2/2 poppet valve

9 a i) ii) & iii) Refer last section

b

Double acting cylinder

The main parts of a hydraulic double acting cylinder are: piston, piston rod, cylinder tube, and end caps. These are shown in Figure. 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.

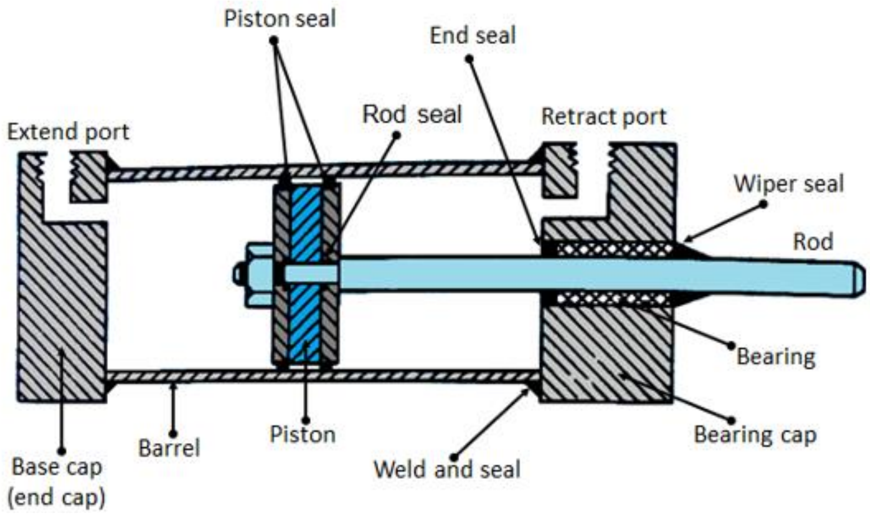


Fig. Double acting cylinder

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.

10 a

b Cascading is a methodological approach to the problem of pneumatic circuit design. Cascading means "in series". In this method the sequence of pneumatic cylinders is controlled by using various type of signaling elements. These signaling elements are of course driven by forward and backward strokes of cylinders but the air supply to pilot lines is delivered through a cascade system. A reversing valve can be used to eliminate signal conflicts. Signal conflict is avoided by allowing the signal to be effective only at times when they are needed. In cascade system the forward and backward motions of pneumatic cylinders are classified into groups. Then the particular groups of movements are controlled with components in cascade system. Then those particular groups of movements are controlled with components in cascade system.

The cascade system consists of group selector valves, bus bar lines and pilot lines. Bus bar lines are basically pneumatic energy lines; those are spread inside the whole plant. These are used to supply pneumatic energy to pneumatic systems.

Sign conventions

Certain sign conventions have to be adopted to denote forward and backward motions of cylinders. These are given below:

Cylinder advance movement designated by +ve sign

Cylinder backward movement designated by -ve sign

Cylinder can be named as A, B, C, D… depending upon their numbers

So we can denote forward motion of cylinder A by the sign A^+ and backward motion by A^-.

Sequencing

Sequencing may be defined as the process to put things in right order. It is the prime step in circuit design depending upon the problem assigned. One can simply apply the mind and can arrange the forward and backward motions of all the cylinders in circuit. Position step diagrams can further show this sequence graphically.

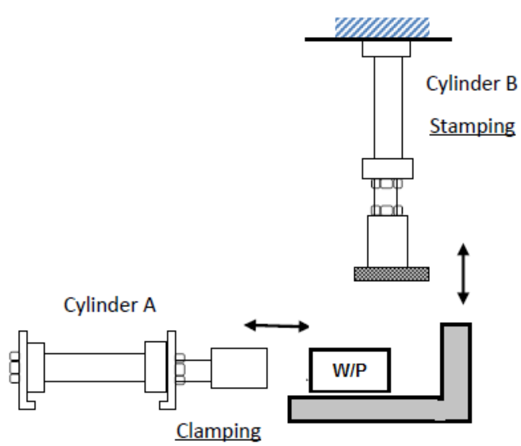
c. Cascading is a methodological approach to the problem of pneumatic circuit design. Cascading means "in series". In this method the sequence of pneumatic cylinders is controlled by using various type of signalling elements. These signalling elements are of course driven by forward and backward strokes of cylinders but the air supply to pilot lines is delivered through a cascade system. A reversing valve can be used to eliminate signal conflicts.

In order to develop control circuitry for multi cylinder applications, it is necessary to draw the motion diagram to understand the sequence of actuation of various signal input switches-limit switches and sensors. Motion diagram represents status of cylinder position -whether extended or retracted in a particular step.

Step 1: Write the statement of the problem:

Let A be the first cylinder (clamping) and B be second cylinder (stamping) as shown in the Figure. First cylinder A extends and clamps the work piece under stamping station where cylinder B is located. Cylinder B then extends and stamps the job. Cylinder A can return back only after cylinder B has retracted fully.

Step 2: Draw the positional layout:



Positional diagram

Step3: Represent the control task using notational form:

Cylinder A advancing step is designated as A+

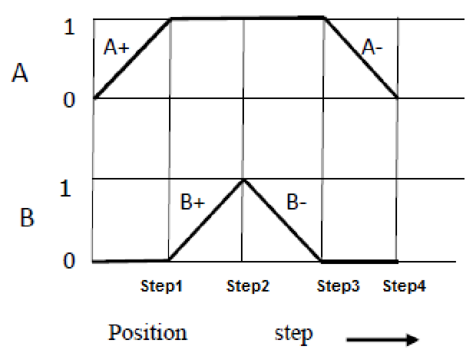
Cylinder A retracting step is designated as A-

Cylinder B advancing step is designated as B+

Cylinder B retracting step is designated as B-

Given sequence for clamping and stamping is A+B+B-A-

Step 4 Draw the Displacement –step diagram:



Displacement step diagram

Step 5 Draw the Displacement –time diagram:

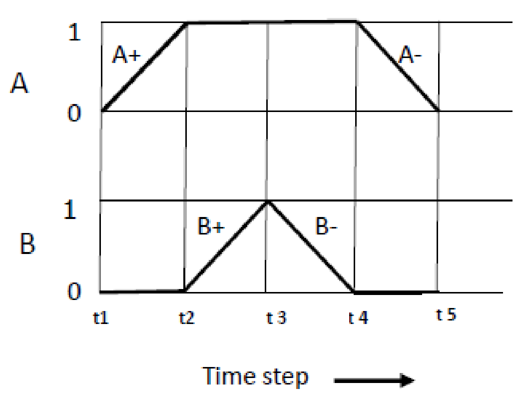


Figure 5.22 Displacement time diagram

Step 6: Analyse and Draw Pneumatic circuit:

Step 6.1 Analyse input and output signals:

Input Signals

Cylinder A - Limit switch at retracted position a0

Limit switch at extended position a1

Cylinder B - Limit switch at retracted position b0

Limit switch at extended position b1

Output Signal

Forward motion of cylinder A (A+)

Return motion of cylinder A (A-)

Forward motion of cylinder B (B+)

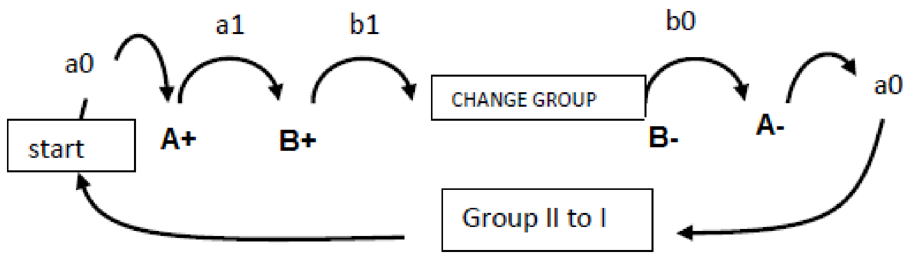
Return motion of cylinder B (B+)

Step 6.2 Using the displacement time/step diagram link input signal and output signal:

Usually start signal is also required along with a0 signal for obtaining A+ motion.

1. A+ action generates sensor signal a1, which is used for B+ motion
2. B+ action generates sensor signal b1, which is used for group changing.
3. B- action generates sensor signal b0, which is used for A- motion
4. A- action generates sensor signal a0, which is used for group changing

Above information (given in figure 5.23) is shown below graphically.



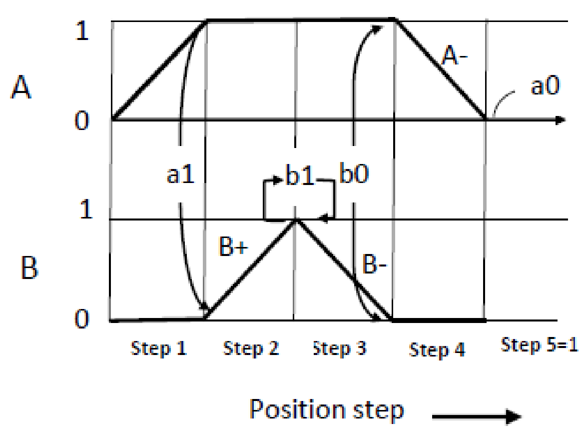


Figure 5.23 Displacement time diagram

Step 7 Draw the power circuit:

i) Divide the given circuits into groups. Grouping should be done such that there is no signal conflict. Do not put A+ and A- in the same group. Similarly B+ and B- should not be put in the same group. In other word A+ and A- should belong to different group to avoid signal conflict.

In our example of A+ B+ B- A- we can group as

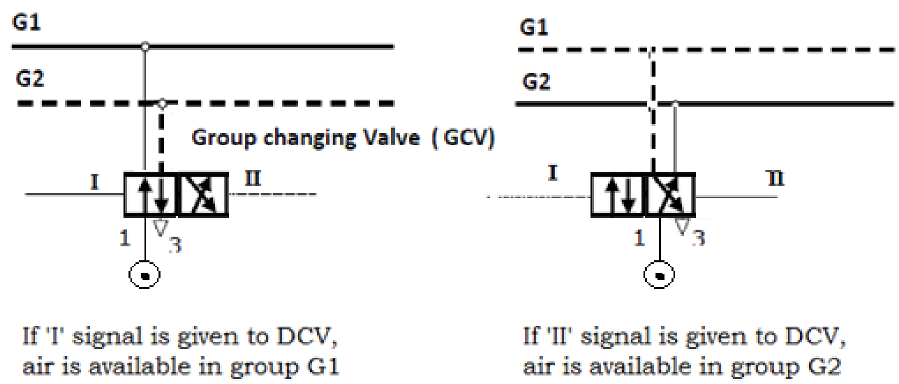
A+ B+	**B- A-**
Group 1	**Group 2**

ii) Choose the number of group changing valve = No of groups - 1

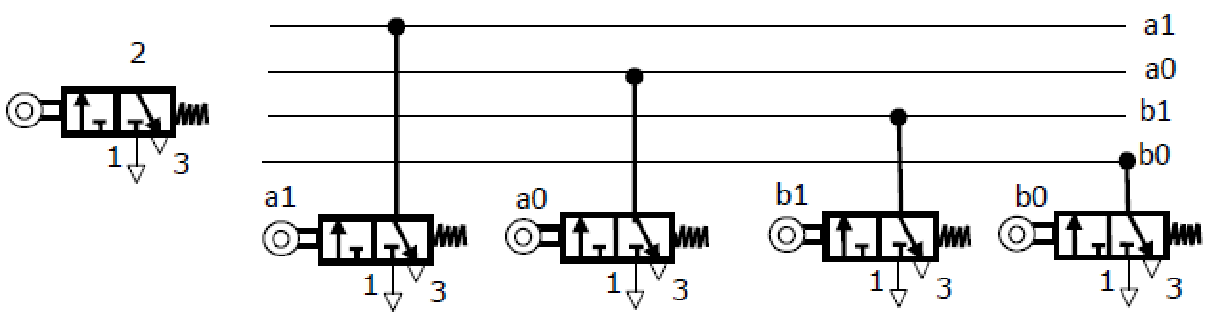
In our example, we have 2 groups so we need one group changing valve

Connect the group changing valve as follows. From the figure it is clear that when the control signals I and II are applied to group changing valve, the air (power) supply changes from Group 1(G1) to Group 2 (G2)

iii) Arrange the limit switch and start button as given below

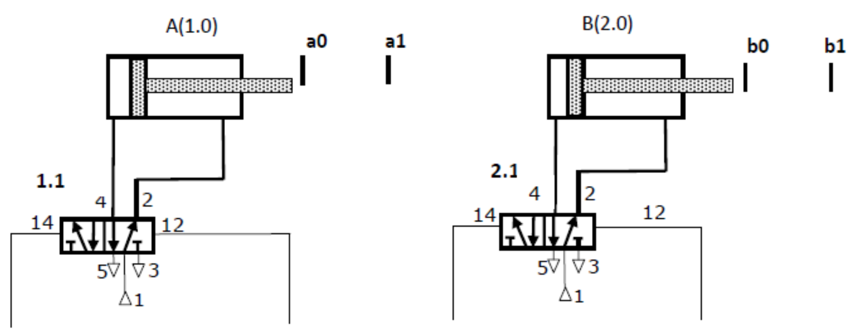


Connection of DCV to group changing valve



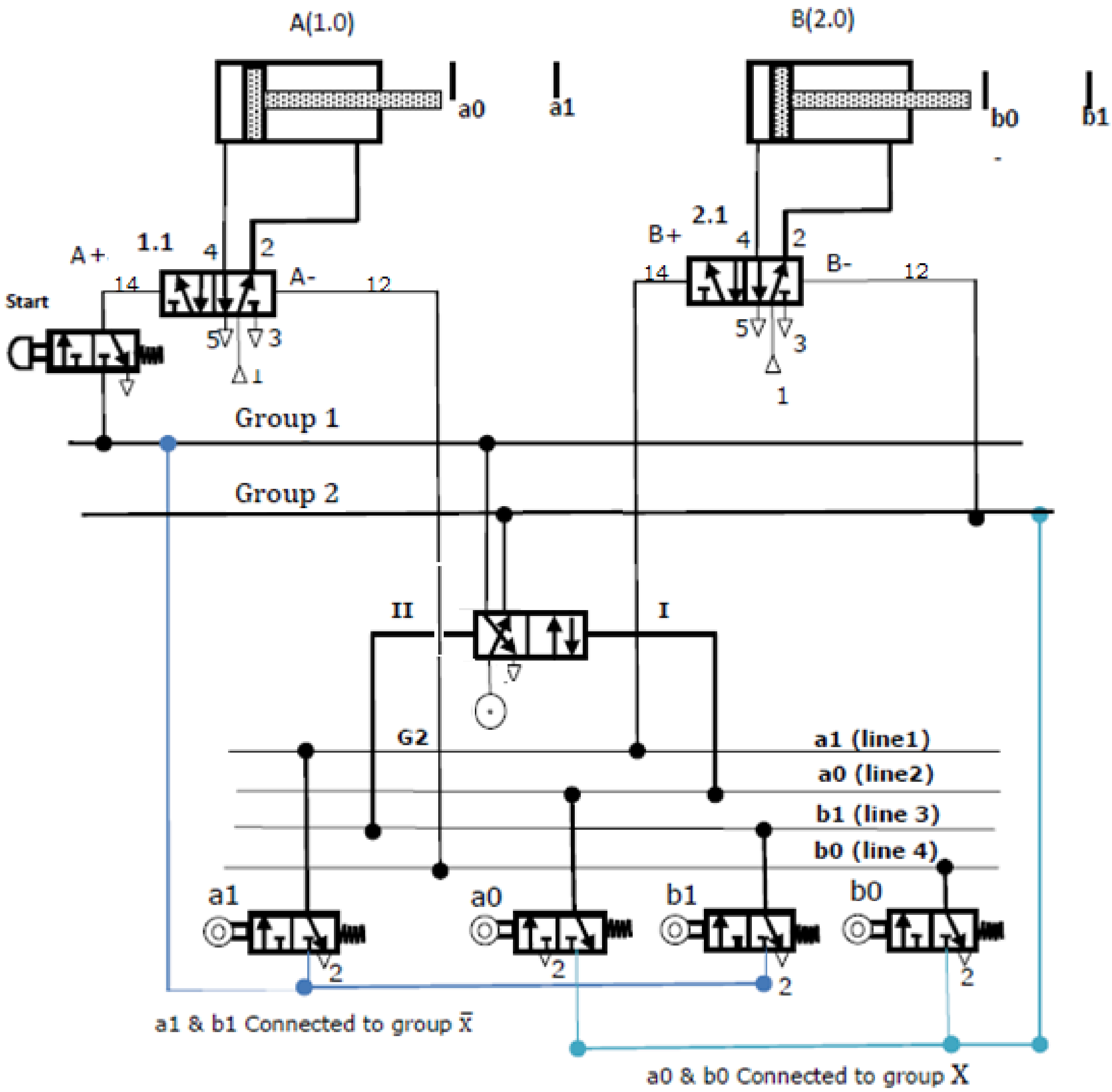
Connection of limit switches and start button

iv) Draw the power circuit:



Power circuit diagram

Step 8 Draw the control circuit:



Pneumatic circuits for A+ B+ B- A-

Step 9 Analysis of pneumatic circuit:

1. Assume that air is available in the line G2 to start with. (Say from previous operation)

2. When the start button is pressed, air supply from Group G2 is directed to line 2 through actuated limit switch a0. Now the air available in line 2 actuates the Group changing valve (GCV) to switch over to position I. This switching of the GCV causes air supply to change from G2 to G1.

3. Now the air is available in line G1. The air supply from group G1 is directed to port 14 of the valve 1.1. As there is no possibility of signal conflict here, valve 1.1 switches over causing the A+ action.

4. Sensor a1 is actuated as the result of A+ action, allowing the air supply from the Group G1 to reach to line 1 through a1. Now the air available reaches port 14 of valve 2.1. As there is no possibility of signal conflict here, valve 2.1 switches over, causing B+ action automatically.

5. Sensor b1 is actuated as result of B+ action, allowing the air supply in line 3. Air from line 3 allows the air to reach port 12 of Group changing valve (also called reversing valve). As a result, the Group changing valve switches over, causing the group supply to change from G1 to G2.

6. Now the air is available in G2. Air from G2 acts on port 12 of the Valve 2.1. As there is no possibility of signal conflict here, valve 2.1 switches over, causing B- action automatically.

7. Sensor b0 is actuated as the result of B- action. Now the air is available in line 4.Air from line 4 reach port 12 of the valve 1.1. As there is no possibility of signal conflict here, valve 2.1 switches over, causing A- action automatically.

Q3. c. Given data

$\eta_v = 96\% = 0.96$

$Q_A = 0.030 \ m^3/min$

$N = 1000 \ rpm$

$V_D = ?$

$\therefore \eta_v = \frac{Q_A}{Q_T}$ (for pump)

$Q_T = \frac{Q_A}{\eta_v} = 0.030/0.96$

$Q_T = 0.03125 \ m^3/min$

Now, V_D, $V_D = \frac{Q_T}{N}$ $(Q_T = V_D \times N)$

$\therefore = 0.03125/1000 \quad \frac{m^3/min}{rev/min}$

$\therefore V_D = 0.00003125 \ m^3/rev$

Q4.c Hydraulic motor:

Model Q? numerical Seems to have wrong data w.r.t Speed & flow rate.

Corrected numerical:

$V_D = 164\ cm^3$

$p = 70 \times 10^5\ N/m^2$

$N = 2000\ rpm$

$Q_A = 0.006\ m^3/s$

$T_A = 170\ N\ m$

$\eta_v = ?$

$\eta_m = ?$

$\eta_o = ?$

Power = ?

1. To find η_v,

$$Q_T = V_D \times N = 0.000164 \times \frac{2000}{60} \left(m^3/rev \times rev/s \right)$$

$$= 0.00547\ m^3/s$$

$$\therefore \eta_v = \frac{Q_T}{Q_A} = \frac{0.00547}{0.006} = 0.912 \Rightarrow \eta_v = 91.2\%$$

2. To find η_m,

$$T_T = \frac{V_D \times P}{2\pi} = \frac{0.000164 \times 70 \times 10^5}{2\pi} = 182.8\ N.m$$

$$\therefore \eta_m = \frac{T_A}{T_T} = \frac{170}{182.8} = 0.930 \Rightarrow \eta_m = 93.0\%$$

3.

$$\eta_o = \eta_v \times \eta_m = 0.912 \times 0.930 = 0.848$$

$$\therefore \eta_o = 84.8\%$$

4. Actual Power $= T_A \times N = 170 \times 2000 \times \frac{2\pi}{60} = 35600\ W$

$$\therefore \text{Power} = 35.6\ kW$$

Q3.6. A Gear pump:

Given: outside dia, D_o = 80 mm

Inside dia, D_i = 55 mm

width, L = 25 mm

pump speed = 1600 rpm

Actual flow rate, Q_A = 95 LPM

To find:

V_D = ?

Q_T = ?

Solution:

$$V_D = \frac{\pi}{4}\left(D_o^2 - D_i^2\right) L$$

$$= \frac{\pi}{4}\left(80^2 - 55^2\right) \times 25$$

$$= 66294.64 \ mm^3/rev$$

→ $V_D = 0.000066294 \ m^3/rev$

Since $1 \ L = 0.001 \ m^3$,

$$V_D = 0.06629 \ L$$

next ∴, $Q_T = V_D \times N$

$$= 0.0000663 \times 1600 \quad \left(m^3/rev \times rev/min\right)$$

$$= 0.10608 \ m^3/min$$

→ or Q_T = 106.08 LPM

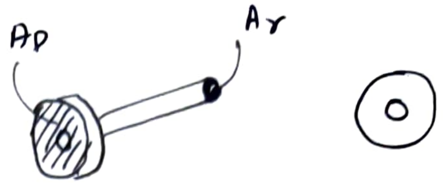
4.1. Hydraulic cylinder

$D_p = 120$ mm

$D_r = 30$ mm

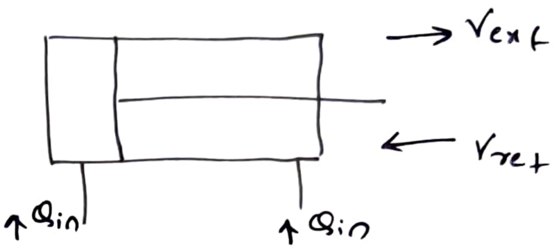
$Q_{in} = 60$ LPM

$= 0.06 \; m^3/min \quad \because (1 L = 0.001 \; m^3)$



To find V_{ext}, V_{ret}

Solution:



$$A_p = \frac{\pi}{4} \times 120^2 = \sout{13885.71}\; 11314.285 \; mm^2$$

$$A_r = \frac{\pi}{4} \times 30^2 = 707.14 \; mm^2$$

$$\therefore \quad V_{ext} = \frac{Q_{in}}{A_p} = \frac{0.06}{\sout{13885.71}\; 11314.285 \times (10^{-3})^2} \quad \left(\frac{m^3/min}{m^2}\right)$$

$$= 5.303 \; m/min$$

$$V_{ret} = \frac{Q_{in}}{A_p - A_r} = \frac{0.06}{(11314.285 - 707.14) \times (10^{-3})^2}$$

$$= \sout{4.55}\; 5.656 \; m/min$$

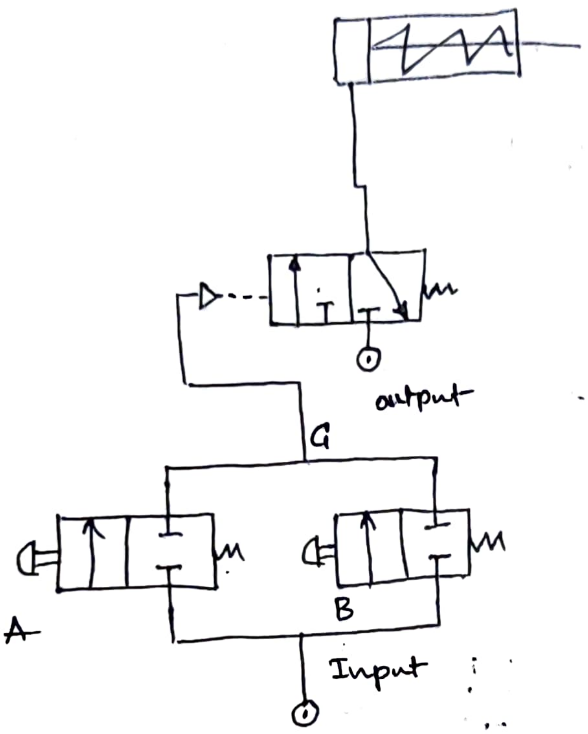
$\therefore$ Extension velocity = 5.303 m/min

→ Retraction velocity = 5.656 m/min

VTU Model QP - 1

Q 9.b

1) OR logic function using 2/2 DCV



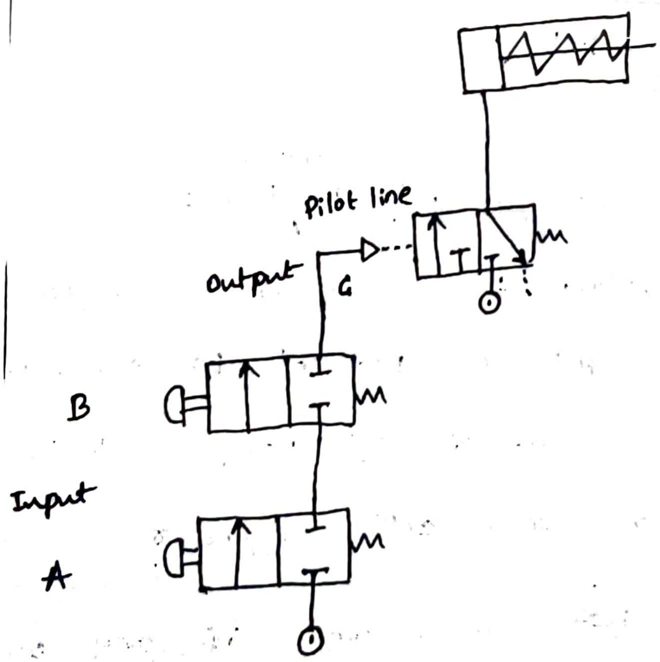
OR function can be generated by using two or more 2/2 Direction control valve. As shown in the figure two 2/2 DCV are connected in parallel to generate a pilot signal to actuate 3/2 DCV, which is used to control a single acting cylinder.

A & B are two valves and if any one is ~~actted~~ actuated will produce an output G, OR logic function can also be generated using ~~one~~ two 3-way, 2-position ~~pilot line~~, spring return DCV in conjuction with ~~two~~ one shuttle valve.

Truth table for OR gate.

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

ii) AND Gate:



AND logic can be designed using two 2/2 DCV as shown in the figure above. If both the valves are actuated simultaneously, there is an output generated to actuate the 3/2 DCV which is connected to a hydraulic cylinder to perform works. If one valve (either A or B) is actuated there will be no output produced.

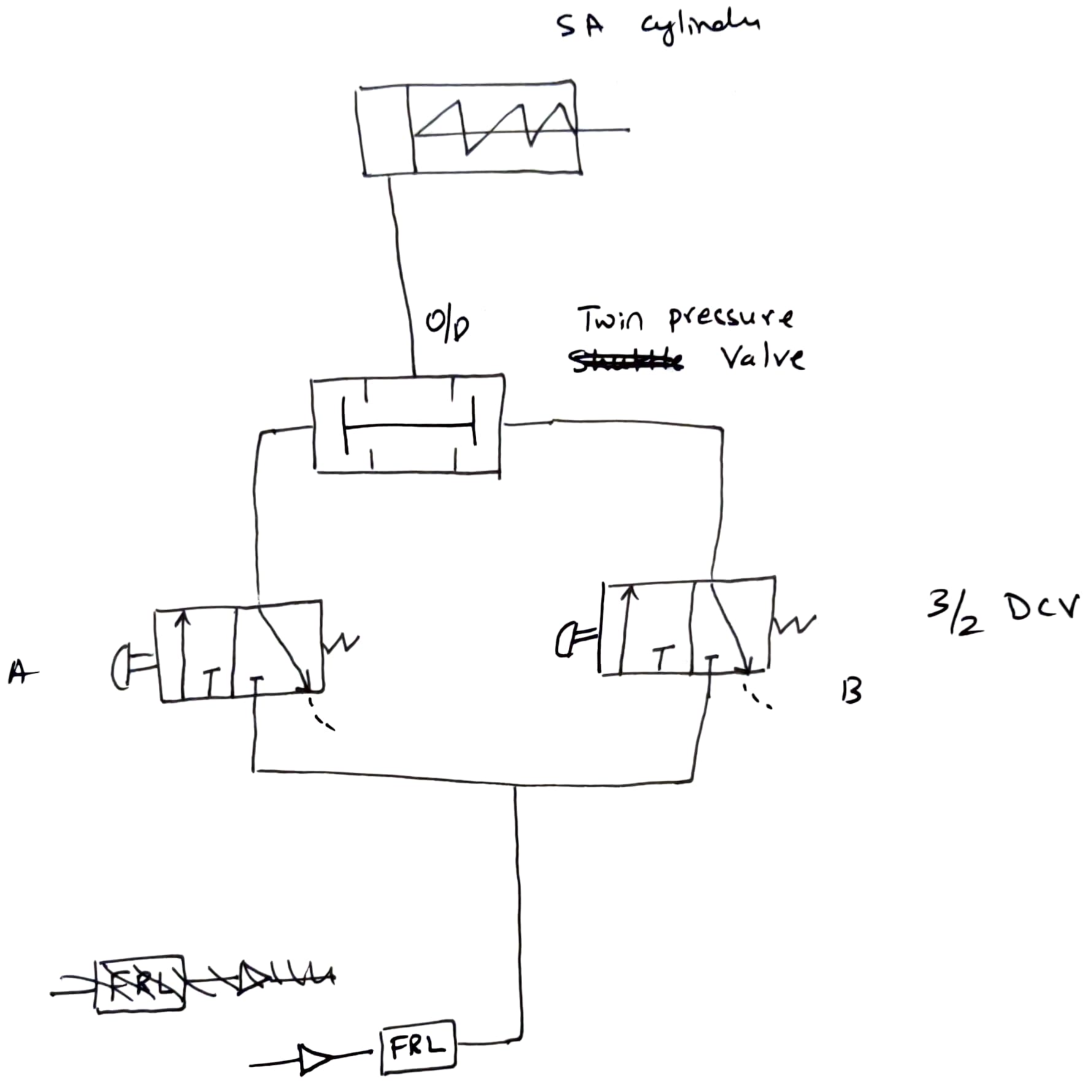
AND logic can also be generated using twin pressure valve.

Truth table for AND logic gate

Input		Output
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

b. Explain quick exhaust valve with symbol

AND ~~OR~~ gate : using ~~shuttle valve~~ twin pressure valve

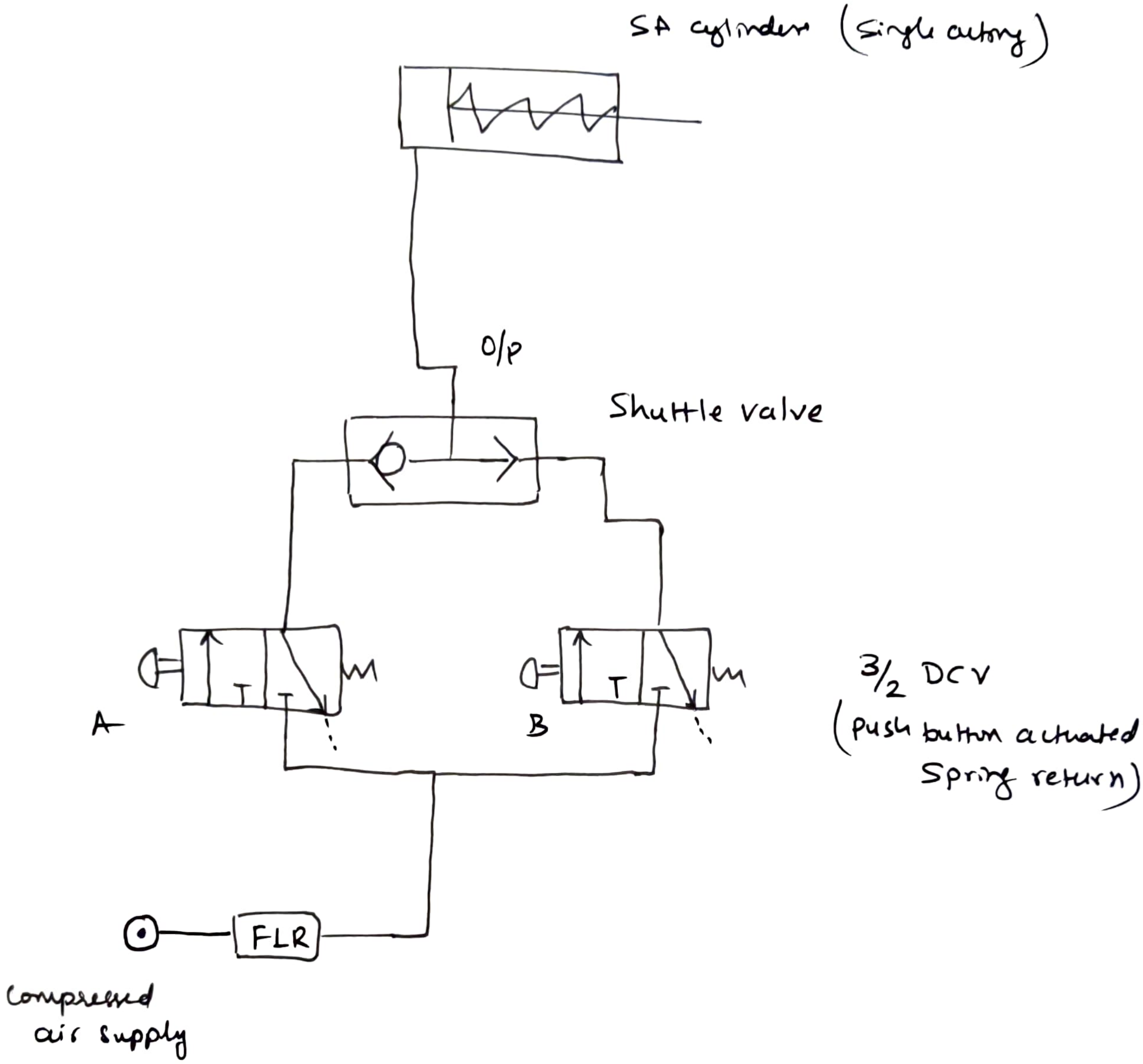


A	B	O/p
0	0	0
0	1	0
1	0	0
1	1	1

} No extension (rows 1–3)

← cylinder extends (row 4)

~~AND~~ OR gate logic using Shuttle valve



A	B	O/P
0	0	0
0	1	1
1	0	1
1	1	1

← cylinder doesn't extend (row 0 0 0)

Extension takes place (rows 0 1 1, 1 0 1, 1 1 1)