CBCS SCHEME

USN 17ME72

Seventh Semester B.E. Degree Examination, Jan./Feb.2021
Fluid Power Systems

Time: 3 hrs. Max. Marks: 100

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

Module-1

1 a. What are the various applications of fluid power systems? (05 Marks)
b. State Pascal's law and mention the various advantages of fluid power systems. (05 Marks)
c. Explain the various components used in hydraulic systems and its symbol. (10 Marks)

OR

2 a. Describe the various functions of hydraulic fluids and its types. (05 Marks)
b. Define the fluid properties such as viscosity, viscosity index, pour point, fire point, flash point. (05 Marks)
c. Explain the working of return line and suction line filtering with the aid of sketches. (10Marks)

Module-2

3 a. What are the various types of positive displacement pump used in fluid power system? (05Marks)
b. Explain with a sketch the construction and working of bladder type accumulator used in fluid power system. (05 Marks)
c. Explain the construction and working of external gear pump with a neat sketch. (10 Marks)

OR

4 a. Explain the construction and working of double acting cylinder with a neat sketch. (05 Marks)
b. An 8 cm diameter hydraulic cylinder has a 4 cm diameter rod. If the cylinder receives flow at 100 LPM and 12 MPa. Find the

Module-3

5 a. List various types of control valves. (03 Marks)
b. With a neat sketch explain the working of pressure relief valve. (07 Marks)
c. Explain the hydraulic regenerative circuit with a neat sketch. (10 Marks)

OR

6 a. With a neat sketch, explain the working of ball type check valve. (05 Marks)
b. With a neat sketch, explain the working of the 4/2 manually operated direction control valve. (05 Marks)
c. Explain the hydraulic cylinder sequencing circuits with a neat sketch. (10 Marks)

Module-4

7 a. Describe the various components used in pneumatic power systems and its symbol. **(05 Marks)**

b. Explain the working of a single acting type of pneumatic cylinder with a neat sketch. **(05 Marks)**

c. Explain the construction and working of lubricator used in pneumatic system with a neat sketch. **(10 Marks)**

OR

8 a. Explain the working of a shuttle valve used in pneumatic system with a neat sketch. **(05 Marks)**

b. What are the various ways the pneumatic cylinders are mounted? **(05 Marks)**

c. Explain the working of solenoid operated valve with a neat sketch. **(10 Marks)**

Module-5

9 a. Explain the speed control pneumatic circuits with a suitable sketch. **(10 Marks)**

b. Explain the OR function of controlling the single acting pneumatic cylinder with a neat circuit. **(10 Marks)**

OR

10 a. Explain the controlling of pneumatic cylinders in a sequence as $A^+ B^+ B^- A^-$ by cascading method. **(10 Marks)**

b. Explain electro pneumatic control of double acting cylinder with a suitable circuit. **(10 Marks)**

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1. a.

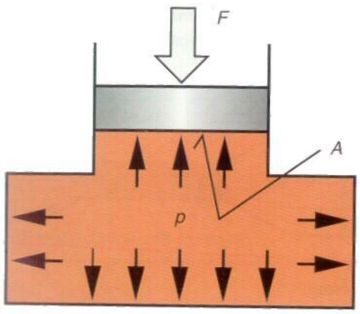
Applications of fluid power systems

1. Fluid power systems find application in automobile industries, such as Power steering, power brakes, suspension systems, hydrostatic transmission.
2. Agriculture equipments such as tractors, mowers, ploughs, chemical and water sprayers, fertilizer spreaders, harvesters.
3. Construction equipments such as excavators, lifts, bucket loaders, crawlers.
4. Amusement park entertainment rides such as roller coasters.
5. Automated machine tools, numerically controlled(NC) machine tools, Automated transfer lines, robotics.
6. Medical equipment such as breathing assistors, heart assist devices, cardiac compression machines, dental drives.
   Fluid power equipments in aviation such as landing wheels in aircraft, Helicopters, aircraft trolleys, aircraft test beds, luggage loading and unloading systems, ailerons, aircraft servicing, flight simulators

1.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.

The principle of Pascal's law was successfully applied by an English engineer, Mr. Joseph Bramah, to develop a hydraulic press in which by applying a small input force a large output force was generated.

Brief the various advantages of fluid power system.

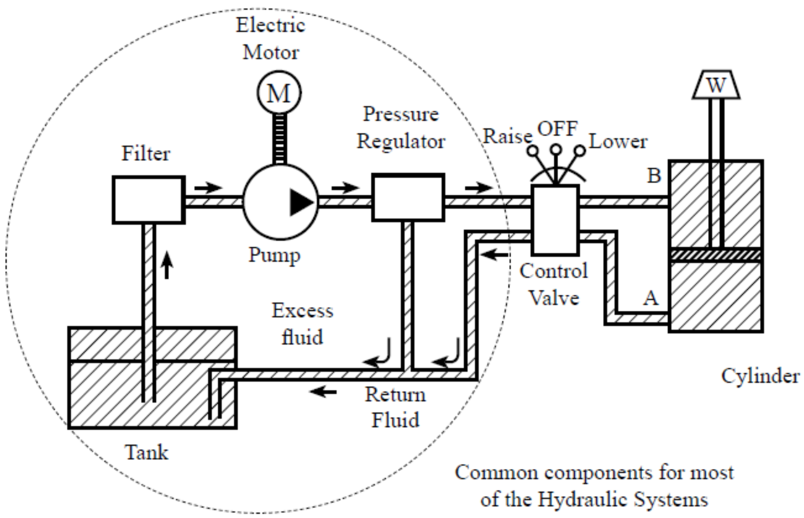
1. High horsepower-to-weight ratio
2. Safety in hazardous environments because they are inherently spark-free and can tolerate high temperatures.

3. Force or torque can be held constant — this is unique to fluid power transmission.
4. High torque at low speed — unlike electric motors, pneumatic and hydraulic motors can produce high torque while operating at low rotational speeds. Some fluid power motors can even maintain torque at zero speed without overheating.
5. Pressurized fluids can be transmitted over long distances and through complex machine configurations with only a small loss in power.
6. Multi-functional control — a single hydraulic pump or air compressor can provide power to many cylinders, motors, or other actuators
7. Elimination of complicated mechanical trains of gears, chains, belts, cams, and linkages. Motion can be almost instantly reversed

c. Brief the various components of hydraulic system and its fluid power symbol.
Ahydraulic 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.



Common components for most of the Hydraulic Systems

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.

2.a **Functions of Hydraulic fluids**

1. The main purpose of the fluid in a fluid power system is to transmit power.
2. Fluid must cool the system by dissipation of heat in a reservoir.
3. Fluids must act as a sealing agent to prevent leaks.
4. Fluids mustlubricate sliding and rotating surfaces.
5. Fluids must not corrode components and must have a long life without chemical breakdown.

Liquids

The term *fluid* refers to both gases and liquids. A liquid is a fluid that, for a given mass, will have a definite volume independent of the shape of its container. This means that even though a liquid will assume the shape of the container, it will fill only that part of the container whose volume equals the volume of the quantity of the liquid. For example, if water is poured into a vessel and the volume of water is not sufficient to fill the vessel, a free surface will be formed, as shown in Figure 2-2(a). A free surface is also formed in the case of a body of water, such as a lake, exposed to the atmosphere [see Figure 2-2(b)].

Liquids are considered to be incompressible so that their volume does not change with pressure changes. This is not exactly true, but the change in volume due to pressure changes is so small that it is ignored for most engineering applications. Variations from this assumption of incompressibility are discussed in Section 2.6, where the parameter *bulk modulus* is defined.

Gases

Gases, on the other hand, are fluids that are readily compressible. In addition, their volume will vary to fill the vessel containing them. This is illustrated in Figure 2-3, 2.b

Viscosity:
Viscosity is the resistance to flow and it is considered as an important property of fluids. For a hydraulic system, the viscosity is inversely depended on the temperature. As the temperature increases, the viscosity will decrease and internal leakages occur. When the temperature decreases, the viscosity will increase and it will resist the flow of fluids. Using hydraulic fluids with suitable viscosity will reduce flow losses and provide precise control over the system.

The **viscosity index** (VI) is an arbitrary, unit-less measure of a fluid's change in **viscosity** relative to temperature change. It is mostly used to characterize the **viscosity**-temperature behavior of lubricating oils. The lower the VI, the more the **viscosity** is affected by changes in temperature.

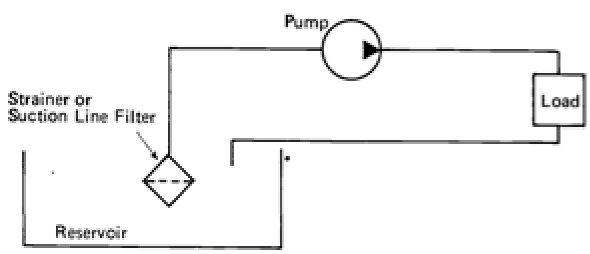
Pour point is defined as the lowest temperature at which the test fluid can be **poured** under the prescribed test conditions. It is one of the properties that determine the low temperature fluidity of a lubricating oil.

Flash point is the lowest temperature at which a liquid can gives off vapor to form an ignitable mixture in air near the surface of the liquid. The lower the **flash point**, the easier it is to ignite the material.

The **fire point** is the temperature to which the product must be heated under the prescribed conditions of the method to burn continuously when the mixture of vapor and air is ignited by a specified **flame**

c.

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.



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.

3.a

Positive displacement pumps can be classified by the type of motion of internal elements. The motion may be either rotary or reciprocating. Although these pumps come in a wide variety of different designs, there are essentially three basic types:

1. Gear pumps (fixed displacement only by geometrical necessity)
   - **a.** External gear pumps
   - **b.** Internal gear pumps
   - **c.** Lobe pumps
   - **d.** Screw pumps

2. Vane pumps
   - **a.** Unbalanced vane pumps (fixed or variable displacement)
   - **b.** Balanced vane pumps (fixed displacement only)

3. Piston pumps (fixed or variable displacement)
   - **a.** Axial design
   - **b.** Radial design

In addition, vane pumps can be of the balanced or unbalanced design. The unbalanced design can have pressure compensation capability, which automatically protects the pump against overpressure. In Sections 5.5, 5.6, and 5.7, we discuss the details of the construction and operation of gear, vane, and piston pumps, respectively.

3.b

Explain the various types of accumulators. Explain the construction and working of bladder type accumulator.

Accumulators:

Hydraulic accumulators are used for temporarily storing pressurized oil. The oil enters a chamber and acts against a piston or bladder to raise a weight, compress a spring or compress a gas. The stored potential energy in the accumulator is a quick secondary source of fluid power capable of doing useful work as required by the system. Accumulators are the equivalent to a capacitor in an electrical system and to a spring in a mechanical system.

Accumulators form an energy store in a hydraulic system and have two common uses

(1) To provide a source of energy that may be required over a short period of time.

(2) To smooth out pressure fluctuations in a system e.g. variations in pump delivery and transient pressures due to sudden changes of fluid velocity in the system.

There are three basic types of accumulator used in hydraulic system. They are:

1. Weight – Loaded, or gravity, type

2. Spring -Loaded type

3. Gas – Loaded type

Gas loaded accumulators fall into two main categories:

1. Non-separator type
2. Separator type

a. Piston type
b. Bladder type
c. Diaphragm type

Bladder type

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

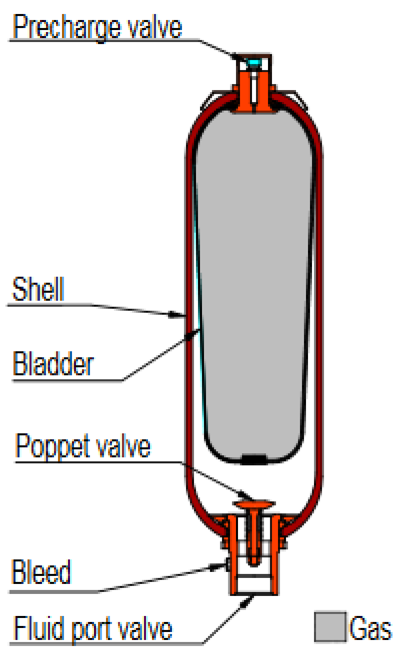
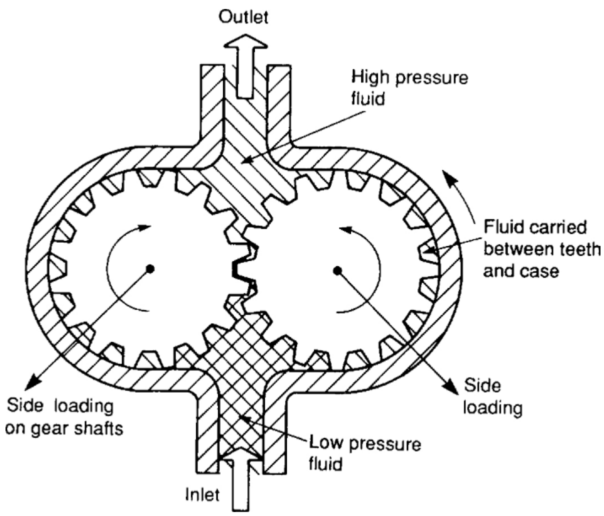


Fig Bladder type accumulator

3.c

With a neat sketch explain the working of external gear pump.

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.



4.a

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 6.4.2. 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.

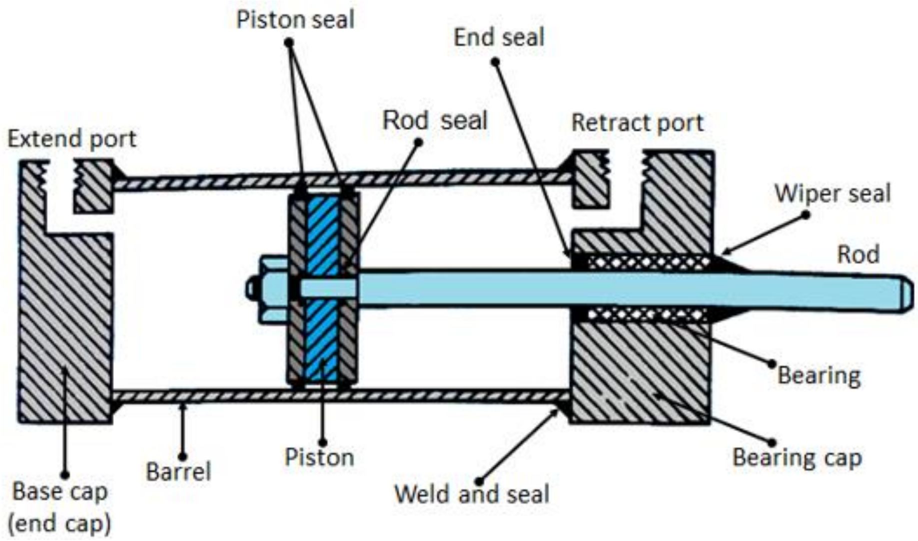


Fig. 2.00 Double acting cylinder

4.b

Example 1.5

An 8 cm diameter hydraulic cylinder has a 4 cm diameter rod. If the cylinder receives flow at 100 LPM and 12 MPa, find the (a) extension and retraction speeds and (b) extension and retraction load carrying capacities.

Solution:

Let us first convert the flow in LPM to m^3/s before we calculate forward velocity Q_{in}=100 LPM = 100/(1000 × 60) =1/600 m^3/s

Now

D_C = Diameter of cylinder = 8 cm = 8×10^{-2} m

d_r = Diameter of piston rod = 4 cm = 4×10^{-2} m

p = 12 MPa = 12×10^6 N/m^2 or Pa

(a) Forward velocity is given by

$$v_{ext} = \frac{Q_{in}}{A_p} = \frac{1/600}{\pi d^2/4} = 0.3315 \text{ m/s}$$

Return velocity is given by

$$v_{ret} = \frac{Q_{in}}{(A_p - A_r)} = \frac{\frac{1}{600}}{\frac{\pi(d_C^2 - d_r^2)}{4}} = 0.442 \text{ m/s}$$

(b) Force during extension is given by

$$F_{ext} = p \times a_p = 12 \times 10^6 \frac{\pi(8 \times 10^{-2})^2}{4} = 60318.57 \text{ N}$$

$$
\begin{aligned}
F_{\text{ret}} &= p \times (A_p - A_r) \\
&= 12 \times \frac{10^6 \times \pi[(8\times10^{-2})^2 - (4\times10^{-2})^2]}{4} \\
&= 42238.9\ \text{N} = 45.24\ \text{kN}
\end{aligned}
$$

4.c

Cylinder Cushioning

The extension and retraction speeds of hydraulic cylinders are managedby controlling the inlet or exit-oil flow rates. When reaching itsend position, the piston is suddenly stopped. In the case of high speedand/or great inertia, the sudden stopping of the piston results in asevere impact force. It affects both the cylinderand the driven mechanism. Therefore, a cushioning arrangement mightbe necessary to reduce the piston speed to a limiting value before piston reaches its end position.

Cushions may be applied at either end or both ends. They operate on the principle that as the cylinder piston approaches the end of stroke; an exhaust fluid is forced to go through an adjustable needle valve that is set to control the escaping fluid at a given rate. This allows the deceleration characteristics to be adjusted for different loads. When the cylinder piston is actuated, the fluid enters the cylinder port and flows through the little check valve so that the entire piston area can be utilized to produce force and motion. A typical cushioning arrangement is shown in Fig. 1. 28.

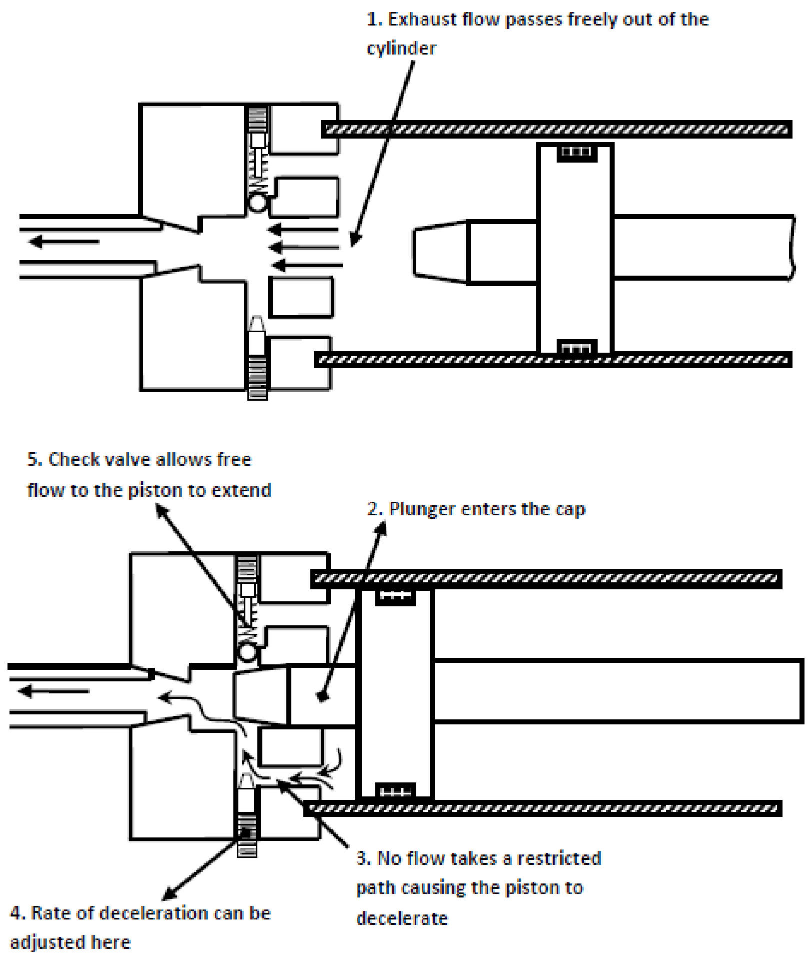


Figure 2.55 working principle of Cylinder cushioning
5.a

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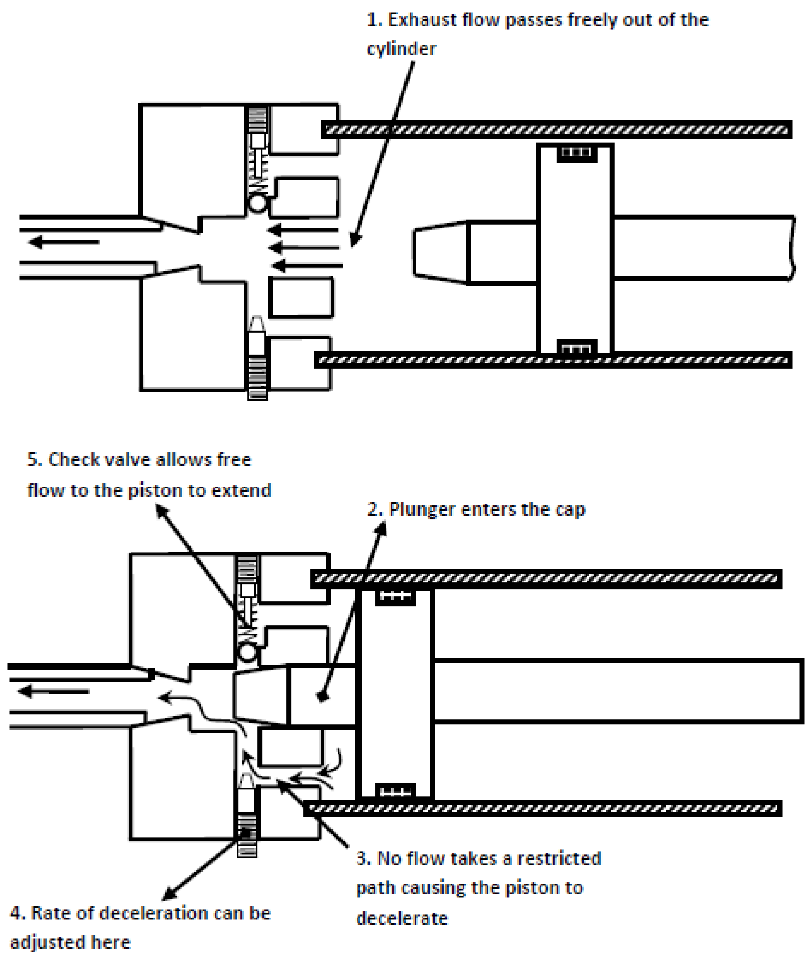


Figure 2.55 working principle of Cylinder cushioning

5.a

<u>Classification of control valves,</u>

The selection of these control components not only involves the type, but also the size, the actuating method and remote control capability. There are 3 basic types of valves.

1. Directional control valves (DCV)

1. Pressure control valves (PCV)

2. Flow control valves. (FCV)

Directional control valves are essentially used for distribution of energy in a fluid power system. They establish the path through which a fluid traverses a given circuit. For example they control the direction of motion of a hydraulic cylinder or motor. These valves are used to controlthe start, stop and change in the direction of flow of pressurized fluid.

Pressure may gradually buildup due to decrease in fluid demand or due to sudden surge as valves opens or closes. Pressure control valves protect the system against such overpressure. Pressure relief valve, pressure reducing, sequence, unloading and counterbalance valve are different types of pressure control 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. For example shock absorbers are designed to smooth out pressure surges and to dampen hydraulic shock.

Components:

Directional Control Valves-symbolic representation,

As the name implies directional control valves are used to control the direction of flow in a hydraulic circuit. They are used to extend, retract or reciprocate hydraulic cylinder and other components for linear motion. Valves contains ports that are external openings for fluid to enter and leave via connecting pipelines, The number of ports on a directional control valve (DCV) is usually identified by the term **" way".** For example, a valve with four ports is named as four-way valve.
Directional control valves can be classified in a number of ways:

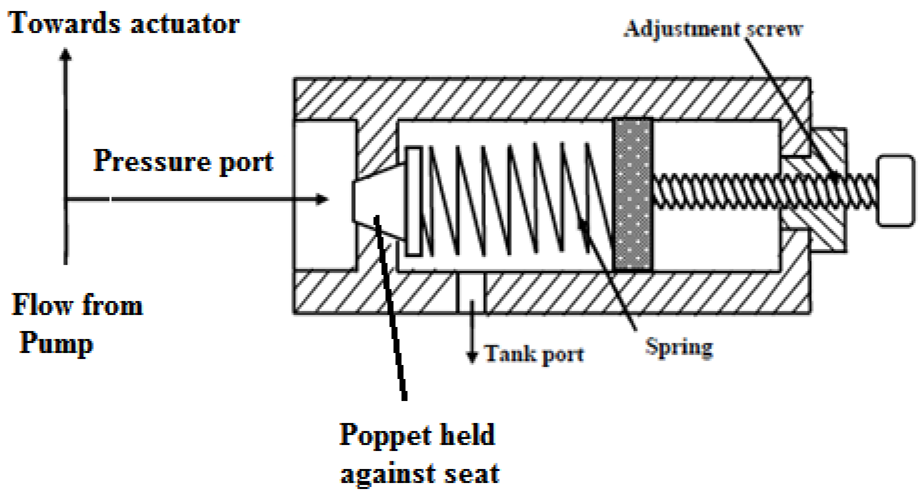
1. According to type of construction:
   - Poppet valves
   - Spool valves
2. According to number of working ports:
   - Two- way valves
   - Three – way valves
   - Four- way valves

3. <u>According to number of switching position</u>:
    - Two – position
    - Three - position
4. Actuating mechanism:
    - Manual actuation
    - Mechanical actuation
    - Solenoid actuation
    - Hydraulic actuation
    - Pneumatic actuation
    - Indirect actuation
5. <u>According to Control method</u>:
    - Direct controlled DCV
      A valve is actuated directly on the valve spool. This is suitable for small-sized valves.
    - Indirect controlled DCV

5.b

Pressure-Relief 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 similar to a fuse in an electrical system. Pressure relief valve is normally a closed type and it opens when the pressure exceeds a specified maximum value by diverting pump flow back to the tank. The simplest type valve contains a poppet held in a seat against the spring force as shown in Figure 5.6.1. The fluid enters from the opposite side of the poppet. When the system pressure exceeds the preset value, the poppet lifts and the fluid is escaped through the orifice to the storage tank directly. It reduces the system pressure and as the pressure reduces to the set limit again the valve closes.



Schematic of direct pressure relief valve is shown in figure 5.6.1. 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.
Note the external adjusting screw, which varies spring force and, thus, thepressure at which the valve begins to open (cracking pressure)(Fig. 1.3). It should be noted that the poppet must open sufficiently to allow full pump flow. The pressure that exists at full pump flow can be substantially greater than cracking pressure. The pressure at full pump flow is the pressure level that is specified when referring to the pressure setting of the valve. It is the maximum pressure level permitted by the relief valve.

5.c

Regenerative Cylinder Circuit

Figure 1.3 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 blockedby 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 Fig. 1.3.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.

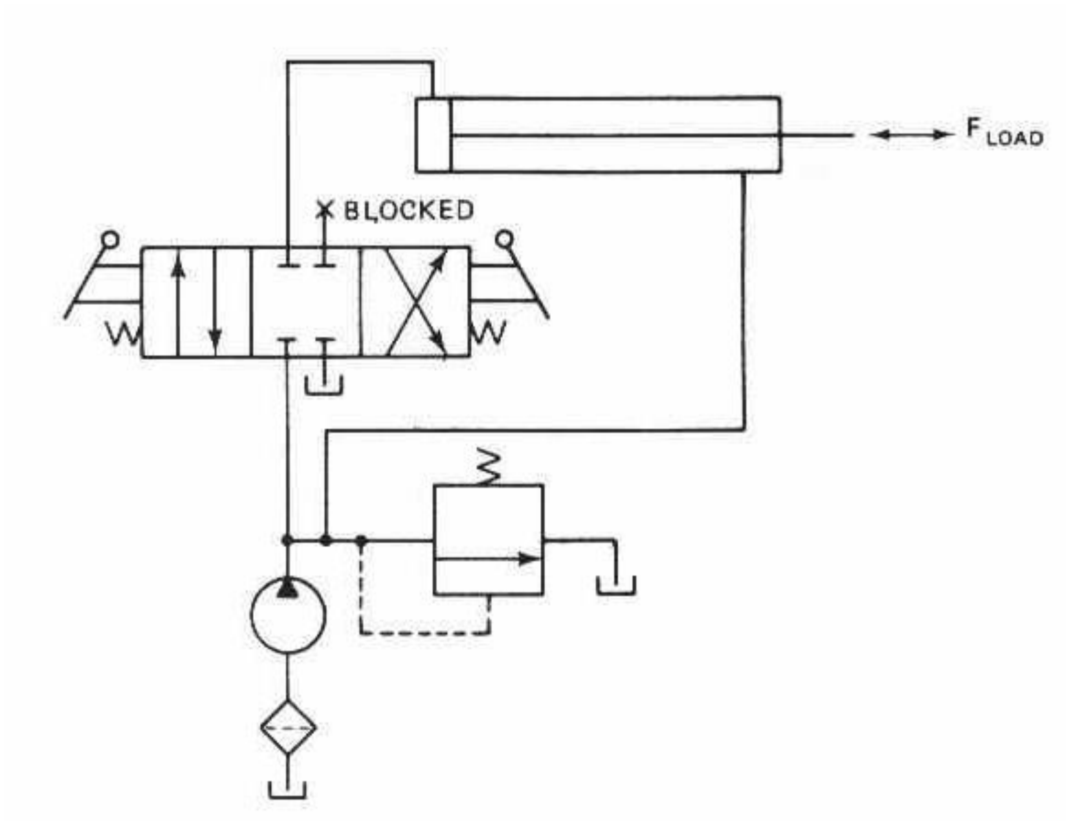


Figure 3.3Regenerative circuit.

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

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

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. The retraction speed is given by

$V_{ret} = Q_P / A_P - A_r$

The ratio of extending and retracting speed is given as

$V_{ext}/V_{ret} = Q_P / A_r / Q_P / A_P - A_r$

$= A_P - A_r / A_r$

$= (A_P / A_r) - 1$

When the piston area equals two times the rod area, the extension and retraction speeds are equal. In general, the greater the ratio of the piston area to rod area, the greater is the ratio of the extending speed to retraction speed.

6.a

With a neat sketch brief the working of check valve.

Check Valve

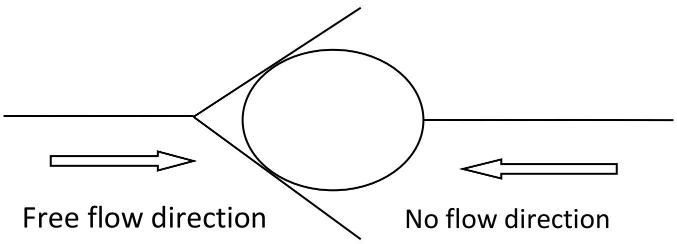
2/2 DCV (Poppet design)

Valve Closed b. Valve Opened

Fig 2/2 DCV (Poppet Design)

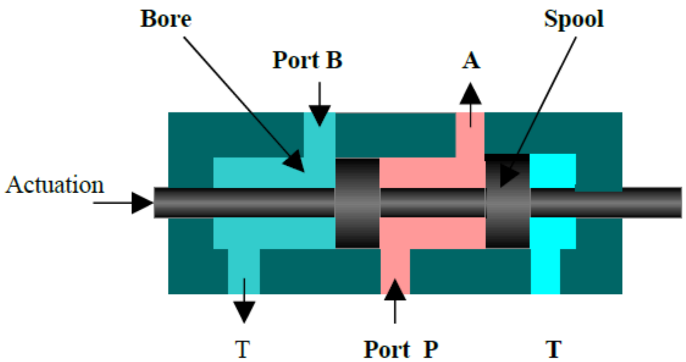
Figure 4.6a Shows a ball poppet type 2 / 2 DCV. It is essentially a check valve as it allows free flow of fluid only in one direction (P to A) as the valve is opened hydraulically and hence the pump Port P is connected to port A as shown in fig b. In the other direction the valve is closed by the ball poppet and hence the flow from the port A is blocked. A poppet is a specially shaped plug element held onto a seat by a spring. Fluid flows through the valve in the space between the seat and poppet. As shown, light spring holds the poppet in the closed position. In the free-flow direction, the fluid pressure overcomes the spring force at about 35kPa.

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 the seat. Thus, increased pressure will not result in any tendency to allow flow in the no flow direction. The symbol for this type of design is same as that of check valve.

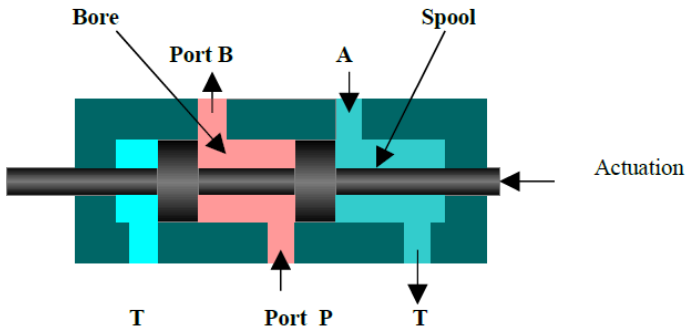


6.b

1. **<u>Four - way DCV</u>**: -
   These valves are also used to operate double acting cylinder. These valves are also called as impulse valve as 2 / 4 DCV has only two switching positions, i.e. it has no mid position. These valves are used toreciprocate or hold and actuating cylinder in one position. They are used onmachines where fast reciprocation cycles are needed. Since the valve actuator movessuch a short distance to operate the valve from one position to the other, this design is used for punching, stamping and for other machines needing fast action. Fig 4.15 a and b shows the two position of 2 / 4 DCV.



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



b. 2 Positon, P to B and A to T

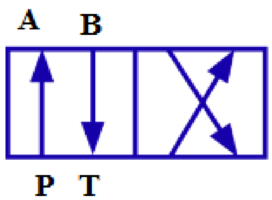


Figure Graphical symbol for 4/2 DCV

These valves are available with a choice of actuation, manual, mechanical, solenoid, pilot & pneumatic. Four-way valve comes with two or three position. One should note that the graphical symbol of the valve shows only one tank port even though the physical design may have two as it is only concerned with the function.
Three- position, four- way DCV have different variety of center configurations. The common varieties are the open center, closed center, tandem center, floating center, & regenerative center with open, closed and tandem are the three basic types A variety of center configurations provides greater flexibility for circuit design.

6.c

Explain the working of sequencing hydraulic circuit.

In many applications, it is necessary to perform operations in a definite order. Hydraulic cylinders can be operated sequentially using a sequence valve. Figure 1.7 shows that two sequence valves are used to sequence the operation of two double-acting cylinders. This sequence of cylinder operation is controlled by sequence valves. This hydraulic circuit can be used in a production operation such as drilling. Cylinder A is used as a clamp cylinder and cylinder B as a drill cylinder. Cylinder A extends and clamps a work piece. Then cylinder B extends to drive a spindle to drill a hole. Cylinder B retracts the drill spindle and then cylinder A retracts to release the work piece for removal.

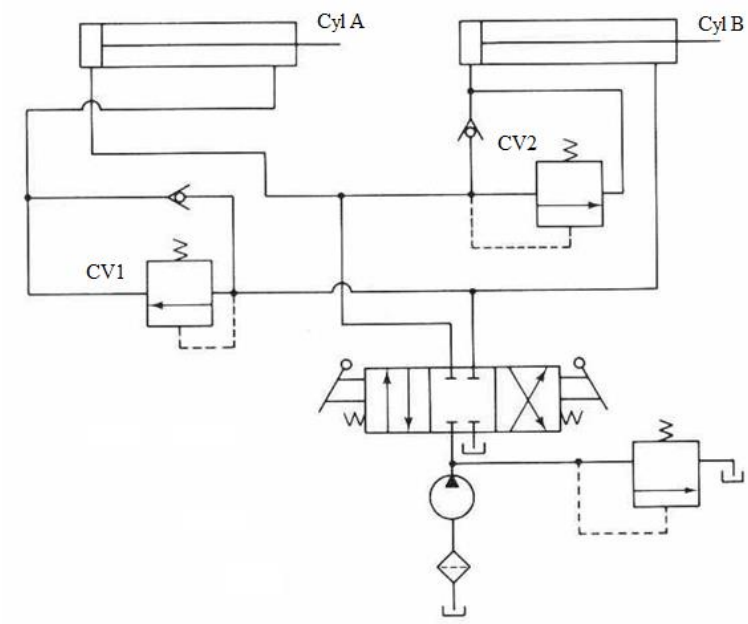


Figure Sequencing circuit.

The sequence of operation realized by the circuit shown in Figure 1.7 is:
Step A – Extend Cylinder A (To clamp the work piece)
Step B – Extend Cylinder B while holding pressure on Cylinder A (To perform drilling operation)
Step C – Retract Cylinder B (To retract the spindle after drilling)
Step D – Retract Cylinder A (To unclamp the work piece)

When the DCV is shifted into its left envelope mode, the cylinder A extends completely. When the pressure reaches the pressure setting of sequence valve (SV1), the valve opens and fluid flow is allowed to the cylinder B as a result cylinder B extends. If the DCV is then shifted into its right envelope mode cylinder B retracts fully, and then the cylinder A retracts. Hence this sequence of cylinder operation is controlled by the sequence valves. The spring cantered position of the DCV locks both cylinders in place.

7a

Brief the various components of a pneumatic systems and its fluid power control.

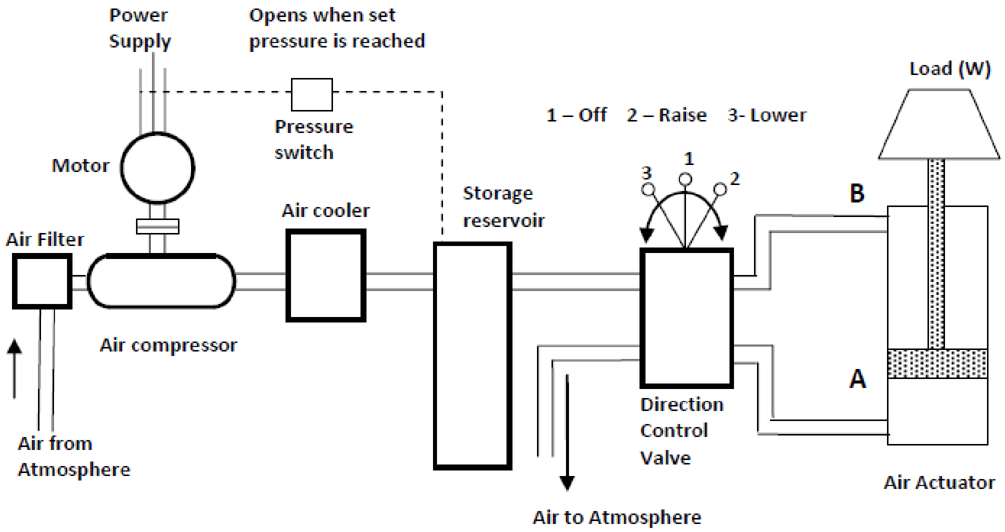


Fig. 4.1 Components of a pneumatic system

Important components of a pneumatic system are shown in fig 4.1

Functions of components

1. Air filters are used to filter out the contaminants from the air.
2. Air coolerare used to reduce the temperature of the compressed air.
3. Compressor is used to compress the fresh air drawn from the atmosphere.
4. External power supply (Motor) is used to drive the compressor.
5. Storage reservoir is used to store a given volume of compressed air.
6. Control valves are used to control the direction, flow rate and pressure of compressed air.
7. Pneumatic actuator converts the fluid power into mechanical power to perform useful work.
8. Piping system carries the pressurized air from one location to another.

Atmospheric air is drawn through air filter and raised to required pressure by an air compressor. As the pressure rises, the temperature of air will also rise and hence air cooler is provided to cool the air with some preliminary treatment to remove the moisture.
The treated pressurized air is stored in the storage reservoir to maintain the required 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 cylinder movement is controlled by pneumatic valve. One side of the pneumatic valve is connected to the compressed air and silencers for the exhaust air and the other side of the valve is connected to port A and Port B of the cylinder.
Position of the valve is as follows
Raise: To lift the weight, the compressed air supply is connected to port A and the port B is connected to the exhaust line, by moving the valve position to the “Raise”.

Lower: To bring the weight down, the compressed air line is connected to port B and port A is connected to exhaust air line, by moving the valve position to the "lower".
Off: The weight can be stopped at a particular position by moving the valve to position to "Off" position. This disconnects the port A and port B from the pressurized line and the retrieval line, which locks the air in the cylinder.
7.b

Single acting cylinder

Single acting cylinders produce work in one direction of motion hence they are named as single acting cylinders. 4.22 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.

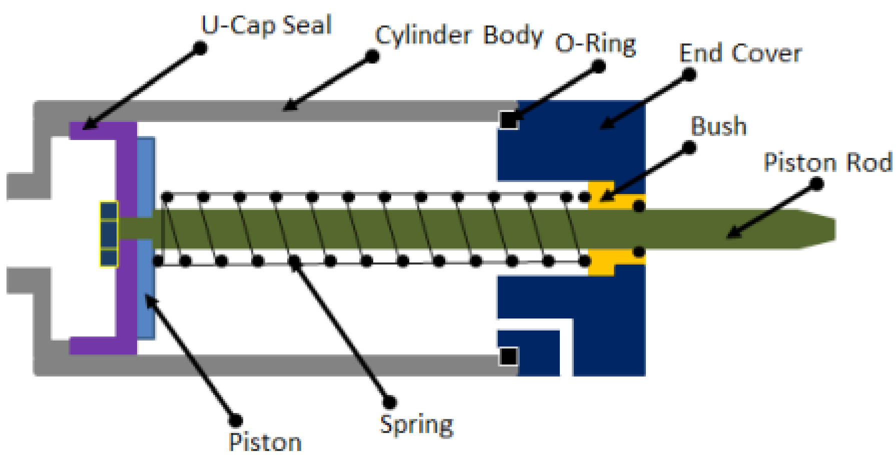


Fig. 4.22 Single acting cylinder

Varying designs of single acting cylinders:

1. Diaphragm cylinder

In diaphragm cylinder, piston is replaced by a diaphragm of hard rubber, plastic or metal clamped between the two halves of a metal casing expanded to form a wide, flat enclosure. Schematic diagram of diaphragm cylinder is shown in Figure 4.23.The operating stem which takes place of the piston rod in diaphragm cylinder can also be designed as a surface element so as to act directly as a clamping surface for example. Only short operating strokes can be executed by a diaphragm cylinder, up to a maximum of 50 mm. This makes the diaphragm type of cylinder particularly adaptable to clamping operations. Return stroke is accomplished by a spring built into the assembly or by the tension of diaphragm itself in the case of very short stroke. Diaphragm cylinders are used for short stoke application like clamping, riveting, lifting, embossing and riveting.

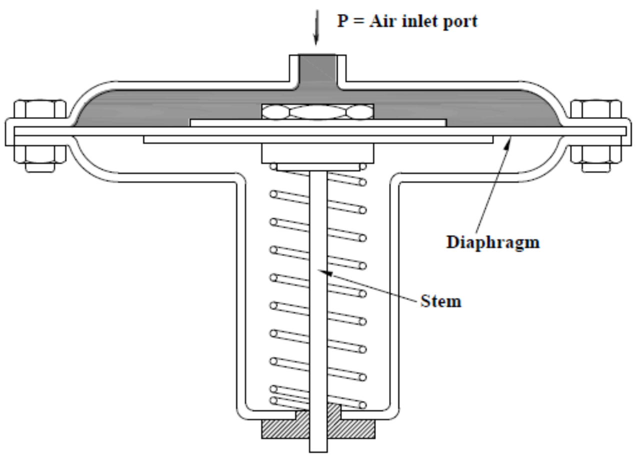
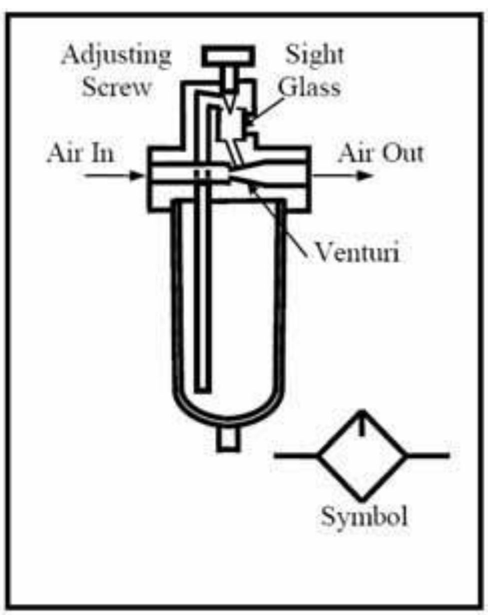


Figure 4.23 Construction features of diaphragm cylinder

7.c

With a neat sketch explain the working of lubricator.

After the combination unit filters and regulates air pressure, some downstream system components may require a small amount of lubrication. (For example: air motors are one item that needs a constant supply of oil to extend their life and maintain torque.) Some cylinders are pre-lubed and most valves require little if any lubrication, so keep oil supply to these units at minimum.



Air line lubricators are designed to send a mist of oil to the parts in the downstream circuit. However, the physical size of some circuits makes it impossible for the mist to stay in suspension long enough to reach some parts. In this case -- and for some air motor applications --

it is necessary to inject oil at the components inlet. There are electric and air-driven lubrication units to meet the needs of these applications.

8.a

Explain the working of shuttle valve.

A shuttle valve is shown in figure. The shuttle valve consists of a valve body and a synthetic ball or a cuboid valving element moving inside the bore in the valve housing. There are three openings P_1, P_2, and A. if an air signal is fed to port P_1, the ball moves, closing port P_2 and air passes to 'A'. If the air is fed to port P_2, port P_1 is closed and moves to 'A'. If air is fed simultaneously to port P_1 and P_2 then also air moves to port A, either from P_1 or P_2 or from both. This element is also called an OR Gate.

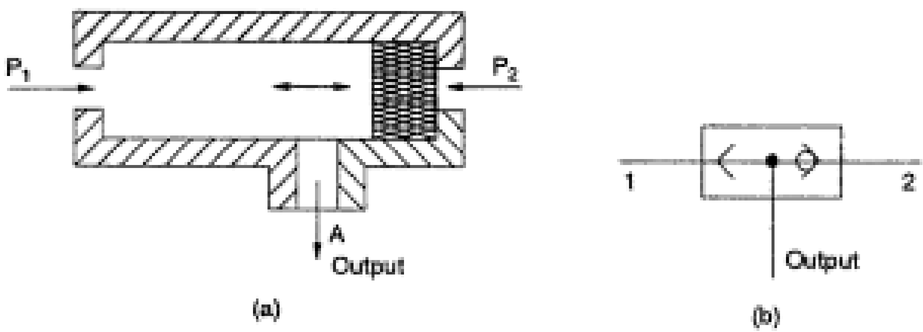


Figure a. Construction of shuttle valve b. graphical symbol

8.b

Cylinder mountings

The way in which the pneumatic cylinder is mounted similar to hydraulic cylinders influences service life, maintenance frequency and success of the entire installation. Poor mounting design can cause excessive side loads and stresses which will bring about early failure of some vital component. There are three main categories of cylinder mounting. The selection of these mountings depends on the application and machine configuration.

1. Fixed Centreline mountings
2. Pivoted centreline mountings
3. Fixed non centreline mountings

1. Fixed Centreline mountings: In this mounting, the cylinder is supported along its centre line. The mounting bolts are thus subjected to shear or simple stress. This mounting needs accurate alignment. Misalignment is not tolerable.
2. Pivot centreline mounting: Many applications need rotational degree of freedom for a cylinder as it reciprocates. The pivot mounting can be clevis type or trunnion type. This mounting permits rotational freedom in one plane. If universal joint is used, greater degrees of freedom are possible.
3. Fixed non centreline mounting: This mounting of cylinder introduces torque under loaded condition. The cylinder may rotate or bend about its mounting bolt when loaded. The stress level on the cylinder is higher as compared to the centre line mounting.

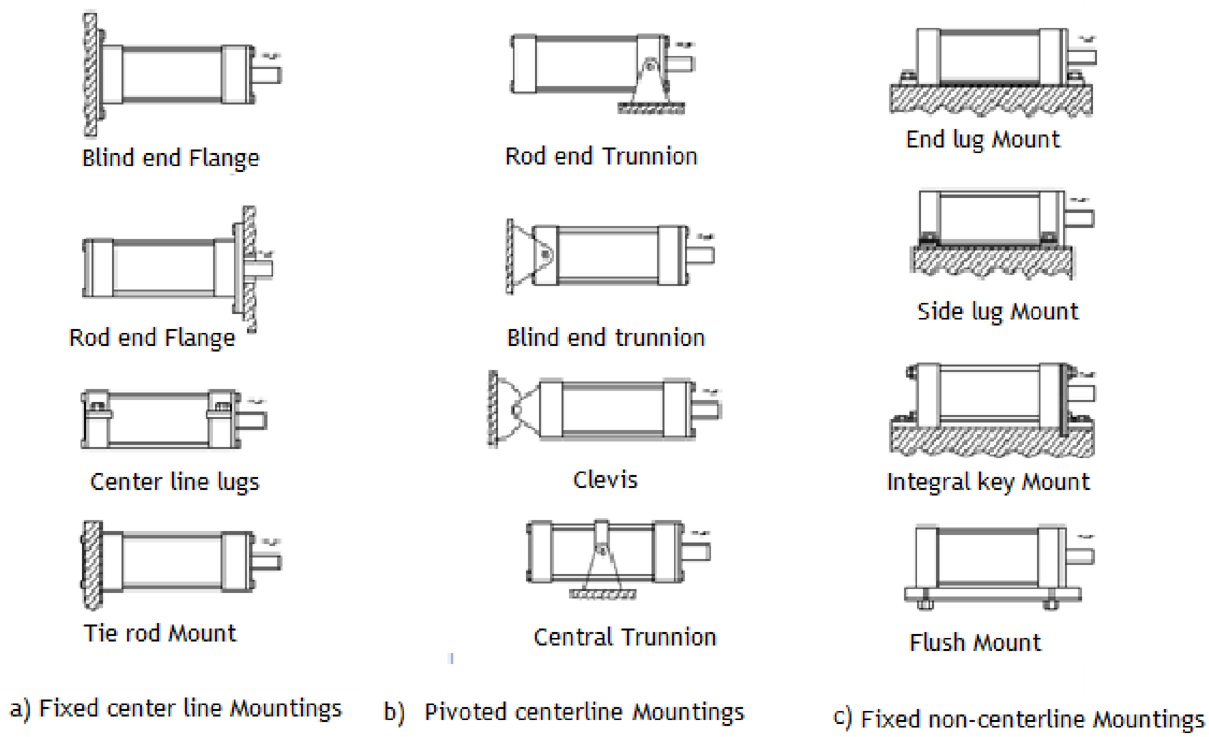


Figure 4.28 Types of mounting a) Fixed centreline b) Pivoted centreline c)

8.c

With a neat sketch, explain electro pneumatic control of double acting cylinder.

A double acting cylinder can be controlled by using a single limit switch and a single solenoid valve as shown in figure 5.38. Figure 5.38a) gives the pneumatic circuit in which the limit switch is labeled 1-LS and the solenoid is labeled SOL A. this method of labeling is required since many systems require more than one limit switch or solenoid.

Electrical circuit diagram in figure 5.38b) shows the use of one relay with a coil designated as 1-CR and two separate, normally open sets of contacts with a coil labeled 1-CR (NO). The limit switch is labeled 1-LS (NC), and also included are one normally closed and one normally open push button switch labeled STOP and START, respectively. This electrical diagram is called a "ladder diagram" Because of its resemblance to a ladder. The two vertical electric power supply lines are called "rungs".

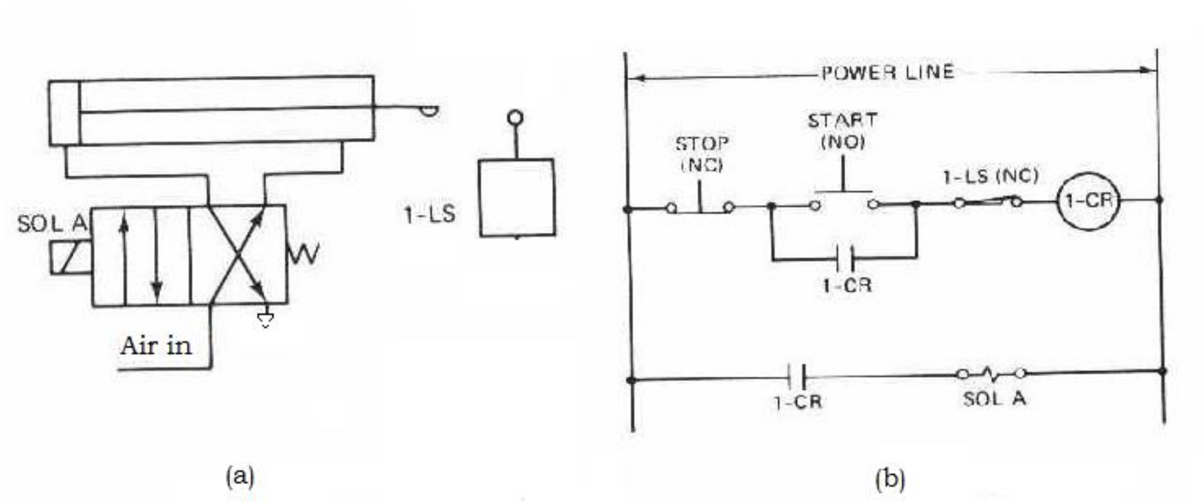


Figure 5.38 control of a double acting cylinder using single limit switch.

When the START button is momentarily pressed, the cylinder extends because coil 1-CR is energized, which closes both sets of contacts of 1-CR. Thus, the upper

1-CR set of contacts serves to keep coil 1-CR energized even though the START button is released. The lower set of contacts closes to energize solenoid A to extend the cylinder. When 1-LS is actuated by the piston rod cam, it opens to de-energize coil 1-CR. This re-opens the contacts of 1-CR to de-energize solenoid A. Thus, the valve returns to its spring-offset mode and the cylinder retracts. This closes the contacts of 1-LS, but coil 1-CR is not energized because the contacts of 1-CR and the START button have returned to their normally open position. The cylinder stops at the end of the retraction stroke, but the cycle is repeated each time the START button is momentarily pressed. When the STOP button is momentarily pressed, it will immediately stop the extension stroke and fully retract the cylinder.

9.a

Speed control of cylinders

It is always necessary to reduce the speed of cylinder from maximum speed based on selected size of final control valve to the nominal speed depending on the application. Speed control of Pneumatic Cylinders can be conveniently achieved by regulating the flow rate supply or exhaust air. The volume flow rate of air can be controlled by using flow control valves which can be either two way flow control valve or one way flow control valve. This is also known as a throttle valve or a flow restrictor.

There are two types of throttling circuits for double acting cylinders:

1. Supply air throttling
2. Exhaust air throttling

Supply air throttling

This method of speed control of double acting cylinders is also called meter–in circuit (Figure 5.5 a). For supply air throttling, one way flow control valves are installed so that air entering the cylinder is throttled. The exhaust air can escape freely through the check valve of the throttle valve on the outlet side of the cylinder. There is no air cushion on the exhaust side of the cylinder piston with this throttling arrangement. As a result, considerable differences in stroking velocity may be obtained even with very small variations of load on the piston rod. Any load in the direction of operating motion will accelerate the piston above the set velocity. Therefore supply air throttling can be used for single acting and small volume cylinders.

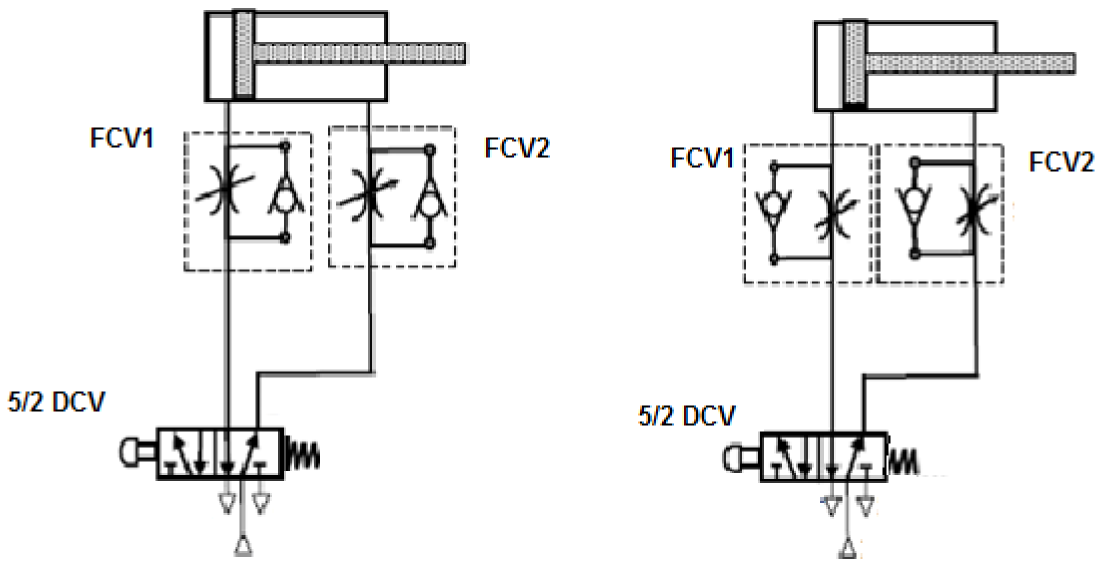


Figure 5.5 a) Supply Air throttling b) Exhaust air throttling
9.b

OR Function

The single acting cylinder in Figure 5.6 can be operated by two input signals. If compressed air signal is applied to input X or input Y, will produce a signal at output Z. If there is no input signal, there is no output signal. If signals are present at both inputs, the signal with the higher pressure reaches the cylinder.

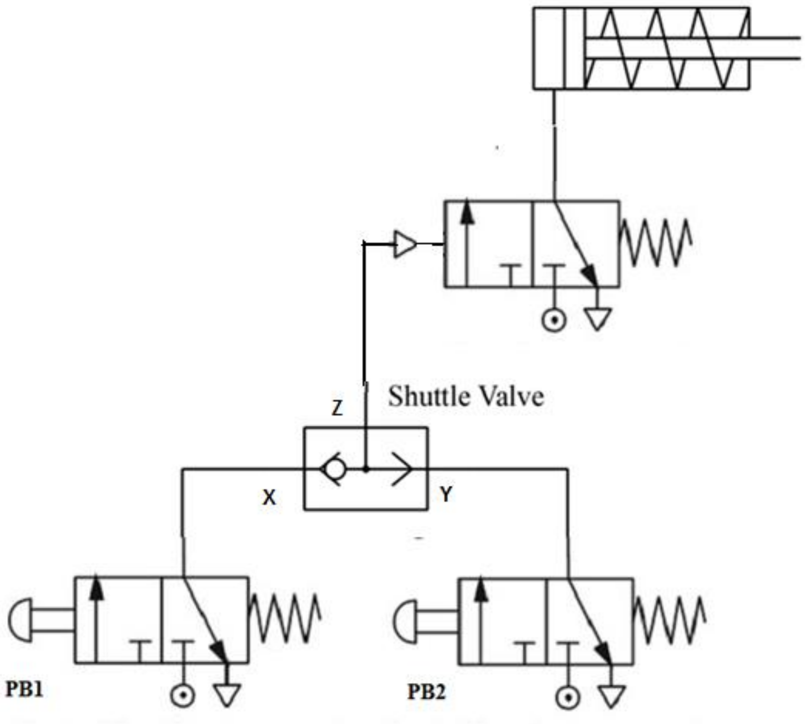


Figure 5.6 Cylinder actuation with OR function

Two 3/2 push button actuated DCV's are connected to the inlet ports (X and Y) of the shuttle valve. The output (Z) of the shuttle valve is connected to pilot port of the 3/2 DCV. This in turn connected to the blank end side of the single acting cylinder. On pressing either of the push buttons PB1 or PB2 the compressed air will be delivered by the shuttle valve to 3/2 DCV through the pilot signal. Pilot signal from the shuttle valve actuates the DCV to allow the compressed air to the actuator inlet port. This results in extension of cylinder.

When the 3/2 push button valves return under spring pressure, they remove the pilot pressure from the 3/2 pilot operated valve, it also retracts under spring pressure allowing the valve to return to its initial position and exhaust the actuator as shown in the circuit diagram. Examples include manual operations and applications relying on automatic circuit signals, that is, when either control valve PB1or PB2 is operated, the cylinder will work (extend or retract).

One application of OR gate can be utilized in door closing (figure 5.7) of a CNC machine during machining process. A double acting cylinder is used to open and close the door. One input may be from the manual push button and another can be from the program itself. Here both input signals are connected to a shuttle valve which in turn connected to the cylinder. Door will be closed if any one input signal is present.

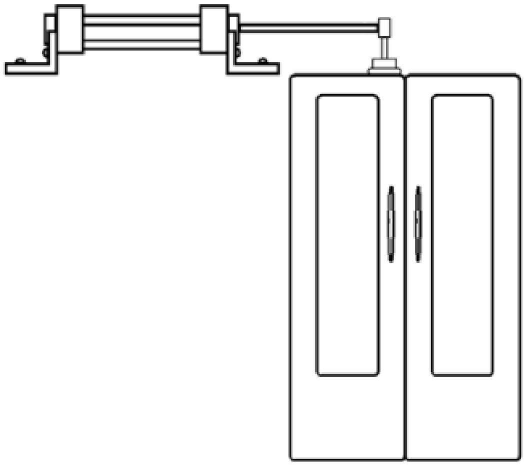


Figure 5.7 OR function in door opening/closing application
10.a

Cascading method (Reversing or group changing valves)

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.
To know and learn how the cascade system is drawn for a problem one must be familiar with components of cascade system. In the following paragraphs the method of cascading is explained step by step by taking by taking an example and also various components of cascade system are explained.

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.
Rest of the procedure is shown step by step taking following examples:

Demonstration of Cascade method

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 5.20. First cylinder A extends and clamps the workpiece 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:

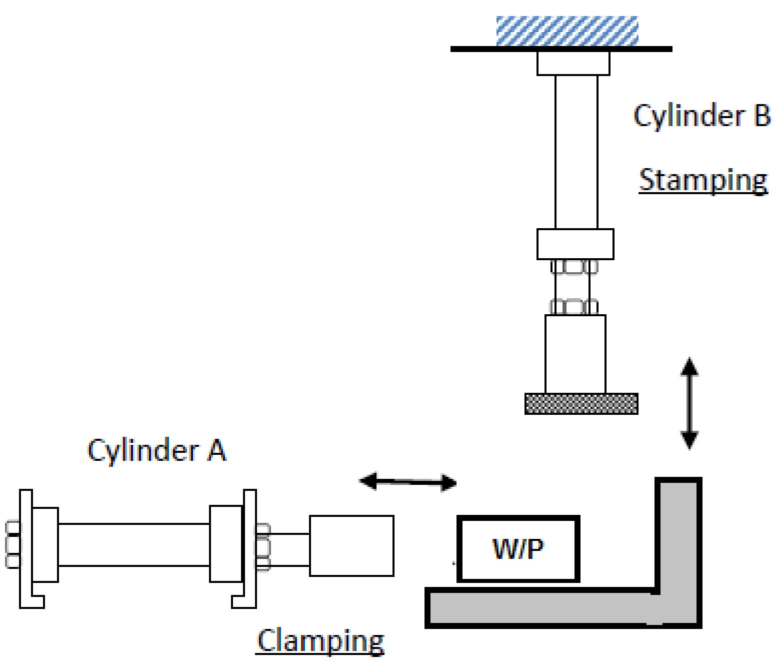


Figure 5.20 Positional diagram

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:

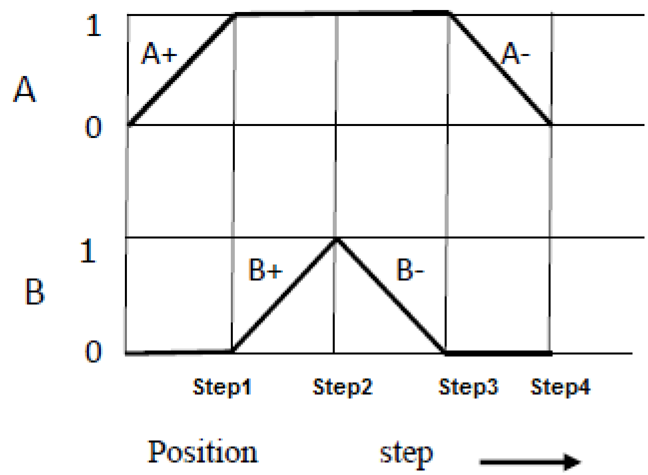


Figure 5.21 Displacement step diagram
Step 5 Draw the Displacement –time diagram:

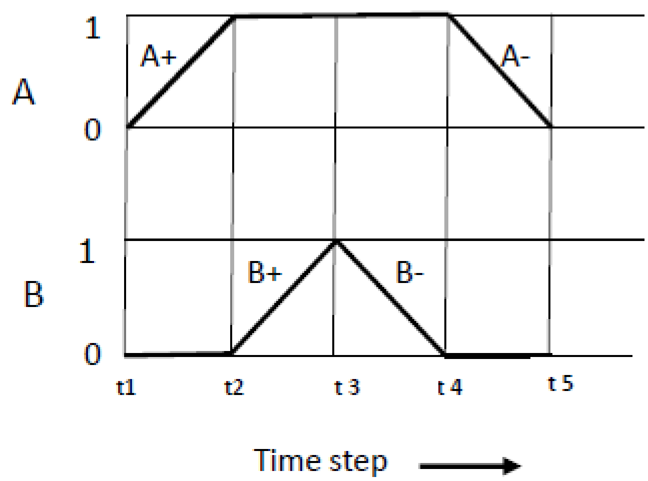


Figure 5.22 Displacement time diagram
Step 6: Analyse and Draw Pneumatic circuit:
Step 6.1 Analyse input and output signals:

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

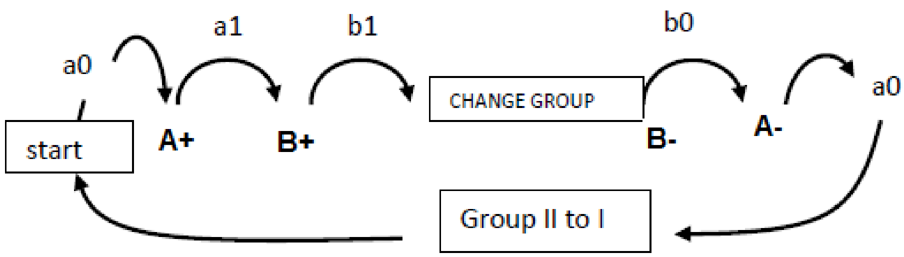
Forward motion of cylinder A (A+)
Return motion of cylinder A (A-)
Forward motion of cylinder B (B+)
Return motion of cylinder B (B+)

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.



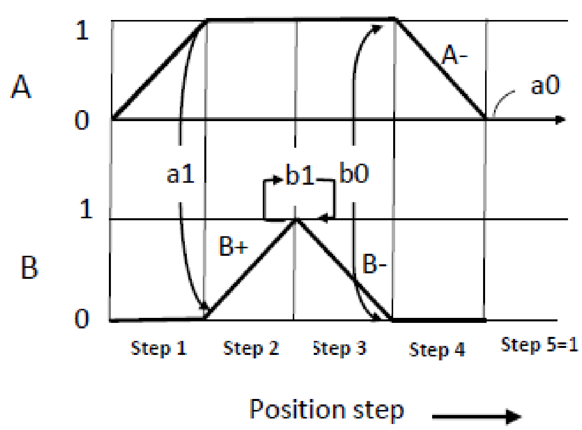


Figure 5.23 Displacement time diagram

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 5.24 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

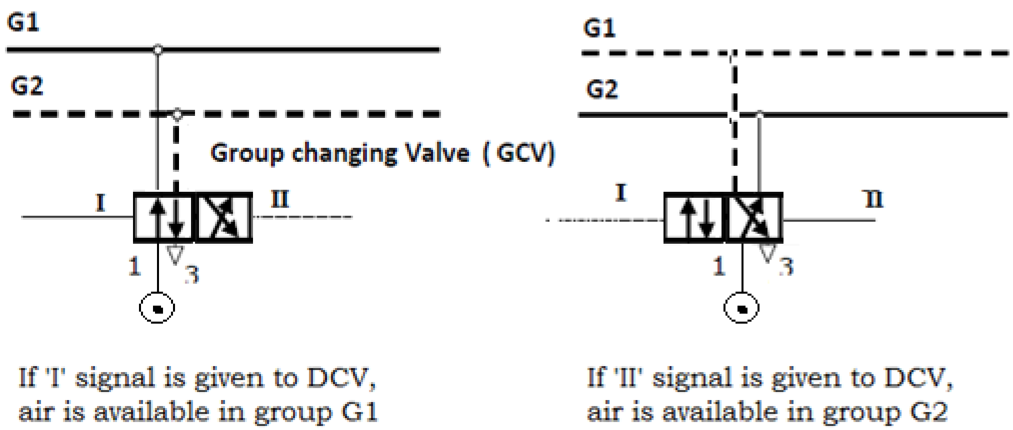


Figure 5.24 connection of DCV to group changing valve

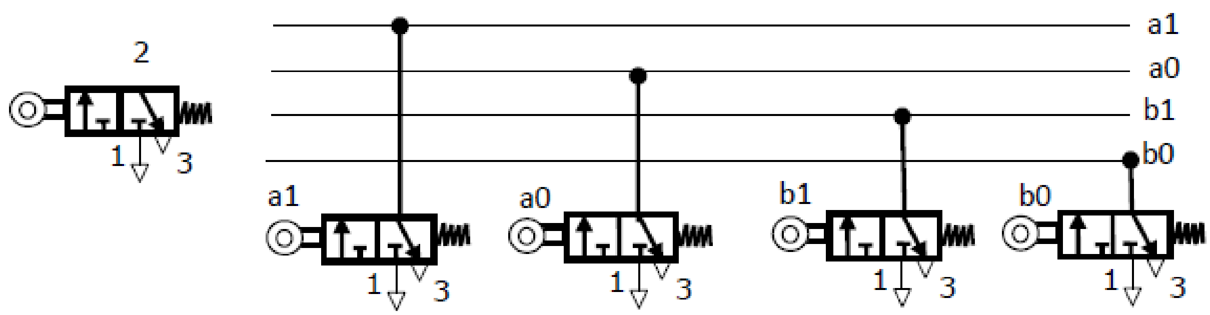


Figure 5.25 Connection of limit switches and start button
iv) Draw the power circuit:

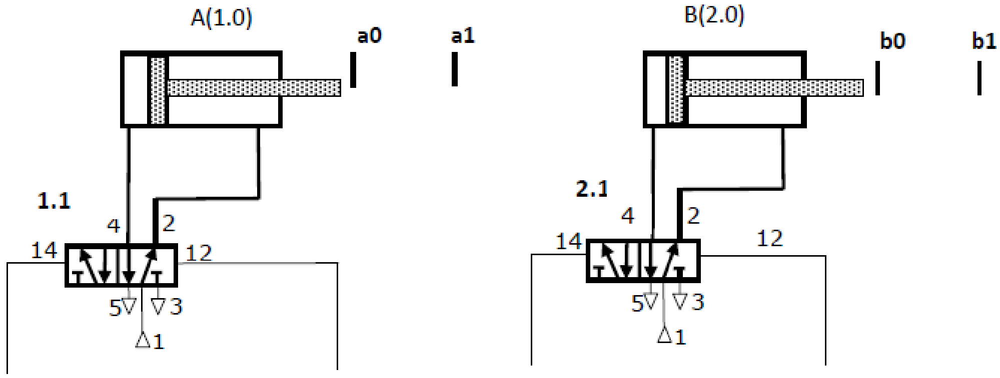


Figure 5.26 power circuit diagram

Step 8 Draw the control circuit:

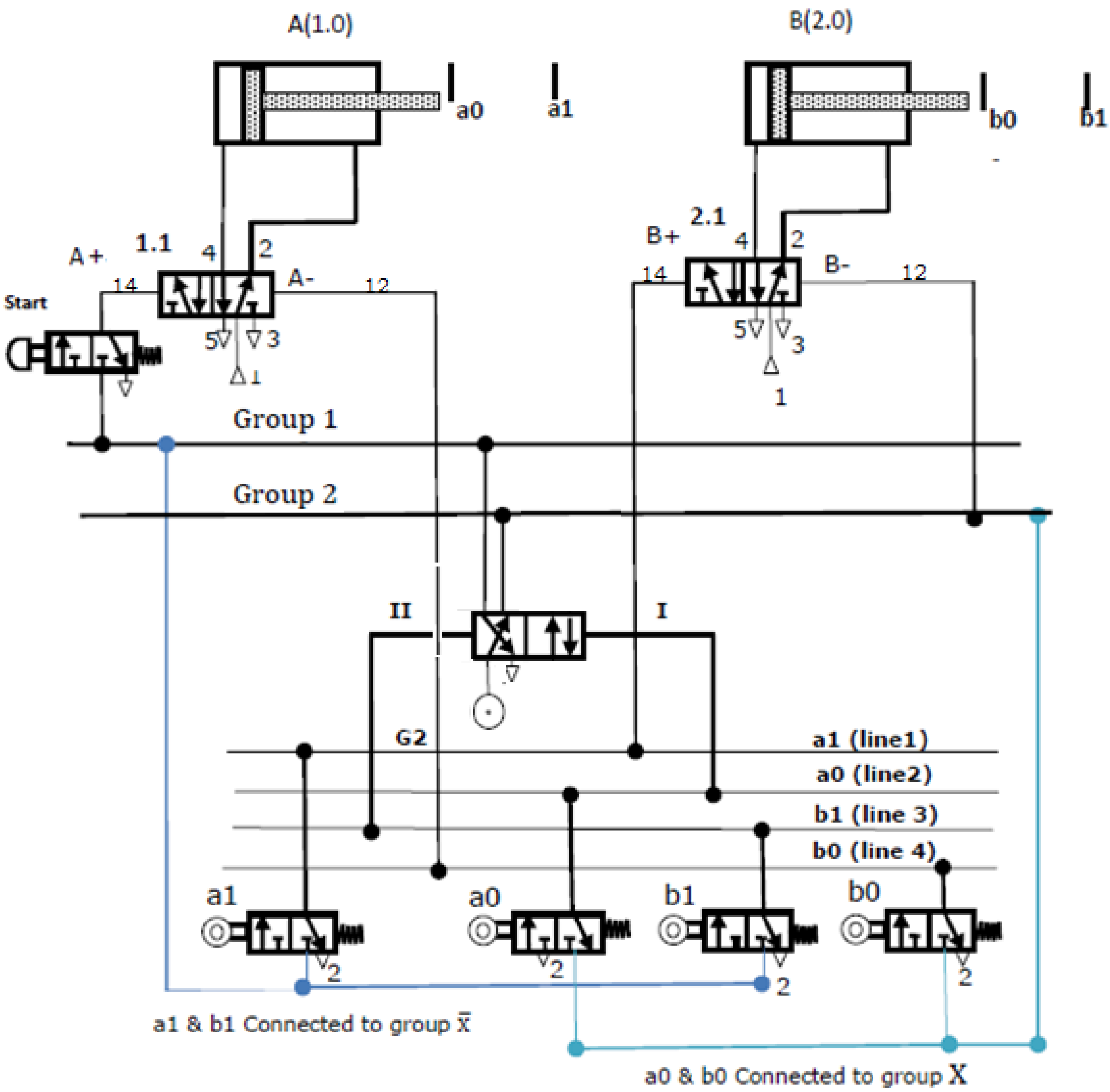


Figure 5.27 Pneumatic circuits for A+ B+ B- A-

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.

The cascade system provides a straightforward method of designing any sequential circuit. Following are the important points to note:

a) Present – the system must be set to the last group for start-up

b) Pressure drop- Because the air supply is cascaded, a large circuit can suffer from more pressure drop.

c) Cost – Costly due to additional reversing valves and other hardware.

10.b

Electropneumatic circuits

Control of a cylinder using a single limit switch

A double acting cylinder can be controlled by using a single limit switch and a single solenoid valve as shown in figure 5.38. Figure 5.38a) gives the pneumatic circuit in which the limit switch is labeled 1-LS and the solenoid is labeled SOL A.

this method of labeling is required since many systems require more than one limit switch or solenoid.
Electrical circuit diagram in figure 5.38b) shows the use of one relay with a coil designated as 1-CR and two separate, normally open sets of contacts with a coil labeled 1-CR (NO). The limit switch is labeled 1-LS (NC), and also included are one normally closed and one normally open push button switch labeled STOP and START, respectively. This electrical diagram is called a “ladder diagram” Because of its resemblance to a ladder. The two vertical electric power supply lines are called “rungs”.

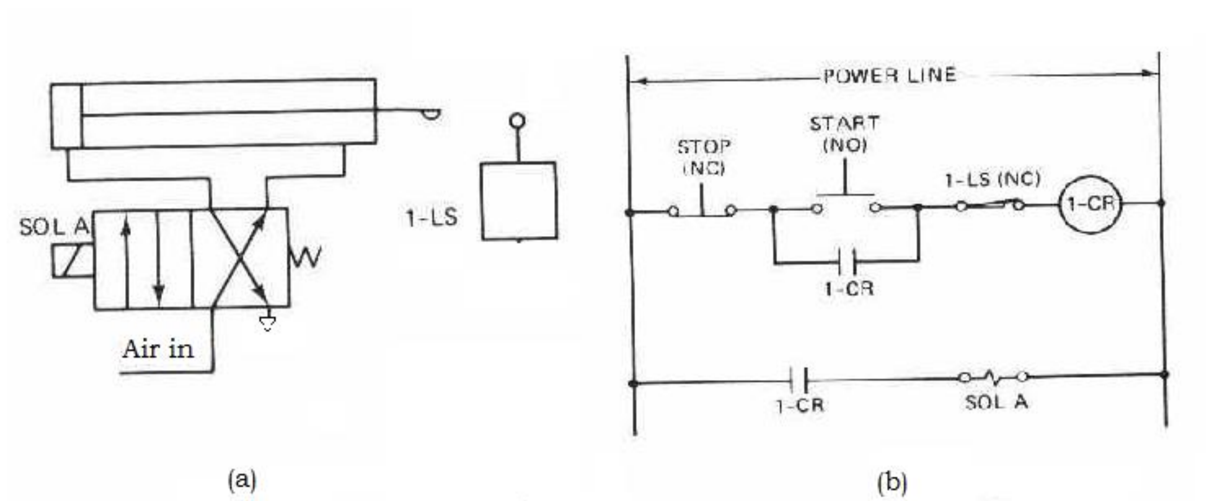


Figure 5.38 control of a double acting cylinder using single limit switch.

When the START button is momentarily pressed, the cylinder extends because coil 1-CR is energized, which closes both sets of contacts of 1-CR. Thus, the upper 1-CR set of contacts serves to keep coil 1-CR energized even though the START button is released. The lower set of contacts closes to energize solenoid A to extend the cylinder. When 1-LS is actuated by the piston rod cam, it opens to de-energize coil 1-CR. This re-opens the contacts of 1-CR to de-energize solenoid A. Thus, the valve returns to its spring-offset mode and the cylinder retracts. This closes the contacts of 1-LS, but coil 1-CR is not energized because the contacts of 1-CR and the START button have returned to their normally open position. The cylinder stops at the end of the retraction stroke, but the cycle is repeated each time the START button is momentarily pressed. When the STOP button is momentarily pressed, it will immediately stop the extension stroke and fully retract the cylinder.

Dual-cylinder sequence circuits

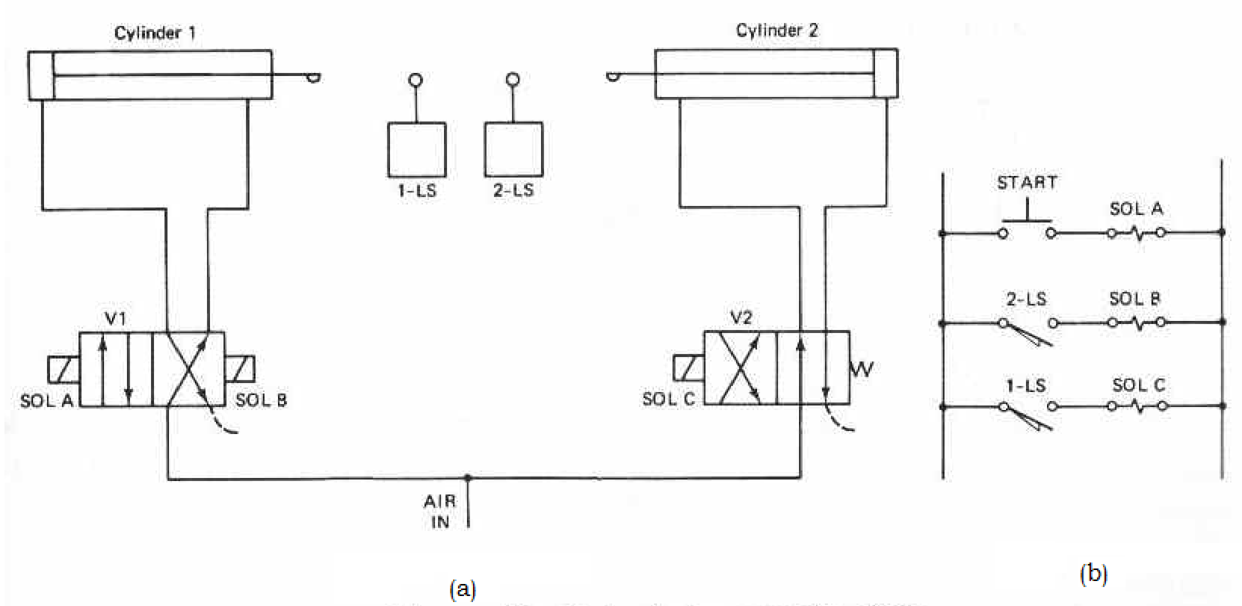


Figure 5.39 dual cylinder sequencing circuits

Figure 15-14 shows a circuit that provides a cycle sequence of two pneumatic cylinders. When the start button is momentarily pressed, SOL A is momentarily energized to shift valve *V*1, which extends cylinder 1. When 1-LS is actuated, SOL C is energized, which shifts valve *V*2 into its left flow path mode. This extends, cylinder 2 until it actuates 2-LS. As a result, SOL B is energized to shift valve *V*1 into its right flow path mode. As cylinder 1 begins to retract, it de-actuates 1-LS, which de-energizes SOL C. this puts valve *V*2 into its spring-offset mode, and cylinders 1 and 2 retract together. The complete cycle sequence established by the momentary pressing of the start button is as follows:

1. Cylinder 1 extends.
2. Cylinder 2 extends.
3. Both cylinders retract.
4. Cycle is ended.