1. **Define hydraulic circuits. What are the basic considerations in designing a hydraulic circuit?**

A hydraulic circuit is a group of components such as pumps, actuators, control valves, conductors and fittings arranged to perform useful work. It gives us an idea about how these components are interconnected.

There are three important considerations in designing a hydraulic circuit:

1. Safety of machine and personnel in the event of power failures.
2. Performance of given operation with minimum losses.
3. Cost of the component used in the circuit.

2. **Derive an expression for the extending speed of a cylinder connected to a regenerative circuit.**

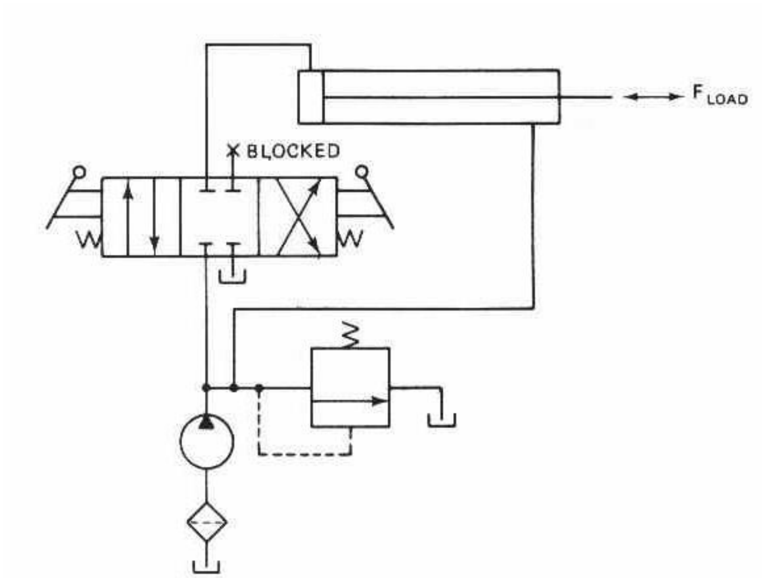


Figure shows a regenerative circuit that is used to speed up the extending speed of a double-acting cylinder. The pipelines to both ends of the hydraulic cylinder are connected in parallel and one of the ports of the 4/3 valve is blocked by simply screwing a thread plug into the port opening. During 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

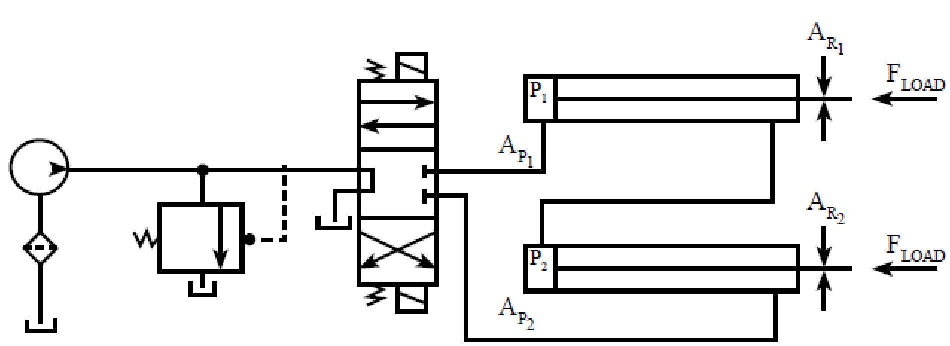
$$V_{ext} = Q_P / A_r$$

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.

3. Explain briefly, with a neat sketch, the cylinder synchronizing circuit, operated together with a pair of cylinders in series in a synchronized manner to lift the load?

In industry, there are instances when a large mass must be moved, and it is not feasible to move it with just one cylinder. In such cases it is necessary to use two or more cylinders to prevent a moment that might distort and damage the load. For example, in press used for molding and shearing parts, the platen (flat platform) used is very heavy. If the platen is several meter wide, it has to be of very heavy construction to prevent the damage when it is pressed down by a single cylinder in the middle. It can be designed with less material if it is pressed down with two or more cylinders. These cylinders must be synchronized. There are two ways that can be used to synchronize cylinders: Parallel and series.

Cylinders in Series



During the extending stroke of cylinders, fluid from the pump is delivered to the blank end of cylinder 1. As cylinder 1 extends, fluid from its rod end is delivered to the blank end of cylinder 2 causing the extension of cylinder 2. As cylinder 2 extends, fluid from its rod end reaches the tank. For two cylinders to be synchronized, the piston area of cylinder 2 must be equal to the difference between the areas of piston and rod for cylinder 1.
Thus, applying the continuity equation,

$$Q_{out\ (cylinder1)} = Q_{in\ (cylinder\ 2)}$$

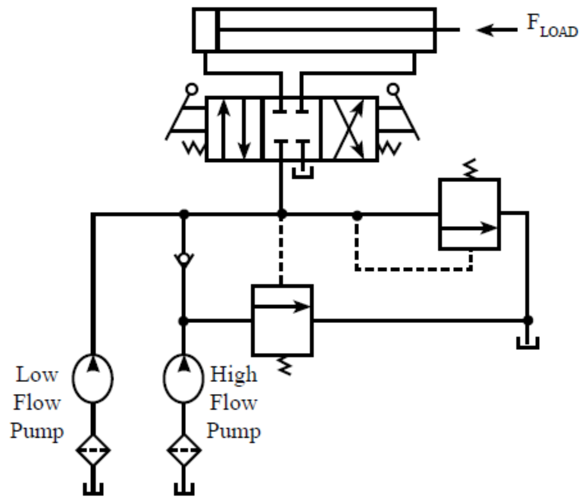
We get,

$$(A_{p1} - A_{r1})\ V_1 = A_{p2}\ V_2$$

For synchronization, V1 = V2. Therefore,
(Ap1 – Ar1) = Ap2 (1)
The pump must deliver a pressure equal to that required for the piston of cylinder 1 by itself to overcome loads acting on both extending cylinders. We know that the pressure acting at the blank end of cylinder 2 is equal to the pressure acting at the rod end of cylinder 1.
Forces acting on cylinder 1
P1Ap1 - P2(Ap1 – Ar1) = F1
Forces acting on cylinder 2
P2Ap2 - P2(Ap2 – Ar2) = F2
Using Eq. (1) and noting that p3 = 0 (it is connected to the tank), we have
P1Ap1 - P2 (Ap2) = F1 (2)
P2 (Ap2) - 0 = F2 (3)
Now, Eq. (2) + Eq. (3) gives
P1Ap1 = F1 + F2 (4)
If Equation(4) is met in a hydraulic circuit, the cylinders hooked in series operate in synchronization.

4. **With hydraulic circuit, explain the operation of a double pump hydraulic system.**

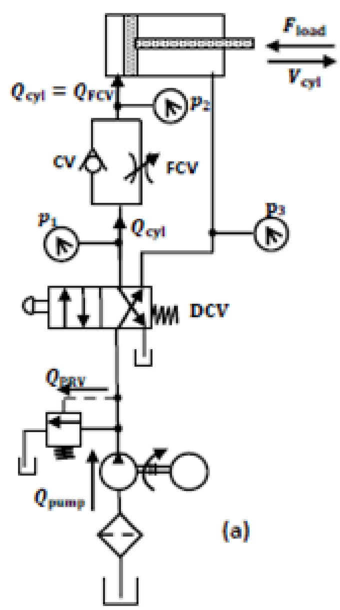
It is a circuit that uses a high pressure, low-flow pump in conjunction with a low-pressure, high-flow pump. A typical application is a sheet metal punch press in which the hydraulic cylinder must extend rapidly over a great distance with low-pressure but high-flow requirements. This occurs under no load. However during the punching operation for short motion, the pressure requirements are high, but the cylinder travel is small and thus the flow requirements are low. The circuit eliminates the necessity of having a very expensive high-pressure, high-flow pump.



When the punching operation begins, the increased pressure opens the unloading valve to unload the low-pressure pump. The purpose of relief valve is to protect the high-pressure pump from over pressure at the end of cylinder stroke and when the DCV is in its spring centered mode. The check valve protects the low-pressure pump from high pressure, which occurs during punching operation, at the ends of the cylinder stroke and when the DCV is in its spring-centered mode.

5. **Illustrate with a circuit diagram i) meter-in circuit ii) meter-out circuit, for controlling the speed of cylinder. List the merits and demerits.**

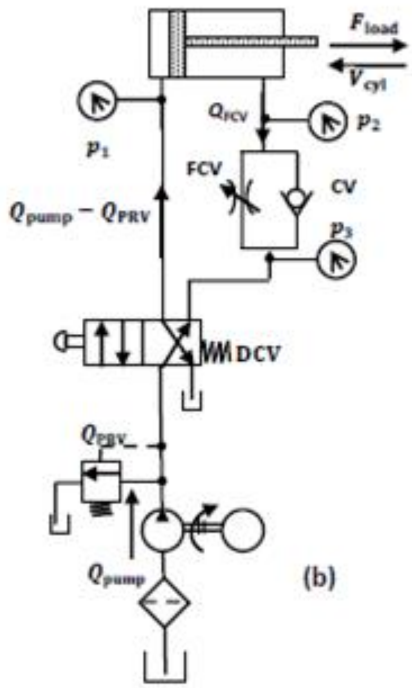
The speed control of a hydraulic cylinder circuit can be done during the extension stroke using a flow-control valve (FCV). This is done on a meter-in circuit and meter-out circuit.



i) meter-in circuit

When the FCV is placed in the line leading to the inlet port of the cylinder. It is called as the meter-in control of speed. Meter-in flow controls the oil flow rate into the cylinder.

When the DCV is actuated, oil flows through the FCV to extend the cylinder. The extending speed of the cylinder depends on the FCV setting. When the DCV is deactivated, the cylinder retracts as oil from the cylinder passes through the check valve. Thus, the retraction speed of a cylinder is not controlled.



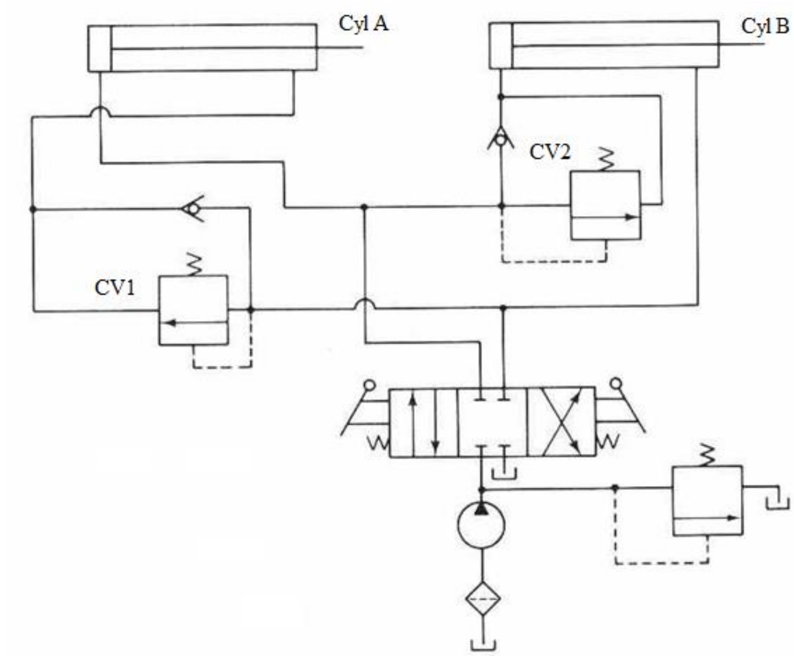
ii) Meter-out circuit

A meter-out flow control system is one in which the FCV is placed in the outlet line of the hydraulic cylinder. Thus, a meter-out flow control system controls the oil flow rate out of the cylinder. Figure below shows meter-out circuit; when DCV is actuated, oil flows through the rod end to retract the cylinder.

Meter-in systems are used primarily when the external load opposes the direction of motion of the hydraulic cylinder. When a load is pulled downward due to gravity, a meter-out system is preferred. If a meter-in system is used in this case, the load would drop by pulling the piston rod, even if the FCV is completely closed.

One drawback of a meter-out system is the excessive pressure build-up in the rod end of the cylinder while it is extending. In addition, an excessive pressure in the rod end results in a large pressure drop across the FCV. This produces an undesirable effect of a high heat generation rate with a resulting increase in oil temperature.

6. Design a hydraulic sequencing circuit used in a drilling machine for clamping work piece and drilling a hole.



In many applications, it is necessary to perform operations in a definite order. Hydraulic cylinders can be operated sequentially using a sequence valve. Figure above 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.

The sequence of operation realized by the circuit shown in Figure 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)

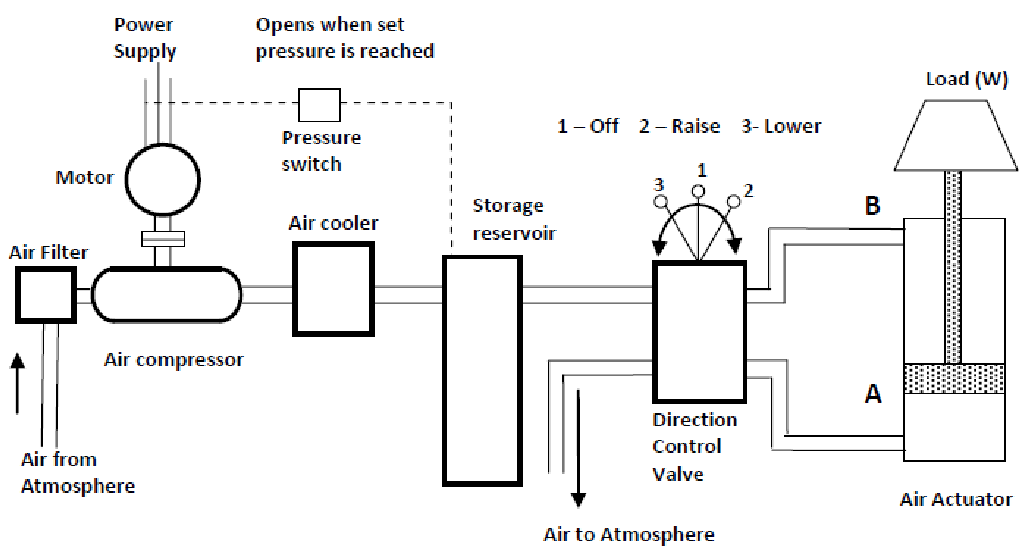
When the DCV is shifted into its left envelope mode, the cylinder A extends completely. When the pressure reaches the pressure setting of sequence valve (SV1), the valve opens and fluid flow is allowed to the cylinder B as a result cylinder B extends. If the DCV is then shifted into its right envelope 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.

7. **Name three reasons for considering the use of pneumatics instead of hydraulics.**
    1. Liquid exhibit greater inertia than do gases. Therefore, in hydraulic systems the weight of oil is a potential problem when accelerating and decelerating actuators and when suddenly opening and closing valves
    2. Liquid also exhibit greater viscosity than do gases. This results in larger frictional pressure and power losses
    3. Hydraulic systems use a fluid foreign to atmosphere, they require special reservoirs and no-leak system designs. Pneumatics use air that is exhausted directly back to surrounding environment. Generally speaking, pneumatic systems are less expensive than hydraulic systems.

8. **Sketch and explain structure of pneumatic control system.**

Pneumatic technology deals with the study of behavior and applications of compressed air in manufacturing automation. Pneumatic systems use air as the medium which is abundantly available and can be exhausted into the atmosphere after completion of the assigned task. Important components of a pneumatic system are shown in figure below.



Functions of the basic components of pneumatic systems:

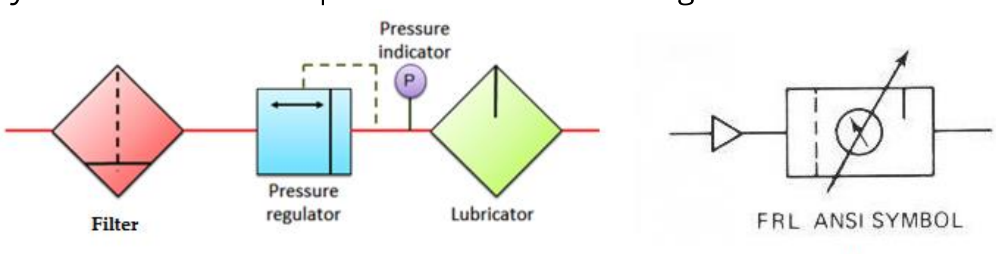
1. Air filters are used to filter out the contaminants from the air.
2. Air cooler are used to reduce the temperature of the compressed air.
3. Compressor is used to compress the fresh air drawn from the atmosphere.
4. External power supply (Motor) is used to drive the compressor.
5. Storage reservoir 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.

9. **What is FRL unit in a pneumatic system? Explain.**

During the preparation of compressed air, various processes such as filtration, regulation and lubrication are carried out by individual components. Preparatory functions can be combined into one unit which is called as 'service unit' or FRL unit. Several manufacturers supply a filter, regulator, and lubricator assembled in one housing. The complete and abbreviated symbols for this component are shown in Fig. below.



(a) (b)

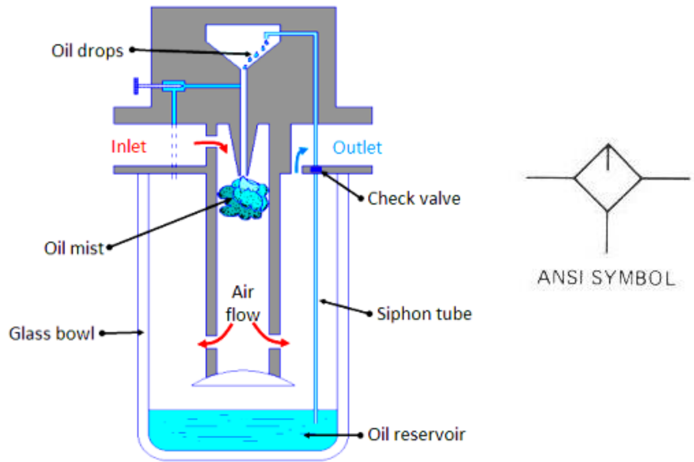
10. **Why would a lubricator be used in a pneumatic system?**

A lubricator for a pneumatic system provides lubrication to internal working parts of pneumatic tools and components, including actuating cylinders, valves and motors. The device injects a stream of oil into the airline, ensuring they perform at the optimum level at all times.
The lubricator is an important element of the pneumatic device as it supplies lubrication to different machines. Pneumatic lubricators are present on:

- Air motors
- Cylinders

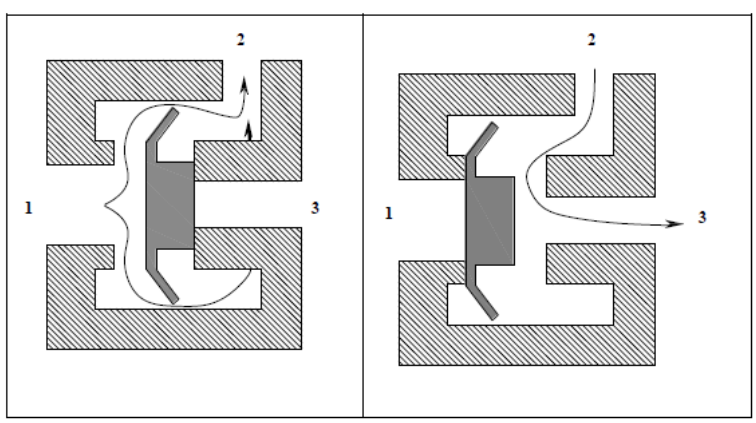
- Gears
- Sliding Surfaces

By having a lubrication system, machinery can benefit from lower friction, smoother operation and speed control which in turn helps the system run efficiently and lowers the running and maintenance costs.

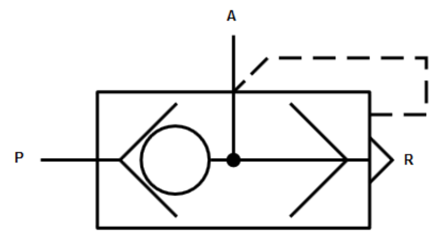


11. Sketch and explain construction and principle of working of a quick exhaust valve.

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 below. 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.



Schematic diagram of Quick exhaust valve



Graphical symbol

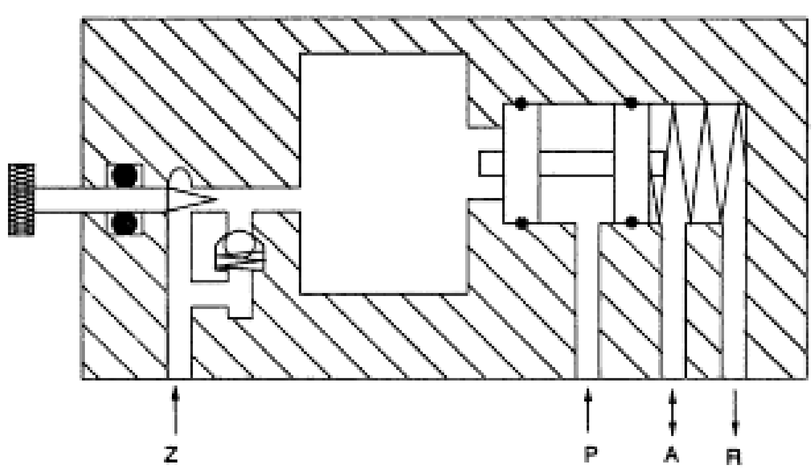
The construction and operation of a quick exhaust valve is shown in Figure. It consists of a movable disc (also called flexible ring) and three ports namely, Supply port 1, which is connected to the output of the directional control valve. The Output port, 2 of this valve is directly fitted on to the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

12. Explain time delay valve used in a pneumatic control system.

The time delay valve consists of an in-built air reservoir, an in-built non-return flow control valve and a pilot controlled spring return 3-way 2-position direction control valve. This valve is used in the pneumatic system to initiate a delayed signal.



When the compressed air is supplied to the port 'P' of the valve, it is prevented from flowing to port 'A' from 'P', as this is blocked by the spring actuated spool. Air is accumulated in an in-built reservoir of the valve from the pilot control port 'Z', the control passage of the same being controlled by the needle of the in-built throttle valve. Pressure starts building up here. When the pressure needed to push the spool is built up in the reservoir, the pilot spool of the 3/2 direction control valve shifts, thus opening port 'P' of the main valve to 'A' and closing 'R'. The time required to build up the pressure in the reservoir, is the amount of delay time offered by the time delay valve. With further increase of pressure, the in-built check valve opens the air from the reservoir gets exhausted and the valve spool returns to its original position.

13. List the advantages and limitations of pneumatic systems.

Pneumatic control systems are widely used in our society, especially in the industrial sectors for the driving of automatic machines. 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.

Limitations of Pneumatic power systems

Although pneumatic systems possess a lot of advantages, they are also subject to many limitations.

1. **Noise**

Noise will be produced when compressed air is released from the pneumatic components.

2. **Processing required before use**

Compressed air must be processed before use to ensure the absence of water vapour or dust. Otherwise, the moving parts of the pneumatic components may wear out quickly due to friction.

3. **Relatively low accuracy**

As pneumatic systems are powered by the force provided by compressed air, their operation is subject to the volume of the compressed air. As the volume of air may change when compressed or heated, the supply of air to the system may not be accurate, causing a decrease in the overall accuracy of the system.

4. **Low loading**

As the cylinders of pneumatic components are not very large, a pneumatic system cannot drive loads that are too heavy.

5. **Uneven moving speed**

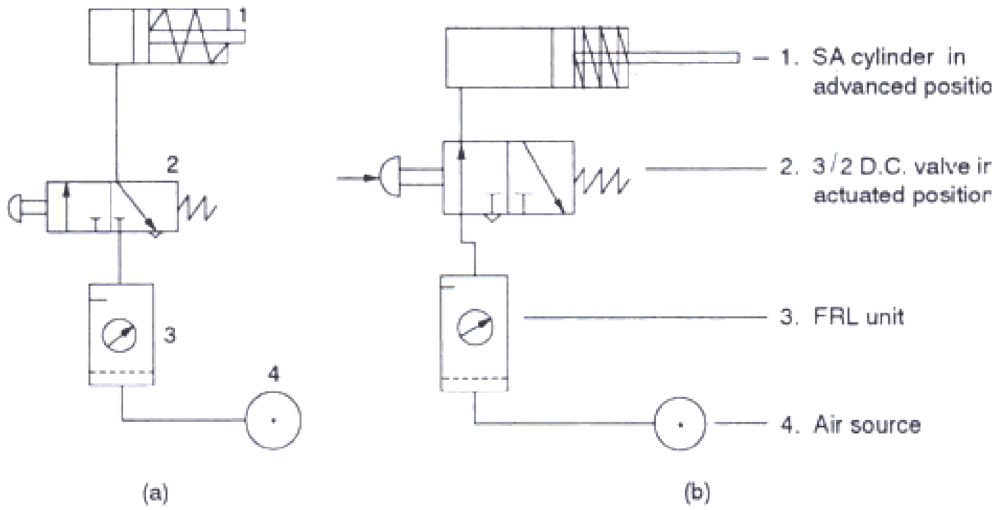
As air can easily be compressed, the moving speeds of the pistons are relatively uneven.

14. **Explain direct and indirect actuation of pneumatic cylinders.**

Direct control of single acting cylinder

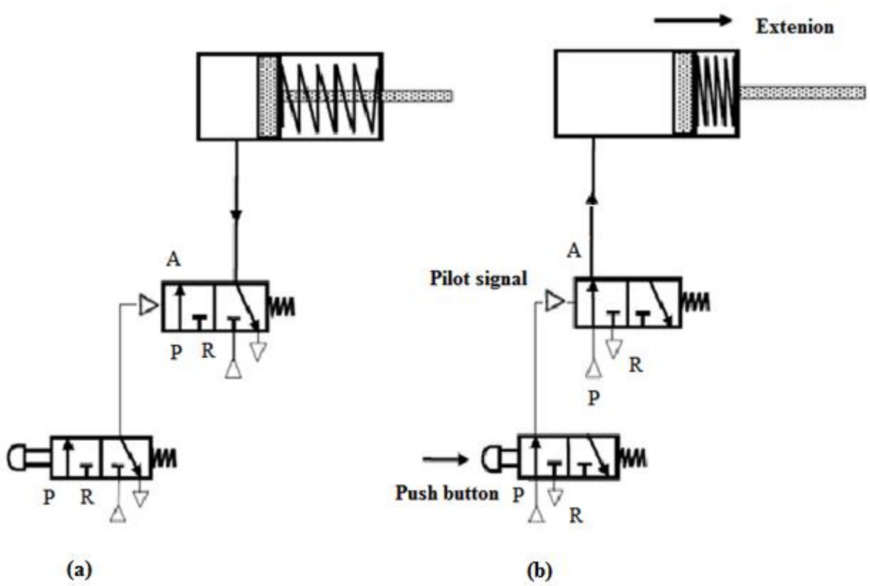
Pneumatic cylinders can be directly controlled by actuation of final directional control valve. These valves can be controlled manually or electrically. This circuit can be used for small cylinders as well as cylinders which operate at low speeds where the flow rate requirements are less.

When the directional control valve is actuated by push button, the valve switches over to the open position, communicating working source to the cylinder volume. This results in the forward motion of the piston rod. When the push button is released, the reset spring of the valve restores the valve to the initial position. The cylinder space is connected to exhaust port there by piston retracts due to spring or gravity.



Indirect control of single acting cylinder

Circuit diagram shown in figure is suitable for large single cylinders as well as cylinders operating at high speeds. The final pilot control valve is actuated by normally closed 3/2 (Three-way Two-position) push button operated valve. The final control valves handle large quantity of air.



When the push button is pressed, 3/2 normally closed valve generates a pilot signal which controls the final valve thereby connecting the working medium to blank end side of the cylinder so as to advance the cylinder. Note that compressor and FRL units here in the circuit are replaced by a simple triangle. A triangle or a circle with a center dot can be used to represent air source in the pneumatic circuit design.

When the push button is released, pilot air from final valve is vented to atmosphere through 3/2 NC – DCV. The signal pressure required can be around 1-1.5 bar. The working pressure passing through the final control valve depends on the force requirement which will be around 6-10 bar. Single piloted valves are rarely used in applications where the piston has to retract immediately on taking out the set pilot signal.

15. Write a short note on application of pneumatics in material handling application.

The application of pneumatic systems is very extensive. New uses for pneumatics are constantly being discovered. In construction, it is indispensable source of power for such tools as air drills, hammers, wrenches, and even air cushion supported structures, not to mention the many vehicles using air suspension , braking and pneumatic tires.

In manufacturing, air is used to power high speed clamping, drilling, grinding, and assembly using pneumatic wrenches and riveting machines. Plant air is also used to power hoists and cushion support to transport loads through the plant. Many recent advances in air – cushion support are used in the military and commercial marine transport industry.

Material handling applications:

- Positioning
- Clamping
- Shifting
- Branching of material flow
- Turning and inverting of parts
- Transfer of materials
- Stacking of components
- Sorting of parts
- Stamping and embossing of components