CBCS SCHEME

Fifth Semester B.E. Degree Examination, Jan./Feb. 2021

Fluid Power Engineering (18ME55)

Time: 3 hrs. Max. Marks: 100

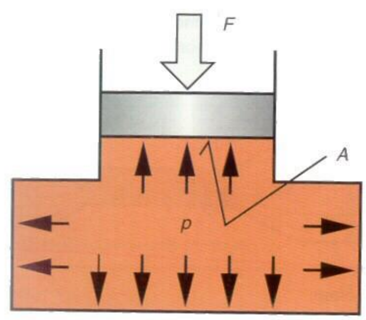
Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1. **a. State Pascal's law. Explain with a sketch its application to simple hydraulic jack. (10 Marks)**

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:

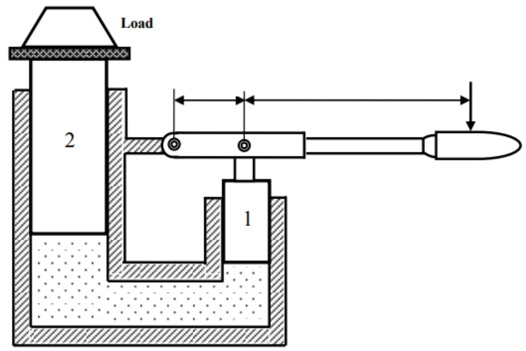
$F = p \times A$

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.



The above figure shows a hand operated hydraulic jack which works on the principles of Pascal's law.

b. Sketch and explain the structure of hydraulic control system. (10 Marks)

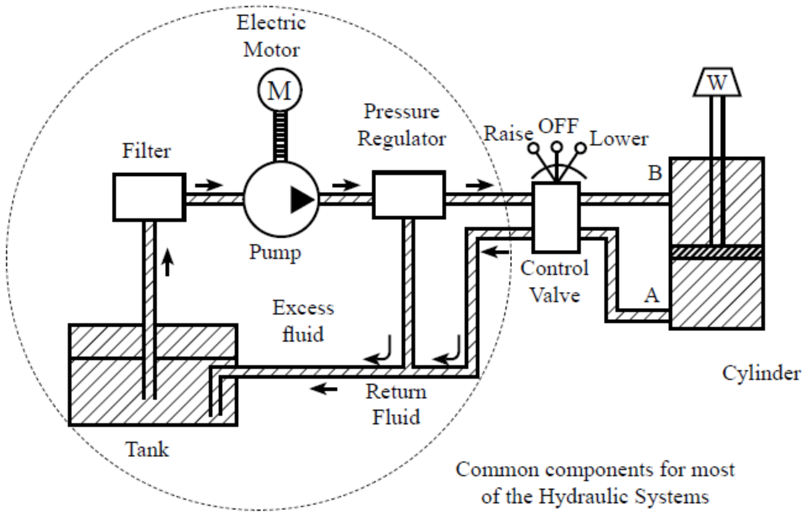
A hydraulic control system is a group of hydraulic components arranged in an order to transmit hydraulic power using oil to perform useful work.

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.



OR

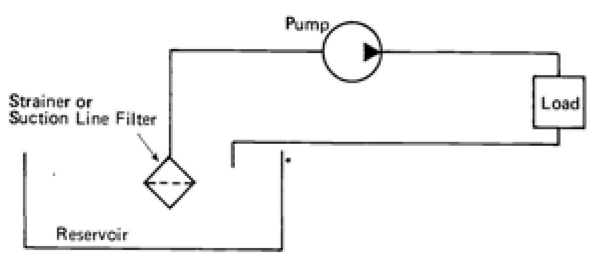
2. a. With the aid of neat sketches explain the following: (10 Marks)

i) Suction line filtering

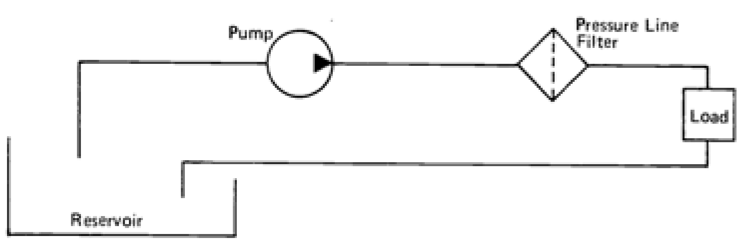
ii) Pressure line filtering

iii) Returns line filtering.

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.

b. Explain briefly the desirable properties of hydraulic fluid. (10 Marks)

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:

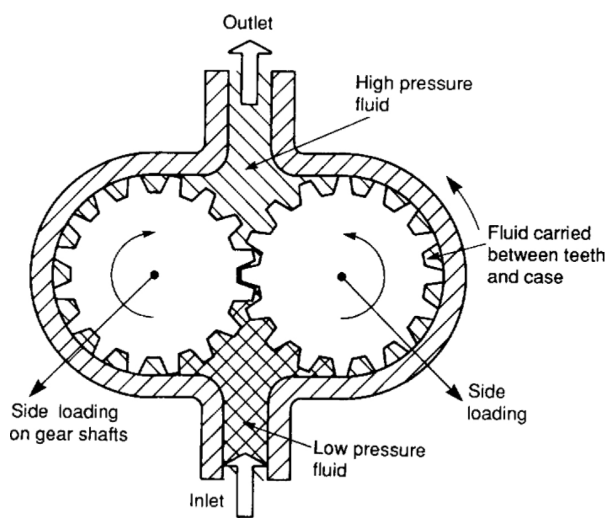
1. Viscosity is the measure of a fluid's resistance to flow and shear. A fluid of higher viscosity will flow with higher resistance compared to a fluid with a low viscosity.
2. Viscosity Index is how the viscosity of a fluid changes with a change in temperature. A high VI fluid will maintain its viscosity 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.
6. Compatibility: The fluid must be fully compatible with other materials used in the hydraulic system, such as those used for bearings, seals, paints, and so on.
7. Chemical stability is an important property of the hydraulic liquid. It is defined as the ability of the liquid to resist oxidation and deterioration for long periods.

8. Cleanliness in hydraulic systems has received considerable attention. Some hydraulic systems, such as aerospace hydraulic systems, are extremely sensitive to contamination.

Module-2

2. a. Sketch and explain the construction and working of 'External Gear Pump' giving expressions for volumetric displacement and theoretical flow rate.

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.



Volumetric displacement is given by $V_D = \frac{\pi}{4}({D_o}^2 - {D_i}^2)\, L$

Theoretical flow rate is given by $Q_T = V_D \times N$

b. A vane pump has volumetric displacement of 82cm. The diameter of rotor is 50mm and that of cam ring is 75mm. If the width of the vane rotor is 40mm. Find eccentricity, maximum eccentricity and maximum volumetric displacement possible, (10 Marks)

Given data: Vane pump,

$V_D = 82\ cm^3/rev$

$D_r = 5\ cm$

$D_c = 7.5\ cm$

$b = 4\ cm$

eccentricity is given by

$$e = \frac{2 \times V_D}{\pi (D_c + D_r) L}$$

$$= \frac{2 \times 82}{\pi (5 + 7.5) \times 4}$$

$$= 1.04\ cm$$

$$e_{max} = \frac{D_c - D_r}{2} = 1.25$$

$$V_{D_{max}} = \frac{\pi}{2} \times (5 + 7.5) \times 1.25 \times 4$$

Maximum possible volumetric displacement

$$V_{D_{max}} = 98.214\ cm^3$$

OR

3. a. Explain with a neat sketch of working of linear actuator with cushioning.

The extension and retraction speeds of hydraulic cylinders are managed by controlling the inlet or exit-oil flow rates. When reaching its end position, the piston is suddenly stopped. In the case of high speed and/or great inertia, the sudden stopping of the piston results in a severe impact force. It affects both the cylinder and the driven mechanism. Therefore, a cushioning arrangement might be 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.

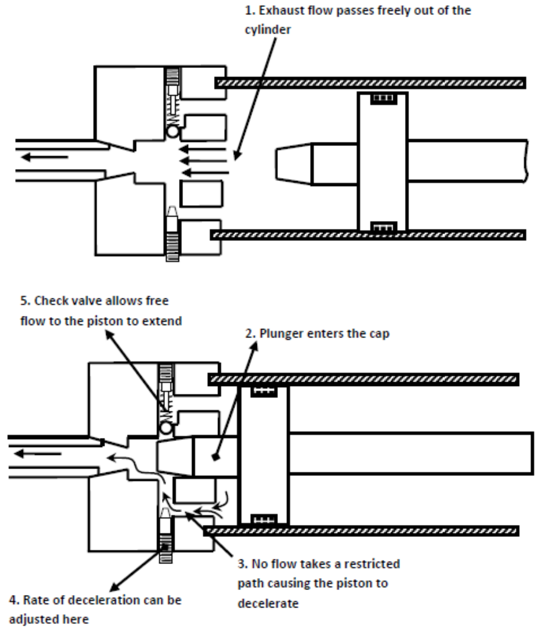


Figure working principle of Cylinder cushioning

b. An 8cm diameter hydraulic cylinder has 4cm diameter rod. If the cylinder receives flow at 100 lpm and 12 MPa. Find

i) Maximum extension and retraction forces

ii) Maximum extension 'and retraction velocities (10 Marks)

Given data

Cylinder diameter = 8cm

rod diameter = 4cm.

Q_{in} = 100LPM = 0.1 m^3/min

$p = 12 \times 10^6 \ N/m^2$

$\therefore \quad A_p = \frac{\pi}{4} \times (8 \times 10^{-2})^2 = 5.026 \times 10^{-3} \ m^2$

$A_r = \frac{\pi}{4} (4 \times 10^{-2})^2 = 2.513 \times 10^{-3} \ m^2$

Now, Extension speed.

$$V_{ext} = \frac{Q_{in}}{A_p} = \frac{0.1}{5.026 \times 10^{-3}} = 19.89 \ m/min$$

retraction speed

$$V_{ret} = \frac{Q_{in}}{(A_p - A_r)} = \frac{0.1}{2.51 \times 10^{-3}} = 39.84 \ m/min$$

Load carrying capacity

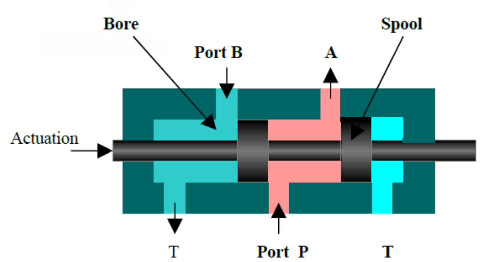
$$F_{ext} = 12 \times 10^{+6} \times 5.026 \times 10^{-3} = 60.31 \ kN$$

$$F_{ret} = 12 \times 10^{6} \times 2.51 \times 10^{-3} = 30.15 \ kN$$

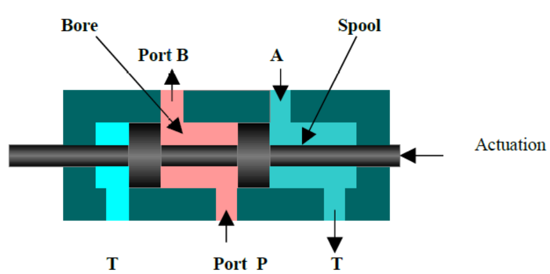
Module-3

5. a. Explain the internal construction and working of 4/2 spool valve. Draw its symbolic representation.

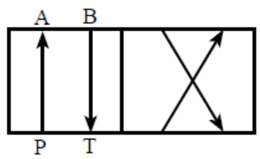
These valves are used to operate double acting cylinder. These valves are also called as impulse valve as 4/2 DCV has only two switching positions, i.e. it has no mid position. These valves are used to reciprocate or hold an actuating cylinder in one position. They are used on machines where fast reciprocation cycles are needed. Since the valve actuator moves such 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.



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



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



Graphical Symbol for 4-way valve

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.

b. With a neat sketch, explain pilot operated check valve. (10 Marks)

Pilot operated check Valve

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

OR

6. a. Explain the meter-in method of speed control of hydraulic cylinder with neat circuit diagram. (10 Marks)

The circuit of Figure 1 depicts a meter-in flow control system, in which the flow control valve is placed in the line leading to the inlet port of the cylinder. Hence a meter-in flow control system controls the oil flow rate into the cylinder. Conversely, a meter-out flow control system is one in which the flow control valve is placed in the outlet line of the hydraulic cylinder. As shown in

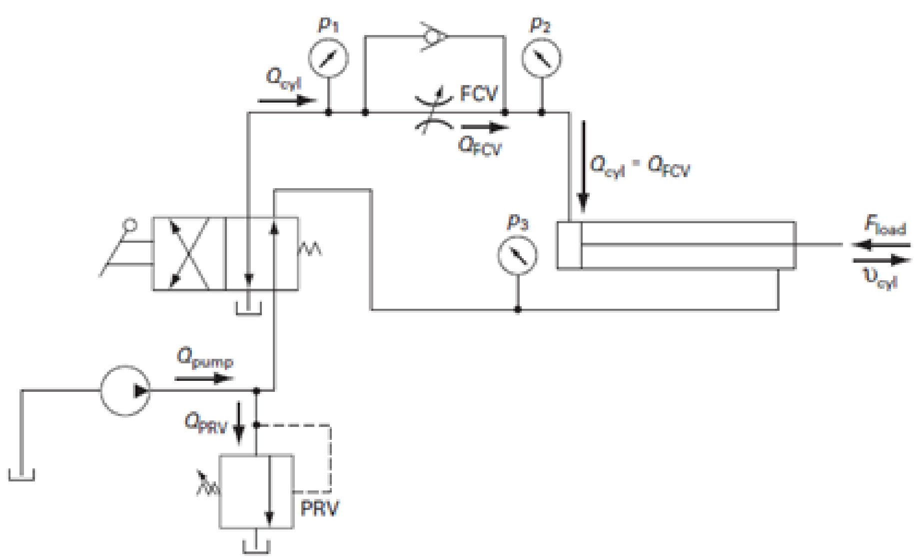


Figure 1 Meter-in speed control of hydraulic cylinder during extending stroke using flow control valve. (*DCV is in manually actuated position.*)

Meter-in systems are used primarily when the external load opposes the direction of motion of the hydraulic cylinder. An example of the opposite situation is the case of a weight pulling downward on the piston rod of a vertical cylinder. In this case the weight would suddenly drop by pulling the piston rod down if a meter in system is used even if the flow control valve is completely closed. Thus, the meter-out system is generally preferred over the meter-in type. One drawback of a meter-out system is the possibility of excessive pressure buildup in the rod end of the cylinder while it is extending. This is due to the magnitude of back pressure that the flow control valve can create depending on its nearness to being fully closed as well as the size of the external load and the piston-to-rod area ratio of the cylinder. In addition an excessive pressure buildup in the rod end of the cylinder results in a large pressure drop across the flow control valve. This produces the undesirable effect of a high heat generation rate with a resulting increase in oil temperature.

b. With neat circuit diagram explain regenerative circuit used in drilling machine application. (10 Marks)

The figure 4.4 shows an application using a four-way valve having a spring centered design with a closed tank port and a pressure port to outlet ports A and B.

The application is for a drilling machine, where the following operations take place:

1. The spring centered position gives rapid advance (extension).
2. The left envelope mode gives slow feed (extension) when the drill starts to cut into the work piece.
3. The right envelope mode retracts the piston.

From the circuit it is evident that oil from the rod end regenerates with the pump flow going to the blank end. This effectively increases pump flow to the blank end of the cylinder during the spring centered mode of operation. It should be noted that the cylinder used in a regenerative circuit is actually a regular double acting cylinder. The way it is hooked up in the circuit makes it a regenerative circuit. The blank end and the rod end are connected in parallel during the extending stroke of a regenerative cylinder. The retraction mode is the same as a regular double acting cylinder.

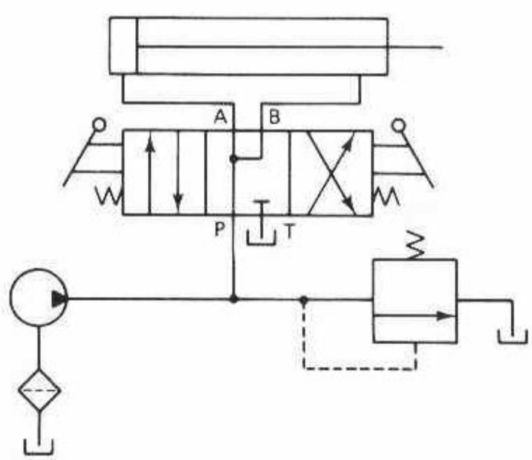


Figure 4.4 Drilling machine application

Module-4

7. a. Sketch and explain the structure of pneumatic control system. (10 Marks)

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

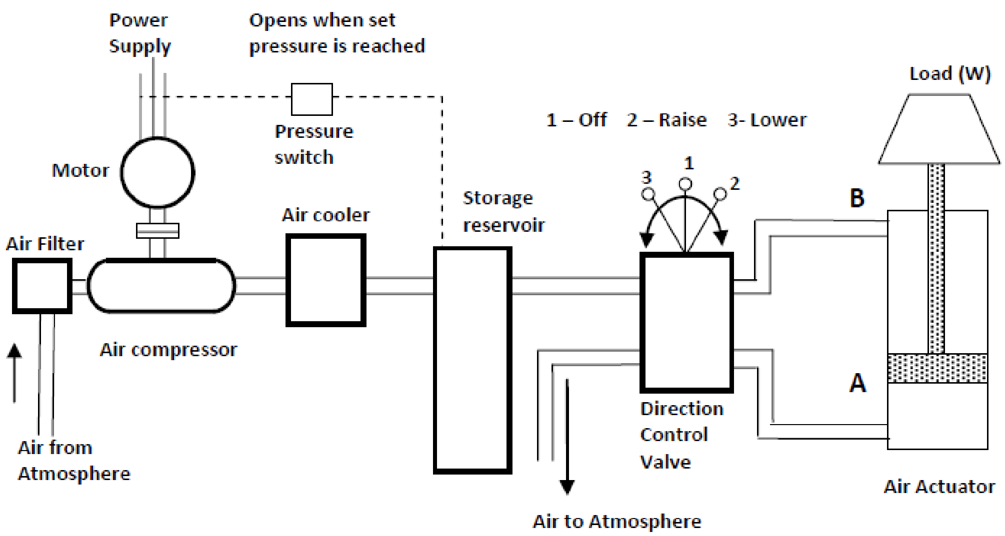


Fig. Components of a pneumatic system

Functions of components

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.
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.

b. List the advantages and limitations of pneumatic power systems. (10 Marks)
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.

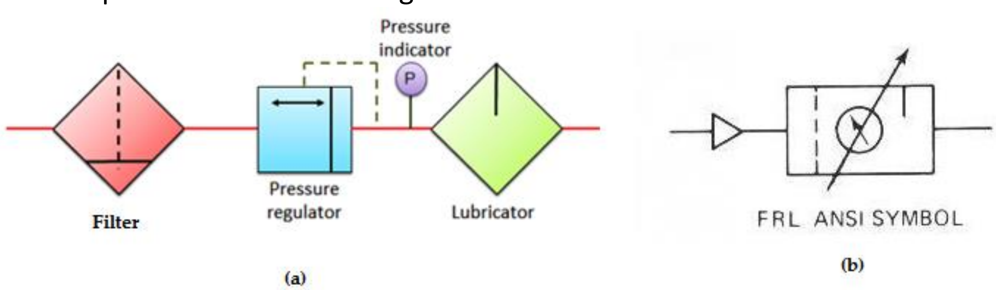
8. **Economical**

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.

OR

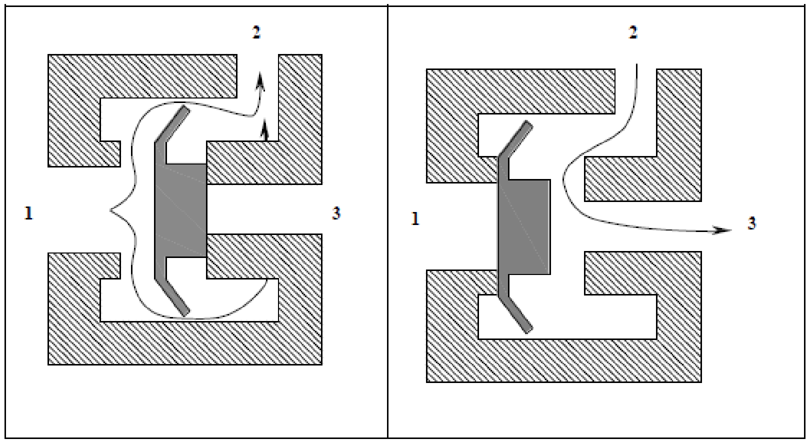
8 . a. What is FRL unit in pneumatic system? Explain its function with symbolic representation. (10 Marks)

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.



b. Explain with a pneumatic circuit how quick exhaust valve can be used to increase the actuation sped of a cylinder. (10 Marks)

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 (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.



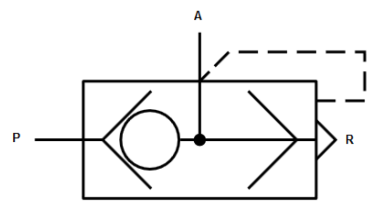


Figure Working of quick exhaust valve and graphical symbol

The construction and operation of a quick exhaust valve is shown in Figure. 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.

Module-5

9 . a. Explain direct control of double acting cylinder using 5 ports/2 position DC valve. (10 Marks)

Direct control of Double Acting Cylinder

As per the construction of double acting cylinder (figure 5.3), there is no return spring in it. Hence, the spring forces are not available to it for retraction of the piston rod as it is in the case of a single acting spring return cylinder.

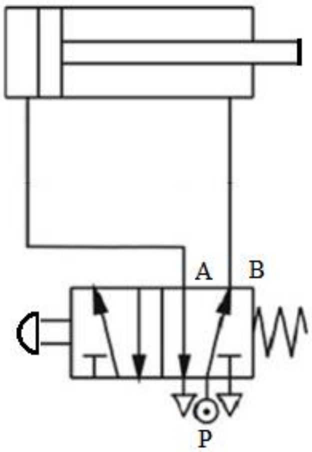


Figure 5.3 Direct control of a double acting cylinder

Here both the forward and return motions of the cylinder are controlled by air pressure and hence a 3/2 DCV is used. Usually, when a double acting cylinder is not operated, outlet ‘B’ and inlet ‘P’ will be connected. In this circuit, whenever the push button is pressed manually, the double acting cylinder will extend and retracts when the push button is released.

b. Explain 'supply air throttling' and 'exhaust air throttling' used in speed control of cylinders.
(10 Marks)

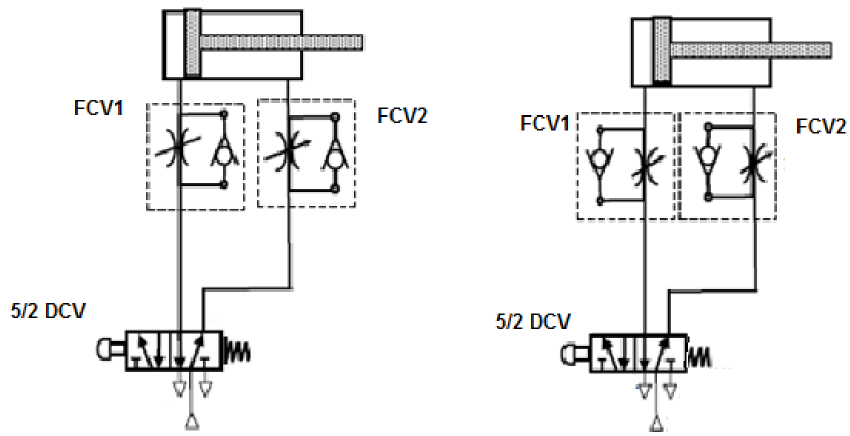
It is always necessary to reduce the speed of cylinder from maximum speed based on selected size of final control valve to the nominal speed depending on the application. Speed control of Pneumatic Cylinders can be conveniently achieved by regulating the flow rate supply or exhaust air. The volume flow 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

1. Supply air throttling

This method of speed control of double acting cylinders is also called meter–in circuit. 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.



a) Supply Air throttling b) Exhaust air throttling

2. Exhaust air throttling

In exhaust air throttling flow control valves are installed between the cylinder and the main valve in such a way that the exhaust air leaving the cylinder is throttled in both directions of the motion of the cylinder (figure 5.5 b). This method of speed control of double acting cylinders is also called meter-out circuit. The supply air can pass freely through the corresponding check valves in each case. In this case, the piston is loaded between two cushions of air while the cylinder is in motion and hence a smooth motion of the cylinder can be obtained. The first cushion effect is due to supply air entering the cylinder through check valve, and second cushion effect is due to the exhaust air leaving the cylinder through the throttle valve at a slower rate. Therefore, exhaust air throttling is practically used for the speed control of double acting cylinders.

OR

10 a. Explain a typical pneumatic circuit based on 'AND' logic function using two pressure valve. (10 Marks)

Two pressure valve

This valve is also called as pneumatic AND valve. A two pressure valve requires two pressurized inputs to allow an output from itself. The cross sectional views of two pressure valve in two positions are given in Figure 4.41. As shown in the figure, this valve has two inputs X and Y and one output A. If the compressed air is applied to either X or input Y, the spool moves to block the flow, and no signal appears at output A. If signals are applied to both the inputs X and Y, the compressed air flows through the valve, and the signal appears at output A.

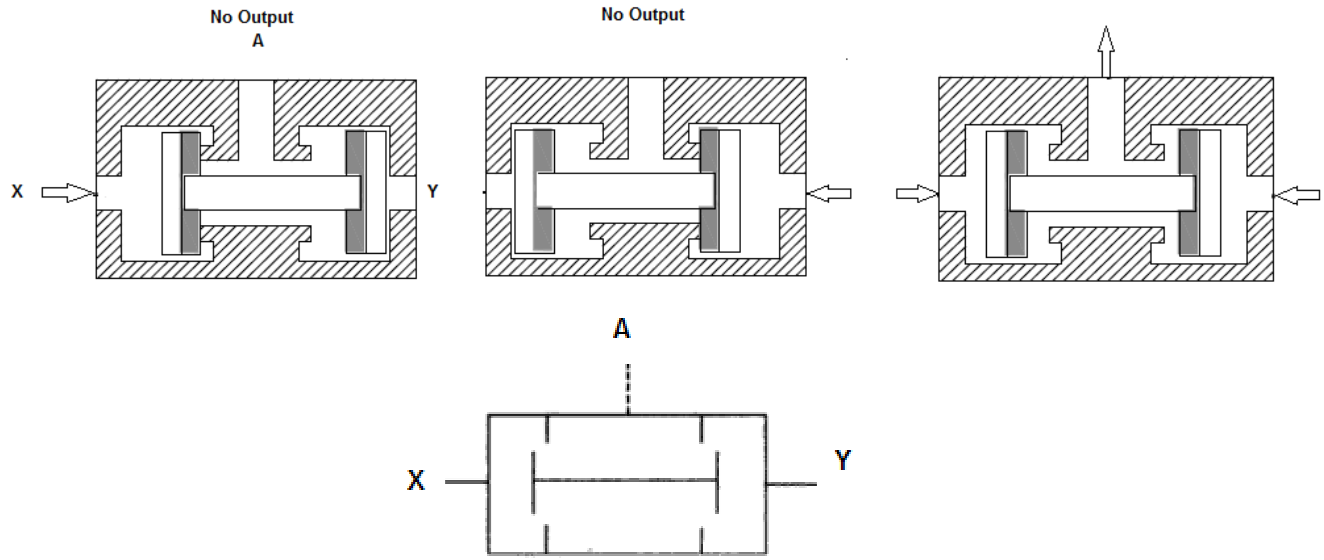


Figure working of two pressure valve and graphical symbol

c. **Explain the working of a solenoid controlled pilot operated DCV. (10 Marks)**

Pilot operated DCV

Directional control valves can also be shifted by applying air pressure against a piston at either end of the valve spool. Springs (located at both ends of the spool) push against centering washers to center the spool when no air is applied. When air is introduced through the left end passage, its pressure pushes against the piston to shift the spool to the right. Removal of this left end air supply and introduction of air through the right end passage causes the spool to shift to the left. Therefore, this is a four-way, three-position, spring centered, air pilot-actuated directional control valve.

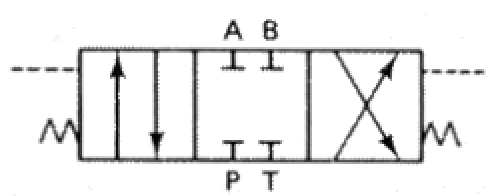


Figure Graphical symbol for Pilot operated DCV

Solenoid actuated valves

A very common way to actuate a spool valve is by using a solenoid, as illustrated in figure 3.9. As shown, when the electric coil (solenoid) is energized, it creates a magnetic force that pulls the armature into the coil. This causes the armature push on the push pin to move the spool of the valve. The solenoid valve has a flow capacity of 45 lpm and a maximum operating pressure of 250 bar.

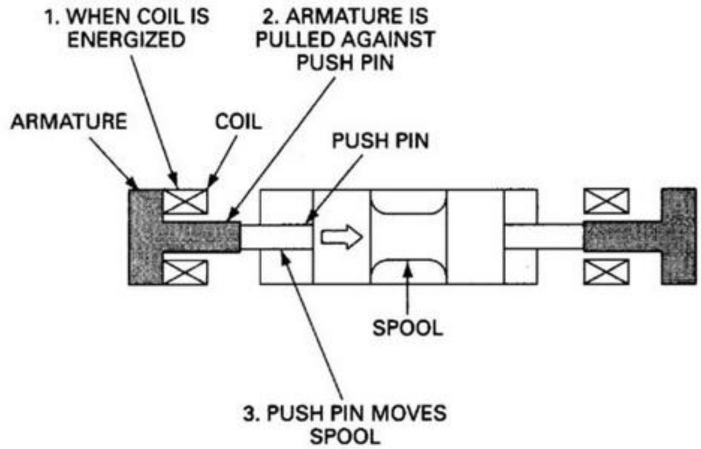


Figure : Operation of a solenoid actuated DCV

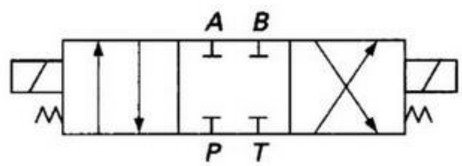


Figure : Solenoid actuated, three-position, spring-centered, four-way DCV

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