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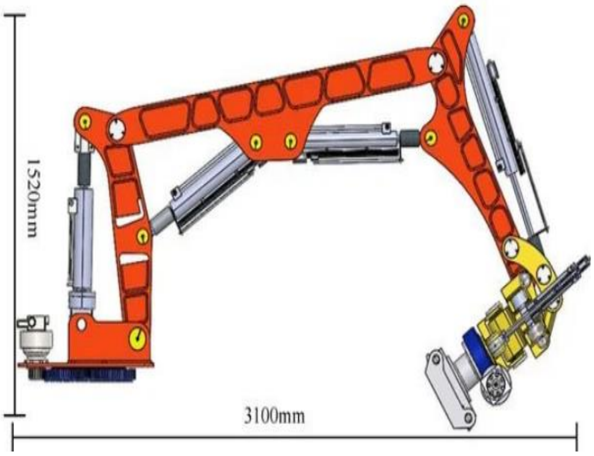

DRIVE SYSTEMS FOR ROBOTICS (22RI34)

UNIT 2: NOTES

HYDRAULIC DRIVES

III SEMESTER, B.E.

DEPARTMENT OF ROBOTICS AND ARTIFICIAL INTELLIGENCE

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Introduction to Fluid power system:

Fluid power systems use fluids - typically hydraulic oils or compressed air - to transmit power and control movements. These systems are commonly used in various applications, including industrial machinery, construction equipment, and automotive systems. They can be broadly categorized into two main types: hydraulic systems and pneumatic systems.

The basic source of power in industries comes from three kinds of sources (prime movers): Electrical, Mechanical and Fluid power. The use of electrical prime movers such as *electric motors* and mechanical prime movers such as *internal combustion engines* is very common. Also the means of power transmission in these systems is well established. For example, the electrical power is transmitted through suitable power cables; while the mechanical power is transmitted using gears, shafts, belts, etc. The third common source of power that is widely used in modern industries is the ***fluid power***. High pressure fluids, both liquids and gases, can be used to transmit power from the point of source to the point of utilization, which in turn can be used to produce rotary or linear motions. Another special application of fluid power is to apply a force on to an object (like in a hydraulic press) and release the force. Though it is possible to apply force through some mechanical means, fluid power is the most convenient way. Fluid power systems that use liquids (like oils) as the working medium are termed *Hydraulic systems* (*hydra* meaning *fluid* in Greek). Fluid power systems that use gases (mostly air or nitrogen in some cases) are termed ***Pneumatic systems*** (*pneuma* meaning *air* in Greek).

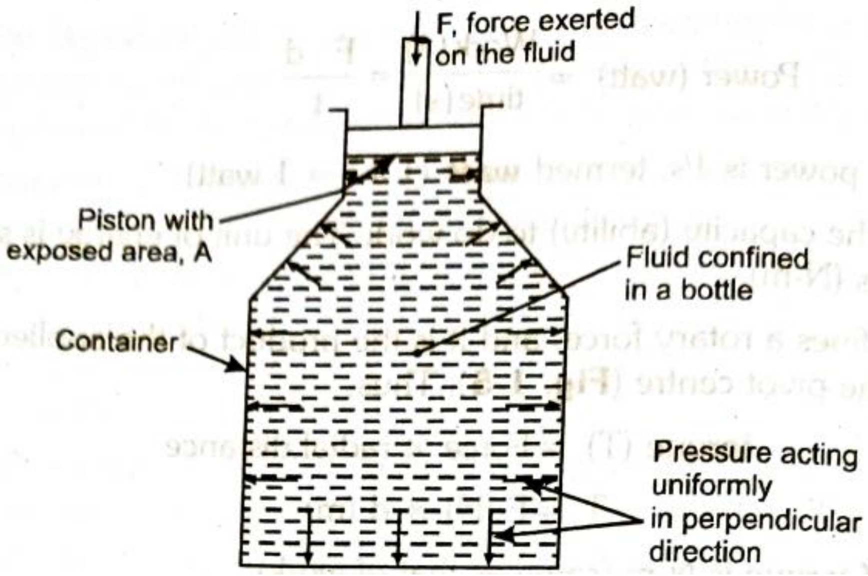
Fluid power refers to the branch of engineering that deals with the use of high pressure fluids (gases, liquids) within confined areas (like hoses, cylinders) to generate, control and transmit power. That means, it can act as a prime mover (power source), control industrial machine motions, and transmit power from one point to another for useful purpose.

Pascal's Law:

The basic principle underlying all the fluid power applications is the *Pascal's law*. This law deals with the *hydrostatics*, the subject related to the transmission of power through a *confined fluid* under pressure. In fact, it is the fundamental principle based on which all the fluid power systems work. The Pascal's law states as follows:

> *The pressure exerted on to a confined fluid is transmitted and acts equally in all directions at the same time, and acts uniformly at right angles to the containing surfaces.*

The Principle of operation is explained here:



In this, the fluid is held confined within a container. The force is applied to a piston with exposed surface area, *A*, which in turn exerts pressure on to the confined fluid. The pressure exerted is uniform throughout the fluid and acts perpendicular to the surfaces.

We can quantify the Pascal's law by relating the force applied on the piston and the pressure exerted on the confined fluid. Mathematically, we have pressure as the force per unit area. Thus, pressure on the fluid is:

$$P = \frac{F}{A}$$

where, F = Force applied on the piston, N

A = Exposed area of the piston, m^2

P = Pressure on the fluid, Pa.

In practical applications, the diameter (D) of the piston is specified. We can calculate the area (A) using the relation:

$$A = \frac{\pi D^2}{4}$$

Related Numerical:

1.In a high pressure hydraulic cylinder, a force of 5000N is applied on to the piston. The diameter of the piston is 150mm.What is the pressure on the fluid in the cylinder?

Solution :

$D = 150 \text{ mm} = 0.15 \text{ m}$

$F = 5000 \text{ N}$

$P = ?$

Area of the piston, $A = \frac{\pi D^2}{4} = \frac{\pi \times 0.15^2}{4}$

$= 0.1767 \text{ m}^2.$

Pressure exerted on the fluid,

$$P = \frac{F}{A} = \frac{5000}{0.1767} = 28296 \text{ N/m}^2$$

$$= 28296 \text{ Pascals (Pa)}$$

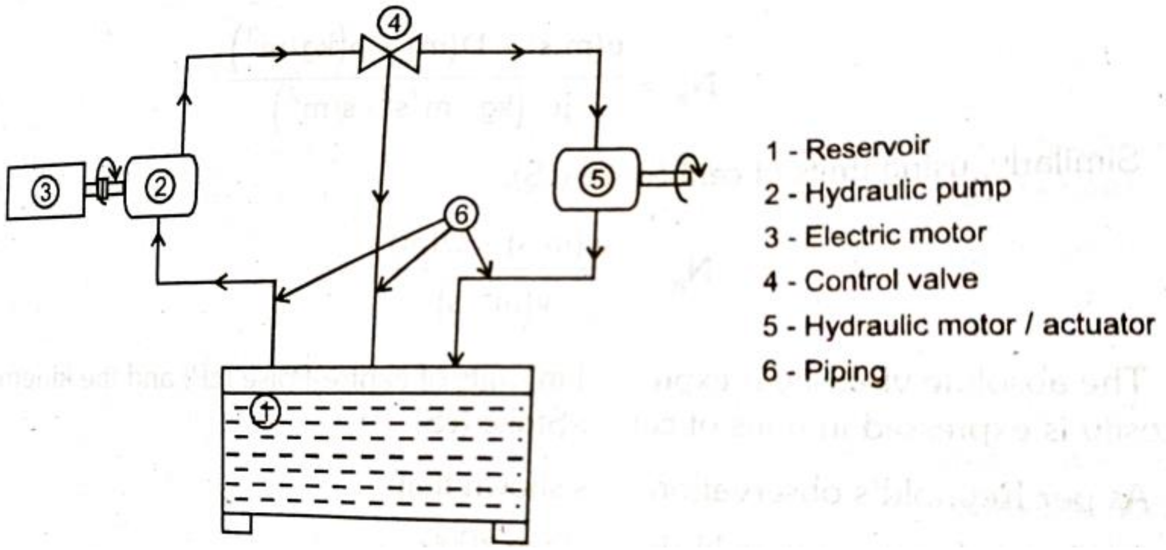
$$\text{or } P = 28.296 \text{ kPa}$$

$$= 2.83 \text{ bar}$$

$$\mathbf{= 0.283 \text{ MPa}}$$

Note: Kindly refer similar problems solved in class.

Hydraulic Structure or Requirements:



1) **Fluid tank or reservoir**: Its function is to keep sufficient quantity of hydraulic fluid, the working medium of the hydraulic system.

2) **Pump**: It is the heart of the system and the main source of power that drives the fluid through the system.

3) **Electric motor**: It is the prime mover that supplies input power to the pump to drive the fluid.

4) **Fluid control valves**: These are the devices that control the fluid flow rate, direction and the pressure for the proper functioning of the fluid power system.

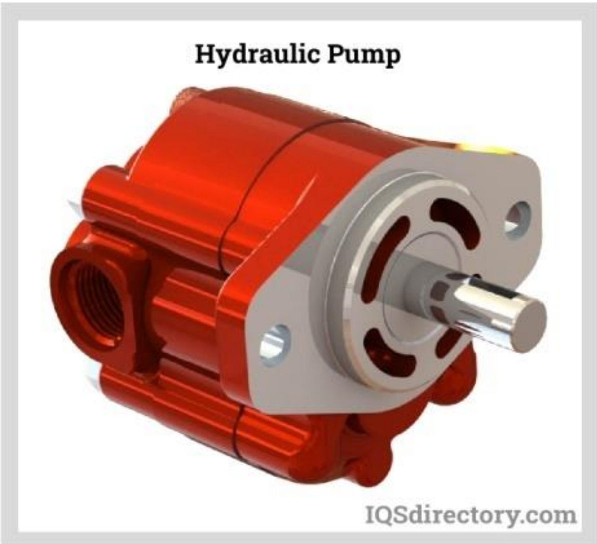
5) **Actuator**: The function of the actuator is to convert the fluid power (fluid flowing under pressure) back into useful mechanical power, which in turn is used to move the load, or perform some mechanical operation.

6) **Piping**: The pipeline carries the fluid from one component to the other, and is designed to withstand the high working pressure of the system.

The hydraulic line running from the sump (reservoir) through the pump till the output point is called the ***pressure line***, obviously for the reason that high pressure fluid is carried in that line. The fluid line running from the output point (after doing the work) back to the sump/reservoir is termed the ***return line***, which carries the low pressure fluid back to the sump.

Other components of a fluid power system include the filters and the seals. The oil from the sump (reservoir) is passed through a filter to remove any foreign particle so as to keep the fluid system clean and efficient, avoid damage to the actuator, valves, etc. Seals (gaskets) are used at all the junctions/hydraulic joints/valves, whose purpose is to minimise oil leakage.

Hydraulic Pumps:



2.1 INTRODUCTION

Pump is the most important part of a fluid power system. It pumps the required energy into the system, hence it is the ***heart*** of any fluid power system. Pump driven by a prime mover (like an electric motor) converts the mechanical input power into fluid power by way of increasing its pressure through continuous pumping action. This pressurised fluid, i.e., the *fluid power*, is then passed through suitable fluid lines, control valves and to the output units such as the actuators to do the useful mechanical work.

There are two major classes of hydraulic pumps: *Positive displacement* type and *non-positive displacement* type.

Positive Displacement Pumps:

Positive displacement pumps are used in *hydrostatic* systems, in which power transmission takes place through fluid pressure. Most industrial applications are based on hydrostatic systems, hence positive displacement pumps are widely used. These pumps input a fixed amount of fluid into the hydraulic systems per revolution of the pump shaft (called *one cycle*) hence the name *positive displacement pump*.

Basically, these pumps create a vacuum at the fluid inlet, leading to the opening of a cavity under atmospheric pressure, a push fluid into the pump. Then they close the cavity, and force out the fluid into the fluid systems. These two steps take half a revolution each and thus complete in one revolution of the pump shaft, which is termed a cycle. In fact, these pumps do not pump fluids under pressure, but they only produce fluid flow.

Advantages of positive displacement pumps

These pumps offer a number of advantages:

1) They are compact in size.
2) They develop high pressures (1000 bars).
3) Less leakage problems in pumps due to close-fitting mating parts.
4) They work over a wide range of pressures.
5) They give high volumetric efficiency.

There are three major types of positive displacement pumps: gear, vane and piston type. The details of construction and operation of these pumps are discussed in the subsequent sections.

Non-Positive Displacement Pumps:

Non-positive displacement pumps are used in *hydrodynamic* systems in which power transmission takes place due to fluid motion. They pump fluid by spinning the fluid with an impeller running within a casing. The fluid is thrown outward radially in the impeller by centrifugal force. Since the impeller and the casing have larger gaps (non-mating), the pressure developed is small. Hence, these pumps are suitable only for low pressure, high volume applications. In fact, because of their low pressures (10-20 bar), these pumps are of no use in the fluid power applications. They are widely used for the transmission of fluid from one point to the other. These pumps are economical to manufacture, operate and maintain as compared to the positive displacement pumps.

How Pressure is built by pumping?

The hydraulic pump produces the amount of flow needed for the production of pressure, which is a function of resistance to fluid flow in the system. For example, the pressure of the fluid at the pump outlet is zero for a pump that is not connected to a system. As the hydraulic fluid enters into the bore of the cylinder it forces the cylinder piston to move upwards. Any resistance to the upward movement of the piston e.g. a load, will result in the fluid pressure increasing as the operator continues to actuate the pump lever up and down.

Operation of Pumping:

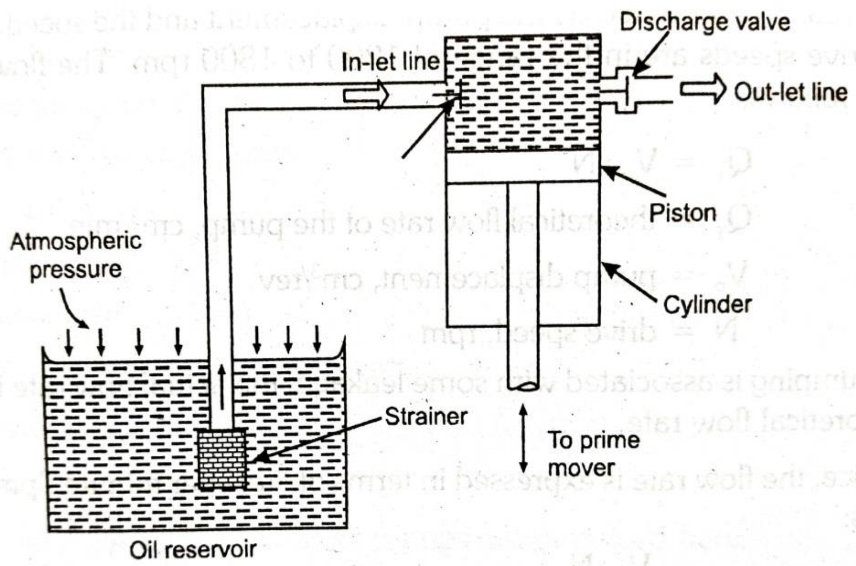


Fig. 2-1 : Operation of a pump

The basic principle of operation of all pumps is to create partial vacuum inside the pumps, due to which the oil is sucked in and then pushed out due to the discharge line. All pumps will have one inlet through which oil enters the pump and one outlet through which oil is ejected into the fluid line. The principle of operations is described below.

The pump comprises a piston-cylinder arrangement with a sliding fit. The space above the piston in the cylinder is the cavity through which the pumping action is performed. The cylinder cavity has inlet and outlet points connected with fluid lines. Also, there are two ball check valves at the inlet and outlet points as shown in figure. The function of check valves is to allow one-way motion of the fluid, and not to allow the reverse flow.

In operation, when the piston (connected to the prime mover through suitable linkages) is retracted, it creates a partial vacuum in the pump cavity. This suction pressure keeps the outlet (discharge) valve closed, while opening up the inlet valve. Due to the vacuum pressure, the atmospheric pressure acting on the reservoir pushes the fluid into the pump cavity through the inlet line/valve. This action continues till the piston reaches the bottom most point, and thus completing the half cycle operation.

In the next action, as the piston raises up, the fluid keeps the inlet valve closed thus not allowing the fluid flow back into the inlet line. At the same time, the fluid pushes the outlet valve to open-up and ejects the oil into the discharge line. This action continues till the piston reaches the upper most point, performing the other half cycle operation. Thus, the fluid suction and ejecting it into the discharge line are performed in one cycle of the pump. This is normally performed in one revolution of the pump shaft/prime mover. The volume of the fluid discharged in one cycle is termed the ***displacement*** (equivalent of term *swept volume* in I. C. Engines).

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Displacement is usually expressed as the volume of fluid discharged per revolution and the common SI unit is cm^3/rev.

Displacement, Flow rate & volumetric efficiency of Gear Pumps

The theoretical volumetric displacement is given by:

$$V_p = \frac{\pi}{4}(D_0^2 - D_i^2)\, w$$

where,
V_p = pump displacement, cm^3/rev
D_0 = outside diameter of gear teeth, cm
D_i = inside diameter of gear teeth
w = width of gear teeth, cm
N = pump revolution, rpm

The theoretical flow rate Q_T in lpm is given by:

$$Q_T = \frac{V_p \cdot N}{1000} \text{ litres per min (lpm)}$$

Example 2-1 : *A pump running at 1500 rpm has a displacement of 60 cm³/rev. What is its theoretical flow rate?*

Solution :

$N = 1500$ rpm

$V_p = 60\ cm^3/rev$

$Q_T = ?$

$$Q_T = \frac{V_p \cdot N}{1000} \text{ lpm}$$
$$= \frac{60 \times 1500}{1000}$$
$$= \mathbf{90\ lpm}$$

Working of External Gear Pumps:

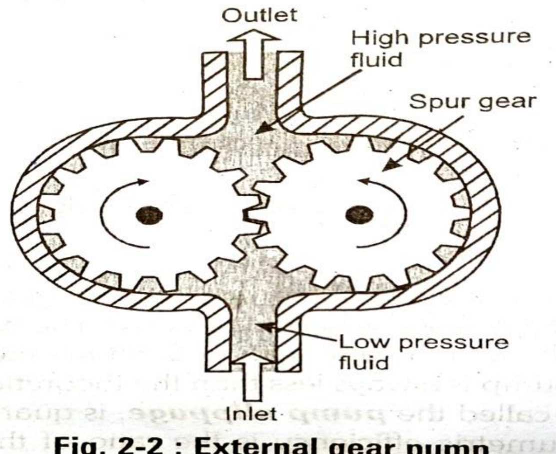


Fig. 2-2 : External gear pump

Only one of the two gears is driven by the prime mover. The driver gear is directly keyed to the prime mover/drive shaft. The other gear (i.e., the idler) is driven by the drive gear. The gears and casing are arranged such that the gear teeth are in contact, or mesh, and have a sliding gap with the casing as shown in figure. As the gears mesh at the centre, they form a seal between the inlet and outlet parts.

In operation, the gears rotate such that they come out of mesh at the inlet port causing volume expansion. This creates a partial vacuum (reduction in atmospheric pressure) at the inlet area, and the fluid is pushed in by atmospheric pressure acting on the oil in the sump. The oil sump is always vented to the atmosphere. The fluid is then carried between the gear teeth (acting as the oil chambers) along the casing. Thus, as the gears rotate, the oil between the teeth is moved from the inlet chamber towards the outlet chamber, and the teeth go into meshing. Here the volume decreases between the mating teeth, and the fluid is forced out from the outlet chamber.

The advantages of this pump include simple construction, only two moving parts (two mating gears), no reciprocating parts, running at constant speed and experience uniform force. However, they have very low efficiency due to leakage between teeth.

Displacement, Flow rate & volumetric efficiency of Gear Pumps

The theoretical volumetric displacement is given by:

$$V_p = \frac{\pi}{4}(D_0^2 - D_i^2)\, w$$

where, V_p = pump displacement, cm³/rev

D_0 = outside diameter of gear teeth, cm

D_i = inside diameter of gear teeth

w = width of gear teeth, cm

N = pump revolution, rpm

The theoretical flow rate Q_T in lpm is given by:

$$Q_T = \frac{V_p \cdot N}{1000} \text{ litres per min (lpm)}$$

Volumetric efficiency:

$$\eta_v = \frac{Q_A}{Q_T} \times 100$$

where, η_v = Volumetric efficiency

Q_A = Actual flow rate, lpm

Q_T = Theoretical flow rate, lpm

$$Q_T = V_P \cdot N$$

where;

Q_T = theoretical flow rate of the pump, cm^3/min

V_P = pump displacement, cm^3/rev

N = drive speed, rpm

Since, pumping is associated with some leakage, the actual flow rate is always les than the theoretical flow rate.

In practice, the flow rate is expressed in terms of liters per minute (lpm), hence th expression is:

$$Q_T = \frac{V_P \cdot N}{1000} \text{ lpm.}$$

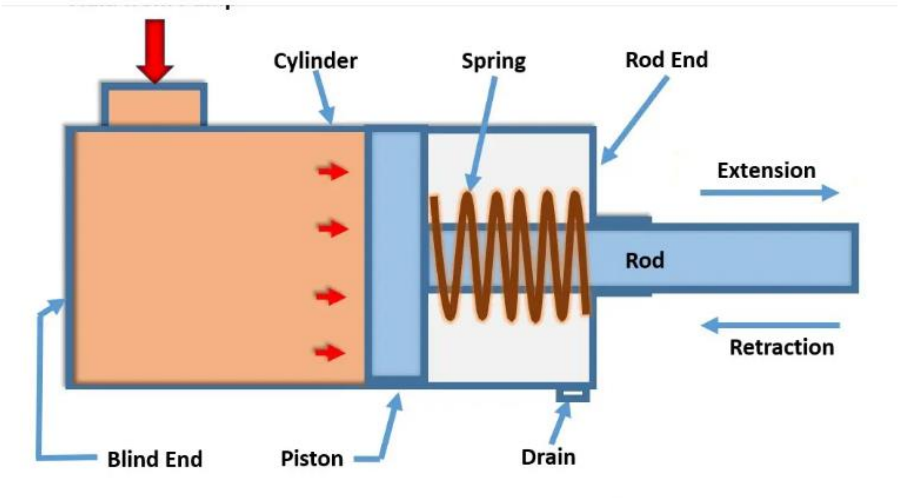
Hydraulic linear actuators:

Hydraulic actuators are devices that convert hydraulic energy into mechanical motion. They use pressurized fluid to create movement, making them vital in various applications such as industrial machinery, aerospace, and automotive systems. Here are the main types of hydraulic actuators:

Types of Hydraulic Cylinders:

- **Single-Acting Cylinders**: These have one port for fluid entry, allowing movement in one direction. Return is achieved through a spring or load.
- **Double-Acting Cylinders**: These have two ports, enabling movement in both directions by applying pressure to either side of the piston.

Single acting cylinders:



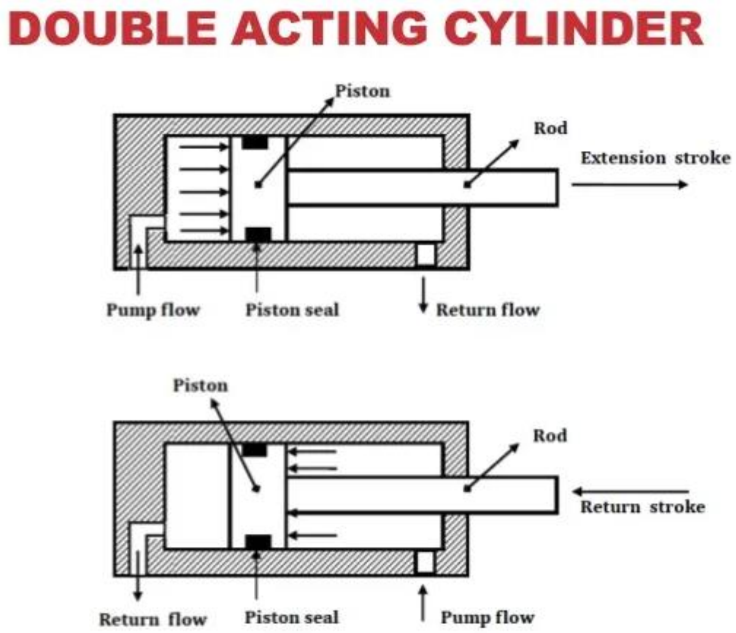
Single acting hydraulic cylinder

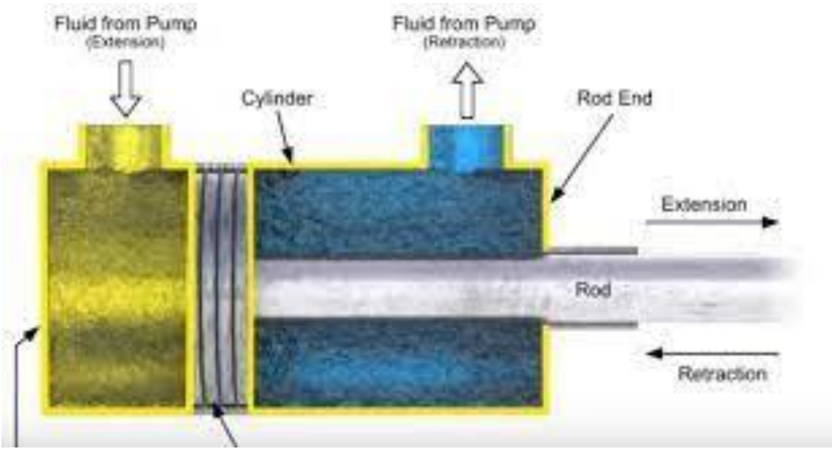
Single-acting cylinders are hydraulic or pneumatic devices that use fluid pressure to perform work in one direction only. In these cylinders, fluid pressure is applied to one side of the piston, causing it to move and perform work, such as lifting or pushing.

When the pressure is released, the piston returns to its original position either through a spring mechanism or by the weight of the load. This design is simpler and generally more cost-effective than double-acting cylinders, which can apply force in both directions.

In operation, the fluid is let in through the inlet port at the cylinder end. As the pressure is built-up in the cylinder, a force is exerted on the piston, which in turn cause the linear motion of the piston-rod (ram) in the rod end. This is termed the *extension*. In single acting cylinders, the *retraction* is not by hydraulic means, but with the help of compression spring, or under the influence of gravity with the external load acting on it.

Double acting Cylinder:

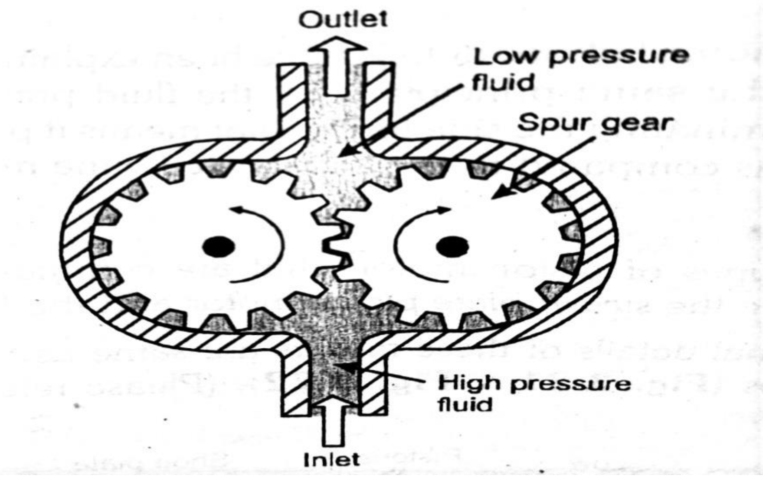




Double acting cylinders produce linear motion, in two directions. The hydraulic power is applied to either side of the piston. The piston is provided piston seal and the rod is provided with road seals, bearing rod wiper. Oil ports are provided on either sides of the piston, so that fluid pressure is alternately applied on both sides of the cylinder.

It has a cylinder (barrel), piston, and piston rod. Both the ends are sealed with end caps, which are either threaded or welded to the main cylinder. In some designs, the end caps are held with the cylinder by tie rods. The piston is provided with piston seal, while the rod is provided with seal, bearing and rod wiper, whose functions are same as those explained under single acting cylinder. Oil ports are provided on either side of the piston, so that the fluid pressure can be applied alternatively on both sides.

Hydraulic Motors-Rotary actuators-Gear Motors:



It has a cylinder (barrel), piston, and piston rod. Both the ends are sealed with end caps, which are either threaded or welded to the main cylinder. In some designs, the end caps are held with the cylinder by tie rods. The piston is provided with piston seal, while the rod is provided with seal, bearing and rod wiper, whose functions are same as those explained under single acting cylinder. Oil ports are provided on either side of the piston, so that the fluid pressure can be applied alternatively on both sides.

Direction Control valves(DCV) of Hydraulic systems:

- The Direction Control Valve (DCV) control the flow directions of fluids in hydraulics/pneumatic systems.
- Both hydraulics and pneumatics systems use DCV to only direct the flow.
- They are not flow rate control valves.
- They are simply on/off types of valves, which only start/stop the fluid supply when actuated.
- The DCV is used for sequential control of systems.
- These valves can be operated to control the flow direction using mechanical, electrical and fluid pressure signals.

Finite/Infinite Position valves & ports in valves:

- Most of control valves are used to allow or block the fluid flow or simply perform ON/OFF type of the operations.
- Such regulating type of valves performing ON/OFF type of operations is termed as the **Finite position valves**.
- **Examples**: Direction Control Valves (DCV's)
- The valves, take up any positions between open and close, they are used for modulating the flow or pressure, these are said be **Infinite position valves.**
- **Examples :** Pressure/Flow Relief valves (PRV'S).

Direction Control Valves :

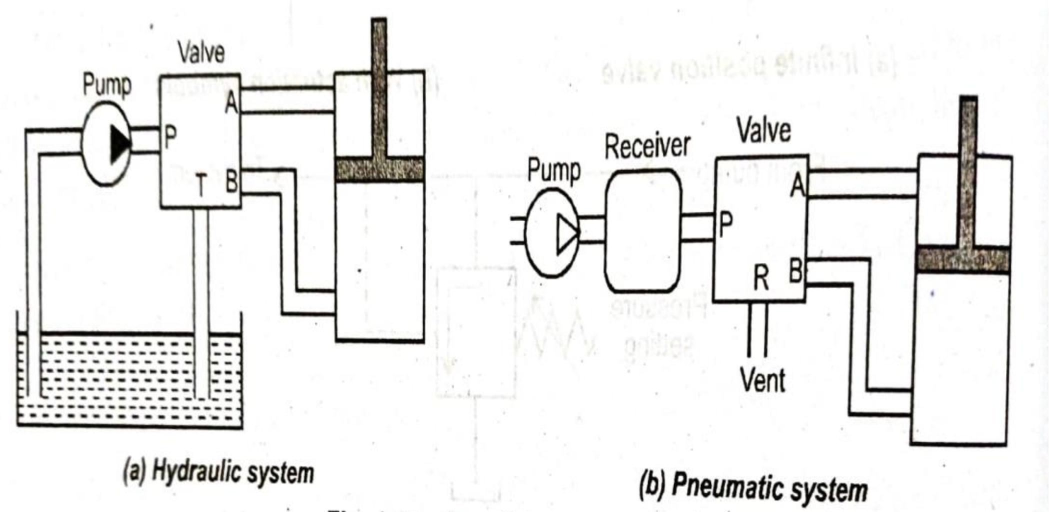


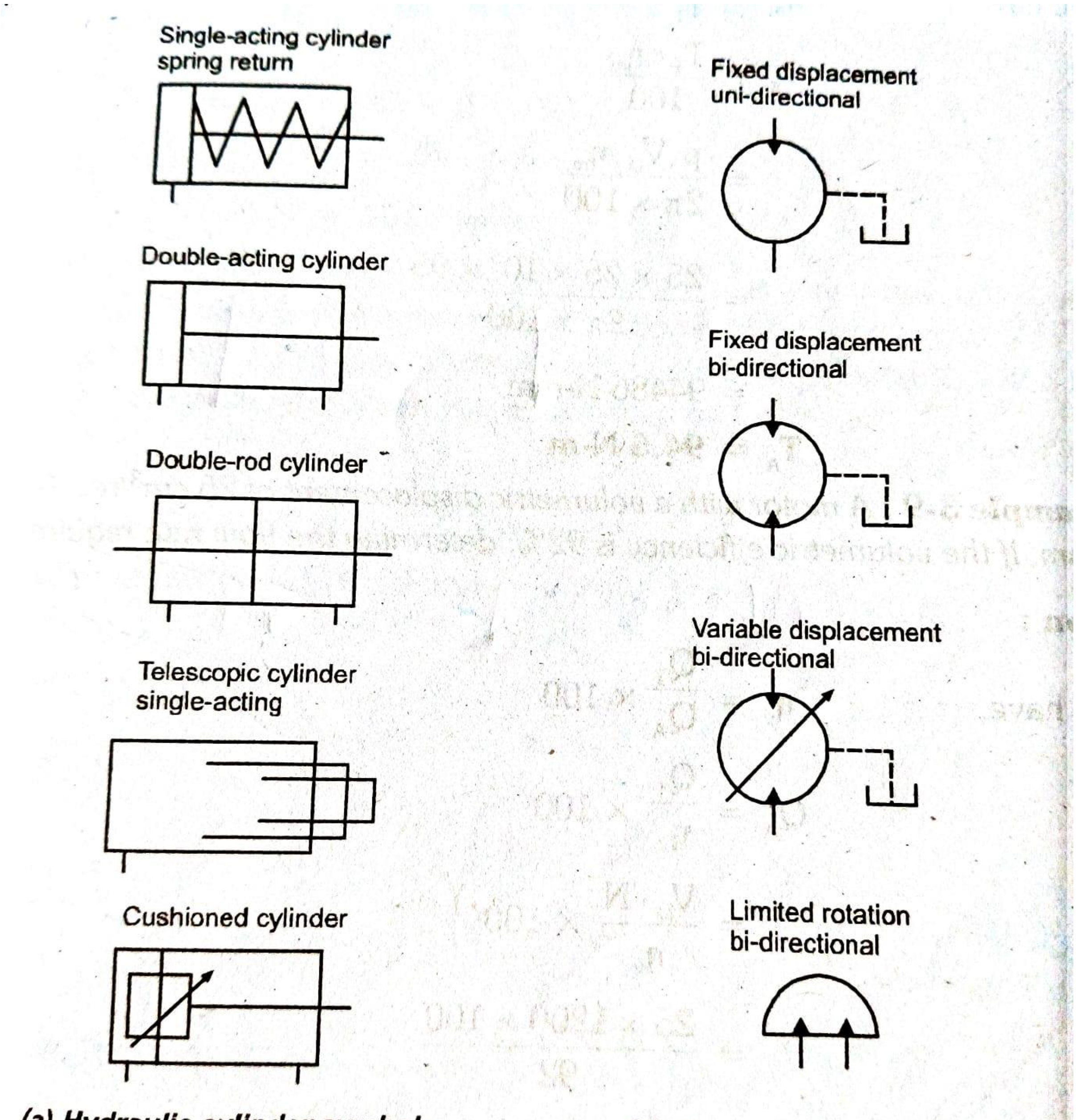
Fig. 4-10. Use of 4 port valve

In these systems, the loading device is connected to ports A and B, and the pressure supply from the oil pump or air compressor is connected to port P. In the hydraulic system, the return fluid is directed to the sump (oil tank) through port T. In a pneumatic system the return air is directed to open atmosphere through the port R.

Valve ways & Valve Positions

Valves can be designed to have a number of ports and control inlet and outlet operations, termed *valve operations*. The valve operation thus depends on the control position of the valve. Let us understand *valve operations* and *positions*, with the help of suitable examples.

Hydraulic drive systems Symbolic representations:



(a) Hydraulic cylinder symbols *(b) Hydraulic motor symbols*

3-Way Valve:

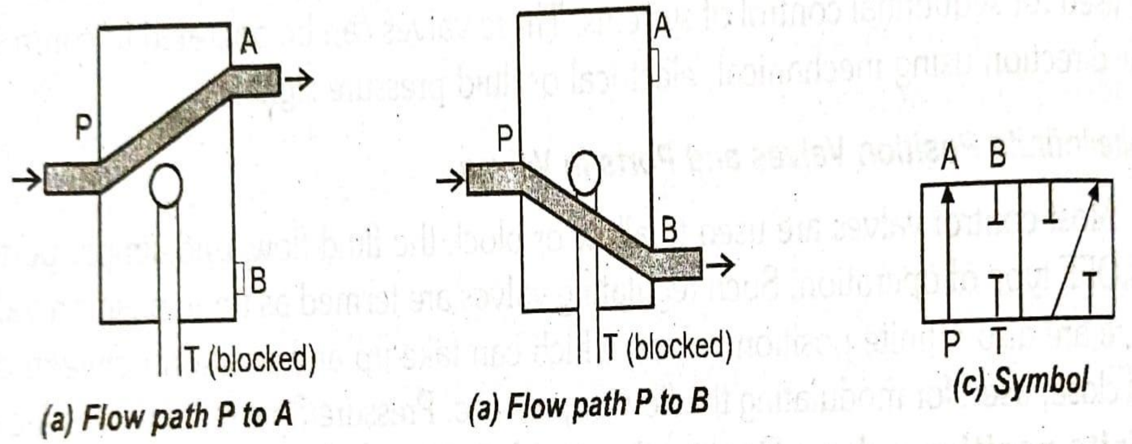


Fig. 4-11. A 3-way valve

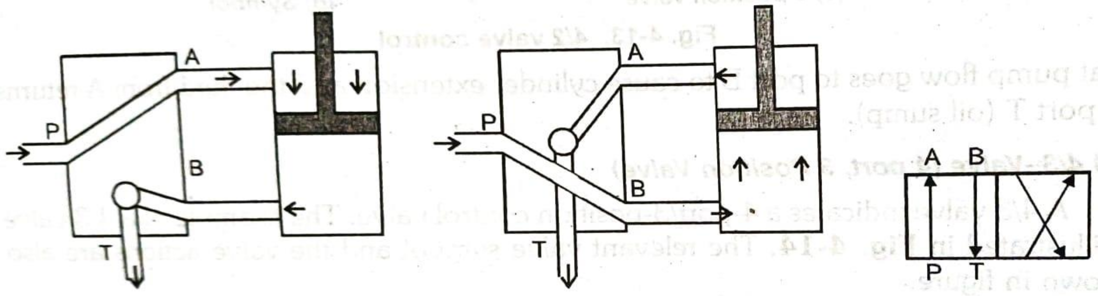
A three-port valve is termed a **three-way valve** and a four-part valve is termed a **four-way valve**. A 4-port valve can also function as a 3-way valve by blocking one of its ports. The example of a 4-port valve used as a 3-way valve is illustrated in **Fig. 4-11**.

In this, the fluid can flow in two directions from P to A and P to B. The port T(Line leading to oil tank) is blocked. Thos, only three ports are operational making the valve a 3-way valve.

4-way Valve:

(b) 4-way Valve

In a 4-way valve, all the four ports are operational. The operation of a four-way valve is illustrated in **Fig. 4-12**. In this, all the four ports are utilised for the flow of fluid, thus making it a four-way valve.



(a) Retract *(b) Extend* *(c) Symbol*

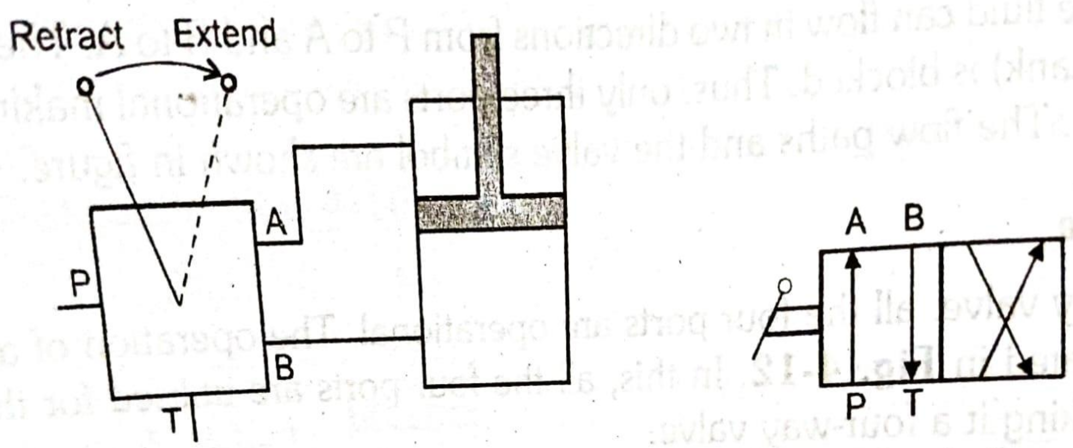
Fig. 4-12. 4-way valve operation

In this case the possible control positions are to supply the fluid from port P to A, so that the piston moves downward, i.e., retracts (**Fig. 4-12a**) or the supply of the fluid from port P to B, so that the piston moves outward, i.e., extends (**Fig. 4-12b**). In these operations, the return lines are connected from port B to T (in retraction) and from port A to T (in extension), respectively. The respective valve positions for cylinder extension and retraction are shown in **Fig. 4-12c**.

Valve Positions and Actions

In direction control valves, **two-position** and **three-position** valve controls are very common. To understand the complete operation of a valve, in addition to the number of ports and positions, even the action has to be described. This can be understood with suitable examples of 4/2– and 4/3– valve operations described below:

Valve positions and actions:4/2-Valve
(4 port, 2position valve)



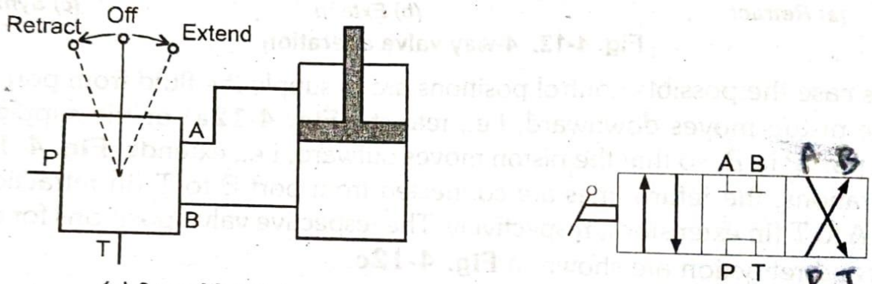
(a) 2 position valve *(b) Symbol*

Fig. 4-13. 4/2 valve control

This valve has two control actions-extended and retract of the cylinder. As seen in the above figure, when lever of the valve is in the retract position, the fluid flows from port P to A, while the fluid from port B flows back to port T (connected to oil pump). In extend position of the lever, the valve connects port P to B and port A to T, so the pump flows goes to port B to cause cylinder extension and the fluid from A returns to port T (oil sump).

4/3-Valve (4 port, 3 positions)

A 4/3 valve indicates a 4-port/3-position control valve. The example of a 4/3 valve is illustrated in **Fig. 4-14**. The relevant valve symbol and the valve actions are also shown in figure.



(a) 3 position valve

(c) Symbol

Fig. 4-14. 4/3 valve control

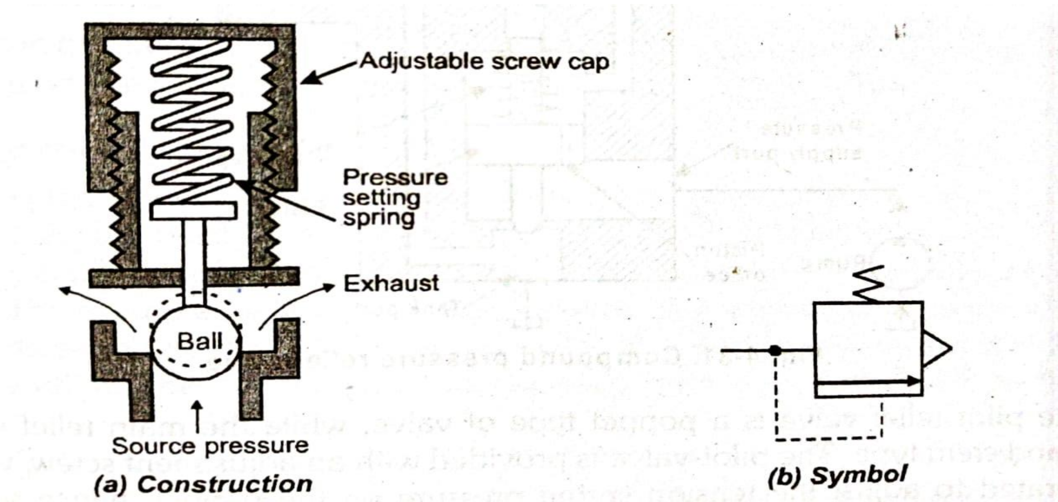
This valve has three control positions - ***extend***, ***off*** and ***retract*** of the cylinder. When the valve lever is in the *retract* position, the valve connects port P to A and port B to T, so that the pump flow goes to port A to cause cylinder retraction, while the fluid returns from B to T (oil sump). In the *off* position, the ports A and B are blocked, while the pump flow is connected P to T, thus simply returning oil back to the sump. Since, ports A and B are blocked, the cylinder is locked in its position. In the third position of the lever, the valve is in the *extend* position. At this position, port P is connected to port B, causing the cylinder extension and port A is connected to port T.

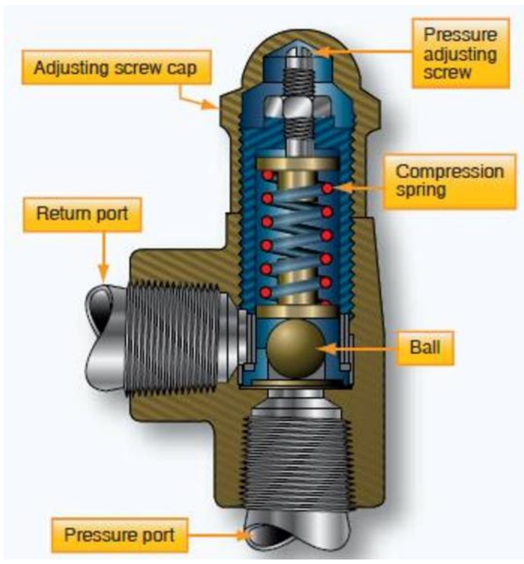
Pressure Control Valves:

- The pressure control valves protect the fluid systems from dangers of the over pressures.
- These valves functions as pressure limiting valves, pressure sequencing valves, unloading, counter balancing valves.
- The pressure regulating valves are used to the operating pressures in the fluid power systems and to maintain the constant pressures.
- Pressure limiting valves limit the pressure of the systems below the set safe valve, they are generally know as pressure relief valves.
- The pressure relief valves open pressure line to open air (in pneumatics) and back to sump or return lines (in case of Hydraulics).
- The pressure sequences valves are used to set operations are to be controlled in pressure related sequences.

Pressure Relief Valve (Simple Pressure Valve)

The pressure reducing valve working principle hinges on adjusting the inlet pressure to a specific required outlet pressure and depending on the medium's energy to maintain the outlet pressure stable. This is achieved through throttling and adjusting the opening and closing parts





It consists of a ball/ball seat which functions as the valve, a spring, a stem connected to the ball, a spring pressure adjustment cap and vents. The ball is always held closed on the ball seat under the spring pressure. The pressure with which it is held, can be adjusted by rotating the screw cap. Higher the spring pressure applied on the ball, higher is the cracking pressure required for valve opening.

In operation, when the force due to fluid pressure exceeds the spring tension (safe pressure limit) the valve crack-opens releasing the fluid (to atmosphere for air, and to the return line for hydraulic fluid) and reduces the system pressure, thereby safeguarding the system. Once the valve crack-opens, the flow rate is dependent on the excess pressure in the line. Higher excessive pressure cause a higher exhaust flow. Once the pressure falls below the cracking pressure the valve closes again under spring pressure.

A relief valve is specified by operating pressure range (i.e., full flow to cracking pressure) and the full flow rate after cracking.

Flow Control Valves:

The function of flow control valves is to regulate the flow rate of fluid in a hydraulic system. This in turn is used to control the speed of actuators. These valves are basically variable area orifice type, in which increasing the orifice area increases the flow rate, and decreasing the orifice area reduces the flow rate.

Types of FCVs

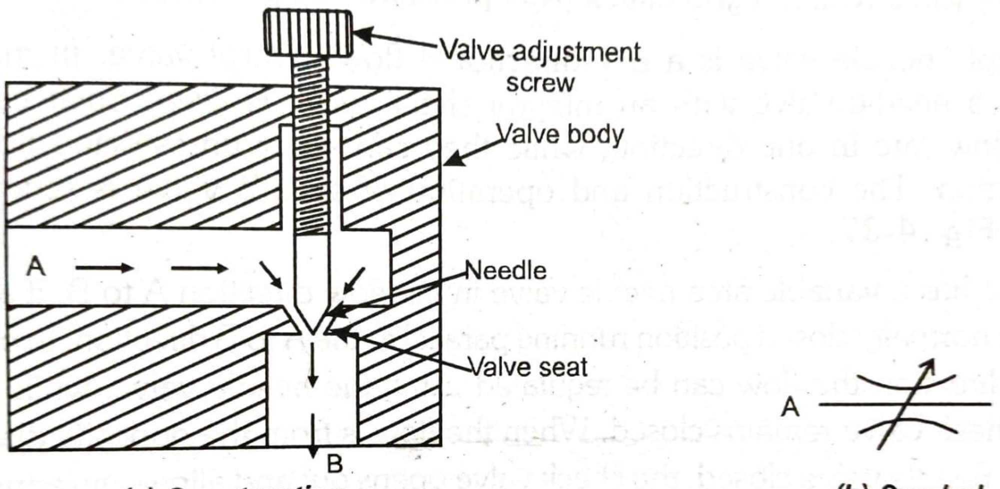
There are three types of FCVs:

1) **Simple needle valve**: The simple needle valve controls the flow, by simply varying the valve area. These are used in manual control fluid systems that require good metering operations. Also, these are used in one-directional flow control.

2) **Non-pressure compensated valve**: The non-pressure compensated valve is a two-direction flow control valve. In one direction, it acts like a simple needle valve controlling the flow rate, while in the reverse direction it allows unrestricted flow. Such valves are used where the system pressures are relatively constant and actuator speeds are not critical. Such valves operate using the principle of constant flow through an orifice, with a constant pressure drop across the valve.

3) **Pressure-compensated valve**: A non-pressure compensated valve is not suitable where the actuator speeds are critical. For such applications, pressure compensates valves are used, which adopt to the variations in pressure drops across the valve. In this type, the orifice opening is automatically adjusted by sensing the system pressure, thereby compensating pressure drop across the valve and maintain the pressure drop around a constant valve.

Simple Needle Valve:



(a) Construction *(b) Symbol*

It is the simplest flow control valve. In this, valve seat is variable area orifice. A matching valve needle is connected to the adjustable screw knob. The opening the opening and the orifice can be adjusted by turning the knob, by raising or lowering the valve stem and the needle.

Needle valves are commonly used as manual control valves in fluid systems that require good metering operations. Metering refers to the control of fluid flow rate leading the speed control of actuators. Needle valves always have a preferred direction of flow, from A to B, as shown in figure.

Flow Rate Through an FCV

As mentioned, a FCV (needle valve) works like a variable area orifice. Thus, the flow rate through an FCV can also be determined with the similar relationship involving the pressure drop and an orifice constant. It is given by the relation for an FCV,

$$Q_{FCV} = C_V \cdot \sqrt{\Delta P / S_g}$$

where, Q_{FCV} = flow rate through FCV, *l*pm

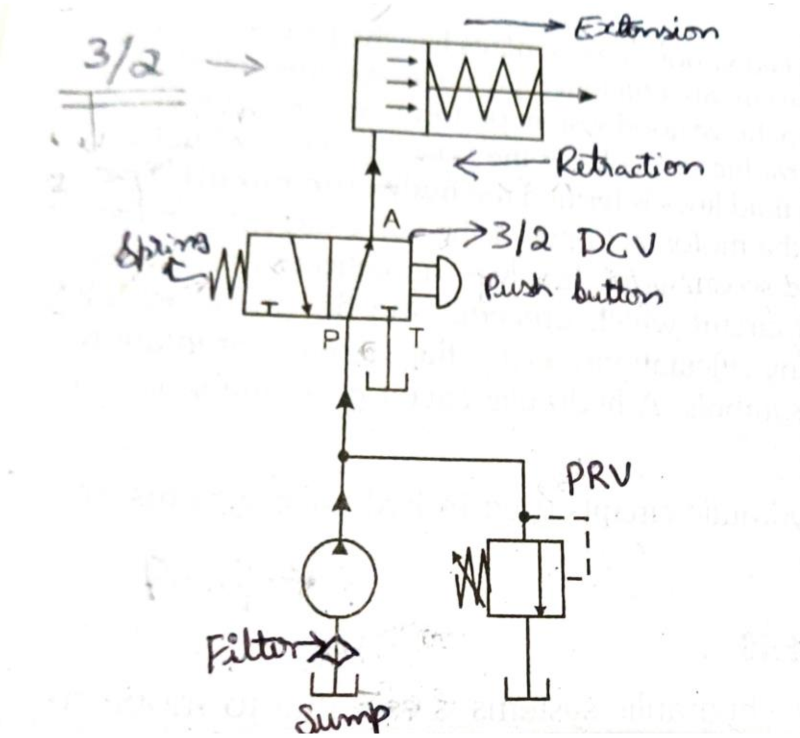
C_V = capacity coefficient (constant), *l*pm/$\sqrt{kPa}$

ΔP = pressure drop across the valve, kPa.

S_g = specific gravity of the liquid

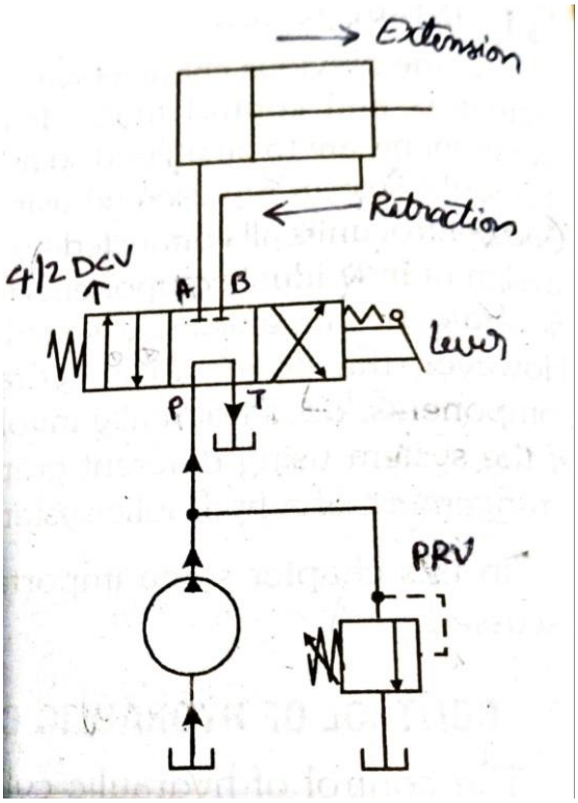
The valve of capacity coefficient is determined experimentally for each of the FCV and is generally specified by the manufacturer. The capacity coefficient can be defined as "*the flow rate of water in lpm (litres per minute) that will flow through the valve at a pressure drop of 1 kPa*". Thus, it is usually expressed with units of "*l*pm/$\sqrt{kPa}$".

Hydraulic Circuit Designs:
Control of Single acting cylinder:



- The circuit has filter, pump, pressure relief valve, a DCV, spring-return single cylinder.
- The DCV has 3/2 three way , two positions normally open with push button actuation and spring return valve.
- The normally open position of the valve, the pressure line is blocked and it allows free flow through the tank.
- In the operation the cylinder is normally retracted position (under spring return position).
- When valve is operated manually, the pressure port **(P)** opens, the pump the pump flow is directed to cylinder **A** and causes extension of the cylinder.
- Once full extension is achieved, the PRV opens-out and flow starts to flow through the bypass line.
- Once DCV is deactivated(release of manual force from the button will cause the valve to open under spring pressure.
- The pressure port is blocked and the pressure line **A** is routed to the tank line **T.**
- The cylinder starts retracting under the spring pressure , oil flows back to tank through the tank port **T,** at this time since the pressure port is blocked , the pump flow passes through PRV.

Control of Double acting cylinder:



- Four way DCV are commonly used to control the operations of double acting cylinders,
- Four way two position DCV can be used, they are not usually suitable for practical applications, since it keeps the actuators under always pressures.
- In this case the neutral position corresponds in which no flow goes to the actuator.

  The hydraulic circuit for controlling a double acting cylinder using 4/3 DCV is illustrated below.

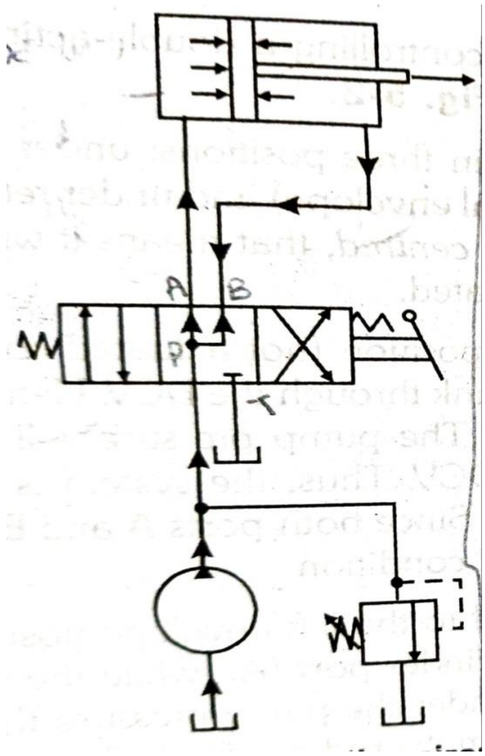
Here the valve is shown in three positions: under *extension* (left envelope), in tandem *neutral position* (central envelope) and under *retraction* (right envelope). This valve shown in figure is *spring centred*, that means it will automatically return to the neutral position when not actuated.

With the valve in neutral position (not actuated condition), the pump flow will continuously flow back to the tank through the DCV. Hence with this, the actuator and the pump are not pressurised. The pump pressure will be limited to the resistance offered in the flow lines and DCV. Thus, the system is not loaded, and the power consumption will be minimum. Since both ports A and B remain closed, the cylinder will be in a hydraulically locked condition.

When the valve is actuated to the left envelope position, the pressure line (P) is connected to the piston-end cylinder port (A), while the rod-end cylinder port (B) is directed to the tank line (T). Under the pump pressure the cylinder extends (P to A) and at the same time, the oil from the rod end freely flows back to the tank through the DCV (B to T). At the end of the stroke until the DCV is deactivated, the flow goes through the PRV.

When the valve is deactuated under the spring pressure, the valve comes to the neutral position thus blocking the ports A and B. This keeps the cylinder in a blocked condition but making P and T direct. When the valve is actuated to the right envelope position, the pressure line (P) is connected to the rod-end port (B), and the piston-end port (A) is connected to the tank line (T). This causes the cylinder retraction, with the oil from piston-end flowing freely back into the tank. At the end of the stroke, the pressure builds up, the PRV opens out and the fluid flows through the relief line. Once the DCV is deactuated, it returns to the neutral position and flow goes directly to the tank line.

Control of Regenerative Circuit:



Regenerative circuits are used to provide faster cylinder extension speeds by taking the oil from the rod end and diverting it to the head end of the cylinder. This means that the effective area during extension is the rod area that will give a faster speed but also a reduced force. The schematic representation of regenerative cylinder circuit is as shown in the above figure.

Functions of Regenerative cylinder circuit:

- The regenerative circuit is one which utilized the waste energy in operation to supplement additional power generated.
- The flow rate is increased, thus speed is increased of the actuator.
- The regenerative circuit uses regular double acting cylinder and 4 way , 3 position DCV.
- Both the ports A and B are connected to the same port P which in parallel.

In the neutral position of the DCV, both the ports of the cylinder (A and B) are connected to the pressure line (P), while the tank port (T) is blocked. Now the pump pressure is applied to both sides of the piston. Since the piston area is larger on the left side and smaller on the rod side, the net force on the left side is higher and the flow causes an extension. At the same time, the flow from the rod-end will flow back to the valve, and adds up with the pump flow. This increases the flow rate to the cylinder, thereby increasing the speed of extension. As compared to a regular double-acting cylinder where the rod-end flow is sent to the tank as a waste, it is utilised in the cylinder inlet along with the pump flow, thereby giving the **regenerative effect**, which in turn increases the speed of extension. When the left envelope of the DCV is actuated, it causes the normal cylinder extension, and the right envelope activation causes the normal cylinder retraction.

Such a regenerative circuit is used in the spindle movement of NC drilling machines to effect a faster operation. In this, when the DCV is in the neutral position, the spindle is moved at a faster rate (the regenerative circuit), thus making a faster extension. In the left envelope position, a normal speed extension of the spindle is effected to perform the drilling operation. Finally, the spindle is retracted by moving the DCV to the right envelope condition.

Advantages:

1) Power multiplication
2) Ease of Power transmission
3) No moving parts
4) Constant force and torque
5) Ease of control
6) Safety and economy.

Disadvantage:

- Hydraulic systems , working medium oil being a liquid it is very messy to handle, leakages in lines are very common in hydraulic systems.
- Being high pressure systems there are chances that fluid lines may burst due to malfunction of devices and components. In such situations may lead to accidents causing damage to equipments.
- Since the systems involves many connections, maintenance is the regular feature of Hydraulic systems.
- Periodical cleaning and replacement of oil filters is necessary.
- Use of incorrect oil can lead to cavitations, corrosion other operational issues.
- Due to seals and leakages across seals results in loss of power and reduction in performance.

Applications:

1) Hydraulic jacks for raising the loads
2) Hydraulic power assisted steering mechanism in automobiles.
3) Hydraulic power assisted braking systems
4) Forklift trucks.

5) Hydraulic power driven toeing trucks in aircraft industry
6) Movements and controls of landing gears in aircrafts
7) In robots movements and controls of various arms.
8) In earth moving equipments and front end loaders
9) In power presses sheet metals and forging operations.
10) In hydraulic cranes in lifting and moving of heavy items.

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