

**Application of Pneumatics**

- Objectives :** At the end of this lesson you shall be able to
- define pneumatics
  - state the application of Pneumatics
  - list the advantages and limitation of pneumatics.

**Overview of Pneumatic**

original world PNEUMA is taken from Greek language which means breathing.

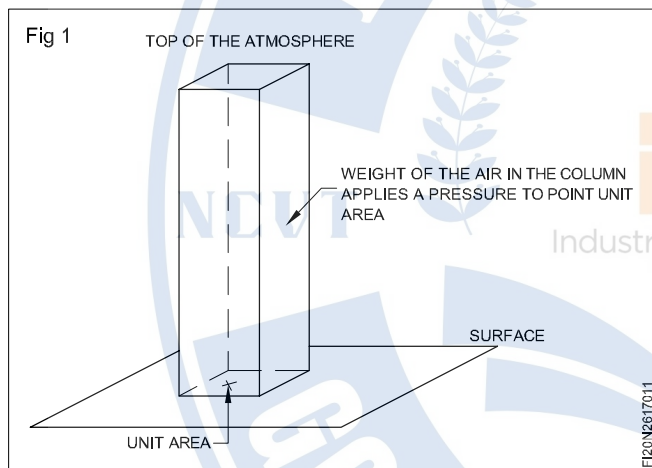
Pneumatic system gets compressed air as an energy input then converts it into a suitable work and after that exhaust back to the atmosphere. This process of intake and exhaust is compared with breathing.

**Definition:** It is the science under which you study properties and application of air.

**Common terms used in pneumatics**

**Pressure**

Pressure is defined as the load acting upon unit area.(Fig1)



Pressure = Force/Area

In pneumatic system three terms related to pressure are commonly used.

**Atmospheric Pressure**

It is pressure caused by weight of column of atmospheric air acting on the surface

**Gauge Pressure**

It is pressure value read through an instrument called Pressure Gauge. It indicates pressure value above the atmospheric pressure.

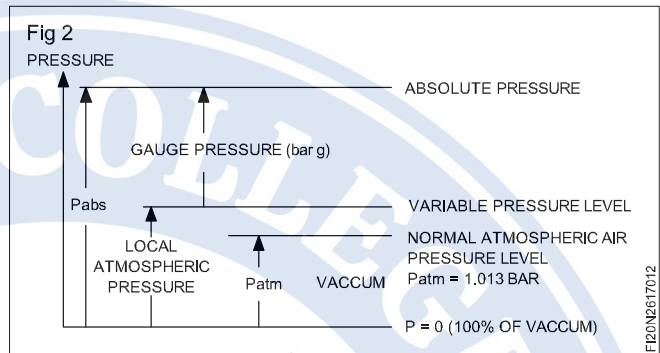
**Absolute Pressure**

It is the pressure value measured with respect to perfect vacuum.

Absolute pressure = Atmospheric pressure + gauge pressure

Abs Pr = Atm Pr + Gg Pr

Fig 2 shows the relation between Absolute pressure, Gauge pressure and Atmospheric pressure.



Units of Pressure: Pressure is measured in Pascal (Pa) in SI unit. 1 pascal = 1 newton per meter square. one pascal is the pressure exerted by a force of magnitude one newton perpendicularly upon an area of one square metre...

Example: Pressure = Bar = 1 Kg/Cm<sup>2</sup> (aprox.)

Bar is a metric unit of pressure equal to 100,000 pa (pascal) standard atmospheric pressure at sea level is 1013.25 milli bar or 101.35 kilo pascal

1 Bar = 1 Kg / Cm<sup>2</sup>

**Force**

Force is the product of pressure and cross section area upon which force is acting.

Force = Pressure x Area ( F = P x A)

Unit of Force: Force is measured in Newton in SI unit

1 newton = 1 kg m /s<sup>2</sup>

**Flow rate**

Flow rate is the volume of air flowing per unit time.

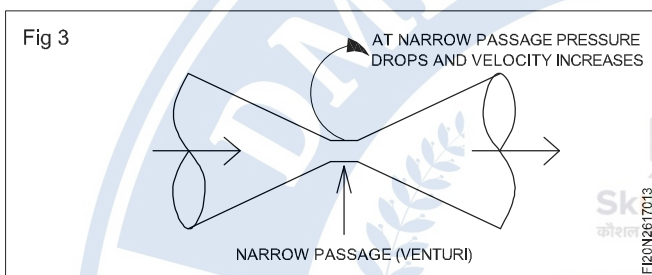
**Units of Flow Rate:** Flow rate is measured in lpm (Litre/ Minute) or M<sup>3</sup>/ Hour.

Example: Flow Rate = 10 Litre/ Minute

Or Flow Rate = 50 M<sup>3</sup>/ Hour

## Properties of Air

- Atmospheric air possesses certain properties as follows:
- Air is a mixture of gases. (Nitrogen - 78%, Oxygen - 21%, Other gases, Water vapour - 1% by Volume)
- It contains dust particles and water vapour.
- Air is compressible means its volume can be reduced.
- Air does not burn itself.
- Volume of air increases with increase in temperature.
- Moisture or water vapour carrying capacity increases with increase in temperature of air or volume of air.
- Pressure of air increases with reduction of volume.
- Air temperature increases with increase in pressure.
- When air passes through narrow passage pressure drops velocity increases. (Refer Fig 3)



**Applications:** Pneumatic is widely used in many industrial automation applications where fast movements of lesser loads are required.

Pneumatics is used to move load with less efforts, general applications are:

- Push - Pull
- Lift - Drop
- Clamp - Unclamp
- Tilt

## Boyle's Law

Robert Boyle (1627-1691), an English scientist, was among the first to experiment with the pressure volume relationship of gas at constant temperature.

**Statement:** If a given mass of a gas is compressed or expanded at a constant temperature, then the absolute pressure is inversely proportional to the volume.

Pressure  $\propto \frac{1}{Volume}$  when temperature = constant

$$pV = \text{constant}, p_1 v_1 = p_2 V_2$$

## Advantages of Pneumatics

Pneumatics is popular in industrial applications as Low Cost Automation because of following advantages:

- Air is available at free of cost.
- Air is available in unlimited quantity every where.
- Air can be compressed, pressurised and can be transported through pipes.
- Air can be exhausted to the environment without any harmful effects.
- Action is fast.
- Speed control is possible.
- System is overload safe.
- Air does not ignite.
- Simple in design and construction.
- Long life and low maintenance
- Components are simple in design and hence cheaper.

## Limitations

- Pneumatic system has certain limitations as follows:
- Pneumatic system is economical up to a limit of 3000 kgf force.
- Pneumatics need fine quality equipment to remove dust and moisture. (Air filters & demister)
- Air exhaust is noisy
- Uniform speed is not possible.
- Special lubrication technique is required to avoid friction between internal components.
- In case of leakage pneumatic system becomes costly.
- Compressing air beyond 7 bar is costlier.

# Introduction of Hydraulic system

**Objectives:** At the end of this lesson you shall be able to

- define hydraulic system
- define Pascal's law
- state the Bernoulli's principle.

Any working or control system that uses liquid as the transmitting fluid is known as hydraulic system.

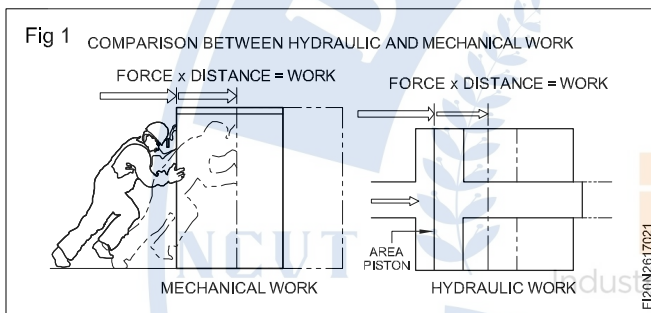
The word hydraulic is derived from Greek words "hydra" meaning water and "aulic" meaning pipe.

Some common examples of hydraulic system include automobile braking, power steering, elevators, earth moving equipments, jacks, presses, riveting machines, tool feeding mechanisms etc. The liquid used in hydraulics is generally viscous petroleum oils.

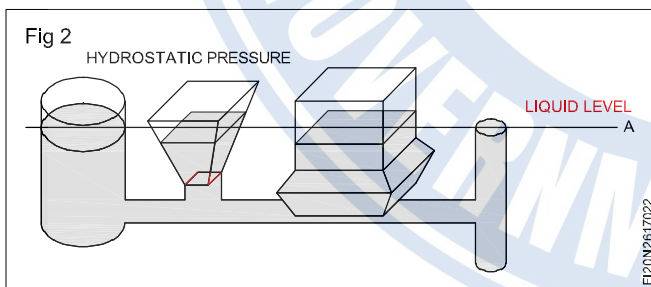
The following paragraphs gives basic physical properties and laws that govern liquids, relevant to hydraulic systems.

"Work" is defined as the product of force and the distance in which the object has moved in the direction of force.

Fig 1 shows the comparison between the work done in a mechanical and hydraulic system.



The Fig 2 shows that different shaped and sized containers inter-connected by a pipe, the level of the liquid remains same. This is because of the internal pressure of the liquid. At any point the liquid attains certain pressure proportional to the height of the liquid above.

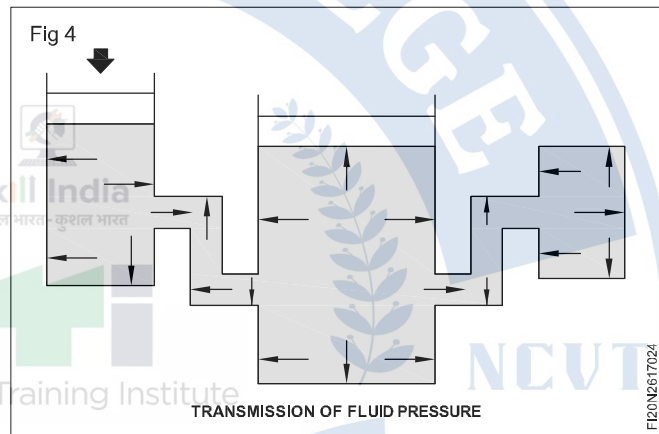
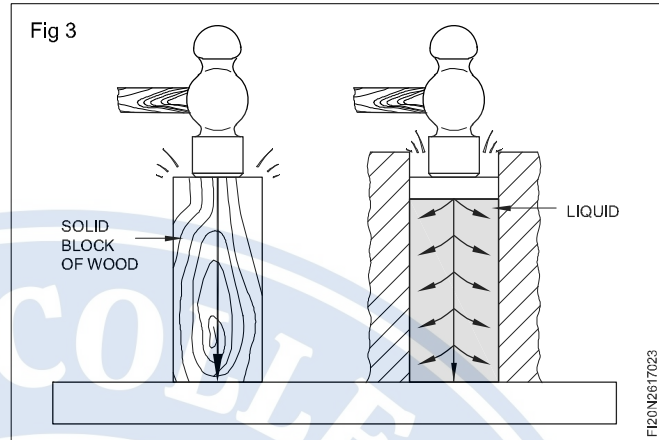


Therefore the higher pressure in any of the container will force the liquid to flow to the next container until the pressure on both the sides are equalised.

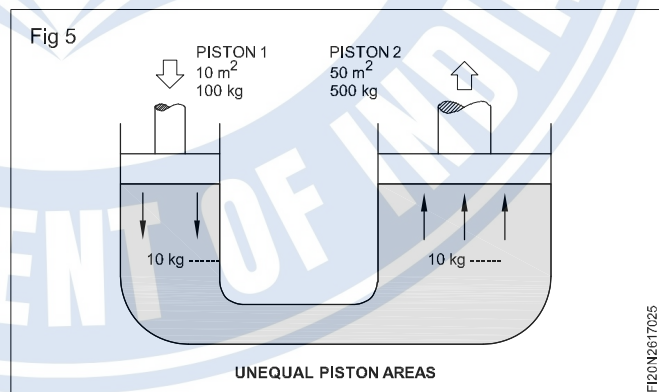
Through the line 'A' the pressure in all the open containers remain the same, since height of liquid columns are same.

## Pascal's Law

It states that the pressure exerted on a liquid is transmitted equally in all the directions. Fig 3 clearly explains this law followed by Fig 4.

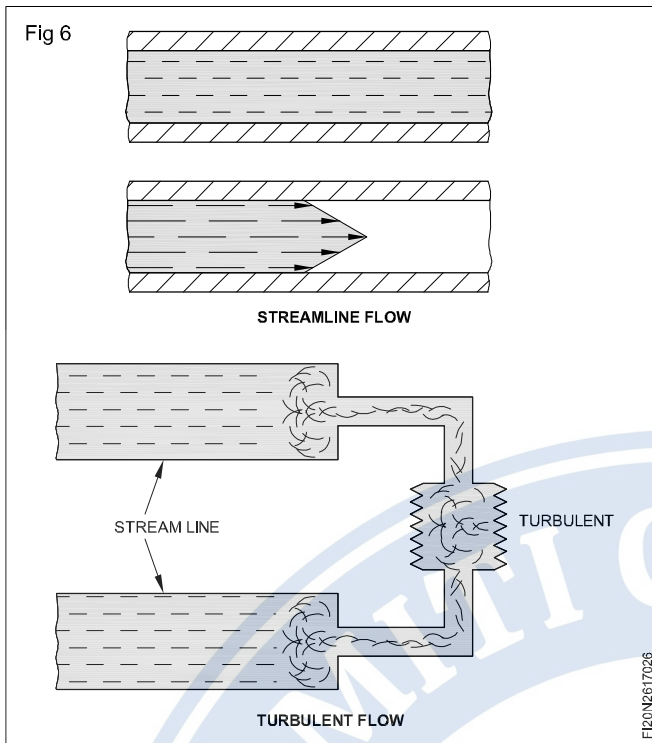


Thus if small amount of pressure is exerted on a smaller piston as shown in Fig 5, the higher force can be attained at the larger piston, since the pressure is equally applied on larger area.



## Cavitation

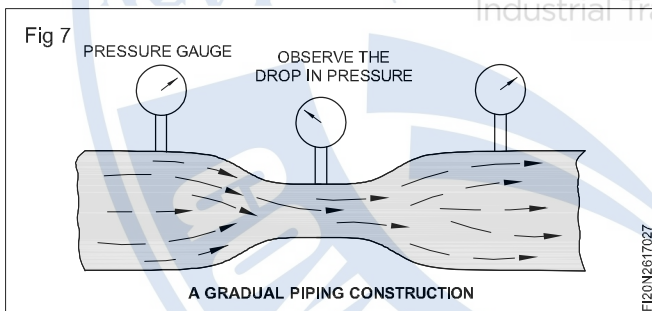
The inter-locked air bubbles and pockets in the hydraulic pipe lines and components is called cavitation. In cavitation the static pressure falls below vapour pressure. The vapour formation condenses resulting in pressure jerks and noise, and heating-up the oil resulting in a turbulent flow. Therefore resulting flow of oil should be a stream line or laminar in the pipe lines (Fig 6).



### Bernoulli's principle

Kinetic energy is the energy present in oil by virtue of its motion. Potential energy is due to the pressure. The total energy is the sum of these two energies.

The Bernoulli's principle states that the total energy of fluid always remains constant. During the course of flow of liquid, the flow increases and pressure decreases when a restriction is encountered. If the flow decreases, liquid pressure increases. Fig 7 Depicts this principle clearly.



### Effect of heat

Since the liquids (oil) full in containers cannot expand or be compressed on heat, it exerts pressure on the container thus developing unwanted stresses.

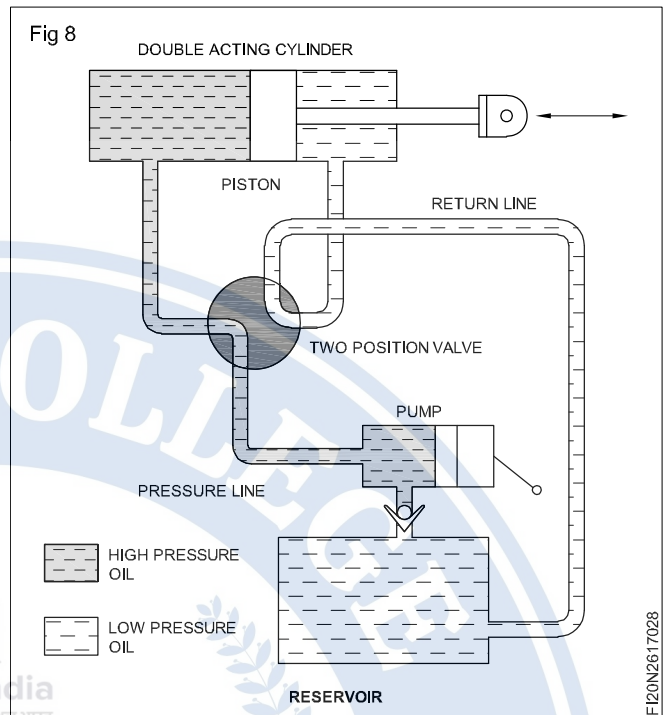
Heat also thins out the oil. The low viscous oil may leak through seals and packings. Heat also causes the deterioration of oil. Hence a suitable cooling system must be provided.

The basic hydraulic system consists of the following elements:

- A reservoir to store the hydraulic fluid
- A pump to provide fluid pressure to the system
- A control valve to direct the flow of fluid
- An actuating unit, such as a cylinder

- A suitable hydraulic fluid
- Piping or tubing to circulate the fluid through the system.

But the following components make up actual hydraulic power system (Fig 8) for a safe and greater range of work.



- A reservoir to store the hydraulic fluid
- A pump to provide fluid pressure to the system
- A filter to remove dust, chips and other foreign particles from the fluid
- A pressure-regulating valve, which keeps the fluid pressure in the main part of the system at the proper level
- An accumulator, which acts as a cushion and prevents large variations in fluid pressure that occurring in the system
- Check valves, which permit fluid flow only in the desired directions.
- A hand pump for operating the system manually if necessary
- A pressure gauge, which indicates the amount of fluid pressure in the system
- A relief valve, which prevents the system pressure from rising too high, if the pressure-regulating valve fails

### Advantages of Hydraulics

- Liquids are incompressible and capable of moving much higher loads providing much higher force.
- No need to bleed off " pressurized air to release pressure on the load.
- Highly responsive compared to pneumatics
- Supply more power than pneumatics
- Also provides Lubrication & cooling.

### Comparison between Pneumatics and Hydraulics

Pneumatics	Hydraulics
<p>Confined pressurized system that use moving/air or other gases</p> <p>Because gases can be compressed, there is a delay in the movement, the force</p> <p>Need for air compressor</p> <p>Examples:</p> <p>Precision drills used by dentists</p> <p>Pneumatic brakes (air brakes) used by buses, trucks, trains</p> <p>tampers used to pack down dirt and gravel</p> <p>lungs</p> <p>nail gun</p> <p>dentist chair</p> <p>most industrial pneumatic application uses pressure of 550 to 690 kpa</p>	<p>Confined pressurized systems that use moving Liquids</p> <p>Liquids are not very compressible, there is no delay in the movement</p> <p>Hydraulic Fluid-liquid inside system.</p> <p>Cylinder-container holding liquid</p> <p>piston-plunger moving inside cylinder</p> <p>Pumps-moves liquid in specific direction (usually against gravity)</p> <p>Valves-controls the flow of direction (allows flow in one direction)</p> <p>Examples:</p> <p>Dump truck lift</p> <p>Hydraulic lift to lift cars</p> <p>Jaws of lift</p> <p>blood in body</p> <p>Used in cars</p> <p>Hydraulic application commonly use from 6.9 to 34.5 mpa. Special high pressure application may exceed 69 mpa.</p>

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## Air compressor parts and function

**Objectives :** At the end of this lesson you shall be able to

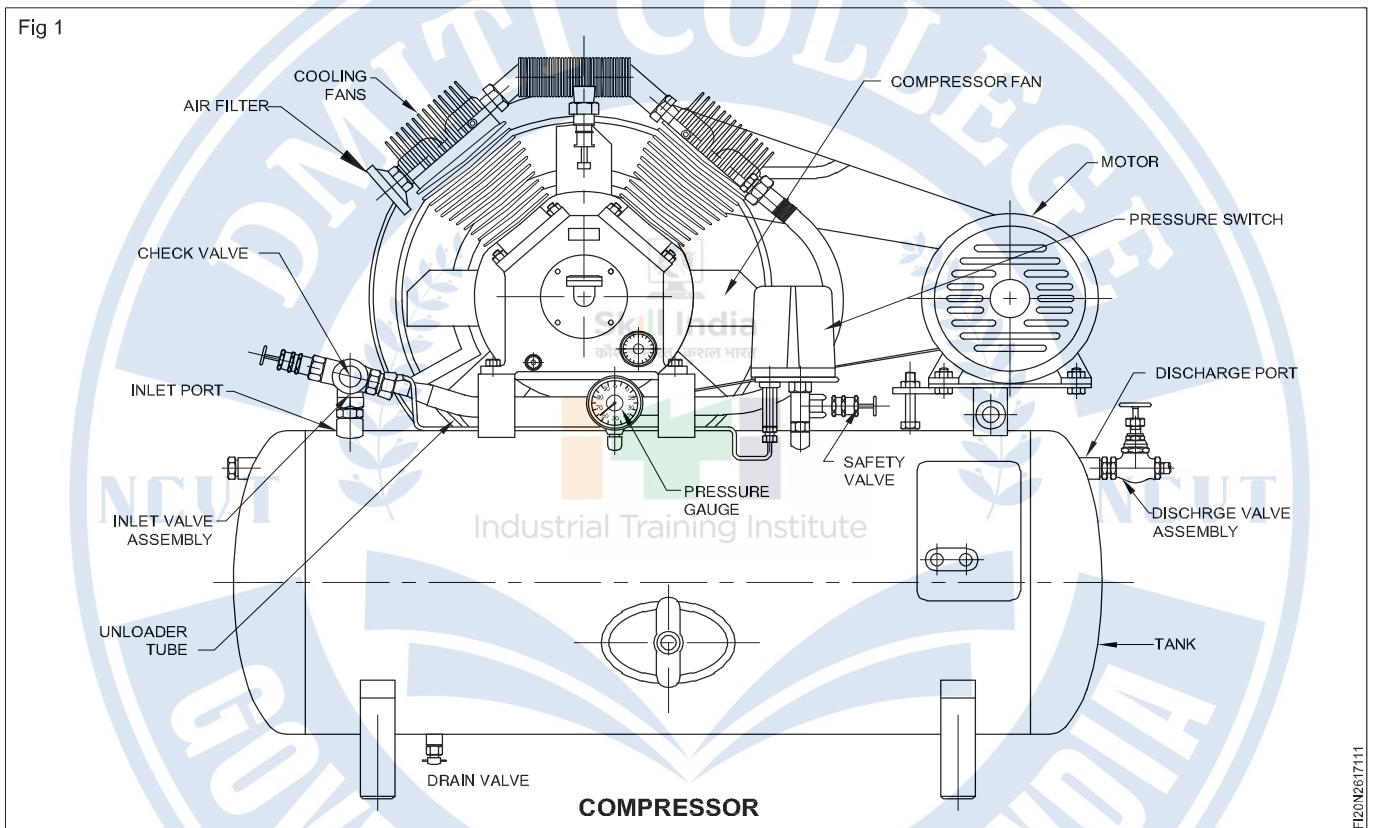
- state construction of compressor
- explain parts of compressor
- describe the working principle of air compressor.

### Air compressor parts and functions

Air compressors are a type of machine tool and they work great with other power tools too. It basically provides other tools the ability to function and the power to do household as well as industrial improvement projects and installations. In order for tools to function at their best, air

compressor must be working in its optimum power and efficiency and that means that the parts of an air compressor must be working 100% of the time to make sure the work is done.

### Parts of an air compressor (Fig 1)



The following are the main parts of an air compressor.

#### Motor

An air compressor needs an electric motor to power up the machine. The motor basically drives two belts a pulley which allows the transfer of power from the motor to the pump pistons and this is done through a flywheel and a crankshaft. One important thing need to install will be a magnetic starter to prevent the motor form overload.

#### Tank

This is the compressor part that stores the air being compressed. It is biggest part of the air compressor and it can range from 1-10 gallons or even more for bigger construction needs. The tank generally made of steel.

#### Pressure switch

The pressure switch automatically shuts down the motor when the receiver reaches the factory-set limit. Once the pressure level drops to a pre-set level then the pressure switch restarts the motor therefore resuming the pumping of air by the compressor. We can also call this as an emergency switch that regulates how much pressure in the tank can take.

#### Drain valve

The main purpose of the drain valve is exactly what its name impiles. It drains the oil,dirt, moisture, and other debris that might be trapped inside the tank. Simple maintenance of air compressors entails draining a tank from impurities and debris from use. Moisture and oil are the most common reasons for rust to develop inside the tank when not drained.

## Pressure gauge

This gauge measures compressed air pressure in the tank of the air compressor. It lets the user know that there is a problem if the measurement is higher than the regulated normal limit and serves as a warning to inspect the air compressor or stop the compression before the gauge reaches even higher pressure. On the contrary if the reading is very low from the normal allowed measurement, it also indicates a problem with the compressor such as a leak in the tank. This should also be checked right away to avoid any more complications and accidents.

## Inlet port

This port is used to guide the inlet air towards the compressor inlet valve.

## Inlet valve assembly

Inlet valve assembly comprises valve plate, and valve spring. Inlet valve controls the flow of air towards the cylinder of compressor. It is opening downwards to allow the air inside when the piston moves downwards. Valve plate is used to hold the inlet valve in proper position.

## Cooling fins

Cooling fins are the extended part provided from the cylinder body to assure heat transfer from cylinder to surrounding. Generally these are made of aluminum.

## Discharge Port

It is the opening provided at the top of compressor cylinder to guide discharge air towards the discharge line.

## Discharge valve assembly

It comprises discharge valve plate, valve plate and valve spring. Valve plate helps to hold the discharge valve in proper position. Valve is aimed for discharge the high pressure air when the piston reaches its top.

## Air filter

Air filter is very important part in an air compressor. It helps to prevent the dirt and dust to enter inside the compressor cylinder. Filter is provided in the suction end of the compressor.

## Safety valve

A safety valve is provided on the air storage tank or air outlet line to prevent the danger occurred when the air pressure reaches beyond the capability of storage tank capacity.

## Regulator

Generally an air regulator is provided in the discharge tube to regulate the high pressure air flow.

## Check valve/Non return valve (NRV) and unloader tube

An one way check valve is provided in the bypass line in between air receiver tank and compressor head. It will open and admit the high pressure air towards the receiver tank while unloading is going on during the starting time. An unloader tube is connected at the inlet port of the

check valve and the valve only opens in one direction (ie from compressor top to receiver air flow). During this time the high pressure air is unloaded towards tank through unloader tube.

## Compressor fan

A compressor fan is connected at one end of the crank shaft to provide sufficient cooling air to compressor. It will prevent overheating of compressor.

## Air compressor working principle

### Working principle (Fig 1)

Air compressors collect and store air in a pressurized tank, and use pistons and valves to achieve the appropriate pressure levels within and air storages tank that is attached to the motorized unit. There are a few different types of piston compressors that can deliver even air pressures to the user.

Automotive compressors are combustion engine compressors that use the up-and-down stroke of the piston to allow air in and pressurize the air with in the storage tank. Other piston compressors utilize a diaphragm, oil-free piston. These pull air in, and pressurize it by not allowing air to escape during the collection period.

Now the air compressor is capable of building extreme pressure in storage tanks capable of storing enormous amounts of pressurized gases for industrial use.

## Air dryer

A compressed air dryer is used for removing water vapor from compressed air.

Compressed air dryers commonly found in a wide range of industrial commercial facilities.

## Usage

Drying air for use in commercial or industrial processes that demand dry air:

Telecom industry (pressurizes its underground cables to repel moisture and avoid shorts).

Painting.

Pneumatic tools.

Textile manufacturing.

Pneumatic control systems.

Feed air for zeolite type oxygen and nitrogen generators.

Dental office air.

Truck and train air brake systems.

The process of air compression concentrates atmospheric contaminants, including water vapor. This raises the dew point of the compressed air relative to free atmospheric air and leads to condensation within pipes as the compressed air cools downstream of the compressor.

Excessive water in compressed air, in either the liquid or vapour phase, can cause a variety of operational problems for users of compressed air. These include freezing of

outdoor air lines, corrosion in piping and equipment , malfunctioning of pneumatic process control instrument, fouling of processes and products and more

There are various types of compressed air dryers. Their performance characteristics are typically defined by the dew point.

- Refrigerated dryers
- Deliquescent dryers
- Desiccant dryer
- Membrane dryers

**Refrigerated dryer**

Refrigeration dryers employ two heat exchangers, one for air-to-air one for air-to-refrigeration. These dryers are used in refrigeration compressors.

**Deliquescent dryer**

A deliquescent dryer typically consists of a pressure vessel filled with a hygroscopic medium that absorbs water vapor. The medium gradually dissolves-or deliquesces-to form a solution at the base of the pressure vessel. The liquid must be regularly drained from the vessel and new medium must be added.

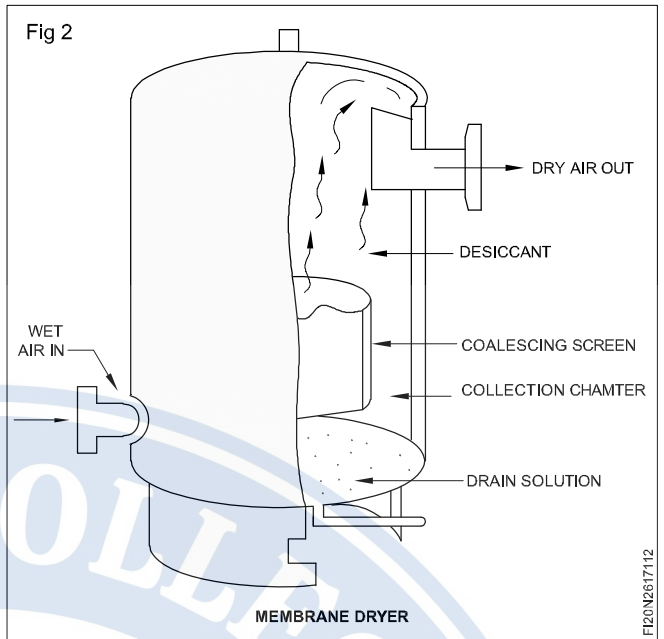
Deliquescent dryers are used for removing water vapour from compressed air, natural gas, and waste gases.

**Desiccant dryer**

The term “desiccant dryer” refers to a broad class of dryers. Other terms commonly used are regenerative dryer and twin tower dryer, and to a lesser extent absorption dryer.

The compressed air is passed through a pressure vessel with two “towers” filled with a media such as activated alumina, silica gel, molecular sieve or other desiccant material. This desiccant material attracts the water from the compressed air via adsorption.

**Membrane dryer (Fig 2)**

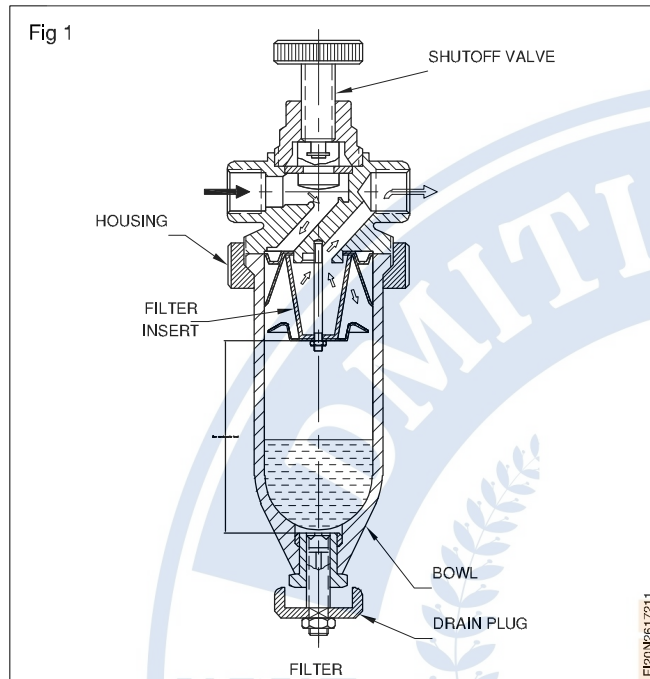


Membrane dryer refers to a dehumidification membrane that removes water vapor from compressed air. Typically, the compressed air is first filtered with a high-quality coalescing filter. This filter removes liquid water, oil and particulate from the the compressed air. The water vapor-laden air then passes through the center bore of hollow fibers in the membrane bundle. At the same time, a small portion of the dry air product is redirected along the outside surface of the fibers to seep out the water vapor which has permeated the membrane. The moisture-laden sweep gas is then vented to the atmosphere, and clean, dry air is supplied to the application. The membrane air dryers are designed to operate continuously, 24 hours per day, 7 day per week. Membrane air dryers are quiet, reliable and require no electricity to operate.

## FRL unit (Filter, regulator, lubricator)

**Objectives :** At the end of this lesson you shall be able to

- define FRL unit
- state the types of FRL
- state the specifications of FRL.



Fitter, regulator, lubricator (FRL) assemblies are pre-packaged or modular assemblies of air filters, pressure regulators, and gauges. Air leaving a compressor is hot, dirty, and wet and can cause damage to equipment and tools if it is not filtered.

The filter cleans compressed air by trapping solid particles and separating liquids, such as oil and water, that are trapped in the compressed air. Filters are installed in the air line upstream of regulators, lubricators, and all pneumatically-powered tools and equipment. They remove contaminants from pneumatic systems, preventing damage to equipment and reducing production losses due to contaminant-related downtime.

Pressure regulators control fluid pressure in compressed air systems. Regulators are also known as pressure reducing valves (PRVs). Pressure regulators maintain a constant output pressure regardless of input pressure variations and demands made on the system by downstream components.

Lubricators add controlled quantities of oil into the compressed air system to reduce the friction between moving components within air tools and other equipment that are powered by the system. Adding lubrication oil to the system also clears compressor oils that travel through the system in vapor form. To prevent build-up of oil within system components, mineral oils are added to the system to flush away the deposits.

Downstream equipment flow and pressure requirements determine the correct regulator and lubricator for the application. Manufacturers offer flow characteristics charts on their products to help choose the correct combination of regulators and lubricators.

### Types

There are several choices for regulator type.

- **General-purpose regulators** are designed for typical industrial use; they generally operate only above atmospheric pressure.
- **High-pressure regulators** are rated for inlet pressures higher than general purpose, typically over 1,000 psi.
- **Low-pressure regulators** have special design characteristics for precise control of pressures typically below 15-20 psi.
- **Differential or bias regulators** maintain a pressure differential between two locations in the system.
- **Pressure-reducing valves** provide a sub-circuit with a supply of fluid at a pressure that is less than the pressure in the main circuit.

### Specifications

#### Performance specifications:

- **Regulating (adjustment) range** - Dictates the limits of adjustment control
- **Maximum flow (gas or air)** - Unnecessary to specify if primary application is liquid
- **Maximum pressure rating** - Refers to the pressure rating for the valve or inlet pressure for the regulator
- **Filter minimum particle size rating** - Applies to filter, regulator, and lubricator (FRL) assemblies. It is the smallest size particle that will be entrapped by the filter. This rating is an indication of the largest opening in the filter element.

#### Other important specifications include:

- Regulator type
- Medium
- Adjustment control
- Connectors or pipe size
- Body material
- Environmental parameters

# Applications of pneumatics

**Objectives :** At the end of this lesson you shall be able to

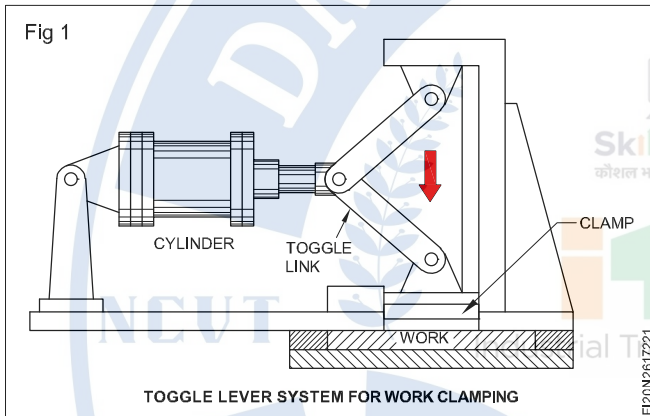
- state the application of pneumatic cylinders
- state various areas of automation
- describe the hazards and safety precautions in pneumatic system.

## Application

In any control system or automation, pneumatics can be economically applied. Besides, in other inaccessible areas like furnaces, Pharmaceutical industry, Food Processing and nuclear/reactors, compressed air is the only choice to operate the control system.

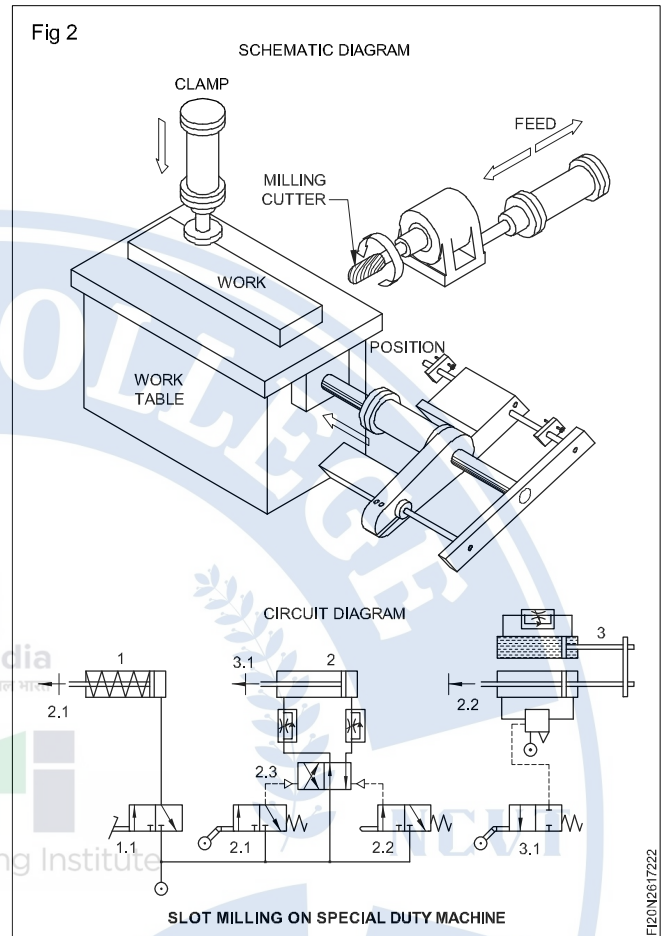
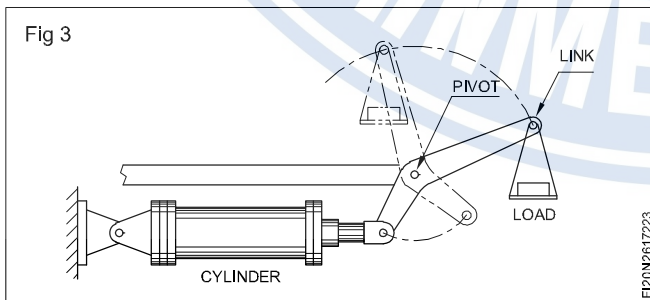
Air cylinders are widely used in pneumatic systems, since the linear motion is the most common requirement of the system. But rotating actuators (motors) find their application in hand tools like portable drilling machine. As a general practice, pneumatics is efficiently used in speed control rather than power requirements.

In Fig 1 the piston moves the toggle link. The free ends of the toggle link move down to clamp the work.

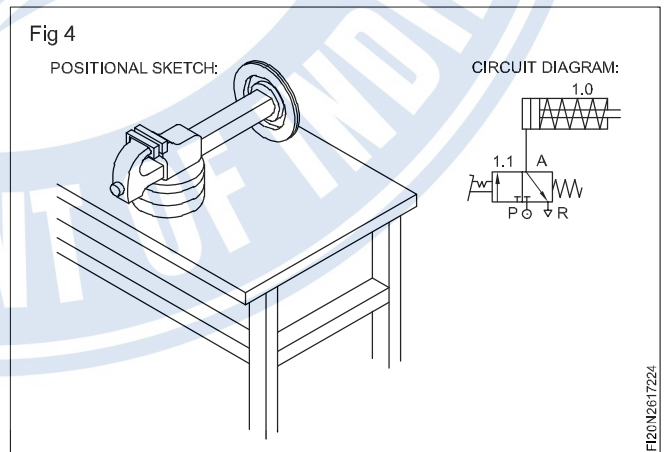


The Fig 2 Shows feed unit. For a slot milling machine. The pedal operates valve 1. 1 clamps the jobs on the table. The piston rod at the end of its travel operated valve 2. 1 and make the cylinder to move forward, in turn operating the valve 3. 1. The valve operates the cylinder 3 to enact the feed to the work.

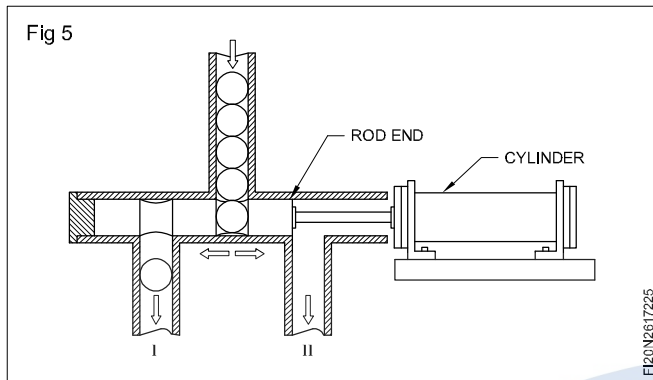
In Fig 3, the movement of the piston rod to the right tilts the pivoted link to the left. By this movement the load is swing to the left hand side.



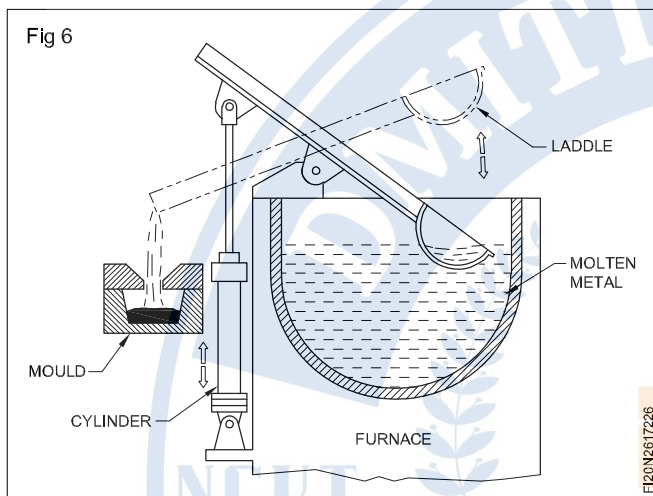
The operation of vice is shown in Fig 4. The 3/2 way valve extends and retreats the single acting cylinder attached to the movable vice.



In Fig 5 the ball falling by gravity is distributed in two passages I & II, by means of the cylinder action.



In Fig. 6 the vertical movement of the piston rod lifts or lowers the ladle of molten metal to pour it into the mould.



### Hazards & Safety precautions in pneumatic system

Whenever you are working with Pneumatic system you must take following safety precautions:

- Take precaution against corrosion in pneumatics components.
- Do not use compressed air to clean body parts.
- Never use kerosene to clean pneumatic system.
- Compressed air does not ignite but can explode due to pressure.
- Pneumatic system operates at high speed, most of the accidents happen due to crushing, hence take care when handling.
- Do not put hands in the path of operating components.
- Avoid contact of plastic pipes with sharp edges.
- Close main valve to unpressurise pneumatic system prior to maintenance work.
- Loose connection may cause withdrawal of pneumatic hose, that whips due air flow. This whipping action may cause injury.

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## Pneumatics actuators

**Objectives :** At the end of this lesson you shall be able to

- define pneumatic actuators
- state the types of pneumatics actuators
- to calculate cylinder forces
- define stroke length.

### Pneumatics actuators

pneumatic actuators are the devices used for converting pressure energy of compressed air into the mechanical energy to perform useful work. In other words, Actuators are used to perform the task of exerting the required force at the end of the stroke or used to create displacement by the movement of the piston. The pressurised air from the compressor is supplied to reservoir. The pressurised air from storage is supplied to pneumatic actuator to do work.

The air cylinder is a simple and efficient device for providing linear thrust or straight line motions with a rapid speed of response. Friction losses are low, seldom exceeds 5% with a cylinder in good condition, and cylinders are particularly suitable for single purpose applications and / or where rapid movement is required. They are also suitable for use under conditions which preclude the employment of hydraulic cylinders that is at high ambient temperature of up to 200 °C to 250 °C

Their chief limitation is that the elastic nature of the compressed air makes them unsuitable for powering movement where absolutely steady forces or motions are required applied against a fluctuating load, or where extreme accuracy of feed is necessary. The air cylinder is also inherently

Limited thrust output by the relatively low supply pressure so that production of high output forces can only be achieved by a large size of the cylinders.

### 1.2. Types of Pneumatics Actuators

Pneumatic cylinders can be used to make linear, rotary and oscillatory motion. There are three types of pneumatic actuator: they are

- 1 Linear Actuator or Pneumatic cylinders
- 2 Rotary Actuator or Air motors
- 3 Limited angle Actuators

### Calculation of cylinder forces - metric based products

#### General Formula

The cylinder output forces are derived from the following formula:

$$F = \frac{P \times A}{10}$$

Where F = Force in N

P = Pressure at the cylinder in Bar

A = Effective area of cylinder piston in square mm.

Prior to selecting the cylinder bore size, properly size the piston rod for tension (pull) or compression (push) loading. (see the piston Rod Selection Chart)

If the piston rod is in compression, use the 'Push Force' table below, as follows:

- 1 Identify the operating pressure closest to that required.
- 2 In the same column, identify the force required to move the load (always round up).
- 3 In the same row, look over to the cylinder bore required.

If the cylinder envelope dimensions are too large for the application, increase the operating pressure, if possible, & repeat the exercise.

**If the piston rod is in tension,** use the 'Deduction for Pull Force' table. The procedure is the same but due to the reduced area caused by the piston rod, the force available on the 'pull' stroke will be smaller. To determine the pull force:

- 1 Follow the procedure for 'push' force as described previously.
- 2 using the 'Deduction for Pull Force' table, identify the force indicated according to the rod & pressure selected.
- 3 Deduct this from the original 'push' force. The resultant is the net force available to move the load.

If this force is not large enough, repeat the process & increase the system operating pressure or cylinder diameter if possible.

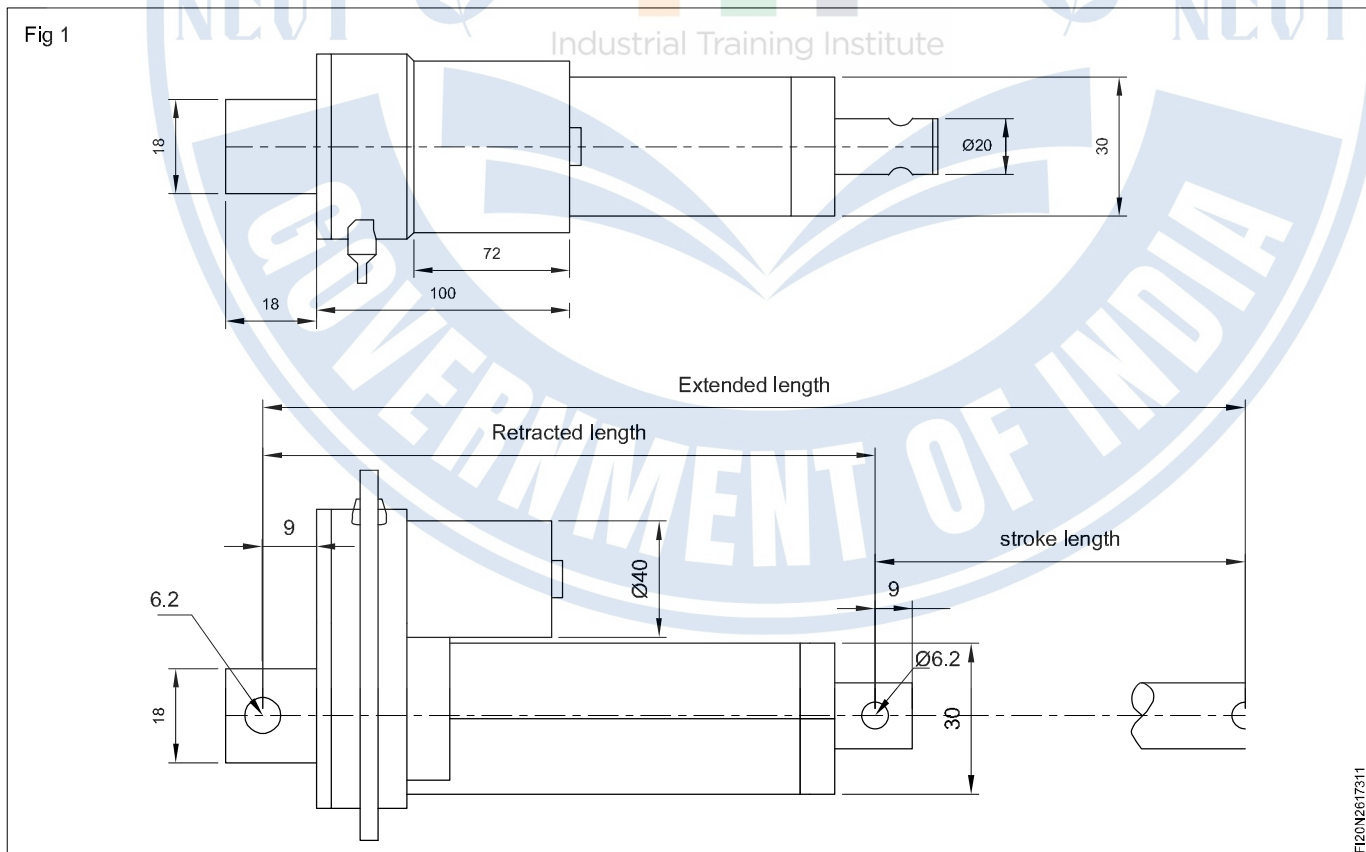
### Deduction for pull force

Piston rod size (mm)	Piston rod Area (mm <sup>2</sup> )	Reduction in Force (N) at various Pressures in Bar			
		1	5	7	10
4	13	1	6	9	13
6	28	3	14	20	28
8	50	5	25	35	50
10	79	8	39	55	79
12	113	11	57	79	113
16	201	20	101	141	201
20	314	31	157	220	314
25	491	49	245	344	491
32	804	80	402	563	804
40	1257	126	628	880	1257

### Push Force

Cylinder Bore size (mm)	Piston Area (mm <sup>2</sup> )	Reduction in Force (N) at various Pressures in Bar			
		1	5	7	10
6	28	3	14	20	28
8	50	5	25	35	50
10	79	8	39	55	79
12	113	11	57	79	113
14	154	15	77	108	154
16	201	20	101	141	201
20	314	31	157	220	314
25	491	49	245	344	491
32	804	80	402	563	804
40	1257	126	628	880	1257
50	1963	196	982	1374	1963
63	3117	312	1559	2182	3117
80	5027	503	2513	3519	5027
100	7854	785	3927	5498	7854
125	12272	1227	6136	8590	12272
160	20106	2011	10053	14074	20106
200	31416	3142	15708	21991	31416

**Stroke** is the distance travelled by an **actuator** in motion. This is a measurement of the capability of a linear **actuator**. ... **Stroke** helps determine key factors such as the weight capacity of the actuator, how much time will it take, the speed of the motion, and the force that can be generated. (Fig 1)



**Single acting cylinder and its application**

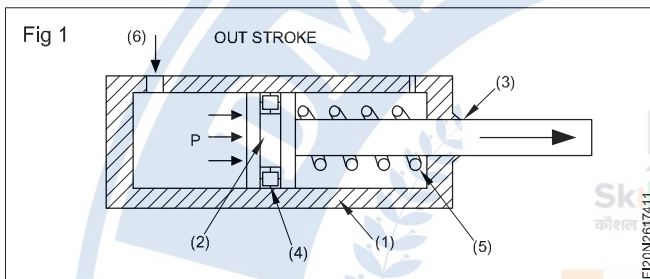
**Objectives :** At the end of this lesson you shall be able to

- identify internal parts of single acting cylinder
- explain working principle of single acting cylinder
- explain working of 3/2 way valve
- interpret circuit to control single acting cylinder.

**Single acting cylinder**

It is an actuator which moves load along the straight line. It can apply pneumatic force only in one direction therefore called single acting. Movement in opposite direction is caused by external force like spring or own weight of the load.

Construction: Construction of single acting cylinder is shown in the Fig 1.



Main parts of single acting cylinder are listed as follows:

- 1 Cylinder
- 2 Piston
- 3 Piston rod
- 4 Seal
- 5 Spring
- 6 Inlet Port

**Working principle of single acting cylinder**

Initially piston remains at the innermost position in the cylinder due to spring force (Fig 1)

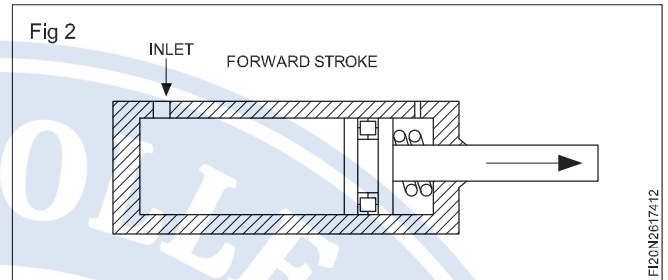
When compressed air is supplied through inlet port, pressure acts on cross section of the piston.

Product of pressure and piston cross section area gives rise to a force which acts opposite to the spring force. If pneumatic force is greater than the spring force then spring gets compressed and piston starts moving.

Seal prevents air leak across the piston.

Continuous flow of air causes continuous motion of piston. Load is attached to piston through piston rod; therefore load also moves with piston.

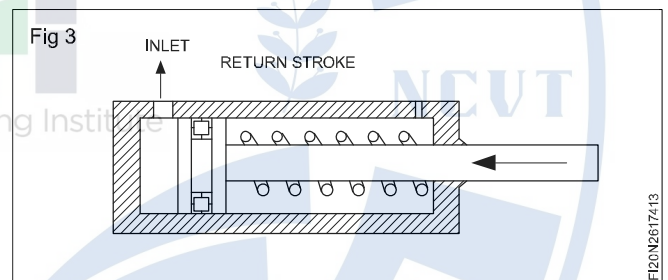
Piston and load move till piston reaches to other end. At the end there is no further space for piston to move, hence piston and load movement stops. (Fig 2)



This piston movement is called forward stroke.

In forward stroke piston rod comes out of the cylinder. If we denote piston by A, then forward stroke is denoted by A

If pressure acting on piston is released, pneumatic force acting opposite to spring becomes weak, therefore spring pushes piston back. (Fig 3)



This stroke is called return stroke.

In return stroke piston rod goes inside the cylinder. Return stroke is denoted by A.

**Direction control of single acting cylinder**

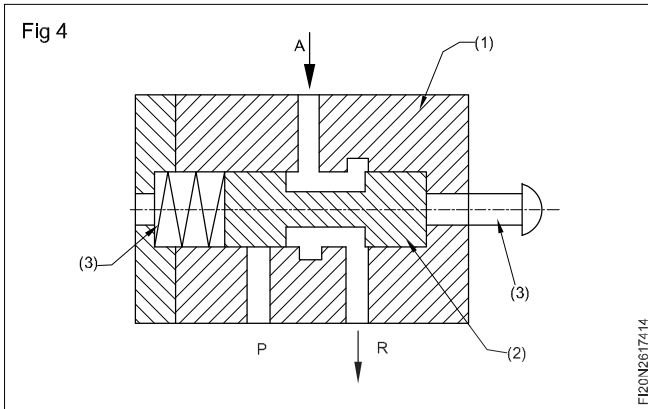
To control single acting cylinder or in other words to push and pull load by single acting cylinder you always need 3 port 2 position direction control valve as main control element.

**Construction of 3 port 2 position valve**

Construction is shown in the Fig 4.

It consists of following parts:

- 1 Valve body
- 2 Spool
- 3 Actuation mechanism: Push button & Spring
- 4 Air flow path
- 5 Ports (P,A,R)



Valve body provides cavity which accommodates spool, internal passage for air flow and actuation mechanism.

Spool is a piston shaped element which when shifts changes air flow path.

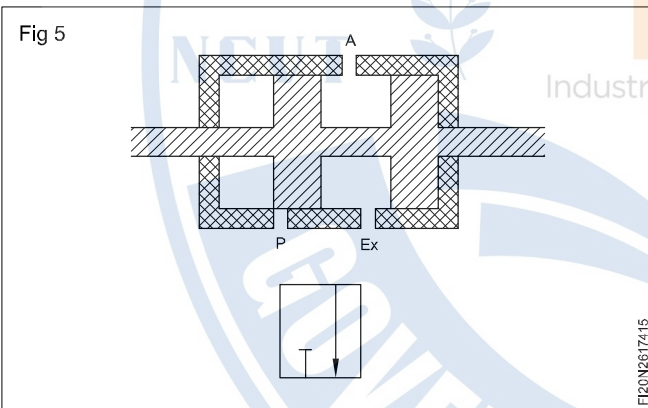
Actuation mechanism provides facility to shift the spool.

Port is a point where you can connect air pipe with the help of connector.

**Working principle of 3 port 2 position valve:**

3 port 2 position valve gives two status or positions of air flow.

Input port is blocked and output is connected to exhaust. In this status compressed air does not flow through the valve. Also output port is connected to exhaust port so that output line remains at atmospheric pressure. (Fig 5)



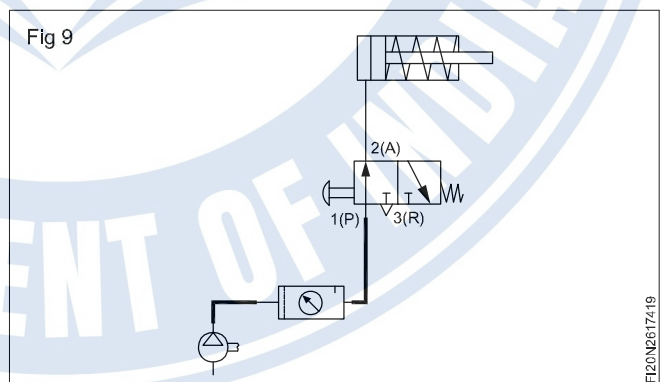
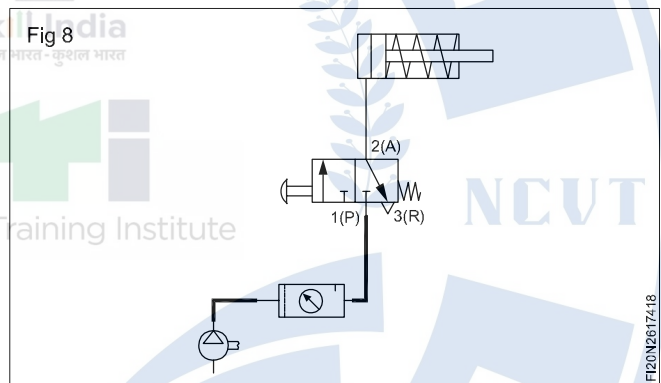
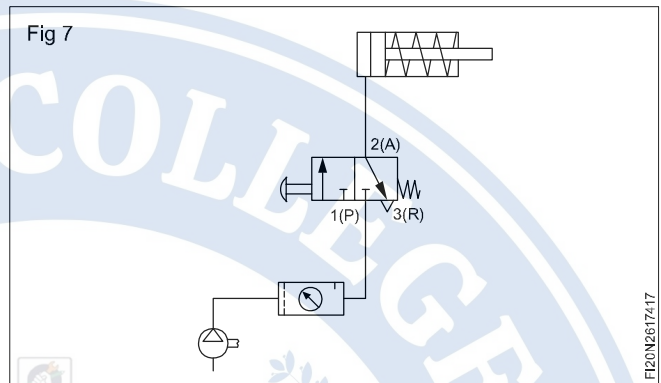
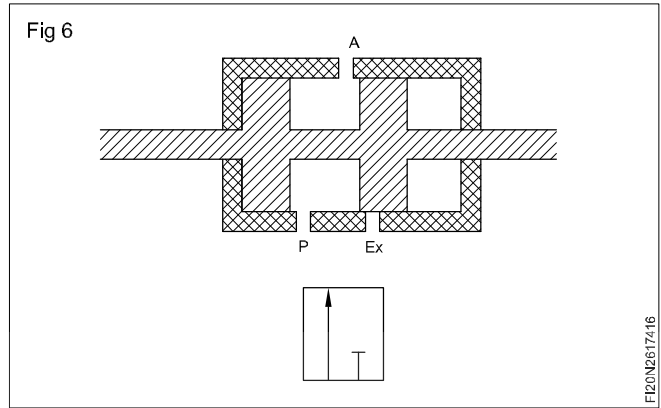
Input port is connected to output port and exhaust port is blocked. In this status compressed air flow through the valve and push the piston. (Fig 6)

Fig 7 shows the circuit to operate single acting cylinder.

When compressor is switched on compressed air is available up to input port "1" (Fig 8)

When push button is pressed, direction of air changes due to valve shift. Piston moves forward. (Fig 9)

Push button is when released piston returns back. (Fig 8)

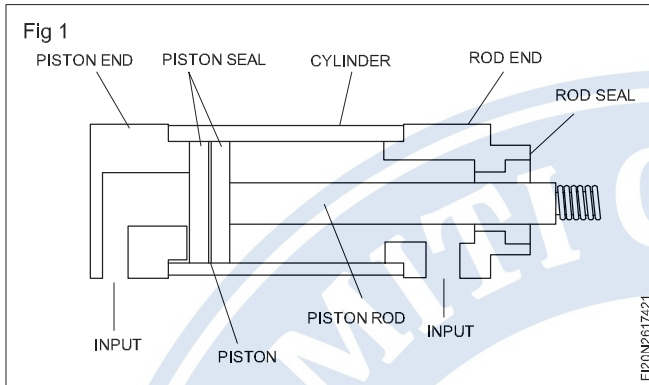


# Double acting cylinder and its application

**Objectives:** At the end of this lesson you shall be able to

- explain working principle of Double Acting Cylinder
- explain operation of 5/2 way valve
- use 5/2 way valve to operate double acting cylinder.

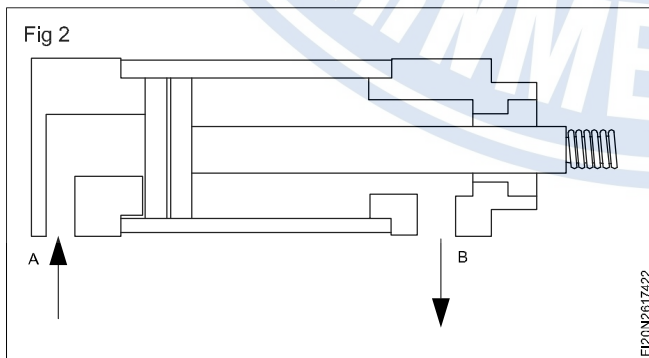
Double acting cylinder is an actuator which can push and pull the load using compressed air. It has two ports for air supply. Fig 1 shows the construction of double acting cylinder.



Input Ports: For air supply

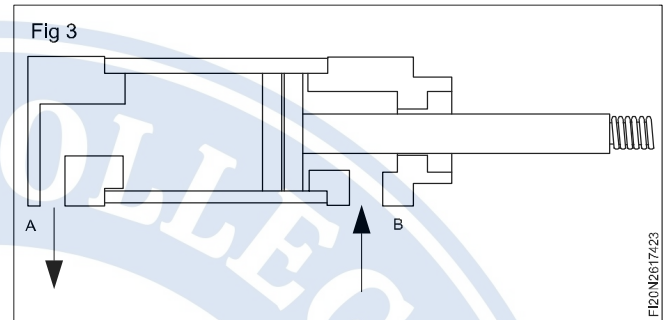
- Piston: Element which moves to and fro inside the cylinder.
- Cylinder: It confines air for the piston movement.
- Piston rod: A rod which connects piston and a load.
- Piston Seal: Seal which prevent leakage across the piston.
- Rod Seal: Seal which prevents air leakage from cylinder to the atmosphere.
- Piston End: Part of the cylinder consisting air passage and connected to the piston side.
- Rod End: Part of the cylinder consisting air passage and connected to the piston side.

When air is supplied through port A, force is exerted on the piston so that it moves in forward direction. This movement is called forward stroke. During forward stroke air already present at the rod side exhausts through port B. (Fig 2)

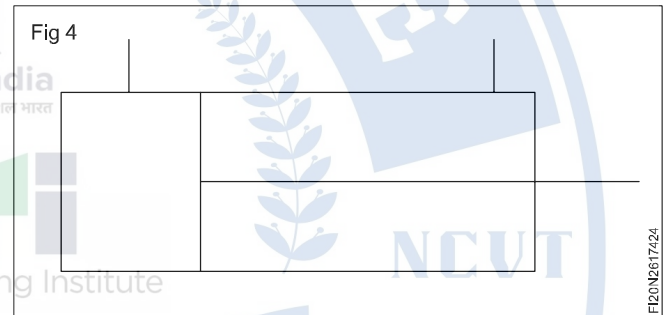


**Piston movement will stop if air does not exhaust.**

When air is supplied through port B, air already present exhausts through port A and piston retracts. (Fig 3)

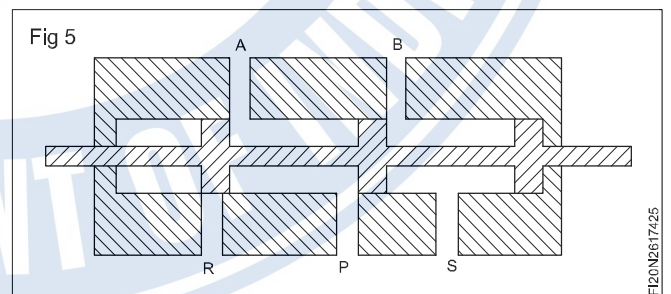


Symbol of double acting cylinder is shown in fig 4



5 port 2 position valve

To operate double acting cylinder it is needed to change the direction of air between ports A & B. Therefore a valve is required which has two output ports. 5 port 2 position valve has two output ports. Construction is shown in fig 5.

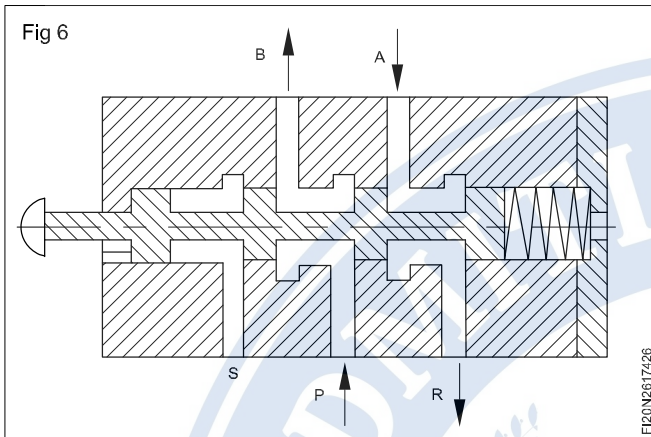


- Valve body: It provide cavity to move spool and ports.
- Spool: It is an element which change flow path when moves inside the valve body.
- Input port: Connection point where air enters into valve. It is denoted by 'P' or number '1'.

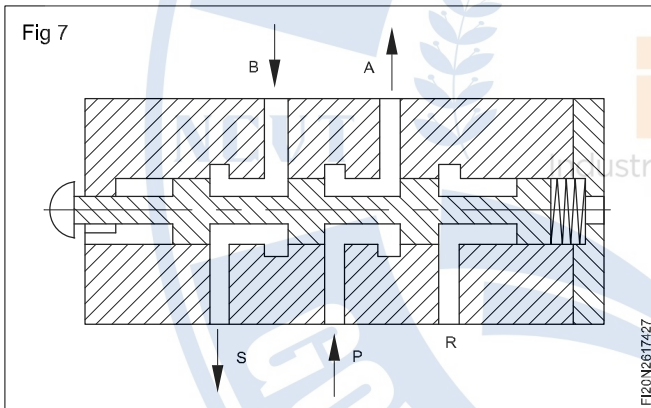
- Output port: Connection points from where air comes out of valve. Output ports are denoted by 'A' & 'B' or number '2' & '4' respectively.
- Exhaust port: Connection points from where air exhausts. Exhaust ports are denoted by 'R' & 'S' or number '3' & '5' respectively.

Position refers to status of direction of air flow path in the valve.

In one position port 'P' is connected to 'B' and port 'A' exhausts through 'R', but exhaust port 'S' closed. (Fig 6)

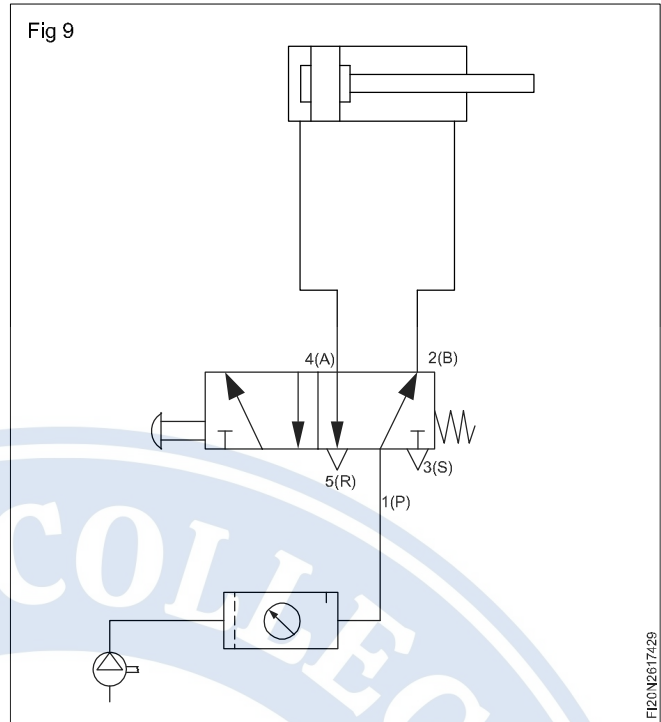
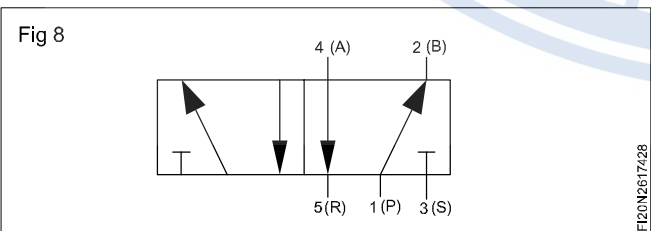


In other position port 'P' is connected to 'A' and port 'B' exhausts through 'S' but exhaust port 'R' is closed. (Fig7)

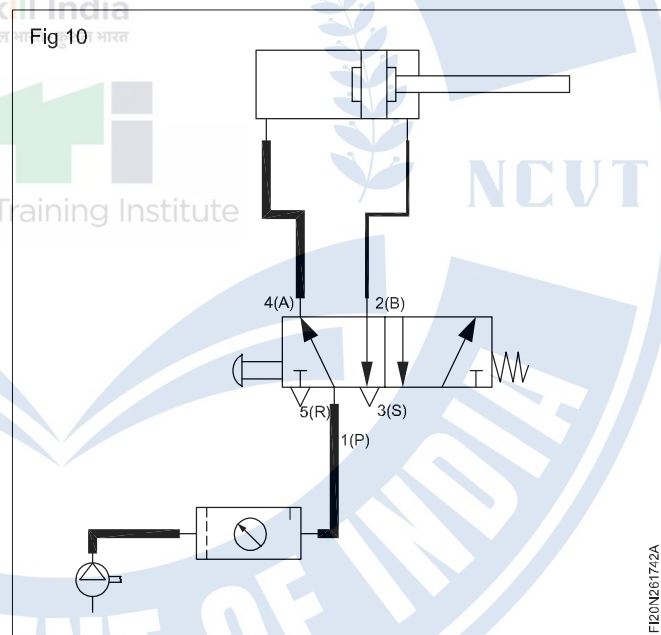


Symbol of 5 port 2 position valve is shown in fig 8

Fig 9 Shows circuit to operate double acting cylinder. initially in normal position (Spring operated position), supply direction is from 1 (p) to 2 (B) and 4 (A) to (R) so that piston is always in retracted position unless actuated. (Fig 9)



When push button is operated air flow path changes inside the valve so that supply direction is 1 (P) to 4 (A) and 2 (B) to 3 (S), thus gauges piston moves forward. (Fig 10)



**Pneumatic valves**

**Objectives:** At the end of this lesson you shall be able to

- state the directional control valve
- list the classification or directional control valve
- state the sealing action in valves
- explain the different types of directional control valve.

Valves are the devices used to control, regulate commence, terminate or change direction of flow and pressure of fluid used in the system.

Valves in pneumatics are grouped according to their function. They are

- Directional control valves
- Non-return valves
- Pressure control valves
- Flow control valves.

These valves will be discussed in the following lessons.

**Directional control valve**

Directional control valves are used to control the (1) direction of flow of the fluid, (2) commencement and termination of the flow of fluid. Direction control valve finds its place in the circuit immediately before the cylinder/air motor.

**Classification of directional control valve**

Directional control valves can be classified according to the following features by virtue of construction and function

- According to the internal design
- According to the number of ports and position
- According to the valve actuating mechanism.

**According to the internal design**

The design of the valve even though not affecting the function, plays an important role in terms of

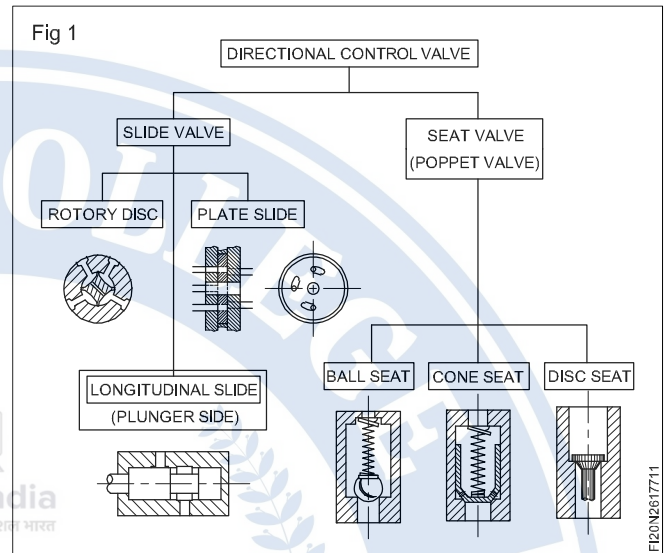
- Life of valve
- Actuating force
- Means of actuation
- Means of connection.

Directional control valves are classified in two major group as shown in Fig 1

**Slide valves**

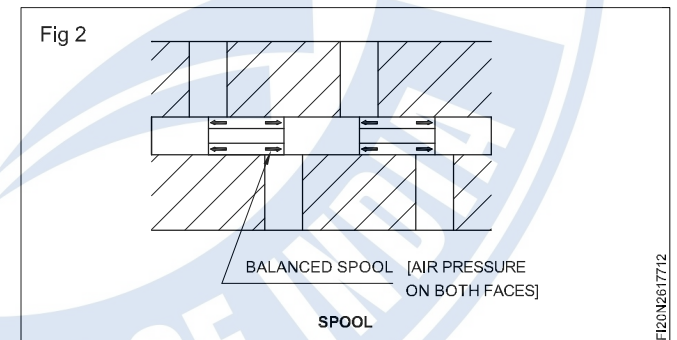
Slide valves are called so, because the opening and closing takes place by sliding of one of its member. Further in slide valve we have

- Rotary disc valve
- Longitudinal slide or spool valve
- Plate slide valve



Slide valves are used extensively in pneumatics because of its advantages like.

- Balanced spool (Fig 2)
- Less force required to actuate



However they have their disadvantages also

- A fine finish and accuracy are required for sliding parts
- Sensitive towards dirt in the air
- Length of actuation is more
- Wear and tear is more
- Life is less.

**Seat valves**

Seat valves are also called as poppet valves. The valve is opened or closed by the lift of seating element.

These valves are further grouped as

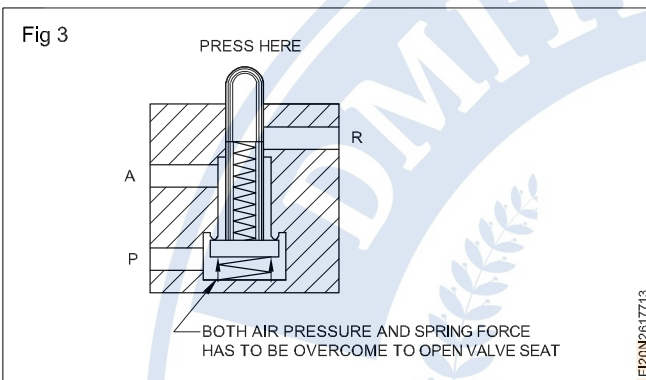
- Ball seat valve
- Cone or taper seat valve
- Disc seat valve.

Seat valve are superior in terms of the following

- Wear and tear is minimum
- Actuating length or lift is very less
- Provides leakproof arrangement
- Long life
- Insensitive to dust/dirt

However these valve also have a few disadvantages

- Force, required to operate is more
- Balancing of force not adequate. (Fig 3)

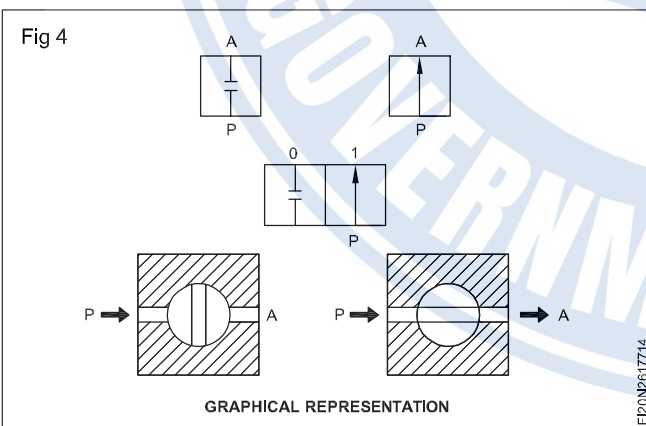


### Valve classification according to the number of ports and position

A directional control valve has a number of ports through which air enters and exits.

It also takes various position according to flow path of air.

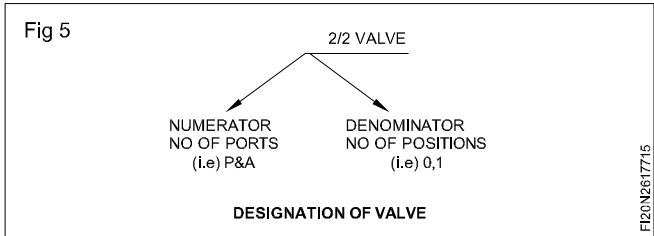
The valve shown has inlet(P) and outlet(A) position. (Fig 4)



It also has two positions.

Initial position - No flow. Final position - Full flow. This is graphically represented as one square for each operating position.

Inside this square the path of flow of air is indicated by arrow marks. The valve shown in the Figs 4 & 5 is designated a 2/2 valve.



The ports are named as follows:

### P - Pressure port

This is to indicate the entry of the compressed air from the compressor into the valve. (which is represented by a square)

A,B,C - working parts

These ports supply air to the cylinder and receive air from cylinder.

R,S,T = Exhaust parts

These are the ports from where used air is exhausted.

X, Y, Z - Control or signal ports.

These ports are used as signal input and signal outputs.

The positions of valves are named as 0, 1 and 2 or 1, 2 according to the type of actuation.

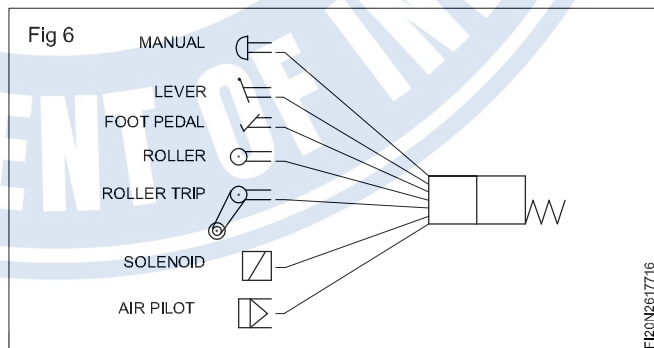
### Valve classification according to the type of actuation

The valves have more than one marking position. For the position to change, an external force is required. The method of actuating the valve plays a very significant role to suit the purpose for which the valve is employed. This also determines the level of automation of the circuit. The actuation is grouped into 2 major groups as

- Spring return valve
- Detent valve

### Spring return

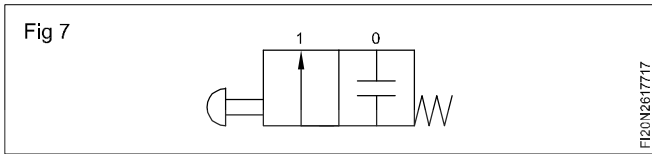
In this mechanism the valve always assumes a particular position because of the spring. When operated it changes its position. Actuation of other end may be of the following types. (Fig 6)



- Manual type
- Levertype
- Pedal type
- Roller type

- Roller trip type
- Solenoid
- Pilot operated

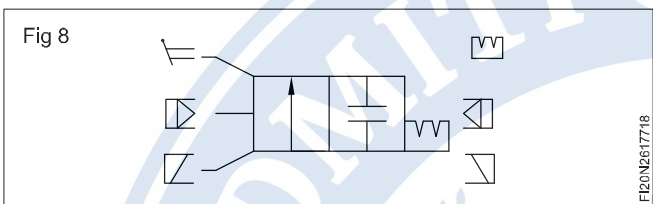
Initial position of a spring return valve is always named as '0' and other position as 1. (Fig 7)



### Detent valve

In this mechanism the change of position of the valve is retained (by latch), unless it is actuated, again. This type of valve is called a detent valve.

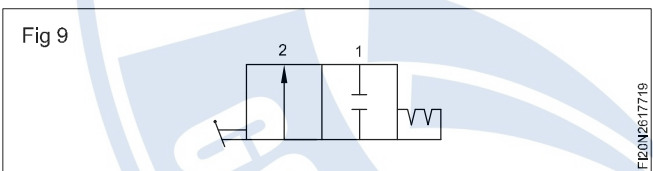
Under this category we have (Fig 8)



- Lever operated
- Impulse operated
- Solenoid operated

The return is also effected by any of the above mechanism.

The positions of these detent valves are indicated as 1 and 2 since it does not have a normal position, that is generally denoted by '0'. (Fig 9)

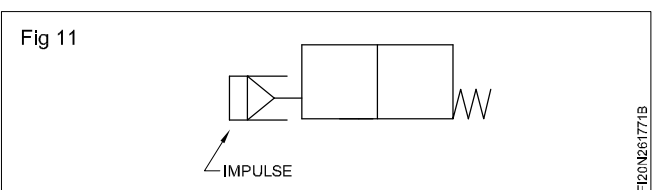
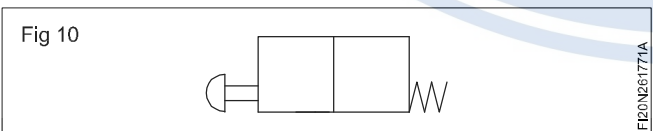


According to the proximity of actuation mechanism from control again actuations can be

- Direct or
- Remote

Direct actuations are hand lever, pedal, roller etc. (Fig 10)

Remote control is by air, air impulse solenoid et (Fig 11)



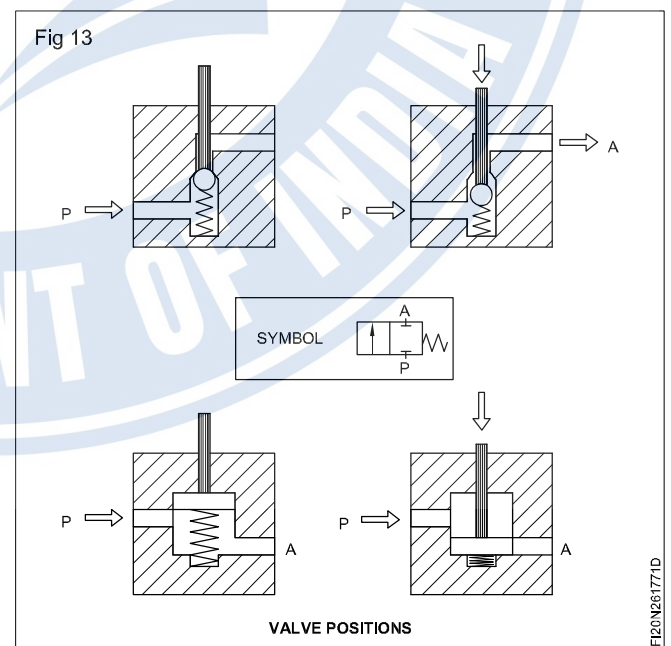
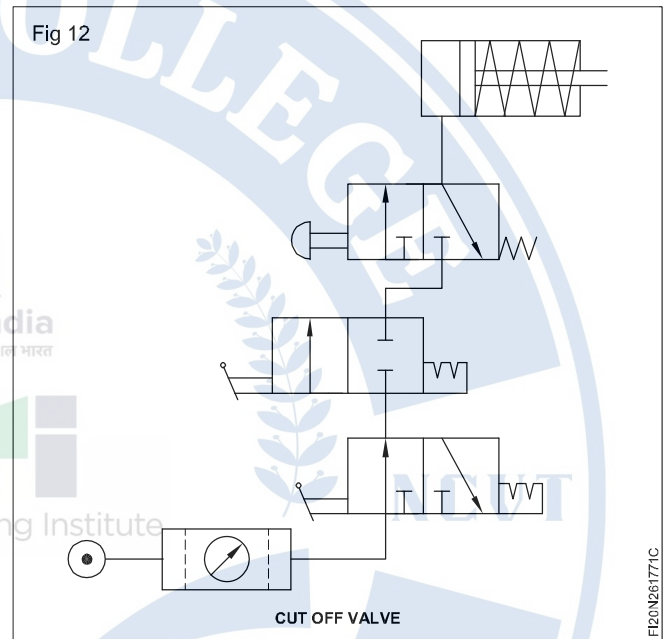
### Various types of directional control valve

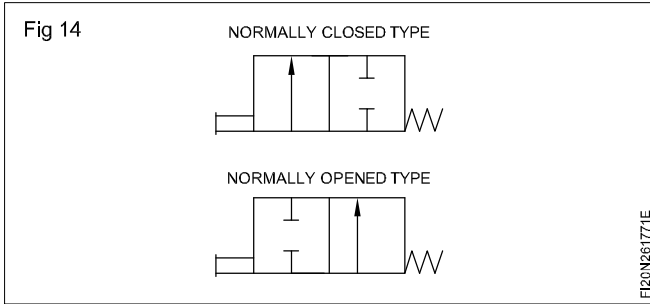
Here we discuss various types of valves according to their function. The type of actuation and constructions are not considered.

### 2/2 directional control valve

This has 2 ports and 2 positions

This valve normally is used for termination and commencement of air flow. This valve ideally serves as a cut-off valve in circuit. For emergency situations a cut-off valve shown in the circuit diagram, (Fig. 12) can stop the cylinder movement, suddenly by cut-off the air supply. The various 2/2 valves according to the internal design are shown in Fig 13 in both normal and operated conditions. These valves can be normally closed type or opened type. (Fig 14)



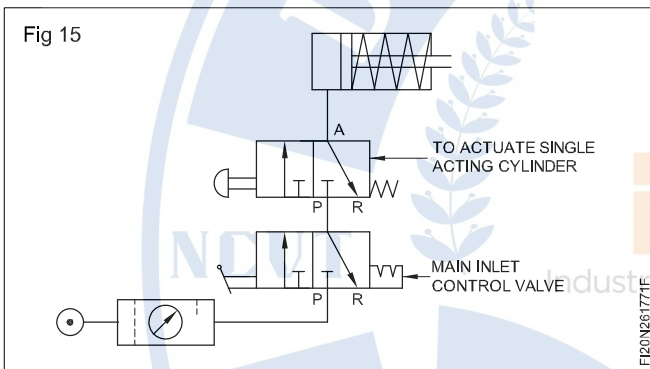


### 3/2 directional control valve

The main advantage of the 3/2 valve is that it gives vent for the used air through the exhaust port. It has 3 ports P, A and R. This facilitates to generate a signal and also to cancel the signal in the valve as shown in the Fig 15 initial position P is blocked, A is connected to R. In the actuated position P gets connected to A, R gets blocked.

A 3/2 valve is ideally suited for an application of inlet valve, and also for actuating a single acting cylinder (Fig 15).

This valve is also very ideal for remote control of main direction control valves as impulse and pilot type. The construction of various 3/2 valves in normal and actuated conditions are shown in Fig 15.



3/2 valves are available as both normally opened type or closed type, which can be selected according to the requirement of the circuit. (Fig 16)

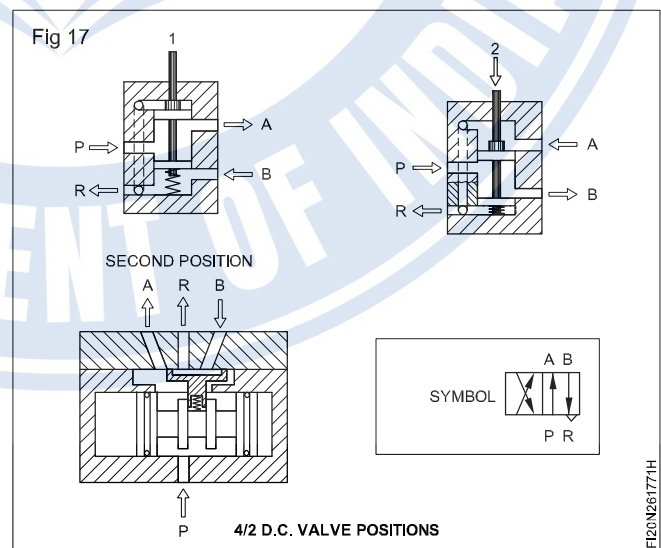
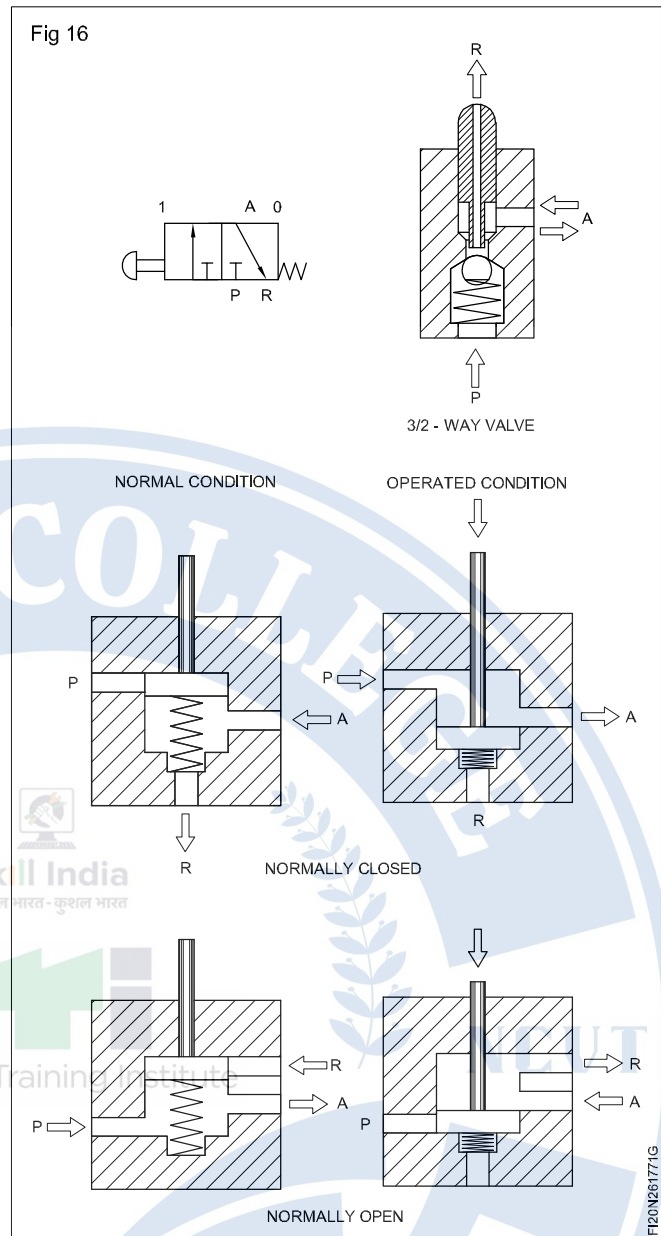
### 4/2 directional valve

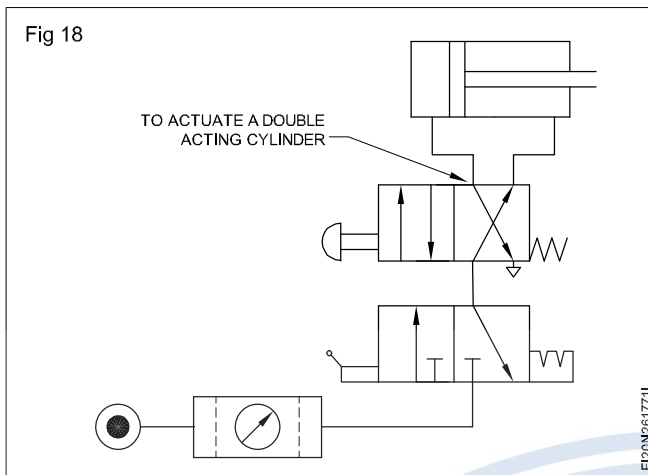
The main application of a 4/2 valve is in actuation of a double acting cylinder. This valve has 4 ports namely

- P - Pressure port
- A & B - Working port
- R - Exhaust port

In normal position (Fig 17) P is connected to A and B is connected to R and vice-versa in the other position.

The application of a 4/2 valve to actuate of double acting cylinder is shown in Fig 18.





### 5/2 directional control valve

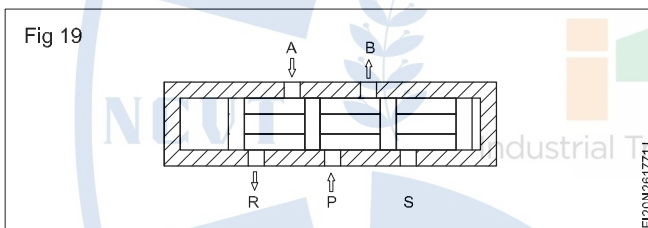
A 5/2 directional control valve functions similar to that of a 4/2 valve, to actuate a double acting cylinder. 5/2 valve has the advantage of having separate exhaust paths for forward and retraction motion, thereby the motion can be controlled independently. 5/2 valve also has advantage in its simple manufacturing process. 5/2 valve has 5 ports

P - Pressure port

A & B - Working ports

R & S - Exhaust ports.

The construction of a 5/2 valve is shown in Fig 19



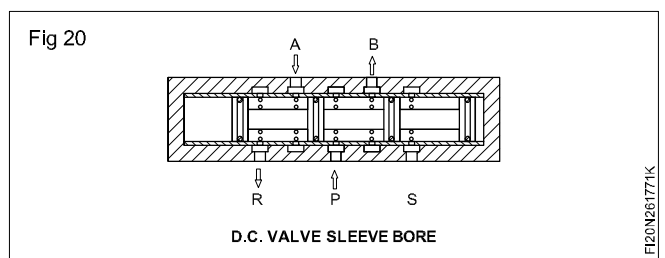
### Sealing action in valves

The body of the valve and the seat or the spool should have minimum leakage between them. This is a very important criteria in the design of valves.

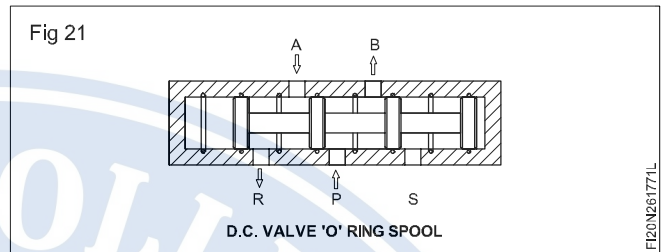
The sealing is done by the following methods.

In spool valves

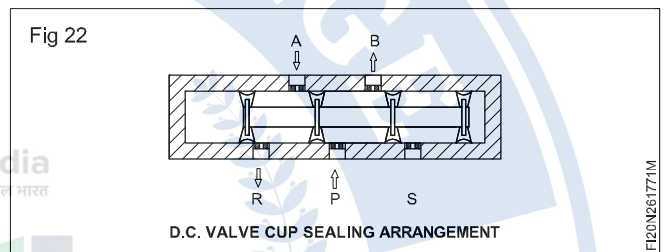
- The bore of the body and spool are matched by super finishing to have a minimum working clearance (Fig 19) and a metal to metal sealing.
- A separate sleeve (Fig 20) is inserted into the body of the valve. The sleeve ID and the spool have a close tolerance, with (Fig 21) 'O' rings on the spool creating a leak proof working.



- 'O' ring mounted on the bore of the body (Fig 21) also helps in sealing.

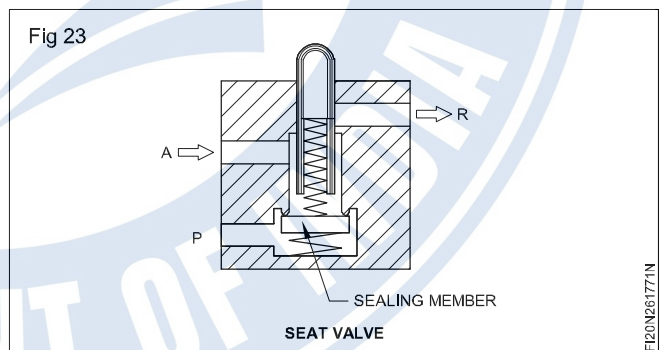


- Cup seats mounted on the spool also helps in having a leak proof (Fig 22) spool movement.



### Sealing in seat valve

In seat valves the seat or the disc is usually made of non-metallic substance like rubber, nylon etc, so as to have perfect sealing of the ports. These valves have better sealing compared to slide valves. Hence seat valves are more reliable. (Fig 23)



# Pneumatic symbols

**Objectives:** At the end of this lesson you shall be able to

- identify components using ISO 1219 symbol
- interpret symbol of direction control valve symbol.

**Symbol:** It is a representation of pneumatic component. Commonly pneumatic symbols are drawn as per IS 1219 standards.

**Symbol does not indicate size of the Component.**

**It does not indicate orientation or arrangement of inner components.**

Symbols use common geometrical shapes which are used to categorise the type of component. The shapes used in general are:

Square: It represents a valve.

Circle: It represents compressor, pneumatic motor and gauge.

Line: it represents piping.

Diamond: It represents filter, dryer, lubricator.

Cylinder: It represents receiver.

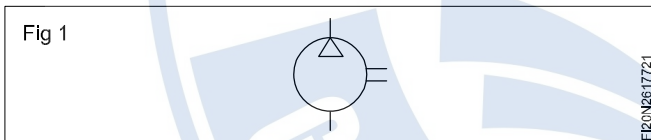
Rectangle: It represents cylinders.

Dotted box: It represents an assembly of various components.

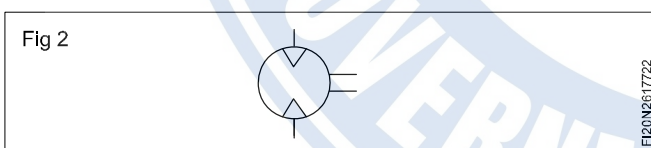
Triangle: It represents pneumatic energy i.e. service air.

Symbol with circle:

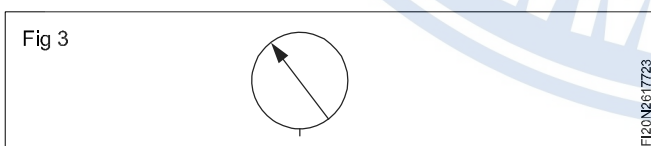
Unidirectional (Fig 1)



pneumatic Motor (Fig 2) Bidirectional

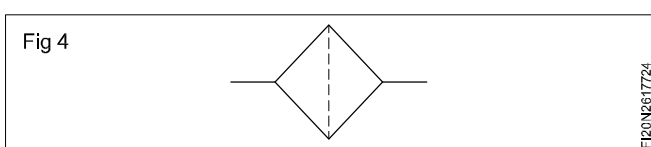


Pressure Gauge (Fig 3)

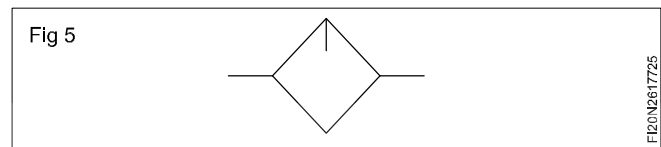


Symbol with diamond shape

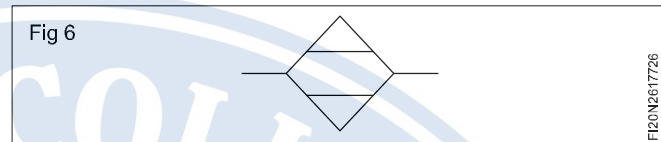
Filter (Fig 4)



Lubricator (Fig 5)

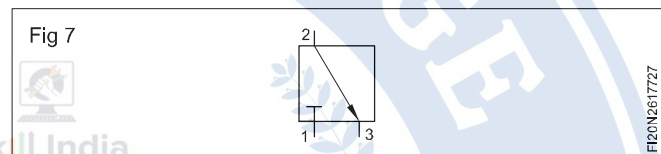


Dryer (Fig 6)



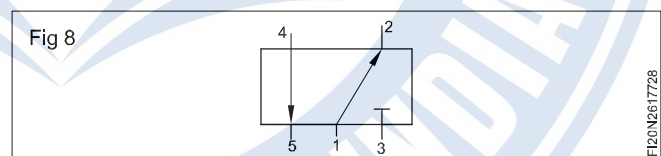
**Symbol with square**

As explained earlier square means valve. Look at the fig 7 given below.



In this figure three extended lines 1, 2, & 3 are shown which show that the port means where you connect pipes. Arrow inside the square shows the path of air flow inside the valve. The figure shows port 1 is closed but port 2 & 3 are connected internally.

In figure 8 there are 5 ports namely 1, 2, 3, 4 & 5 where you can connect pipes. The figure shows that ports 1 & 2 are connected such a way that flow direction is from 1 to 2, similarly ports 4 & 5 are connected in such a way that flow direction is 4 to 5. But port 3 is closed.



The port numbering has certain meaning as follows:

**Input port:** Port where incoming compressed air is connected. It is always "1" and also represented by port "p".

**Output port:** From where air comes out of the valve is always even number "2" and "4". Output ports are also represented by port "A" & "B".

**Exhaust port:** From where air is vented to the atmosphere is always odd number "3" and "5". Output ports are also represented by port "R" & "S".

**Types of Valves**

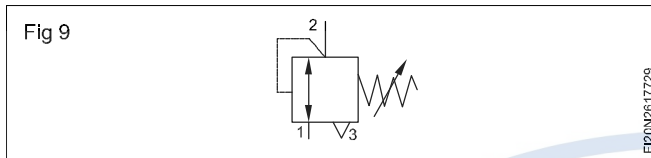
There are three types of valves used in pneumatic system.

**Pressure Valve:** Used to control pressure there by force in the pneumatics. It is always represented by single square.

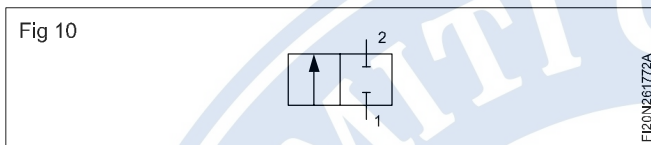
**Direction control valve:** Used to control the direction of movement of load connected to piston rod; like forward or reverse, clockwise or counter clockwise. It is always represented by combination of minimum two squares.

**Flow control valve:** Used to control speed of load, in this case square is not used.

**Pressure Regulator:** Symbol of pressure regulator is shown in Fig 9



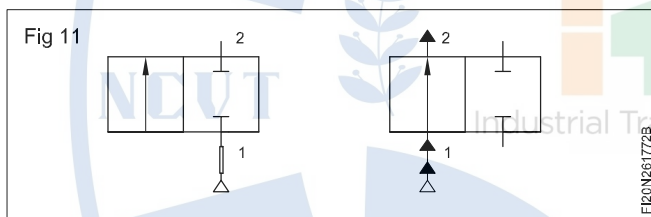
**Direction control valves:** Look at the symbol shown in Fig 10



In this symbol there are two squares drawn side by side. A square indicates position, thus right square indicate one position and left square other position.

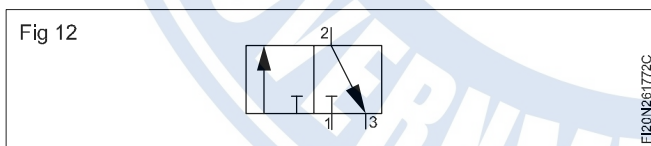
Position refers to status. In the right position port 1&2 are closed, but in the left position both ports are connected.

Let us compare the two positions as shown in Fig 11.

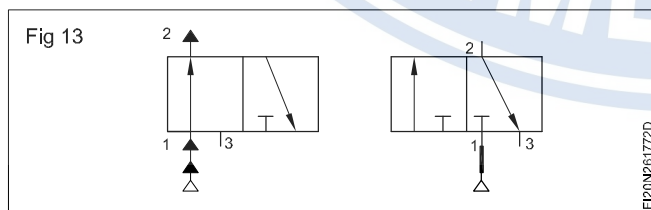


In this valve there are 2 ports and 2 positions, hence called two port two position valve or simply 2/2 way valve.

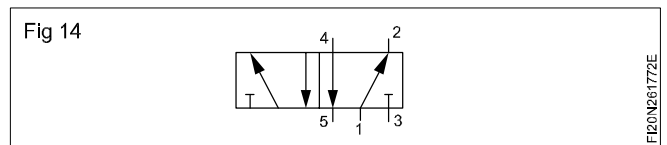
**3/2 Way valve:** By name it is clear this valve is having 3 ports and 2 position. Symbol is shown Fig 12



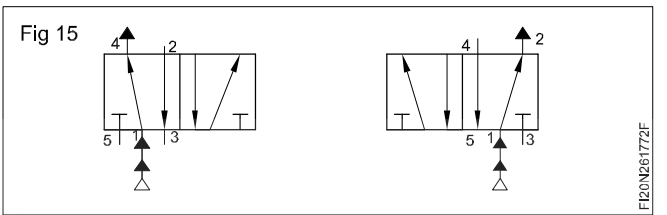
Compare the two positions as shown in fig 13



**5/2 Way valve:** By name it is clear this valve is having 5 ports and 2 position. Symbol is shown in Fig 14



Compare the two positions as shown in Fig 15



### Actuation Type

It is a device which indicates how to operate the valve There are several types available but our scope is limited to following types.

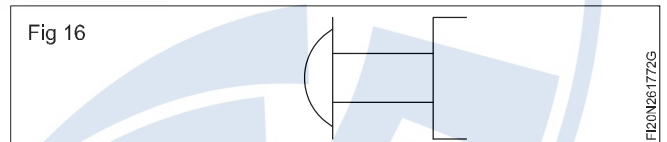
- Manual Type
- Mechanical Type
- Pilot Type
- Solenoid Type

### Manual Type

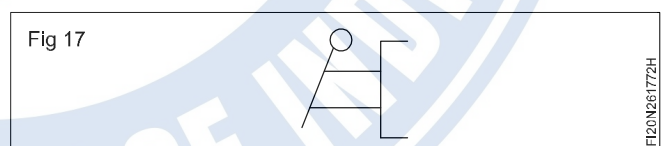
This mechanism is operated by a person, like

- Push Button
- Lever
- Foot pedal

**Push Button:** It is a button type device when pressed by operator valve actuates (Fig 16)

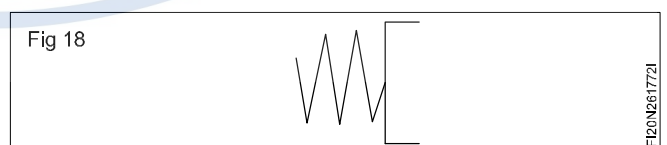


**Lever:** It is a handle type device when pressed by operator valve actuates (Fig 17)

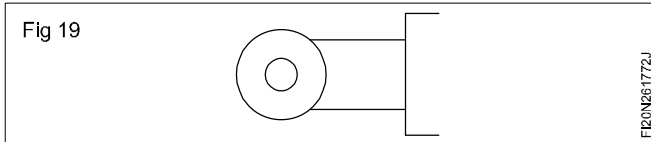


**Mechanical Type:** Valve is operated by some mechanical force.

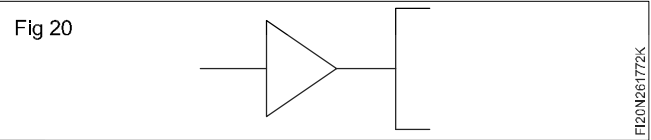
**Spring:** Common compression spring which actuates valve on de-compression (Fig 18)



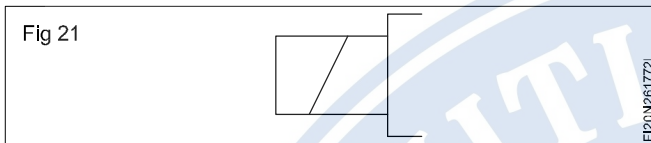
**Roller:** It is like a lever with small wheel type device when pressed by some object valve actuates (Fig 19)



**Pilot:** It is air operated type (Fig 20)



**Solenoid:** It is electrical operated type (Fig 21)



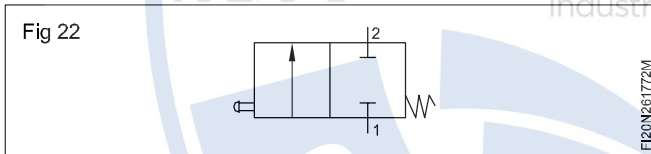
Identifying the direction control valve

To identify direction control valve follow the procedure given below.

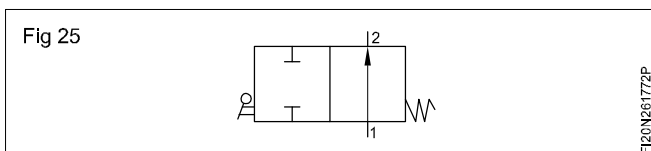
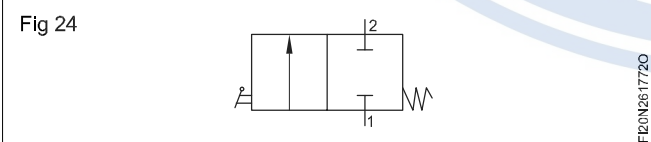
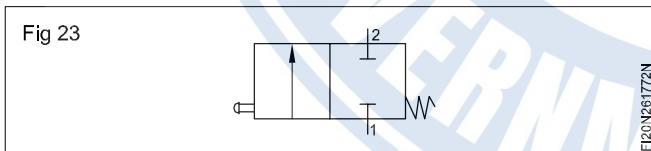
- Identify number of ports.
- Identify number of positions.
- Identify actuation mechanism.
- Observe air flow path in the symbol, in each position.

Observe the symbol given in Fig 22

In the fig 22



**Symbol**



- No of ports: Two (1 & 2)
- No of positions: Two; (2 Squares)
- Actuation methods: Push Button (at left side), spring (at right side)

Write this information in the format given:

-----Port-----Position-----operated-----return

So you get:

2 port 2 position push button operated spring return Direction control valve. Whenever you observe spring in the symbol it means "Normal" position exists. Normal position refers to predominant unactuated condition.

In the symbol shown in Fig 22, right side position is achieved due to spring when there is no force applied on push button, means right side position is the normal position.

**It is important to note that whether input port (1 or p) is open or closed in normal position.**

**If input port is closed, we say normally closed valve.**

**If input is connected to output port (2,4 or A, B then we say normally open valve:**

In the symbol shown above, in normal position input port is closed therefore valve is normally closed valve.

We can rewrite complete designation of the valve as follows:

2 port 2 position push button operated spring return normally closed Direction Control Valve.

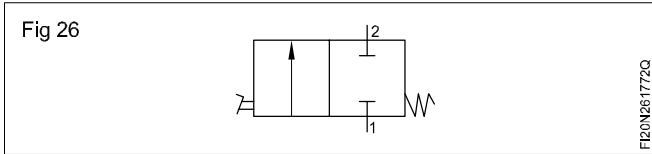
Lets try to identify valves given in the next pages. (Fig 23 to Fig 59)

**Designation**

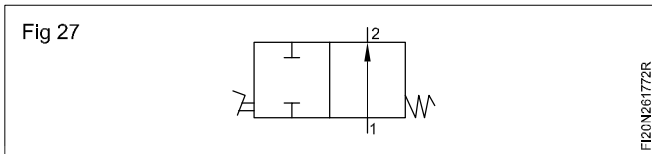
2 port 2 position push button operated spring return normally closed Direction Control Valve.

2 port 2 position lever operated spring return normally closed Direction Control Valve.

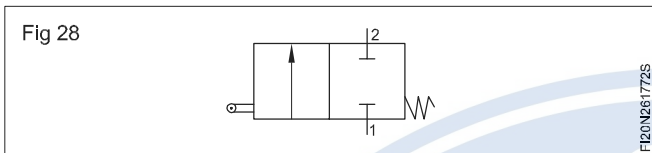
2 port 2 position lever operated spring return normally open Direction Control Valve.



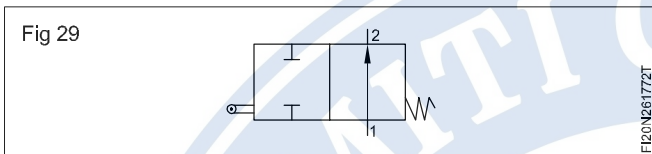
2 port 2 position foot pedal operated spring return normally closed Direction Control Valve.



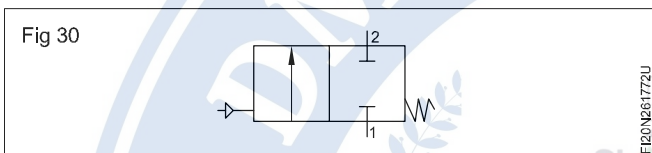
2 port 2 position foot pedal operated spring return normally open Direction Control Valve.



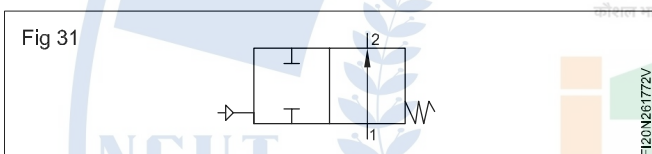
2 port 2 position roller operated spring return normally closed Direction Control Valve.



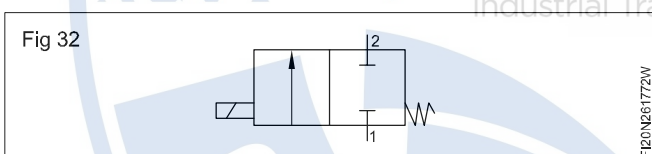
2 port 2 position roller operated spring return normally open Direction Control Valve.



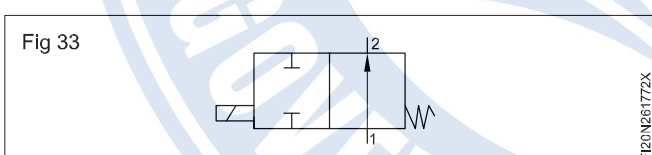
2 port 2 position pilot operated spring return normally close Direction Control Valve.



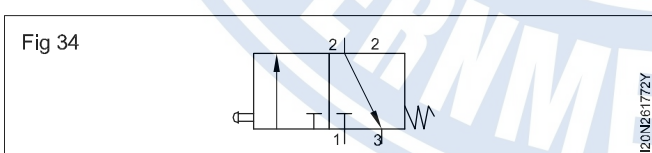
2 port 2 position pilot operated spring return normally closed Direction control Valve.



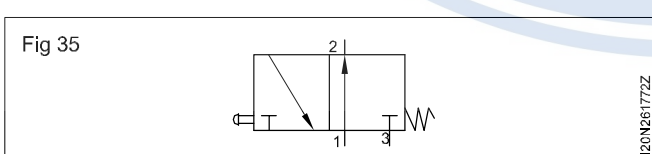
2 port 2 position Solenoid operated spring return normally closed Direction Control Valve.



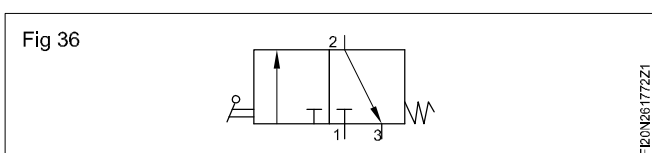
2 port 2 position Solenoid operated spring return normally open Direction Control Valve.



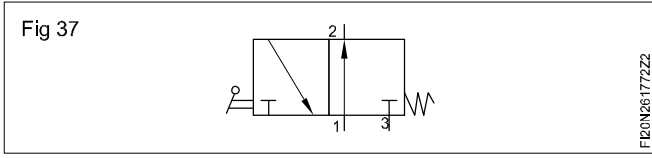
3 port 2 position push button operated spring return normally closed Direction Control Valve.



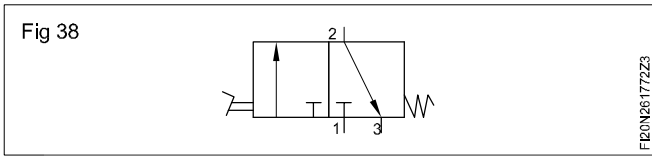
3 port 2 position push button operated spring return normally open Direction Control Valve.



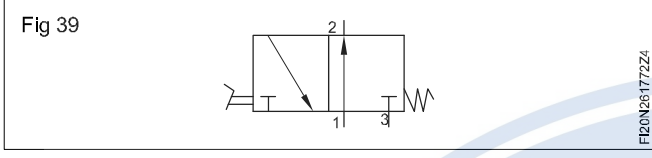
3 port 2 position lever operated spring return normally closed Direction Control Valve.



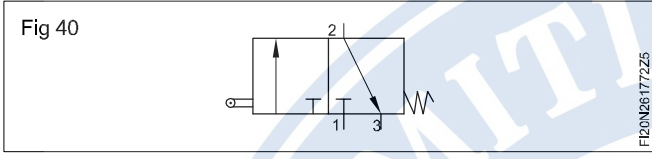
3 port 2 position lever operated spring return normally open Direction Control Valve.



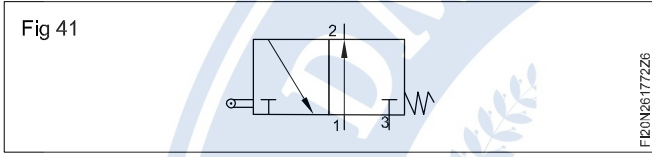
3 port 2 position foot pedal operated spring return normally close Direction Control Valve.



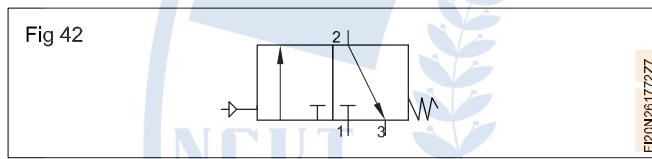
3 port 2 position foot pedal operated spring return normally open Direction Control Valve.



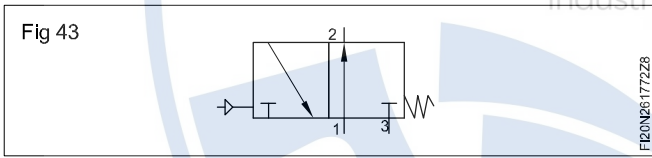
3 port 2 position roller operated spring return normally close Direction Control Valve.



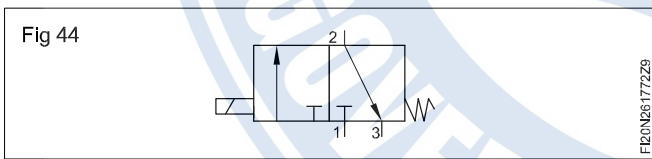
3 port 2 position roller operated spring return normally open Direction control Valve.



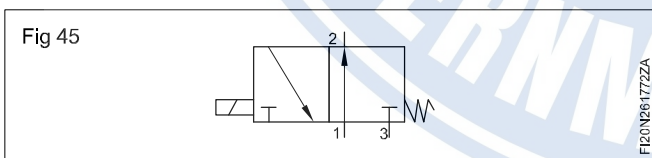
3 port 2 position pilot operated spring return normally close Direction Control Valve.



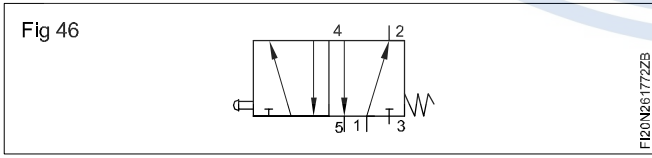
3 port 2 position pilot operated spring return normally open Direction Control Valve.



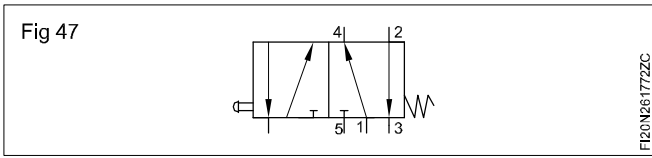
3 port 2 position solenoid operated spring return normally close Direction Control Valve.



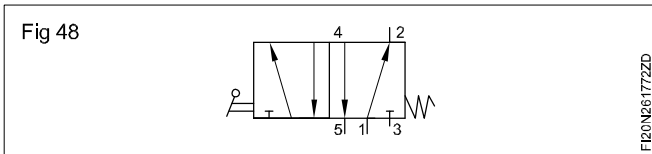
3 port 2 position solenoid operated spring return normally open Direction Control Valve.



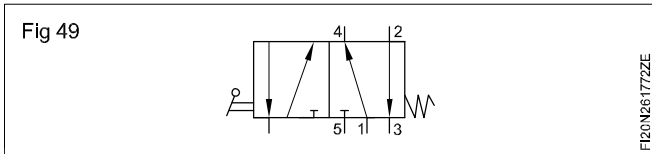
5 port 2 position push button operated spring return Direction Control Valve, normally 1 is connected to 2.



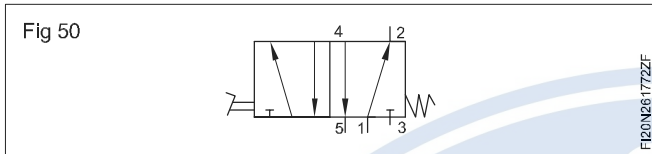
5 port 2 position push button operated spring return Direction Control Valve, normally 1 is connected to 4.



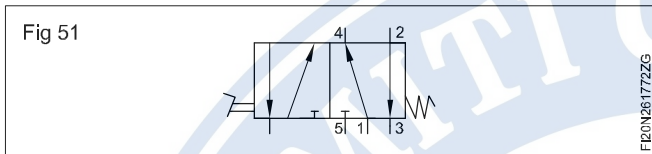
5 port 2 position lever operated spring return Direction control valve, normally 1 is connected to 2.



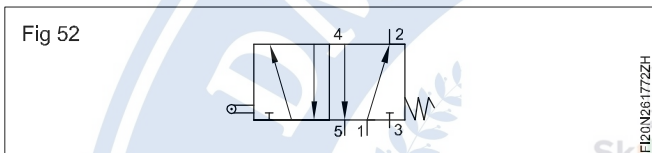
5 port 2 position lever operated spring return Direction Control Valve normally 1 is connected to 4.



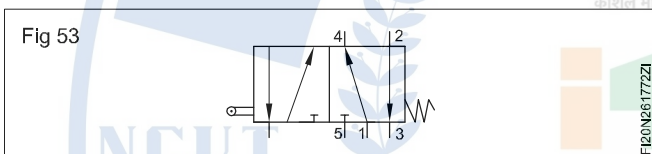
5 port 2 position foot pedal operated spring return Direction Control Valve normally 1 is connected to 2.



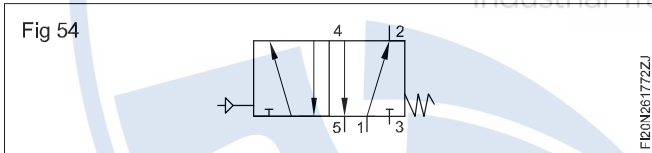
5 port 2 position foot pedal operated spring return Direction Control Valve normally 1 is connected to 4.



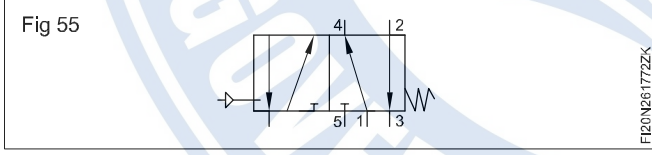
5 port 2 position roller operated spring return Direction Control Valve normally 1 is connected to 2.



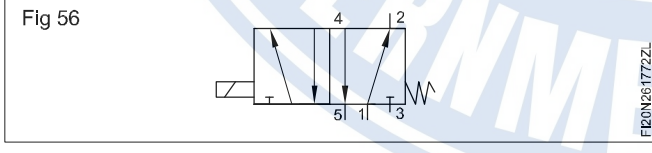
5 port 2 position roller operated spring return Direction Control Valve normally 1 is connected to 4.



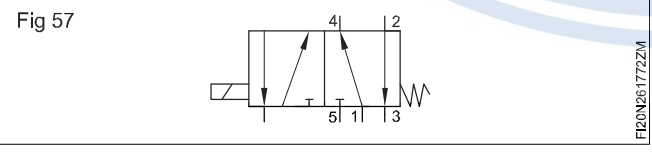
5 port 2 position pilot operated spring return Direction Control Valve normally 1 is connected to 2.



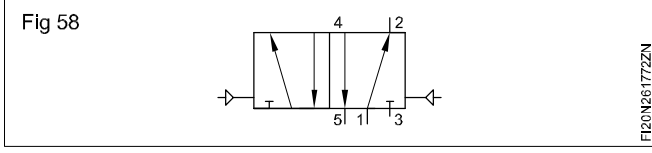
5 port 2 position pilot operated spring return Direction Control Valve normally 1 is connected to 4.



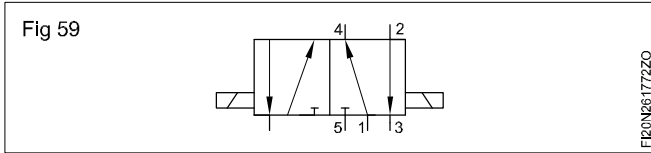
5 port 2 position solenoid operated spring return Direction Control Valve, normally 1 is connected to 2.



5 port 2 position Solenoid operated spring return Direction Control Valve, normally 1 is connected to 4



5 port 2 position double pilot operated Direction Control Valve.

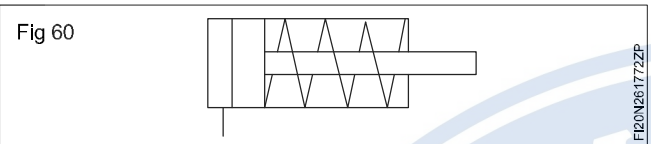


5 port 2 position double solenoid operated Direction Control Valve.

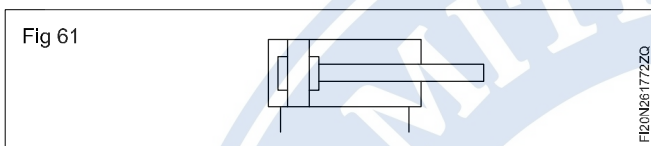
### Symbol with Rectangle

In general rectangle is used to represent linear actuator like single acting cylinder and double acting cylinder.

Single acting cylinder (Fig 60)



Double acting cylinder (Fig 61)



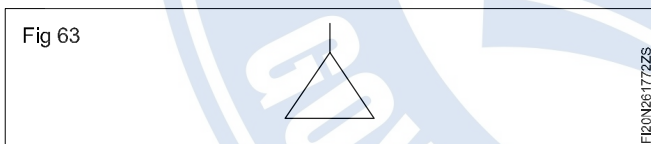
Symbol with cylinder:

In general cylindrical shape is used to represent air receiver or air storing device (Fig 62).



Symbol with triangle:

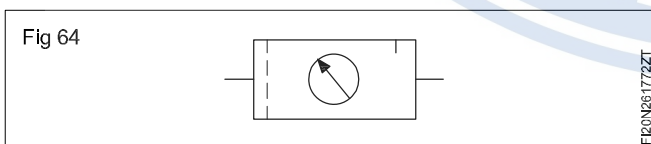
In general triangular shape is used to represent air source (Fig 63).



Symbol with dotted box:

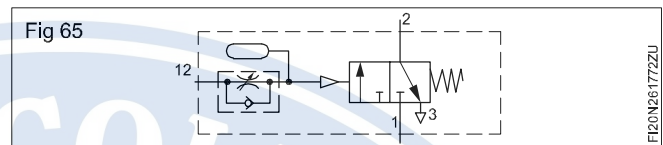
Symbol shown in dotted box represents assembly of components like FRL, Time delay valve.

FRL: It is an assembly of Filter, regulator and lubricator. (Fig 64).



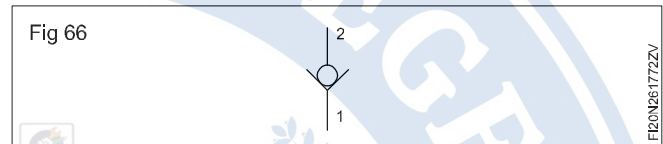
Time delay valve

It is an assembly of flow control valve, 3/2 way valve and an air receiver (Fig 65.)

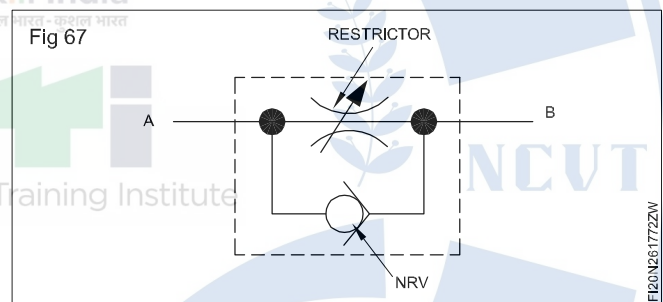


Other Symbols

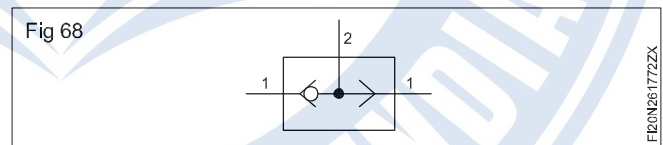
Non return valve (Fig 66)



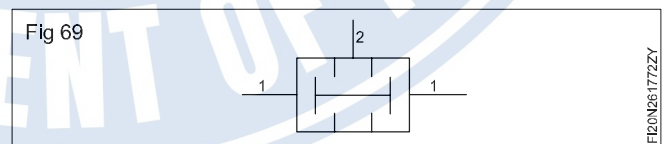
Flow control valve (Fig 67)



Shuttle valve (Fig 68)



AND valve (Twin pressure valve) (Fig 69).



**Non-return valve/check valve**

**Objectives :** At the end of this lesson you shall be able to

- name the parts of a non-return valve
- state the working principle of a non-return valve
- differentiate between swing and ball type check valves.

**Non-return valve**

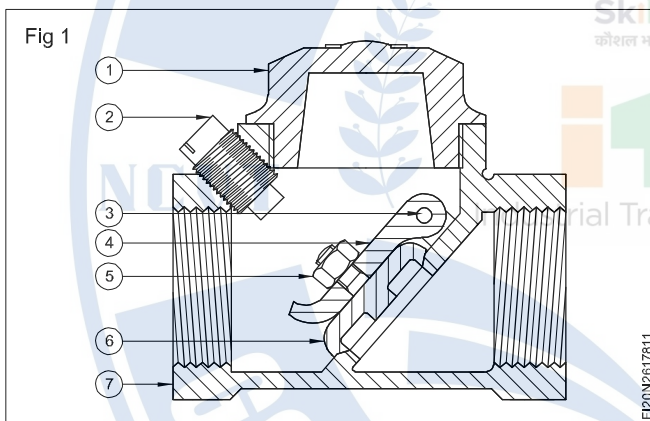
Water supply piping systems use several mechanical devices to control and regulate the fluids and gases flowing through them.

The non-return valve allows one-way flow in water supply or drainage lines. It is also called a check valve. Valves are made of cast iron, brass, bronze or plastic.

Sometimes two or more different kinds of material are used on a single valve. There are many types of check valves available in the market.

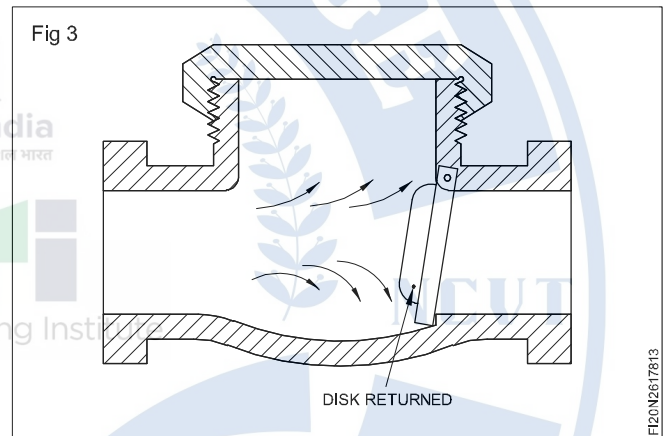
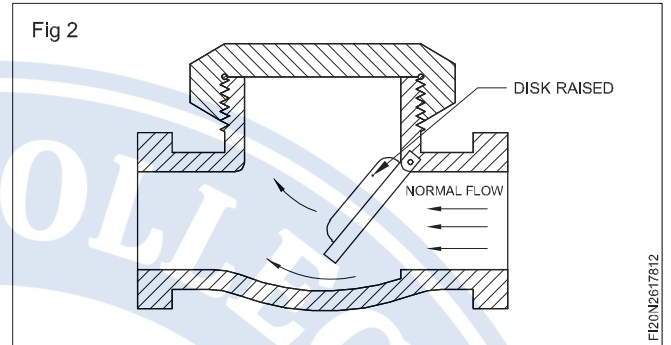
The swing check valve consists of the following parts. (Fig 1)

- 1 Cap

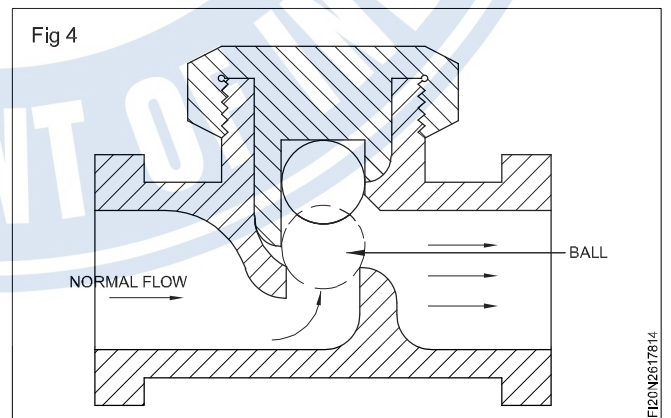


- 2 Stop plug
- 3 Hinge pin
- 4 Hinge
- 5 Disc hinge nut
- 6 Disc
- 7 Body

In the swing check valve, the flow of a fluid or gas in one direction lifts the disc and allows one-way flow only. The return of the disc to its seating position prevents the flow in the reverse direction. (Figs 2 & 3)



In the ball-type check valve, the flow of a fluid or gas in one direction lifts the ball; when the pressure is released the ball falls against its seating and prevents flow in the reverse direction. (Fig 4)



# Flow control valve

**Objectives :** At the end of this lesson you shall be able to

- explain the flow control valve
- state the difference between variable and one way flow control valve
- interpret and draw meter - in speed control hydraulic control
- explain meter - out speed control method
- explain bleed - off speed control circuit and its function.

The purpose of flow control in a hydraulic system is to regulate speed of a cylinder or the R.P.M. of a motor. Since both values are dependent on the flow rate, however constant pumps supply a uniform flow rate.

Reduction in the flow rate is achieved according to the following principle

A reduction in the flow cross - section in the flow control valve causes an increase in pressure ahead of this. This pressure causes the pressure relief valve to open and flow rate is divided. This division of the flow rate causes enough flow volume required for the r.p.m. or speed to flow to the actuator and the excess delivery to be discharged via pressure relief valve.

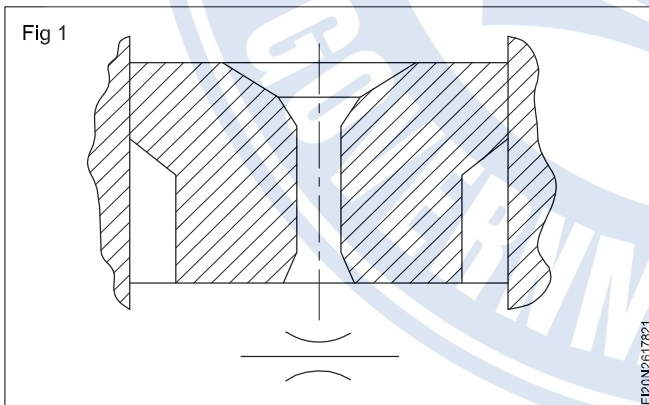
Flow control valve is a orifice or restrictor in hydraulic system.

### Orifices

- A simple orifice is the most elementary method for controlling flow.
- The orifice is always placed in series with the pump.
- A fixed orifice can be a drilled hole in a fitting, but variable orifice is a calibrated needle valve.

### Fixed orifice (Fixed flow control valve)

Fixed orifice is a simple small opening in line which is not variable. (Fig 1)

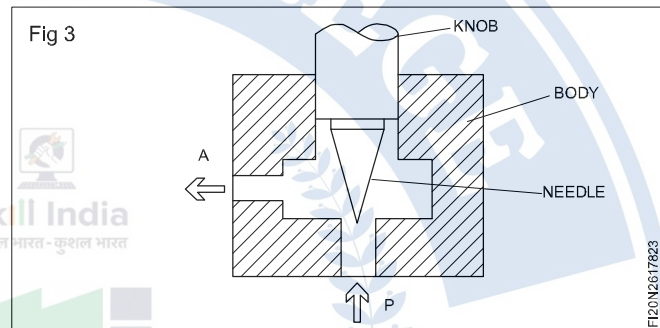
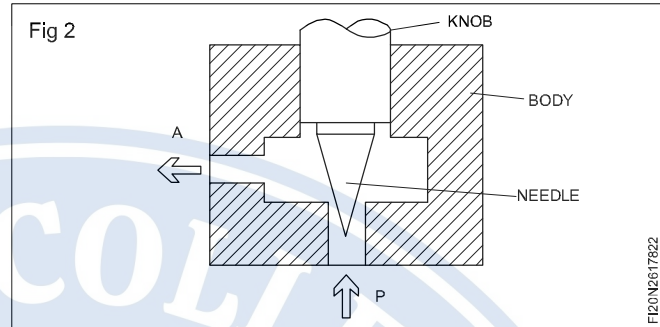


### Variable flow control valve

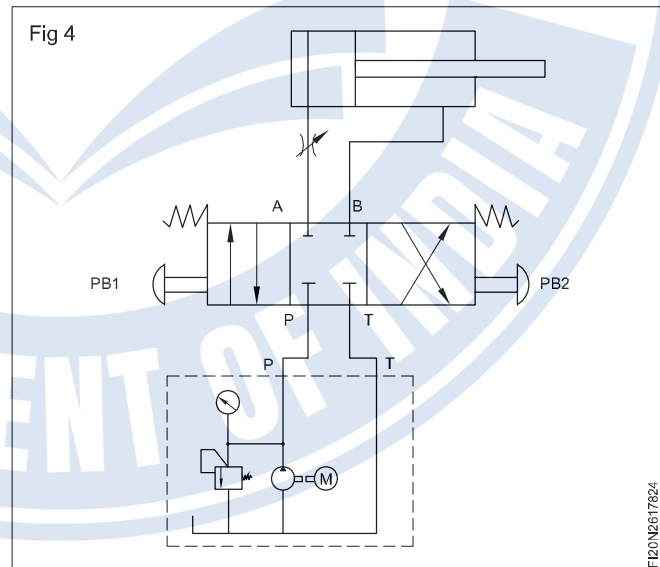
Throttle and orifice valves are used to achieve a certain pressure drop. This is done by creating a specific flow resistance.

If needle of flow control valve moves closer to the seat then opening is less and flow also reduced. (Fig2)

When needle move away from valve seat (Fig 3) opening increases and flow also increases.



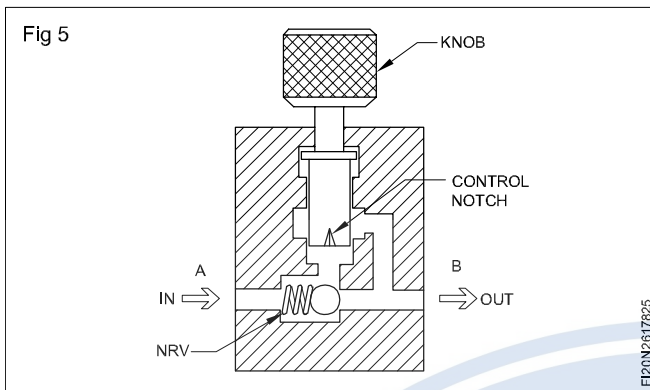
One advantage of this design is that it is simple and inexpensive. Hydraulic circuit diagram with variable flow control valve is given below in fig 4



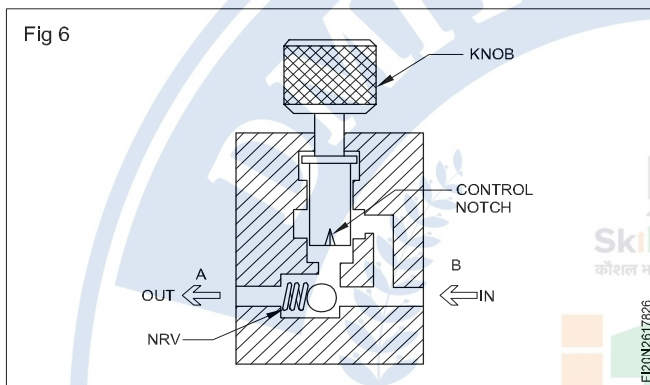
### One - way flow control valve

The one - way flow control valve is a combination of an orifice or throttle valve and a non - return valve. The restrictor controls the flow rate in a single direction dependent on flow. In the opposite direction, the full cross - sectional flow is released and the return flow is at full, pump delivery.

The flow is throttled in the flow direction from A to B. So less flow is going inside the actuator and speed of actuator is reduced. (Fig 5)



Flow is not restricted in the opposite direction from B to A because the non - return valve is lifted from its valve seat and the full cross - section flow is released. (Fig 6)



With adjustable one - way flow control valves, the throttling point can either be enlarged or reduced.

### Speed - control Methods

Three methods are generally used to control the speed of actuator

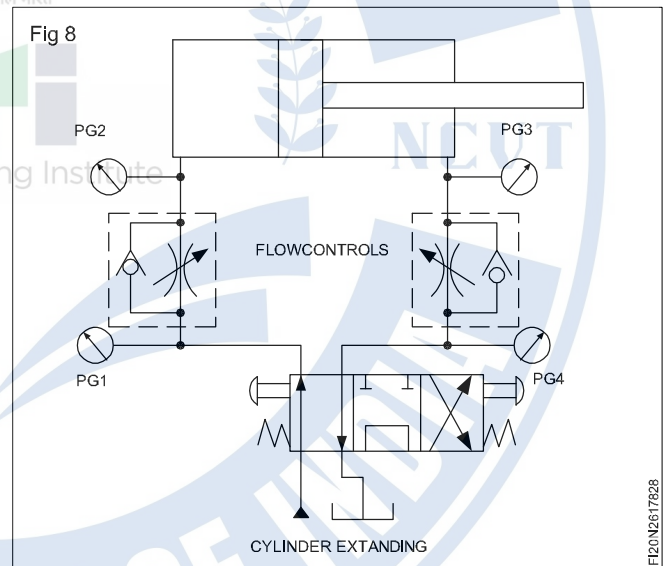
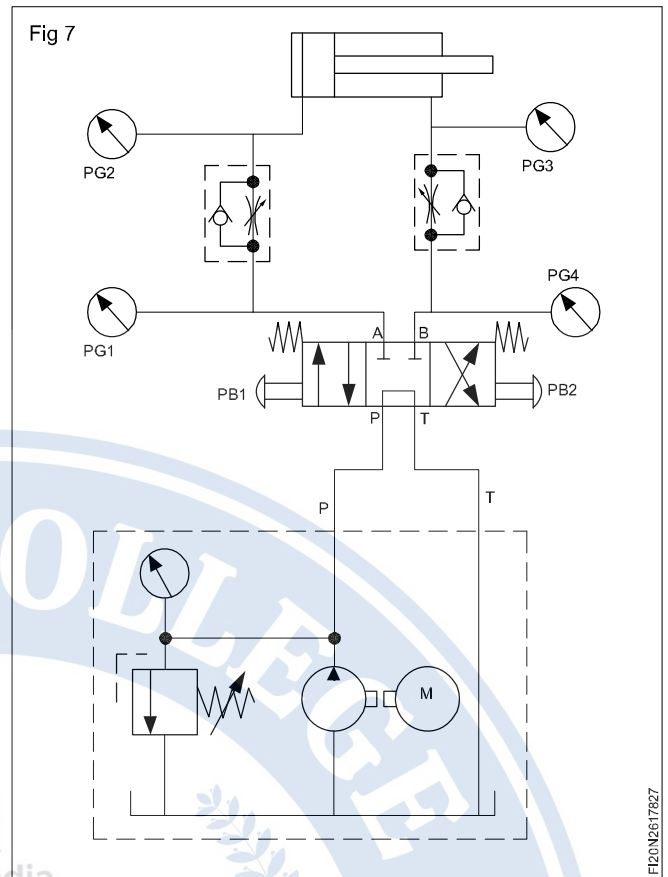
- Meter - in speed control
- Meter - out speed control
- Bleed off speed control

### Meter - in speed control

Fig 8 provides a schematic drawing of a meter - In flow control circuit restriction fluid as it enters an actuator port. Meter -in circuits work well with hydraulic fluids, but can give erratic action with air. Meter - in flow controls only work on resistive loads because a running - away load can move the actuator faster than the circuit can fill it with fluid.

The method in which the flow of oil is reduced which is going inside the actuator is known as meter - in speed control method.

In Fig 7 pump running in unload condition due to open centre valve. Notice that the check valves in the flow controls force fluid through the orifices as it enters the cylinder and lets fluid by pass them as it leaves.



It is obvious that if the cylinder had an external force pulling on it, it would extend rapidly. Because fluid enters the cap end at a reduced flow rate, a vacuum void would form there until the pump had time to fill it.

- For any normal application meter - in speed control method is preferable.
- It gives finer & smooth speed control

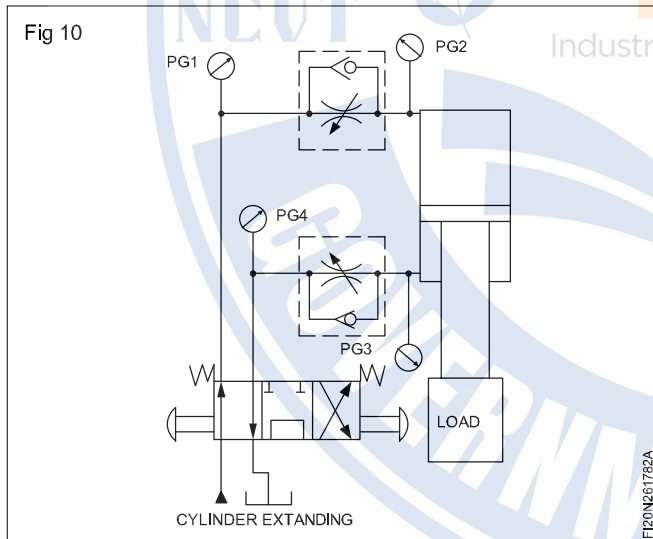
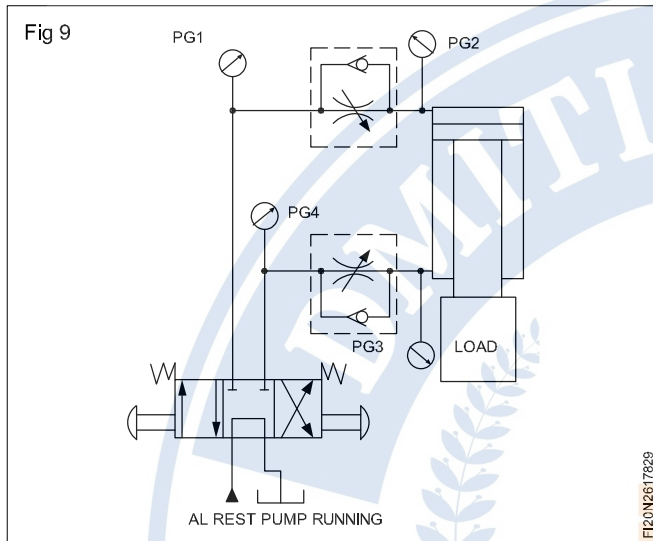
### Meter - out speed control

Fig 10 shows a schematic drawing of a meter - out flow control circuit that restricts fluid as it leaves an actuator port. Meter - out circuits work well with both hydraulic

and pneumatic actuators. Cylinder - mounting attitude is not important because outlet flow is restricted and an actuator cannot run away. Meter - out flow controls work on resistive loads or running away loads.

**Speed control by regulating flow coming out of actuator is called Meter out method.**

Below circuit in Figure 9 is shown at rest with the pump running. Notice how check valves in the flow controls allow fluid to pass the orifices and freely enter the cylinder. As fluid leaves the cylinder, it is forced through the orifices at a set rate. Only PG3 pressure gauge will show the pressure because the load on the cylinder rod is inducing pressure at the valve's blocked port.



- If nature of load on actuator is pulling type or pushing type then meter - out speed control is preferable method to use.
- This circuit maintains a constant back pressure during rod extension if the load drops quickly or reverses.

The below circuit shows conditions when the cylinder is extending. The directional control valve shifts to straight arrows and pump flow by passes the upper flow control to go to the cylinder cap end. Fluid leaving the cylinder

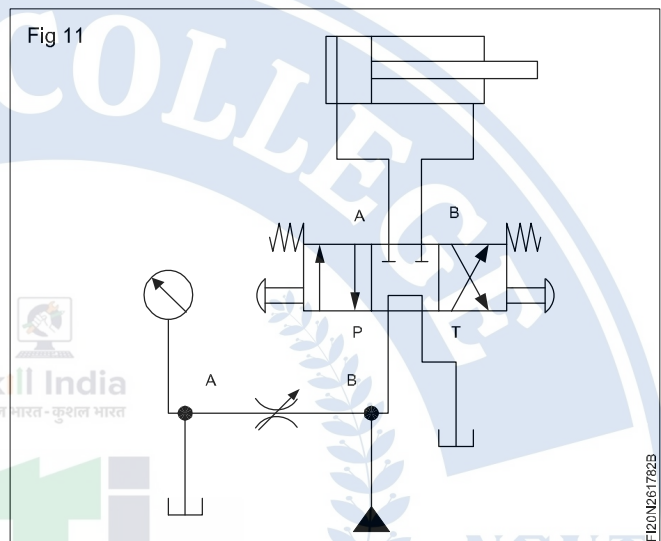
end is held back before it goes to tank even with an external load trying to move it. The cylinder extends at a reduced speed in hydraulic circuits until it meets a resistance.

**Bleed - off speed control**

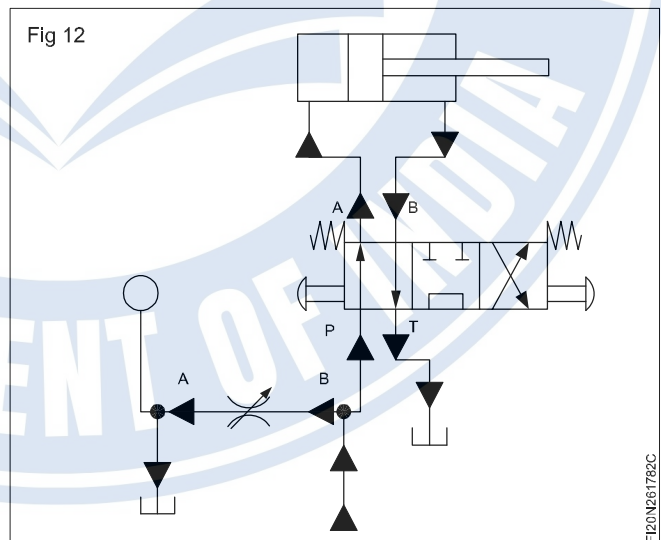
Bleed - off flow control circuits are found only in hydraulic systems and normally only in those with fixed - volume pumps.

Speed control by metering part of the pump flow to tank is known as bleed off flow control (Fig 11)

Fig 11 shows a bleed - off circuit at rest with the pump running. One port of flow control valve (Needle valve) is connected to P port or any output (A or B port) and another port of flow control valve is connected to T port.



When the directional valve in Fig 12 shifts or actuated in parallel port position then all pump flow passes from P port to A port through direction control valve.



On the way to the actuator, part of the flow is bled off to tank, so the actuator forward speed is decreased as per setting of bleed off flow control valve.

This circuit is more efficient than meter - in or meter -out, as pump output is only high enough to overcome resistance, but part of pump output is wasted.

# Shuttle valve and application to control single acting cylinder

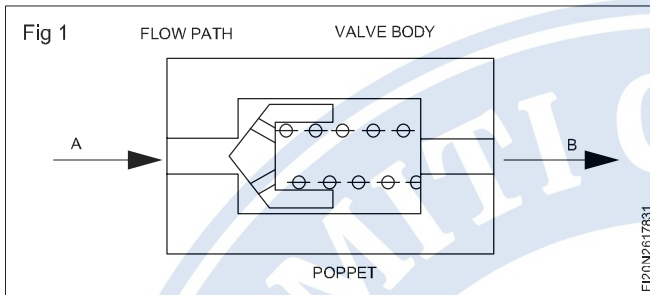
**Objectives :** At the end of this lesson you shall be able to

- explain working principle of non return valve (NRV) and shuttle valve
- state use of shuttle valve in pneumatic applications
- draw circuit to operate single acting cylinder using two 3/2 way valves and shuttle valve.

Working principle of Non Return Valve:

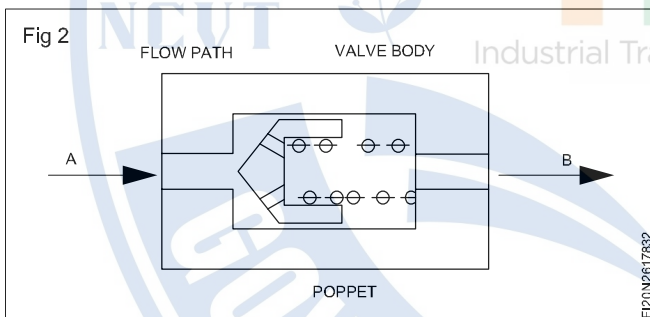
This valve allow air flow in one direction but does not allow air to flow in opposite direction. Non return valve is also known as check valve.

Fig 1 shows the construction of non return valve.

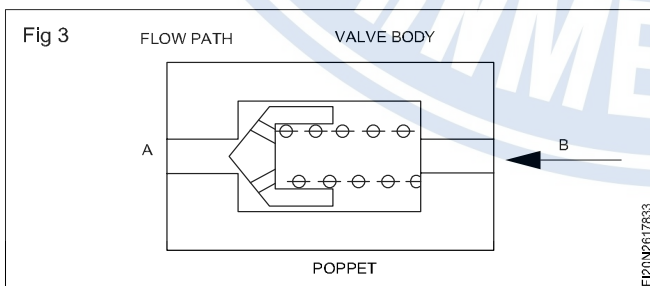


It consists of a valve body having flow path and accommodates poppet and spring. Spring exerts very small force on poppet so that it is closing the path and poppet does not dislocate even if NRV is connected vertically or at an angular position.

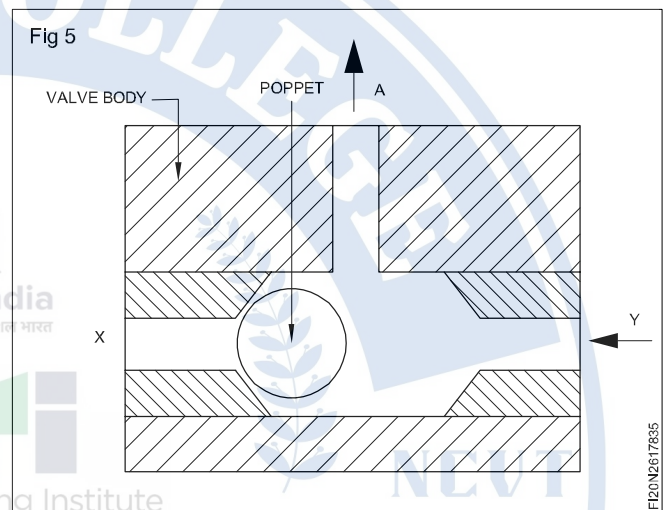
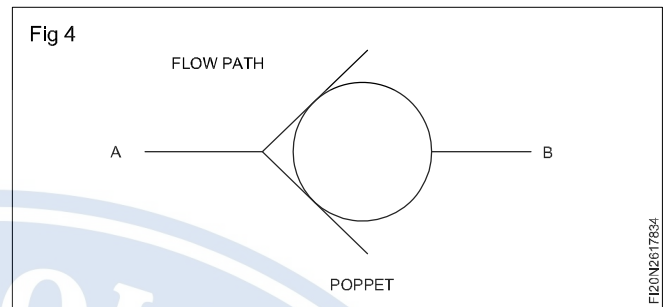
When air flows from port A to B, pneumatic force acts on poppet and spring gets compressed. It causes poppet to shift right side and air flow freely in A to B direction (Fig 2)



When flow direction is reversed (fig 3) means directed from port B, air pressure acts on poppet which further blocks flow path tightly thus no flow from port A.

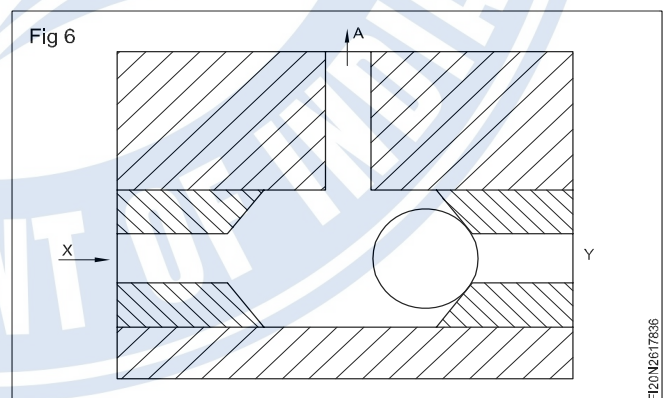


Symbol of NRV is shown in fig 4



If air is supplied through port Y as shown in fig 5, poppet shifts and block port x, thus air flow from Y to A.

If air is supplied through port X as shown in fig 6 poppet shifts and block port Y, thus air flow from X to A



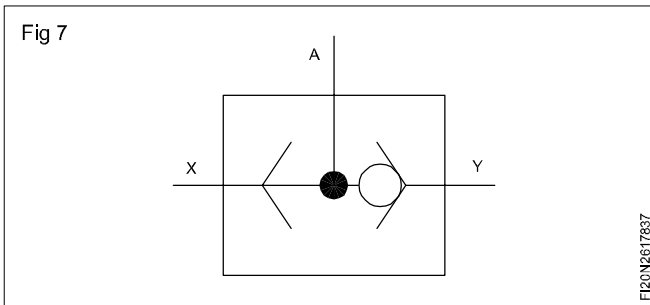
You can conclude that if air is supplied either from X or Y, poppet shuttles between the ports and you get the output from A. Symbol of shuttle valve is shown in fig 7.

## Working principle of Shuttle Valve

Shuttle valve is a combination of two NRV placed face to face, but having common poppet as shown in the Fig 5.

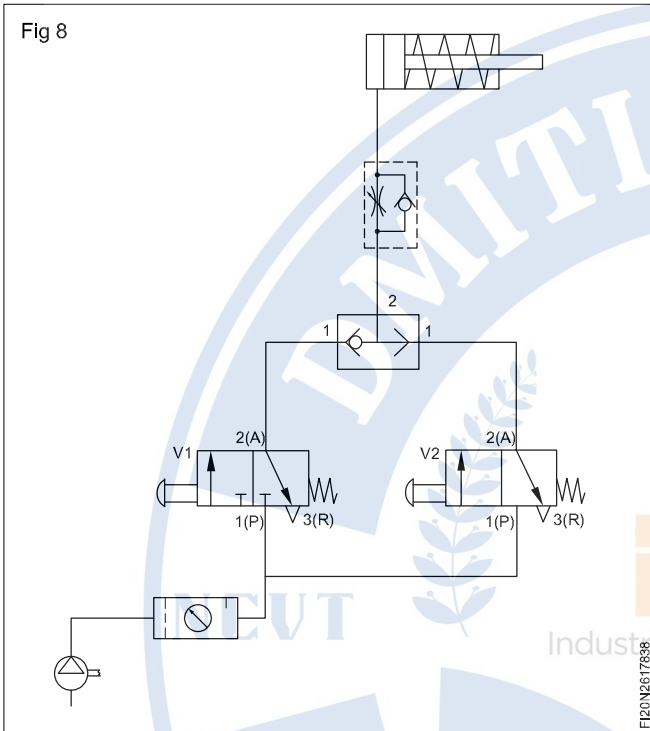
## Application

If we use two 3/2 way valves and connect their outputs for ports x & y then on actuation of any of the valves we get output from A.



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Fig 8 shows the application of shuttle valve in pneumatic circuit to operate single acting cylinder from two different locations.



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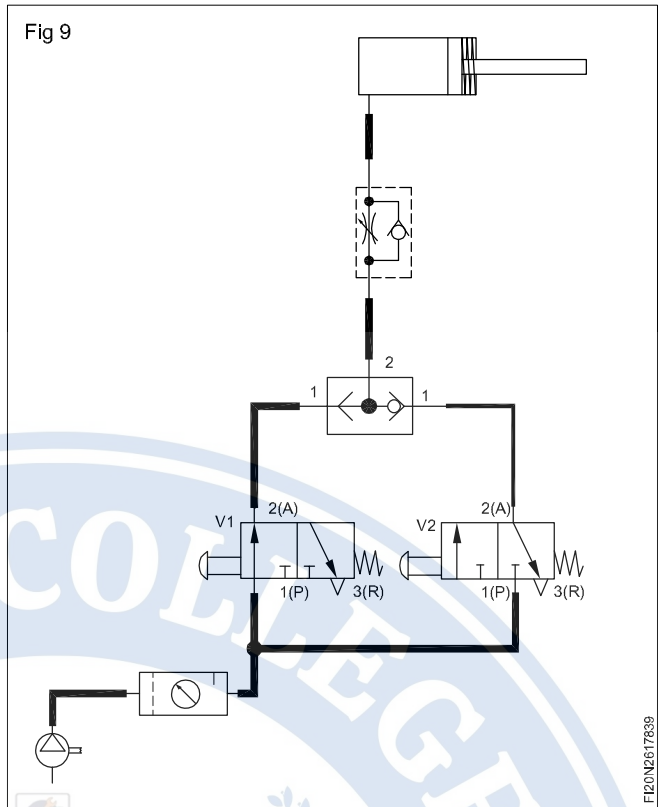
When you operate valve V1 air flows through shuttle valve to cylinder and piston moves forward. (Fig 9)

As soon as valve is released cylinder side air exhausts through valve V1 and piston retracts.

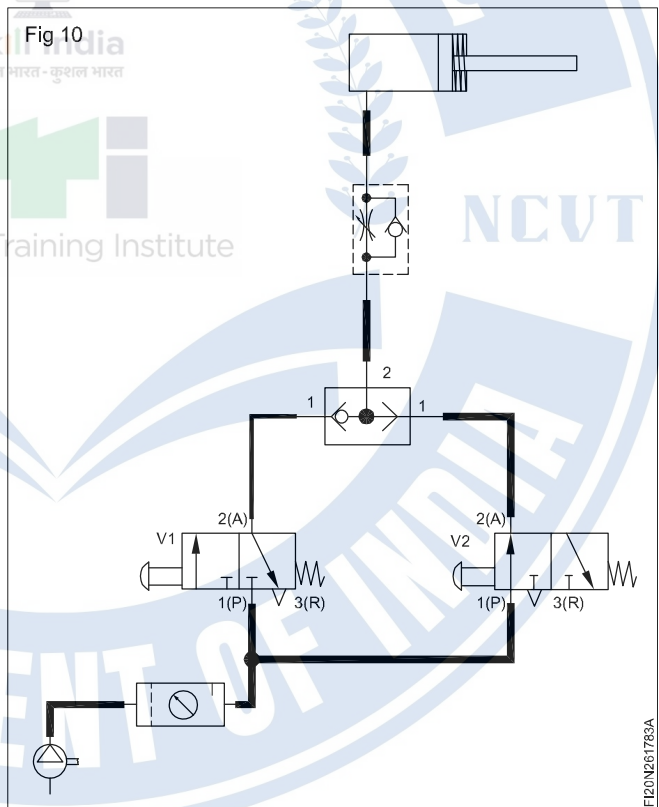
When Valve V2 is operated air flows through shuttle valve to cylinder and piston moves forward. (Fig 10)

As soon as valve is released cylinder side air through valve V2 and piston retracts.

If you operate both valves V1 & V2 simultaneously, poppet shifts due to flow from either of the valves and air flow to cylinder, thus piston moves forward. (Fig 11)



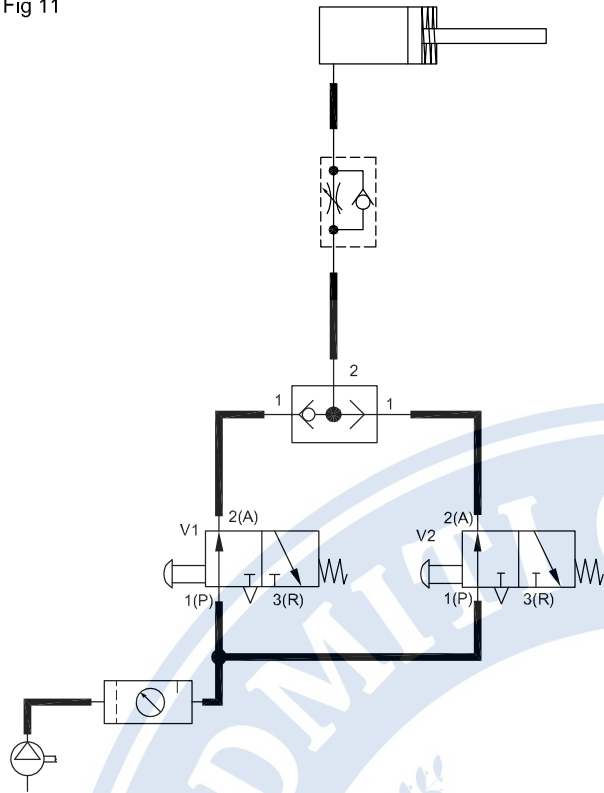
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As soon as both valves are released cylinder side all exhausts through either of the valves and piston retracts. (Fig 12)

Fig 11



FI20N261783B

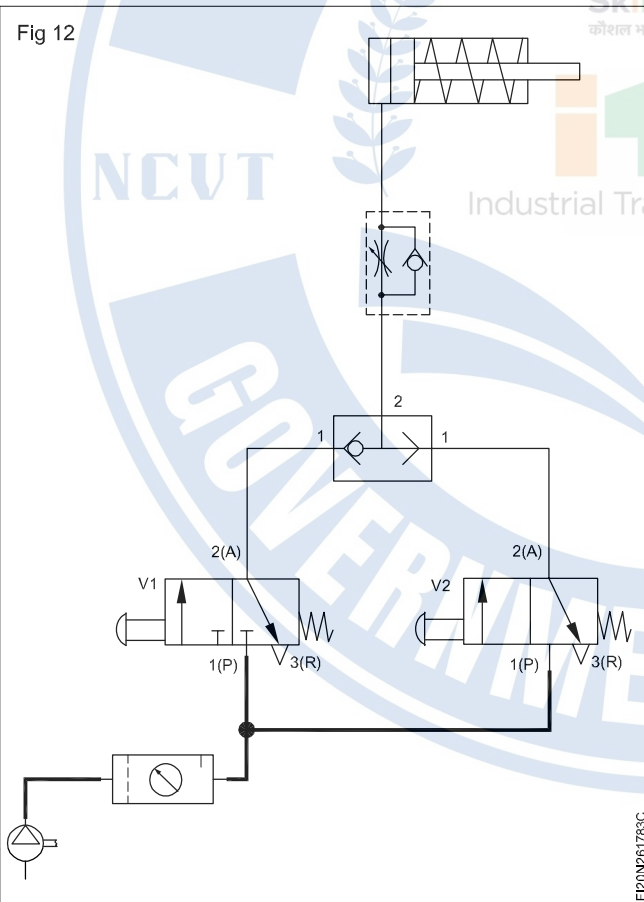
### Roller valve

Pneumatic roller lever valves, used for mechanical position sensing in machine automation systems. The linear horizontal movement of a machine part of passing material, for example on a conveyor line, moving over the roller operates the valve. The wheel rotates in the direction of the moving part which reduces friction, this minimises wear and tear of both the pneumatic roller lever valve and the travelling part, for this reason, a preferred method of mechanical sensing.

Pneumatic roller lever valves, constructed from a die-cast zinc aluminium alloy that is machined and lacquered offering strength and reliability, an overall excellent quality product. We offer 2 or 3-way normally closed, or a 5 way roller lever valve in either poppet or spool designs. Choose from a standard pneumatic roller lever valve or a compact design should space be limited. An air pilot assisted version can be ordered, used when less force is available to actuate the lever for lighter operation.

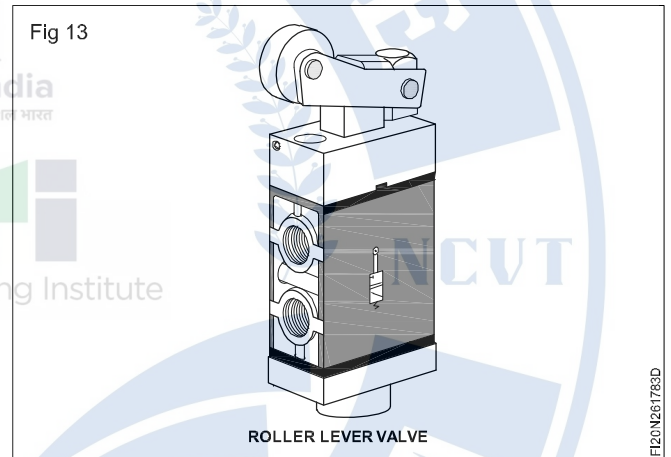
Order one-way or two-way roller levers with spring return, air pilot return or double rollers. A double roller lever is used on machine carriages to reverse the direction of travel. Port sizes are G 1/8 as standard.

Fig 12



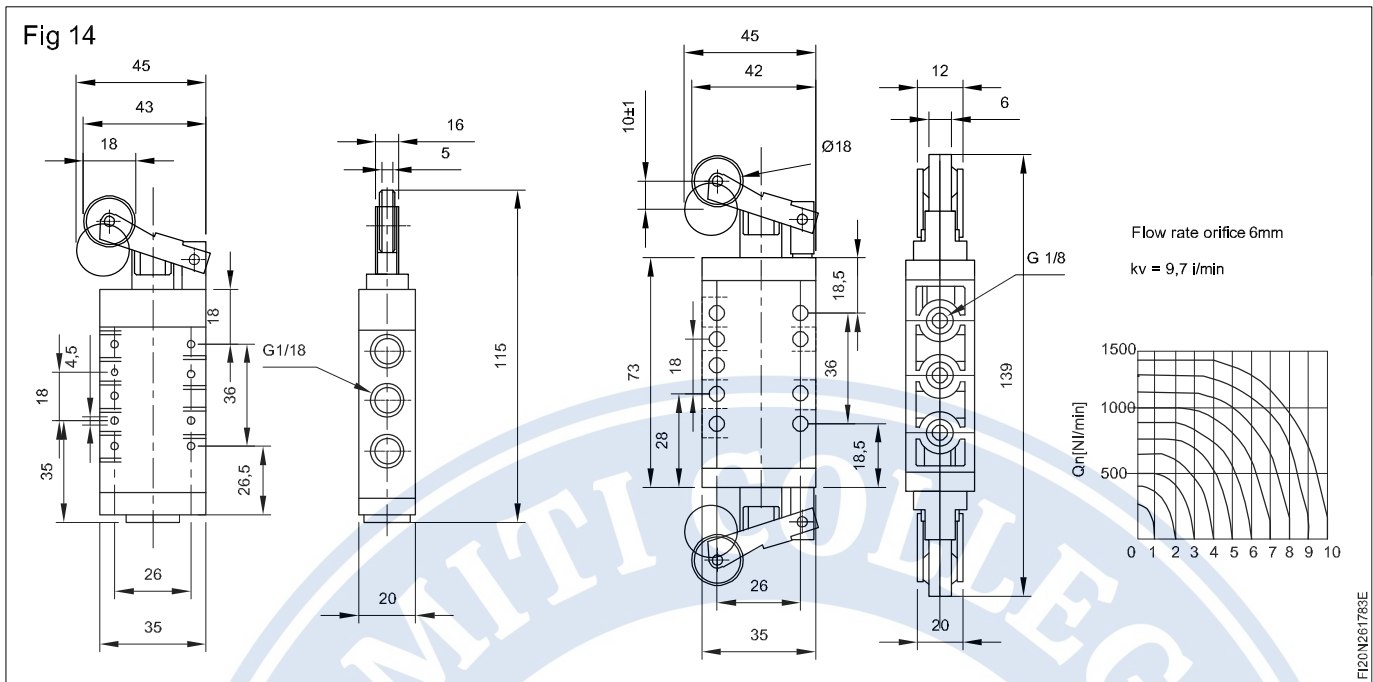
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Fig 13



FI20N261783D

## Dimensional drawings



## Pressure control valve

**Objectives :** At the end of this lesson you shall be able to

- differentiate pressure relief valve, pressure reducing valve, pressure regulator and explain their function
- interpret counter balancing and sequencing.

To control and regulate the pressure various pressure valve are used in hydraulics systems, like:

### Classification of Pressure control valve

- Pressure relief valve.
- Pressure reducing valve
- Pressure regulator.

### Pressure relief valve

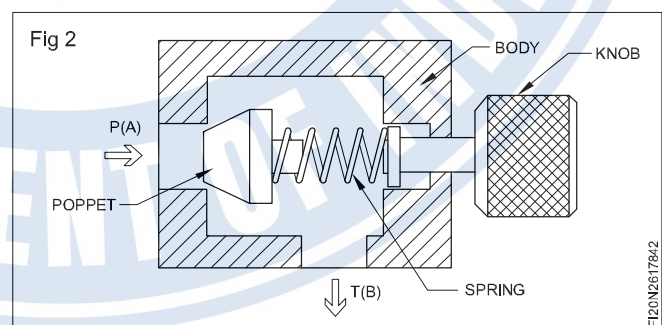
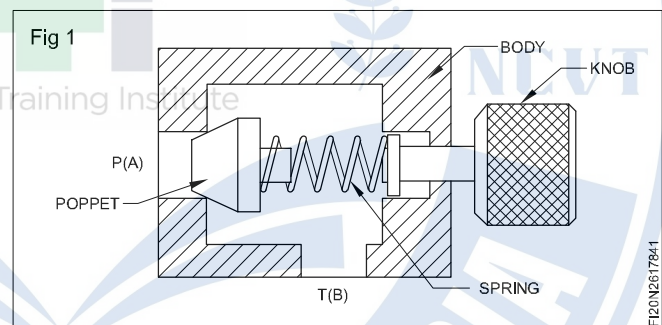
The pressure in the system is set and restricted by pressure relief valve. Pressure relief valve also help to remove excess amount of oil from system to tank to overcome excess pressure.

In this design incorporating a poppet valve, a seal is pressed against the inlet port P by a spring when the valve is in its normal position. The input pressure (P) acts on the surface of the sealing element generates the force.

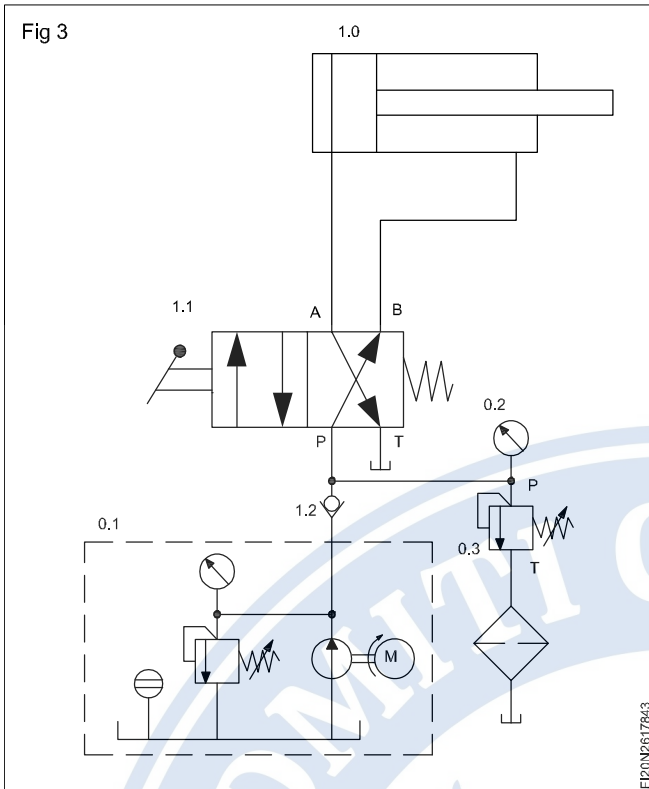
$$F = p_1 A_1$$

The Spring force by which the sealing element is pressed onto the seat is adjustable

If the force generated by the input pressure exceeds the spring force, the valve starts to open. This causes a partial flow of the liquid to the tank. If the input pressure continues to increase, the valve opens until the complete pump delivery flows to the tank.



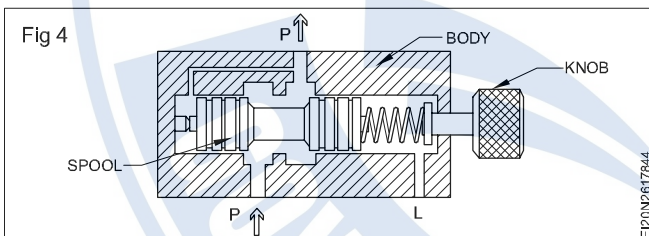
The resistances at the outlet (tank line, filter) must be added to the force of the spring in the pressure relief valve. Application of PRV is shown in the Fig 3



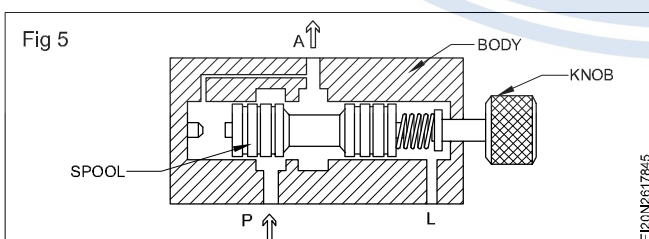
### Pressure reducing valve (2 - way valve)

Pressure regulators reduce the inlet pressure to an adjustable outlet pressure. It is appropriate to use these in hydraulic system only if different pressures are required.

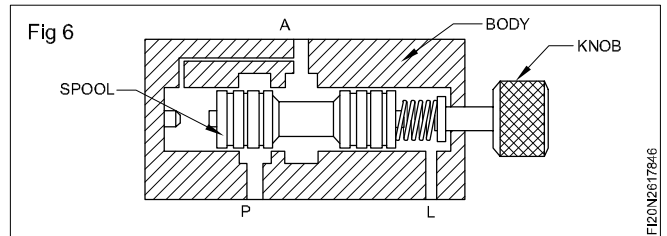
This valve is normally open. The outlet pressure (A) acts via a pilot on the left - hand surface of the pilot piston against an adjustable spring force. (Fig 4)



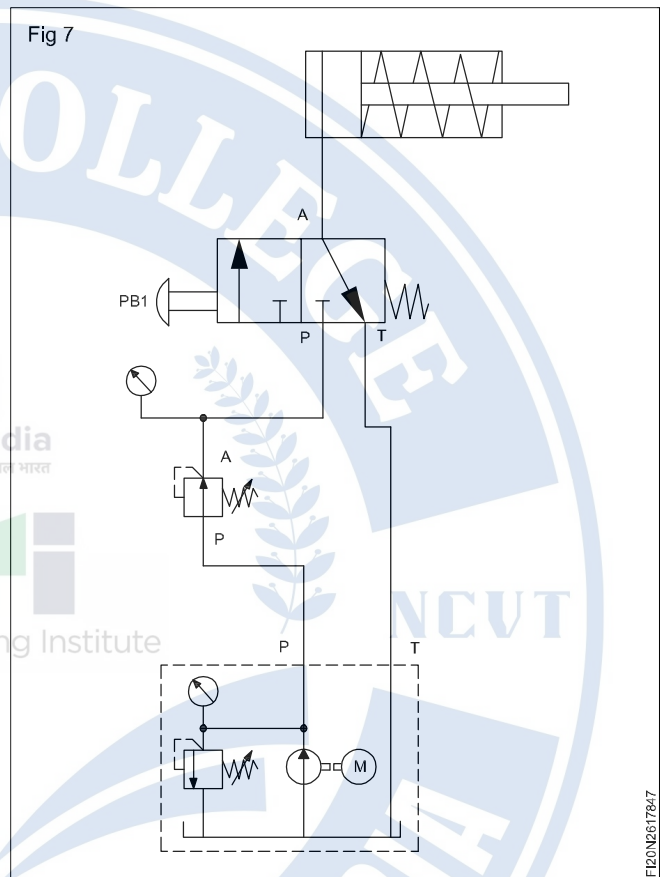
When the pressure rises at outlet A, the force at the left hand surface of the pilot piston becomes increases, the piston is displaced to the right and the throttle gap becomes narrower. This causes a pressure drop. In the case of slide valves, it is also possible to design the control edges in such way that the opening gap increases only slowly. This gives greater control precision. (Fig 5)



When the preset maximum pressure is reached, the throttle point closes completely. (Fig 6)



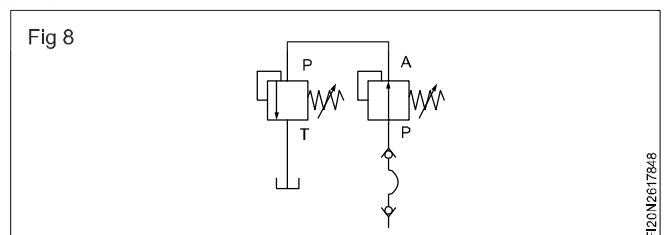
The pressure at the outlet A of the pressure regulator is less than the system pressure at P and constant. The piston rod of the cylinder is now in its forward end position. Application of pressure reducing valve is shown in the Fig7



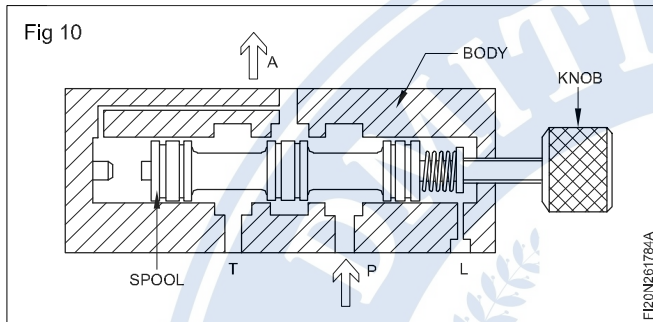
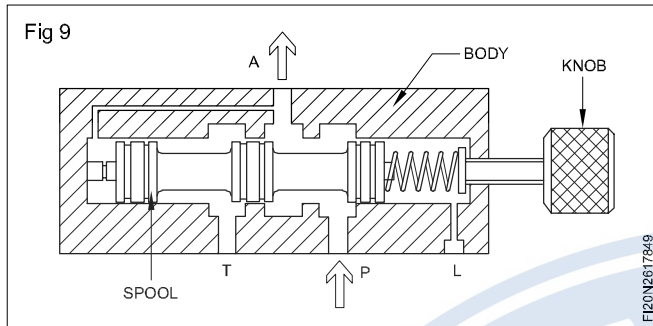
### Pressure regulator (3- way Valve)

When the 2 - way pressure regulator close fully, then any impact vibration in cylinder will responsible to increase the output pressure above the set value which is not desirable. One method of rectifying this would be to install a pressure relief valve at the output.

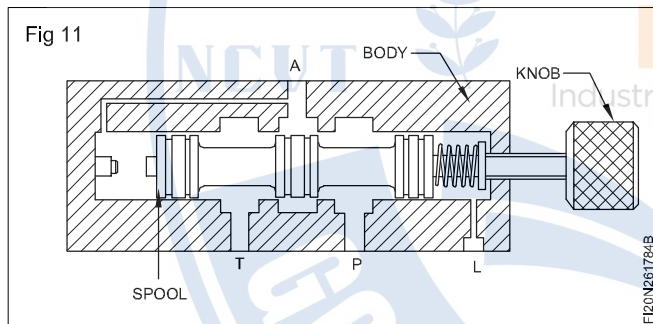
The 3-way pressure regulator can be regarded as a combination of a 2- way pressure regulator (PR) and a pressure relief valve (PRV) (Fig 8)



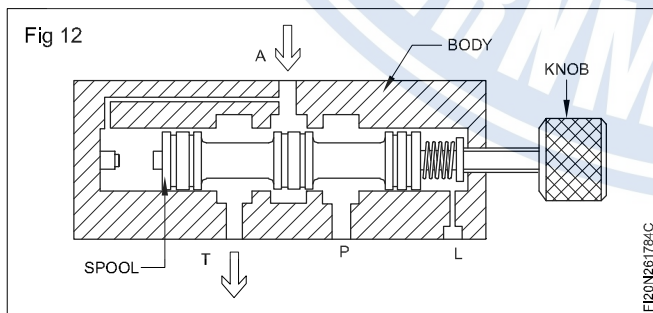
When the pressure at A raises the result of external conditions, this pressure acts via a pilot line on the left hand piston surface of the pilot piston against an adjustable spring force. Every pressure increase causes the throttle gap to become narrower, resulting in a pressure drop. (Figs 9 & 10)



When the maximum preset pressure is reached, the throttle point closes completely. (Fig 11)

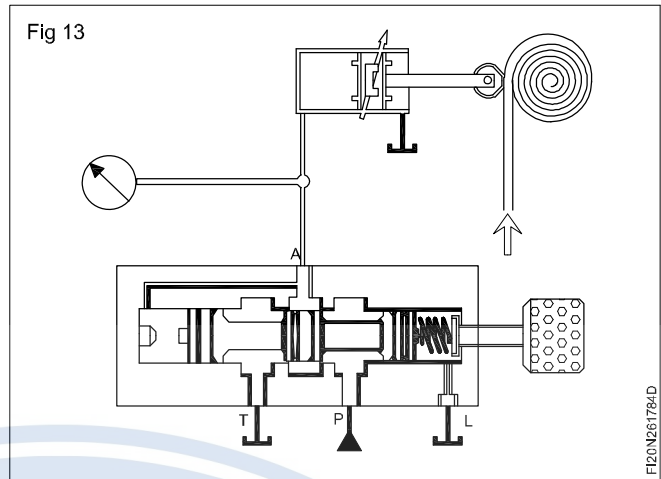


If the pressure rises above the preset value as the result of an external load at outlet A, the valve opens to allow from A to the tank port T (pressure - limiter - function). (Fig 12)



Example of pressure regulator is shown in the fig 13

Pressure regulator help to maintain constant pressure in line and also safe the sytem from excess pressure, so you able to get approximate constant pressure in line.

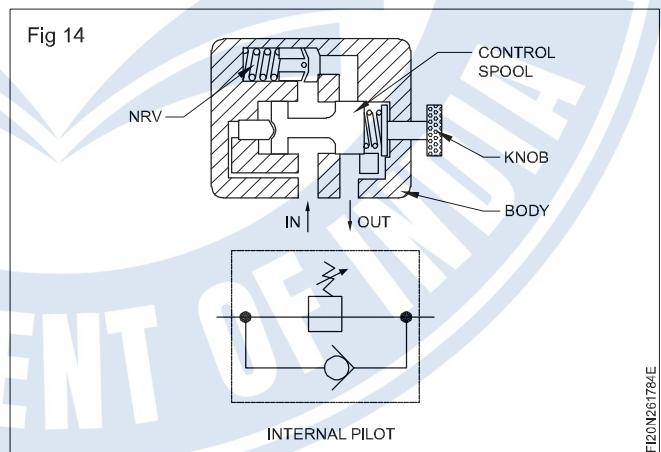


### Counter Balancing

Cylinders with external forces such as weight from a platen, machine members, or tooling acting against them will over run when oil flowing out of them is not restricted. A meter - out flow control circuit is one way to control over running loads but it has one main drawback. A flow control's speed is fixed except for manual adjustment. Because flow is fixed, the actuator will continue at the same speed, even when working flow to it increases or decreases.

The valve which is used to create a back pressure against pushing or pulling types of load to maintain normal speed of cylinder is known as counterbalance valve.

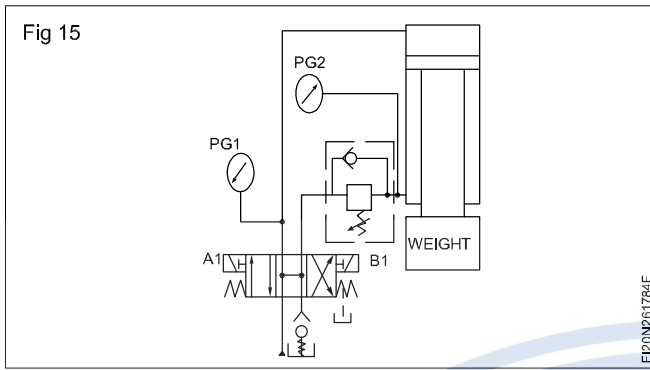
A counterbalance valve keeps an actuator from running away regardless of flow changes because it responds to pressure signals, not flow. A counter balance valve is almost the same as a sequence valve. The figure of counter balance valve and symbols are shown in Fig 14



A counterbalance valve usually has a bypass check valve for reverse flow because its most common use is in controlling actuators with running away or overrunning loads.

Fig 15 shows a vertically oriented cylinder with rod facing down and a load trying to extend it . To keep the cylinder from running away, the counterbalance valve must resist the load - induced pressure from the weight. The load -

induced pressure can be calculated and the counterbalance valve could be preset at 100 to 150 psi higher on a test stand.



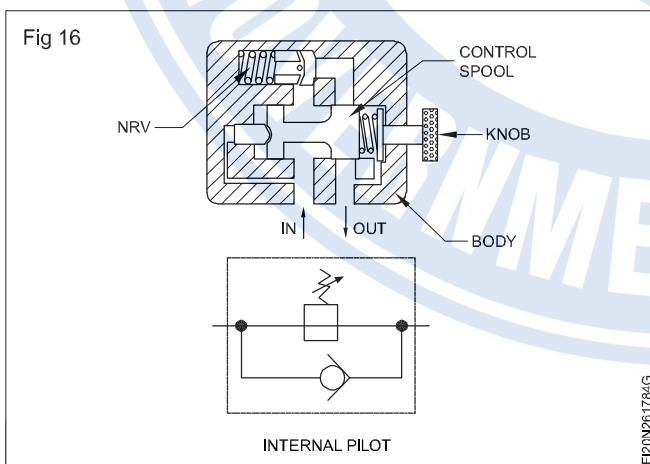
In the centre position of directional control valve ports A and B are connected to tank in the center condition. There is no chance of extra pressure buildup in the pilot line while the circuit is at rest. If ports A or B? were blocked, pressure could not build and counterbalance valve will not open, not allowing the cylinder to drift.

Press PB1 oil flows to the cylinder cap end. As pressure builds there, pressure also increases in the rod end. When pressure at the cylinder rod end reaches 100 to 150 psi above the load- induced pressure, the cylinder starts to extend as fast as the pump fills the cap end. When flow increases, cylinder speed increases and when flow decreases, cylinder speed decreases. Back pressure at the cylinder rod end is present during the entire extend stroke.

When PB2 is operated oil flows to rod end via check valve thus by passing the counterbalance hence piston retracts.

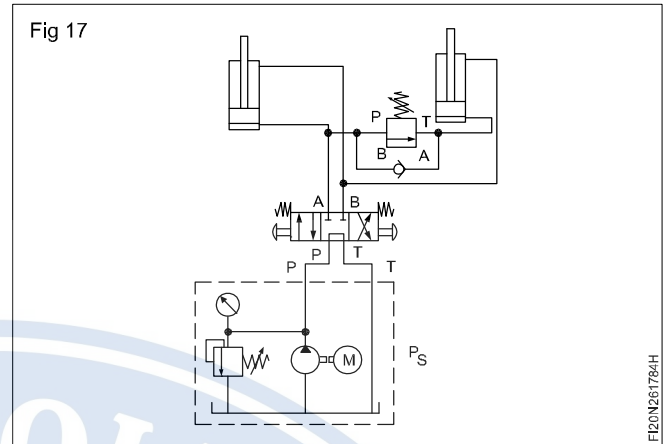
### Sequencing

To operation of number of hydraulic actuators in desired steps sequencing is done. A sequence valve is the simplest mechanism to achieve desired steps. Fig 16 shows the sectional view and symbol of sequencing valve.

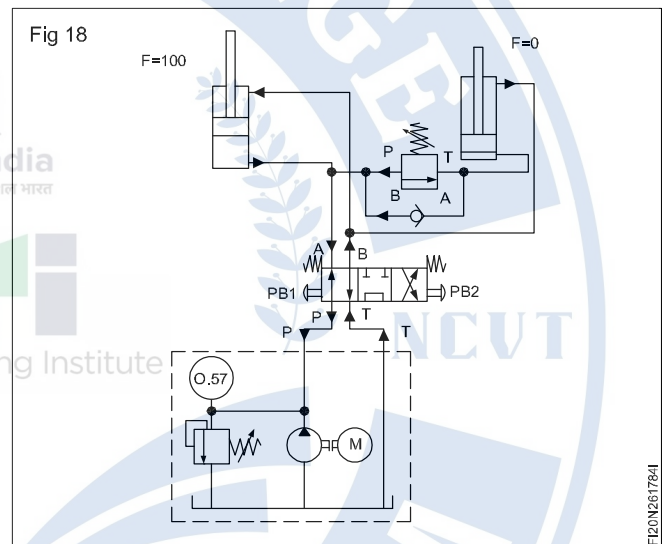


A balanced spool held in place by an adjustable - force spring blocks fluid at the hydraulic sequence valve's inlet. When pressure at the inlet reaches the spring setting, pressure in the internal pilot line pushes the spool up to allow enough flow to the outlet. A by pass check valve

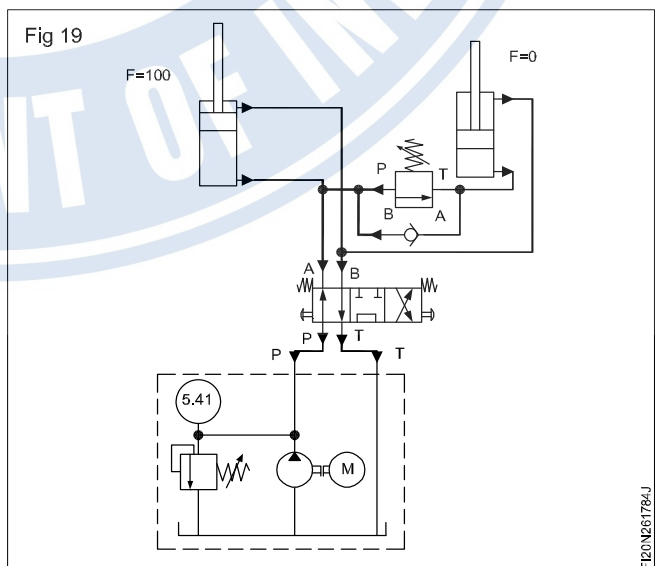
allows reverse flow without pressure sequencing. In this circuit 4/3 way valve is in neutral position Fig 17 so the pump flow is flowing into tank without any resistance.



In the actuated condition (Fig 18) the loaded cylinder will complete it's stroke first then after no load cylinder start moving. This is the sequencing of actuation for cylinder with the help of pressure sequence valve.



In other actuated condition (Fig 19) cross connection of port in direction control valve, loaded piston will return back at faster speed as compare to the no load piston.



**Electro- pneumatics**

**Objectives :** At the end of this lesson you shall be able to

- explain about the electro pneumatic control system
- list the basic electrical devices
- explain the operation of switches
- describe the purpose and constructional details of solenoid valves.
- explain purpose and operation of relay.

**Introduction**

Electro pneumatic control consists of electrical control systems operating pneumatic power system. In this solenoid valves, are used as interface between the electrical and pneumatic system. Devices like switches are used as feedback elements.

In electro pneumatics, the signal medium is the electrical signal either AC or DC source is used. Working medium is compressed air. Operating voltages from around 12v to 220 v are used. The final control valve is actuated by solenoid activation.

In electro pneumatic controls, mainly three important steps are involved.

**Signal input devices**

Signal generation such as switches and contactor, various types of contact and proximity sensors.

**Signal processing**

Use of combination of contactors of relay or using programmable logic controllers.

**Signal outputs**

Outputs obtained after processing are used for activation of solenoids, indicators or audible alarms.

**Basic electrical devices**

Basic electrical devices commonly used in the control of fluid power systems are

Manually actuated push button switches

Limit switches

Pressure switches

Solenoids

Relays

Temperature switches

**Push button switches**

A push button is a switch used to close or open an electric control circuit. They are primarily used for starting and stopping of operation of machinery. They also provide manual override when the emergency arises. Push button switches are actuated by pushing the actuator into the housing. This causes set of contacts to open or close.

Push buttons are of two types

Momentary push button

Maintained contact or detent push button

Momentary push buttons return to their unactuated position when they are released. Maintained (or mechanically latched) push buttons has a latching mechanism to hold it in the selected position.

The contact of the push buttons, distinguished according to their functions.

- Normally open (NO) type
- Normally closed (NC) type
- Change over (CO) type.

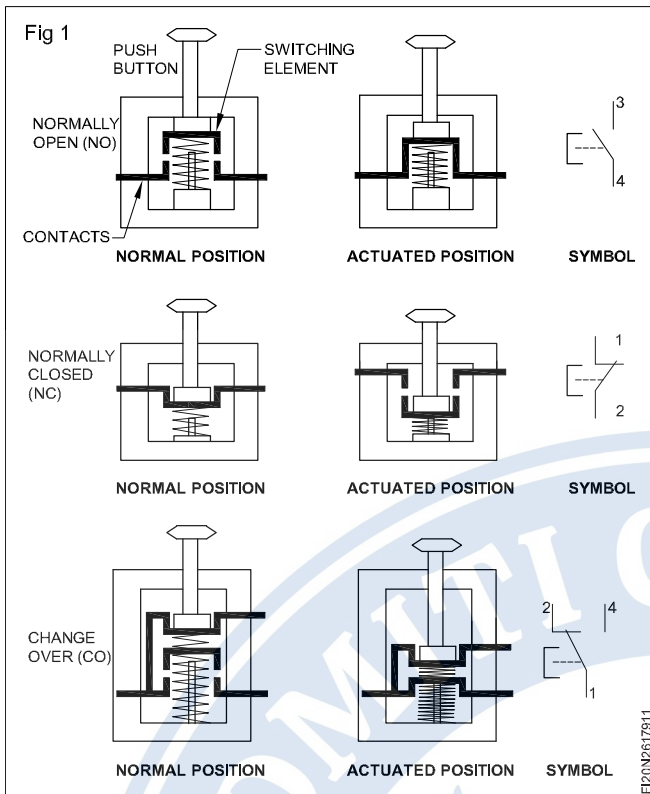
The cross section of various types of push buttons in the normal and actuated positions and their symbols are given in the fig 1. In the NO type, the contacts are open in the normal position, inhibiting the energy flow through them. But in the actuated position, the contacts are closed, permitting the energy flow through them. In the NC type, the contacts are closed in the normal position, permitting the energy flow through them. And, the contacts are open in the actuated position, inhibiting the energy flow through them. A changeover contact is a combination of NO and NC contacts.

Type of devices	Terminal numbers	
	Normally closed contacts	Normally open contacts
Push buttons and relays	1 and 2	3 and 4

**Limit switches**

Any switch that is actuated due to the position of a fluid power component (usually a piston rod or hydraulic motor shaft or the position of load) is termed as limit switch. The actuation of a limit switch provides an electrical signal that causes an appropriate system response.

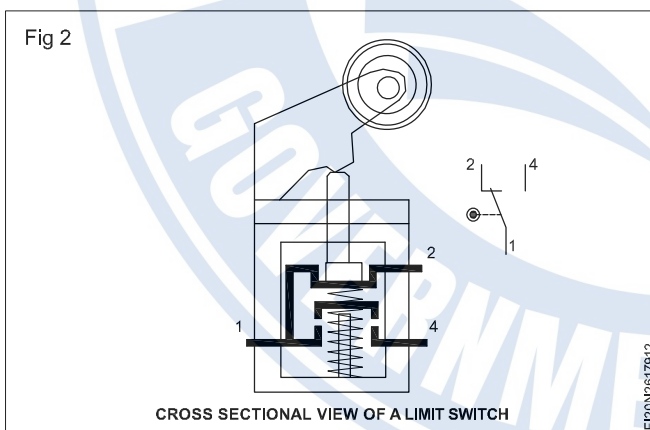
Limit switches perform the same function as push button switches. Push buttons are manually actuated whereas limit switches are mechanically actuated.



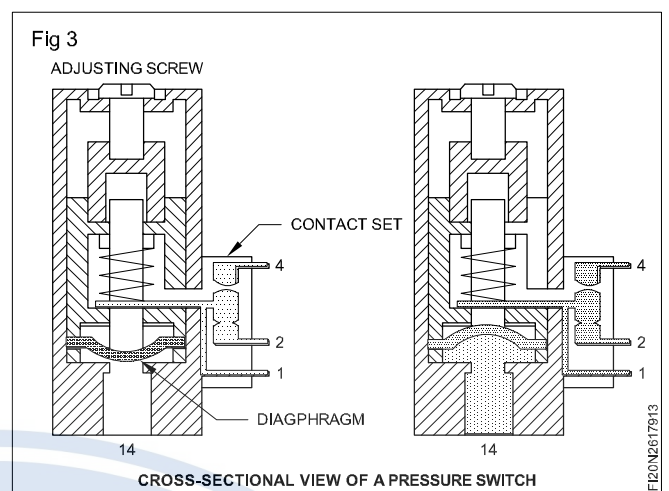
There are two types classification of limit switches depending upon method of actuation of contacts

- Lever actuated contacts
- Spring loaded contacts

In lever type limit switches, the contacts are operated slowly. In spring type limit switches, the contacts are operated rapidly. Figure 2 shows a simplified cross sectional view of a limit switch and its symbol.



A **pressure switch** is a pneumatic - electric signal converter. Pressure switches are used to sense a change in pressure, and opens or closes an electrical switch when a predetermined pressure is reached. Bellow or diaphragm is used to sense the change of pressure. Bellows or diaphragm is used to expand or contract in response to increase or decrease of pressure. Figure. 3 shows a diaphragm type of pressure switch. When the pressure is applied at the inlet and when the pre-set pressure is reached, the diaphragm expands and pushes the spring loaded plunger to make/break contact.



### Temperature switch

Temperature switches automatically sense a change in temperature and opens or closes an electrical switch when a predetermined temperature is reached. This switch can be wired either normally open or normally closed.

Temperature switches can be used to protect a fluid power system from serious damage when a component such as a pump or strainer or cooler begins to malfunction.

### Solenoids

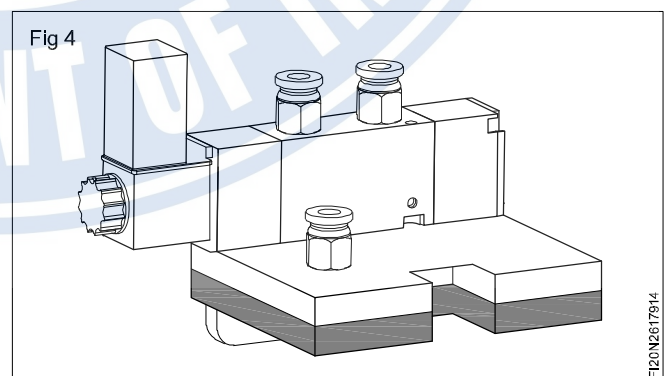
Electrically actuated directional control valves form interface between the two parts of an electro pneumatic control. The most important tasks of electrically actuated DCVs include.

- Switching supply air ON or OFF
- Extension and retraction of cylinder drives.

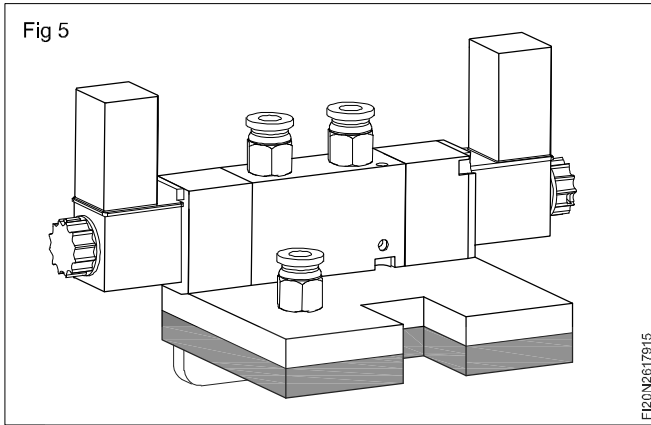
Electrically actuated directional control valves are switched with the aid of solenoids. A solenoid is like a coil of the relay. When it is energized, it will switch on the valve, similar to turning on the hand lever of a normal valve.

They can be divided into two groups

- Spring return valves (single solenoid valve) only remain in the actuated position as long as current flows through the solenoid (fig 4)

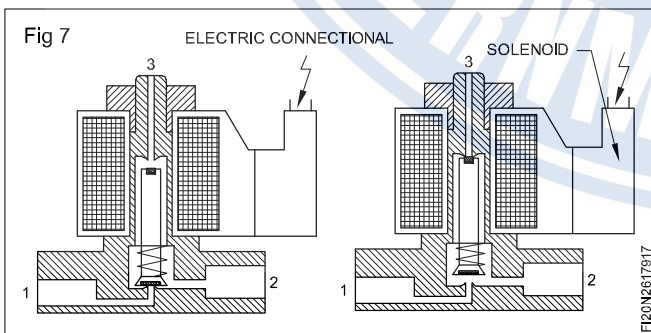
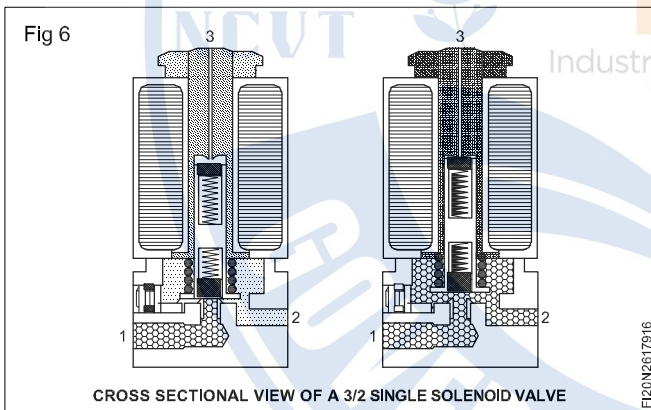


- Double solenoid valves (double solenoid valve) retain the last switched position even when no current flows through the solenoid (fig 5)



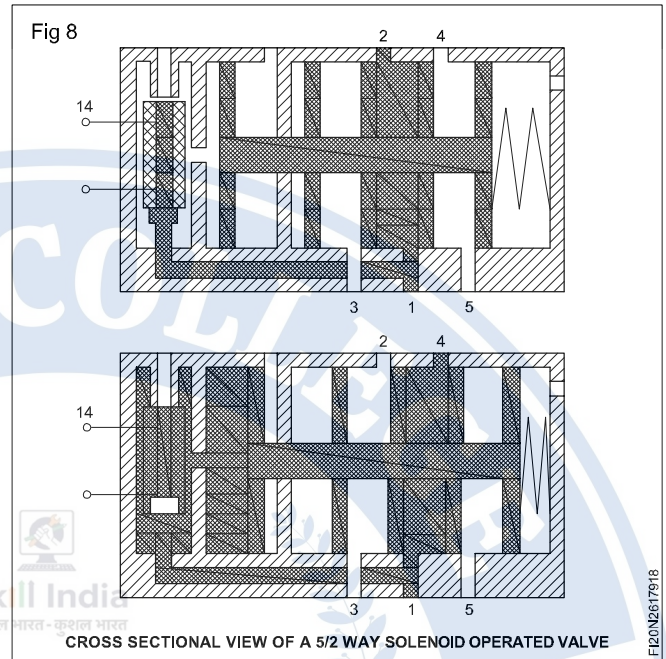
In the initial position, all solenoids of an electrically actuated DCVs are de-energized and the solenoids are inactive. A double valve has no clear initial position, as it does not have a return spring. The possible voltage levels for solenoids are 12V Dc, 12V Ac, 12V 50/60 Hz, 24V 50/60 Hz, 110/120V 50/60 Hz, 220/230V 50/60 Hz

**3/2 way signal solenoid valve, spring return :** The cross sectional view of 3/2 way single solenoid valve in the normal and actuated positions are shown in fig 6. In the normal position, port 1 is blocked and port 2 is connected to port 3 via back slot (details shown in the circle) when the rated voltage is applied to coil, armature is pulled towards the centre of the coil and in the process the armature is lifted away from the valve seat. The compressed air now flows from port 1 to port 2, and ports 3 is blocked. When the voltage to the coil is removed, the valve returns to the normal position. Fig 7 shows 2/2 solenoid operated valve.

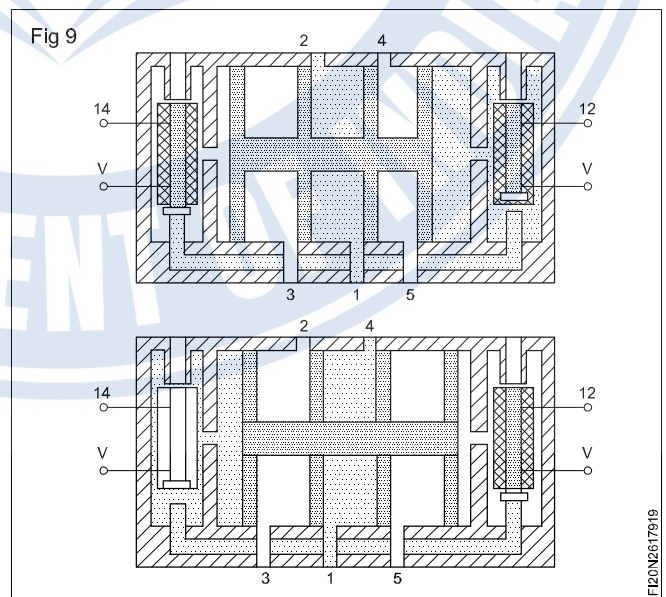


**5/2 way single solenoid valve, spring return**  
The cross section view of 5/2 way single solenoid in the normal and actuated positions are shown in figure 8. In normal position, port 1 is connected to port 2, port 4 is

connected to port 5, and port 3 is blocked. When the rated voltage is applied to coil 14, the valve is actuated through an internal pilot valve. In actuated position, port 1 is connected to port 4, port 2 is connected to port 3, and port 5 is blocked. The valve returns to the normal position when the voltage to the armature coil is removed. This type of valves is normally used as final valve to control double acting cylinders.



**5/2 way single double solenoid valve**  
The cross section view of 5/2 way double solenoid in the normal and actuated positions are shown in the fig 9 when the rated voltage is applied to coil 14, the valve is actuated to a one switch in position with port 1 connected to port 4, port 2 connected to port 3, and port 5 blocked. When the rated voltage is applied to the coil 12, the valve is actuated to the other switching position with port 1 connected to port 2, port 4 connected to port 5 and port 3 blocked.



The symbols for the various solenoid/pilot actuated valves are given in table 1

Fig 10

SYMBOL	DETAILS
	3/2 WAY SINGLE SOLENOID VALVE (SPRING RETURN)
	3/2 WAY PILOT OPERATED SINGLE SOLENOID VALVE (SPRING RETURN)
	5/2 WAY SINGLE SOLENOID VALVE (SPRING RETURN)
	5/2 WAY DOUBLE SOLENOID VALVE
	5/2 WAY PILOT OPERATED DOUBLE SOLENOID VALVE (SPRING RETURN)

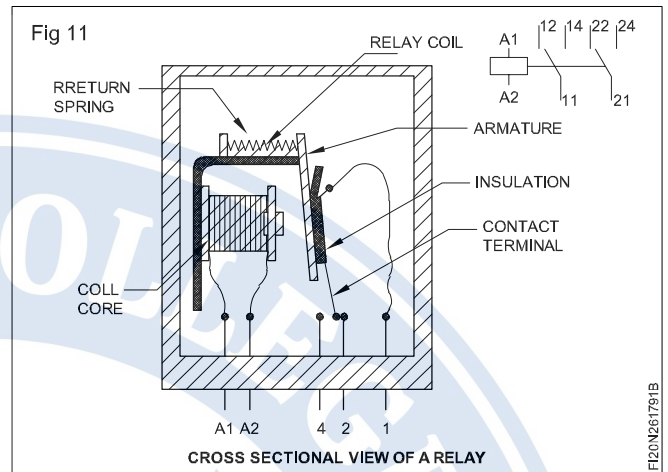
VARIOUS SYMBOLS FOR DCVs

### Relay

A relay is an electro magnetically actuated switch. It is a simple electrical device used for signal processing. Relays are designed to withstand heavy power surges and harsh environment conditions. When a voltage is applied to the solenoid coil, an electro magnet field results. This causes the armature to be attracted to the coil core. The armature actuates the relay contacts, either closing or opening them, depending on the design. A return spring returns the

armature to its initial position when the current to the coil is interrupted. Cross sectional view of a relay is shown in fig 11.

A large number of control can be incorporated in relays in contrast to the case of a push button station. Relays are usually designated as K1, K2, and K3 etc. Relays also possess interlocking capability that is an important safety feature in control circuits. Interlocking avoids simultaneous switching of certain coils.



**Symbols for hydraulic components**

**Objectives :** At the end of this lesson you shall be able to

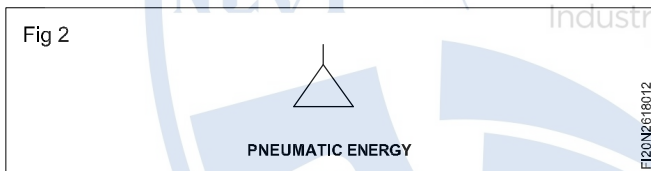
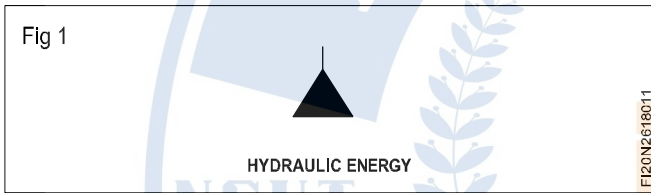
- read and interpret the circuit symbol
- state the uses of symbol in hydraulic components.

In a hydraulic circuit symbols are used to represent individual component to impart representation of hydraulics system in diagrams. A symbol identifies a component and its function. These symbols are as per ISO 1219 standards.

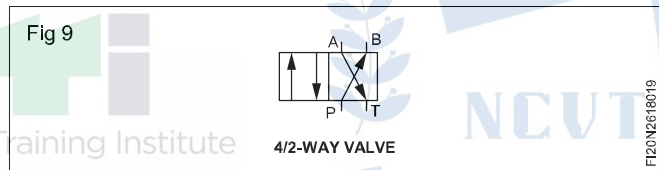
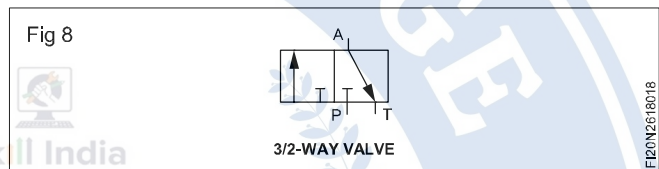
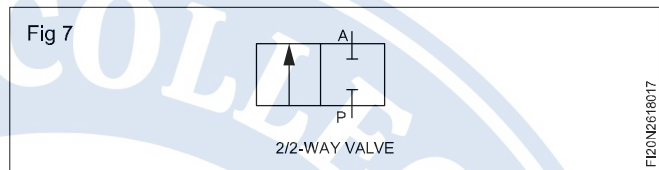
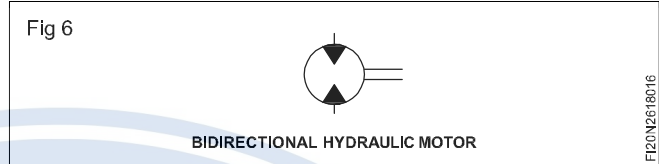
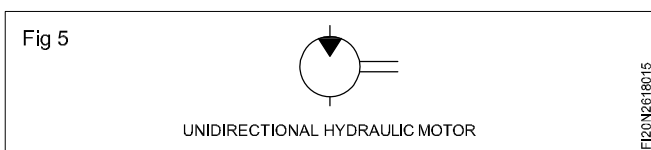
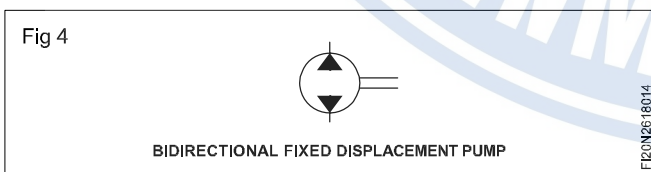
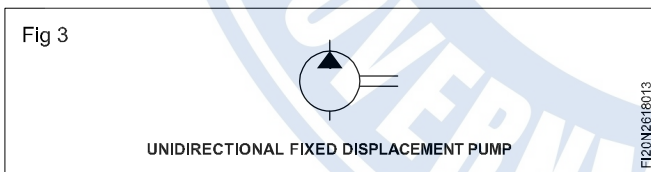
**Pump and motor**

Hydraulic pump and motor are represented by means of a circle. Triangle within the circle represent the direction of flow and position of triangle differentiates between the symbol of pump or motor.

If triangle is filled darkened means it is meant for hydraulics fluid but if triangle is not filled means it is for gaseous pressure media or Pneumatic energy. (Figs 1 & 2)



**Symbols of pump and motor (Figs 3 to 9)**



**Direction control valve**

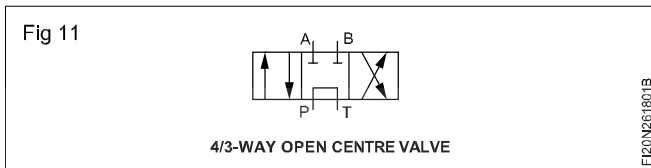
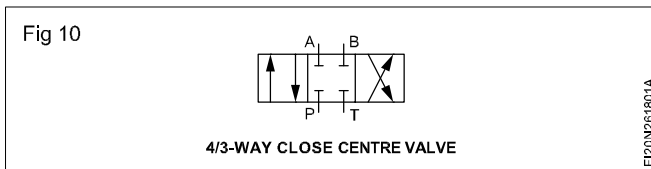
Direction control valves are represented by several connected squares.

- The number of squares indicates the number of switching positions.
- Arrows in the squares indicate the direction of flow.
- Lines indicate how the ports are interconnected in the different switching position.

**Port designation**

- P Pressure port
- T Tank port
- A Service port (output port)
- B Service port (output port)
- L Leakage port

## Symbols of Direction control valve (Figs 10 to 11)



Port should always be represented in the neutral position of valve.

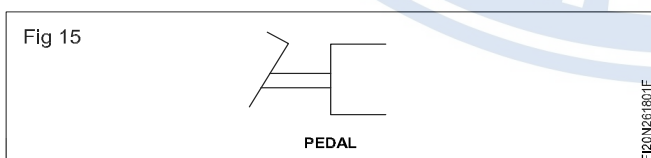
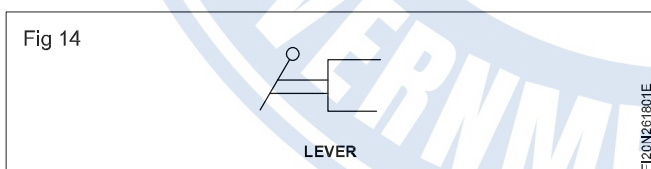
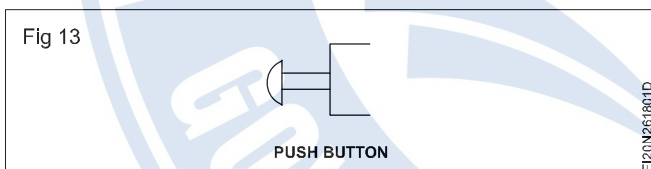
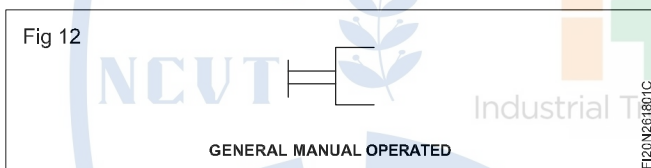
**The neutral position is a position which automatically come in valve due to spring force when no any command is available in valve, it is also the initial position unless otherwise actuated.**

### Actuating mechanism of Valve

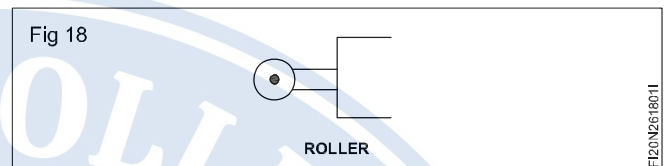
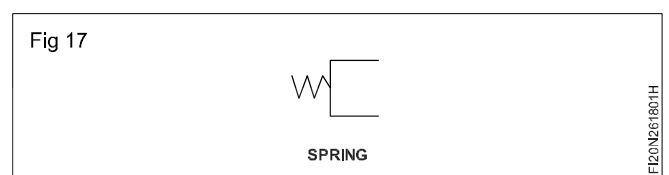
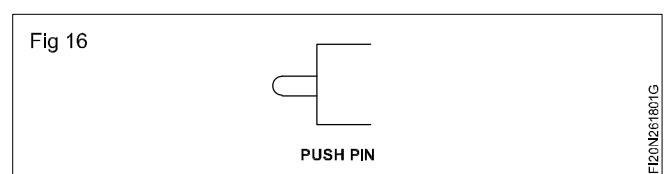
The switching position of direction control valve can be changed by various actuation methods.

Different mechanisms of actuation of valve are shown in fig.12 to fig.19.

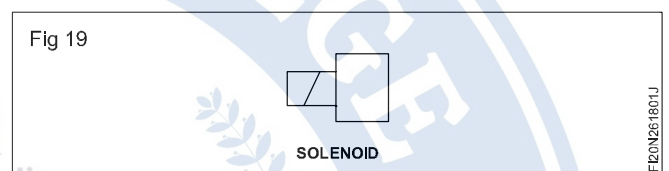
### Mechanical actuation



## Manual actuation



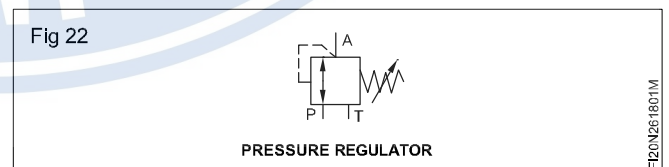
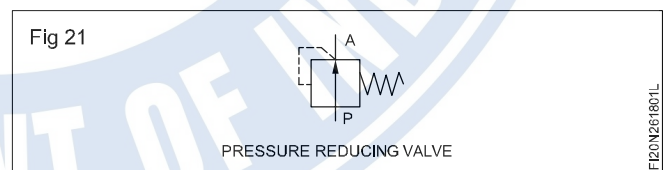
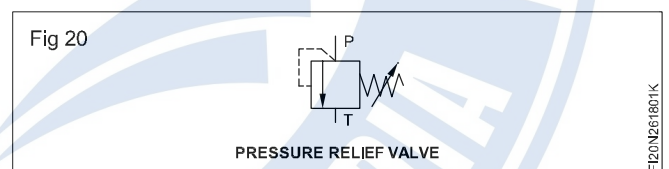
## Electrical actuation



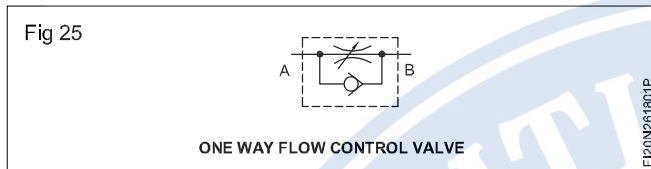
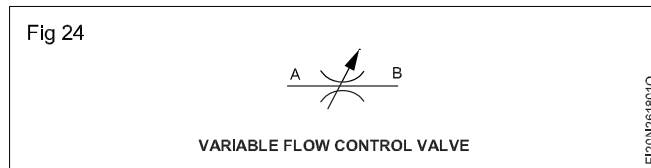
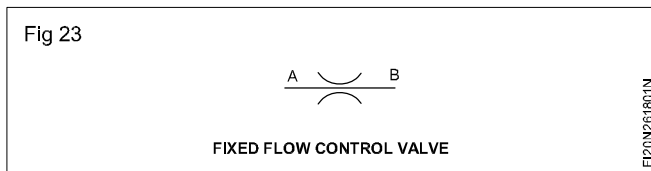
## Pressure control valve

Pressure control valve are represented by a single squares. Arrow within the square indicate the direction of fluid flow. The position of arrow within the square indicates whether the valve is normally open or normally closed.

### Symbols of pressure control valve(Fig.20 to Fig.22)

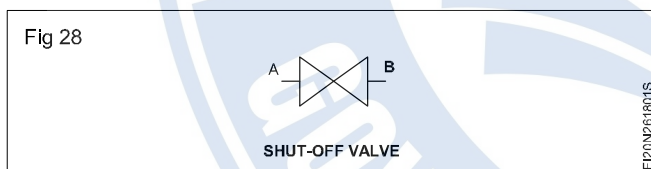
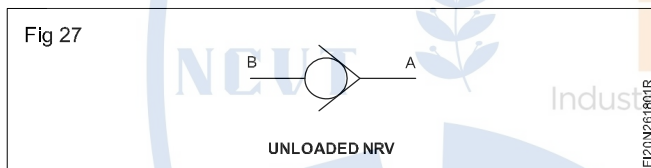
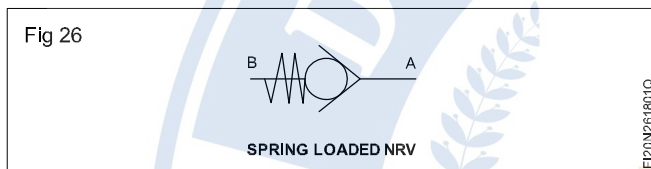


### Flow control valve(Fig.23 to Fig.25)



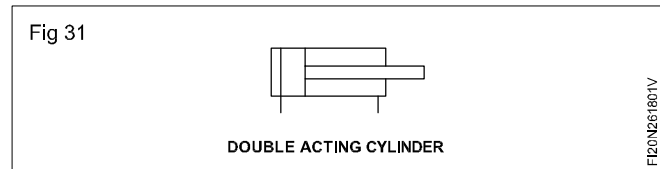
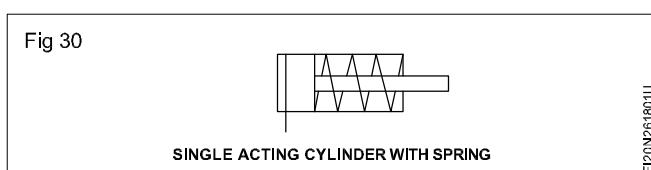
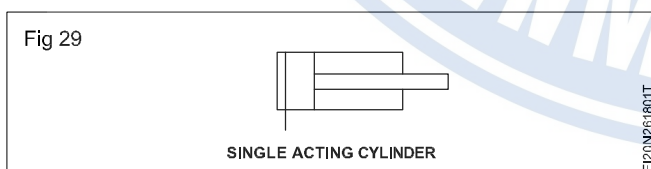
### Non-return valves

The symbol of non-return valve is a ball which is pressed against a sealing seat. (Fig. 26 to Fig.28)



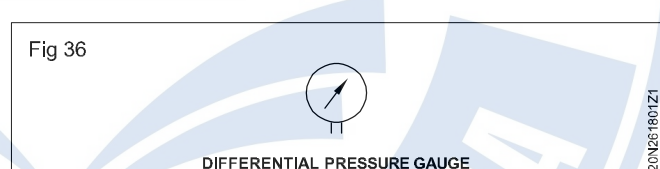
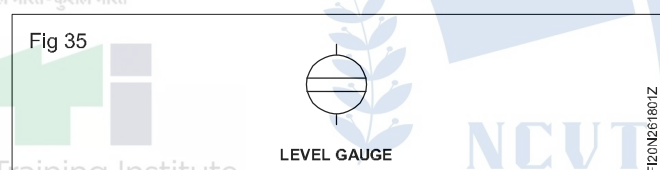
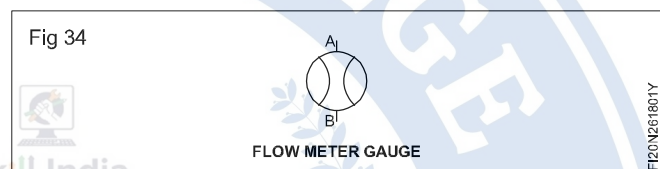
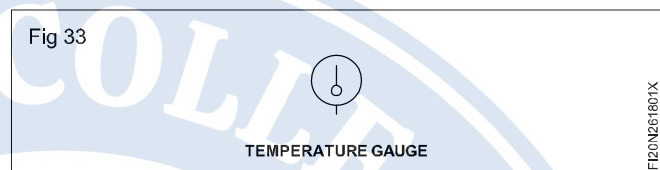
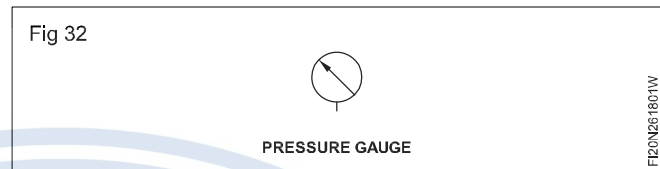
### Cylinder

Single acting cylinders have one port and double acting cylinder have two ports. (Fig.29 to Fig.31)

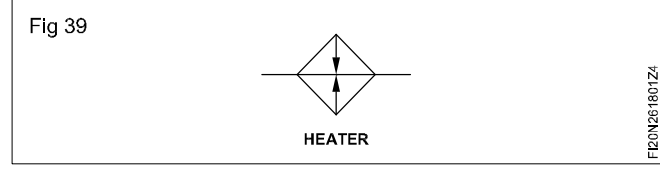
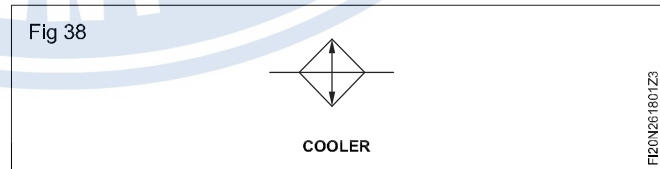
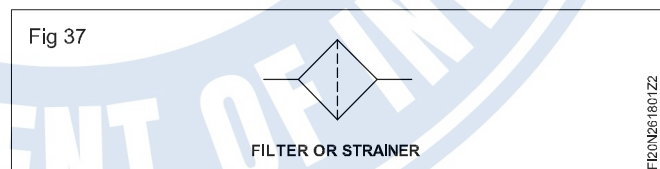


### Measuring devices

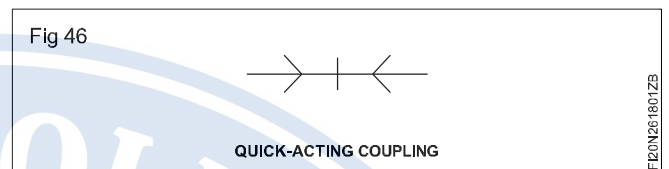
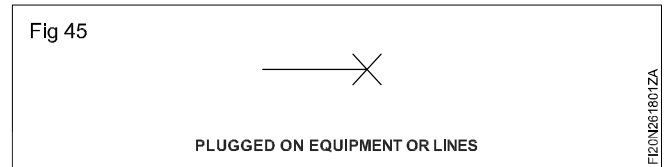
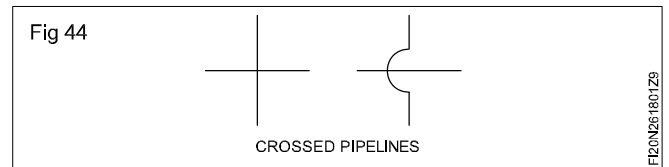
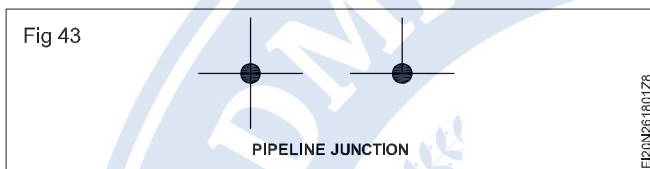
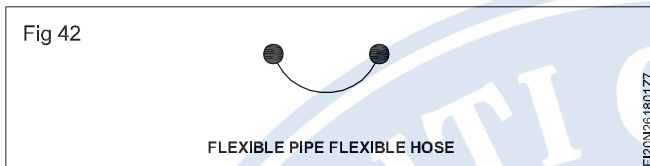
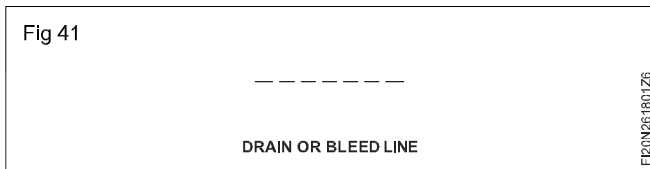
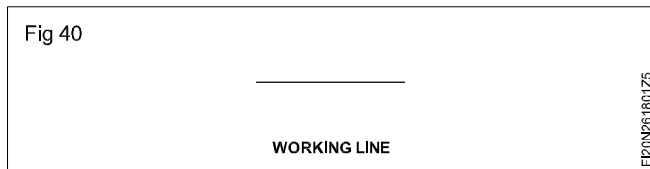
Measuring devices are shown in the Fig.32 to Fig.36.



### Other symbols(Fig.37 to Fig.39)



## Symbols using Line (Fig 40 to Fig 46)



### Hydraulic oil Functions and properties

The primary function of a hydraulic fluid is to convey power. In use, however, there are other important functions of hydraulic fluid such as protection of the hydraulic machine components. The table below lists the major functions of a hydraulic fluid and the properties of a fluid that affect its ability to perform that function:

Function	Property
Medium for power transfer and control	<ul style="list-style-type: none"> <li>Non compressible ( high bulk modulus)</li> <li>Fast air release</li> <li>Low foaming tendency</li> <li>Low volatility</li> </ul>
Medium for heat transfer	<ul style="list-style-type: none"> <li>Good thermal capacity and conductivity</li> </ul>
Sealing Medium	<ul style="list-style-type: none"> <li>Adequate viscosity and viscosity index</li> <li>Shear stability</li> </ul>
Lubricant	<ul style="list-style-type: none"> <li>Viscosity for flim maintenance</li> <li>Low temperature fluidity</li> <li>Thermal and oxidative stability</li> <li>Hydrolytic stability / water tolerance</li> <li>Cleanliness and filterability</li> <li>Demulsibility</li> <li>Antiwear characteristics</li> <li>Corrosion control</li> </ul>
Pump efficiency	<ul style="list-style-type: none"> <li>Proper viscosity to minimize internal leakage</li> <li>High viscosity index</li> </ul>

Special function	Fire resistance Friction modifications Radiation resistance
Environmental impact	Low toxicity when new or decomposed Biodegradability
Functioning life	Material compatibility

### Types of Hydraulic fluids

According to ISO there are three different types of fluids according to their source of availability and purpose of use.

#### Mineral- Oil based Hydraulic fluids

As these have a mineral oil base, so they are named as Mineral- Oil-Based Hydraulic fluids. This kind of fluids will have high performance at lower cost. These mineral oils are further classified as HH, HL and HM fluids.

Type HH fluids are refined mineral oil fluids which do not have any additives. These fluids are able to transfer power but have less properties of lubrication and unable to withstand high temperature. These types of fluid have a limited usage in industries. Some of the uses are manually used jacks and pumps, low pressure hydraulic system etc.

The HL fluids are refined mineral oils which contain oxidants and rust inhibitors which help the system to be protected from chemical attack and water contamination. These fluids are mainly used in piston pump applications.

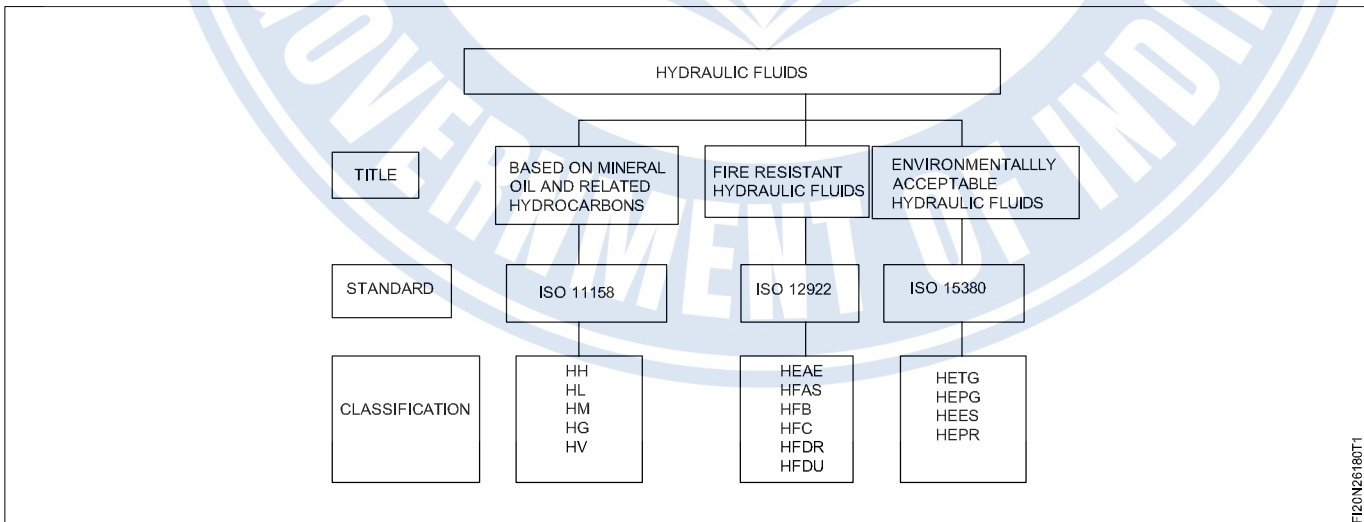
HM is a version of HL- type fluids which have improved anti- wear additives. These fluids use phosphorus, zinc and sulphur components to get their anti-wear properties. These are the fluids mainly used in the high pressure hydraulic system.

### Fire Resistant Fluids

These fluids generate less heat when burnt than those of mineral oil based fluids. As the name suggests these fluids are mainly used in industries where there are chances of the hazards, such as foundries, military, die-casting and basic metal industry. These fluids are made of lower BTU (British Thermal Unit) compared to those of mineral oil based fluids, such as water-glycol, phosphate ester and polyol esters. ISO have classified these fluids as HFAE (soluble oils), HFAS (high water-based fluids), HFB(invert emulsions), HFC(water glycols), HFDR(phosphate ester ) and HRDU (polyol esters).

### Environmental Acceptable Hydraulic Fluids (EAHF)

These fluids are basically used in the application where there is a risk of leakage or spills into the environment, which may cause some damage to the environment. These fluids are not harmful to the aquatic creatures and they are biodegradable. These fluids are used in forestry, lawn equipment, off - shore drilling, dams and maritime industries. The ISO have classified these fluids as HETG (based on natural vegetable oils), HEES (based on synthetic esters), HEPG (polyglycol fluids) and HEPR (polyalphaolefin types).



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## Controlling of Contamination

While the fluid is at operating temperature, completely drain the system. paying attention to the reservoir, all lines, cylinders, accumulators, filter housings or any area of fluid accumulation. Also, replace the filters.

With a lint-free rag, clean the reservoir of all sludge and deposits. Make sure the entire reservoir is free of any soft or loosened paint.

Flush the system with a lower viscosity fluid that is similar to the fluid to be used. A Reynolds number between 2,000 and 4,000 should be selected to achieve enough turbulence to remove particles from the lines. Stroke valves frequently to ensure they are thoroughly flushed. The fluid should be filtered and the flushing should continue until reaching one level beyond the system's target cleanliness levels. For example, if the target is ISO 15/13/11, continue to flush the system until ISO 14/12/10 is reached.

Drain the flushing fluid as hot and as quickly as possible. Replace the filters and inspect/ clean the reservoir again.

Fill the system to approximately 75 percent with the fluid to be used. Bleed/vent the pump. If the pump has a pressure relief or bypass, it should be wide open. Run the pump for 15 seconds, then stop and let it sit for 45 seconds. Repeat this procedure a few times to prime the pump.

Run the pump for a minute with the bypass or pressure relief open. Stop the pump and let it sit for a minute. Close the bypass and permit the pump to operate loaded for no more than five minutes. Allow the relief valve to lift to confirm that it is flushed as well. Do not operate the actuators at this time. Stop the pump and let the system sit for about five minutes.

Start the pump and operate the actuators one at a time, allowing fluid to return to the reservoir before moving to the next actuator. After operating the final actuator, shut down the system. Keep an eye on the fluid level in the reservoir. If the level drops below 25 percent, add fluid and fill to 50 percent.

Refill the reservoir to 75 percent and run the system in five- minute intervals. At each shutdown, bleed the air from the system. Pay close attention to the system sounds to determine if the pump is cavitating.

Run the system for 30 minutes to bring it to normal operating temperature. shutdown the system and replace the filters. Inspect the reservoir for obvious signs of cross-contamination. If any indication of cross-contamination is present, drain and flush the system again.

After six hours of operation, shut down the system, replace the filters and sample and test the fluid.

The sampling frequency should be increased until you are confident that the system fluid is stable.

## Contamination of oil and its control

Contamination in hydraulic systems can be classified into particle contaminants (Metal particles from wear, dirt ingress) or chemical contaminants (water, air, heat, etc). Examples of damage from contamination are: accelerated component wear, orifice blockage, formation of rust or other oxidation, depletion of additives, formation of other chemicals, oil degradation.

### Types of contamination

#### Particle contaminants

Particle sizes are generally measured in micrometers or microns. Some examples of microns: Grain of salt 100 microns, human hair 70 microns, lower limit of visibility 40 micron, milled flour 25 micron, average bacteria 2 micron. Note that most damage-causing particles in hydraulic or lubrication systems are smaller than 14  $\mu\text{m}$  micrometers, so they cannot be seen.

#### Chemical contaminants

##### Water

The most common chemical contaminant in hydraulic systems is water. The presence of water in hydraulic oil can have wide- ranging effects on system components because of its effect on the physical and chemical properties of hydraulic oil. Rust in tanks, reduced lubrication characteristics resulting in accelerated metal surface wear are some of the most obvious physical results of excessive water, however the effects could be as diverse as the jamming of components due to ice crystals at low temperatures. Chemical effects include additive depletion or deposition, oxidation, unwanted reactions which can result in the formation of acids, alcohols or sludges. Oil becomes cloudy when it's contaminated with water above its saturation level. The saturation level is the amount of water that can dissolve in the oil's molecular chemistry and is typically 200 to 300 ppm at 20° C for mineral hydraulic oil. SKF state that hydraulic oil containing just 0.1% water by volume cuts bearing life in half, while 1% reduces bearing life by 75%

##### Air

Air in hydraulic system can exist in either a dissolved or entrained (undissolved, or free) state. Dissolved air may not pose a problem, providing it stays in solution. When a liquid contains undissolved air, problems can occur as it passes through system components. There can be pressure changes that compress the air and produce a large amount of heat in small air bubbles. This compressibility of air means that control of the system is lost. Air bubbles and frothing in the oil reservoir can cause major damage to pumps or it can also cause oil to "boil" out of the tank.

##### Heat

Excessive heat in hydraulic systems can also result in additive depletion or chemical changes to the oil.

## Hydraulics filter

**Objectives:** At the end of this lesson you shall be able to:

- explain hydraulic filters
- list the types of filters
- state the difference between mechanical, absorbent, adsorbent and magnetic filter.

### Filter

Filter is a device which removes solid contaminants from the fluid.

Hydraulic filters are available in several shapes, sizes, micron ratings and construction materials. Hydraulic filters provide in built protection and minimize hydraulic system breakdowns that are quite often caused by contamination.

The life of a filter in a hydraulic system depends primarily on the system pressure, level of contamination and nature of contaminants.

Filters is a very important components used in hydraulic system for the reliable functioning and long service life of the components.

Filter and Strainer are the two terms commonly used.

### Use of Hydraulic Filters

One of the main cause of failure or poor functioning of a hydraulic system is contamination of hydraulic oil or fluid. Hydraulic filters are used for handling and removing contamination from hydraulic oil.

Contaminants of hydraulic fluid are broadly defined as any substance that impairs the proper functioning of the fluid.

Contaminants are classified as

- Solids
- Liquids
- Gaseous
- Bacteria
- Organic

### Types of Filters

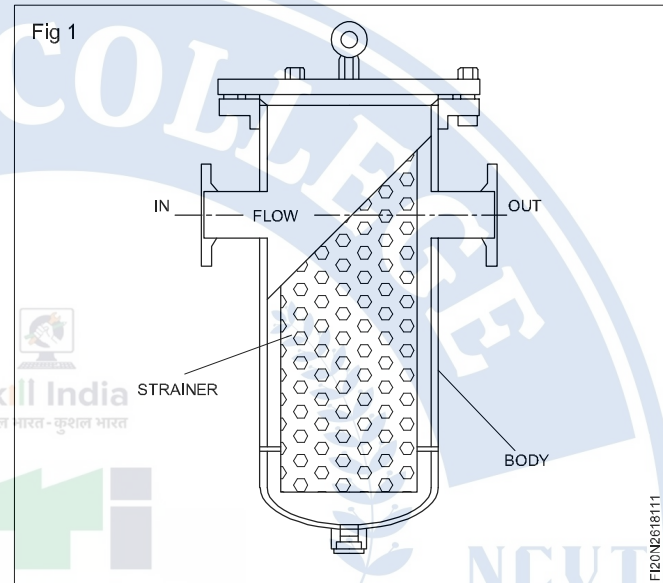
There are four types of filters generally used in hydraulic system.

- Mechanical filter
- Absorbent filter
- Adsorbent filter
- Magnetic filters

### Mechanical filter

Mechanical filters contain closely woven metal screens or discs. They generally remove only fairly coarse particles. Mechanical filter is known as strainer in

hydraulic system. These filters are located in the suction line of the pump, hydraulic oil is drawn from the reservoir through the filter. (Fig.1)



Grade of Mechanical filter: 60-100 $\mu$ m

$\mu$ m is the micron which is 1/1000 part of 1 mm.(ie)

$$1\mu\text{m} = .001 \text{ mm}$$

### Absorbent filter

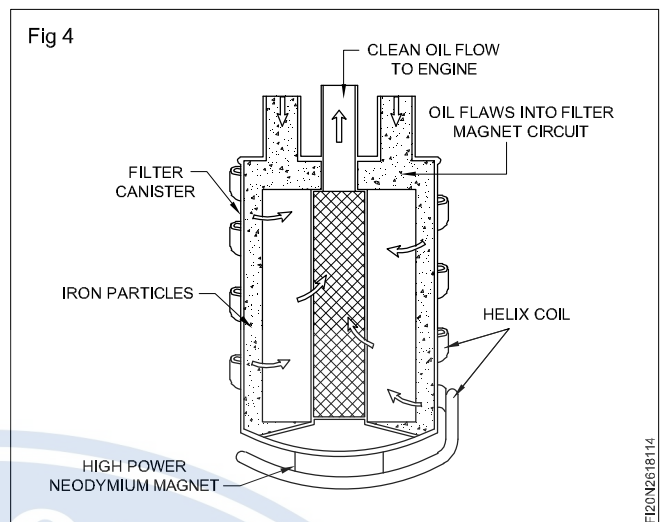
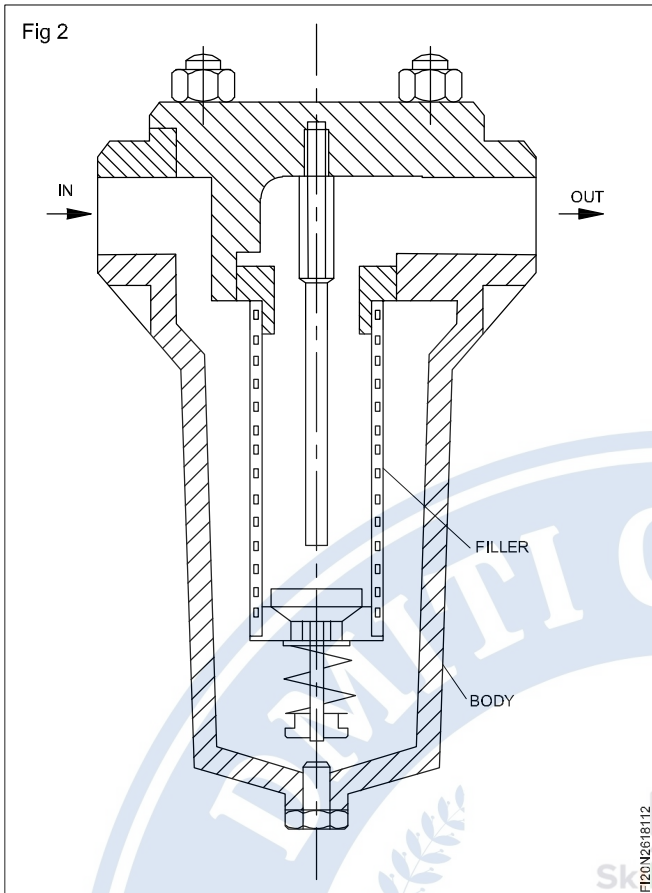
Absorbent filters, such as cotton, wood pulp, yarn, cloth, or resin, remove much smaller particles; some remove water and water-soluble contaminants. The elements often are treated to make them sticky to attract the contaminants found in hydraulic oil.

These filters are installed in the pressure line of a hydraulics system at the pressure port of the pump.

Since this filter is subjected to the maximum operating pressure, it must be of robust design. (Fig.2)

### Adsorbent filter

A filter used for trapping various sizes of particulate matter. Adsorbent filters consist of clay, chemically treated paper and desiccant. (Fig.3)



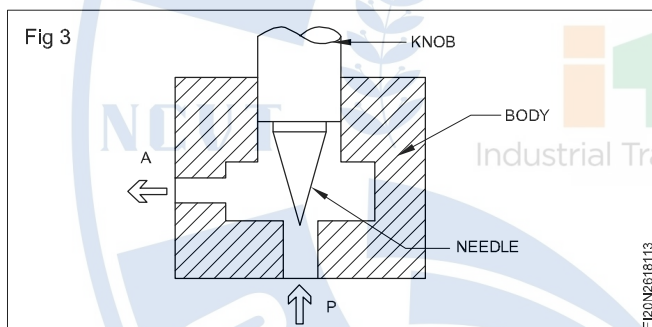
Generally filter can be classified on the basis of their location in hydraulic system:

- Suction strainer
- Pressure line filter
- Return line filter
- Off line filter

#### Filter types on the basis of location

##### Suction strainer

Suction filters serve to protect the pump from fluid contamination. They are located in the upstream of pump's inlet port. Inlet strainers are submersed in fluid in the tank. Suction filters have relatively coarse elements, due to cavitations limitations of pumps. (Fig.5)



##### Magnetic filter

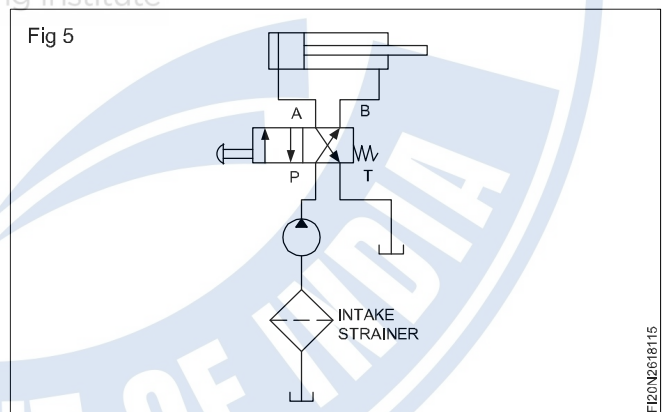
Magnetic filters are basically used to remove the ferrous material from oil along with contaminants.

Magnet are geometrically arranged outside or inside the filter which produce a strong magnetic field that help to arrest the ferrous particles from oil.

In most of magnetic filter permanent magnet is used to create magnetic field.

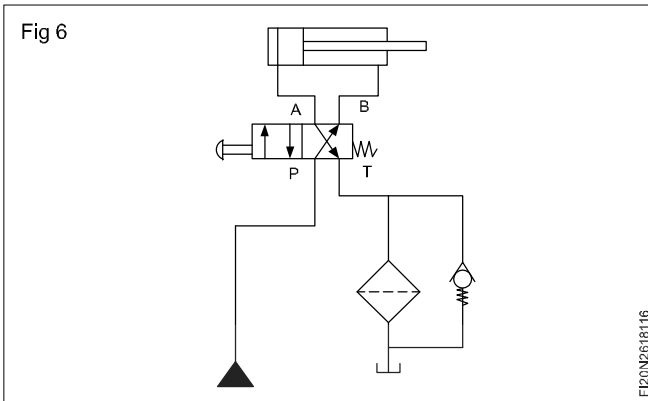
These filters are commonly used in the automotive industry but are also utilized in a number of low-pressure industrial applications.

Filter is wrapped by magnetic ring which transmit a magnetic field through the steel filter bowl in order to trap ferromagnetic debris it is held tightly against the internal surface of the bowl which we can easily separate during servicing. (Fig.4)



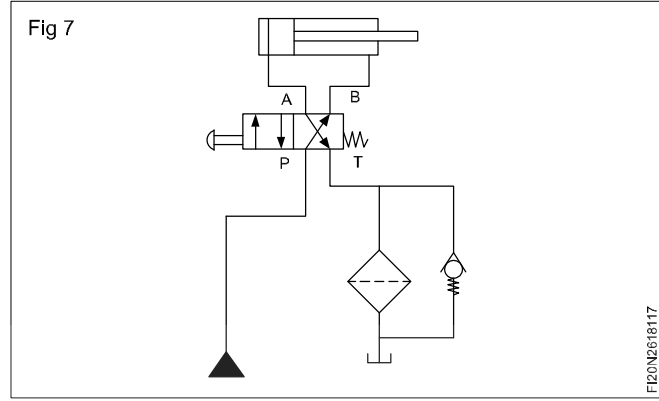
##### Return line filter

Return line filters may be the best choice if the pump is particularly sensitive to contamination. In most systems, the return filter is the last component through which fluid passes before entering the reservoir. Therefore, it captures wear debris from all of the system's working components and any particles that enter through worn cylinder rod seals before such contaminant can enter the reservoir and be pumped back into the system. Because this filter is located immediately upstream from the reservoir, its pressure rating and cost can be relatively low. (Fig.6)



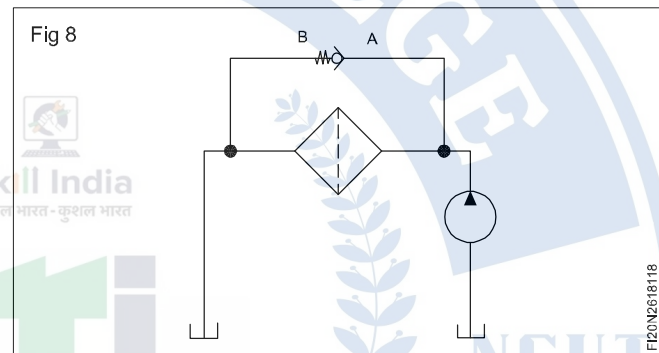
### Pressure line filter

Pressure filters are located downstream from the system pump. They are designed to handle the system pressure and are sized for the specific flow rate in the pressure line where they are located. Pressure filters are especially suited for protecting sensitive components, such as servo valves, because pressure filters are located just downstream from the pump, they also help to protect the entire system from any pump-generated contamination. (Fig.7)



### Off line filter

An off-line filtration circuit includes its own pump and electric motor, a filter and the appropriate connecting hardware. These components are installed off-line as a small subsystem separate from the working lines, or they may be included in a fluid-cooling loop. Fluid is pumped continuously out of the reservoir, through the off-line filter and back to the reservoir (Fig 8).



## Hazard and safety precautions in hydraulic system

**Objectives :** At the end of this lesson you shall be able to

- state the safety precaution while working with hydraulic fluids
- describe related hazards of hydraulic fluid.

### Safety precautions

There are numerous hazards involved, like skin irritation, fires, explosions, environmental damage and a slippery workplace. But hydraulic fluids are required for many machines to function. Therefore it is necessary to follow certain precautions while using these fluids. With proper knowledge of these hazards, working with hydraulic fluid can be safe.

- In order to avoid skin irritations, it is necessary to wash contaminated skin immediately. It is also necessary to keep your clothing clean.
- Wearing masks and gloves while using hydraulic fluids is also helpful.
- To avoid environmental dangers, there is biodegradable hydraulic fluid option, though it is more expensive.
- To avoid fires, materials and fluids soaked in hydraulic fluid should be stored in sealed metal containers and disposed of at proper places.
- To check for leaks, use cardboard.

- Never use hands or fingers to search for hydraulic leaks.
- Maintain a clean work area free of slipping hazards.
- Use chemical resistant gloves, splash goggles and a chemical resistant apron to avoid prolonged or repeated skin or eye contact.
- Never begin work on a hydraulic system until fully trained.

### Related hazards

#### Health problems while using hydraulic fluids

People can become exposed to the chemicals in hydraulic fluids. The exposure to chemicals may be due to inhalation, ingestion or touch. There are instances of people suffering from skin irritation or weakness in hands while handling hydraulic fluids. There are also cases of intestinal bleeding, pneumonia or death through hydraulic fluid ingestion though no serious hazards are reported with hydraulic fluid inhalation.

Similar to ingestion, fluids can be accidentally injected into the skin as well. This takes place when the high pressure hydraulic system hose is disconnected and toxic fluids are leaked and injected into the skin. If there is a small leak in the hydraulic pipe and someone runs there hand along it, at 2000 psi, they can easily incur an injection of hydraulic fluid and may not even be aware that it happened until gangrene begins to set in.

#### **Fire dangers associated with hydraulic fluids**

When working with hydraulic fluid, there is every chance that the hydraulic fluid gets heated to high temperatures. And it is evident that most petroleum - based hydraulic fluids will burn and thereby create explosions and burns.

#### **Environmental problems related to hydraulic fluids**

Another hazard of hydraulic fluid is that when the hydraulic hose or pipe leaks, the chemicals of the fluids can either stay on top of the soil or sink into the ground. If the chemicals get mixed in a water body, they will sink to the bottom. In fact in such cases the chemicals can stay there for more than a year. Aquatic life can absorb the

toxic hydraulic fluid, leading to illness or death to the animal or anything higher on the food chain. For example, a hawk that eats a fish that has been contaminated by hydraulic fluid that was mixed in water could become ill as well.

#### **Fluid texture problems**

Although the slimy texture of hydraulic fluids may not seem like a danger or a problem, a spill can cause a person to slip and fall. Also when there is fluid on the hands of a person, it can cause him to slip while climbing on a machine. It can also cause the operator to lose steering control.

#### **Injuries from loose hydraulic hoses**

Due to high pressure with in a hydraulic system, the impact force of a disconnected and flailing hydraulic hose can cause abrasions, temporary unconsciousness, bruise, fractures and lacerations. Proper maintenance and good pre - shift equipment inspections can minimise these hazards



**Hydraulic pumps**

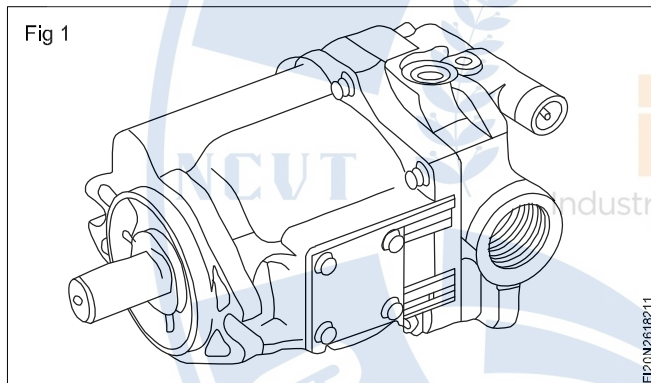
**Objectives :** At the end of this lesson you shall be able to

- **define hydraulic pump**
- **differentiate between positive and non-positive displacement pump**
- **explain working of gear pump**
- **explain the working of vane pump**
- **explain the working of piston pump.**

**Hydraulic Reservoir and Accessories**

Hydraulic reservoirs are storage tanks that hold liquids or gases used for fluid power applications. They are usually rectangular and cylindrical shaped. The purpose of the hydraulic reservoir is to hold a volume of fluid, transfer heat from the system allow solid contaminants to settle and facilitate the release of air and moisture from the fluid.

A hydraulic pump fig 1 is a device which converts mechanical force and motion into hydraulic energy. Many different sources provide mechanical power to the pump. They are electric motors, air motors, engines and manual operation.



**Classification of pumps**

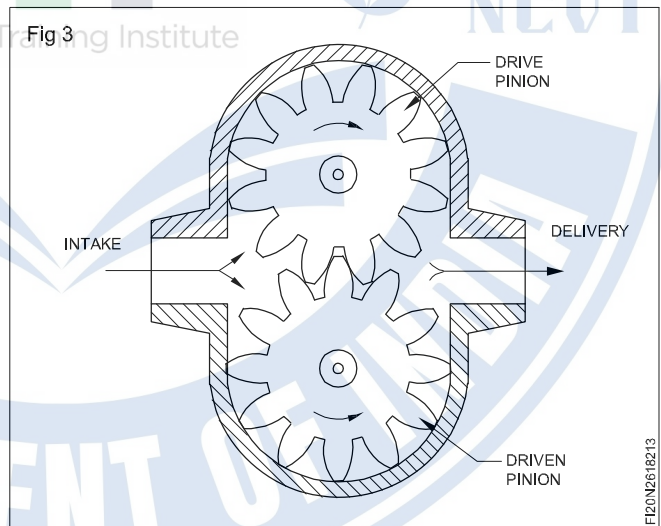
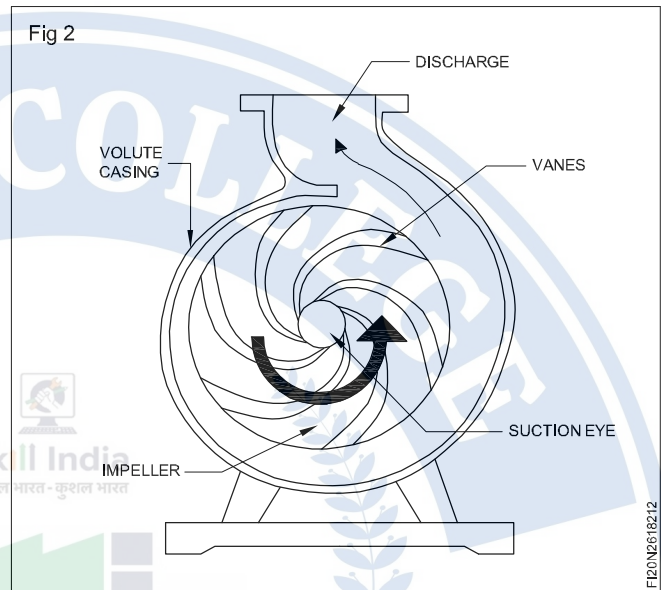
Pumps are classified as either non-positive or positive displacement. This describes the fundamental division of pumps.

**Non-positive displacement pumps**

- The non-positive displacement type pump gives continuous discharge.
- The non-positive displacement pump does not provide a good seal against slippage, causing pump output to vary as the system pressure changes.
- The volume of fluid delivered during each cycle will depend on resistance to flow in the system.
- Centrifugal pumps are the Non-positive displacement pumps.(Fig 2)

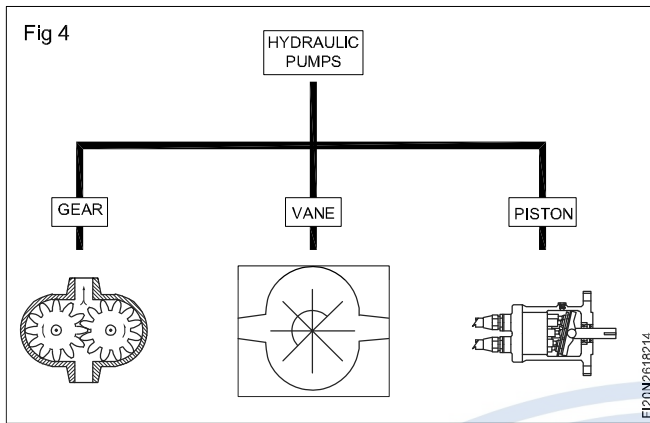
**Positive displacement pumps (Fig 3)**

- A positive displacement pump provides positive internal seal against slippage.



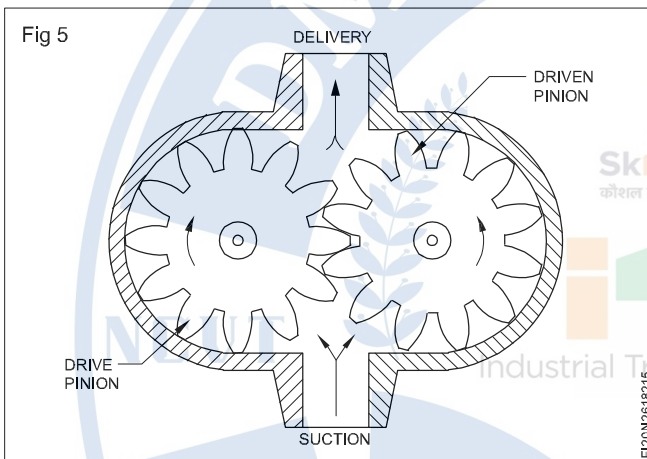
- This type of pump is capable of delivering a definite volume of fluid for each cycle of pump operation.
- Closing the outlet of a positive displacement pump causes an instantaneous increase of pressure. This increase in pressure can stall the equipment or break up of components.
- Gear pump is an example of positive displacement pump.

## Types of Hydraulic pumps(Fig 4)



### External Gear pump

External gear pump is the most common type rotary pump. In this pump the drive gear is turned by a drive shaft, which engages the power source. The inlet port is connected to the supply line and the outlet is connected to the pressure line. (Fig 5)



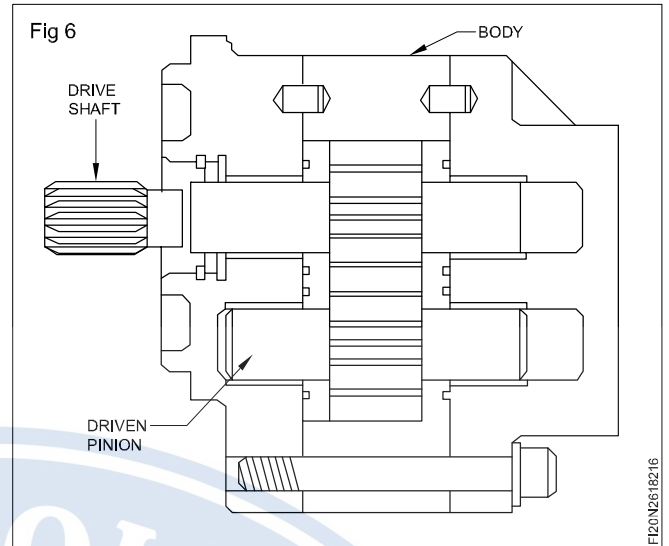
As gears rotate the volume of area on the inlet increases, thereby decreasing the pressure and making it possible for the atmospheric pressure exerted on the surface of the liquid in the reservoir to push the liquid into the inlet port. This causes liquid to be trapped in the gear space as the gears rotate and to be carried from the inlet port to the discharge port.

This action produces flow of liquid into the system.

A tighter seal against slippage can be accomplished by a metallic contact between the teeth ensures the seal against slippage. (Fig 6)

### Important parameters

- Displacements volume 0.2 to 200 Cm<sup>3</sup>/rev
- Suitable for pressure up to 300 bar
- Fixed displacement only
- Generally noisy
- Compact and low weight
- Low cost

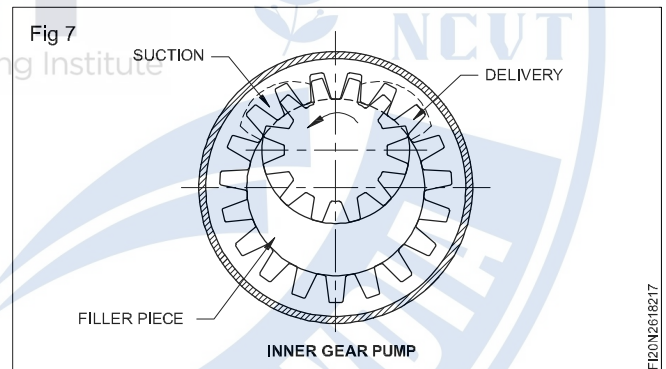


### Gear pump applications

Gear pump is generally used to transfer lubricating oil in industrial & automobile application. Some time it is also used in some hydraulics power application.

### Internal gear pump

Two gears are available in internal gear pump. The spur gear is mounted inside a large ring gear (outer gear). The smaller spur gear is in mesh with one side of the larger gear and kept apart by a crescent-shaped separator on the other side. The crescent-shaped separator isolates the inlet port from the outlet port. In the internal gear pump, both gears rotate in the same direction. (Fig 7)



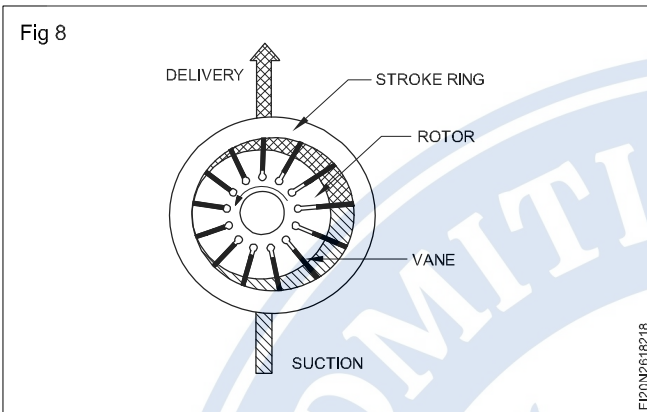
As the gear teeth un-mesh, a partial vacuum is created on the inlet side. Atmospheric pressure forces liquid into the space created, and with the rotation of the gears, liquid is carried around the periphery of the gears and the crescent-shaped separator until it reaches the outlet port. A continuous flow of liquid is pushed out through the outlet port.

### Important parameters

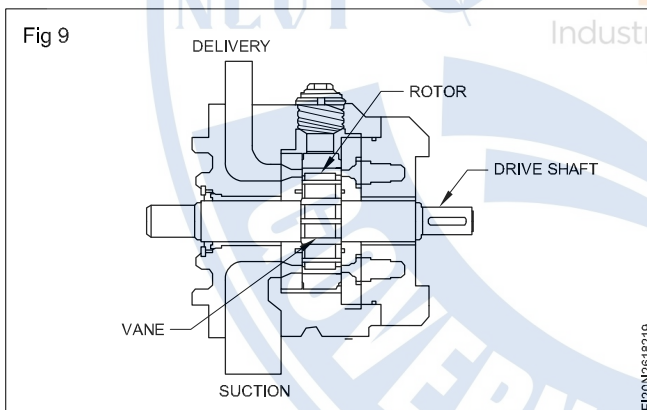
- Internal gear pumps are suitable for pressure up to 3500 psi.
- Working a wide viscosity range up to 2200 cSt, depending on flow rate.
- Generally quiet.
- Internal gear pumps have a high efficiency even at low fluid viscosity.

## Vane Pump

Vane pump is very common type of pump. The vanes pump having slots in the rotor. When the rotor spins, centrifugal force pushes the vanes out to touch the casing, where they trap and propel fluid. Springs are used to push the vanes outward. When the vanes reach the delivery side they are pushed back into the rotor by the casing. Fluid escapes through a channel or groove of the casing. In this vane pump there is considerable unbalanced force is acting on the drive shaft because high-pressure area is available on outlet side. (Fig 8)



The inlet port is located in that part of the pump where the chambers expand in size so a partial vacuum is formed to allow liquid to flow into the pump. The liquid is trapped between the vanes and is carried to the outlet side of the pump. The chambers at the outlet side contract in size, and this action forces liquid through the outlet port into the system. (Fig 9)

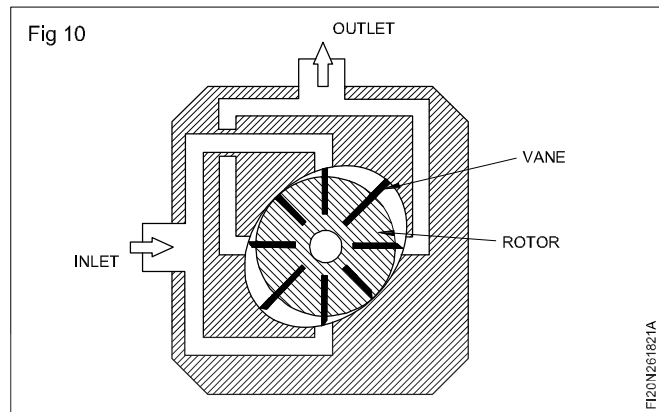


### Balance Vane pump

This design results in two pressure cycles per revolution. The two outlet ports are spaced 180° apart so that the pressure forces on the rotor are balanced. These pumps can develop much higher pressures at high rotational speeds. (Fig 10)

### Vane pump characteristics

- Typical use for higher flow application.
- Typical pressures upto 160 bar
- Simple multiple assemblies



- Range of pump controls

- Low noise

### Vane pump applications

Vane pump is used for higher discharge & low pressure application. It is used to transfer lubricating oil in industry & also used in medium machine tools and presses.

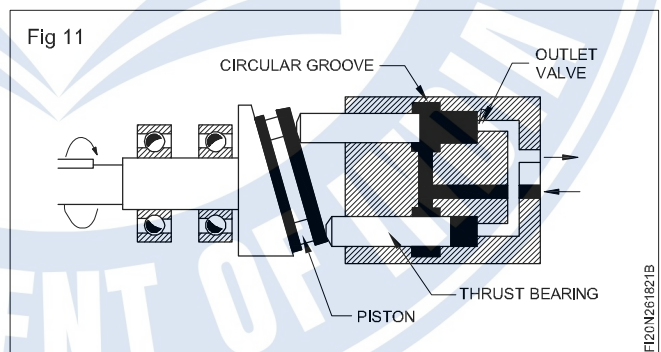
### Piston pump

Piston pump is a common pump used for high pressure application. Following three types of pump are come in this category:-

- Axial piston pump
- Bent axis piston pump
- Radial piston pump

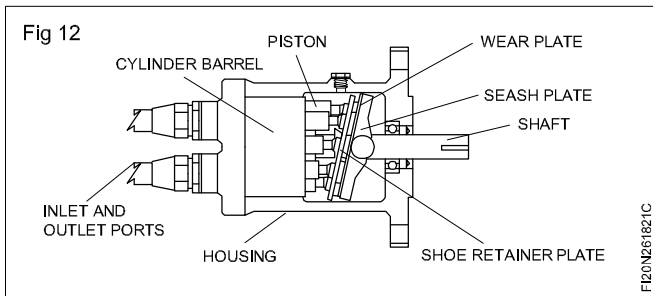
### Axial piston pump

In the axial piston pump the block and the piston rotates on a shaft in such a way that the piston reciprocates in their cylinders bores, axially. This motion is called axial motion. The pumping action is made possible by a universal joint or a link and a swash plate. (Fig 11)



The main parts of the pump are the drive shaft, pistons, cylinder block, and the swash plate. Atmospheric pressure forces liquid in one port; and it is forced out the other port by the reciprocating action of the pistons.

A fill port is located in the top of the cylinder housing. The opening is normally plugged but it can be opened for testing pressure in the housing or case. If a new or repaired pump is installed, this plug must be removed and the housing filled with the recommended fluid. (Fig 12)



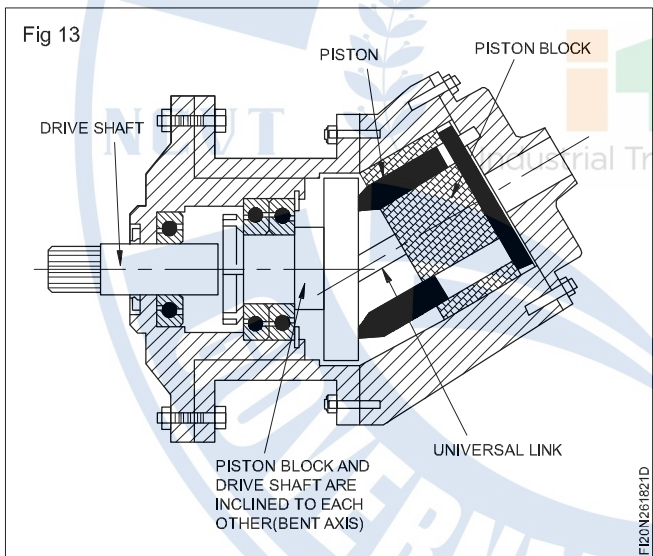
As the drive shaft rotates, it rotates the cylinder block and the pistons. The offset position of swash plate in pump block causes the pistons to move back and forth in the cylinder block. The shaft, pistons and cylinder block rotate together.

As the pistons reciprocate in the cylinder block, liquid enters through one port and is forced out through the other. This action provides a steady, non-pulsating flow of liquid.

Pumping action depends upon tilt angle of the swash plate. If there is no tilt; there is no pumping action.

### Bent axis piston pump

Like the swash plate pump, this pump is also of the axial piston type. There are several pistons those are parallel to each other and reciprocate axially in a piston-block. However unlike the swash plate pump, the drive shaft is inclined at an angle to the piston-block and hence the termed bent axis (Fig 13).

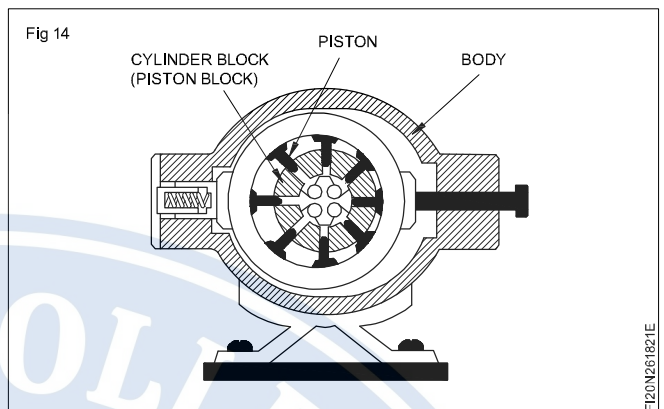


There are several piston housing within slots in the piston-block and they are connected to the drive shaft-flange. A universal link key the piston-block to the drive shaft to maintain alignment and to assure that they rotate together.

As the drive shaft rotates, it transmits drive to the pistons and piston-block. At the suction side, along the direction of rotation between the piston-block and drive shaft-flange distance increases and the piston are pulled out, thus resulting induction. Alternately, the pistons are pushed in as they pass along the discharge port, thus resulting in discharge. This reciprocating of the piston as the drive shaft rotates result in the pumping of the liquid.

### Radial piston pump

A typical picture of a radial piston pump is illustrated. The pump has several pistons those are uniformly spaced and housed radially in a cylinder block (Piston-block). The pistons reciprocate in radial direction to the cylinder-block axis and hence the term radial piston pump. (Fig14)



The drive shaft transmits drive torque to the piston-block by means of a cross-disc coupling. The piston-block rotates around a pintle, which has ducts routed to inlet and outlet connections behind the pump. There are several piston arranged radially inside slots in the piston-block, which against a stoke ring through slipper pads. The piston is connected to the slipper pad by means of a ball and socket joint and the slipper pad is guided in the stoke ring by means of two overlapping rings. The stoke ring is eccentrically located with respect to the piston-block.

When the piston block is rotated, the pistons are forced against the stoke ring by centrifugal force and hydrostatic pressure. Sometime springs are also used for this purpose. Since the stoke ring is eccentric to the piston-block, in one half of the rotation the piston move away from the piston-block. Thus liquid is drawn through inlet port in the pintle into slots in the piston-block. In the other half of the rotation, the piston move into the piston-block, thus forcefully discharge liquid trapped in the slots, into outlet ports in the pintle. If the eccentricity increases the stoke length also increases and it amounts to twice the eccentricity.

### Important parameters

#### Piston pump applications:

Piston pump are commonly used for high pressure and low discharge application.

- Displacements to 750 cm<sup>3</sup>/r
- Pressure capabilities to 350/400 bar
- High noise level
- Sensitive to poor inlet conditions & contamination
- High overall efficiency
- Good life expectancy
- Large, bulky units
- High cost.

#### Piston pump applications

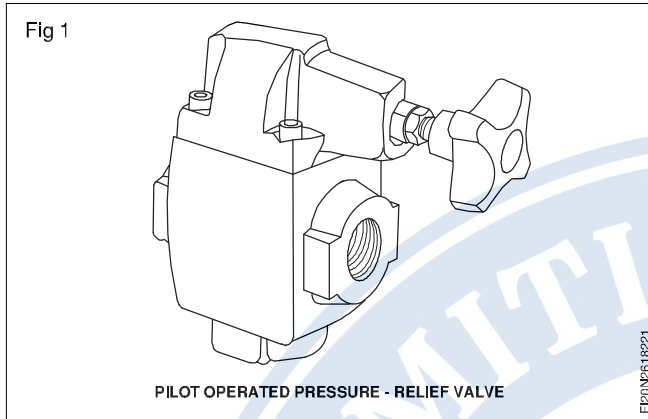
Piston pump are commonly used for high pressure and low discharge application.

# Pressure relief valve

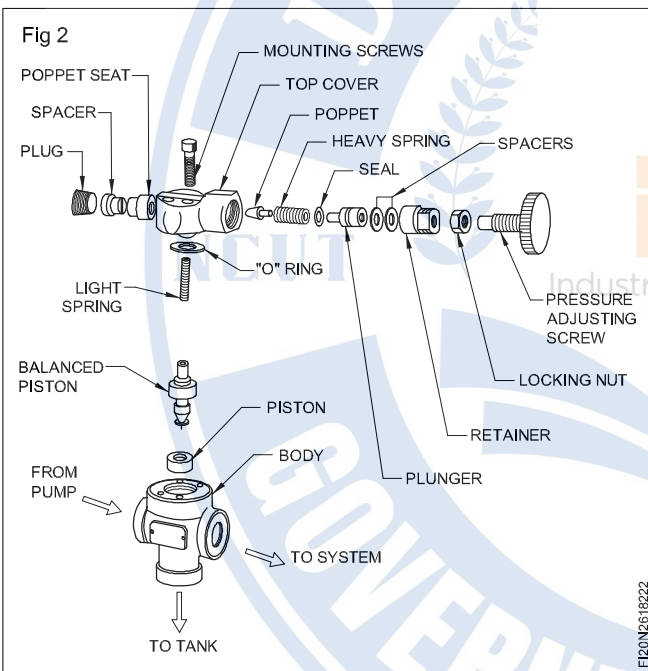
**Objectives:** At the end of this lesson you shall be able to

- identify different parts of a pressure relief valve
- explain the functional features of a different parts of a pressure relief valve
- explain the constructional features of a pressure relief valve.

The general outlook of a pressure relief valve is shown in (Fig 1). Knob is the main controlling element from outside.



The following are main parts (Fig 2) of a pilot operated relief valve:



- |              |                 |
|--------------|-----------------|
| Body         | Poppet          |
| Top cover    | Poppet seat     |
| Piston       | Heavy spring    |
| Light spring | Adjusting screw |
| Piston seat  |                 |

## Body

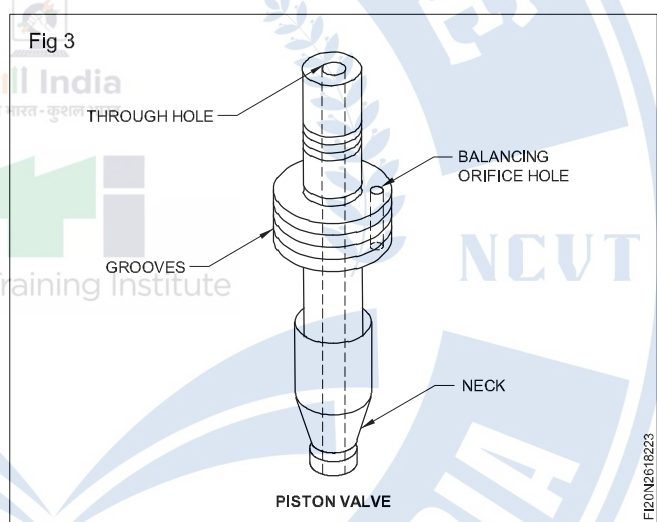
Body of the valve is a fine grade cast iron. The inside of the casting is accurately machined to accommodate piston, piston seat and tight spring. Body is fixed with top cover by screws. Ports for inlet outlet and drain connections are provided in the body, as threaded holes. The body accommodates the main relieving mechanism.

## Top cover

The top cover is also a fine grade casting. It is machined inside to accommodate - poppet, heavy spring, adjusting screws, seals and vent plug. The top cover is fixed with the body by means of screws. The top cover houses the pilot operating mechanism, by means of the stated elements.

## Piston

It is the main relieving valve element in the body. It is made of wear resistant steel, hardened and ground. The sliding portions of the valve are provided with shallow grooves. These groove retain oil, to give oil film for lubrication. There is a through hole at the centre of the valve piston. (Fig 3) There is an orifice hole on a flat side of large diameter. The purpose of through hole is to relieve oil at the time of cracking. The orifice hole fill up the area above piston from the inlet pressure area to balance the piston.



The bottom of the valve is tapered to have a cone seating in closed condition. Piston is accommodated in the body.

## Light spring

The purpose of light spring is to retain the piston down against the seat in a balanced condition. It is accommodated in between the large diameter of the piston and body portion around the upper stem of the piston. This spring is not adjustable one, for its tension.

## Piston seat

It is a liner bush tightly fixed in the body. It is made of wear-resistant steel, hardened and ground. The inner side of the bush has a taper to seat the tapered portion of the piston valve.

## Poppet

Poppet is a conical member housed in the top cover. Poppet serves as a pilot valve. It is held in position by a

heavy spring. It is also made of a wear resistant steel with a fine conical ground surface.

This conical seat will have perfect sealing against oil from pilot port. Poppet is retained by a heavy spring.

### **Poppet seat**

It is a seat for the poppet valve. It has got a conical seat within to match the tapered surface of a poppet. It is a hardened ground and rigidly fixed inside the top-cover by press-fit.

### **Heavy spring**

This spring has to seat the poppet in the pilot port.

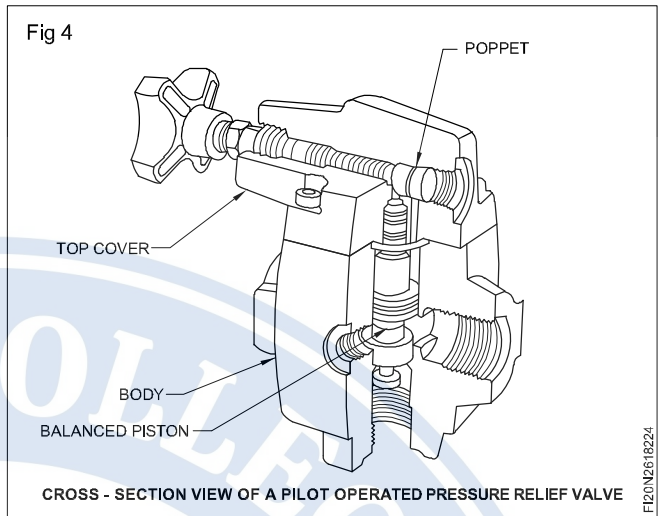
This spring is housed in between a plunger and maximum diameter of the poppet. When the force exerted by the oil at pilot port is more, the heavy spring lift off the poppet, to relieve oil. The tension of spring is adjustable by means of knob.

### **Adjusting screw**

Adjustable screw is a fine pitched screw along with knob accommodated in the top cover. The matching thread for this screw is provided by the retainer rigidly fixed in the body, by a locking nut. Spacers are used in initial setting to adjust the tension of spring.

Leakage between the cast bodies and screw end are prevented by suitable seals made of heat and oil resistant rubber. Plug is used to dummy the port.

The complete assembly of all parts in a pilot operated relief valve is shown in Fig 4 by a cross-sectional view.



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## Tube and pipe assembly

**Objective:** At the end of this lesson you shall be able to

- state the various types of tubes and pipes fitting in an hydraulic system.

### Tubings in hydraulic system

In any hydraulic system the fluid should pass from one element to the other without breaking. For this purpose tubing is employed. Tubes act as a leakproof carrier for hydraulic fluid from and to the various elements used in the hydraulic circuits.

These pipes/tubes should be capable of withstanding pressure and also temperature. Thus the pipes also act as a area where the fluid dissipates the heat.

Normally the term tube and pipe is always leading to a confusion. What is the exact definition of a tube?

### Difference between a tube and pipe

The difference between a pipe and tube is very narrow. Tube walls are usually thin contrary to the pipe walls which are thicker.

Tube generally is seamless in its design, whereas pipe may beveled.

Tubes, because of its thin wall cannot be threaded, whereas pipes can be threaded without affecting the strength.

Both tube and pipe are available in steel, but tubes are available in copper, brass, steel and also in plastic.

Bending of tubes are relatively easier compared to pipes, so tube have better flexibility over the pipes.

A main difference of the tube to a pipe is the inner wall of a tube is smooth, so as to provide a smooth flow of liquid resulting in a LAMINAR flow, which usually is a turbulent flow in a pipe, having not such a smoother inner side.

But generally even now in workplaces, both pipes and tubes are mentioned not precisely.

### Tube material

Tubes are usually specified by their outside diameter and the length. Usually the length is made to customer requirement by cutting the tubes. Tubes are available in various materials such as copper, brass, aluminium, carbon steel and stainless steel. All tubes are usually seamless drawn tubes.

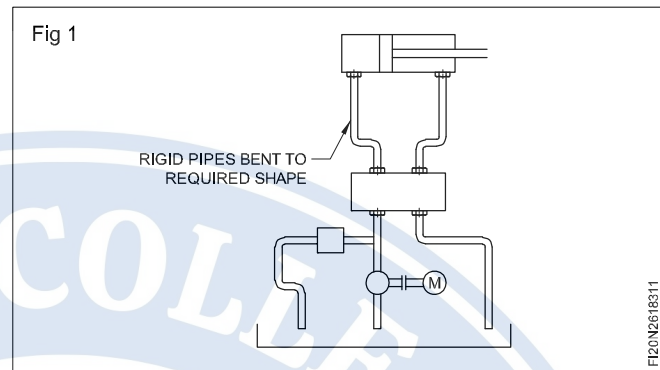
### Classification of pipe fitting in hydraulics

Tube/pipe fitting in hydraulics is usually classified as

- Rigid connections
- Flexible connection.

### Rigid connections

Rigid tubing is done using metallic tubes. The tube is bent to the required length and shape and the various elements of the circuit is connected. (Fig. 1)

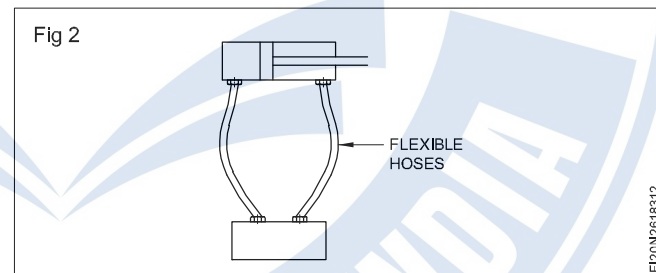


This type of connection is done where the circuit only built will not have any change in design or change in the position of the elements in future.

If there is a change then the existing pipes have to be disconnected and new pipes have to be bent fresh.

### Flexible connection

This is a system in which the elements are connected with flexible tubes normally called as hoses. Flexible hoses are made of synthetic rubber tube reinforced with one or two braids of high tensile steel wire or with synthetic yarn suitably covered with weather resistant rubber. (Fig. 2)



Flexible hoses are very good in taking up pulsating pressure which is dampened by the hose itself. In case of rigid pipe this would have resulted in vibration ultimately causing breakage or loosening of connector.

### Advantages of using hoses

- Insulates against shock noise and vibration
- Connects stationary parts
- Makes connection easier in congested space
- Makes good temporary connections
- Provides connections and disconnections which are to be frequently changed.

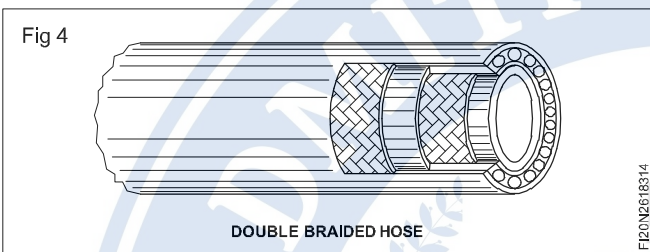
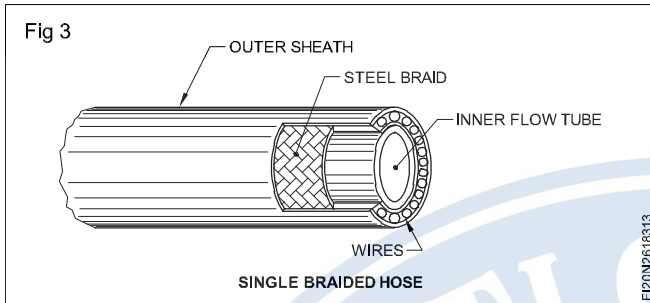
## Types of flexible hoses

Flexible hoses again are available to cater various pressures and temperature ranges.

Hoses are usually classified according to the:

### Type of construction

(a) Wire braided-single (Figs. 3 & 4) or double braid



(b) Synthetic yarn braid (Cotton, fibre, asbestos etc).

Normally the flexibility of synthetic yarn braided hoses are more flexible but the operating pressure is a limitation.

Whereas wire braided hoses because of steel wire used is good in withstanding high pressures up to 300 cm<sup>2</sup> but is not as flexible as synthetic yarn braided hose.

### Pressure and temperature withstanding capacity

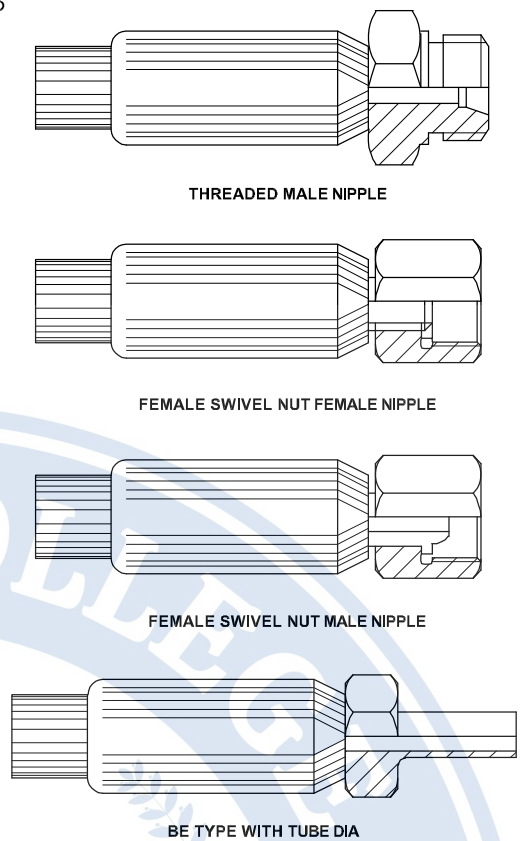
Hoses are used in hydraulic circuits and are subjected to pressure from the oil flowing through it. So hoses are classified according to its pressure withstanding capacity also this is given by the specification standard SAEJ517 as SAE100R1, SAE100R2 etc.

The number R1, R2 indicates the withstanding capacity in pressure and temperature and the construction. This has to be noted while selecting the hoses keeping in mind the maximum pressure produced in the circuit under construction. For actual values of pressure and temperature the manufacturers catalogue has to be referred.

### Type of pipe end fitting

Since hoses are used in various applications and has to be mounted to suit a variety of connectors, it is also available with various end fitting. There are many type of end fitting available as required by customer. Some of them shown in the Fig. 5.

Fig 5



### Specification of hoses

Flexible hoses are specified according to the following informations,

- Internal diameter
- Length between the two end connectors
- Pressure and temp withstanding capacity
- Type of end fitting.

All these can be readily referred from manufacturers catalogue for the specific application. An example is given below.

dia. 10 x 1000 x SAE100R2 x both ends female nuts.

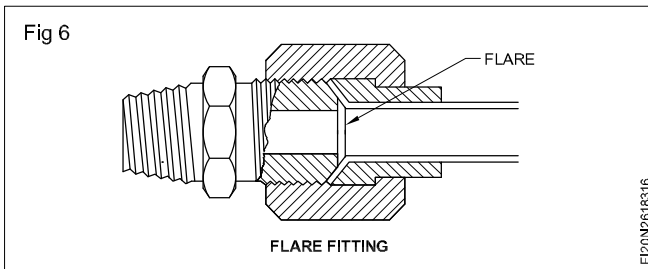
### Connectors

Connectors are the elements which connects the tube ends to the body of the various hydraulic elements. Connectors also serve various other purposes like change in size of tube, change in direction of flow, restriction of flow etc. Connectors can be grouped according to various parameters.

- According to the type of sealing design.
- According to the shape, size and purpose used for.

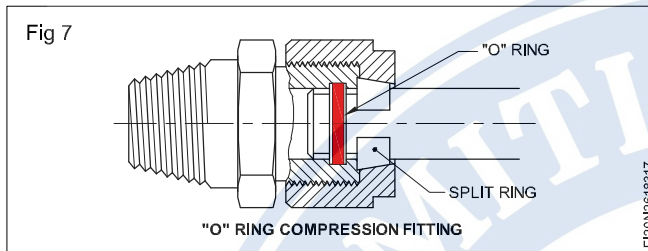
## According to the type of sealing design

### Flared fitting (Fig 6)



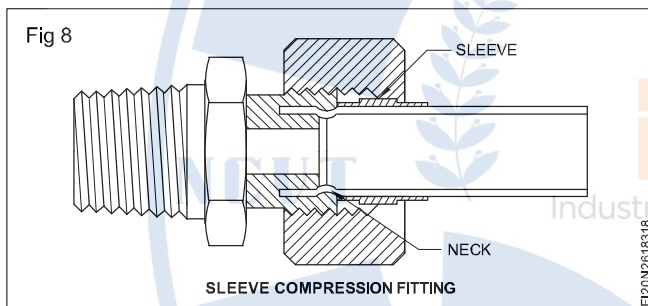
In this, the pipe is flared and fitted to the suitable connector.

### 'O' ring compression fitting (Fig 7)



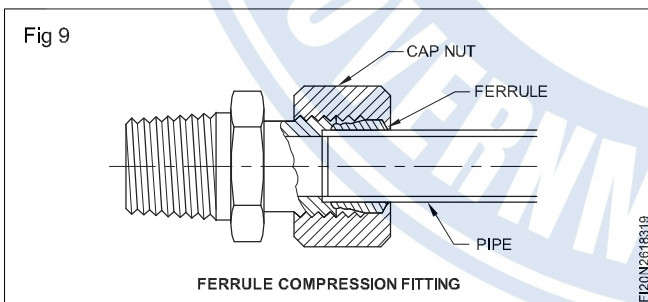
In this type of 'O' ring seals the pipe outside diameter. The split ring clamps the pipe in position.

### Sleeve compression fitting (Fig 8)



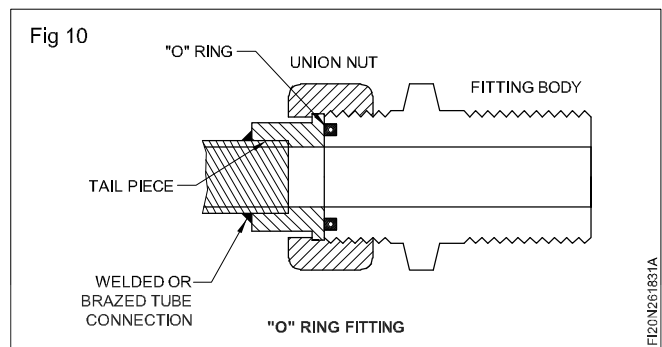
In this the pipe is formed the neck seals the path for oil along with the sleeve.

### Ferrule compression fitting (Fig 9)



In this, the ferrule is of a special design, ferrule bites into the tube to form a permanent seal.

### O' ring fitting (Fig 10)



The pipe is welded with a ring with a flat face, this face seals against a 'O' ring.

Various fitting have been illustrated, each of these fittings have the corresponding connectors. The connection will be perfect only when the connection is made according to the manufacturers instructions.

The selection of the right type of connector depend upon various factors like

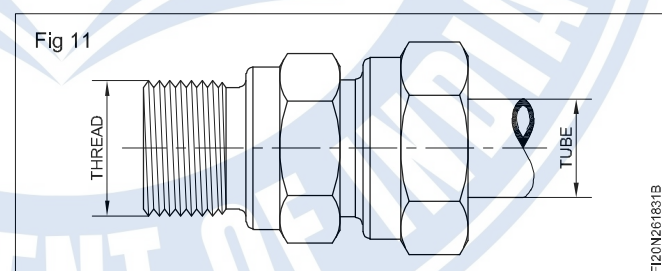
- Working pressure of system
- Frequency of assembly and disassembly
- Vibration or shock level in circuit
- Working area.

### According to the size, shape and purpose of use

Connectors are used to connect either a tube to the body of a hydraulic element or a tube end to another tube end.

### To connect a hydraulic element to a tube end

The connector shown (Fig 11) has threads which is screwed on to the body of the hydraulic element. On the other side a tube is fixed with proper sealing. This sealing is done by various methods as discussed in the previous exercise.



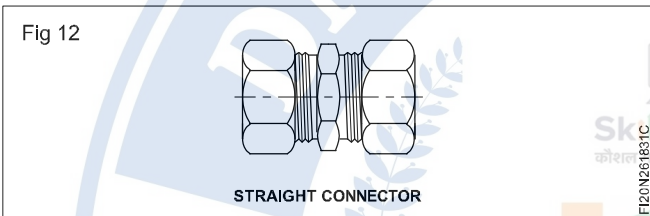
These connectors are available in various size according to the pipe it has to accommodate. The chart shows the pipe size and the threads on the connector.

Pipe outside dia	British standard pipe thread (BSP)	Metric Fine thread
6	R 1/4"	M22 x 1.5
8	R 1/4"	M14 x 1.5
10	R 3/8"	M16 x 1.5
12	R 3/8"	M18 x 1.5
14	R 1/2"	M20 x 1.5
16	R 1/2"	M22 x 1.5
20	R 3/4"	M27 x 2
25	R 1	M33 x 2
30	R 1 1/4"	M42 x 2
38	R 1 1/2"	M48 x 2

The various types of connectors in this category to take care of the flow direction of fluid as follows

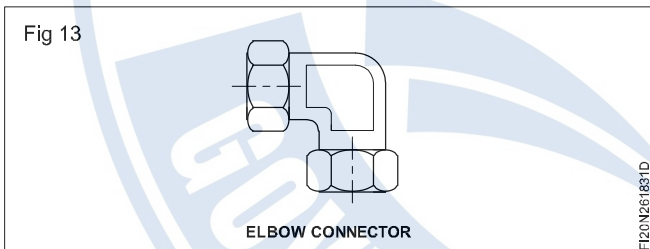
#### Straight connector (Fig 12)

To connect tube perpendicular to the body.



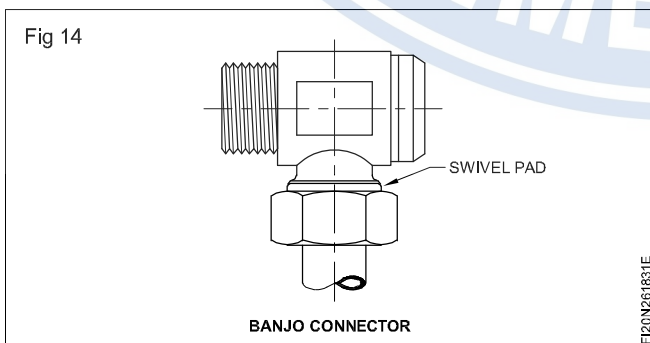
#### Elbow connector (Fig 13)

To connect the tube end parallel to the body of the hydraulic elements.



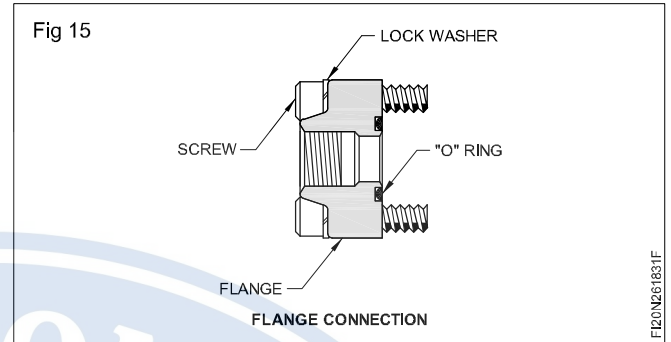
#### Banjo connector (Fig 14)

Banjo connector is similar to an elbow, but has the flexibility to turn 360 degree with the port axis. This helps in easy positioning of the pipe, with hydraulic elements.



#### Flange connection (Fig 15)

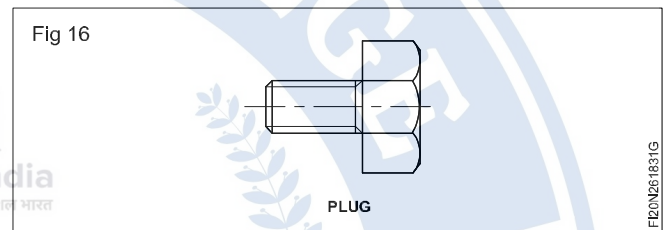
Big size valves do not have threaded ports. They only have a hole as a port. In these case a flange is mounted on the body and the connector is mounted on the flange. This is also called as flush mounting.



#### Plug (Fig 16)

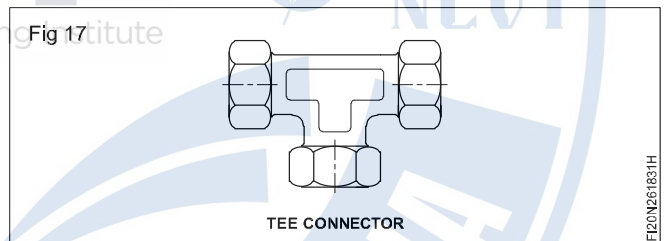
A plug is used to block any port of the hydraulic element.

To connect a tube end to another tube end



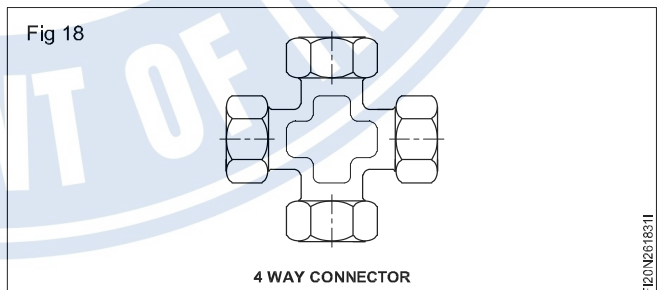
#### 'T' connector (Fig 17)

Used to connect three pipe ends at a junction.



#### 4 way connector (Fig 18)

Connect 4 pipe ends at a junction.



#### Reducer (Fig 19)

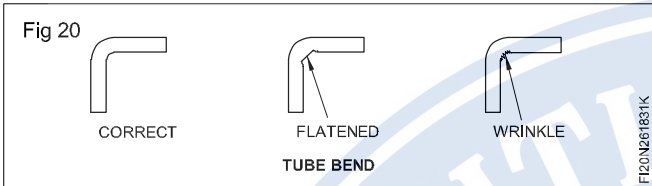
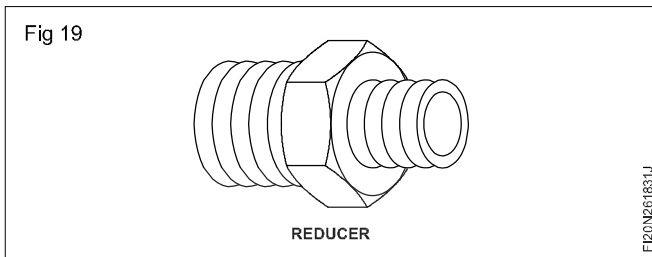
Connect two pipe ends of different size.

Do's and don'ts in tube/hose fitting:

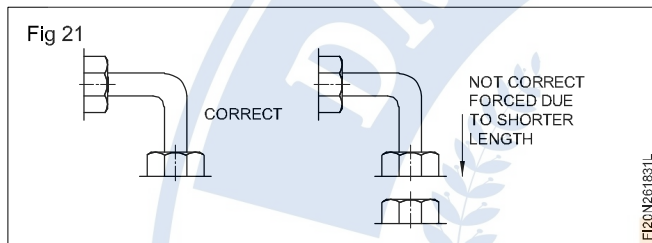
Life of tube/hose fitting depends very much on how the fitting has been designed and installed.

In case of the rigid connections the following has to be observed:

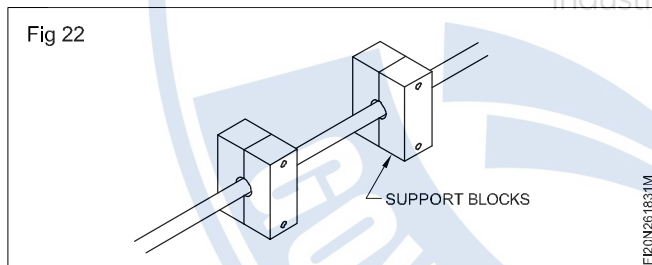
Tubes should be bent such that the bend has no flats or wrinkle at the bent corners. (Fig 20)



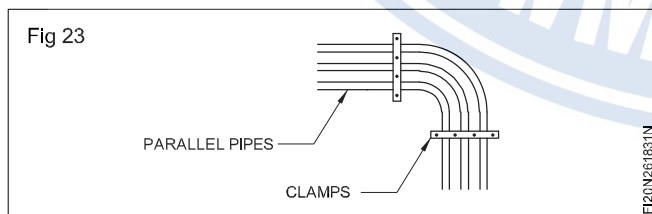
Tubes should be installed and removed without springing, bending or damaging the tubing. (Fig 21)



Support for tubes along the length if more than 1 meter long. (Fig 22)



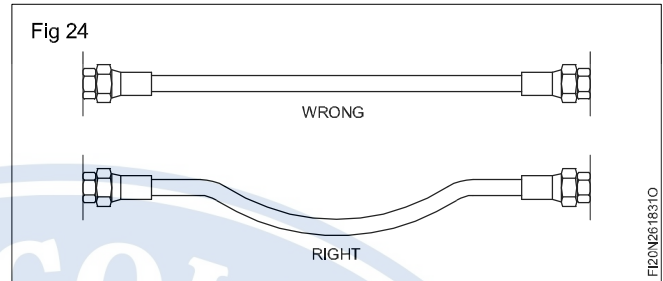
- Use minimum number of connectors.
- Use minimum number of bends in tubing.
- Design pipe lines in a neat and straight way to make fixing and maintenance easy. (Fig 23)



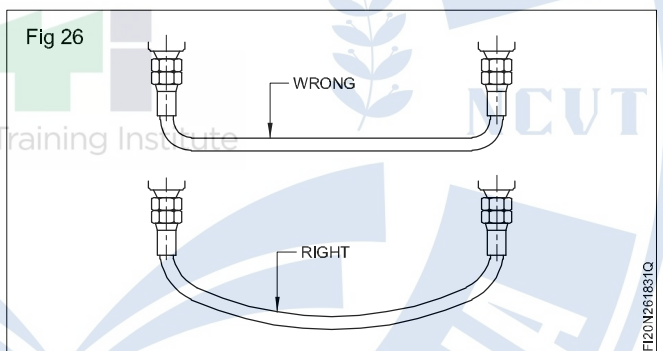
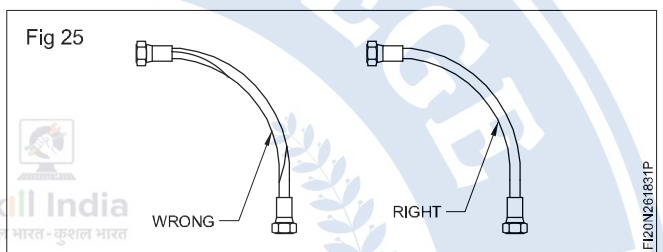
- Use tubes and connectors according to the working pressure of the circuitry.
- Make sure tubes are kept clean and clear from chips dust etc. that enables to deduct apparent oil leakages.

### Points to note while using flexible hose connections

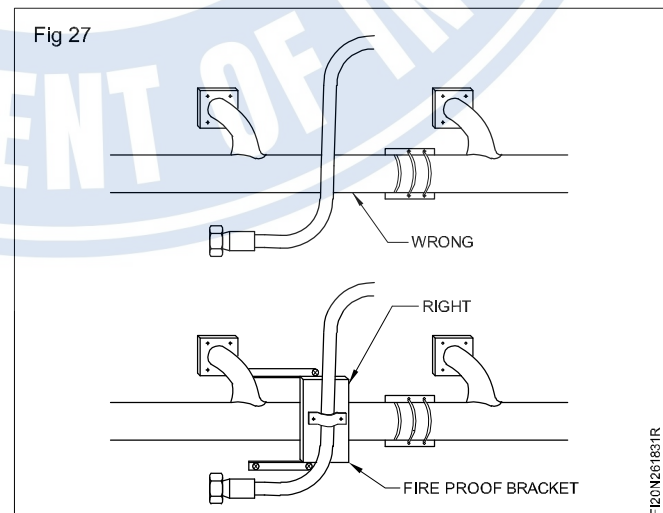
- Flexible hoses are costly. Use of them has to be justified.
- Remember that the hose will change in length from +2% to +4% when pressurised. Provide slack or bend in the hose to compensate for any change in length which might occur. (Figs 24 and 26)



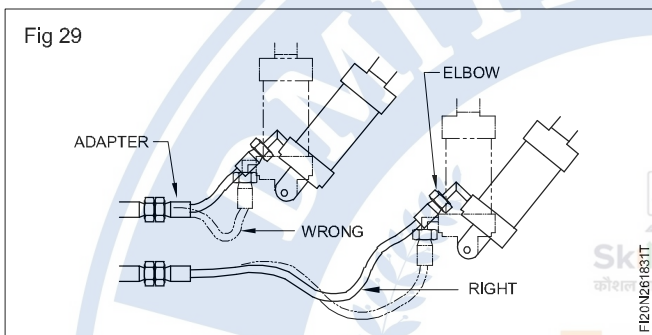
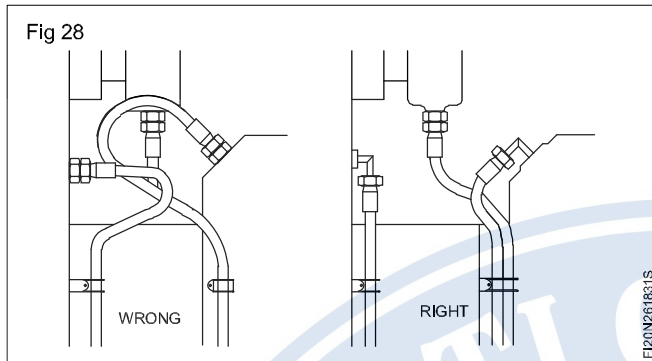
- If high operating pressures are applied to a twisted hose, the hose may fail or the attaching nut becomes loose.



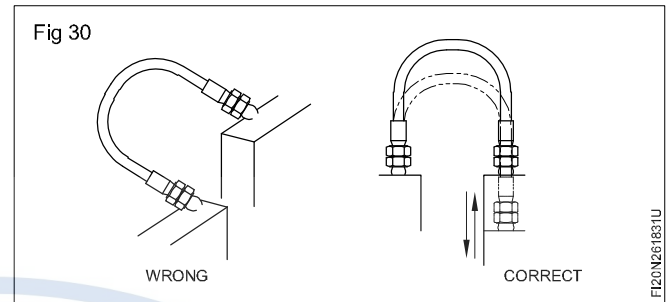
- Keep the bend radii of the hose as large as possible to avoid collapsing of line and restriction of flow. (Figs 26 and Fig 25)



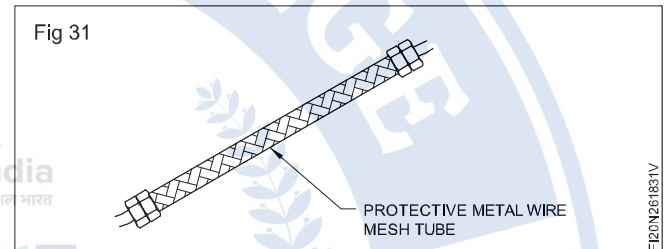
- When hose lines pass close to a hot exhaust manifold protect the hose with a fire proof boot or metal baffle. (Fig27)
- Use elbows and adapters to ensure easier, cleaner installation for quick inspection and maintenance. (Fig29)



- When a hose assembly is to be subjected to considerable flexing or vibration remember that the metal hose fittings are not part of the flexible portion. (Figs 28, 29, 30)



- Hose must be bent in the same plane as the motion of the part to which the hose is connected. (Figs 28, 29 and 30)
- Use metal wire mesh to cover the tube in areas where the hoses may come in contact with hot chips etc. (Fig31)



## Hydraulic cylinders (linear actuators)

**Objectives:** At the end of this lesson you shall be able to

- state the basic principle of hydraulic cylinder
- explain the construction of hydraulic cylinders
- state the sealing arrangement in a hydraulic cylinder
- name the parts of the hydraulic cylinder
- specify the hydraulic cylinder
- state the application of hydraulic cylinders
- calculate speed and force of a cylinder.

### Linear actuator

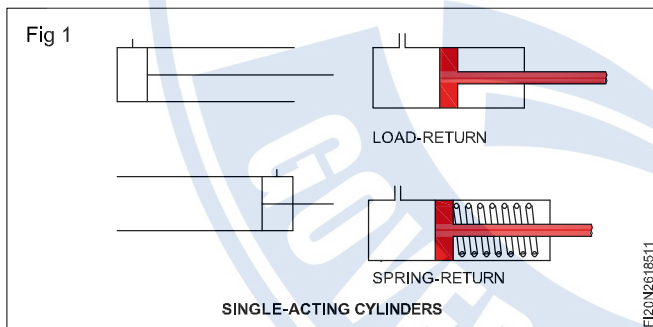
A hydraulic linear actuator is basically a cylinder, used to convert the hydraulic pressure and flow into a linear mechanical motion or force. Cylinder can be coupled with different types of mechanical linkages to produce enhanced or restricted movements in the combination of linear and rotary motions. Likewise with the arrangements, force can be multiplied or reduced.

In a cylinder, the hydro-static pressure energy of the oil is converted into mechanical motion.

### Working principle

#### Single acting cylinder

The Fig. 1 shows the cross-section of a single acting cylinder. Pressurised oil from the pump enter the pressure port. The pressure of oil exerts onto the piston and piston is moved (also against the force of spring tension), to other side.

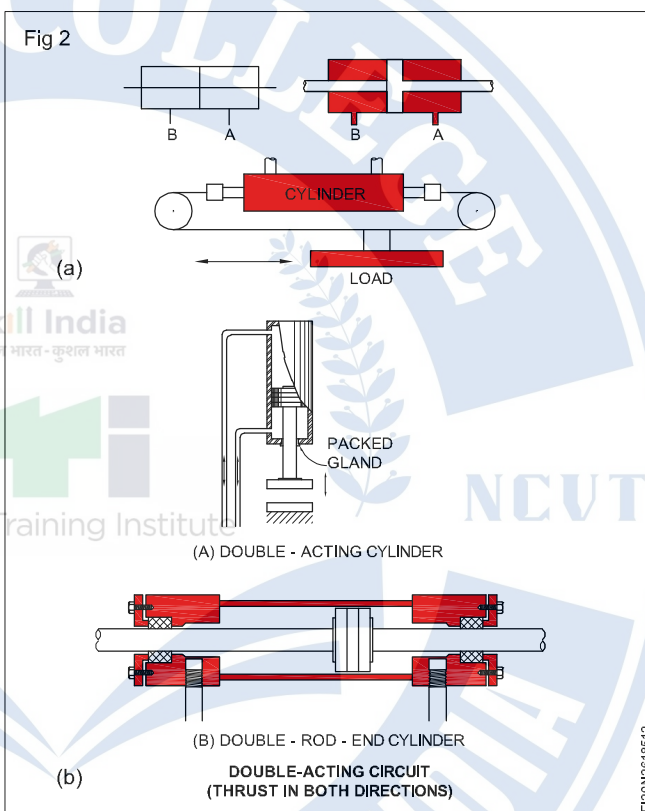


Useful work or movement can be attained from the free end of the piston-rod. After expansion of the oil, the spring tension overcomes the oil pressure. Now the spring pushes the piston to the left hand side. The oil is expelled through the same port.

#### Double acting cylinder

In a double acting cylinder Fig 2. Oil is supplied to both the sides of piston through ports A and B. When oil is supplied to port B, piston moves slowly. This is due to lesser area on the port side B, because force is proportional to the area. When the piston starts moving from left to right side, by the supply of oil pressure through port A, pressureless oil present on the right side is expelled through port 'B' and vice versa.

To have an equal force on both the strokes, piston rod is provided on the left side of the piston also. (Fig 2a and 2b)



#### Construction of a double acting cylinder (Fig 3a)

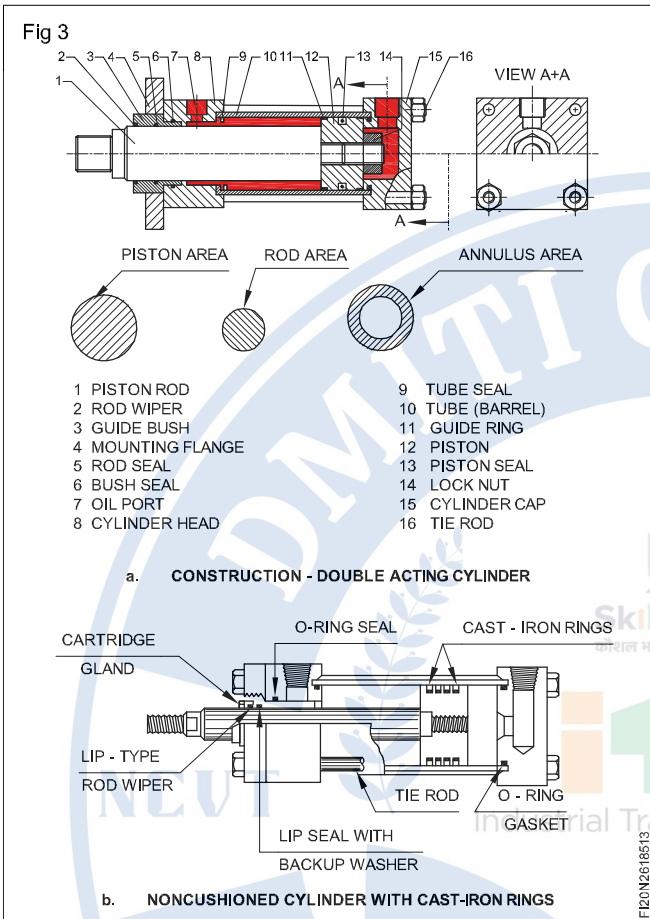
The general construction of a double acting cylinder is shown in Fig 3a. Piston rod is made of a chrome plated and piston is made of cast steel. Cylinder head is honed inside and has rod bearing support and a port. Cylinder cap blocks the end of the cylinder and firmly attached to head by means of tie-rods and nuts.

Static seals keeps the cylinder air-tight. Viper seals prevent the dust or other foreign particles from entering inside. The rod-bearing is usually replaceable by means of fasteners.

Piston seal prevents the oil from either-side of the piston, piston rings are made of high quality alloy steel/cast iron. (Fig 3b) For high pressures, cup packed seals are used.

These seals generally made of composition of rubber. For some right temperature applications, teflon seals are also used. Ports are threaded to connect the pipe ends/ connectors.

Leakage in between cylinder and head is prevented by O-rings made up of rubber as shown in the Fig. 3b. Better view of sealing arrangement can be seen in Figs. 3b.



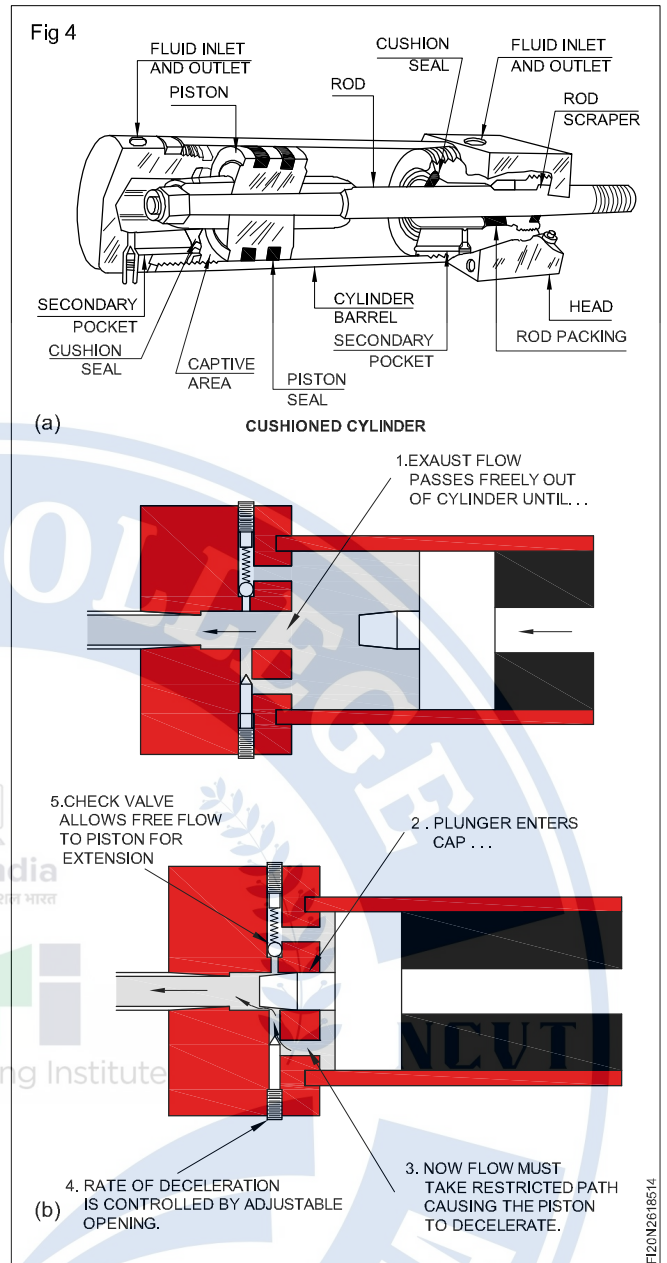
### End cushioning

High pressure oil at the ends of the stroke will make the piston to impact on the ends of cylinder. To avoid this, end cushioning is generally provided. Springs find common application. But when the spring is compressed beyond its full home length, it is prone to damage. Hence cushioning is done by restricting the oil outlet as shown in the Fig. 4a. This arrangement is provided in the end portion of cylinder heads.

As shown in Fig. 4b the other side of the piston is provided with a plunger or cushioning piston. In the cylinder head, the check valve connects the passage from outlet to the cylinder. Another passage is connected by a restricted orifice 'O'.

**This orifice can be adjusted by a screw.**

As the piston travel to the left-hand side, the plunger or cushioning piston enters outlet port 'E'. Now oil can escape through limited passages C and O only. But the check-valve blocks the oil passage by means of a ball. Now the oil can pass through the passage 'O' only. Thus travel of the piston is slowed down at the ends.



### Pressure and speed of piston

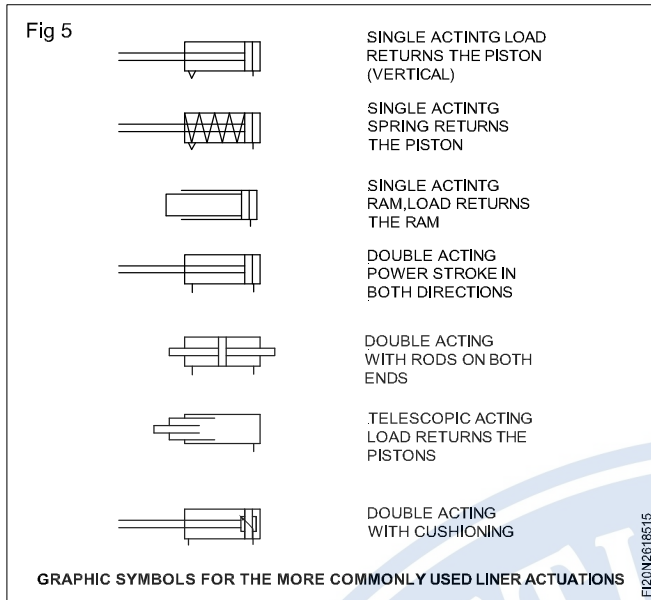
Pressure exerted by the piston = Pressure (Kg/cm<sup>2</sup>) x Area of cross section of piston (cm<sup>2</sup>)

$$\text{Speed of the piston (cm/min)} = \frac{1000 \times \text{LPM}}{\text{Area of piston (cm}^2\text{)}}$$

Where LPM = Litres Per Minute.

### Symbol

The symbols for hydraulic cylinders resembles the symbols of pneumatic cylinders. The symbols for commonly used cylinders are given in Fig 5.



### Classification of cylinders

Two basic types of cylinders are

- Single acting cylinders
- Double acting cylinders

Single acting cylinders are further classified into

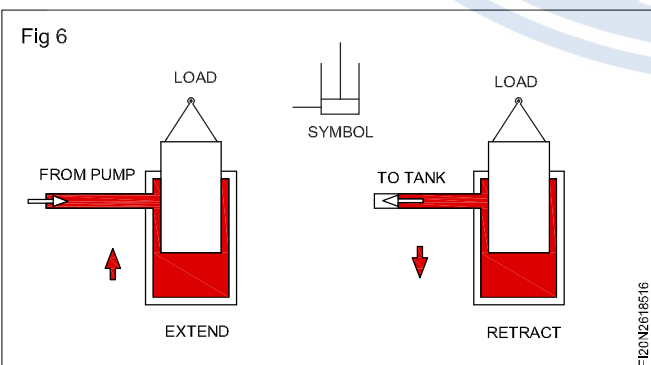
- Plunge type
- Piston type
- Ram type
- Telescopic type.

Double acting cylinders can be further classified into

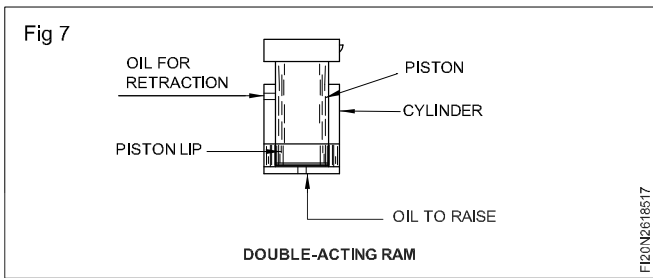
- Single piston rod type
- Double sided piston rod
- D.A. cylinder with end cushioning
- Telescopic type
- Pressure intensifier
- Tandem cylinder.

### Ram

It is the simplest linear actuator as shown in Fig 6. It has only one chamber for oil. They are usually mounted vertical and ram descends down by its self weight. Rams are practically suitable for long strokes and used in elevators jacks and automobile.

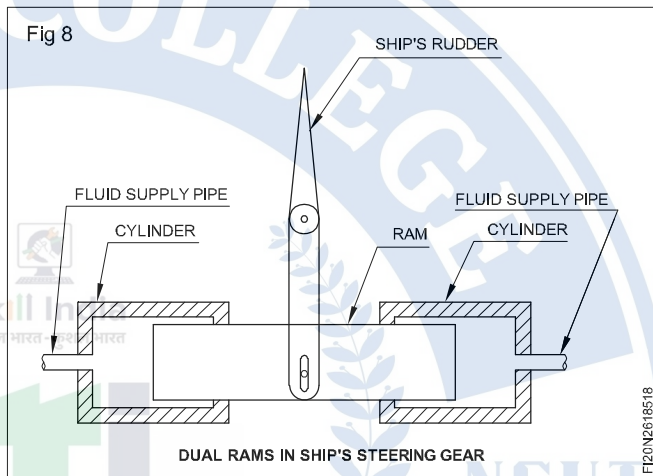


Since the diameter of the Ram is throughout and there is no piston rod, if the Ram has to descends down at a faster rate than gravity, oil has to be supplied to the top as in the case of a double acting cylinder. (Fig 7)



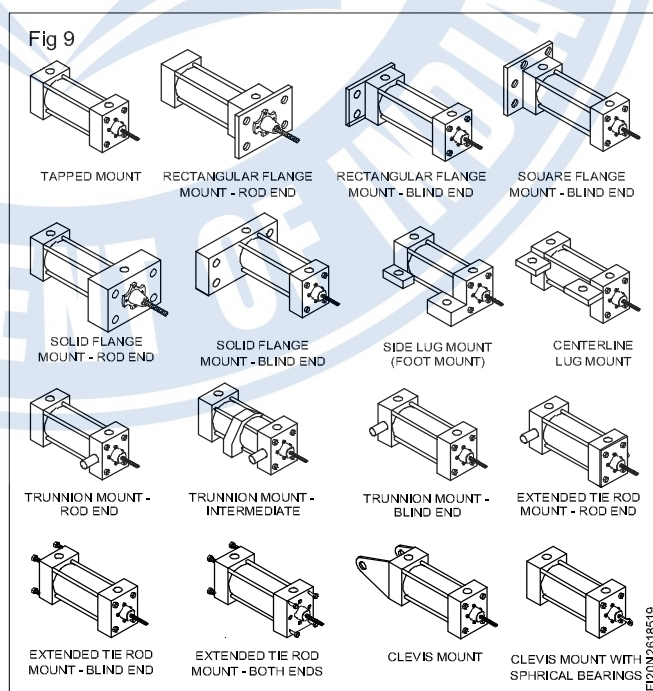
However, the diameter of the Ram can be reduced only to a little extent to have piston rod.

The application of a double sided or dual Ram in turning the rudder of a ship is shown in Fig 8.



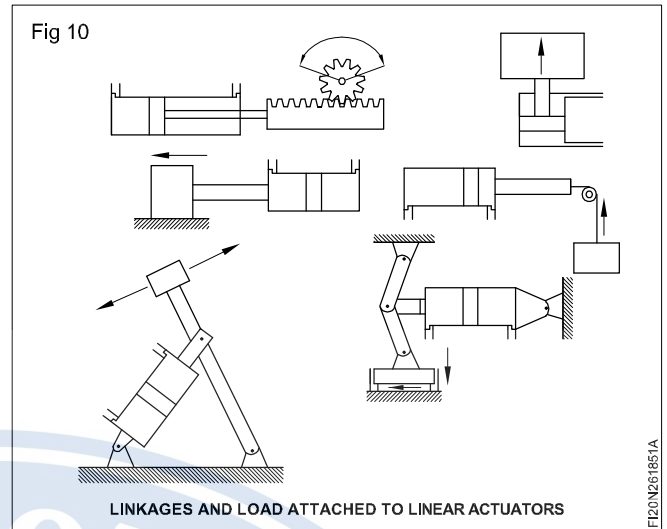
### Mountings of cylinders

Cylinders are mounted on different points to have a desirable movement space limitations, severity of load, direction of actuation etc. Fig 9 shows the possible methods of mounting a hydraulic cylinder.



## Actuation by linkages

Fig 10 shows the various methods of handling load, clamping, oscillation, lift, tilt and other kinds of applications of a cylinder along with mechanical linkages.



## Hydro motors (Rotary actuators)

**Objectives:** At the end of this lesson you will be able to

- state the principle of working of hydromotor
- state various types of hydromotor
- state the specification of hydromotor
- calculate the efficiency of hydromotor
- name the parts of the hydromotor.

### Hydromotor

This is a rotary actuator used in hydraulics, also called as hydraulic motors. This is very useful when a rotary motion is required. (The rotary action is achieved by this hydromotors) Similar to linear actuators, this also can be controlled in terms of displacement, direction of rotation, pressure or torque requirement. Nearly all elements used in linear circuits are used in rotary circuits also.

Cylinders provide linear motion where as hydromotors provide rotary motion.

### Various types of hydromotors

Hydromotors are classified according to their internal design. Hydromotors are of three types namely:

- Gear type
- Vane type
- Piston type.

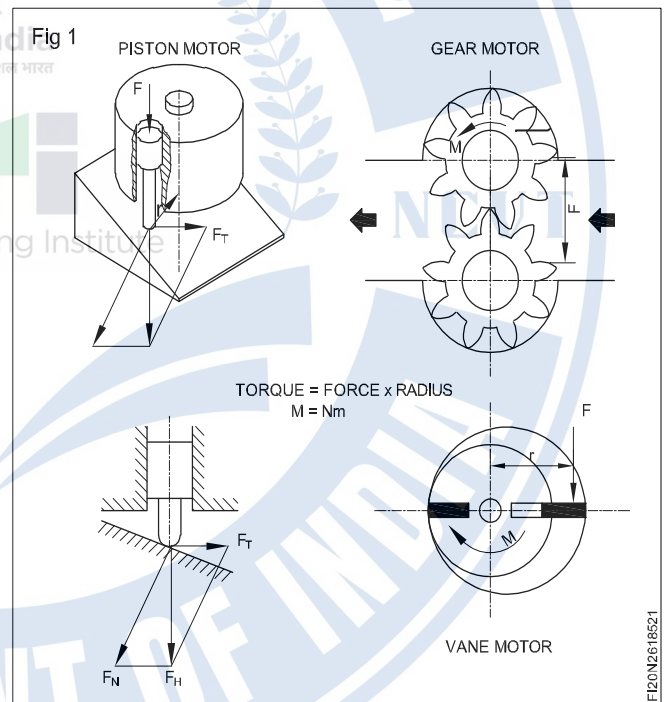
All these types have the common principle of working. These almost resemble a hydraulic pump in construction.

Operation of hydraulic motor is opposite to that of hydraulic pump.

The principle of working is shown with a simple line sketch in Fig 1

### Gear type motors

Gear motors are designed either as

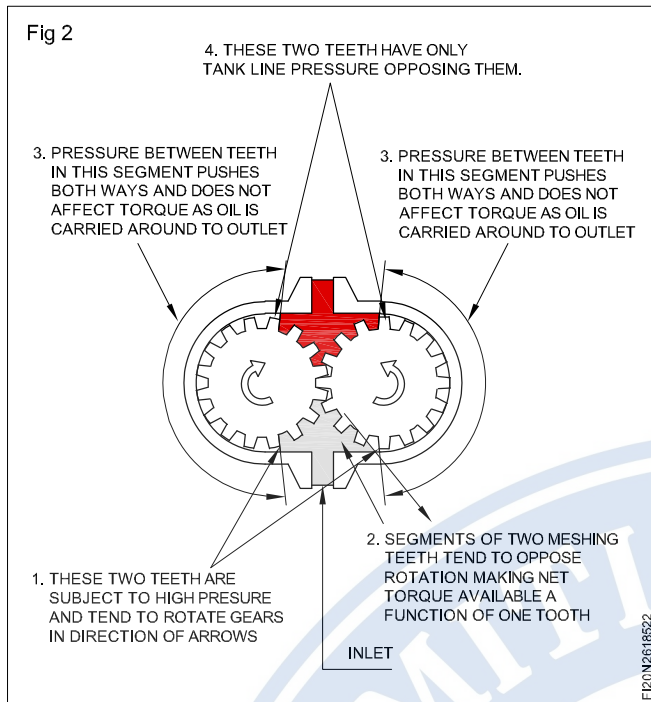


1 Gear on gear motor (external gear)

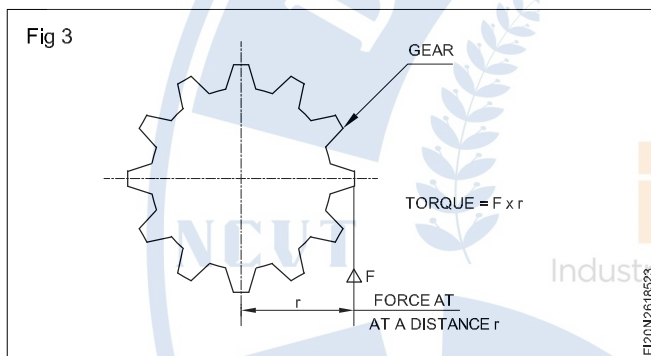
or

2 Gear in gear motor (internal gear).

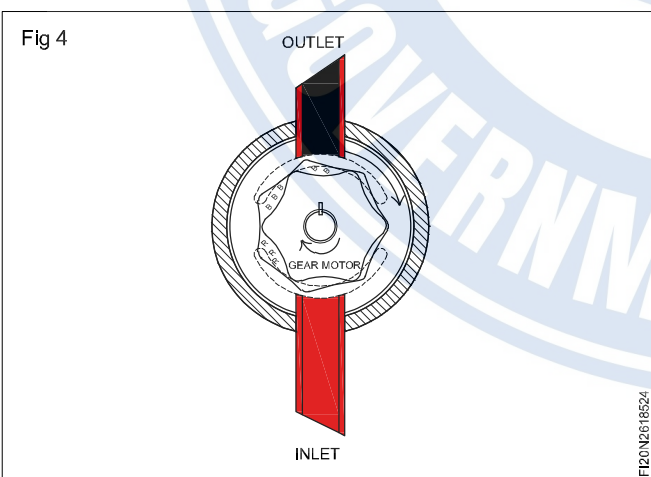
The figure 2 shows the gear on gear motor, oil enters the inlet port with pressure, this oil forces the gears to rotate and the oil flow out of the outlet. The speed of the motor depends on the amount of flow/minute and the motor torque depends on the pressure of oil. These motors have the lowest volumetric efficiency of about 70 to 80%.



The pressure of oil creates the torque in the same way as that of on a lever. (Fig 3)



The internal gear motor usually of gear type shown in the Fig 4.

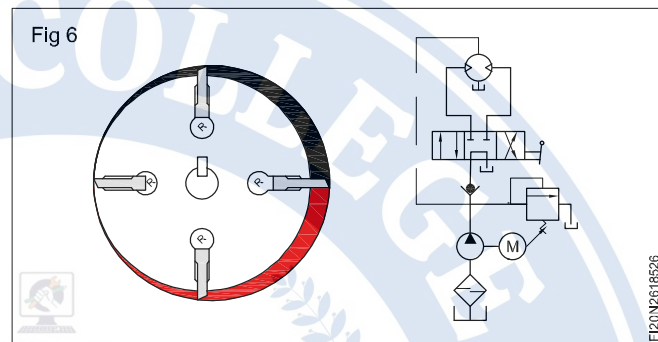
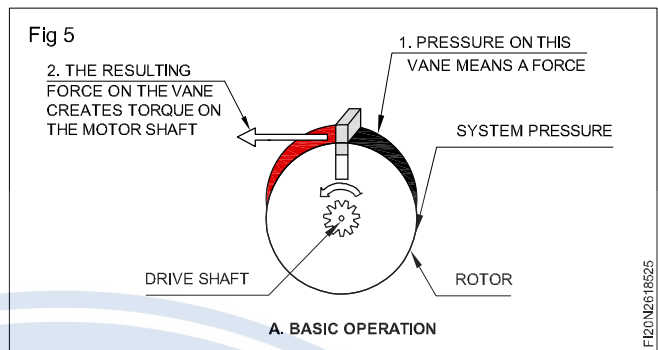


This is a motor which is very smooth in running and compact in design.

### Vane type motors

This differs in the design when compared to gear motor. The simple line sketch in figure 5 shows the vane being

moved along with the shaft by the oil flow. The prominent feature of the vane motor is the sliding vane. Each shaft will have more than one vane which ensures continuous rotation of the shaft. (Fig 6)

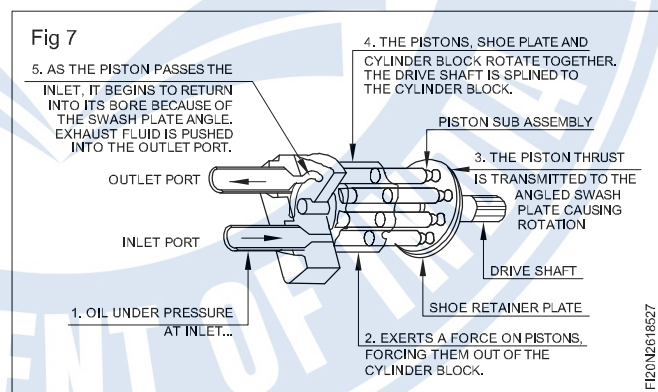


The vanes in the slots extent out by the action of centrifugal force and oil pressure. This has a high speed operating character.

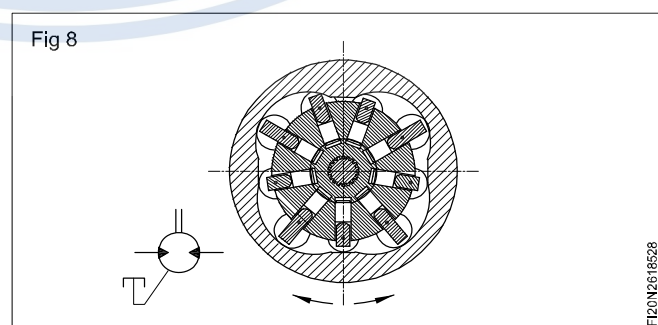
### Piston type motor

Piston motor is totally different from the other two types in its construction. Piston motors are of two types namely

#### 1 Axial piston motors (Fig 7)



#### 2 Radial piston motors (Fig 8)



These motors are the most volumetrically efficient motors rating up to 95% efficiency.

The operating principle of these type of motors are shown in Fig 7&8. In a piston and barrel assembly when oil with pressure is allowed, it pushes the piston out.

This piston in turn in tune with the other pistons starts the rotary motion and continue the rotation.

Piston motors have the high volumetric efficiency and it is found its place in high efficiency, fast operating, high pressure circuitry.

### Control of hydromotors

Hydromotors to perform effectively has to be controlled for it is speed and torque and direction.

#### Speed control of hydromotor

This is controlling the rpm of the hydromotor. This is usually done by controlling the quantity incoming fluid. This is also called as the displacement of the hydromotor. The control of flow of oil can be done by various methods which will be discussed in coming chapters.

Speed of a hydromotor depends on the quantity of oil passing through motor.

#### Torque control of hydromotor

Torque obtained in a hydromotor is the function of the fluid pressure. Thus by controlling the fluid pressure of the hydromotor the torque is also controlled.

#### Direction control of hydromotor

This is done by using a direction control valve in the circuit. This very much resembles the method of controlling the direction of movement of a double acting cylinder.

Direction of rotation of hydromotor depends on flow path of the oil.

### Specification of a hydromotor

A hydromotor is usually designed and specified by the following parameters:

- max torque required
- max RPM required (outlet)
- max operating pressure
- efficiency.

### Efficiency of hydromotor

Most of the times the hydromotor does not function as calculated. This is indicated by the various efficiencies of hydromotors. They are as follows

#### Volumetric efficiency

During operation same amount oil slip away without performing any work. This is a volumetric loss which is reflected in the volumetric efficiency

$$\eta(\text{Vol}) = \frac{\text{Theoretical flow rate}}{\text{Actual flow rate}}$$

#### Mechanical efficiency

During operation, particularly at low rpm and at high pressure conditions, there is a lot of mechanical losses. This is given by mechanical efficiency.

$$\eta(\text{Mech}) = \frac{\text{Actual torque}}{\text{Theoretical torque}} \times 100$$

#### Overall efficiency

This is used to calculate the power output of a hydraulic motor. It is expressed as the product of volumetric and mechanical efficiency.

$$\eta_o = \frac{\eta \text{Vol} \times \eta \text{Mech}}{100}$$

## Direction control valve

**Objectives:** At the end of this lesson you will be able to

- explain function of various direction control valves and non return valve
- interpret direction control valve function in a hydraulic circuit
- define meaning of by - pass circuit

Direction control valve are components which change, open or close flow path in hydraulics system. They are used to control the direction of motion of hydraulic actuator as well as responsible to stop the motion of actuator.

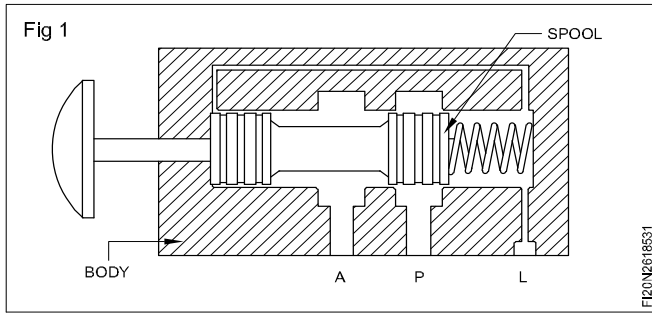
Direction control valves are classified as following according to the number of ports and positions:-

- 2/2-Way valve
- 3/2-Way valve

- 4/2-Way valve
- 4/3-Way valve

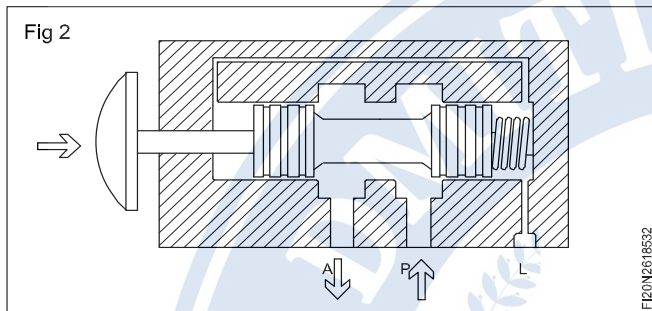
#### 2/2 Way valve

The 2/2-way valve has a working port A, a supply port P and a leakage- oil port L. In the case of the valve shown here, of slide design, flow from P to A is closed in the normal position. (Fig 1)



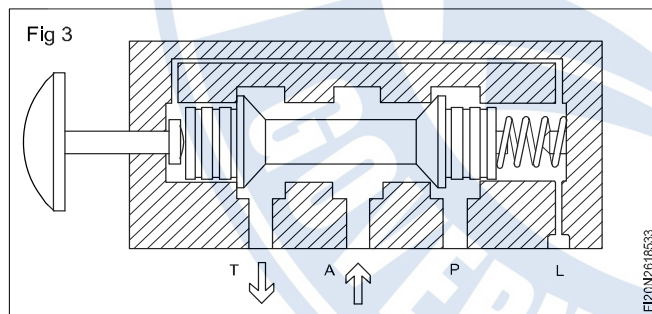
A relief line leading to the leakage - oil port is provided to prevent a build -up of pressure in the spring and piston chambers.

The 2/2-way valve is actuated and the passage from P to A is open. 2/2 -way valves are also available which are normally open from P to A. (Fig 2)

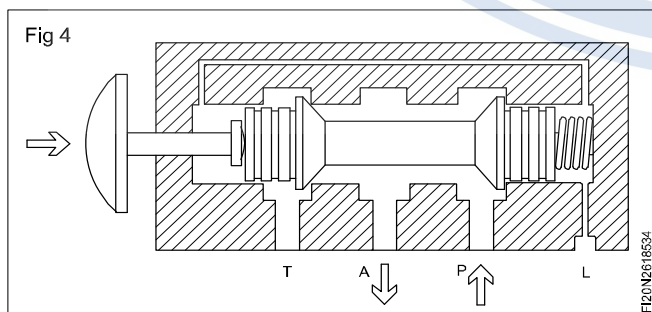


### 3/2-Way valve

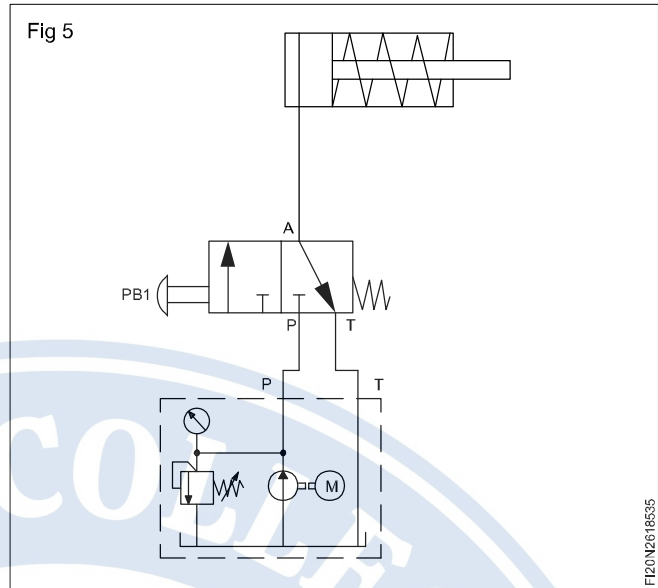
The 3/2-way valve has working port A, a supply port P and a tank port T. Volumetric flow can be routed from the supply port to the working port or from the working port to the tank port. The third port in each case is closed. In the normal position shown, P is closed and flow released from A to T. (Fig 3)



The 3/2-Way valve is actuated; flow is released from P to A, the outlet T is closed. 3/2-Way valves which are normally open from P to A and T closed are also available. (Fig 4)

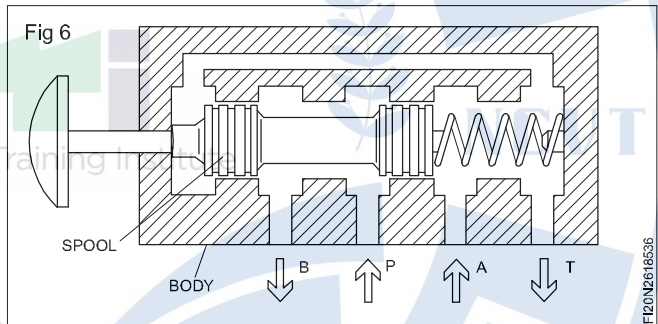


Example of 3/2 way circuit with single acting cylinder. (Fig 5)

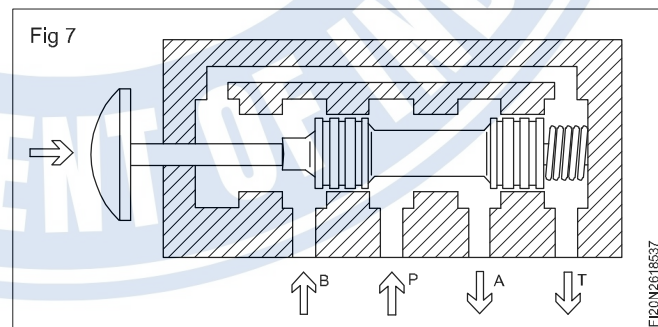


### 4/2 Way valve, two pistons

The 4/2-Way valve has two working ports A and B, a supply port P and a tank port T. The supply port is always connected to one of the working ports, while the second working port is routed to the tank. In the normal position, there is flow P to B and from A to T. (Fig 6)

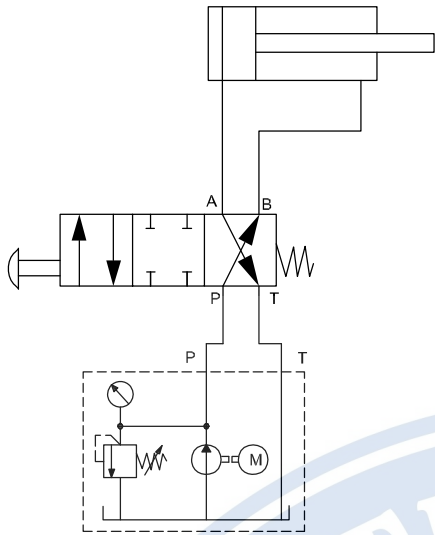


The 4/2-Way valve is actuated, and there is flow from P to A and from B to T. 4/2-way valves are also available which are normally open from P to A and from B to T. (Fig 7)



Example of 4/2 way circuit with double acting cylinder. (Fig 8)

Fig 8



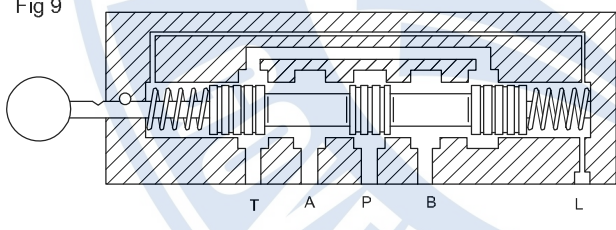
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### 4/3- Way valve

From the logic point of view, 4/3-way valves are 4/2-way valves with an additional mid-position. There are various versions of this mid-position (in the mid-position in the example shown, the supply port P is directly connected to the tank T, see next illustration). In the switching position shown, there is flow from p to B and from A to T.

The 4/3-way valve is in its mid-position; there is flow from P to T, while A and B are closed. Since the output from the pump flows to the tank, this switching position is called pump bypass or also pump recirculation. In the case of pump bypass, the pump needs to operate only against the resistance of the valve, which has a favorable effect on the power balance. (Fig 9)

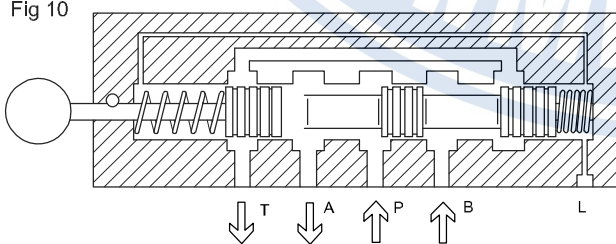
Fig 9



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The valve is in its left-hand switching position; there is flow from P to A and from B to T. (Fig 10)

Fig 10

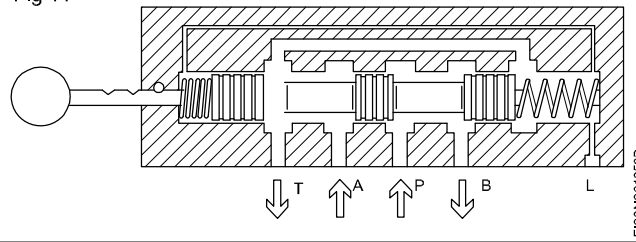


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And the valve is in its right hand switching position there is flow from P to B and A to T. (Fig 11)

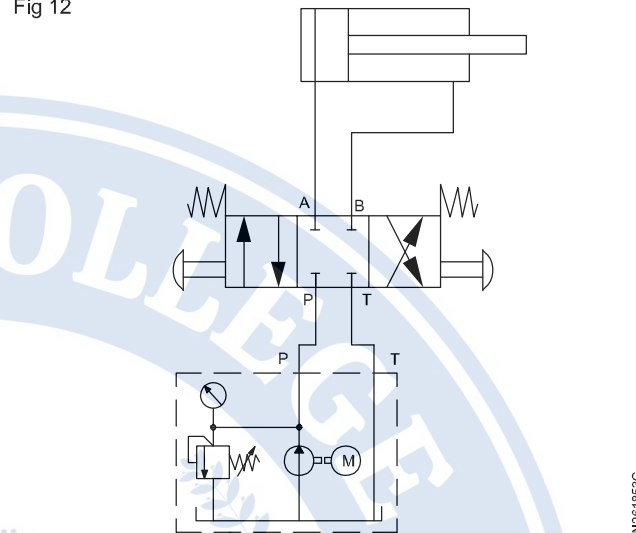
Example of 4/3 way circuit with double acting cylinder. (Fig 12)

Fig 11



FI20N261853B

Fig 12

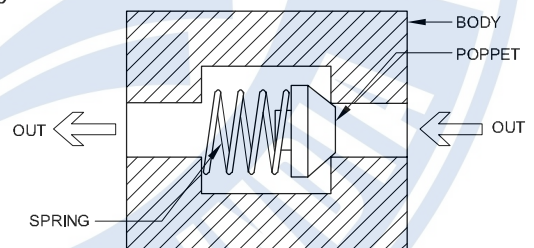


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### Non-return valve

Non-return valves block flow in one direction and allow free flow in the other. In the direction of flow shown, the sealing element is pressed against a seat by a spring and the hydraulic fluid. (Fig 13)

Fig 13



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A spring loaded Non-return valve is shown in fig 13. If oil pressure is more on left side of NRV, poppet of valve will not open as well as it will not allow the flow of oil.

And when oil pressure is more on right side of valve then poppet of valve will move for opening and oil will flow through the valve. (Fig 14)

Fig 15 shows the application of non-return valve for pump protection. (Fig 15)



## Flow control valve

**Objectives:** At the end of this lesson you shall be able to

- state the need for flow control in a hydraulic circuit
- state the principle of operation of flow control valve
- draw different symbols of flow control valves and state the functions from the symbols.

The whole purpose of a flow control valve is to vary the speed of an actuating cylinder or motor. This is possible by controlling the flow rate of the fluid.

A flow control valve accomplish any one or more of the following control functions:

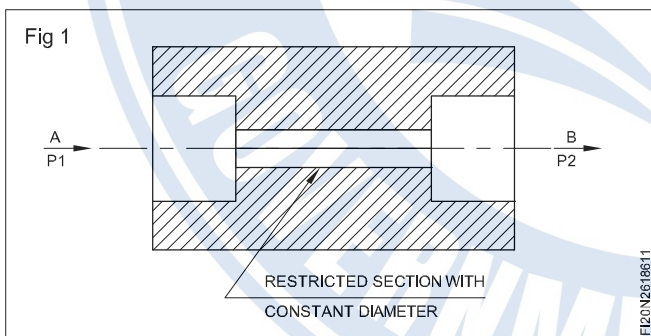
- To limit the maximum speed of the linear or rotary actuators

$$\left( \frac{\text{flow rate}}{\text{piston area}} = \text{piston speed} \right)$$

- To limit the maximum pressure available to branch circuits by limiting the flow. (power = flow rate x pressure)
- Proportionately divide or regulate the flow from pump to various branch circuits.

### Principle of operation

As shown in Fig 1, the oil under pressure P1 enters the valve at A and flows through a restricted section, into the outlet B. While passing through the restricted passage, oil attains heat due to the friction. Thus the hydraulic energy in terms of pressure is converted into heat energy. The loss of energy is the result of drop in pressure.

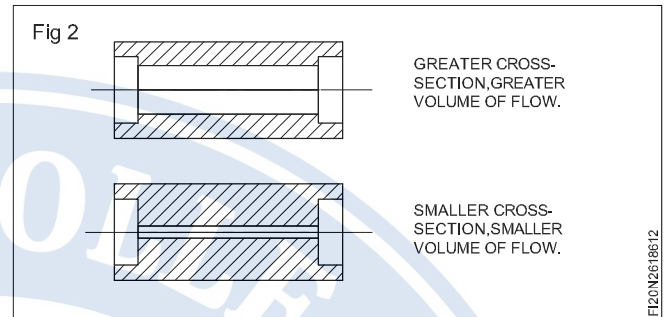


The difference between the two pressure is called pressure drop.

$$p = p_1 - p_2$$

The volume of flow (litres/min) is mainly dependent on the:

- Cross-section of restriction (Fig 2)
- Shape and length of orifice
- Pressure difference p
- Viscosity of the hydraulic oil.



The basic principle can be understood from Fig 3.

### Symbol

As a general norm, the basic envelop is represented by a square to denote a valve. The flow line passes past through the square. The flow restrictions are denoted by curvatures above and below the flow line.

The arrow mark stroked across the curvatures means that, the flow restriction is adjustable. Sometimes full flow is to be ensured in the reverse direction. This can be made possible by connecting a check valve (non-return valve) in a right direction across the flow control valve. As indicated in Fig 3, in the forward direction, oil flows from pressure port (P) to working port (A). In the reverse direction oil flows from port A to port P, by pushing the spring loaded valve.

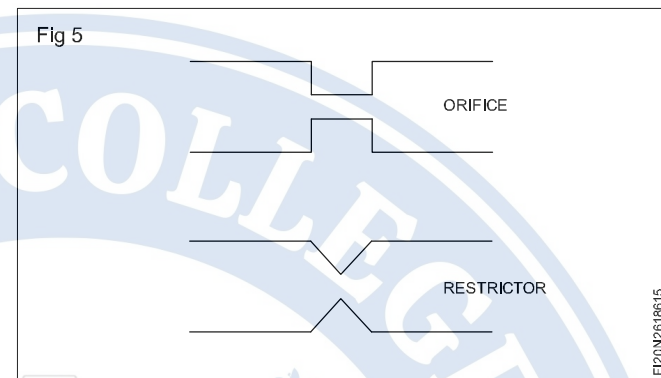
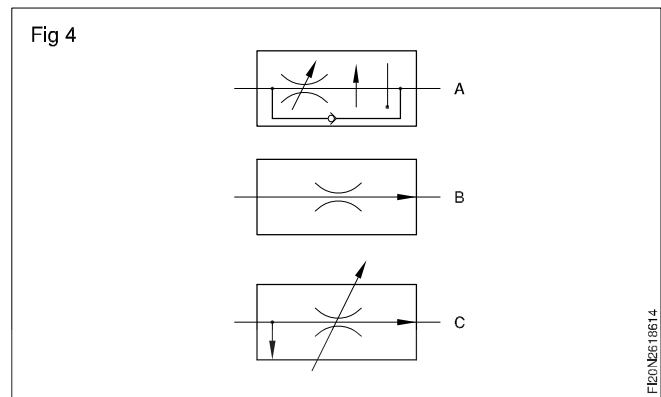
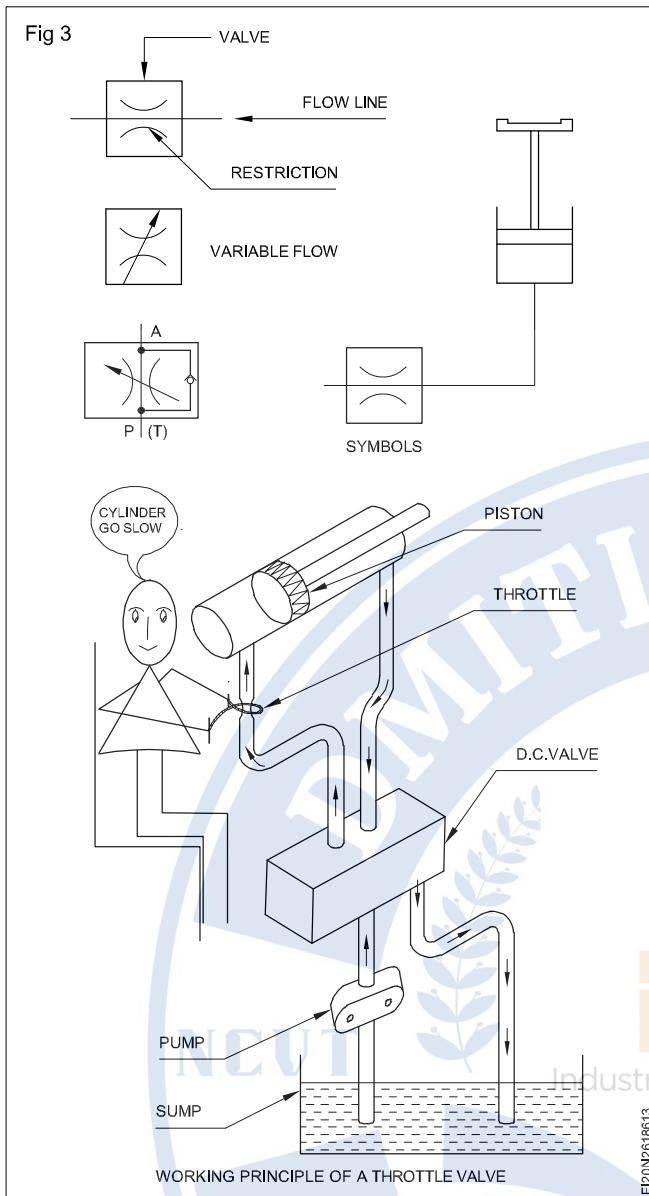
In case, if the return oil is to flow to the tank, the pressure port P will become tank port 'T' by means of a direction control valve in the circuit.

In Fig 4 symbols are given in combined operations. Fig 4A shows a control valve is adjustable and compensation is given for pressure as well as temperature. Fig 4B show a symbol for fixed type orifice and reducing valve-type compensation. Fig 4C indicates an adjustable orifice and relief valve type compensation.

The shape of an orifice and restrictor are shown in Fig 5. Restrictor is less sensitive to temperature variation.

The flow characters are changed in the following aspects

- The velocity past the valve.
- The pressure at the outlet of the valve is less than that of the inlet.



## Variable flow control

**Objectives:** At the end of this lesson you shall be able to

- state the need for a flow control valve
- state the principle of operation of a simple flow control valve
- name the different area of applications of a variable flow control valve
- distinguish the construction of a one way flow control valve
- name the areas of applications of one way flow control valves and different adjustable restrictors
- state the concept of maintaining constant flow rate.

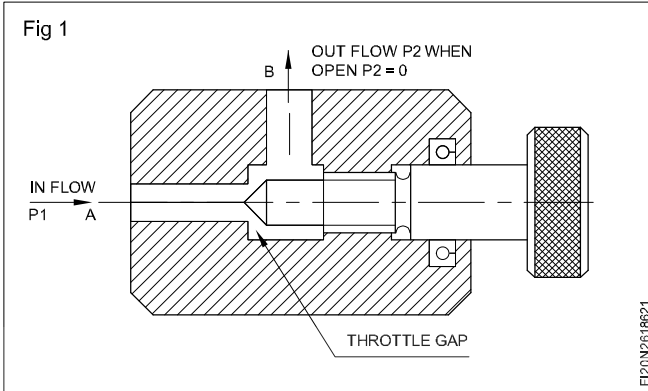
### Need for flow control

In a hydraulic circuit, to have a control over the speed of an actuator, the flow rate should be under control. This can be done by adjusting a variable delivery pump and a pressure relief valve. But the frequent adjustment of these elements will result in a power loss and reduction in their efficiency. Hence the need for separate flow control valve arises.

To enable the supply of variable flow to the circuits a flow control valve can be made adjustable. Tuning of a flow control valve to supply different flow rates is called 'Throttling' and the valve is also called throttle valve.

### Principle of operation

As shown in Fig 1 oil enters the port A and its restricted flow enters port B. Flow is limited in the restricted passage called throttle. The amount of this gap can be varied by throttling screw. When the screw is fully closed, there is no flow at the outlet B.



It can be understood that the flow rate is dependent on the

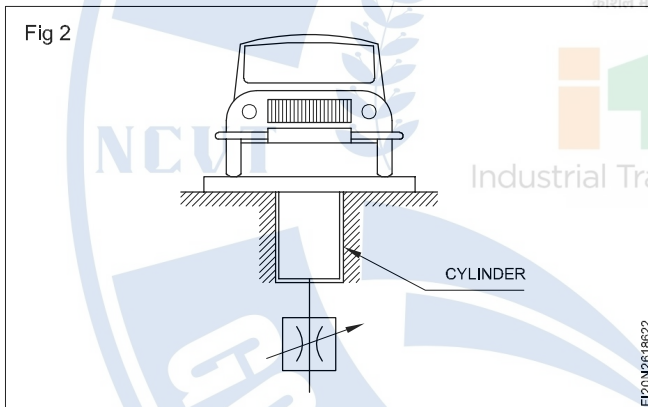
- Pressure difference  $p = p_1 - p_2$
- The size of throttle gap and
- Viscosity of oil.

It is to be noted that valve can be operated in both the direction.

### Application

By means of throttling, speed can be infinitely variable.

As shown in Fig 2, the platform for lifting a car can be raised faster or slower by means of cylinder movement. The cylinder movement, in turn can be varied by restricted oil supply through a flow control valve.

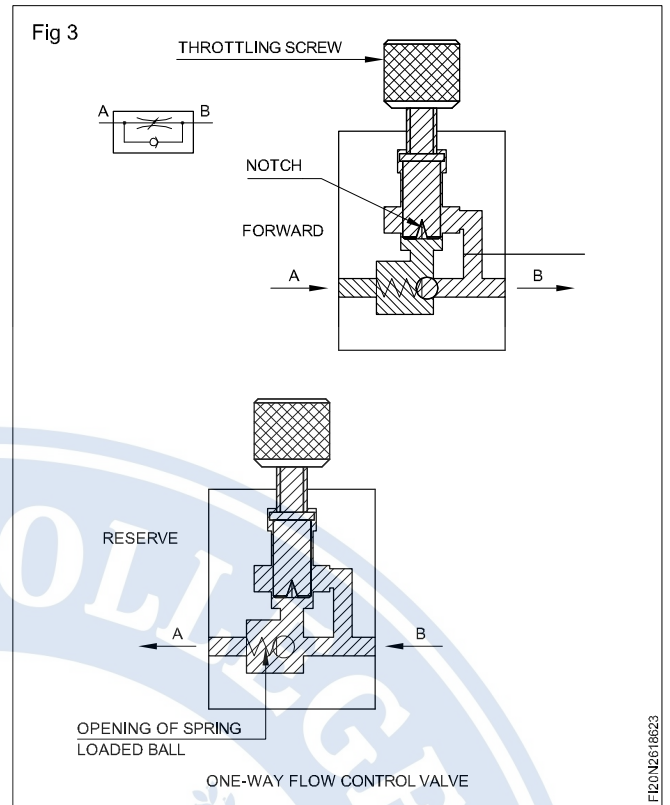


### One-way flow control valve (Fig. 3)

A specific requirement of a flow control valve is that, an adjustable flow is required in one direction and a full flow is required in the reverse direction. It is possible, by the induction of a check valve.

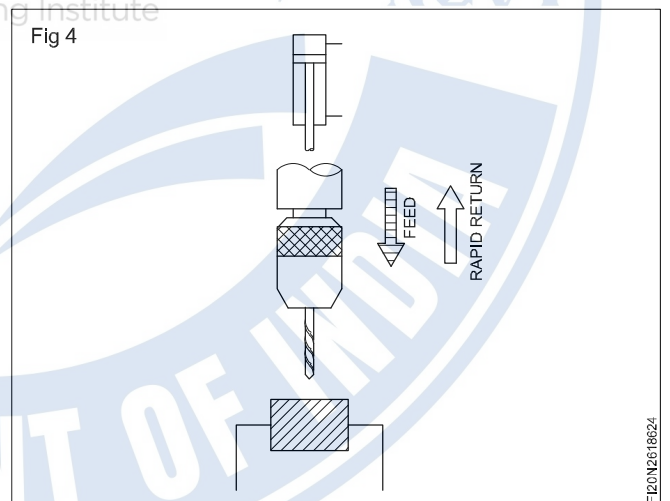
As shown in Fig 3, the restricted passage is by means of a longitudinal notch in the valve body. Full flow oil coming from port A is restricted through this passage and only a limited oil flow through the outlet port B. It can be noticed that oil also acts on the ball in the spring direction, so that the ball firmly closes the port, that connects outlet port B.

Whereas in the reverse direction, i.e. from B to A, oil force acts on the ball against the spring force. Thus the ball is lifted off its seat and oil rushes to port A. At the same time, a limited passing of oil through the throttling passage also enters port A. Thus the full flow of oil is ensured at port A.



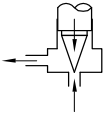
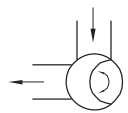
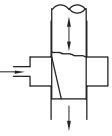
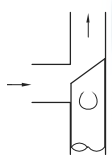
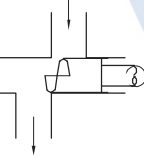
### Application

For an auto feed of the drilling operation as shown in Fig 4, the slow feed in vertical direction is imparted by a cylinder, receiving restricted flow of oil. After finishing the operation the drill head has to move fast in upward direction. This is possible by admitting full flow of oil against the check valve.



The following chart illustrates various designs of orifice restrictions, resistance offered, their dependence on viscosity, case of adjustment and effectiveness of the design.

## Adjustable restrictors

Type	Resistance	Dependence on viscosity	Ease of adjustment	Design
Needle restrictor 	Increase in velocity, high friction owing to long throttling path	Considerable due to high friction	Excessive cross-sectional design	Economical simple
Circumferential restrictor  By radial slot	As above	As above, but lower than for the needle restrictor surface, total adjustment travel only 90°	Steady cross-sectional enlargement. Adjustment upto 90°	Economical, simple design more complicated than the needle restrictor
Longitudinal restrictor  (By linear slot)	As above	As above	As above, however sensitive adjustment owing to long adjustment travel	As for circumferential restrictor
Gap restrictor or poppet 	Majority; increase in velocity, low friction short throttling path	Low	Unfavourable, even cross-sectional enlargement, adjustment travel of 180°	Economical
Gap restrictor with helix 	Increase in velocity, maximum friction	Independent	Sensitive, even cross-sectional enlargement adjustment travel to 360°	Expensive to produce helix

### Requirements of adjustable restrictions

- Build-up of resistance
- Change in temperature and in turn the viscosity should not affect the resistance
- Adjustment of flow depends on the orifice cross-sectional area and control surface area
- It should be economical in design
- Possibly it could allow the flow in either directions.

### Maintaining constant flow-rate

The amount of flow out of a flow control valve, depends on the throttle passage, pressure difference and oil viscosity, set by the temperature.

The viscosity and passage remaining constant, the pressure difference on either side of the throttle alone affects the amount of flow. Hence if the flow is to be constant, the pressure, differential should also be constant. The flow control valve operating on this principle is called "Pressure compensated flow control valve". This type of valve can be also operated in either directions.