



RQF LEVEL V

**TRADE: HYDROPOWER
ENERGY**

MODULE CODE: HPEPH501

TEACHER'S GUIDE

**Module name: PNEUMATIC AND
HYDRAULIC SYSTEMS INSTALLATION**

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Acronyms

ILO: International Labor Organization

PPE: Personal Protective Equipment

ROM: Read Only Memory

REQF: Rwandan Education Qualification Framework

TVET: Technical and Vocational Education and

Introduction

The trainer manual presents a coherent and significant set of competencies to acquire to perform the occupation of a **solar power plant technician**. It is designed with an approach that takes into account the training needs, the work situation, as well as the goals and the means to implement training. The indicative content of the learning outcome include a description of the expected results at the end of module. They have a direct influence on the choice of the theoretical and practical learning activities. The learning outcome are the targets of training: the acquisition of each is required for certification.

Module Code and Title : HPOPH 501 PNEUMATIC AND HYDRAULIC SYSTEMS INSTALLATION

Learning Units:

1. Prepare the workplace
2. Lay down pneumatic/hydraulic circuit devices
3. Test and commission
4. Clean the workplace

Learning Unit 1: Prepare the workplace



STRUCTURE OF LEARNING UNIT

Learning outcomes:

- 1.1 Interpret pneumatic/ hydraulic drawings
- 1.2. Identify tools and material/equipment
- 1.3. Arrange materials and tools into the working area
- 1.4. Identify PPE (Personal Protective Equipment)

1.5. Prepare the pipe way

Learning outcome 1.1 Interpret pneumatic/ hydraulic drawings



Duration: 3hrs



Learning outcome 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identification of pneumatic/ hydraulic symbols
2. Review on types of pneumatic/ hydraulic drawings
3. Interpret pneumatic/ hydraulic drawings



Resources

Equipment	Tools	Materials
<ul style="list-style-type: none">-Motor-pump- Air compressor- Hydraulic pump- Hydraulic and Pneumatic Transfer Hoses and Fittings- Hydraulic Flanges	<ul style="list-style-type: none">Chalkpencil	<ul style="list-style-type: none">-Books-Drawing- Valves-Manual



Advance preparation:

- . All learners must have drawing instrument
- . Drawing manual must be available



Indicative content 1.1.1: Identification of pneumatic/ hydraulic symbols

✓ Proper identification of pneumatic/ hydraulic symbols

Now, we shall explain below the symbols, one by one, in the following section

Hydraulic & Pneumatic Symbols

Pumps and motors are the energy producing to the fluid power systems. The basic general graphic symbols related to them are given below:

Circle



Represent pump, motor, compressor or any rotary devices

Filled triangle



Indicates the direction of flow for hydraulic fluid (systems)

Unfilled triangle



Indicates the direction of flow for pneumatic fluid (system)

Line with an arrow



Indicates variable displacement

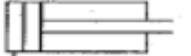
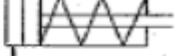
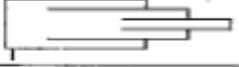
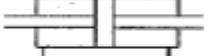
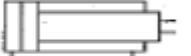
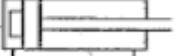
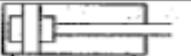
B. Graphic symbols used for motor and pumps

Description	Symbol	Diagram	
		Hydraulic	Pneumatic
Fixed displacement, unidirectional pump	S1		
Fixed displacement, bidirectional pump	S2		
Variable displacement, unidirectional pump	S3		
Variable displacement, bidirectional pump	S4		
Fixed displacement, unidirectional motor	S5		
Fixed displacement, bidirectional motor	S6		
Variable displacement, unidirectional motor	S7		
Variable displacement, bidirectional motor	S8		
Oscillating motor	S9		

C. Cylinders

The cylinders are actuators used to convert the energy of the fluid into reciprocating mechanical energy.

► The graphical symbols related to them are given below.
Single acting cylinder has one port and double acting cylinder has two ports.

Description	Symbol	Diagram
Single acting cylinder, returned by external force	S10	
Single acting cylinder, with spring return	S11	
Single acting telescopic cylinder	S12	
Double acting cylinder with single piston rod	S13	
Double acting cylinder with through piston rod	S14	
Differential cylinder	S15	
Double acting telescopic cylinder	S16	
Double acting cylinder with single end position cushioning	S17	
Double acting cylinder with end position cushioning at both ends	S18	
Double acting cylinder with adjustable end position cushioning at both ends	S19	

D. Directional control valves

- ✓ Directional control valves are used to determine the path of the fluid which should travel with a *given circuit.
- ✓ Directional control valves are shown by means of several connected squares
- ✓ Number of squares – indicates the number of switching positions possible. Arrow within square - indicate how the ports are inter-connected in the various switching positions.
- ✓ Naming connection for valves: number of ports/ number of switching positions" way valve" example: 4/3 valve has 4 port and 3 switching, positions.
- Graphic symbols used for directional control valve

Description	Symbol	Diagram
2/2-way valve	S20	
3/2-way valve	S21	
4/2-way valve	S22	
4/3-way valve	S23	

E. Pressure valves

- ✓ Pressure valves are used to produce the fluid power system against over pressure
- ✓ Pressure valves are indicated using squares, arrow- indicates flow direction
- ✓ Table below presents the various standard symbols used for pressure valves

Graphic symbols used for pressure valves

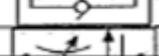
Description	Symbol	Diagram
set pressure relief valve	S24	
adjustable pressure relief valve	S25	
3-way pressure regulator	S26	

F. Flow control valves

- ✓ Flow control valves are used to control the flow rate and hence to control the actuator speed
- ✓ The flow control valves use the following basic general symbols:
 - Orifice: flow control valves unaffected by viscosity
 - Throttle: constitute resistance in a hydraulic system.
 - Rectangle: indicates flow control valve.
 - Diagonal arrow: indicates the valve is adjustable.

Table bellow presents the various standard symbols used for flow control valves

Graphic symbols used for flow control valves

Description	Symbol	Diagram
adjustable flow control valve with throttle	S27	
adjustable flow control valve with orifice	S28	
adjustable bypass	S29	
adjustable and pressure compensated with bypass	S30	
adjustable temperature and pressure compensated	S31	

G. Non-return valves

The non-return valves use the following general symbols:

- Circle/ ball: indicates the non-return valve
- Open triangle: indicates sealing seat
- Broken line: indicates the pilot control connection for the valve
- Two triangles facing: indicates shut-off valve

Table bellow presents the various standard symbols used for non-return valves

Graphic symbols used for non-return valves

description	symbols	diagram
spring loaded non-return valve	S32	
unloaded non-return valve	S33	
shut-off valve	S34	
pilot controlled non-return valve	S35	

H. Methods of operation/ actuation

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

The symbol for the valves is elaborated by the addition of the symbol indicating the actuation method.

Table below presents the various standard symbols used for methods of operation

Graphic symbols used for methods of operation

Description	Symbol	Diagram
lever	S42	
pilot pressure	S43	
solenoid	S44	
solenoid controlled,pilot press oper	S45	
spring	S46	
servo	S47	

Description	Symbol	Diagram
pressure compressor	S36	
detent setting	S37	
manual	S38	
mechanical	S39	
pedal treadle	S40	
push button	S41	

j. Energy transmission

Table below presents the various standard symbols used in circuit diagram for energy transfer and conditioning of the pressure medium.

 **Graphic symbols used in energy transmission**

Description	Symbol	Diagram
Hydraulic pressure source	S48	
Electric motor	S49	
Non-electric drive unit	S50	
Pressure, power, return line		
Control (pilot) line		
Drain line		
Plugged port	S51	
Flexible line	S52	
Line connection	S53	
Line crossing	S54	
Exhaust, continuous	S55	
Quick-acting coupling connected with mechanically opening non-return valves	S56	
Vented reservoir	S57	
Pressurized reservoir	S58	
Filter	S59	
Cooler	S60	
Heater	S61	

Description	Symbol	Diagram
Accumulator	S62	
Spring loaded accumulator	S63	
Gas charged accumulator	S64	
Weighted accumulator	S65	

A. Measuring devices

The following Table presents the various standard symbols used for Measuring devices in circuit diagrams.

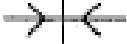
 **Graphic symbols used for Measuring devices**

Description	Symbol	Diagram
Pressure gauge	S66	
Thermometer	S67	
Flowmeter	S68	
Filling level indicator	S69	

A. Couplings

Table below presents the various standard symbols used for coupling in circuit diagrams

Graphic symbols used for coupling in circuit diagrams

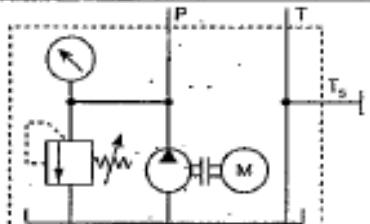
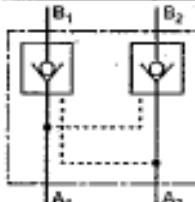
Description	Symbol	Diagram
Coupled without check valve	S70	
Coupled with check valve	S71	
Half of quick release-coupling without valve	S72	
Half of quick release-coupling with check valve	S73	

B. Combination of devices

If several devices are brought together in a single housing the symbols for individual devices are placed into a box made up of broken lines from which the connections are led away.

The following Table presents standard symbols for combination of devices

Graphic symbols used for combination of devices

Description	Symbol	Diagram
Hydraulic power pack	S74	
Pilot-operated double non-return valve	S75	



✓ Theoretical learning Activity

- ✓ Brainstorming on pneumatic/ hydraulic symbols
- ✓ Group discussion on types of pneumatic/ hydraulic system's drawings



✓ Practical learning Activity

- ✓ Practical exercises on interpretation of pneumatic/ hydraulic drawings



Points to Remember (Take home message)

The pneumatic/ hydraulic symbols illustrate flow paths, connections, and component functions but they do not indicate operating parameters and/or construction details



Indicative content 1.1.2: Review on types of pneumatic/
✓ hydraulic drawings

A. Hydraulic circuit

- ✓ Hydraulic circuit is defined as graphic representation of the hydraulic components in anhydraulically operated machine.
- ✓ In other words, hydraulic circuit is an arrangement of interconnected components (such as pumps, actuators, control valves, and pipings), selected to achieve the desired work output.

B. Assential components required for a hydraulic circuit design

1. Hydralic power pack: it consists of the pump, drive motor, mechanical couplings, oil reservoir, strainers, filters, coolers, etc.
2. Hydralic control elements: they include various types of directional control valves, pressure control valves, flow control valves, electrical control valves, etc
3. Since fluid power circuits are developed with the use of components graphic symbols, therefore the readers should be familiar and thorough with the fluid power symbols before they study power circuits.
4. Power drive units(or actuator) : they are hydraulic cylinders and hydraulic motor

System accessories: they include pipes and other fluid conductors, accumulators, boosters, pressure and temperature guages, filters. Etc

Factors to be considered

The four important factors should be considered while designing any fluid power (hydraulic/ pneumatic)circuit are:

1. Safety of operation,
2. Efficiency of operation,

3. Performance of desired function, and
4. Cost

C. Pneumatic circuit

- ✓ A pneumatic circuit may be defined as the graphic representation of the pneumatic components in a pneumatically operated machine.
- ✓ Pneumatic circuit diagrams can be drawn in similar fashion to the hydraulic circuit diagrams.

D. Pneumatic circuit versus hydraulic circuits

Through both hydraulic circuits are quite similar, the two important differences are given below:

1. Unlike in hydraulic systems, pneumatic systems directly exhaust the used air from the air cylinder to the atmosphere. Therefore the return lines are not required in pneumatic circuits, this is depicted by a short dashed line leading from the exhaust port of each valve.
2. Since most pneumatic circuits use a centralized compressor as their source of energy, generally no input device (such as a pump in a hydraulic circuit) is shown in these circuits. Also the input to the circuit can be located at some convenient manifold, which leads directly into the FRL (Filter- Regulator-Lubricator) unit.

✓  Theoretical learning Activity

- ✓ Group discussion on types of pneumatic/ hydraulic drawing
- ✓ interpretation of schematic diagram of pneumatic/ hydraulic systems



✓ Practical learning Activity

- ✓ Trainees in pair perform Practical exercises on interpretation of pneumatic/ hydraulic drawings



Points to Remember (Take home message)

Drawing helps to understand, design, analyses, and apply the fluid power systems

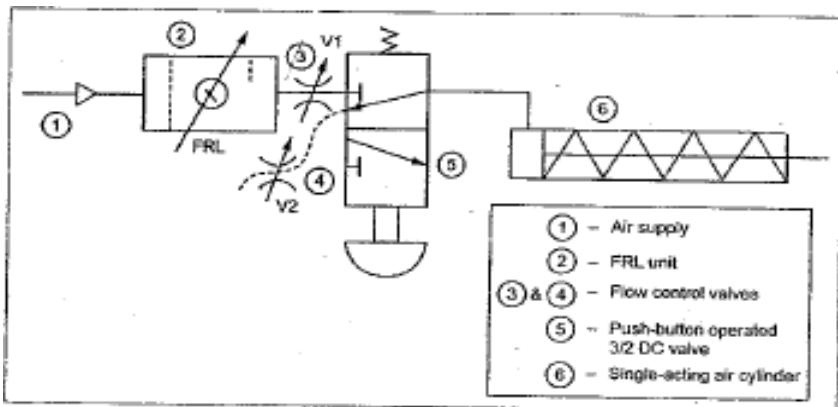


Indicative content 1.1.3: Interpretation of pneumatic/ hydraulic drawings

Interpret pneumatic circuit design

- A. Control of a single acting pneumatic cylinder
- ✓ Circuit

The figure below illustrate a simple circuit of a single acting air cylinder being controlled by a 3/2 DC valve, this circuit has a FRL unit, a push-button operated spring return 3/2 DC valve, and single-acting pneumatic cylinder



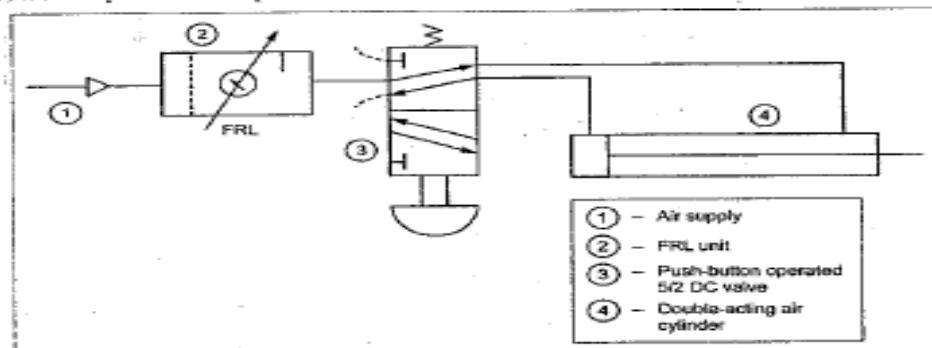
✓ Operation

For extension: when the push-button is pressed, the 3/2 DC valve is shifted to bottom envelope flow path configuration. So the compressed air flows into the blind end of the cylinder and hence the cylinder extend. Retraction: when the push-button is released, 3/2 DC valve is shifted to top envelope flow path configuration. Now the spring located at the load end of the cylinder retracts the piston to exhaust the air to the atmosphere. In this circuit, the adjustable flow control valves V1 and V2 are used to control the speed of extension and retraction of cylinder- it may be noted in the circuit that the short dashed line leading from the exhaust port represents the exhausted air released directly into the atmosphere.

B. Control of a double- acting pneumatic cylinder

✓ Circuit

The figure below illustrate a circuit that can be used to control a double acting air cylinder. This circuit has a push-button 5/2 DC valve and a double-acting air cylinder.

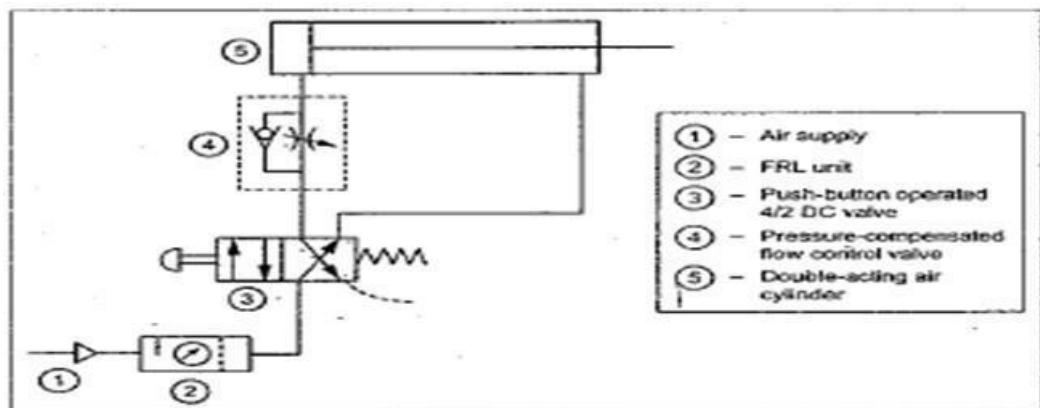


✓ Operation

Extension: When the push-button is activated (i.e, Pressed), the 5/2 DC valve is shifted to bottom envelopflow path configuration. So the compressed air flows into the blind end of the cylinder and hence the cylinder extends. At the same time, the air at the rod end of the cylinder is exhausted directly to the atmosphere.

Retraction: When the push-button is deactivation (i.e, released), the 5/2 DC valve is shifted to spring offsetmode. Now the compressed air flows into the rod end of the cylinder and hence cylinder retracts. At the same time, the air at the blind end of cylinder is exhausted directly to the atmosphere.

Meter-in speed control of Pneumatic Cylinder



Extension: When 4/2 DC valve is shifted to its left mode, air flows to the blind end of the cylinder via the flowcontrol valve. This air flow extends the cylinder. Here the extending speed of the cylinder depends on the setting of the flow control valve. Thus

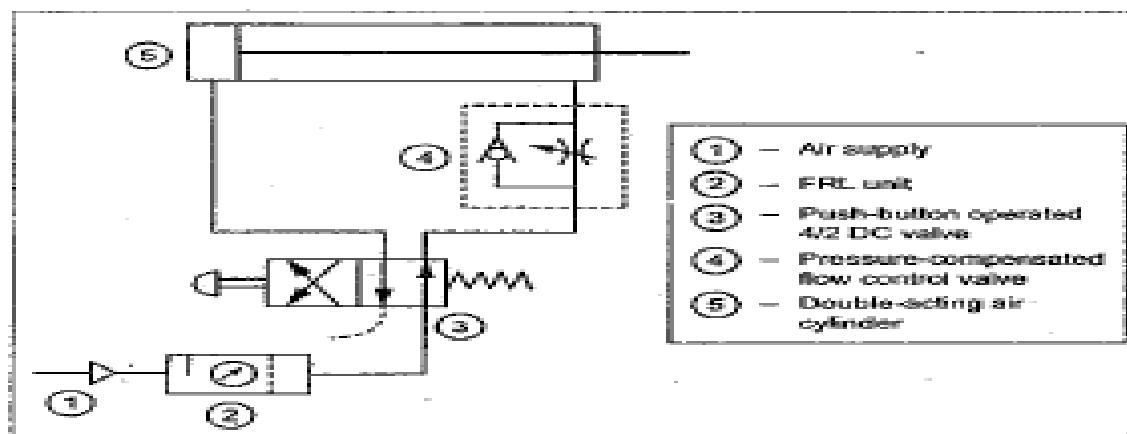
the extending speed can be regulated by just regulating the air flow in the flow control valve.

Retraction: When 4/2 DC valve is shifted to its right mode, air flows to the rod end of the cylinder and hence the cylinder retracts. The air from the blind end of the cylinder is exhausted to the atmosphere through the check valve as well as the flow control valve.

Meter-out Speed Control of Pneumatic Cylinder

Circuit: The following figure illustrates a meter-out circuit to control the speed of an air cylinder.

Operation: The operation of meter-out circuit is very much similar to that of the meter-in circuit. The only difference is that meter-out flow control system controls the air flow rate out of the cylinder. In other words, meter-out circuit controls the retracting speed of the air cylinder.



✓   **Theoretical learning Activity**

- ✓ Trainer ask trainees to brainstorm about pneumatic/ hydraulic symbols, interpretation of schematic diagram of pneumatic/ hydraulic systems



Practical learning Activity

- ✓ Trainees in groups perform Practical exercises on interpretation of pneumatic/hydraulic drawings



Points to Remember (Take home message)

symbols are used to represent individual component in fluid power circuit diagrams, which identify components and their functions uniquely

Reference:

Hydraulic, valves, pumps and accumulators, Q.S. Khan 2. Festo, hydraulics basic level textbook, D. Merkle, B.Schrader, M.Thomes, 2003 3. Basic pneumatics, Jay F.Hooper, 2003



Learning outcome 1 formative assessment

Written assessment

I choose correct answer

i) What is the symbol for a hydraulic cylinder on a schematic diagram?

- A) Triangle
- B) Circle

C) Square D) Rectangle

Answer: D) Rectangle

ii) What does the symbol of a circle with an X through it indicate on a pneumatic/hydraulic drawing?

- A) A flow control valve
- B) A pressure relief valve
- C) A check valve
- D) A shut-off valve

Answer: B) A pressure relief valve

II. reply by true or false

i) The symbol of a square with an arrow pointing to the right indicates a flow control valve on a pneumatic/hydraulic drawing.

Answer: False.

ii) The symbol of two overlapping circles indicates a check valve on a pneumatic/hydraulic drawing.

Answer: True

III. What is the purpose of a pressure gauge in a pneumatic/hydraulic system, and what symbol is typically used to represent it on a drawing?

Answer:

A pressure gauge is used to measure the pressure of fluid within a pneumatic or hydraulic system. It helps to ensure that the system is operating at the correct pressure levels and can be used to troubleshoot any problems that may arise. The symbol typically used to represent a pressure gauge on a drawing is a circle with a pointer indicating the pressure reading.

IV. What is the purpose of a flow control valve in a pneumatic/hydraulic system, and what symbol is typically used to represent it on a drawing?

Answer:

A flow control valve is used to regulate the flow of fluid within a pneumatic or hydraulic system. It is typically used to control the speed or timing of a particular operation. The symbol typically used to represent a flow control valve on a drawing is a square with an arrow pointing to the right, indicating the direction of fluid flow. Additional symbols may be added to indicate the type of flow control valve, such as an adjustable needle valve or a fixed orifice.

Practical assessment

✓ NA

References:

Hydraulic, valves, pumps and accumulators, Q.S. Khan 2. Festo, hydraulics basic level textbook, D. Merkle, B.Schrader, M.Thomes, 2003 3. Basic pneumatics, Jay F.Hooper, 2003

Learning outcome 1.2 Identify tools and material/equipment



Duration: 3 hrs



Learning outcome 1.2 , objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify types of tools used in installation of pneumatic/ hydraulic systems
2. Identify types of materials used in installation of pneumatic/ hydraulic systems
3. Identify types of equipment used in installation of pneumatic/ hydraulic systems.



Resources

Equipment	Tools	Materials
<ul style="list-style-type: none">- Air compressor - Hydraulic pump - Hydraulic and Pneumatic Transfer Hoses and Fittings - Hydraulic Flanges, - Valves Electrical motors- Hydraulic and Pneumatic	toolkit - Plumber toolkit - Flow sensors - Portable Electrical drilling machines	Books - Internet - Manual Valves- lubricant- Oils

<p>reservoir and system</p> <p>Accessories - Hydraulic and Pneumatic</p> <p>cylinders - Filter, Gauges, Pressure reducing valves, - Accumulators - Couplings - Hydraulic and Pneumatic</p> <p>Solenoids - Rotary Actuators, Slides, Grippers - Thermometers - Hydraulic Flow</p> <p>Meters - Pneumatic and Hydraulic Motors - Electro-mechanical</p>		
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Advance preparation:

- . Tools material and equipments must be available in the workplace



Indicative content 1.2.1: Identification of types of tools used

in installation of pneumatic/ hydraulic systems

A. Electro-mechanical toolkit

Are set that hold all those tools that can be use in mechanical and electrical work

This kit includes the most complete selection of fastener tools we offer. Everything from cushion **grip screwdrivers**, **fixed handle nut drivers**, **combination wrenches** and **socket set** are included to make any install or repair go quicker and easier. In addition to the mechanical tools, we have also added many items critical for electrical



repair like a **heavy duty 35- watt soldering iron** and hot cover,

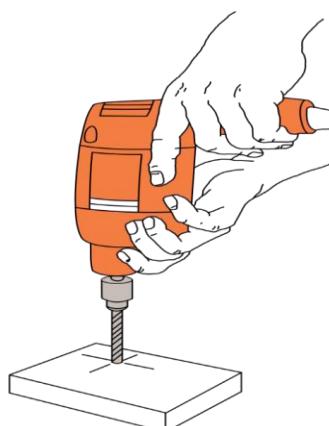
B. Plumber toolkit

Is a set or bag that hold tools used to perform work related with plumbing such as spanner, Allenwrench, tape measure, pliers, etc.



C. Hand Electrical drilling machines

A **drill** is a tool primarily used for making round holes or driving fasteners. It is fitted with a bit, either a drill or driver, depending on application. Some powered drills also include a hammer function.



Hydraulic and Pneumatic Transfer Hoses and Fittings



✓ Theoretical learning Activity

- ✓ Ask trainees to brainstorm about Brainstorming on pneumatic/ hydraulic materials, tools and installation instruments



✓ Practical learning Activity

- ✓ Practical exercises on identification of pneumatic/ hydraulic materials, tools and installation instruments



Points to Remember (Take home message)

There are a variety of tools which help and facilitate in performance of pneumatic and hydraulic system



Indicative content 1.2.2: Identification of types of materials

used in installation of pneumatic/ hydraulic systems

Identification of types of materials used in installation of pneumatic/ hydraulic systems

1. Hydraulic and pneumatic transfer hoses and fittings
 - Hose is sometimes manufactured by adding a nylon braid between the inner and outer layers of tubing and attaching a rigid and a swivel fitting. Whether

the hose is rubber or lighter weight polyurethane or other materials, it's strong, flexible and kink resistant—and thus an easy way to connect shop air to blow guns or other pneumatic tools. Hoses are commonly available in 1/4", 3/8" and 1/2" diameters with national pipe thread (NPT) or quick disconnect fittings (QD). Check diameters carefully as hoses are often specified by inside diameter to ensure proper flow for the application.



Selecting the Right Tubing Material

There are a variety of materials used to make extruded plastic pneumatic tubing including:

- *Polyurethane*
- *PVC*
- *Nylon*
- *Polyethylene*
- *PTFE*

Thread Standards

Pipe thread and tubing OD are two completely different things. A 1/4" tube fitting doesn't necessarily have a 1/4" threaded connection at the opposite end, so specify carefully. There are also several standard pipe threads including:

- NPT (National Pipe Taper)
- BSPT (British Std Pipe Taper)

- BSPP (British Std Pipe Parallel)

Getting Fitted

Fittings for connection to tubing and hose come in a variety of configurations including barb fittings, compression fittings, plastic/brass push-to-connect fittings, all metal push-to-connect fittings such as plated brass or stainless steel, brass threaded fittings, and quick-disconnect air couplings which are mostly used with hose.

Barb fittings are a simple way to connect flexible tubing or hose. The tubing is simply pushed over a barb that is slightly larger than the inside diameter of the tubing. A hose clamp is often added to secure the tubing more tightly. While easy to use, barb fittings have a higher risk of leaking or of the tubing popping out.

Compression fittings use a small barrel-shaped piece called a ferrule that slips over the outside diameter of the tube and is then compressed between a nut and the other half of the fitting. While creating a very secure connection, removing the tubing later can be difficult and often the tubing is deformed to the point that a new tube must be used to reconnect the fitting.

With push-to-connect fittings, flexible tubing is easily connected by inserting the tubing end into the fitting. To release the tubing, the circular release ring is pressed and the tubing is pulled out. This has become one of the most popular fittings for machinery and automation assemblies.

Plastic/brass push-to-connect fittings typically use strong thermoplastic with stainless steel tube-gripping claws, and threaded components made of nickel-plated brass. These fittings provide an excellent solution for most applications.

Brass threaded fittings are a good choice for miscellaneous connections to many pneumatic devices, but typically don't connect to tubing or hoses. Quick-disconnect air couplings are great for changing tool or hose connections and come in several sizes and materials.

Special Fittings

Getting tubing connected between valves and cylinders often requires more than just a simple male connector or elbow. Several special purpose push-to-connect fittings are available to improve integration and operation of pneumatic systems. For example, flow control valves are often used on cylinders to control their speed, and they frequently require these special fittings.

Other useful and convenient fittings include mini shutoff valves, mini gauges, check valves and quick exhaust valves. These devices should be considered to control

machine pneumatic functionality and to monitor air usage.

- Specifying and installing fittings and tubing sometimes feels like a puzzle, and you will likely find during the assembly process that you missed some fittings. It's common to require multiple orders to get everything working as desired.

2. Flow sensors

These types of devices are going to be able to measure the flow rate, often for a fluid. These sensors are usually a part of a flow meter, which will be able to record the flow rate. Today, many different types of flowsensors are available. It is possible to find air flow sensors as well, which can sense and determine the velocity of air movement.



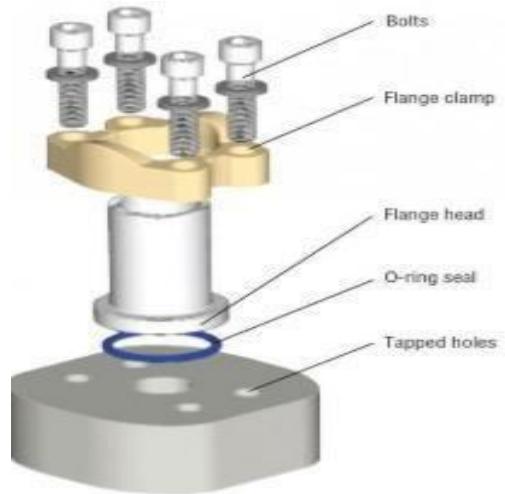
3. Hydraulic Flanges,

Flanges offer advantages over their fitting counterparts and can connect ports directly to tubes and hoses without having to use threaded connectors or adapters

Flange connections are used in the most demanding mobile equipment applications because they:

- are well suited for high pressure, shock and vibration, especially in larger sizes,
- allow easy connection between hose and tube/pipe where flexibility is needed, without adding adapters,

- allow for easy connection between rigid lines (tube-to-tube or pipe-to-pipe) and aid in installation and repair,
 - maintain a high resistance to loosening in severe hydraulic service,



4. Control system

control system refer to how the fluid power can be controlled within interconnected pneumatic/ hydraulic component by using different devices such as: Filter, Gauges, Pressure reducing valves, lubricant,

✓ Hydraulic and Pneumatic Filters

The life of a hydraulic or pneumatic component depends on the type, amount, and size of contaminant particles passing through it. Since each component has a different resistance to contamination, the filtration level must be matched to the system's most sensitive component. To ensure maximum reliability, a ratio could be specified to maintain contaminant levels far below those actually required. But this approach increases both initial and maintenance costs; therefore, filter rating and size must be carefully matched to system needs to produce the most economical system. Another important factor controlling system reliability is filter location. Placement of the filter in the suction, pressure, return, or bypass line could require different filter specifications because system parameters such as pump flow rate, reservoir size, reservoir contaminant level, contaminant ingestion rate, and flow rate can change

with filter location. All these parameters combine to control the required filter ratio.

- ⊕ A suction-line filter removes contaminants before they enter the pump. Since the reservoir collects all generated and ingested contaminants, it can be considered as the contaminant ingestion point for the circuit.
- ⊕ A pressure-line filter removes contaminant either between the pump and the other components or between any of the components. The ingestion point is either between the pump and filter or at the reservoir. Similarly, with a return-line filter, the ingestion point can be either between the work components and filter or at the reservoir.
- ⊕ A bypass circuit allows a large portion of the total pump flow to bypass the filter. In such a circuit, the filter handles only the amount of flow necessary to maintain the contamination level required by the system components. This lower flow specification allows the use of a smaller, less-costly filter, but can still provide maximum component life. In the bypass circuit, the ingestion point can be after the work components but before the bypass line or at the reservoir.

✓ Gauges

Measuring the operating parameters of a circuit is essential to be able to verify whether it lies in the correct range or to detect and identify the reasons why it may not be working properly. A pressure gauge is the instrument used for measuring fluid pressures in both hydraulic and pneumatic circuits, and generally determines the difference in pressure between the fluid and the local pressure. Given that most pressure gauges measure the difference between the pressure of the liquid and the local atmospheric pressure, the latter must be added to the value indicated by the pressure gauge to find the absolute pressure. A negative reading on the gauge is caused by a partial vacuum.

TYPE OF GAUGES

The different types of pressure gauges available come in a series of copper alloys, stainless steels and nichrome. Copper alloys give better results in some respects, but stainless steels offer greater resistance to corrosion. Nickel iron alloys are also used. Their coefficient of expansion is very small, meaning that the pressure reading is not affected by the temperature of the instrument.

✓ Pressure reducing valves

As the name suggests, a pressure reducing valve is used to supply a prescribed reducing outlet pressure in a circuit and to maintain it at a constant value. Generally, these types of valves are used in multi-pressure systems where some part of the circuit is required to operate at reduced pressure. Or Pressure-reducing valves provide a steady pressure into a part of the system that operates at a pressure lower than normal system pressure. A reducing valve can normally be set for any desired downstream pressure within its design limits. Once the valve is set, the reduced pressure will be maintained regardless of changes in the supply pressure and system load variations.

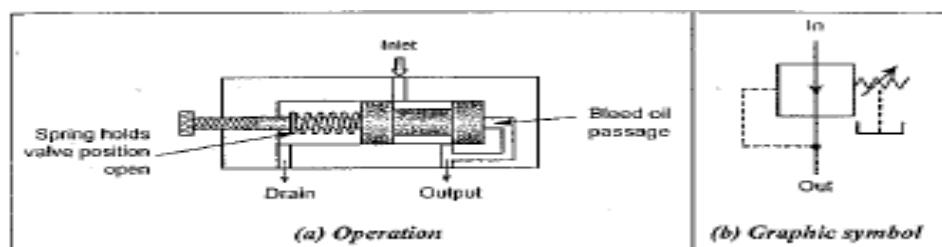
TYPES OF PRESSURE REDUCING VALVES

Like in pressure relief valves, the two important types of pressure reducing valves are: direct-acting pressure reducing valves or spring loaded reducer and pilot-operated pressure reducing valves

- Spring-Loaded Pressure-Reducing Valves or direct-acting pressure reducing valves*

Construction and operation

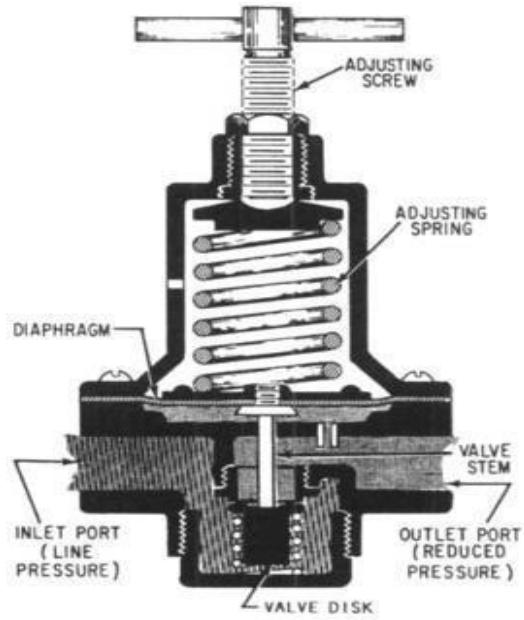
The construction and operating of a direct-acting pressure reducing valve is illustrated in the following figure, it has a spring loaded spool to control the downstream (outlet) pressure.



When the main supply pressure is below the valve setting pressure, fluid will flow freely from the inlet to the outlet. It can be noted from the figure above that an internal connection from the outlet passage transmits the outlet pressure to the spool end opposition the spring. When the downstream (outlet) pressure increases to the valve setting pressure, the spool moves to the left to partly block the outlet port.

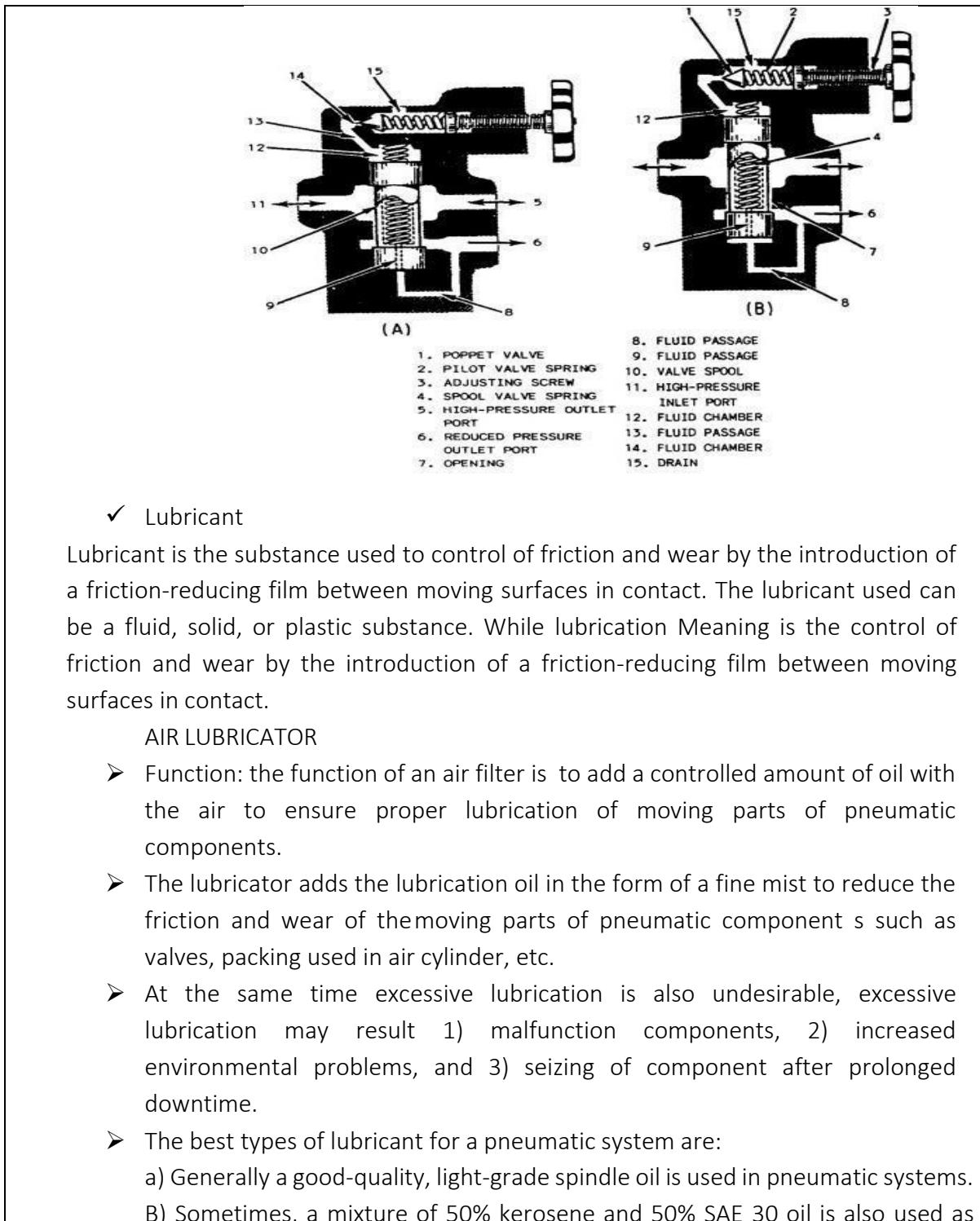
During this period, only enough flow is passed to the outlet to maintain the preset pressure.

If the valve closes completely, leakage could cause the spool pressure to build up. In order to avoid this, a continuous bleed to the tank is permitted to keep the valve slightly open. A separate drain passage is provided to drain this fluid to the tank. It is often referred to as a pressure regulator.



b) Pilot-Controlled Pressure-Reducing Valves

Figures below illustrate the operation of a pilot-controlled valve. This valve consists of an adjustable pilot valve that controls the operating pressure of the valve, and a spool valve that reacts to the action of the pilot valve.



✓ Lubricant

Lubricant is the substance used to control of friction and wear by the introduction of a friction-reducing film between moving surfaces in contact. The lubricant used can be a fluid, solid, or plastic substance. While lubrication Meaning is the control of friction and wear by the introduction of a friction-reducing film between moving surfaces in contact.

AIR LUBRICATOR

- Function: the function of an air filter is to add a controlled amount of oil with the air to ensure proper lubrication of moving parts of pneumatic components.
- The lubricator adds the lubrication oil in the form of a fine mist to reduce the friction and wear of the moving parts of pneumatic components such as valves, packing used in air cylinder, etc.
- At the same time excessive lubrication is also undesirable, excessive lubrication may result 1) malfunction components, 2) increased environmental problems, and 3) seizing of component after prolonged downtime.
- The best types of lubricant for a pneumatic system are:
 - a) Generally a good-quality, light-grade spindle oil is used in pneumatic systems.
 - B) Sometimes, a mixture of 50% kerosene and 50% SAE 30 oil is also used as

lubricant.

Accumulators

- ✓ An accumulator is basically pressure storage reservoir in which a non-compressible hydraulic or pneumatic fluid is retained under pressure from an external source.
- ✓ In other words, hydraulic or pneumatic accumulator is a device used to store the energy of fluid pressure and make this energy available as a quick secondary source of power to hydraulic or pneumatic machines (such as presses, lifts, and cranes)

Example: In case of hydraulic crane or lift, the liquid under pressure needs to be supplied only during the upward motion of the load. This energy is supplied from hydraulic accumulator. But when the lift is moving

downward, no large external energy is required and during that period the energy from the pump is stored in the accumulator.

SUITABILITY AND APPLICATIONS OF ACCUMULATORS

- ❖ Suitability: accumulators are suitable for the following types of application:
 1. For hydraulic shock suppression
 2. For fluid make-up in closed hydraulic system
 3. For leakage compensation
 4. For source of energy power in case of power failure
 5. For holding high pressures in long periods of time without keeping the pump unit
- ❖ Application: accumulators in conjunction with hydraulic systems are used on large hydraulic presses, hydraulic lifts, hydraulic cranes, farm machinery, power brakes and landing gear mechanisms on airplanes, diesel engine starters, and other devices and machinery.

Types of accumulators are:

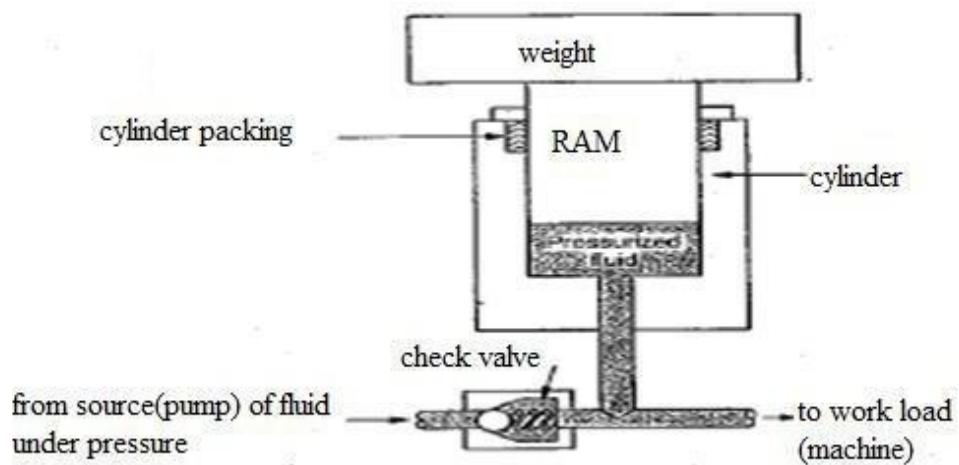
Accumulators are classified in terms of the manner in which the load is applied, the three basic types of accumulator used in hydraulic systems are:

1. *Weight-loaded (or dead-weight) accumulators,*
2. *Gas-loaded accumulators.*
3. *Spring-loaded accumulator*

Weight-loaded (or dead-weight) accumulators,

The construction of dead-weight type accumulator is illustrated in figure below, it consists of a piston rod or plunger loaded with dead weight and moving within a cylinder to exert pressure on hydraulic oil. The dead weight may be providing the potential energy to compress the fluid.

One side of accumulator cylinder is connected to the fluid source (pump) and the other side to the work load (machine).



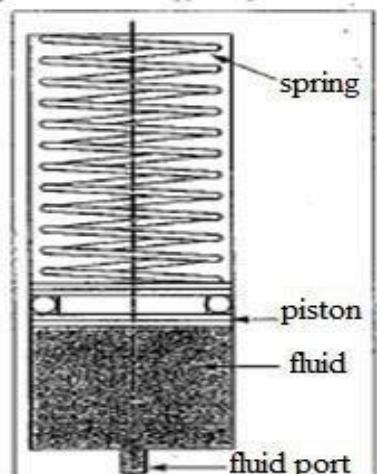
Spring-loaded accumulator CONSTRUCTION

The Spring-loaded accumulator are similar in construction to that of dead weight type accumulators, in this type, instead of loading the ram with dead weight, it is preloaded with compression spring, as shown in the figure below, it consists of a cylinder body, a movable piston, and a compression spring. The spring provides the compression energy required for this accumulator.

operation

As the spring is compressed by the piston, the hydraulic fluid is forced into the accumulator cylinder. The pressure in the accumulator is dependent on the size and preloading of the spring. The accumulator pressure increases as the spring gets compressed, because incoming fluid flow increases the load required to compress the spring.

When the fluid is discharged out of the accumulator, it causes the spring to expand. As the spring approaches its free length, the accumulator pressure drops to a minimum. Thus the pressure exerted by the spring-loaded type accumulator on the fluid is not constant as in the dead-weight type.



spring-loaded type accumulator

Advantages

1. The spring loaded accumulators are usually smaller and less expensive than dead weight type accumulators
2. They are easy to maintain Disadvantages
1. The pressure exerted to the fluid is not constant
2. They are used for low volume, low pressure systems.
3. For high-pressure and volume applications, they tend to be bulky and costly.

Gas-loaded accumulators

- ✓ Gas-loaded accumulators, also popularly known as *hydro-pneumatic accumulators*, are the most commonly used accumulators in almost all the industrial applications.
- ✓ They work on the basis of the Boyle's gas law. They Boyle's gas law states that for a constant temperature process, the pressure of the gas varies inversely with its volume. Mathematically,

$$P \propto \frac{1}{V} \text{ when } T \text{ is constant, or } PV = \text{constant.}$$

Types of gas-loaded accumulators

The two types of gas-loaded accumulators are:

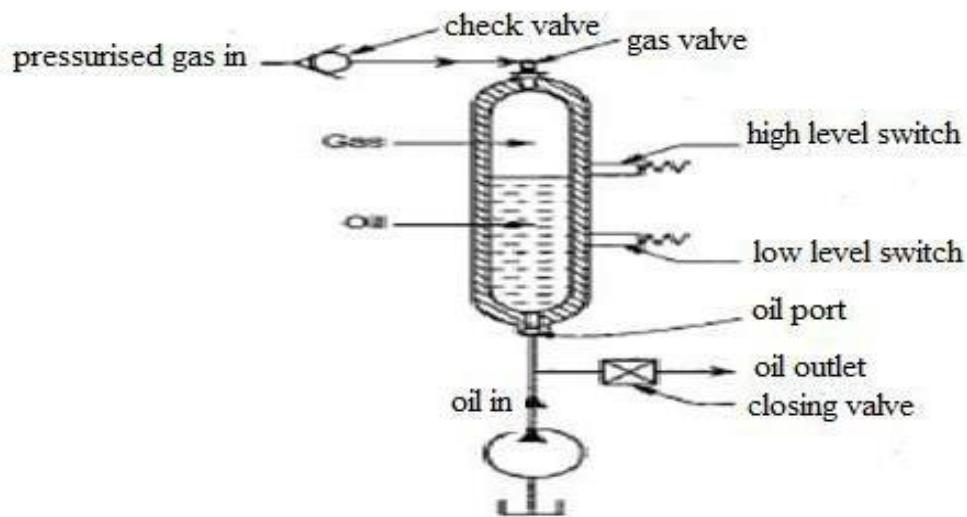
1. Non-separate type, and

2. Separate type

- Piston type
- Diaphragm type
- Bladder type.

In the non-separator type, the gas which provides the load is in direct contact with the hydraulic fluid, whereas in the separator type, they are separated by a piston, diaphragm, or bladder.

Non-separator type accumulator type



Advantages

The non-separator type accumulator can handle large volume of oil Desadvantages

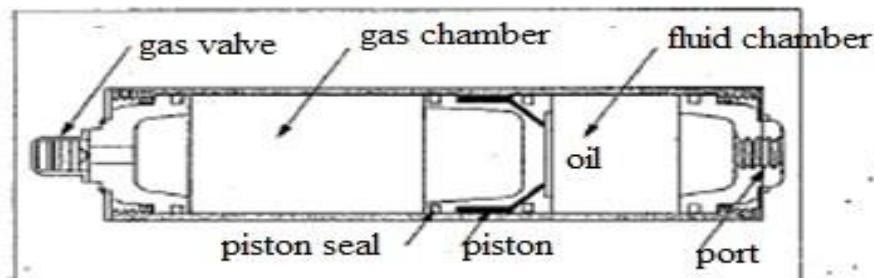
1. Due to the absence of separator, the gas is absorbed and also entrapped in the oil.
2. This accumulator type is not preferred for use with high speed pumps because entrapped gas in the oil may cause cavitation and damage to the pump.
3. The absorption of gas in the oil makes the oil compressible, and thus results spongy operation of hydraulic actuators.
4. Always this type of accumulator must be installed vertically so as to keep the gas confined at the top of the shell.
5. The problem of aeration of the oil often limits their use in hydraulic systems.

Separator type accumulator

- ✓ The above said drawbacks of the non-separator type accumulators can be eliminated by using the separator type accumulators by providing a barrier between the pressurizing gas and the hydraulic fluid.
- ✓ The separator pneumatic-loaded accumulators are the most commonly used. Because they are small, light weight and can be mounted in any position.
- ✓ **Types :** Based on the barrier used, the separator type accumulators can be classified into three types, as :
 1. Piston type accumulator,
 2. Diaphragm type accumulator, and
 3. Bladder type accumulator.

○ Piston type Construction

The construction of a physical piston type accumulator is illustrated in the figure below, it consists of a cylinder body and a movable piston with proper seals



Advantages

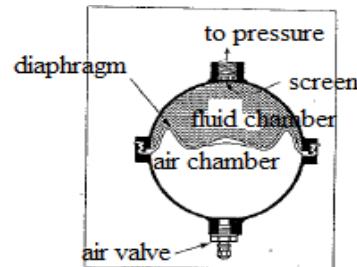
The piston type accumulator has the ability to handle very high or low temperature system fluid

Disadvantages

1. In piston type accumulators, the pressure does not remain constant when the complete oil is being displaced.
2. The piston type-accumulators are expensive to manufacture.
3. In low pressure applications, there may be a problem of piston and seal friction.
4. There is always appreciable leakage over a long period requiring frequency pre-charging.

○ Diaphragm type Construction

The construction of a typical diaphragm-type accumulator is shown in the figure below. The spherical vessel is separated into two compartments by a flexible diaphragm. One compartment is connected to the hydraulic system and the other to high-pressure gas system. Thus the diaphragm serves as an elastic barrier between the oil and the gas.



Advantages

The diaphragm type accumulator has small weight to volume ratio. Which makes it most suitable for many air borne application.

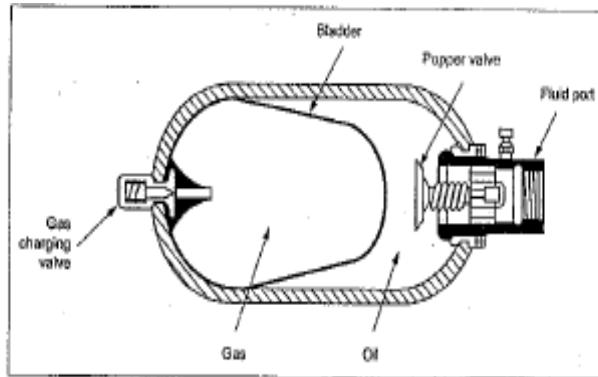
Disadvantages

- The diaphragm type accumulators do not provide constant fluid pressure outlet.
- Sometimes the diaphragm material may become incompatible with a certain fire retardant and synthetic fluids

Bladder type accumulator

Construction

The construction of a typical bladder type accumulator is depicted on the figure below, it consists of a bag or bladder of synthetic material which is precharged with gas to a determined pressure. This bladder is placed within the accumulator shell and the balance of the space filled with oil. Thus bladder serves as an elastic barrier between the gas and oil.



Advantages

1. Type accumulators respond quickly to changes in the system demand.
2. They possess positive scaling between the gas and oil chambers
3. Because of the low inertia of the bladder, they are especially suitable for damping pulsations.
4. This bladder type can be used for ratios of maximum to minimum pressure up to about 5 to 1. Disadvantages

There is a possibility of bladder failure

5. Couplings

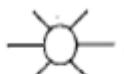
Couplings are devices that are used to join two things together or A coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power. The primary purpose of couplings is to join two pieces of rotating equipment while permitting some degree of misalignment or end movement or both.

6. Hydraulic and Pneumatic Solenoids

- ✓ Solenoids is an electromagnetic mechanical transducer that converts an electrical signal into a mechanical output force
- ✓ Solenoids provide a push or pull force to remotely operate fluid power valves.
- ✓ The figure a shows the graphical symbols used to represent the solenoid.



(a) solenoid



(b) indicator lamp

- ✓ An indicator lamp is used to indicate the state of specific circuit component

- ✓ Indicator lamps are used:
 - I. To identify which solenoid operator of DC valve is energized, and
 - II. To indicate whether a hydraulic cylinder is extending or retracting

A solenoid valve is an electrically activated valve, typically used to control the flow or direction of air or liquid in fluid power systems. Solenoid valves are used in both pneumatic and hydraulic fluid power systems, the most basic solenoid valves are two-way, two-position poppet valves, which simply open and close to allow flow when their coil is energized. They are available as “normally-open” and “normally-closed” versions, which means normally-flowing and normally-blocked, respectively. Normally-open in fluid power is the opposite of normally-open in electronics, which means the switch or contact is open and not flowing electrons.

Rotary Actuators, Slides, Grippers

A rotary actuator is an actuator that produces a rotary motion or torque. The simplest actuator is purely mechanical, where linear motion in one direction gives rise to rotation. The most common actuators though are electrically powered. Other actuators may be powered by pneumatic or hydraulic power, or may use energy stored internally through springs.

The motion produced by an actuator may be either continuous rotation, as for an electric motor, or movement to a fixed angular position as for servomotors and stepper motors.

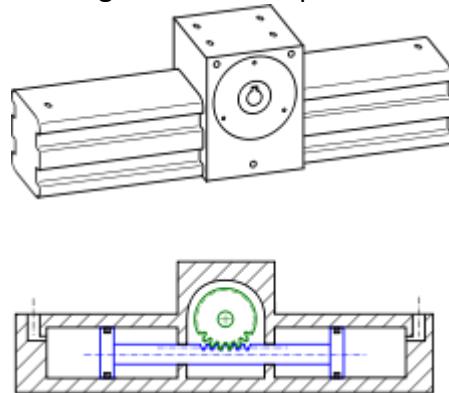


Rotary actuator

Fluid power actuators

Both hydraulic and pneumatic power may be used to drive an actuator, usually the larger and more powerful types. As their internal construction is generally similar (in principle, if

not in size) they are often considered together as *fluid power* actuators. Fluid power actuators are of two common forms: those where a linear piston and cylinder mechanism is geared to produce rotation (*illustrated*), and those where a rotating asymmetrical vane swings through a cylinder of two different radii. The differential pressure between the two sides of the vane gives rise to an unbalanced force and thus a torque on the output shaft. Vane actuators require a number of sliding seals and the joints between these seals have tended to cause more problems with leakage than for the piston and cylinder type.



7. Thermometer

A thermometer is a device that measures temperature or a temperature gradient. A thermometer has two important elements: (1) a temperature sensor (e.g. the bulb of a mercury-in-glass thermometer or the pyrometric sensor in an infrared thermometer) in which some change occurs with a change in temperature; and (2) some means of converting this change into a numerical value (e.g. the visible scale that is marked on a mercury-in-glass thermometer or the digital readout on an infrared model). Thermometers are widely used in technology and industry to monitor processes, in meteorology, in medicine, and in scientific research.



Figure: Thermometer

Hydraulic Flow Meters

Flow meter is the measurement of the volume of a liquid that passes a fixed point in a unit of time. For most hydraulic applications, flow is measured in litres per minute.



Oils

Hydraulic oil is a fluid lubricant used in hydraulic systems for transmitting power.

Common hydraulic system consists of:

- Oil tank;
- Hydraulic pump;
- Oil filter;

- Control valves;
- Pistons;
- Pipes.

The following characteristics and properties are important for hydraulic oils:

- Low temperature sensitivity of viscosity;
- Thermal and chemical stability;
- Low compressibility;
- Good lubrication (anti-wear and anti-stick properties, low coefficient of friction);
- Hydrolytic stability (ability to retain properties in the high humidity environment);
- Low pour point (the lowest temperature, at which the oil may flow);
- Water emulsifying ability;
- Filterability;
- Rust and oxidation protection properties;
- Low flash point (the lowest temperature, at which the oil vapors are ignitable);
- Resistance to cavitations;
- Low foaming;
- Compatibilit

y with sealant
materials. Viscosity
of hydraulic oils

Viscosity of a hydraulic fluid depends on its composition and the temperature. Low viscosity limit is determined by the lubrication properties of the oil and its resistance to cavitations.

AE Designation of hydraulic oils by viscosity

The Society of Automotive Engineers (SAE) established a viscosity grading system for oils.

According to the SAE viscosity grading system all oils are divided into two classes: mono-grade and multi-grade:



Mono-grade hydraulic oils

Mono-grade hydraulic oils are designated by one number (10, 20, 30, 40, etc.). The

number indicates a level of the oil viscosity at a particular temperature. The higher the grade number, the higher the oil viscosity. Viscosity of hydraulic oils designated with a number only without the letter "W" (SAE 10, SAE 20, SAE 30 etc.) was specified at the temperature 212°F (100°C). These oils are suitable for use at high ambient temperatures.

Viscosity of hydraulic oils designated with a number followed by the letter "W" (SAE 10W, SAE 20W, SAE 30W etc.) was specified at the temperature 0°F (-18°C). The letter "W" means *winter*. These grades are used at low ambient temperatures.

Multi-grade hydraulic oils

Viscosity of hydraulic oils may be stabilized by polymeric additives (viscosity index improvers). Viscosity of such oils is specified at both high and low temperature. These oils are called multi-grades and they are designated by two numbers and the letter "W" (SAE 5W30, SAE 10W20, SAE 10W30 etc.). The first number

of the designation specify the oil viscosity at cold temperature, the second number specifies the oil viscosity at high temperature.

For example: SAE 10W30 oil has a low temperature viscosity similar to that of SAE 10W, but it has a high temperature viscosity similar to that of SAE 30.

Multi-grade hydraulic oils are used in a wide temperature range.

ISO Designation of hydraulic oils

International Standardization Organization (ISO) established a viscosity grading (VG) system for industrial hydraulic oils. According to the system hydraulic oils are designated by the letters ISO followed by a number equal to the oil viscosity measured in centistokes at 40°C (104°F): ISO VG 32, ISO VG 46 etc.

- ✓  **Theoretical learning Activity**
 - ✓ ask trainees to discussion on pneumatic/ hydraulic materials

- ✓ Brainstorming on pneumatic/ hydraulic materials



Practical learning Activity

- ✓ Ask trainee to make a Documentary Research about pneumatic material
- ✓ Practical exercises on identification of pneumatic/ hydraulic materials



Points to Remember (Take home message)

Viscosity of a hydraulic fluid depends on its composition and the temperature. Low viscosity limit is determined by the lubrication properties of the oil and its resistance to cavitations



Indicative content 1.2.3: Identification of types of equipment

used in installation of pneumatic/ hydraulic systems

A. Air compressor

Introduction

As we know the vast majority of pneumatic systems use compressed atmospheric air as the working medium. The performance of the pneumatic system and its components mainly depends on the compressed air supply. The compressor compresses the atmospheric air into the compressed air and supplies the necessary quantity of air with required pressure.

Definition

Compressor: is a device used to compress air (or any gas) from a low inlet pressure (usually atmospheric pressure) to a higher desired pressure level

- ✓ In pneumatic system compressor are used to compress and supply the required quantity of air
- ✓ As per the laws of perfect gas, the compressor increases the pressure of the air by reducing its volume.

Types of air compressors

- ✓ There are two basic types of compressor, based on their method of energy transfer and pressure generation, they are:

1. Positive

displacement

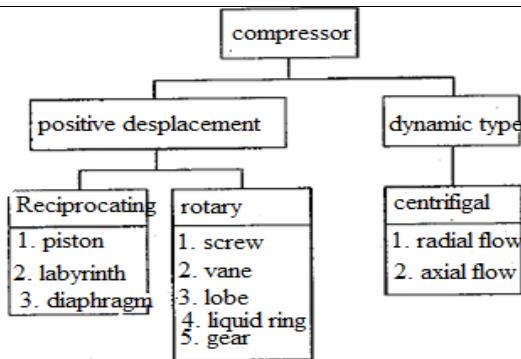
compressor, and 2.

Dynamic type

compressor

- Positive displacement compressor work on the principle of increasing the pressure of a definite volume of air by reducing that volume in an enclosed chamber
- Dynamic compressors, also known as turbo compressors, employ rotating vanes or impellers to increase the pressure of the air.

The table below shows detailed sub-classification of compressor



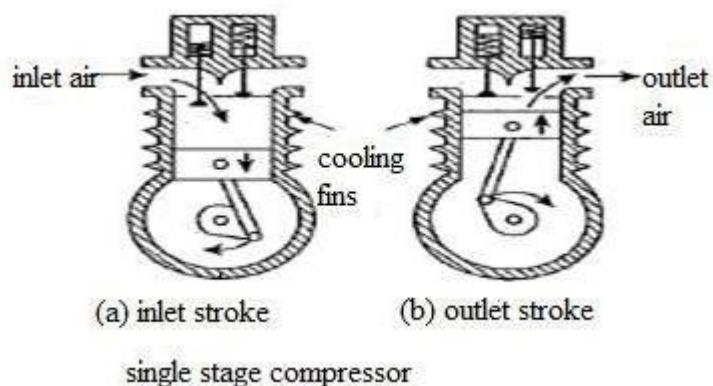
However, the study of piston, screw, and vane type compressors are more important from our subject point of view.

❖ **PISTON-TYPE RECIPROCATING COMPRESSOR**

- ✓ Piston compressors are the most commonly used compressor in the fluid power industry.
- ✓ The construction of piston type reciprocating compressor is very much similar to that of an internal combustion (IC) engine

Construction

A typical piston type reciprocating compressor consists of a cylinder, cylinder head, piston with piston rings, inlet and outlet valves, connecting rod, crank, crankshaft, bearings, etc. the arrangement of single compressor is illustrated in the following figure.



Outlet stroke: as the piston starts moving (shown on the figure above (b)), the inlet

valve is closed and the pressure starts increasing continuously until the pressure inside the cylinder is above the pressure of the delivery side which is connected to the receiver, then the outlet valve opens and air is delivered during the remaining upward motion of the piston to the receiver.

Multicylinder piston compressor

Though a single cylinder compressor can provide pressure up to about 10 bars, usually multicylinder compressors (having 2 to 16) are used for increasing compression capacity and also due to many practical reasons.

Single stage compressor and multi-stage compressors

In single stage compressor, the compression of the air from the initial pressure to the final pressure is carried out in one cylinder only.

- ✓ When the compression of the air from the initial to the final pressure is carried out in more than one cylinder, then the compressor is known as multi-stage compressor.
- ✓ Staging: staging means dividing the total pressure among two or more cylinders by allowing the outlet from one cylinder into the inlet of the next cylinder and so on.

Advantages of piston compressor

1. Piston type compressors are available in wide range of capacity and pressure.
2. The overall efficiency of piston compressors are high when compared to other compressors
3. Very high air pressure and air volume flow rate can be obtained by using the multistage compressors
4. Better mechanical balance can be achieved with multi-stage compressor
 - ❖ Screw compressors

Screw compressors are used in many applications medium pressure (<10 bar) and medium volumes of air (upto 500 m³/hr) are required

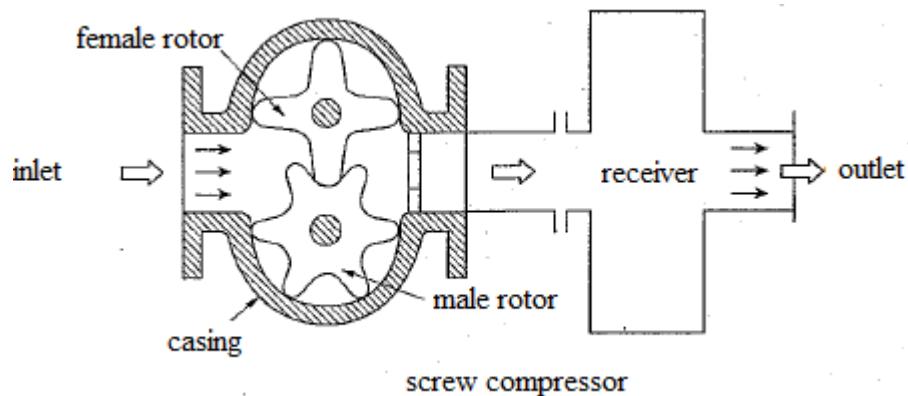
Construction

The construction of a screw compressor is very similar to a hydraulic screw pump, a typical screw compressor having unsymmetrical profile of screw rotors is illustrated in the following figure.

As shown in the figure it consists of two screws, one with convex and the other with concave contour, generally called male and female rotor respectively.

Also a minimal clearance is maintained between the two

intermeshing rotating screws.



Advantages of screw compressor

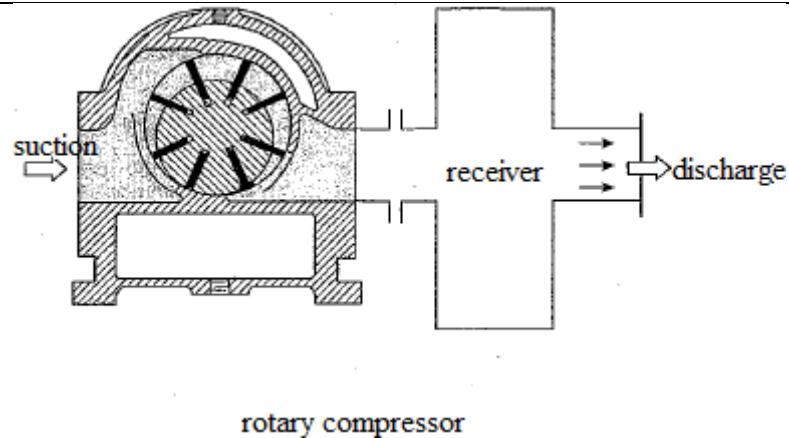
1. Simplicity
2. Fewer moving parts rotating at a constant speed
3. Steady delivery of air without pressure pulses

❖ Rotary vane compressor

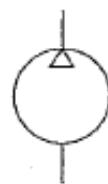
the rotary vane type compressor are used in applications where low-pressure and low-volume are needed. For example, they are used for instrument and other laboratory-type air needs.

Construction

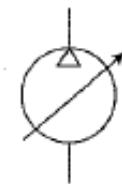
The construction of a rotary vane compressor is very much similar to a hydraulic vane pump, a typical sliding vane-type rotary compressor is illustrated in the figure below; it consists of a rotor located electrically in cylindrical casing. The rotor carries a set of spring-loaded vanes in the slots of the rotor, as shown in the following figure.



Graphica symbol



single fixed
displacement
compressor graphical symbol



single variable
displacement
compressor graphical symbol

Advantages

1. Rotary vane compressor are pulse free and therefore can be used without a receiver
2. They are smaller in size and lighter in weight.
3. They can work at high speed
 - A. Hydraulic pump

Hydraulic pumps are used in hydraulic drive systems and can be hydrostatic or hydrodynamic. A hydraulic pump is a mechanical source of power that converts mechanical power into hydraulic energy (hydrostatic energy i.e. flow, pressure). It generates flow with enough power to overcome pressure induced by the load at the pump outlet.

Moving fluids plays a major role in the process of a plant. Liquid can only move on its own power, and then only from top to bottom or from a high pressure to a lower pressure system. This means that energy to the liquid must be added, to moving the liquid from a low to a higher level. To add the required energy to liquids, pumps are used. There are many different definitions of a pump but this is best described as:

- A machine used for the purpose of transferring quantities of liquids, gases and even solids from one location to another.
- A hydraulic pump is a device which converts mechanical energy into hydraulic energy.

The pump is used to impart motion to a liquid. It provides the force required to transmit power and motion. The pump does not produce pressure. It produces only fluid flow

0. Pump theory(Principle of Pump)

Normally the powered electric motor converts the electrical energy into mechanical energy which is used to drive the shaft of the pump. The pump in turn converts the mechanical energy into hydraulic energy by creating a partial vacuum at the inlet, which induces the atmospheric pressure to force the fluid through the inlet line. Then the internal design of the pump mechanically pushes the fluid to the outlet line.

1. How a pump works?

The working principle of the pump can be better explained by referring to the simple piston pump as shown on the figure below:

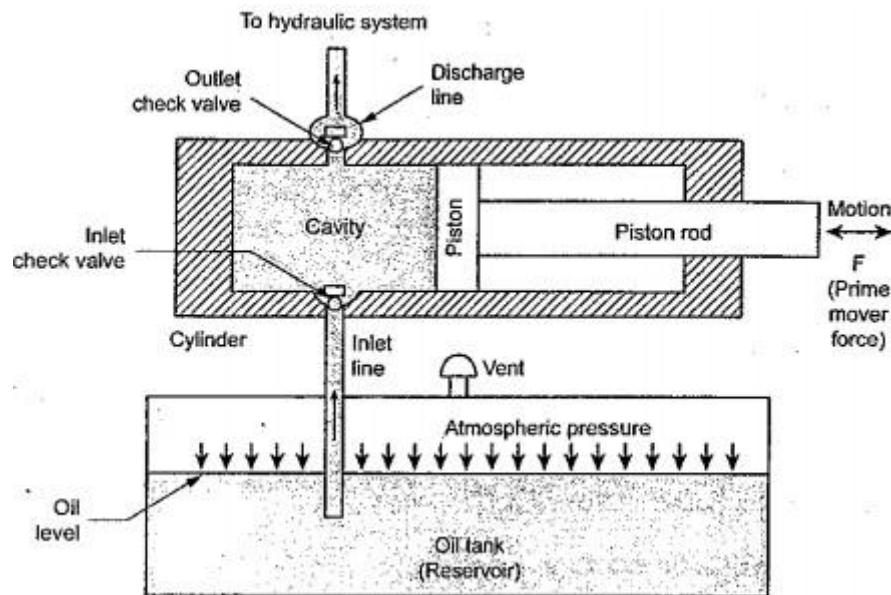


Figure: Pumping action of a simple piston pump

- ⊕ The pump has the following two ball-check valves:
 - ✓ **Inlet check valve:** It is connected to the pump inlet to allow fluid to enter the pump
 - ✓ **Outlet check valve:** It is connected to the pump outlet to allow fluid to leave the pump

When the piston is pulled to the right, a partial vacuum is generated in pump cavity. The vacuum created in the cavity makes the outlet check valve to close the outlet line and allows the atmospheric pressure to push fluid from the reservoir into the pump via the inlet check valve.

When the piston is pushed to the left, the fluid movement forces the inlet check valve to close and open the outlet check valve. The quantity of fluid displaced by the piston is ejected out through the outlet line. Thus the pump produces flow of fluid.

2. Applications of pumps

The most popular application of pumps is shown below:

- Pumping water from the wells

- Water cooling and fuel injection in automobile
- Pumping oil or gas and operating cooling towers in energy industry
- They also have their uses in waste water recycling, pulp and paper, chemical industry etc.

3. PUMP CLASSIFICATION

With reference to the fluid power applications, pumps can be broadly classified into different ways and must be considered in any discussion of fluid power equipment.

1. Classification based on displacement:
 - Non-positive displacement pumps (hydrodynamic pumps).
 - Positive displacement pumps (hydrostatic pumps).
2. Classification based on delivery:
 - Constant delivery pumps.
 - Variable delivery pumps.
3. Classification based on motion:
 - Rotary pump.
 - Reciprocating pump.
4. Classify the positive displacement pumps

Based on the construction, Hydrostatic pumps are classified

- 1) Gear Pumps (fixed displacement pumps
 - (a) External gear pump
 - (b) Internal gear pump
 - a. Lobe pump
 - b. Gerotor pump
 - (c) Screw pump
- 2) Vane Pumps (fixed or variable displacement pumps)
 - (a) Balanced Vane pump
 - (b) Unbalanced Vane pump
- 3) Piston Pumps (fixed or variable displacement pumps)

(a) Axial piston pump b)Radial piston pump

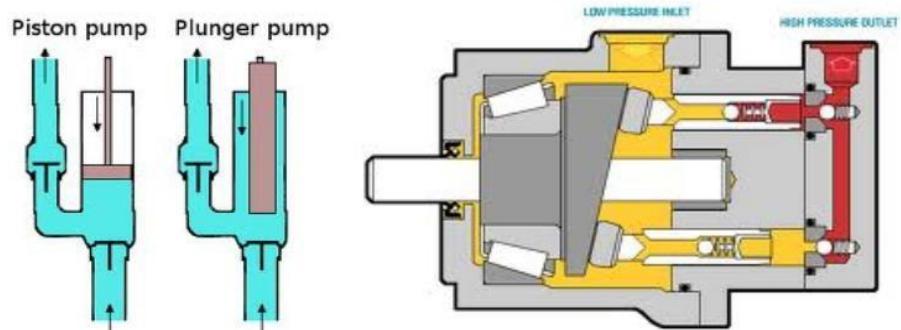


Figure : Some reciprocating pumps

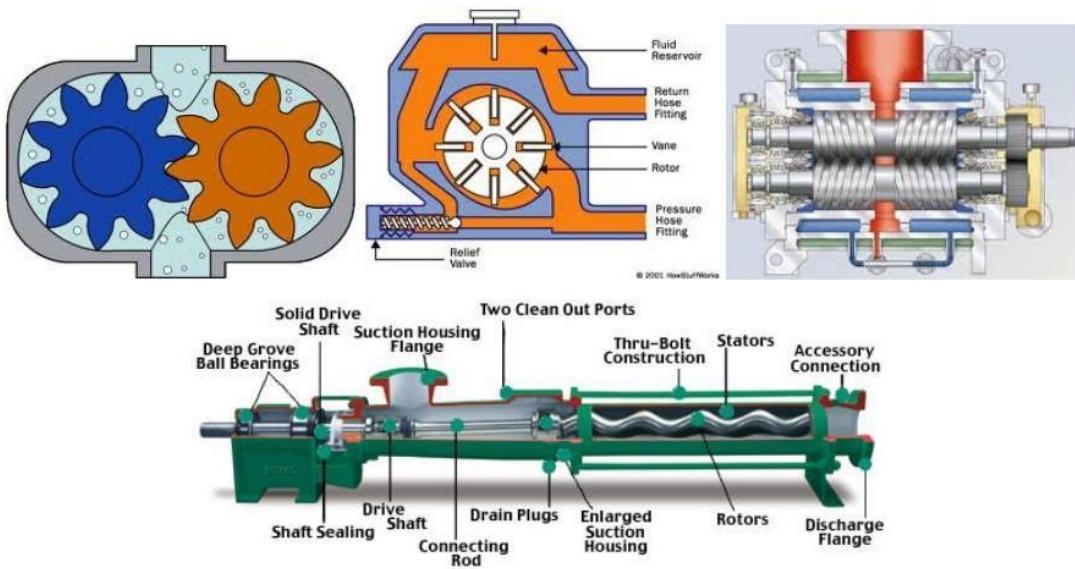


Figure : Some rotary pumps

A. CLASSIFICATION BASED ON DISPLACEMENT

1. Non-Positive Displacement Pumps

Non-positive displacement pumps are primarily velocity-type units that have a great deal of clearance between rotating and stationary parts. Non-displacement pumps are characterized by a high slip that increases as the back pressure increases, so that the outlet may be completely closed without damage to the pump or system.

Non-positive pumps do not develop a high pressure but move a large volume of fluid at low pressures. They have essentially no suction lift. Because of large clearance

space, these pumps are not self-priming. In other words, the pumping action has too much clearance space to seal against atmospheric pressure. The displacement between the inlet and the outlet is not positive. Therefore, the volume of fluid delivered by a pump depends on the speed at which the pump is operated and the resistance at the discharge side.

These pumps are not used in fluid power industry as they are not capable of withstanding high pressure. Their maximum capacity is limited to 17–20 bars. These types of pumps are primarily used for transporting fluids such as water, petroleum, etc., from one location to another considerable apart location.

The two most common types of hydrodynamic pumps are the centrifugal and the axial flowpropeller pumps.

❖ Advantages and disadvantages of non-

positive displacement pumps

The advantages are as follows:

- Non-displacement pumps have fewer moving parts.
- Initial and maintenance cost is low.
- They give smooth continuous flow.
- They are suitable for handling almost all types of fluids including slurries and sledges.
- Their operation is simple and reliable.

The disadvantages are as follows:

- Non-displacement pumps are not self-priming and hence they must be positioned below the fluid level.
- Discharge is a function of output resistance.
- Low volumetric efficiency.

B. Positive (or Hydrostatic) Displacement pumps

- ✓ As the name implies, the functioning of a positive-displacement pump derives from changes of the volume occupied by the fluid within the pump.
- ✓ Since the operation of the pumps depend only on mechanical and hydrostatic principles, these pumps are also called as *hydrostatic displacement pumps*.
- ✓ Positive displacement pumps are primarily used where pressure development is the prime requirement. This type of pumps is capable of delivering high pressure fluid, so it is universally used in fluid power systems.
- ✓ These pumps discharge a fixed quantity of fluid into the hydraulic system per revolution of pump shaft rotation. Since the flow of fluid is guaranteed on every revolution of the shaft, this type of pump is named as '*positive displacement pump*'.
- ✓ **Types :** Positive displacement pumps can be further divided into :
 1. Fixed displacement pumps, and 2. Variable displacement pumps.
 1. **Fixed Displacement Pumps :** In fixed displacement pumps, the amount of fluid ejected per revolution (displacement) is constant and it cannot be varied.
 2. **Variable Displacement Pumps :** In variable displacement pumps, the displacement can be varied by changing the physical relationships of various pump elements. This change in pump displacement produces a change in output of fluid flow even though pump speed remains constant.

Examples: Some of the positive displacement pumps are gear; vane; piston and screw pumpsPositive displacement pumps are classified based on the following characteristics:

1. Type of motion of pumping element: Based on the type of motion of pumping element, positive displacement pumps are classified as follows:
 - Rotary pumps, for example, gear pumps and vane pumps.
 - Reciprocating pumps, for example, piston pumps.
2. Displacement characteristics: Based on displacement characteristics, positivedisplacement pumps are classified as follows:

- Fixed displacement pumps.
- Variable displacement pumps.

3. Type of pumping element.

The advantages of positive displacement pumps over non-positive displacement pumps are as follows:

1. They can operate at very high pressures of up to 800 bar (used for lifting oils from very deep oil wells).
2. They can achieve a high volumetric efficiency of up to 98%.
3. They are highly efficient and almost constant throughout the designed pressure range.
4. They are a compact unit, having a high power-to-weight ratio.
5. They can obtain a smooth and precisely controlled motion.
6. By proper application and control, they produce only the amount of flow required to move the load at the desired velocity.
7. They have a great flexibility of performance. They can be made to operate over a wide range of pressures and speeds.

Table 1. Differences between positive displacement pumps and non-positive displacement pumps

Positive Displacement Pumps	Non-positive Displacement Pumps
The flow rate does not change with head	The flow rate decreases with head
The flow rate is not much affected by the viscosity of fluid	The flow rate decreases with the viscosity
Efficiency is almost constant with head	Efficiency increases with head at first and then decreases
<ul style="list-style-type: none"> ❖ The four parameters that affect noise level of hydrostatic pump Pressure <ul style="list-style-type: none"> o Size of the pump 	

- o Speed of the pump
- o Entrained air bubbles

1. Gear pumps

This is the simplest of rotary positive displacement pumps consisting of two meshed gears rotating in a closely fitted casing. Fluid is pumped around the outer periphery by being trapped in the tooth spaces. It does not travel back on the meshed part, since the teeth mesh closely in the centre. It is widely used on car engine oil pumps, and also in various hydraulic power packs. There are two main variations; external gear pumps which use two external spur gears and internal gear pumps which use an external and an internal spur gear. Some gear pumps are designed to function as either a motor or a pump.

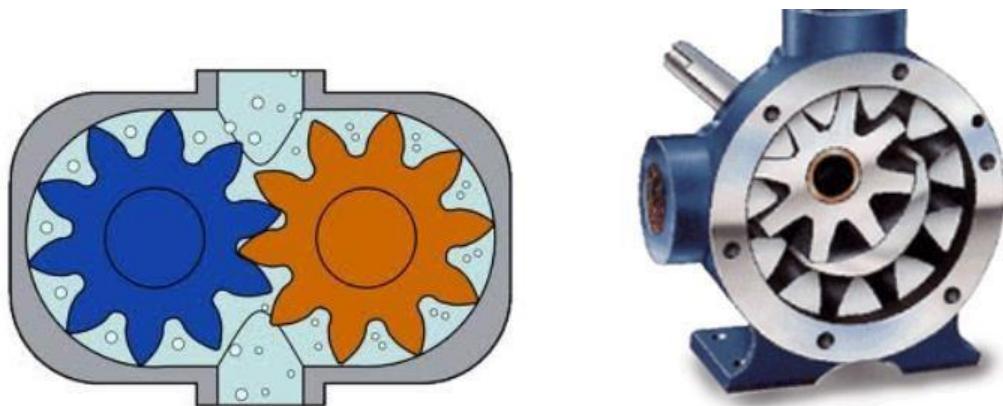


Figure: (left) external gear pump (right) internal gear pump

a. External gear

External gear pumps are the most popular hydraulic pumps in low-pressure ranges due to their long operating life, high efficiency and low cost. They are generally used in a simple machine. The most common form of external gear pump is shown in Figs1. It consists of a pump housing in which a pair of precisely machined meshing gears runs with minimal radial and axial clearance. One of the gears, called a driver, is driven by a prime mover. The driver drives another gear called a follower. As the teeth of the two gears separate, the fluid from the pump inlet gets trapped between the rotating gear cavities and pump housing. The trapped fluid is then carried around the periphery of the pump casing and delivered to outlet port. The teeth of precisely meshed gears provide almost a perfect seal between the pump inlet and the pump outlet when the outlet flow is resisted;

pressure in the pump outlet chamber builds up rapidly and forces the gear diagonally outward against the pump inlet.

When the system pressure increases, imbalance occurs. This imbalance increases mechanical friction and the bearing load of the two gears. Hence, the gear pumps are operated to the maximum pressure rating stated by the manufacturer. It is important to note that the inlet is at the point of separation and the outlet at the point of mesh. These units are not reversible if the internal bleeds for the bearings are to be drilled to both the inlet and outlet sides'. So that the manufacturer's literature should be checked before attempting a reversed installation.

If they are not drilled in this manner, the bearing may be permanently damaged as a result of inadequate lubrications.

Advantages and disadvantages of gear pumps

1. They are self-priming.
2. They give constant delivery for a given speed.
3. They are compact and light in weight.
4. Volumetric efficiency is high. The disadvantages are as follows:
 1. The liquid to be pumped must be clean, otherwise it will damage pump.
 2. Variable speed drives are required to change the delivery.
 3. If they run dry, parts can be damaged because the fluid to be pumped is used as lubricant.

Expression for the theoretical flow rate of an external gear pump Let

D_o = the outside diameter of gear teeth

D_i = the inside diameter of gear teeth

L = the width of gear teeth

N = the speed of pump in RPM

VD = the displacement of pump in m/rev

M = module of gear z = number of gear teeth α = pressure angle

Volume displacement is: Theoretical

$$V_D = \frac{\pi}{4} (D_o^2 - D_i^2) L$$

$$D_i = D_o - 2(\text{Addendum} + \text{Dendendum})$$

$$Q_T (\text{m}^3/\text{min}) = V_D (\text{m}^3/\text{rev}) \times N (\text{rev/min})$$

If the gear is specified by its module and number of teeth, then the theoretical discharge can be found by:

$$Q_T = 2\pi L m^2 N \left[z + \left(1 + \frac{\pi^2 \cos \alpha}{12} \right) \right] \text{ m}^3/\text{min}$$

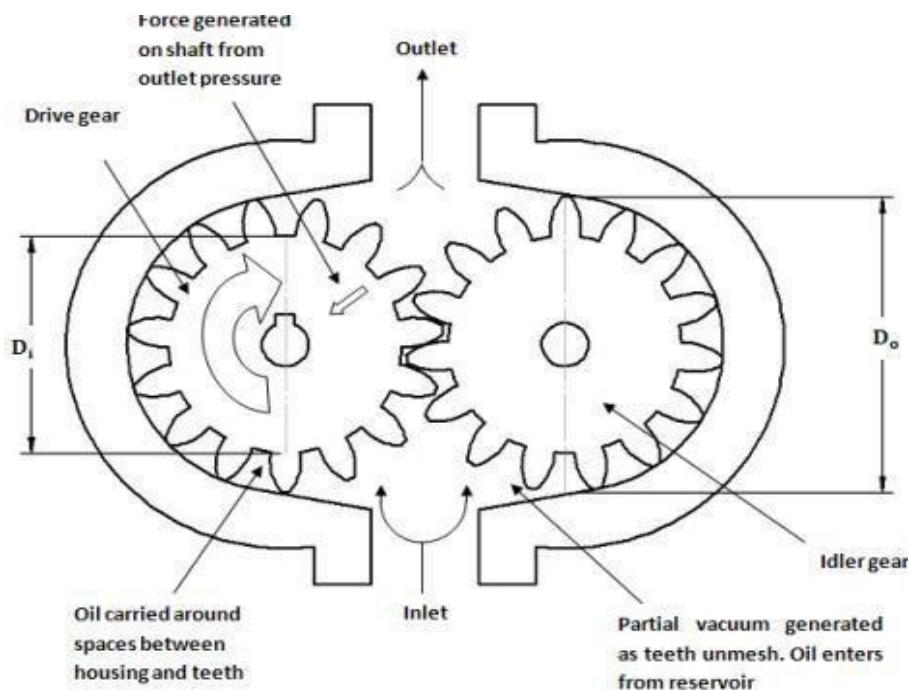


Figure a. Operation of an external gear pump
Volumetric Efficiency

Volumetric efficiency, $\eta_v = \frac{\text{Actual flow rate of the pump}}{\text{Theoretical flow rate of the pump}} = \frac{Q_A}{Q_T}$

Obviously there will be a small radial clearance between the gear teeth and the casing so as to achieve the gears rotation. As a result, some of the fluid may leak inside the system without discharging at the outlet port. This internal leakage, also known as '*pump slippage*', results in lesser flow rate (Q_A) than the theoretical flow rate (Q_T). This is represented by the volumetric efficiency.

b. Internal gear pumps

Another form of gear pump is the internal gear pump, which is illustrated in Fig.2. They consist of two gears: An external gear and an internal gear. The crescent placed in between these acts as a seal between the suction and discharge. When a pump operates, the external gear drives the internal gear and both gears rotate in the same direction.

$$\text{Volumetric efficiency, } \eta_{vol} = \frac{Q_A}{Q_T} \times 100$$

where Q_A and Q_T are actual and theoretical flow rate of the pump respectively.

Since the internal leakage increases with the increase in discharge pressure, the volumetric efficiency will be lower for the high discharge pressure.

The fluid fills the cavities formed by the rotating teeth and the stationary crescent. Both the gears transport the fluid through the pump. The crescent seals the low-pressure pump inlet from the high-pressure pump outlet. The fluid volume is directly proportional to the degree of separation and these units may be reversed without difficulty. The major use for this type of pump occurs when a through shaft is necessary, as in an automatic transmission. These pumps have a higher pressure capability than external gear pumps.

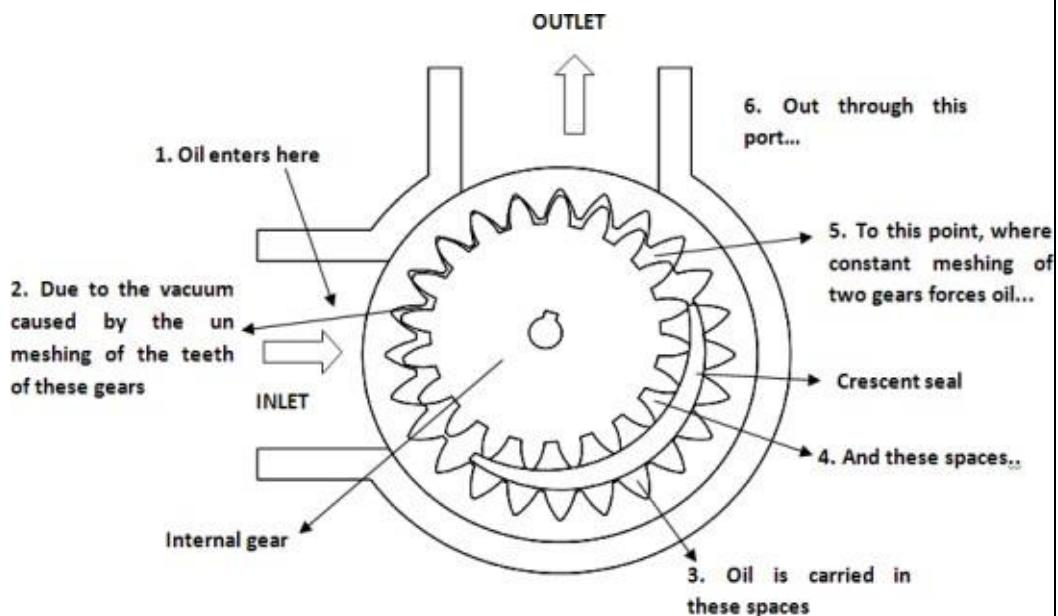


Figure 2. Operation of an internal gear pump

- ❖ What are the reasons for the popularity of external gear pumps?
 - o Simple to design

- o Because gear pumps have only two moving parts, they are reliable, simple to operate, and easy to maintain.
- o Low cost compared to other pumps

- ❖ What is the most important application for internal gear pumps?

- o The speed of the internal gear pumps is considered relatively slow compared to centrifugal types. Speeds up to 1,150 rpm are considered common. Because of their ability to operate at low speeds, internal gear pumps are well suited for high-viscosity applications and where suction conditions call for a pump with minimal inlet pressure requirements.

- o They're also bi-rotational, meaning that the same pump can be used to load and unload applications

c. Gerotor Pumps

Gerotor pumps operate in the same manner as internal gear pumps. The inner gear rotor is called a gerotor element. The gerotor element is driven by a prime mover and during the operation drives outer gear rotor around as they mesh together. The gerotor has one tooth less than the outer internal idler gear. Each tooth of the gerotor is always in sliding contact with the surface of the outer element. The teeth of the two elements engage at just one place to seal the pumping chambers from each other. On the right-hand side of the pump, shown in Fig.3, pockets of increasing size are formed, while on the opposite side, pockets decrease in size. The pockets of increasing size are suction pockets and those of decreasing size are discharge pockets. Therefore, the intake side of the pump is on the right and discharge side on the left.

Pumping chambers are formed by the adjacent pair of teeth, which are constantly in contact with the outer element, except for clearance. Refer to Fig 3, as the rotor is turned, its gear tips are accurately machined so that they precisely follow the inner surface of the outer element. The expanding chambers are created as the gear teeth withdraw. The chamber reaches its maximum size when the female tooth of the outer rotor reaches the top dead center. During the second half of the revolution, the spaces collapse, displacing the fluid to the outlet port formed at the side plate.

The geometric volume of the gerotor pump is given as:

$$V_D = b Z (A_{\max} - A_{\min})$$

where b is the tooth height, Z is the number of rotor teeth, A_{\max} is the maximum area between male and female gears (unmeshed – occurs at inlet) and A_{\min} is the minimum area between male and female gears (meshed – occurs at outlet).

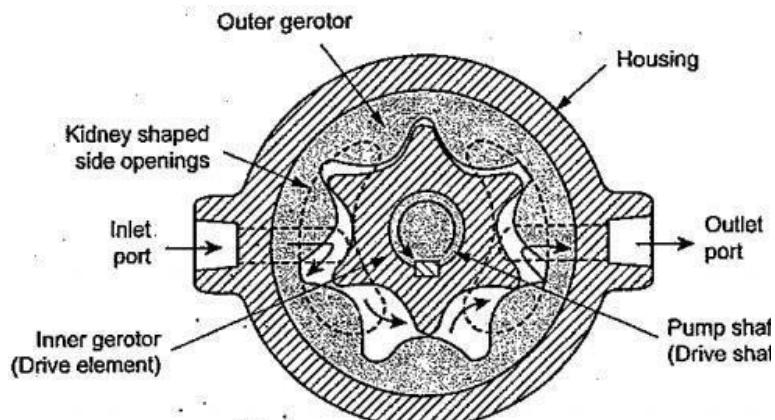


Figure 3.Gerotor gear pump

E.g 1: A gear pump has an outside diameter of 80mm, inside diameter of 55mm and a width of 25mm. If the actual pump flow is 1600 RPM and the rated pressure is 95 LPM what is the volumetric displacement and theoretical discharge.

Solution: We have Outside diameter $D_o = 80$ mm

Inside diameter $D_i = 55$ mm

Width $d = 25$ mm

Speed of pump $N = 1600$ RPM Actual flow rate = 95 LPM Now

$$Q_A = 95 \text{ LPM} = 95 \times 10^{-3} \text{ m}^3/\text{min}$$

$$V_D = \frac{\pi}{4} \times (D_o^2 - D_i^2) \times L$$

$$V_D = \frac{\pi}{4} \times (0.080^2 - 0.055^2) \times 0.025 = 6.627 \times 10^{-5} \text{ m}^3/\text{rev}$$

Theoretical flow rate

$$Q_T = \frac{\pi}{4} \times (D_o^2 - D_i^2) \times L \times N$$

$$= \frac{\pi}{4} \times (0.080^2 - 0.055^2) \times 0.025 \times 1600$$

$$= 0.106 \text{ m}^3/\text{min}$$

Eg2. Calculate the theoretical delivery of a gear pump. Module of the gear teeth is 6mm and width of gear teeth is 25mm. Number of teeth on driver gear is 18 and pressure angle of the gear is 20. Pump speed is 1000 RPM. Volumetric efficiency is 90%.

Solution: If the gear is specified by its module and number of teeth, then the theoretical discharge can be found by

$$\begin{aligned} Q_T &= 2\pi L m^2 N \left[z + \left(1 + \frac{\pi^2 \cos \alpha}{12} \right) \right] \text{ m}^3/\text{min} \\ &= 2\pi (0.025) (6 \times 10^{-3})^2 \times 1000 \times \left[18 + \left(1 + \frac{\pi^2 \cos^2 20}{12} \right) \right] \text{ m}^3/\text{min} \\ &= 0.1118 \text{ m}^3/\text{min} \end{aligned}$$

Eg3. Calculate the theoretical delivery of a gear pump. Module of the gear teeth is 6mm and width of gear teeth is 65mm. Number of teeth on driver gear is 16 and pressure angle of the gear is 20. Pump speed is 1600 RPM. Outer diameter of gear is 108 mm and Dedendum circle diameter is 81mm. volumetric efficiency is 88%at 7 MPa.

Solution: If the gear is specified by its module and number of teeth, then the theoretical discharge can be found by

$$\begin{aligned} Q_T &= 2\pi L m^2 N \left[z + \left(1 + \frac{\pi^2 \cos^2 20}{12} \right) \right] \text{m}^3/\text{min} \\ &= 2\pi(0.065)(6 \times 10^{-3})^2 \times 1600 \times \left[16 + \left(1 + \frac{\pi^2 0.939^2}{12} \right) \right] \text{m}^3/\text{min} \\ &= 0.416 \text{ m}^3/\text{min} \end{aligned}$$

Alternatively we can use

$$V_D = \frac{\pi}{4} \times (D_o^2 - D_i^2) \times L$$

$$Q_T = \frac{\pi}{4} \times (0.108^2 - 0.081^2) \times 0.065 \times 1600 = 0.416 \text{ m}^3/\text{rev}$$

Exg4. The inlet to a hydraulic pump is 0.6 m below the top surface of an oil reservoir. If the specific gravity of the oil used is 0.86, determine the static pressure at the pump inlet.

Solution: We know that

$$\text{Pressure} = \rho gh$$

The density of water is 1 g/cm³ or 1000 kg/m³.

Therefore, the density of oil is 0.86 × 1 g/cm³ or 860 kg/m³.

Pressure at the pump inlet is

$$\begin{aligned} P &= 860 \times 0.6 \text{ kg/m}^2 = 516 \text{ kg/m}^2 = 0.0516 \text{ kg/cm}^2 = 0.0516 \times \\ &= 0.0506 \text{ bar} \end{aligned}$$

(Note: 1 kg/cm² = 0.981 bar.)

Eg5. A hydraulic pump delivers 12 L of fluid per minute against

a pressure of 200 bar. (a) Calculate the hydraulic power.

(b) If the overall pump efficiency is 60%, what size of electric motor would be needed to drive the pump?

Solution:
$$\text{Hydraulic power (kW)} = 12 \text{ L/min} \times \frac{200 \text{ (bar)}}{600} = 4 \text{ kW}$$

(a) Hydraulic power is given by

(b) We have

$$\text{Electric motor power (power input)} = \frac{\text{Hydraulic power}}{\text{Overall efficiency}}$$

Substituting we get

$$\text{Electric motor power (power input)} = \frac{4}{0.6} = 6.67 \text{ Electric motor power} = \frac{4}{0.6} = 6.67 \text{ kW}$$

2. VANE PUMPS

There are two types of vane pumps:

a. Unbalanced vane pump: Unbalanced vane pumps are of two varieties:

- Unbalanced vane pump with fixed delivery
- Unbalanced vane pump with pressure compensated variable delivery

b. Balanced vane pump

❖ UNBALANCED VANE PUMP

The main components of the unbalanced vane pump are the cam surface and the rotor. The rotor contains radial slots splined to drive shaft. The rotor rotates inside the cam ring. Each radial slot contains a vane, which is free to slide in or out of the slots due to centrifugal force. The vane is designed to mate with surface of the cam ring as the rotor turns. The cam ring axis is offset to the drive shaft axis.

When the rotor rotates, the centrifugal force pushes the vanes out against the surface of the cam ring. The vanes divide the space between the rotor and the cam ring into a series of small chambers. During the first half of the rotor rotation, the volume of these chambers increases, thereby causing a reduction of pressure. This is the suction process, which causes the fluid to flow through the inlet port. During the second half

of rotor rotation, the cam ring pushes the vanes back into the slots and the trapped volume is reduced. This positively ejects the trapped fluid through the outlet port. In this pump, all pump action takes place in the chambers located on one side of the rotor and shaft, and so the pump is of an unbalanced design. The delivery rate of the pump depends on the eccentricity of the rotor with respect to the cam ring.

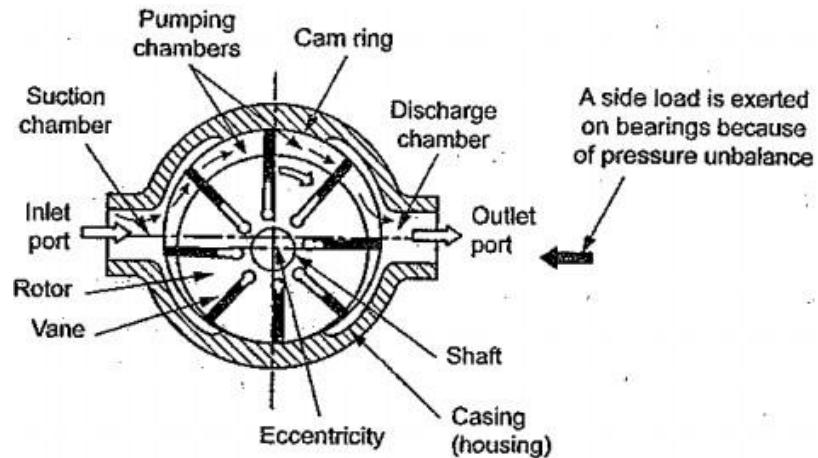


Figure: Unbalanced vane pump

Pressure-Compensated Variable Displacement Vane Pump
(an Unbalanced Vane Pump with Pressure-Compensated Variable Delivery)

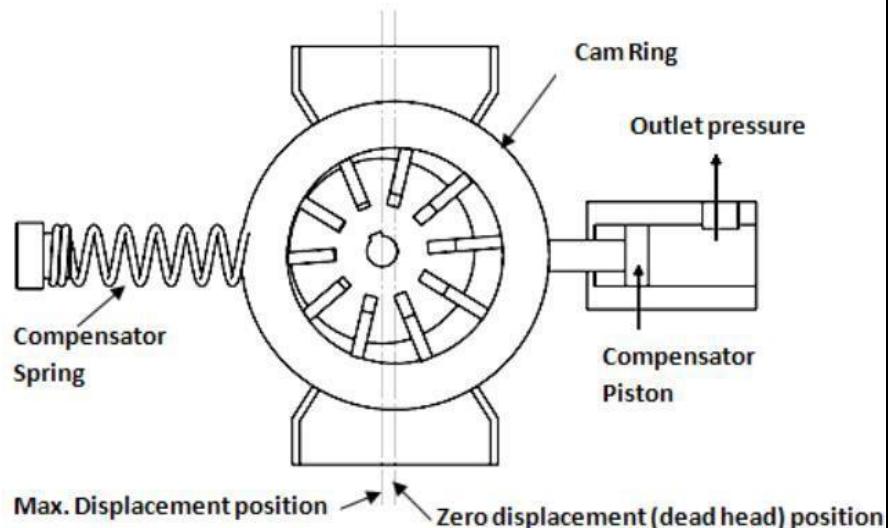


Figure: Operation of a variable displacement vane pump

Schematic diagram of variable displacement vane pump is shown in Fig: Operation of a variable displacement vane pump Variable displacement feature can be brought into vane pumps by varying eccentricity between the rotor and the cam ring. Here in this pump, the stator ring is held against a spring loaded piston.

The system pressure acts directly through a hydraulic piston on the right side. This forces the cam ring against a spring-loaded piston on the left side. If the discharge pressure is large enough, it overcomes the compensated spring force and shifts the cam ring to the left. This reduces the eccentricity and decreases the flow. If the pressure continues to increase, there is no eccentricity and pump flow becomes zero.

❖ BALANCED VANE PUMP

Advantages and disadvantages of Vane Pumps

The advantages of vane pumps are as follows:

1. Vane pumps are self-priming, robust and supply constant delivery at a given speed.
2. They provide uniform discharge with negligible pulsations.
3. Their vanes are self-compensating for wear and vanes can be replaced easily.
4. These pumps do not require check valves.
5. They are light in weight and compact.
6. They can handle liquids containing vapors and gases.
7. Volumetric and overall efficiencies are high.
8. Discharge is less sensitive to changes in viscosity and pressure variations.

The disadvantages of vane pumps are as follows:

1. Relief valves are required to protect the pump in case of sudden closure of delivery.
2. They are not suitable for abrasive liquids.
3. They require good seals.
4. They require good filtration systems and foreign particle can severely damage pump.

Advantages and disadvantages of balanced vane pumps

The advantages of balanced vane pumps are as follows:

1. The balanced pump eliminates the bearing side loads and therefore high operating pressure can be used.
2. The service life is high compared to unbalanced

type due to less wear and tear.

The disadvantages of balanced vane pumps are as follows:

1. They are fixed displacement pumps.
2. Design is more complicated.
3. Manufacturing cost is high compared to unbalanced type.

i. ANALYSIS OF VOLUMETRIC DISPLACEMENT OF VANE PUMPS

The volumetric displacement of the vane pump can be determined by using the following relation:

$$\text{Volumetric displacement, } V_D = \frac{\pi}{2} (D_C + D_R) e L$$

Let D_C be the diameter of a cam ring in m, D_R the diameter of rotor in m, L the width of rotor in m, e the eccentricity in m, and V_D the pump volume displacement in m^3/rev

$$e = \text{Eccentricity in m} = \frac{(D_C - D_R)}{2}$$

If N = Rotor speed in rev/min RPM, then the theoretical flow rate (discharge) can be given by:

$$Q_T = v_D \times N \quad ; \quad Q_T = \frac{\pi}{2} (D_C + D_R) e L \text{ m}^3/\text{min}$$

Eg1: A vane pump has a rotor diameter of 63.5 mm, a cam ring diameter of 88.9 mm and a vanewidth of 50.8 mm. What must be eccentricity for it to have a volumetric displacement of 115cm³?

Solution: Volumetric displacement is

$$V_D = \pi \left(\frac{D_C + D_R}{2} \right) L e$$

Where D_C is the diameter of the cam ring, D_R is the diameter of the rotor, e is the eccentricity and L is the width of the vane pump.

So we have:

$$115 \times 10^{-6} = \pi \times \frac{0.0889 + 0.0635}{2} \times e \times 0.0508$$

Therefore eccentricity

$$e = 9.456 \times 10^{-3} \text{ m} = 9.456 \text{ mm}$$

3. Piston pumps

- ✓ In piston pumps, the pumping action is affected by a piston that moves in a reciprocating cycle through a cylinder. The basic operation of piston pumps are very similar to that of the reciprocating engines.
- ✓ **Classification :** Piston pumps can be classified by the motion of the piston relative to their drive shaft as :
 1. Axial piston pumps, and
 - (a) Bent axis type, and (b) Swash plate type.
 2. Radial piston pumps.
- ✓ In axial piston pumps, a number of pistons and cylinders are located in a parallel position with respect to the drive shaft, while in the radial type they are arranged radially around the rotor hub.

a. AXIAL PISTON PUMP

In the axial piston pump, rotary shaft motion is converted to axial reciprocating motion which drives the piston. Most axial-piston pumps are multi-piston designs and utilize valves or port plates to direct liquid flow from inlet to discharge. Output can be controlled by manual, mechanical, or pressure compensated controls.

- In-Line Axial Piston Pump

An axial piston pump, in which the pistons are in line with the axis of the drive shaft, is illustrated in figure below

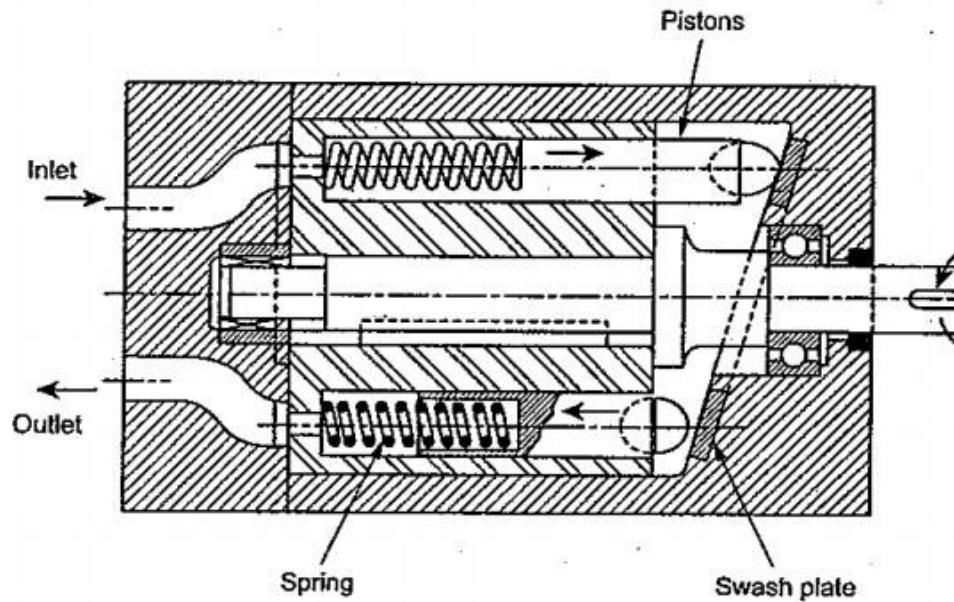


Figure: In-line axial piston pump

As shown in figure: in-line axial piston pump, the rotary drive motion is converted to reciprocating, axial piston motion by means of the swash plate (also known as thrust cam or wobble plate), mounted on the drive shaft. Thus the rotation of the swash plate produces in- and out motion of the pistons in their cylinders and hence the fluid is discharged.

- Fixed – Displacement In-Line Axial Pump

The axial pump illustrated on Figure: In-line axial piston pump is a constant-displacement piston pump. That means constant volume of oil is discharged for a set rotor speed. In these, pistons are stroked by a fixed angle plate.

- Variable- Displacement in- Line Axial Pump (Swash Plate Design)

This type of pump can also be designed to have variable displacement capability. This can be achieved by altering the angle of the swash plate. Because in the swash plate axial pump, the angle of tilt of the swash plate determines the piston stroke and hence the pump displacement. This is schematically illustrated in figure below

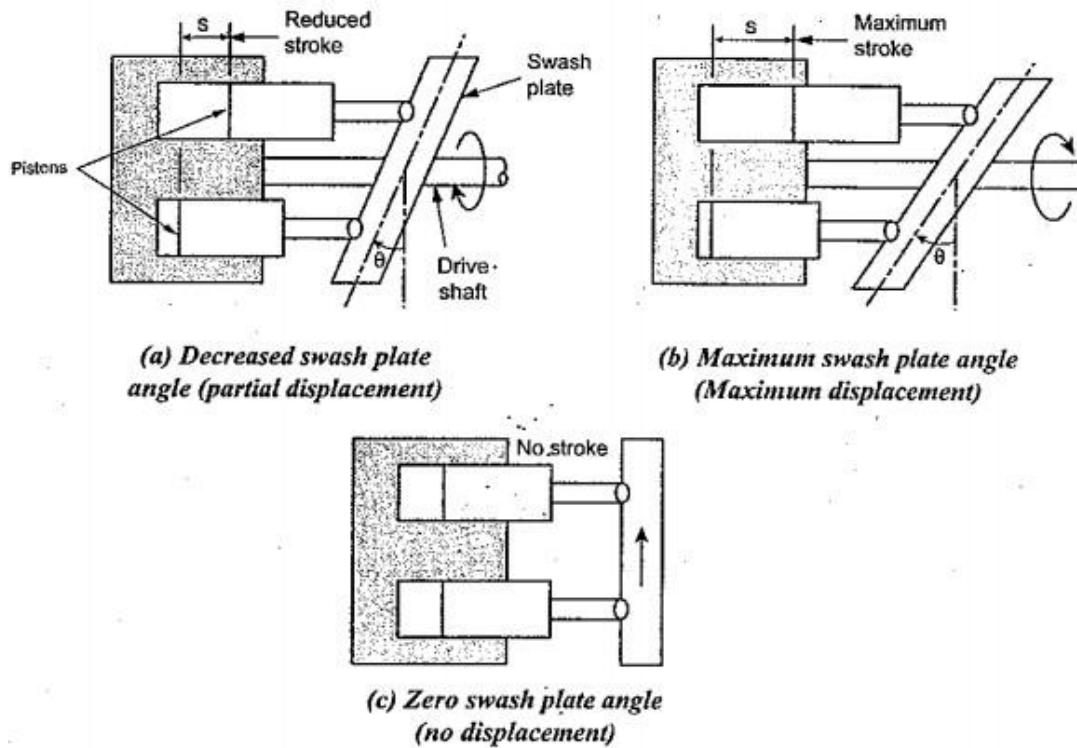


Figure: variation in pump displacement with swash plate angle

As could be seen from the Figure: variation in pump displacement with swash plate angle. The increase in the swash plate angle (θ) will increase the piston stroke and hence the fluid displacement. When the swash plate is vertical (i.e., angle is zero), then the displacement will be zero. Even one can reverse the flow direction by changing the angle of swash plate. However, the maximum swash plate angle is generally limited to $17\frac{1}{2}$, due to various design considerations.

- Bent axis type axial piston pump

A typical 3D bent axis type axial piston pump is illustrated in Figure below. This type of pump contains a cylinder block rotating with the drive shaft. The centerline of the cylinder block is set at an offset angle relative to the centerline of the drive shaft. The cylinder block has a number of pistons and cylinders arranged along a circle. The ball and socket joints connect the piston rods with the drive shaft flange. When the distance between the drive shaft flange and cylinder block changes, the pistons move in and out of the cylinder. In order to provide alignment and positive drive, a universal link is used to connect the block to the drive shaft.

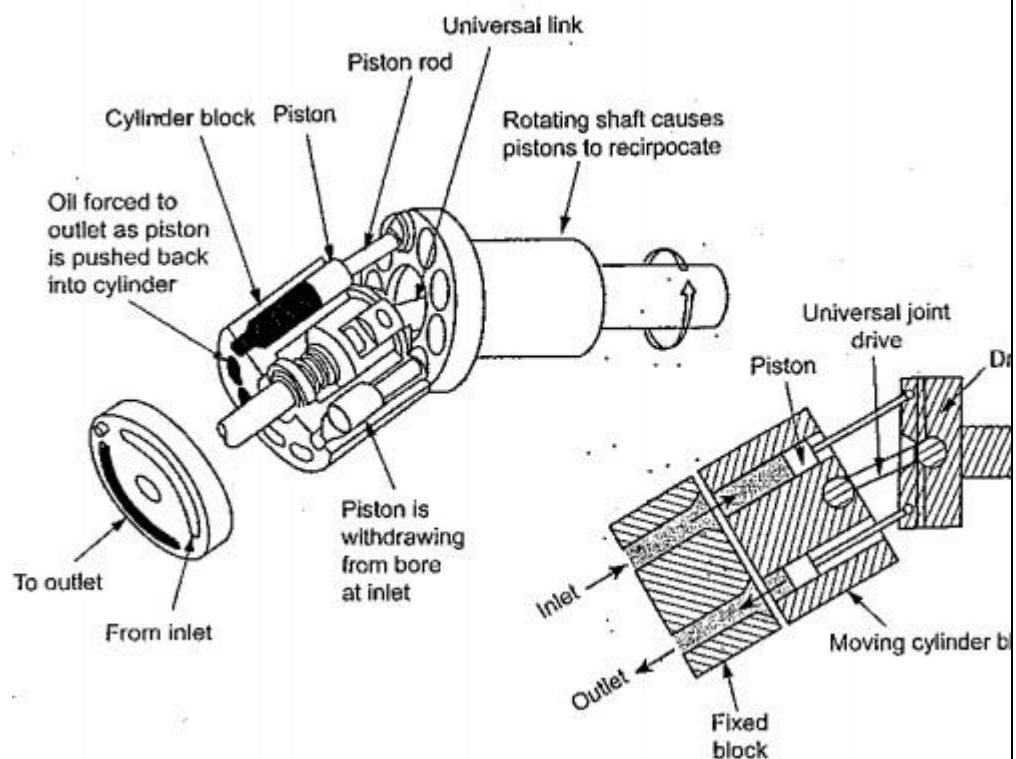


Figure: Bent axis type axial piston pump and bent axis pump

- Operation

When the piston carrying body turns, the exit passages in the cylinder bores move along the control slots of a firmly positioned control plate and are thus connected alternatively to the suction or discharge pipelines.

Fixed –Displacement Bent axis type axial piston

In fixed displacement pumps, the pumps are mounted in a fixed casing so that swing (or offset) angle cannot be adjusted. So the fixed displacement of the piston and hence the constant discharge of fluid are achieved.

Variable –Displacement Bent Axis Piston Pump

In variable-displacement pumps, the swing (or offset) angle can be varied. Because the volumetric displacement of the pump varies with the offset angle. The variation in pump displacement with respect to offset angle is schematically illustrated in Fig. below

As could be seen from Fig. below the increase in the offset angle (θ) will increase the piston stroke and hence the fluid displacement. When the offset angle is zero, then the displacement will be zero. However, for practical reasons, θ is to be varied from 0° to a maximum of about 30° .

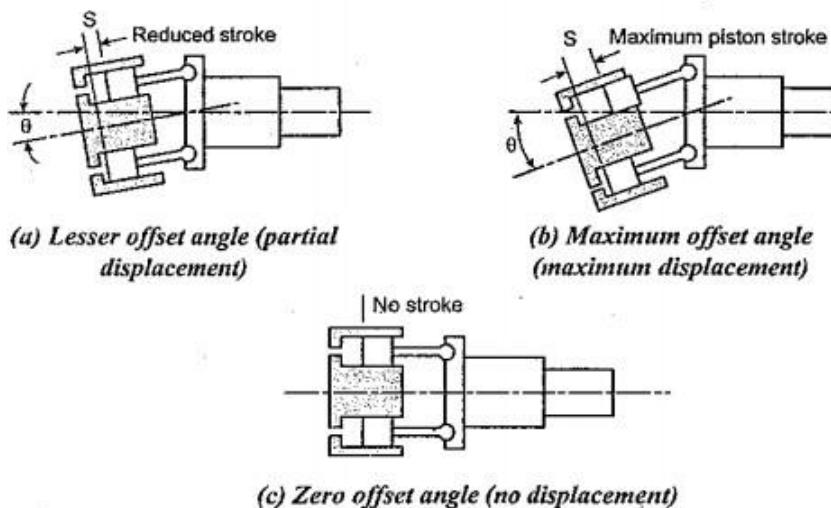


Figure: Variation in pump displacement with offset angle

VOLUMETRIC DISPLACEMENT AND THEORETICAL FLOW RATE OF AN AXIAL PISTON PUMP

For any axial piston pump, the volumetric displacement and theoretical flow rate can be determined as follows :

Let θ = Offset angle in degrees,

S = Piston stroke in m,

D = Piston circle diameter in m,

d = Diameter of piston in m,

A = Cross-sectional area of the piston in $m^2 = \frac{\pi}{4} d^2$,

Y = Number of pistons, and

N = Rotor speed in rpm.

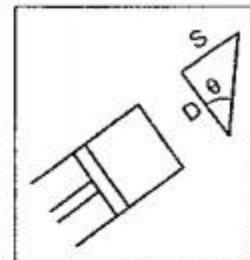


Fig a

From the geometry of a piston (Fig a), we get

$$\tan \theta = \frac{S}{D}$$

$$\text{or } S = D \tan \theta \quad \dots (1)$$

We also know that,

$$\begin{aligned} \text{Total displacement volume} &= (\text{Displacement volume/Piston}) \times \text{Number of piston} \\ \therefore V_D &= (\text{Area} \times \text{Stroke}) \times Y = A S Y \end{aligned} \quad \dots (2)$$

Substituting equation (1) in (2), we get

$$V_D = Y A D \tan \theta \quad \dots (3)$$

Then the theoretical flow rate is given by,

$$Q_T = Y A N D \tan \theta \quad \dots (4)$$

Eg : What is the theoretical flow rate from a fixed-displacement axial piston pump with a nine bore cylinder operating at 2000 RPM? Each bore has a diameter of 15 mm and stroke is 20 mm. Solution: Theoretical flow rate is given by

$$Q_T = \text{Volume} \times \text{RPM} \times \text{Number of pistons}$$

$$= \frac{\pi}{4} \times D^2 \times L \times N \times n$$

$$= \frac{\pi}{4} \times 0.015^2 \times 0.02 \times \frac{2000}{60} \times 9$$

$$= 10.6 \times 10^{-3} \text{ m}^3/\text{s}$$

$$= 1.06 \text{ LPS} = 63.6 \text{ LPM}$$

- a. Radial piston pumps
- Construction and operation

The radial piston pump has a number of radial pistons (in similar fashion to the spokes of a wheel) in a cylinder block which revolves around a stationary eccentric cam. In these pumps, the pistons move perpendicularly to the shaft centerline. As the cylinder block rotates, the eccentricity of the cam causes an in-and-out or pumping motion of the pistons.

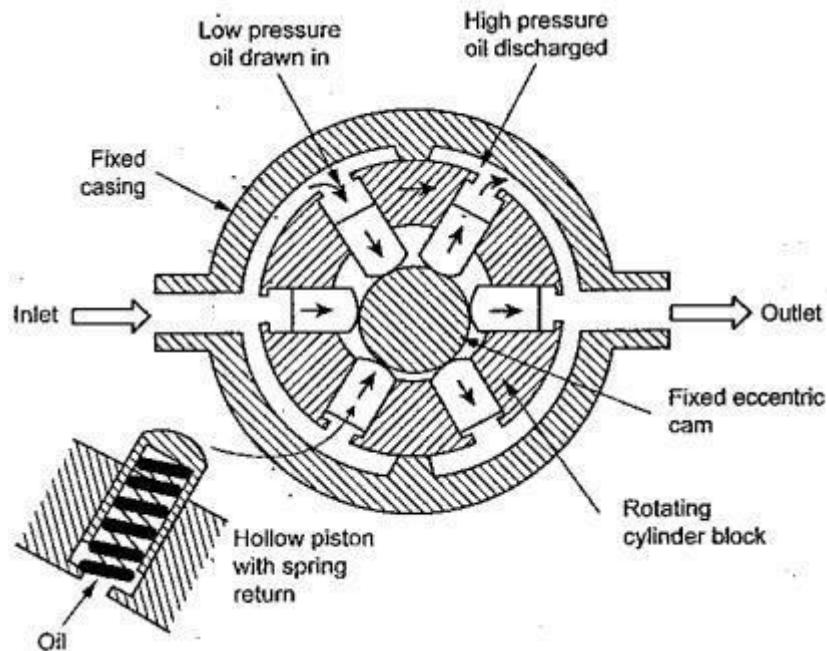


Figure: Radial piston pump

As could be seen from the figure of piston pump, the fluid in flow and outflow at each piston is controlled through revolving ports. During the down stroke, each piston is connected to the fluid inlet and hence the fluid is drawn inside the cylinders. During the upward stroke, each piston is connected to the fluid outlet and hence fluid is discharged outside the pump.

- Theoretical flow rate of a radial piston pump

The theoretical discharge of a radial piston pump can be calculated by using

$$Q_T = 0.5 e Y \pi d^2 N \text{ m}^3/\text{min}$$

the following relation:

where e = Eccentricity in m,
 Y = Number of pistons,
 d = Diameter of piston in m, and
 N = Rotor speed in rpm.

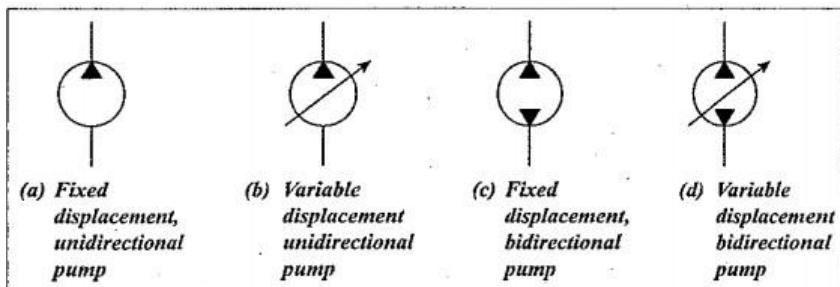
- Advantages and disadvantages of piston pumps

Table: Advantages and Disadvantages of piston pumps

Advantages	Disadvantages
<ul style="list-style-type: none"> ✓ Piston pumps are capable of delivering high operating pressures. ✓ They can handle oils in a wide viscosity range. ✓ They can handle liquids containing vapours and gases. ✓ They can provide a variable delivery of liquid. ✓ They are self-priming. ✓ They are quite in operation. ✓ They have exceptionally long life. 	<ul style="list-style-type: none"> ✓ They tend to be heavy and bulky. ✓ They have a pulsating discharge. ✓ Power pumps cannot be operated against a closed discharge. Hence relief valves are required. ✓ Most types require inlet and discharge valves.

❖ GRAPHIC SYMBOLS FOR PUMPS

The four different standard symbols used for hydraulic pumps are given below:



❖ Pump Performance

The performance of a pump is a function of the precision of its manufacture. An ideal pump is one having zero clearance between all mating parts. Because this is not

possible, working clearances should be as small as possible while maintaining proper oil films for lubrication between rubbing parts. The performance of a pump is determined by the following efficiencies:

1. Volumetric efficiency (η_v): It is the ratio of actual flow rate of the pump to the theoretical flow rate of the pump. This is expressed as follows:

$$\text{Volumetric efficiency} = \frac{\text{Actual flow rate produced by the pump}}{\text{Theoretical flow rate that the pump should produce}} \times 100$$

$$\eta_{vol} = \frac{Q_A}{Q_T} \times 100$$

Significant: Volumetric efficiency (η_v) indicates the amount of leakage that takes place within the pump. This is due to manufacture tolerances and flexing of the pump casing under designed pressure operating conditions.

For gear pumps, $\eta_v = 80\% - 90\%$. For vane pumps, $\eta_v = 92\%$.

For piston pumps, $\eta_v = 90\% - 98\%$.

2. Mechanical efficiency (η_m): It is the ratio of the pump output power assuming no leakage to actual power delivered to the pump:

$$\text{Mechanical efficiency} (\eta_m) = \frac{\text{Pump output power assuming no leakages}}{\text{Actual power delivered to the pump}}$$

Mechanical efficiency (η_m) indicates the amount of energy losses that occur for reasons other than leakage. This includes friction in bearings and between mating parts. This includes the energy losses due to fluid turbulence. Mechanical efficiencies are about 90%–95%. We also have the relation

$$\eta_m = \frac{p Q_T}{T_A N}$$

Where p is the pump discharge pressure in Pa or N/m², Q_T is the theoretical flow rate of the pump in m³/s, T_A is the actual torque delivered to the pump in Nm and N is the speed of the pump in rad/s. It (η_m) can also be computed in terms of torque as follows:

$$\eta_m = \frac{\text{Theoretical torque required to operate the pump}}{\text{Actual torque delivered to the pump}} = \frac{T_T}{T_A}$$

The theoretical torque (T_T) required to operate the pump is the torque that would be required if there were no leakage.

The theoretical torque (T_T) is determined as follows

$$T_T (\text{N m}) = \frac{VD_N}{2\pi} \left(m^3 \times \frac{N}{m^2} \right) = \text{N m}$$

The actual torque (T_A) is determined as follows

$$\text{Actual torque } T_A (\text{N m}) = \frac{P}{\omega} \left(\frac{\text{N m/s}}{\text{rad/s}} \right) = \text{N m}$$

where $\omega = 2\pi N/60$. Here N is the speed in RPM.

- Overall efficiency (η_o): It is defined as the ratio of actual power delivered by the pump to actual power delivered to the pump

$$\text{Overall efficiency } (\eta_o) = \frac{\text{Actual power delivered by the pump}}{\text{Actual power delivered to the pump}}$$

Overall efficiency (η_o) considers all energy losses and can be represented mathematically as follows:

$$\text{Overall efficiency } (\eta_o) = \eta_v \eta_m$$

$$\Rightarrow \eta_o = \frac{Q_A}{Q_T} \times \frac{pQ_T}{T_A N}$$

Eg1. A gear pump has an outside diameter of 82.6 mm, inside diameter of 57.2 mm and a width of 25.4 mm. If the actual pump flow is 1800 RPM and the rated pressure is 0.00183 m^3/s , what is the volumetric efficiency?

Solution: We have

Outside diameter $D_o = 82.6 \text{ mm}$

Inside diameter $D_i = 57.2 \text{ mm}$

Width $d = 25.4 \text{ mm}$

Speed of pump $N = 1800 \text{ RPM}$

Actual flow rate = $0.00183 \text{ m}^3/\text{s}$

Theoretical flow rate

$$\begin{aligned} Q_T &= \frac{\pi}{4} \times (D_o^2 - D_i^2) \times d \times \frac{N}{60} \\ &= \frac{\pi}{4} \times (0.0826^2 - 0.0572^2) \times 0.0254 \times \frac{1800}{60} \\ &= 2.125 \times 10^{-3} \end{aligned}$$

Volumetric efficiency is

$$\eta_v = \frac{0.00183}{2.125 \times 10^{-3}} \times 100 = 86.11\%$$

Eg 2. A pump having a volumetric efficiency of 96% delivers 29 LPM of oil at 1000 RPM. What is the volumetric displacement of the pump?

Solution:

Volumetric efficiency of the pump $\eta_v = 96\%$ Discharge of the pump = 29 LPM

Speed of pump $N = 1000 \text{ rpm}$ Now

$$\begin{aligned} \eta_v &= \frac{\text{Actual flow rate of the pump}}{\text{Theoretical flow rate of the pump}} = \frac{Q_A}{Q_T} \\ &\Rightarrow 0.96 = \frac{29}{Q_T} \\ &\Rightarrow Q_T = 30.208 \text{ LPM} \end{aligned}$$

Volumetric displacement

$$V_D = \frac{Q_T}{N} = \frac{30.208 \times 10^{-3} \times 60}{60 \times 1000} = 30.208 \times 10^{-6} \text{ m}^3 / \text{rev} = 0.0302 \text{ L / rev}$$

Eg3. A positive displacement pump has an overall efficiency of 88% and a volumetric efficiency of 92%. What is the mechanical efficiency?

Solution: The overall efficiency is

$$\eta_o = \eta_m \times \eta_v$$

$$\Rightarrow \eta_m = \frac{\eta_o}{\eta_v} = \frac{88}{92} \times 100 = 95.7\%$$

Eg4. Determine the overall efficiency of a pump driven by a 10 HP prime mover if the pump delivers fluid at 40 LPM at a pressure of 10 MPa.

Solution:

$$\text{Output power} = pQ$$

$$= 10 \times 10^6 \text{ N/m}^2 \times 40 \text{ L/min} \times \frac{\text{m}^3/\text{s}}{1000 \text{ L/s}} \times \frac{1 \text{ min}}{60 \text{ s}}$$

$$= 6670 \text{ W}$$

$$\text{Input power} = 10 \text{ HP} \times \frac{746 \text{ W}}{1 \text{ HP}} = 7460 \text{ W}$$

Now

$$\eta_o = \frac{\text{Pump output power}}{\text{Pump input power}}$$

$$= \frac{6670}{7460} = 0.894 = 89.4\%$$

Eg5. How much hydraulic power would a pump produce when operating at 140 bar and delivering 0.001 m³/s of oil? What power rated electric motor would be selected to drive this pump if its overall efficiency is 85%?

Solution:

Operating pressure of the pump = 140 bar

Flow rate $Q = 0.001 \text{ m}^3/\text{s}$. Now

$$\begin{aligned}\text{Power of pump} &= \text{Pressure} \times \text{Flow rate} \\ &= 140 \times 10^5 \times 0.001 \\ &= 14 \text{ kW}\end{aligned}$$

Overall efficiency of pump $\eta_o = 85\%$

Power to be supplied is

$$\frac{\text{Power of pump}}{\eta_o} = \frac{14 \text{ kW}}{0.85} = 16.47 \text{ kW}$$

Eg6. A pump has a displacement volume of 98.4 cm³. It delivers 0.0152 m³/s of oil at 1000 RPM and 70 bar.

If the prime mover input torque is 124.3 Nm. What is the overall efficiency of pump? What is the theoretical torque required to operate the pump?

Solution:

Volumetric discharge = 98.4 cm³

Theoretical discharge is

$$Q_T = V_D \times \frac{N}{60} = 98.4 \times \frac{1000}{60} = 1.64 \times 10^{-3} \text{ m}^3/\text{s}$$

Volumetric efficiency is

$$\eta_v = \frac{1.52 \times 10^{-3}}{1.64 \times 10^{-3}} \times 100 = 92.68 \%$$

Overall efficiency is

$$\eta_o = \frac{Q_A \times \text{pressure}}{T \times \omega} = \frac{1.52 \times 10^{-3} \times 70 \times 10^5 \times 60}{124.3 \times 2 \times 1000 \times \pi} \times 100 = 81.74\%$$

The mechanical efficiency is

$$\eta_{\text{mechanical}} = \frac{\eta_{\text{overall}}}{\eta_{\text{volumetric}}} = \frac{81.74}{92.78} = 88.2$$

- ❖ What is cavitations ?. Name four popular methods to reduce cavitation
- During the working of positive displacement pump a vacuum is created at the inlet of the pump. This allows atmospheric pressure to push the fluid in. In some situations the vacuum may become excessive, and a phenomenon known as Cavitation occurs.
- The four popular methods to reduce cavitation are:
 - 1) Keep the suction line velocities below 1.5 m/s
 - 2) Keep the pump inlet as short as possible
 - 3) Minimize the number of fittings in the inlet line
 - 4) Mount the pump as close as possible to the reservoir.

Now

$$\text{Theoretical torque} = \text{Actual torque} \times \eta_{\text{mechanical}} = 124.3 \times 0.882 = 109.6 \text{ N}$$

Note: Mechanical efficiency can also be calculated as

$$\begin{aligned} \eta_m &= \frac{pQ_T}{T\omega} \\ &= \frac{70 \times 10^5 \text{ N/m}^2 \times 0.00164 \text{ m}^3 / \text{s}}{124.3 (\text{N m}) \times \frac{1000}{60} \times 2\pi \text{ rad/s}} \\ &= 0.882 = 88.2\% \end{aligned}$$

- ❖ Name the three ways by which noise of pump can be reduced
- Noise is a significant factor used to determine the performance of pumps
- Any increase in noise level normally indicates wear and danger of failure of pump

- Noise is measured in units of decibels (dB)
- Table presents the approximate noise levels for various pump designs. Generally speaking external gear and the piston pumps are the noisiest while screw pumps are very quiet; vane and internal gear pumps have noise levels somewhere in between a piston and screw pumps.
- Table : noise levels for various pump designs

Pump type	Noise level (dB)
Gear	80 ~ 100
Vane	65 - 85
Piston	60 - 80
Screw	50 - 70

- o By proper design of pump
- o By proper clamping of hydraulic distribution like pipes , fittings etc.
- o By using sound absorption material in the design of fluid power systems.

❖ The important considerations in the selection of a pump for any given application are:

- 1) Flow rate requirement
- 2) Operating speed of pump
- 3) Pressure rating
- 4) Performance/application
- 5) Reliability
- 6) Maintenance
- 7) Cost
- 8) Noise level of the pump
- 9) Oil compatibility

- 10) Type of pump control
- 11) Pump contamination tolerance
- 12) Availability of pump and spars
- ❖ Slip
 - Slip is the leakage occurs between the discharge and suction sides of a pump through the pump clearances
 - The extent of this leakage depends on the width, length and shape of the clearances, the viscosity of the pumped liquid, and the pressure difference between the discharge and suction sides of the pump.

Pump speed does not influence slip. But slip increases with increasing liquid viscosity

A. Electrical motors

Electrical motors for pneumatic and hydraulics is used as driving pump or compressor with means of coupling.

B. Valves

Valves are devices that regulate, direct or control the flow of a fluid by opening, closing, or partially obstructing various passageways. Valves are technically fittings, but are usually discussed as a separate category. In an open valve, fluid flows in a direction from higher pressure to lower pressure.

- One of the most important considerations in any fluid power system is control. If control components are not properly selected, the entire system does not function as required. In fluid power, controlling elements are called valves.
- A valve is a device that receives an external signal (mechanical, fluid pilot signal, electrical or electronics) to release, stop or redirect the fluid that flows through it.
- Valves are devices used to control pressure, flow direction, or flow rate in hydraulic circuits
- The control valves utilize mechanical motion to control the distribution of hydraulic energy within the system.

1. Types of valves:

Control valves are classified into three basic types, based on their function in the hydraulic system, as:

a. Directional control valves (DCVs)

They determine the path through which a fluid transverses a given circuit.

b. Pressure control valves

They protect the system against overpressure, which may occur due to a sudden surge as valves open or close or due to an increase in fluid demand.

c. Flow control (or volume control) valves

Shock absorbers are hydraulic devices designed to smooth out pressure surges and to dampen hydraulic shock. In addition, the fluid flow rate must be controlled in various lines of a hydraulic circuit. For example, the control of actuator speeds can be accomplished through use of flow control valves. Non-compensated flow control valves are used where precise speed control is not required because the flow rate varies with pressure drop across a flow control valve.

Note: *Valve can be hydraulic and pneumatic*

❖ PNEUMATIC AND HYDRAULIC VALVES

2. Pneumatic valves

2.1. Air control valves

- The main functions of

Air control valves

are:

i. To start and stop

pneumatic

energy

ii. To control the directional flow of compressed air

iii. To control the flow rate of the compressed air

iv. To control the pressure rating of the compressed air

2.1.1. Types of Air control valves

Pneumatic valves can be classified in many ways

I. Classification of DCVs Based on the main function

1. DCVs can be classified as follows:

- Check valves.
- Shuttle valves.
- Two-way valves.
- Three-way valves.
- Four-way valves.

2. Pressure control valves

3. Flow control valves

II. Classification based on their construction

- Poppet (or seat) type valve
- Sliding spool type valves
- Rotary spool type valves

Now we shall see some important air control valves in the following sections

2.1.1.1. Check valves

- Check valves are the most commonly used and the simplest type of directional control valves
- Functions: The check valves are used :
 - i. To allow free flow of compressed air in only one direction.
 - ii. To prevent any flow of compressed air in the opposite direction
- Since check valves block the reverse flow of the fluid, they are also

known as non-return valves. Construction and operation

The sectional view and ANSI symbol of pneumatic check valves are shown in figure below:

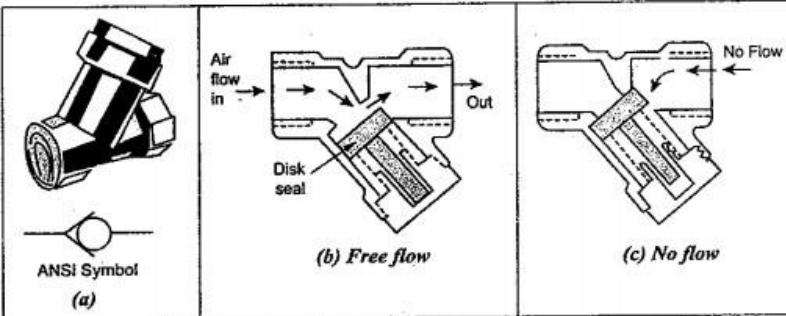


Figure: Pneumatic check valve

As shown in fig (b), when flow is in the forward direction, the compressed air pressure pushes the disk seal and thus the valve allows free flow. Instead, if flow is attempted in the opposite direction as shown in fig(C), the compressed air pushes the disk seal in the closed position. Hence no flow is permitted in opposite direction.

2.1.1.2. Directional control valves

- As the name suggests, the function of a directional control valve (DCV) is to control the direction offlow in a pneumatic circuit.
- The DCVs are used to start, stop and regulate the direction of air flow and to help in the distributionof air in the desired line.
- DCVs can be classified in many different ways
 1. Based on the construction
 - Poppet (or seat) type valve
 - Sliding spool type valves
 - Rotary spool type valves
 2. Based on the number of ports present:
 - Two -way valves.
 - Three-way valves.
 - Four-way valves

2.1.1.3. Two – way valves

Basically two-way valve is an on-off type valve. This 2/2 way has two ports (a supply port and exhaust port) and two position (open and closed). As shown in fig below, 2/2 way valve is available to operate either normally open or normally closed conditions.

A normally open two-way valve (fig (a)) permits flow in its normal or in its rest position and blocks flow whenactuated. The normally closed valve (fig (b)) block flow in its

normal position and permits flow when actuated. These valves have long life and can be used to handle dry and lubricated air.

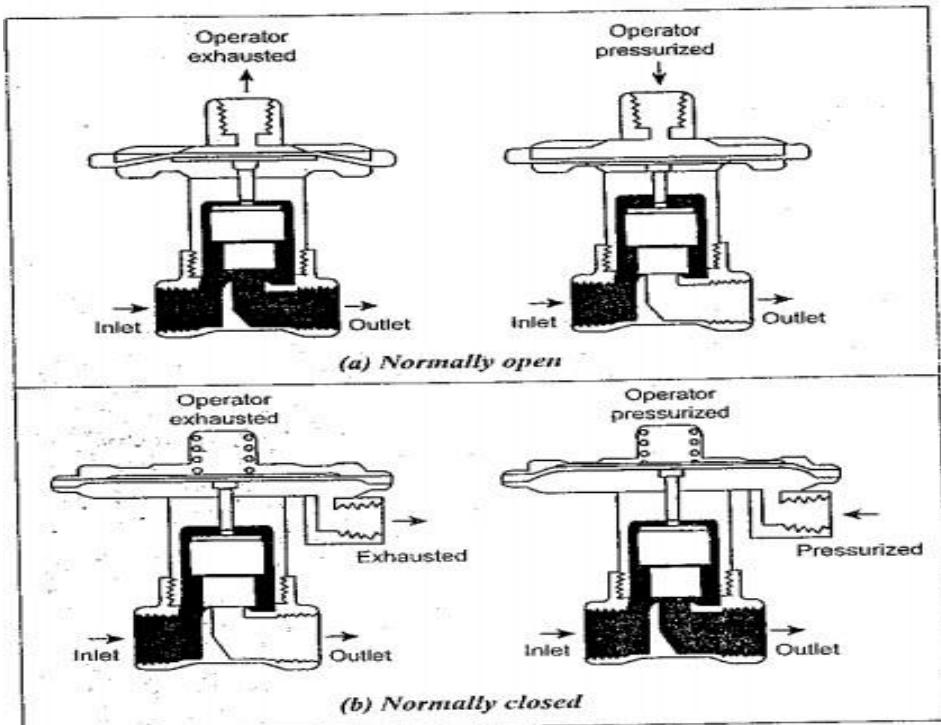


Figure: Two-way valves

2.1.1.1. Three - way valve

The three- way type valves have three ports: An inlet, an exhaust and a cylinder port

As could be seen from fig (a) below one flow port is connected to either of the other two ports .This valve may also be used to pressurize one port and exhaust the other port. Thus these valves can be used as a pilot relay to operate the other valves.

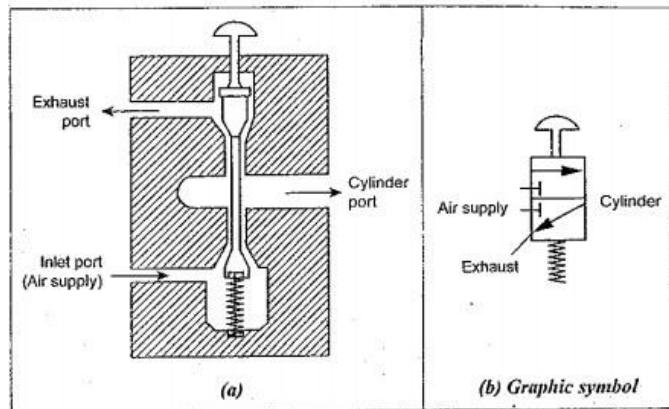


Figure: 3/2 way DC valve

2.1.1.2. Four-way valves

The four way type valves have four ports: An inlet; an exhaust, and two cylinder ports. The construction and operation of a typical valve-seat type four-way two-position (i.e, 4/2) Pneumatic valve is illustrated in fig (a), fig (b) below shows the graphic symbol of the 4/2 way valve.

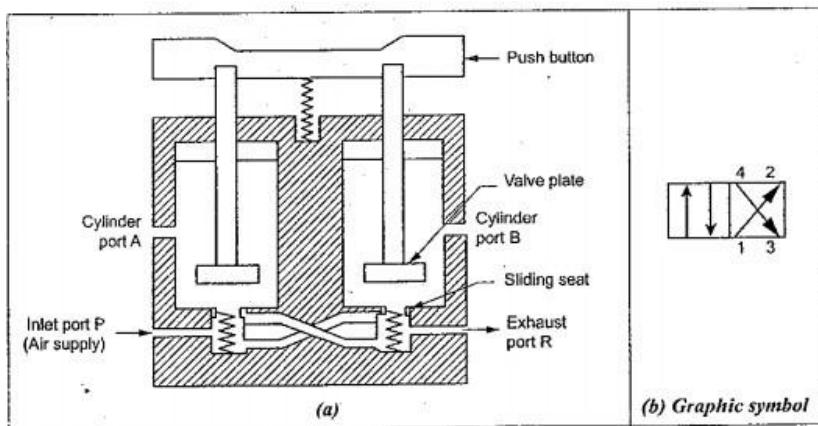


Fig. 4/2 way DC valve

As shown in figure, the inlet port P connects to cylinder ports A and B to exhaust port R.

When the valve elements are actuated by means of the push button, they are unseated and port P connects to cylinder ports B and A to exhaust port R.

Notes: Generally two way DC valves are used as an-off type valves; Three way DC valves are used to control single-acting linear actuators and Four way DC valves

are used to control double-acting actuators.

2.1.1.4. Shuttle valves

- Shuttle valves also known as double check valves, are used when control is required from more than one power source.
- In other words, shuttle valves are used to select the higher of the two input pressures automatically and connect to output port. This valve is also known as 'ORGATE'

The construction and operation of a typical three port spool-type shuttle valve is illustrated in fig(a) below. The alternative ball-type shuttle valve for the same purpose is shown in fig (b) below.

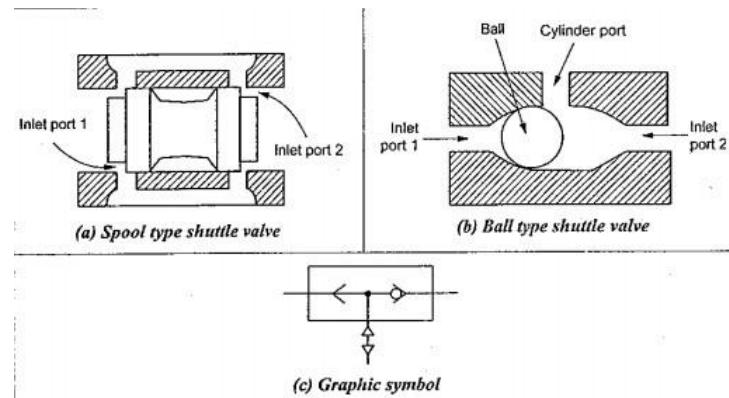


Fig. *Shuttle valve*

As shown in fig (a) and (b), this valve consists of two inlet ports and one outlet port. As long as pressure in the right inlet port is greater than the left, the spool (or ball) closes the left port. When pressure at the left port becomes greater than at the right, the spool (or ball) moves to the right, closing the right port and opening the left.

2.1.1.5. Quick exhaust valve

- A *quick exhaust valve* is a typical shuttle valve. The *quick (or fast) exhaust valve* is used to exhaust the cylinder air to the atmosphere quickly.
- It is basically used with spring return single – acting pneumatic cylinders to increase the piston speed of cylinders
- The construction and operation of a typical quick exhaust valve is shown in fig below. It consists of a movable disc and three ports- an inlet port (P), and

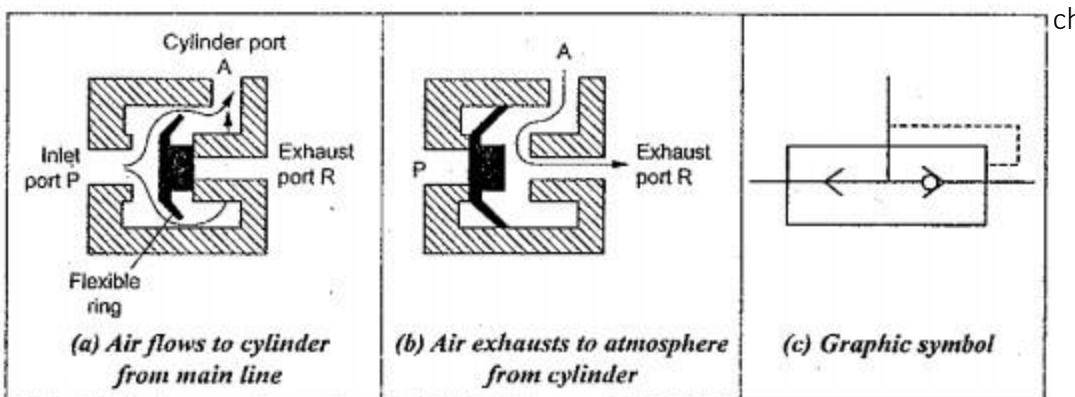


Fig. Quick exhaust valve

When the air flowing to the cylinder from the DC valve is applied at port P, then the flexible ring covers the exhaust port R, whereby the compressed air passes from port P to the cylinder through port A (fig a).

But the return air from the cylinder pushes the flexible ring to cover the inlet port P, whereby the exhaust air immediately expelled to the atmosphere (fig b). Thus the resistance to piston movement is reduced considerably and the speed of the piston in the cylinder is accelerated proportionately.

III. Pressure regulating valves

- ✓ As the name suggests, the pneumatic pressure regulator is used to supply a prescribed reduced outlet pressure in a pneumatic circuit and to maintain it at a constant value.
- ✓ Usually these pneumatic pressure regulators are installed at the inlet of the each separate pneumatic circuit. Sometimes they are installed within a circuit to provide two or more different pressure levels for separate portions of the circuit.

IV. Flow control valve

- Flow control valves also known as volume – control valves, are used to regulate the volumetric flow of the compressed air to different parts of the pneumatic system.
- The construction and operation of a typical spring – loaded disk flow control valve is illustrated in figure below:

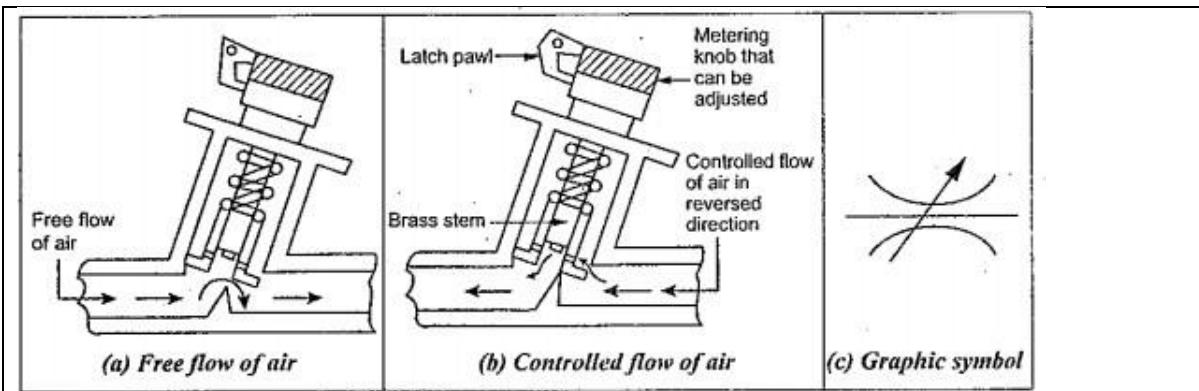


Figure: Flow control valve

As shown in figure (a) and (b), the spring loaded disk allows free flow in one direction and an adjustable or controlled flow in the opposite direction. A tapered brass stem controls the adjustment by controlling the flow through the cross hole in the disk.

0.2. Hydraulic valves

What are hydraulic valves?

- Hydraulic valves are devices used to control pressure, flow direction ,or flow rate in hydraulic circuits
- These control valves utilize mechanical motion to control the distribution of hydraulic energy within the system.

0.2.1. Types of control valves

Control valves are classified into three basic types, based on their function in the hydraulic system. They are:

1. Directional control valves
2. Pressure control valves
3. Flow control(or volume control) valves

0.2.2. Valves configuration

There are essential types of control valves based on their configuration or modes of operation .They are:

- Poppet (or seat) valves
- Sliding spool valves, and
- Rotary spool valves

Let see a brief understanding before discussing the construction and operation of different types of control valves

0.2.3. Poppet (or seat) valves

- Construction and operation

The most common form of poppet valve is shown on the figure below. Normally this valve is in the closed condition and hence there is no connection between port 1 and port 2. In the poppet valves, balls, discs or cones are used to control the flow.

When the push button is depressed, the ball is pushed out of its seat and hence the flow is permitted from port 1 to port2. When the push button is released, spring and fluid pressure force the ball back up against its seat and so closes off the flow.

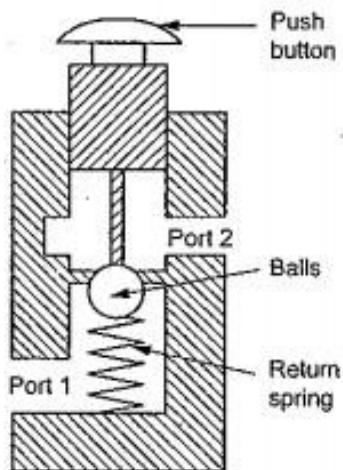


Figure: Poppet seat

- Advantages of poppet seat

Poppet valves exhibit the following advantages:

- i. Simple design
- ii. Less expensive
- iii. Very robust
- iv. Less sensitive to fluid contamination
- Disadvantages of poppet valves
 - The force required to operate the poppet valves are more. Therefore they are suitable mostly for low pressure applications.
- Application of poppet valves

Poppet valves are essentially two-way valves. Therefore they are limited to :

- i. Applications in which flow reversal is not required .e.g: check valves and relief valves ,and
- ii. Low- power applications because of their relatively high leakage rate

0.2.4. Sliding spool valves

The sliding- spool valves are the most frequently used type in hydraulic systems

- Construction and operation

A spool moves horizontally within the valve body to control the flow. The raised areas called 'land' block or open port to give the required operation.

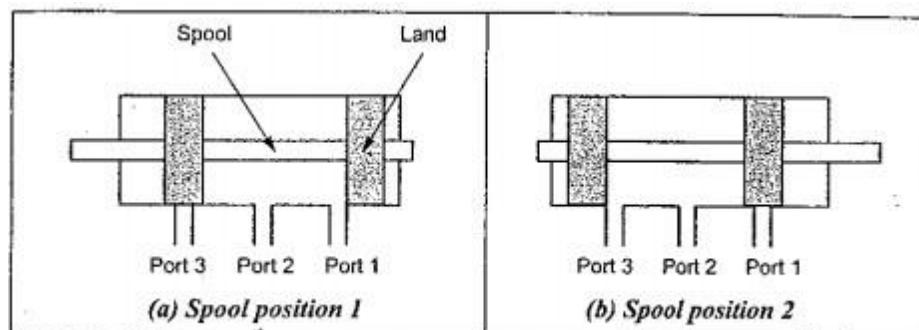


Figure: construction and operation of sliding –spool valve

In fig(a),the fluid supply is connected to port 1 and now port 3 is in closed position. Thus the flow is permitted from port 1 to port 2. In fig (b) , when the spool is moved to the left, the fluid supply is cut off and port 2 is connected to port 3. Thus the flow is permitted from port2 to port 3.

- Advantages of sliding-spool valves
 - i. Different operations can be achieved with a common body and different spool.
 - ii. Reduced manufacturing cost
 - iii. Reduced fluid leakage rate
 - iv. All types of actuation are easily adaptable
 - v. They are used for high pressure applications

0.2.5. Rotary spool valves

Rotary spool valves have a rotating spool which aligns with holes in the valve casing to give the required operation.

- Construction and operation

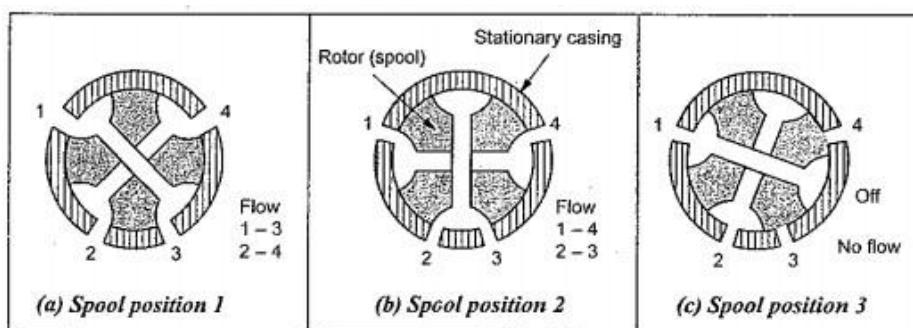


Figure: Construction and operation of a rotary-spool valve

The figure above illustrates the construction and operation of a typical rotary spool valve, with centre off action. When the spool rotates, it opens and closes port and subsequently allows and prevents the fluid flow through those ports.

The figure has four ports 1, 2, 3, and 4. For the position of spool as in fig (a), the flow is permitted from port 1 to port 3, and from port 2 to port 4.

When the spool rotates to a position as shown in fig (b), the flow is permitted from port 1 to port 4, and from port 3 to port 2. For the spool position shown in fig(c), there is no fluid flow as all the four ports are blocked.

- Advantages of rotating spool valves
 - i. They are simple and compact in design and operation
 - ii. They have low operating forces

iii. They are widely used for low pressure applications

0.2.6. Directional control valves

- As the name suggests, the function of a directional control valve (DCV) is to control the direction offlow in a hydraulic circuit.

The DCVs are used regulate the direction in which the fluid flows in a hydraulic circuit

The function of a DCV is to control the direction of fluid flow in any hydraulic system. A DCV does this by changing the position of internal movable parts. To be more specific, a DCV is mainly required for the following purposes:

- To start, stop, accelerate, decelerate and change the direction of motion of a hydraulic actuator.
- To permit the free flow from the pump to the reservoir at low pressure when the pump's delivery isnot needed into the system.
- To vent the relief valve by either electrical or mechanical control.
- To isolate certain branch of a circuit.

Any valve contains ports that are external openings through which a fluid can enter and exit via connecting pipelines. The number of ports on a DCV is identified using the term "way." Thus, a valve with four ports is a four-way valve A DCV consists of a valve body or valve housing and a valve mechanism usually mounted on a sub-plate.

The ports of a sub-plate are threaded to hold the tube fittings which connect the valve to the fluid conductor lines. The valve mechanism directs the fluid to selected output ports or stops the fluid from passing through the valve.

- Classification of Directional control Valves

The directional control valves can be classified in many different ways

I. The directional control valves are basically classified, according to the construction DCVs areclassified into three groups, as:

- Poppet (or seat) valves
- Sliding spool valves, and
- Rotary spool valves

II. Based on the number of ports present, DCVs may be classified as:

- Two way valves

- Three way valves, and
- Four way valves

III. Based on mode of actuation, the directional control valves can be classified as:

- Manually operated DCVs
- Mechanically operated DCVs
- Solenoid operated DCVs
- Pilot operated DCVs

IV. However for our study we can classify the directional control valves into three:

- Check valves
- Position valves, and
- Shuttle valves

Now, we shall discuss the construction and operation of some of the important directional control valves in the following sections.

0.2.6.1. Check valves (or two way valves)

a. Introduction

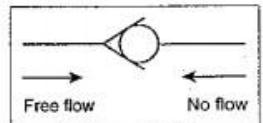
- Check valves are the most commonly used and the simplest type of directional control valves
- The check valve is a two-way valve because it contains two ports. Also a check valve is analogous to a diode in electric circuits
- Functions : The check valves are used:
 - i. To allow free flow in only one direction , and
 - ii. To prevent any flow in the other direction
- Since check valves block the reverse flow of fluid, they are also known as non-return valves
- The symbolic representation of a check valve, is shown on the figure below and illustrates its function clearly.

b. Types of check valves

Check valves are of several types. But the two important types of check valves are:

1. Poppet-type check valves, and

2. Pilot-operated type check valves



Symbolic representation of a check valve

c. Poppet-Type (or Simple) check valves

- Construction and operation

The construction and operation of a typical poppet type check valve is illustrated in figure below. Normally a spring holds the poppet in the closed position.

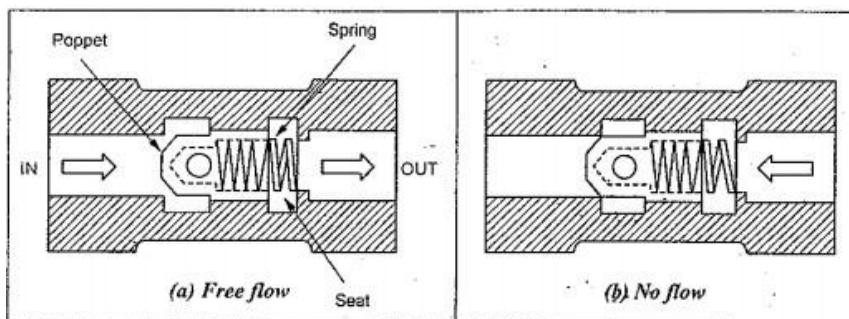


Figure: construction and operation of a poppet-type check valve

When flow is in the normal direction, the liquid pressure acts against the spring tension to hold the poppet off the seat. When the liquid pressure overcomes the spring force, as shown in fig (a), the valve allows the free flow. When flow stops, the spring seats the poppet and liquid cannot pass in the reverse direction.

Instead, if flow is attempted in the opposite direction as shown in fig (b), the liquid pressure along with the spring force pushes the poppet in the closed position. Hence no flow is permitted in opposite direction.

- Applications of simple check valves

Usually poppet type check valves are used to provide the pilot pressure to operate larger valves.

2.2.6.2. Pilot – Operated check valves

The piloted operated check valve allows free fluid flow in one direction, but reversed flow depends upon the pilot actuation. That means, this type check valve also allows the reverse flow, provided pilot pressure is applied at the pilot pressure port of the valve to overcome the spring force of the poppet.

a. Construction and operation

First the free flow in the normal direction from port A to port B is achieved in the usual manner. But the reverse flow is blocked as the fluid pressure pushes

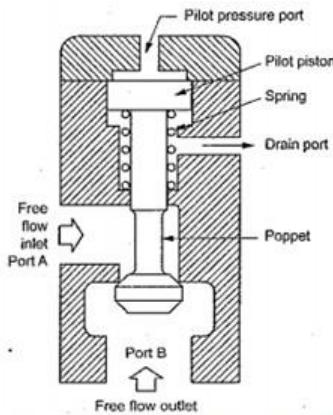


Figure: Pilot-Operated check valve

the poppet into the closed position.

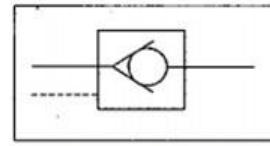


Fig: Symbol of a pilot-operated check valve

In order to permit the fluid flow in the reverse direction i.e. from port B to port A, a pilot pressure is applied through the pilot pressure port. The pilot pressure pushes the pilot piston and the poppet down. Thus the fluid flow in the reverse direction is also obtained. The purpose of the drain port in the circuit is to prevent oil from creating a pressure build up on the bottom of the pilot piston.

Note: The dashed line presents the pilot pressure line

b. Applications of pilot-Operated check valves

The pilot – operated check valves are widely used to hydraulically lock the cylinders such as in a hydraulic jack.

2.2.6.3. Position valves

a. Introduction

- The function of the position valve is to control the introduction of fluid to the lines of the system. When the valve is operated, the liquid lines within it are shifted
- The position valves are usually described by the following relation: (Number of ports/Number of positions) valve

For example a 4/2 valve has 4 ports and 2 positions

The ports of a directional control valve are designated by letter, as listed in table below

Ports	Designation
Working lines	A, B, C, and so on.
Pressure (power) supply	P
Return/Exhaust lines	R, S, T and so on. (Normally T for hydraulic systems, R and S for pneumatic systems.)
Control (pilot) lines	Z, Y, X, and so on.

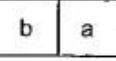
Table: Ports' designations

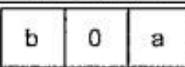
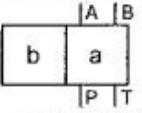
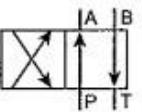
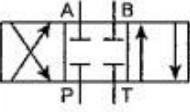
- Valve position
 - ✓ A direct control valve has two or three working positions generally. They are :
 1. Normal or zero position or neutral position.
 2. Working positions (such as retract and extend positions).
 - ✓ It is necessary to differentiate between neutral and operating positions. In directional control valves with spring return, the neutral position is defined as the position to which the valve returns after the actuating force has been withdrawn.
 - ✓ In all fluid control systems, the valve positions can be represented by letters *a*, *b*, *c*, and so on, with '0' being used for central neutral position.
 - ✓ The starting (or initial) position is the position taken up by the valve (due to spring in case of spring actuated directional control valve) after installation. The valve attains the working positions when actuated.
 - Valve symbols

For representing valves in circuit diagrams, symbols are used. Generally a valve is represented by a square for each of its switching positions. Two positions are represented by two adjacent squares. It should be noted that symbols show only the functional aspect of the valve and not its principle of design or constructional details.

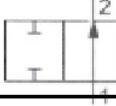
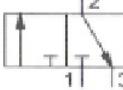
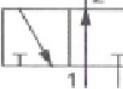
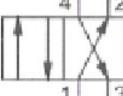
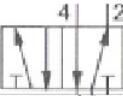
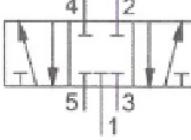
The basic valve symbols and their description are presented in Table

Table Basic valve symbols and their description

	Valve symbol	Description
Valve position		A valve position is represented by a square.
Two position valve		A number of squares is equal to the number of distinct positions that the valve can take up. Therefore the figure shows the two position valve.

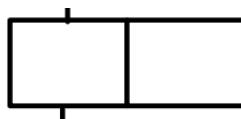
	Valve symbol	Description
Three position valve.		Three adjacent squares indicate the three position valve.
Flow path		Inside a square, the line indicates the flow and the arrow the direction of flow.
Flow shut off		Cut-offs of fluid flow are shown by short transverse lines inside the square.
Initial convections		The ports of a valve are added on the outside of the square box. The connections to inlet and outlet ports are drawn only to a initial (or neutral) position.
4/2 valve		Figure shows the 4 ports (A, B, P and T) and 2 positions (a and b) valve.
4/2 valve		In position 'a', the fluid is delivered from port P to port A and returned from port B to port T. In position 'b', flow is reversed. i.e., the fluid is delivered from port P to port B and returned from port A to port T. [Note: Here ports are drawn only to the initial position. For the other position, readers should mentally identify the ports.]
4/3 valve		Figure shows a 4 ports and 3 positions valve. In position 'a', the fluid is delivered from port P to port A and returned from port B to port T. In position '0', the load is in the off (or neutral) position. Since all A, B, P and T ports are blocked, therefore no fluid flow. In position 'b', the flow is reversed. [Note: Here ports are shown only to the neutral position; for other two positions, readers should mentally identify the ports.]

Note The above valve symbols are to be used in hydraulic circuits. The corresponding symbols unfilled arrow heads can be used in pneumatic circuits.

SYMBOL	EXPLANATION
	2/2 - way directional control valve, normally open
	3/2 – way directional control valve normally closed
	3/2 – way directional control valve, normally open
	4/2 – way directional control valve Flow from 1 to 2 and from 4 to 3
	5/2 – way directional control valve Flow from 1 to 2 and 4 to 5
	5/3 – way directional control valve Mid position closed

b. Valve Ports

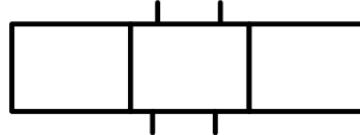
Every valve port, which appears on the outside of the valve, is supposed to be shown on the symbol. But the ports are shown on only one of the boxes, the box that represents the flow paths that exist at the start of the machine cycle. Some examples are:



A 2-position 2-port valve



A 2-position 3-port valve



A 3-position 4-port valve

c. Classification of position valves

Position valves are classified in terms of the number of fluid ports and the number of valve positions, as:

- Two way, two position valves (2/2 valves)
- Three way, two position valve(3/2 valve)
- Four way, two position valves (4/2 valves)
- Four way , three position valves (4/3 valves), and so on

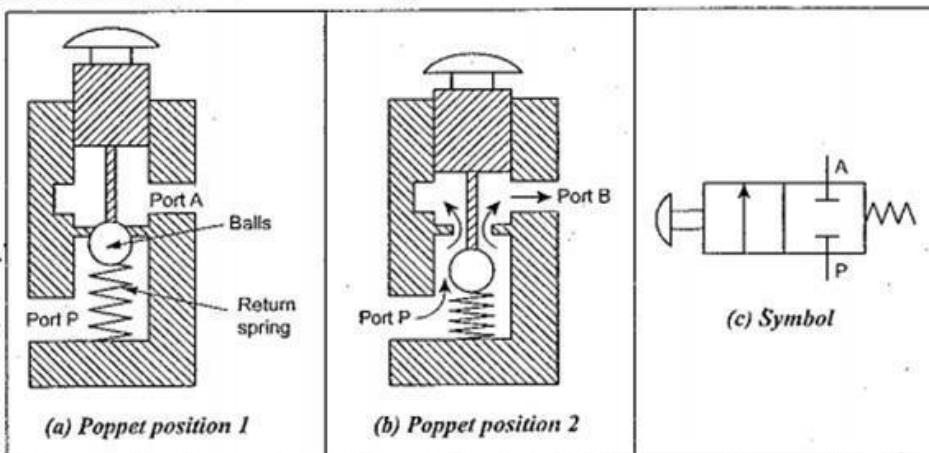
Two position valves

2/2 Directional Control Valves

The 2/2 valves have 2 ports and 2 positions.

Construction and Operation

The poppet-type check valve illustrated in Fig. is a typical 2/2 valve. However, the construction and operation of a similar type 2/2 DC valve



Operation of a 2/2 DC valve

Position 1 : When the push-button is in normal position, spring and fluid pressure force the ball up, therefore the flow is blocked, as shown in fig(a)

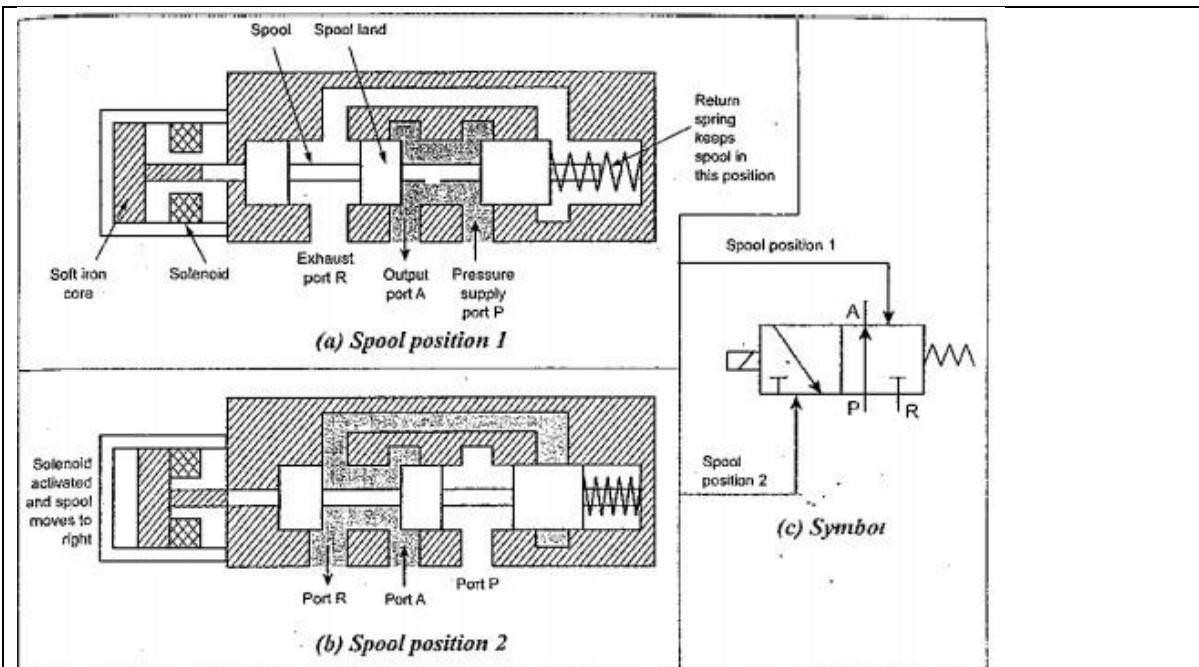
Position 2 : When the pressure of the push-button pushes the ball off its seat, then the flow is permitted from port P to port A, as shown in fig(b)

➤ 3/2 DCVS

The 3/2 valves have 3 port and 2 positions

Construction and Operation

The construction and operation of a typical sliding-spool type, solenoid-actuated 3/2 DC valve is illustrated in Figure . It has three ports or openings : pressure supply port (P), output port (A), and exhaust port (R).



Construction and operation of a solenoid-actuated 3/2 vane

As shown in Figure : (a) and (b), the valve is actuated by a current passing through a solenoid and, returned to its original position by a spring. The spool slides over the finely finished valve bore inside the valve housing.

Spool position 1 : In the original or neutral position of the spool, (Figure : (a)), the pressurized fluid flows from port P to port A to move the actuator, the exhaust port (R) remaining closed.

Spool position 2 : When the solenoid is activated (Figure : (b)), the spool moves to the extreme left. In the extreme spool position, the fluid from port P gets closed and hence the fluid is permitted to flow from port A to port R.

Thus the valve alternately connects and disconnects fluid supply to the cylinder by the sliding spool.

-Graphic Symbol

Figure : (c) shows a graphic symbol of a solenoid actuated, spring return 3/2 valve, illustrating the above operation.

➤ 4/2 DCVs

The 4/2 valves have 4 ports and 2 distinct positions

The construction and operation of a typical sliding-spool type 4/2 DC valve is illustrated in Figure : It has four ports or openings, P, A, B, and T.

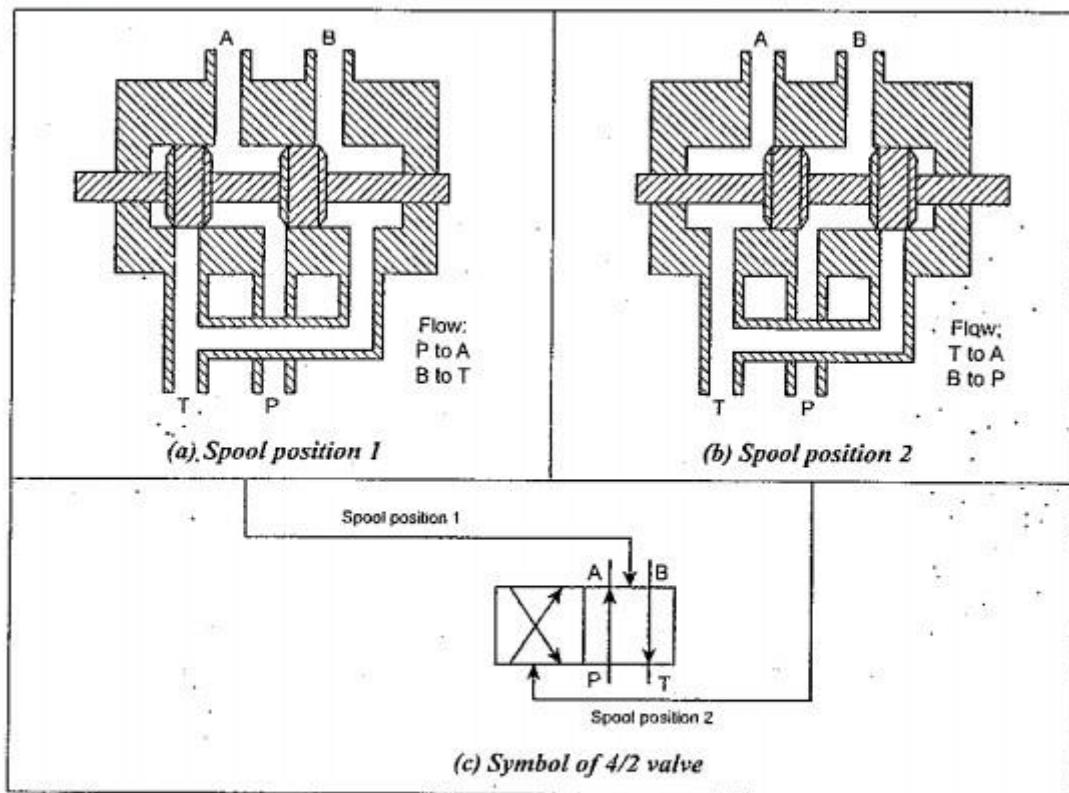


Figure : Operation of a 4/2 DC valve

Spool position 1 : When the spool is in position as shown in Figure :(a), the fluid can flow from port P to port A and return from port B to port T.

Spool position 2 : When the spool is in the position as shown in Figure :(b), the fluid can flow from port T to port A and return from port B to port P.

The graphical symbol is represented on fig(c)

- Three position valves

The 4/3 directional control valves have 4 ports and 3 distinct positions. This valve also has four ports P, A, B and T.

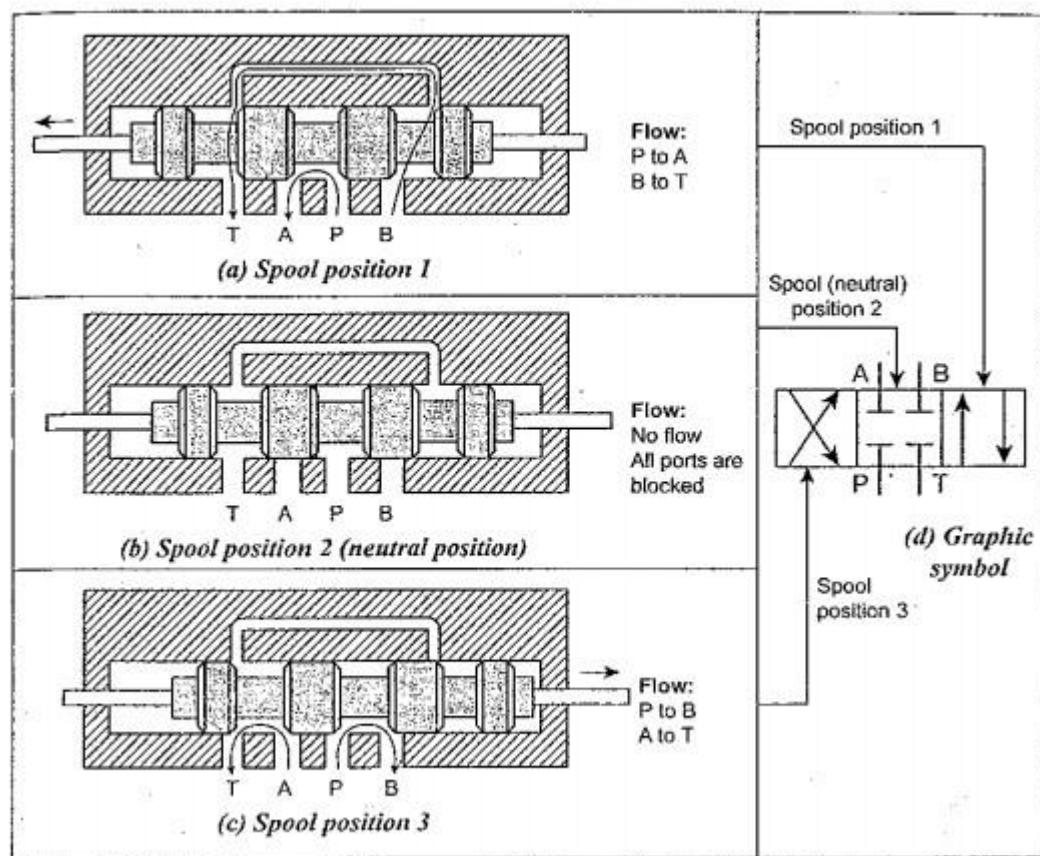


Figure: operation of a 4/3 DC valve

Spool position 1 : For the spool position shown in Figure : (a), the fluid can flow from port P to port A and return from port B to port T.

Spool position 2 : During the neutral position shown in Figure : (b), all the ports are blocked.

Spool position 3 : For the spool position shown in Figure : (c), the reverse flow is permitted. i.e., fluid can flow from port P to port B and return from port A to port T.

- **Graphic Symbol**

Figure : (d) represents the graphic symbol for the above 4/3 DC valve.

- **Centre Flow Configurations for Three-Position, Four-Way Valves**

As we discussed, the two extreme positions of a 4/2 control valve controls the two extreme direction of motion of fluid. In 4/3 valves, the third position usually is an intermediate or a centre position. Varieties of centre positions are possible in 4/3 DC valves by suitably designing the spool. Figure : illustrates some of the widely used centre flow path configurations for 4/3 valves.

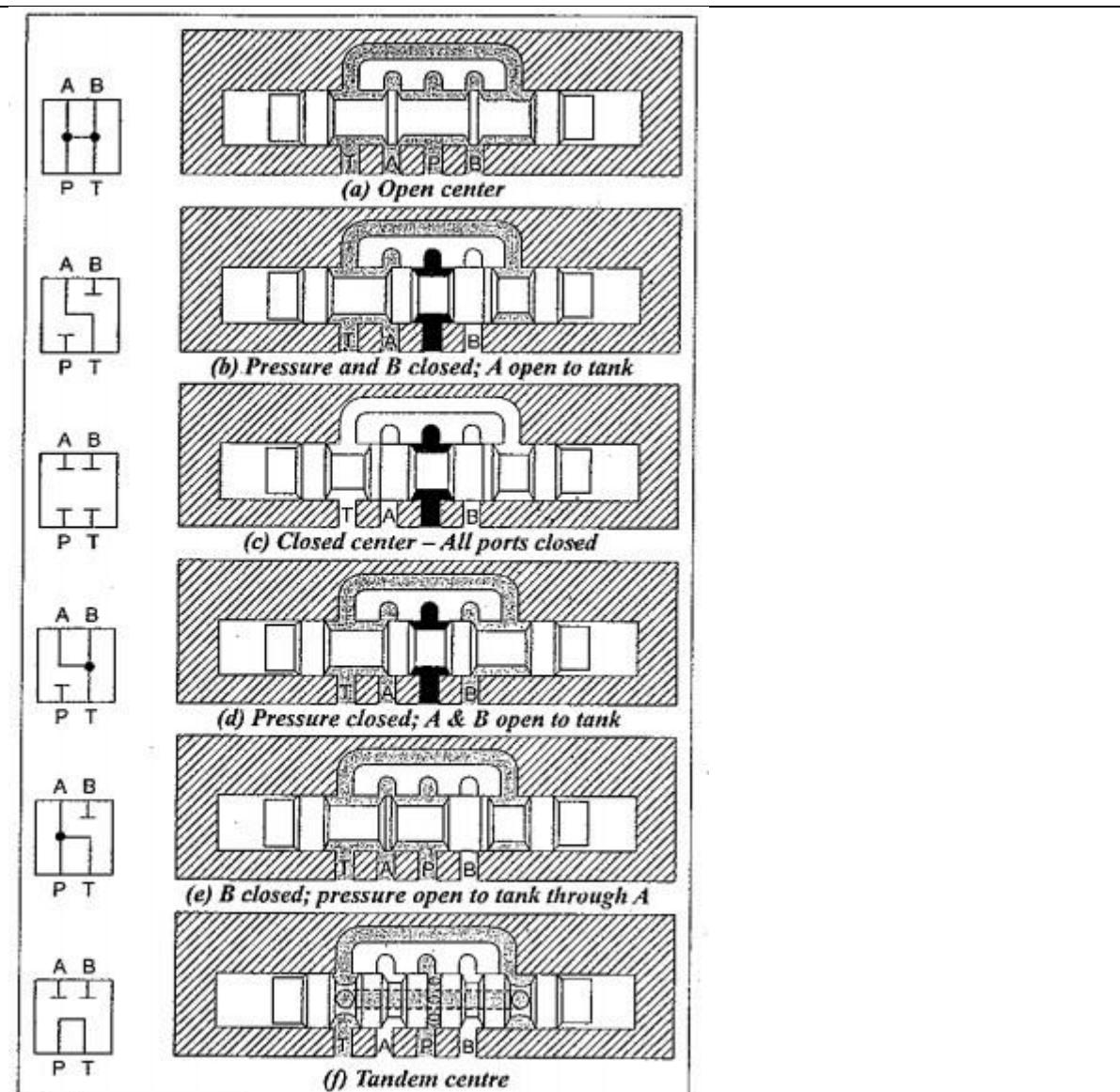


Figure: Various center flow paths for the three- position, four-way valves

These centre positions are briefed below :

1. Open Centre : ✓ In open centre type, all ports of the valve P, A, B, and T are open to each other, as shown in Fig(a)

✓ **Advantage :** As soon as the cylinder completes its cycle, the open centre DC valve allows the pump flow to return to back the tank (reservoir) at a minimum pressure. This prevents unnecessary heat build-up in the system.

✓ **Disadvantage :** When the valve is centred, no other cylinder can operate. Therefore, open-centre type valve is used mostly for a single cylinder or single motor circuit.

2. Closed Centre : ✓ In closed centre type, all the ports P, A, B, and T are blocked to each other, as shown in Figure : (c).

✓ **Advantage :** The closed centre type valve can use the pump flow for other parts of the circuit. Therefore closed typed valves are used when multiple functions are to be accomplished from one source.

✓ **Disadvantage :** When the valve is in closed centre position, the pump flow cannot be unloaded to the tank. So the hydraulic cylinder or fluid motor cannot be moved.

3. Tandem Centre : ✓ The tandem centre type valve, as shown in Figure : (f), directs the pump flow out of the reservoir port T with the other two working ports A and B closed when in the centre position.

✓ **Advantage :** Like open centre valve, this type valve also unloads the pump at essentially atmospheric pressure. The application of this design is to permit the flow to be connected to a series of valves for multiple circuits.

✓ **Disadvantage :** When a number of cylinders are operated from a single source, the pressure differential for each tandem centre valve will be 3 to 4 bar each while the valve is in its centre position.

4. Floated Centre : ✓ The floated centre type valves allow independent operation of cylinders connected to the same power source, as shown in Figure : (b), (d), and (e).

✓ **Advantage :** This type does not build up any pressure in the cylinder lines. Therefore, there will not be any drifting of cylinders during this condition.

✓ **Disadvantage :** The load cannot be locked in this position during the neutral position.

- Applications of Position Valves

- ✓ *Two way directional valves* are generally used as shut off valves. Unlike a check valve, the two-way valve can block flow in both directions.
- ✓ Generally *three way directional control valves* are used to control single-acting linear actuators.
- ✓ The *four way directional control valves* are used to control double-acting actuators.
- ✓ A *three-position valve* can be used : (i) to isolate an actuator from the circuit, (ii) to provide a bypass to the reservoir around the actuator, or (iii) to hold an actuator in an intermediate position.

- Specification of Directional Control Valves

The DC valves are usually specified by the following parameters :

1. Rated flow,
2. Rated pressure,
3. Outlet and inlet port size,
4. 3 way or 4 way spool,
5. Open or closed centre application,
6. Spring centred or not,
7. Solenoid type and power, etc.

2.2.7. Pressure control valves

- ✓ As the name suggests, *pressure control valves* are the devices used to control the fluid pressure in a system.
- ✓ **Functions :** The pressure control valves perform one or more of the following functions :
 - (i) To limit the maximum pressure in various circuit components as a safety measure.
 - (ii) To maintain the desired pressure levels in various parts of the circuits.
 - (iii) To unload system pressure, i.e., to change the direction of all or part of the flow when the pressure at a certain point reaches a specified level.
 - (iv) To assist sequential operation of actuators in a circuit with pressure control.

Types of Pressure control valves

The important types of pressure control valves and their functions are presented in tableTable: Types of pressure control valves and their functions

Sl.No.	Type	Function/Description
1.	Pressure limiting valve (relief valve)	Relief valve limits the maximum pressure that can be applied to the part of the system to which it is connected.
2.	Pressure reducing valve (pressure-regulator valve)	Pressure reducing valve maintains a prescribed reduced pressure at its outlet regardless of the valve inlet pressure.
3.	Sequence valve	Sequence valve directs flow to more than one portion of a fluid circuit in sequence.
4.	Counterbalance valve (Back-pressure valve)	Counterbalance valve permits free flow in one direction and restricted flow in the opposite direction.
5.	Unloading valve	Unloading valve allows pressure to build up to an adjustable setting, then bypasses the flow as long as a remote source maintains the preset pressure on the pilot port.
6.	Pressure switch	Pressure switch is used when a pressure-actuated electric signal is required for system control.
7.	Hydraulic fuse	<ul style="list-style-type: none"> ✓ Hydraulic fuse employs a frangible diaphragm, which establishes the maximum pressure in a hydraulic circuit by rupturing at a preset pressure valve. ✓ Hydraulic fuse, analogous to an electric fuse, is used to prevent the system pressure from exceeding beyond the allowable limit in order to protect the system components from damage.

Now we shall discuss the construction and operation of the pressure-limiting, pressure-reducing and sequence valves in details in the following sections.

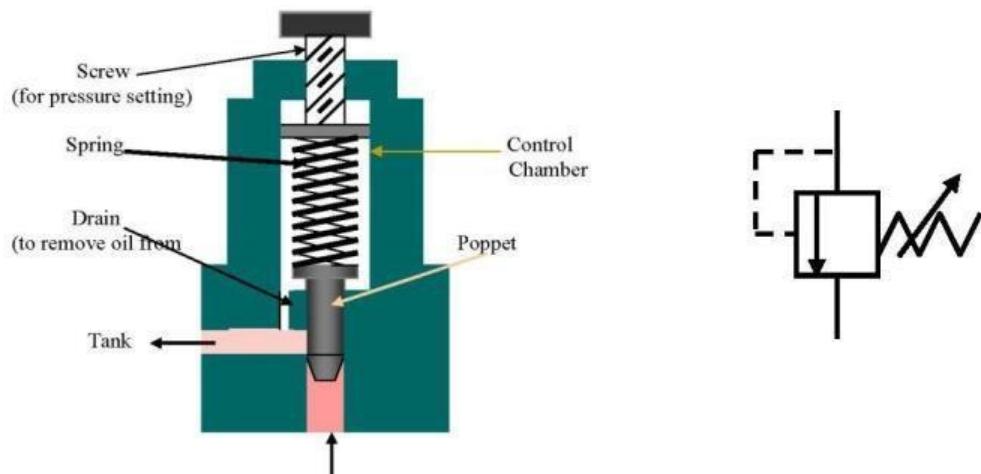
Note: It may be noted that relief, sequence, counterbalance, and unloading valves are normally closed valves whereas the pressure-reducing valves are open valves

1. Pressure limiting valve(Relief Valves)

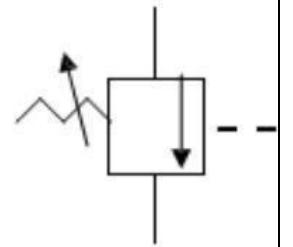
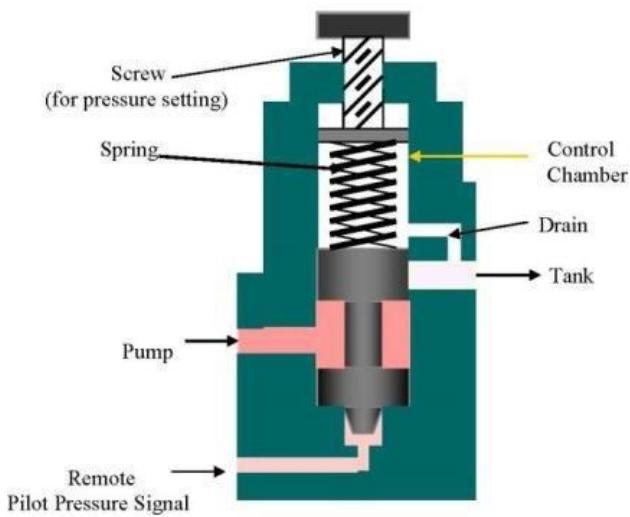
The pressure relief valve is used to protect the hydraulic components from excessive pressure. It is one of the most important components of a hydraulic

system and is essentially required for safe operation of the system. Its primary function is to limit the system pressure within a specified range. It is normally a closed type and it opens when the pressure exceeds a specified maximum value by diverting pump flow back to the tank. The simplest type valve contains a poppet held in a seat against the spring force as shown in the figure. The fluid enters from the opposite side of the poppet. When the system pressure exceeds the preset value, the poppet lifts and the fluid is escaped through the orifice to the storage tank directly. It reduces the system pressure and as the pressure reduces to the set limit again the valve closes. This valve does not provide a flat cut-off pressure limit with flow rate because the spring must be deflected more when the flow rate is higher. Various types of pressure control valves are discussed in the following sections:

Pressure Relief Valve: When the system pressure exceeds a set value, the poppet raises up and allows fluid to flow back.

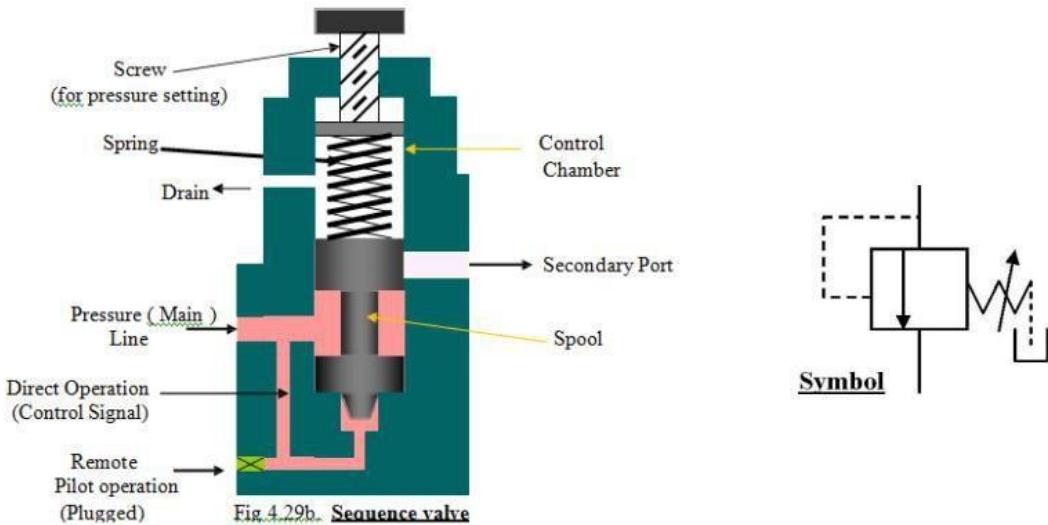


1. **Unloading Valve:** An unloading valve is used to permit a pump to operate at minimum load. The unloading valve is normally a closed valve with the spool closing the tank port. When a pilot pressure is enough to overcome the spring force, the spool moves up and flow is diverted to tank. When the pilot pressure is relaxed, the spool moves down and lets the flow to the circuit for operation.

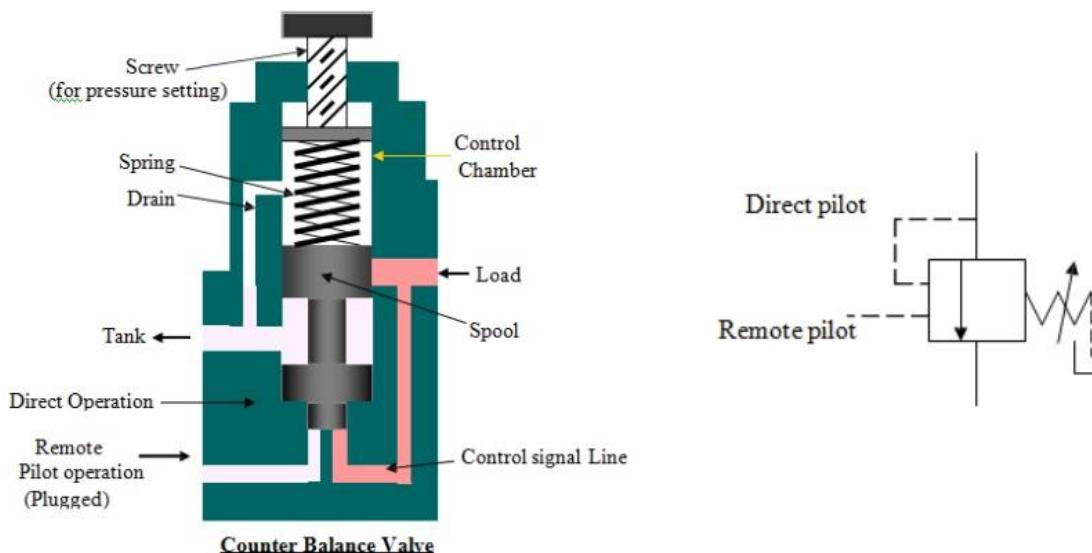


The unloading valve is used in system having one or more fixed delivery pump to control the amount of flow at any given time. A well designed hydraulic circuit uses the correct amount of fluid for each phase of a given cycle of machine operations. When pressure builds up during the feed phase of the cycle, the pilot pressure opens the unloading valve, causing the large discharge pump to bypass its flow back to the tank.

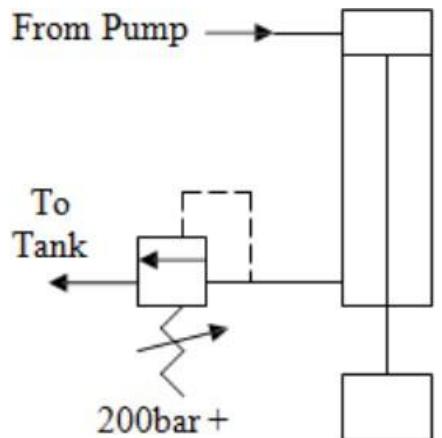
2. Sequence valve: A sequence valve's primary function is to divert flow in a predetermined sequence. It is a pressure-actuated valve similar in construction to a relief valve and normally a closed valve. When the main system pressure overcomes the spring setting, the valve spool moves up allowing flow from the secondary port.



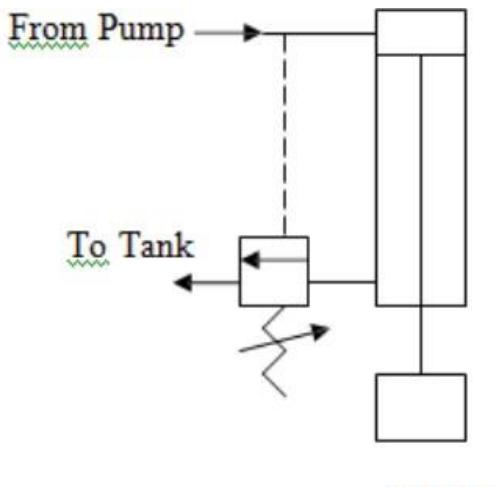
2. Counter balance Valve: A Counter balance valve is used to maintain back pressure to prevent a load from failing. One can find application in vertical presses, lift trucks, loaders and other machine tool that must position or hold suspended loads.



When a counterbalance valve is used on large vertical presses, it may be important to analyze the source of pilot pressure. Figures (a) and (b) illustrate the comparison between direct and remote pilot signal.

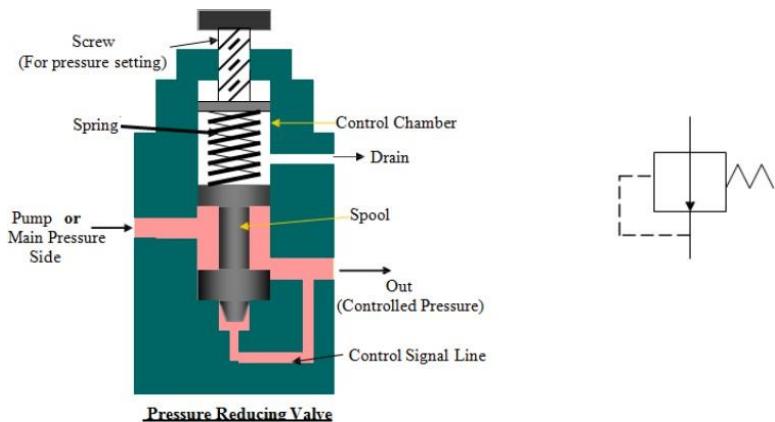


(a)



(b)

3. Pressure Reducing Valve: Pressure reducing valve is used to limit its outlet pressure. Reducing valves are used for the operation of branch circuits, where pressure may be less than the main system pressure. The pressure reducing valve is normally an open type valve. When the secondary pressure is high, it lifts the spool against the spring force and throttles the flow till such extent that the secondary pressure reaches the value as set by spring.



Note:

➤ **Pressure control valves**

Pressure control valves :

- ❖ Pressure regulating valves- controls the pressure in a control circuit and keeps the pressure constant irrespective of any pressure fluctuations in the system.
- ❖ Pressure limiting valves are utilised on the up-stream side of the compressor to ensure the receiver pressure is limited, for safety, and that the supply pressure to the system is set to the correct pressure.
- ❖ Pressure sequence valve senses the pressure of any external line and compares the pressure of the line against a pre-set adjustable value, creating a signal when the pre-set limit is reached.

FLOW CONTROL VALVES

What are Flow Control Valves ?

- ✓ *Flow control valves, also known as volume-control valves, are used to regulate the rate of fluid flow to different parts of a hydraulic system.*
- ✓ Since control of flow rate is a means by which the speed of hydraulic machine elements is governed, therefore flow control valves are also known as *speed-control valves*.
- ✓ The flow rate to a particular system component is varied by throttling or by diverting the flow.

Types of Flow Control Valves

The two basic types of flow control valves are :

1. Non-pressure compensated flow control valves, and
 - (i) Globe valve, and (ii) Needle valve.
2. Pressure compensated flow control valves.

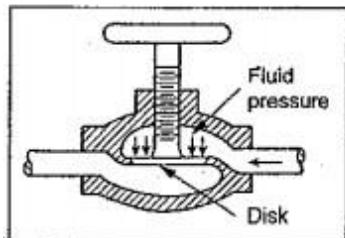
1. Non-pressure compensated flow control valves

1. What are Non-Pressure Compensated Flow Control Valves ?

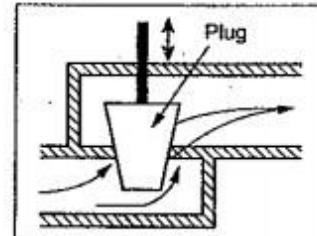
- ✓ The non-pressure compensated type flow control valves are used where pressures vary considerably and precise flow-rate controls are not required.
- ✓ These valves operate based on the principle that the flow through an orifice is constant, if the pressure drop remains constant.
- ✓ All the simple valves such as globe, needle, butterfly, gate, and ball valves are non-pressure compensated valves.

- Globe valve

In a globe valve , flow rate can be changed by means of disk, plug ,or ball which nests against a seat as shown on figure below



Disk-type globe valve



Plug-type globe valve

1. Disk-type globe valve : Disk-type globe valve, also known as a *butterfly valve*, consists of a large disc which is rotated inside the pipe, the angle determining the flow rate, as shown in Fig. 10

2. Plug-type globe valve : Plug-type globe valve has a tapered plug that can control the flow rate by varying the vertical plug position, as shown in Fig.

3. Ball-type globe valve : Ball-type globe valve has a ball with a through-hole which rotates inside a machined seat, as shown in Fig.

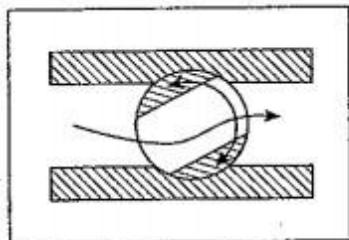
- ✓ The needle valve has a pointed stem that can be adjusted manually to control the flow rate of fluid through the valve, as shown in Fig.
- ✓ Needle valves have a smaller flow area and higher pressure drop than the globe valve.

Applications of Non-Pressure Compensated Flow Control Valves

1. The globe valves are used to throttle only in lines where the liquid velocity is relatively low.
2. In comparison to globe valves, needle valves are more suitable in throttling the flow for any velocity.

Limitations of Non-Pressure Compensated Flow Control Valves

In both globe and needle valves, changes in the pressure drop produce variations in the flow rate. Therefore precise accuracy in flow-rate control and hence the speed control cannot be achieved by using non-pressure compensated flow control valves.



Ball-type globe valve

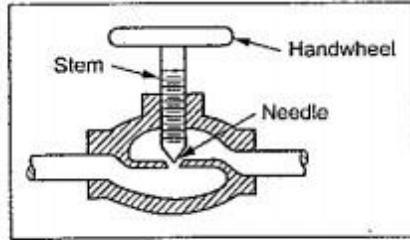
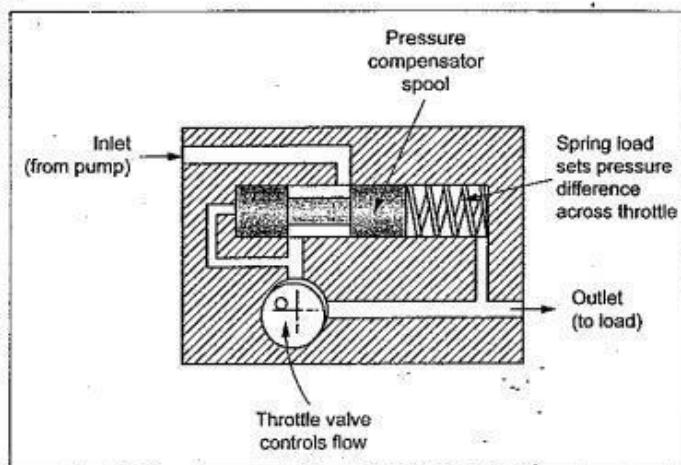


Fig. 7.23.

Construction and Operation

The construction and operation of a typical pressure-compensated flow control valve is illustrated in Fig.



Pressure-compensated flow control valve

The valve actually has two main parts arranged in series. They are :

1. Throttle valves : Similar to a needle valve, the throttle valve has an orifice whose area can be adjusted by an external knob setting. This throttle valve setting determines the flow rate is to be controlled.

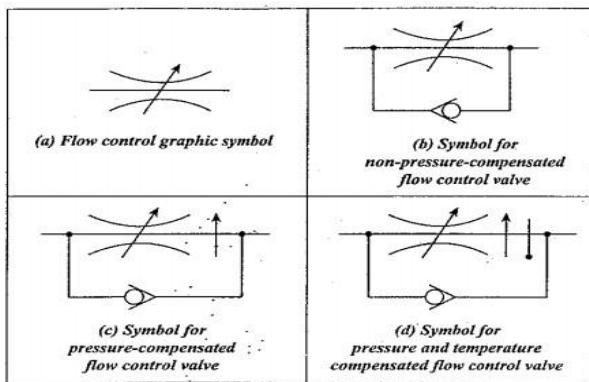
2. Pressure compensator : The pressure compensator spool controls the size of the inlet orifice and maintains a constant pressure drop across the throttle valve.

As inlet pressure increases and overcomes the spring force, the pressure compensator spool closes the inlet passage. It blocks off all flow in excess of the throttle setting. As a result, the valve permits the fluid flow only to the amount for which the throttle is already set.

When the fluid passes through the throttle valve, the pressure builds up in the spring side of the compensator. This pressure drop produces a rapid compensation in the form of spool motion. This spool adjustment causes the pressure drop to return quickly to its original value, thus maintaining constant flow.

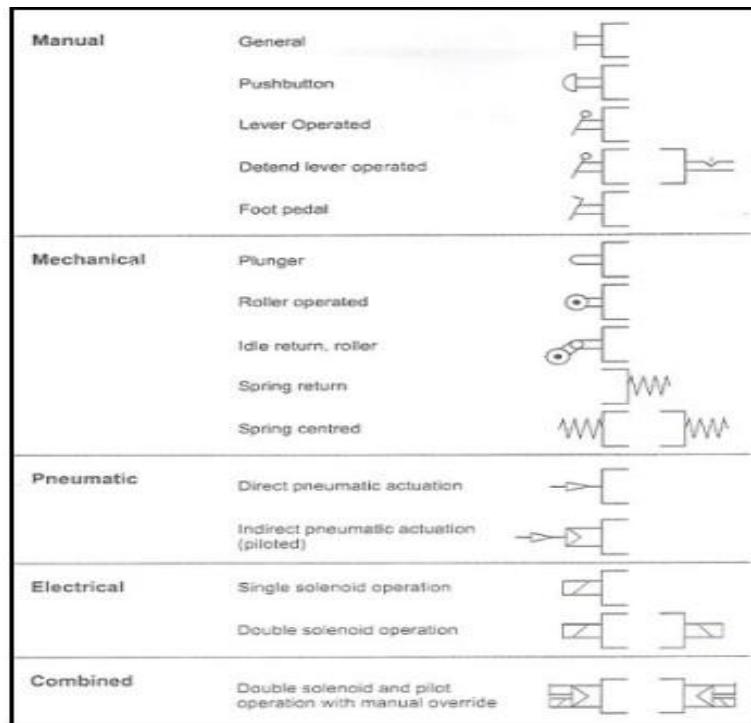
Note Flow control valves can also be affected badly by temperature changes which change the viscosity of the fluid. Therefore often flow control valves have temperature compensation.

Flow control valves symbols



a. Valve actuation symbols

The symbols for the methods of actuation are detailed in ISO 1219. The types of actuation may vary e.g. manually actuated, mechanically actuated, pneumatically actuated, electrical, combined actuation.



Directional control valves can be actuated by different methods.

The four actuation methods normally used are:

- Manually actuation
- Mechanical actuation
- Electrical actuation , and
- Fluid actuation

1. Manually –actuated Valve:

A manually actuated DCV uses muscle power to actuate the spool. Manual actuators are hand lever, pushbutton, pedals. The following symbols show the DCV actuated manually

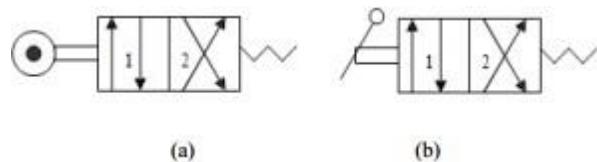


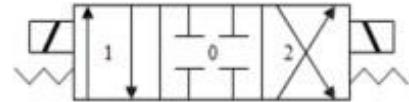
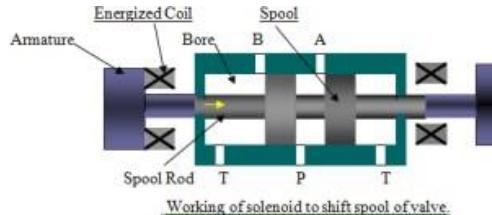
Fig a & b shows the symbol of 2 / 4 DCV manually operated by hand lever to 1 and spring return to 2. In the above two symbols the DCV spool is returned by springs which push the spool back to its initial position once the operating force has stopped.

2. Mechanical Actuation

The DCV spool can be actuated mechanically, by roller and cam, roller and plunger. The spool end contains the roller and the plunger or cam can be attached to the actuator (cylinder).. When the cylinder reaches a specific position the DCV is actuated. The roller tappet connected to the spool is pushed in by a cam or plunger and presses on the spool to shift it either to right or left reversing the direction of flow to the cylinder. A spring is often used to bring the valve to its center configuration when deactivated

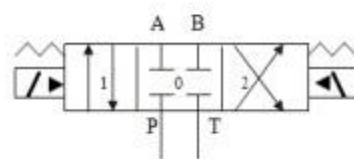
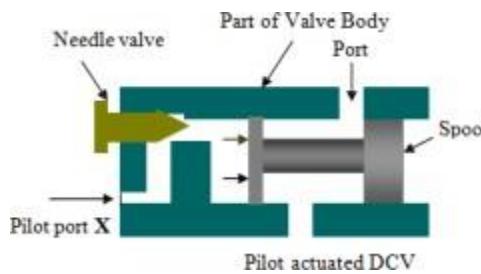
1. Solenoid Actuated DCV or electrical actuation

A very common way to actuate a spool valve is by using a solenoid as illustrated in the figure. When the electric coil (solenoid) is energized, it creates a magnetic force that pulls the armature into the coil. This causes the armature to push on the spool rod to move the spool of the valve.. The advantage of a solenoid valve is that the switching time is less.



2. Hydraulic actuation:

This type actuation is usually known as pilot-actuated valve. The hydraulic pressure may be directly used on the end face of the spool. The pilot ports are located on the valve ends. Figure shows a DCV where the rate of shifting the spool from one side to another can be controlled by a needle valve. Fluid entering the pilot pressure port on the X end flows through the check valve and operates against the piston. This forces the spool to move towards the opposite position. Fluid in the Y end (right end, not shown in the figure) is passed through the adjustable needle valve and exhausted back to tank. The amount of fluid bled through the needle valve controls how fast the valve will shift.



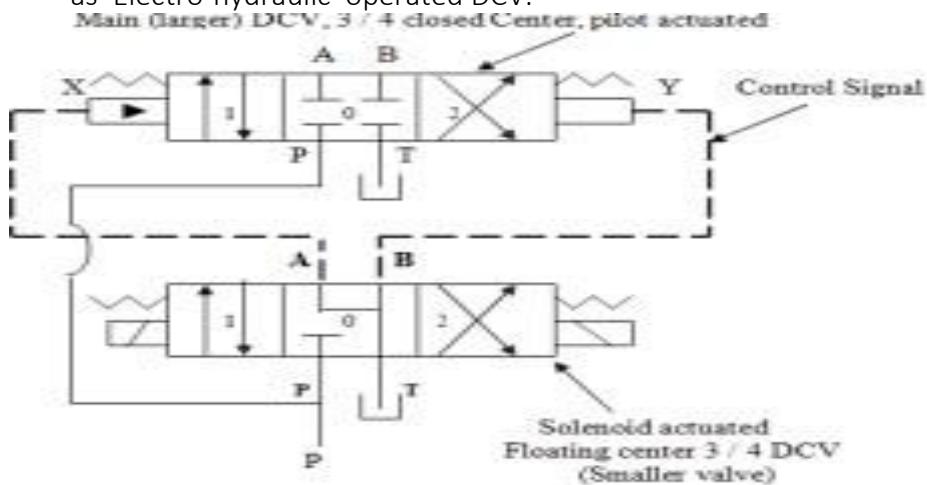
3. Pneumatic actuation

DCV can also be operated by applying compressed air against a piston at either end of the valve spool. The construction of the system is similar to the hydraulic actuation as shown in Figure above. The only difference would be the actuation medium. The actuation medium is the compressed air in pneumatic actuation system.

4. Indirect actuation of directional control valve

The direction control valve can be operated by manual, mechanical, solenoidal (electrical), hydraulic (pilot) and pneumatic actuations. The mode of actuation does not have any influence on the basic operation of the hydraulic circuits. Mostly, the

direct actuation is restricted to use with smaller valves only because usually lot of force is not available. The availability of limited force is the greatest disadvantage of the direct actuation systems. In practice, the force required to shift the spool is quite higher. Therefore, the larger valves are often indirectly actuated in sequence. First, the smaller valve is actuated directly and the flow from the smaller valve is directed to either side of the larger valve. The control fluid can be supplied by the same circuit or by a separate circuit. The pilot valve pressure is usually supplied internally. These two valves are often incorporated as a single unit. These valves are also called as Electro-hydraulic operated DCV.



Indirect actuation of directional control valve

C. Hydraulic and Pneumatic Reservoir & System Accessories

A properly constructed reservoir is more than just a tank to hold oil until the system demands fluid (*Figure below*). It should also be capable of the following:

- Dissipating heat from the fluid.
- Separating air from the oil.
- Settling out contamination in the oil.

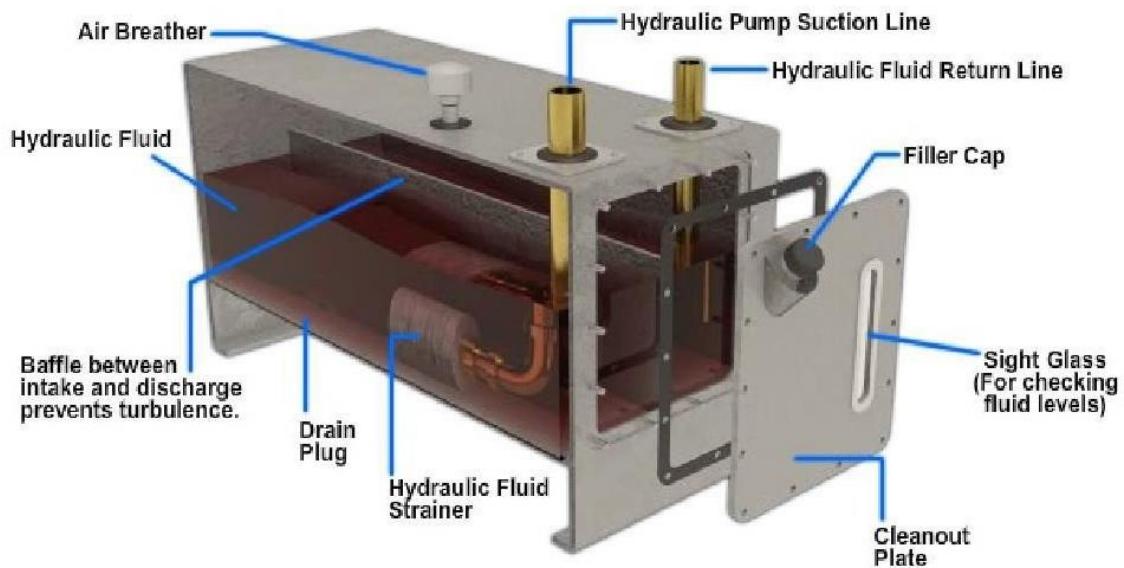


Figure: Typical hydraulic reservoir

Ideally, the reservoir should be high and narrow rather than shallow and broad. The oil level should be as high as possible above the opening to the pump suction line. This condition prevents the vacuum at the line opening from causing a vortex or whirlpool effect. Anytime you see a whirlpool at the suction line opening, the system is taking in air. As a rule of thumb, the reservoir level should be two to three times the pump output per minute.

By this rule which works well for stationary machinery, a 20-gallon per minute (gpm) system would require a 40- or 60-gpm reservoir. However, this is not possible for mobile equipment. You are more likely to find a 20- or 30-gallon tank to support a 100-gpm system. This is possible because mobile systems operate intermittently rather than all the time. The largest reservoirs are on mobile equipment. These reservoirs may have a 40- or 50-gallon capacity, capable of handling more than 200-gpm output. The reservoir must be sized to ensure there is a reserve of oil with all the cylinders in the system fully extended. The reserve must be high enough to prevent a whirlpool at the suction line opening. Also, there must be enough space to hold all the oil when the cylinders retract with some space to spare for expansion of hot oil.

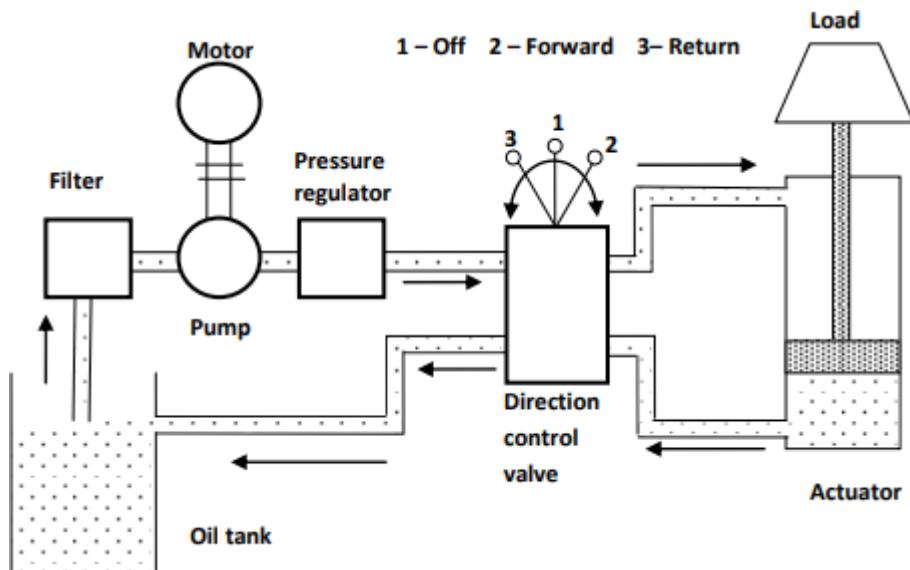
An air vent allows the air to be drawn in and pushed out of the reservoir by the ever changing fluid level. An air filter is attached to the air vent to prevent drawing

atmospheric dust into the system by the ever changing fluid level. A firmly secured filling strainer of fine mesh wire is always placed below the filler cap. The sight gauge is provided so the normal fluid level can always be seen, as it is essential that the fluid in the reservoir be at the correct level. The baffle plate segregates the outlet fluid from the inlet fluid.

Although not a total segregation, it does allow time to dissipate the air bubbles, lessen the fluid turbulence (contaminants settle out of non-turbulent fluid), and cool the return fluid somewhat before it is picked up by the pump.

Basic Components of a Hydraulic System

Hydraulic systems are power-transmitting assemblies employing pressurized liquid as a fluid for transmitting energy from an energy-generating source to an energy-using point to accomplish useful work. Figure 1.1 shows a simple circuit of a hydraulic system with basic components.



Functions of the components shown in Fig. 1.1 are as follows:

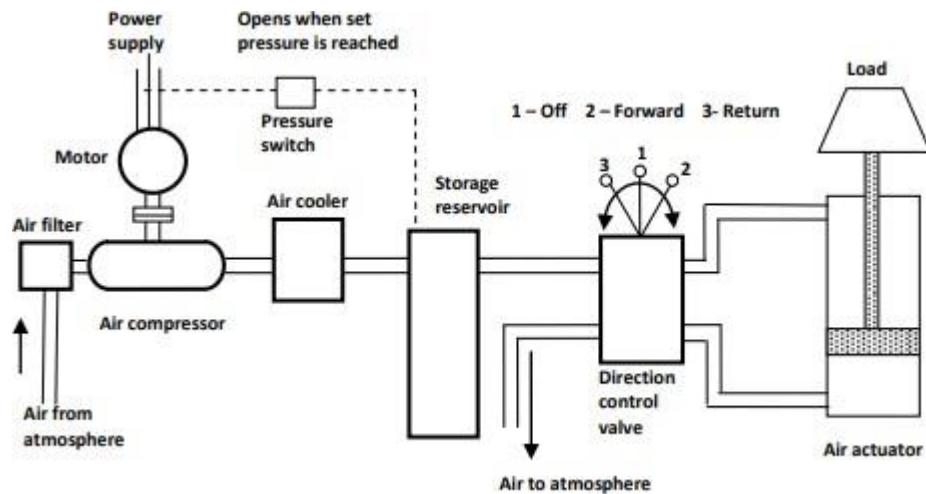
1. The hydraulic actuator is a device used to convert the fluid power into mechanical power to do useful work. The actuator may be of the linear type (e.g., hydraulic cylinder) or rotary type (e.g., hydraulic motor) to provide linear

or rotary motion, respectively.

2. The hydraulic pump is used to force the fluid from the reservoir to rest of the hydraulic circuit by converting mechanical energy into hydraulic energy.
3. Valves are used to control the direction, pressure and flow rate of a fluid flowing through the circuit. Motor 1 – Off 2 – Forward 3 – Return 3 2 1 Load Direction control valve Pump Oil tank Filter Actuator Pressure regulator.
4. External power supply (motor) is required to drive the pump.
5. Reservoir is used to hold the hydraulic liquid, usually hydraulic oil.
6. Piping system carries the hydraulic oil from one place to another.
7. Filters are used to remove any foreign particles so as to keep the fluid system clean and efficient, as well as to avoid damage to the actuator and valves.
8. Pressure regulator regulates (i.e., maintains) the required level of pressure in the hydraulic fluid. The piping shown in Fig. 1.1 is of closed-loop type with fluid transferred from the storage tank to one side of the piston and returned back from the other side of the piston to the tank. Fluid is drawn from the tank by a pump that produces fluid flow at the required level of pressure. If the fluid pressure exceeds the required level, then the excess fluid returns back to the reservoir and remains there until the pressure acquires the required level.

✓ Basic Components of a Pneumatic System

A pneumatic system carries power by employing compressed gas, generally air, as a fluid for transmitting energy from an energy-generating source to an energy-using point to accomplish useful work. Figure 1.3 shows a simple circuit of a pneumatic system with basic components.



The functions of various components shown in Fig. 1.3 are as follows:

1. The pneumatic actuator converts the fluid power into mechanical power to perform useful work.
2. The compressor is used to compress the fresh air drawn from the atmosphere.
3. The storage reservoir is used to store a given volume of compressed air.
4. The valves are used to control the direction, flow rate and pressure of compressed air.
5. External power supply (motor) is used to drive the compressor.
6. The piping system carries the pressurized air from one location to another.

D. Hydraulic and Pneumatic cylinders and pistons

Pneumatic cylinder(s) (sometimes known as air cylinders) are mechanical devices which use the power of compressed gas or air to produce a force in a reciprocating linear motion. Like hydraulic cylinders, something forces a piston to move in the desired direction.

Types

Although pneumatic cylinders will vary in appearance, size and function, they generally fall into one of the specific categories shown below. However, there are also numerous other types of pneumatic cylinder available, many of which are designed to fulfil specific and specialized functions.

1. Single-acting cylinders

Single-acting cylinders (SAC) use the pressure imparted by compressed air to create a driving force in one direction (usually out), and a spring to return to the "home" position.

2. Double-acting cylinders

Double-acting cylinders (DAC) use the force of air to move in both extends and retract strokes. They have two ports to allow air in, one for outstroke and one for in stroke.

3. Multi-stage, telescoping cylinder

Also known as telescopic cylinders can be either single or double-acting. The telescoping cylinder incorporates a piston rod nested within a series of hollow stages of increasing diameter.

Other types

Although SACs and DACs are the most common types of pneumatic cylinder, the following types are not particularly rare:

- Through rod air cylinders: piston rod extends through both sides of the cylinder, allowing for equal forces and speeds on either side.
- Cushion end air cylinders: cylinders with regulated air exhaust to avoid impacts between the piston rod and the cylinder end cover.
- Rotary air cylinders: actuators that use air to impart a rotary motion.
- Rod less air cylinders: These have no piston rod. They are actuators that use a mechanical or magnetic coupling to impart force, typically to a table or other body that moves along the length of the cylinder body, but does not extend beyond it.
- Tandem air cylinder: two cylinders assembled in series
- Impact air cylinder: high velocity cylinders with specially designed end covers that withstand the impact of extending or retracting piston rods.

An actuation device that makes use of a pressurized hydraulic fluid is known as a hydraulic pump. This mechanism is used for producing linear motion and force in applications that transfer power. In other words, a hydraulic cylinder converts the energy stored in the hydraulic fluid into a force used to move the cylinder in a linear

direction.

➤ **Classification of Hydraulic Cylinders According To Function:**

Single Acting Cylinders

In single acting cylinders the fluid is pressurized from only one side of the cylinder during both the expansion as well as the retraction process. A spring or an external load is used to return the cylinder top to its original position i.e. when pressure of the fluid is cut off.

Double Acting Cylinders

In the double acting cylinders, the pressure from the fluid is applied in both the directions. Single cylinders that consist of springs are not used in large stroke applications because there are inherent mechanical problems associated with the spring.

The double acting rods could be of two types:

- a. Single rod ended*
- b. Double rod ended*

➤ **Classification of Cylinders According to Specifications**

1. Plunger Cylinders

These cylinders are also known as Ram cylinders. These types of hydraulic cylinders are placed in an upright position. This is done so that once the supply of the fluid is stopped, the weight on the cylinder will make it return to its original position. The cylinders used in automobile service centers are a good example of the plunger cylinders.

2. Telescoping Cylinders

Telescopic cylinders are also known as multistage hydraulic cylinders. These cylinders have at the most six stages. These are specially used in applications where there is

less area. Telescopic cylinders can either be single action or double action. The stroke of these cylinders is long and is used in applications such as cranes and forklifts, etc.

3. Cable Cylinders

The cable cylinders can either be hydraulic or pneumatic powered cylinders that are of the double acting type. These cylinders have long strokes and produce moderate force. The cable cylinders can be operated in limited space.

4. Diaphragm Cylinders

Diaphragm cylinders are of two type's i.e. flat diaphragm and rolling diaphragm. These cylinders have zero leaks around the piston.

E. Pneumatic and Hydraulic Motors

➤ A pneumatic motor (air motor) or compressed air engine is a type of motor which does mechanical work by expanding compressed air. Pneumatic motors generally convert the compressed air energy to mechanical work through either linear or rotary motion. Linear motion can come from either a diaphragm or piston actuator, while rotary motion is supplied by either a vane type air motor, piston air motor, air turbine or gear type motor.

Classification of pneumatic motor

1. Linear

In order to achieve linear motion from compressed air, a system of pistons is most commonly used. The compressed air is fed into an air-tight chamber that houses the shaft of the piston. Also inside this chamber a spring is coiled around the shaft of the piston in order to hold the chamber completely open when air is not being pumped into the chamber.

2. Rotary vane motors

A type of pneumatic motor, known as a rotary vane motor, uses air to produce rotational motion to a shaft. The rotating element is a slotted rotor which is mounted on a drive shaft. Each slot of the rotor is fitted with a freely sliding rectangular vane. The vanes are extended to the housing walls using springs, cam action, or air pressure,

depending on the motor design. Air is pumped through the motor input which pushes on the vanes creating the rotational motion of the central shaft. Rotation speeds can vary between 100 and 25,000 rpm depending on several factors which include the amount of air pressure at the motor inlet and the diameter of the housing.

➤ Hydraulic motor

Hydraulic motors are rotary actuators that convert hydraulic or fluid energy into mechanical power. They work in tandem with a hydraulic pump, which converts mechanical power into fluid, or hydraulic power. Hydraulic motors provide the force and supply the motion to move an external load.

Three common types of hydraulic motors are used most often today—gear, vane and piston motors—with a variety of styles available among them. In addition, several other varieties exist that are less commonly used, including gerotor or gerotor (orbital or roller star) motors.

✓ Three common designs

Keep in mind that the three different types of motors have different characteristics. Gear motors work best at medium pressures and flows, and are usually the lowest cost. Vane motors, on the other hand, offer medium pressure ratings and high flows, with a mid-range cost. At the most expensive end, piston motors offer the highest flow, pressure and efficiency ratings.



extenal gear motor



vane motor



variable, axial piston motor, with the bent- axial design



radial piston motor

- ✓ The function of a rotary actuator is to convert hydraulic energy into rotary mechanical energy.
- ✓ Rotary actuators are the hydraulic equivalents of electric motors. Hence rotary actuators are also called as *hydraulic motors*.
- ✓ The hydraulic motors are very much identical in construction and size to rotary type pumps. They work on exactly the reverse principle to that of rotary pumps.
- ✓ Instead of pushing the fluid as pumps do, in a hydraulic motor the rotating elements (i.e., vanes, gears, pistons, etc.) are pushed by the pressurized fluid. This enables the hydraulic motor to develop the necessary output torque and rotating motion.
- ✓ The hydraulic motors are usually rated/specify in terms of the torque developing capacity or differential pressure.

Classification of Hydraulic Motors

The hydraulic motors can be classified based on their degree of angular movement as :

1. Continuous rotary hydraulic motors, and
 - (i) Gear motors, (ii) Vane motors, and (iii) Piston motors.
2. Limited rotation hydraulic motors[†]
 - (i) Vane type, and (ii) Piston type.

Now we shall discuss the construction and operation of gear, vane, and piston motors, the following sections.

CONTINUOUS ROTARY HYDRAULIC MOTORS

1. Gear motors

Like gear pumps, gear motors are fixed displacement devices. Also, gear motors can be classified as external or internal gear units. External gear motors include the gear-on gear units such as the spur gear motor. Internal gear motors include the crescent seal types and the gerotor type unit.

- Construction and operation

The figure below illustrates the operation of a gear motor. In this type, both the gear

wheels are driven and one of the gear wheels has an extended shaft to provide output torque.

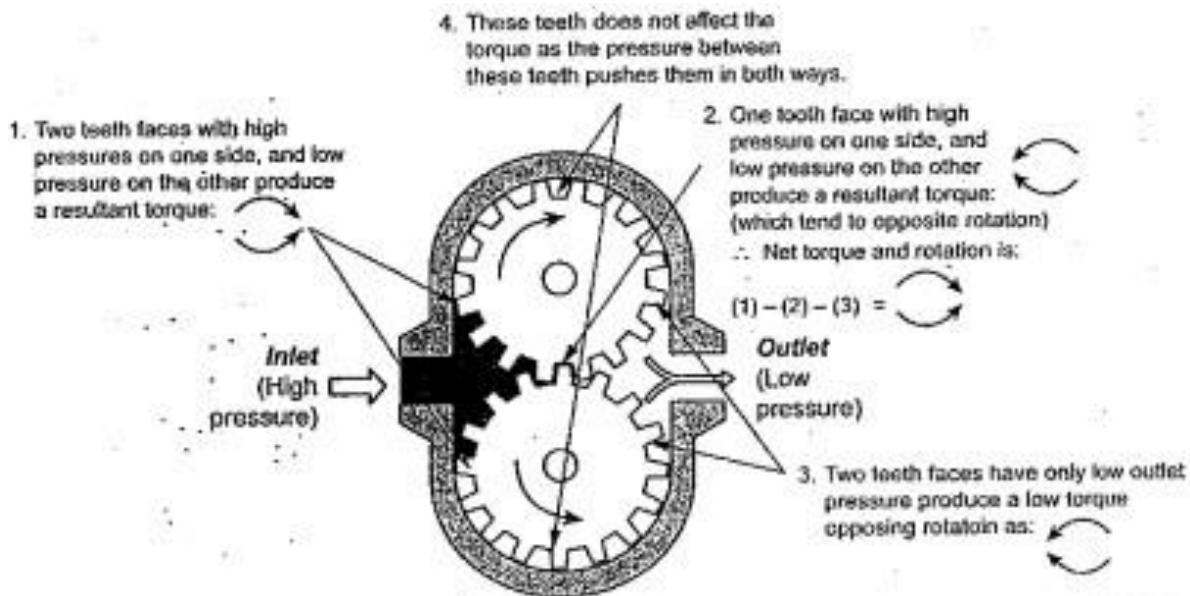


Figure: torque development by a gear motor

In the gear motor, rotary motion is produced by the unbalanced hydraulic forces on gear teeth. The hydraulic imbalance in a gear motor is caused by gear teeth unmeshing. During gear teeth unmeshing, all teeth subjected to system pressure are hydraulically balanced, for one side of one tooth on one gear. This imbalance of force on gears, as shown in Figure 1, develops the torque. It should be noted that the larger the gear tooth or higher the pressure, more is the torque produced.

Advantages of Gear Motors

The gear motors are simple in design, and very cheap in cost.

Disadvantages of Gear Motors

- ✓ Gear motors are subjected to relatively high internal leakage. Therefore, they are not suitable for high torque, low speed applications.
- ✓ The high pressure at the inlet, coupled with the low pressure at the outlet, generate very high bearing loads.

Ranges

- ✓ The gear motors are available for peak operating pressures upto about 125 bars, with rated capacities upto 10 Lps, and maximum speeds of about 3000 rpm.

VANE MOTORS

Vane motors work on the same principle as vane pumps in reverse. In these motors, the pressurised fluid acting on the vanes cause them to rotate and thus developing the torque output. They are suitable for low speed applications than gear motors.

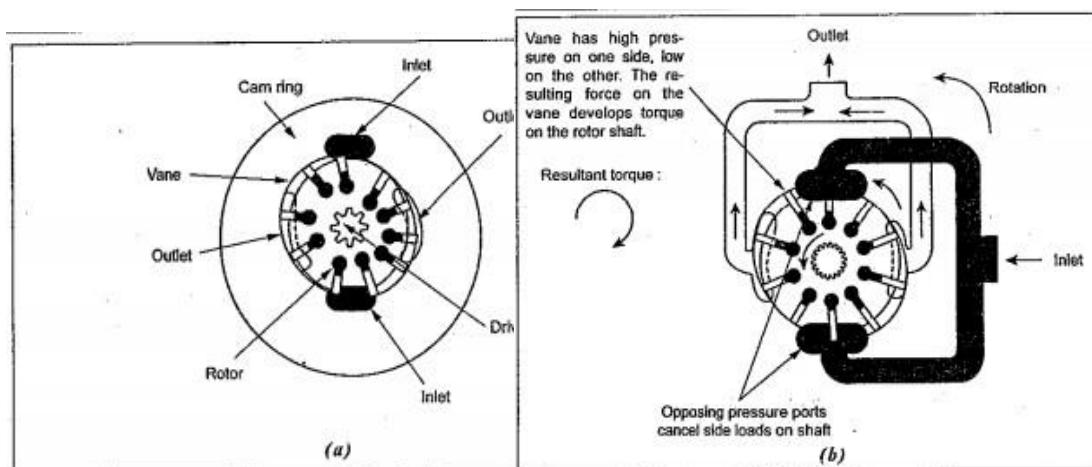


Figure : Operation of a balanced vane motor

Like vane pumps, vane motors can be classified as unbalanced or balanced vane motors. But most vane motors used universally are of the balanced-rotor type. Because hydraulic unbalance causes large radial bearing loads which limit the use of unbalanced vane motors to low pressure operation. Therefore most vane motors have a mechanical configuration similar to that of the balanced vane pump. Also balanced vane motors are fixed-displacement units.

Figure: illustrates the construction and operation of a balanced-type vane motor.

The vane motor produces torque by the hydraulic pressure that acts on the exposed surfaces of the vanes, which slide in and out of the rotor connected to the driver shaft. To accommodate starting and low-speed operation, it is usually necessary to provide a force, in addition to the centrifugal force, to move the vane radially outward. Springs are commonly used for this purpose. The larger the exposed area of the vane, or higher the pressure, more is the torque developed. Also, as the inlet connects to two opposing pressure passages, the side loads on the rotor are balanced with each other (Figure(b)).

PISTON MOTORS

- ✓ Piston motors are positive displacement motors which can develop an output torque at the shaft by allowing pressurised fluid to act on the pistons.
- ✓ The piston motors can be either fixed or variable-displacement devices.
- ✓ They are suitable for low speed, high torque traction applications such as earth-moving machinery, agricultural tractors, railway locomotive and other industrial applications.
- ✓ The piston motors are the most efficient and can operate at the highest speeds and pressures, when compared to gear and vane type motors.
- ✓ *Types* : Piston motors can be classified in terms of the piston motion as :
 1. Axial-piston motors, and
 2. Radial-piston motors.

Axial Type Piston Motors

Construction and Operation : The operation of an axial type piston motor is essentially the same as that of an axial piston pump except for the direction of flow

The pressurised liquid introduced through the motor inlet forces the piston assembly against the thrust cam or swash/wobble plate. The angular application of this force causes the plate to rotate and this rotation is transmitted by the shaft. The displacement can be varied by changing the angle of the thrust cam.

Radial Type Piston Motors

Construction and Operation : The operation of a radial type piston is also essentially the same as that of an radial piston pump except for the direction of flow

Fluid enters the piston chamber through a central eccentric cam. The piston is forced radially outward against the thrust ring, thereby producing a force tangent to the piston chamber. The resulting torque causes the shaft to rotate.

LIMITED ROTARY HYDRAULIC ACTUATORS

- ✓ The limited-rotation motors provide an oscillating power output. In other words, limited-rotation motors provide rotary output motion over a finite angle. Usually the rotation of the shaft of these motors is 90° , 180° , or 270° .

✓ **Types** : The two types of limited-rotation motors used to obtain an oscillatory output are :

1. Vane type limited rotation motors, and
2. Piston type limited rotation motors.

Vane Type Limited Rotation Motors

There are two types of limited rotation vane motors, the single-vane and the double-vane. Fig. (a) and (b) illustrate the operation of a typical single-vane and double-vane rotation motors respectively. In both the single- and the double-vane units, seals are maintained between the rotor and the barriers, and between the vanes and the housing.

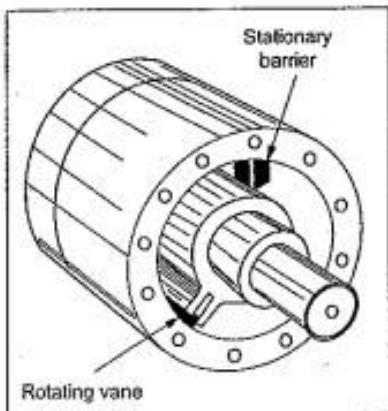


Fig. (a). Single-vane rotation motor

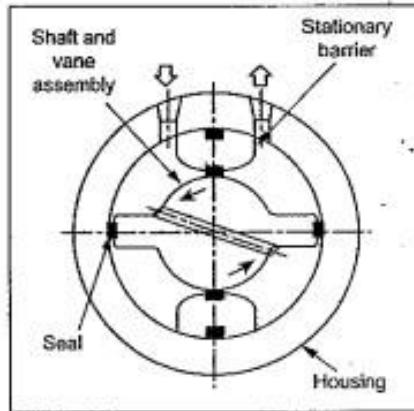


Fig.(b). Double-vane rotation motor

Single-Vane Rotation Motor

As shown in Fig(a) , the single-vane unit consists of a cylindrical housing, a shaft with a single vane, a barrier which limits the vane rotation, and end pieces which support the shaft. Pressurised liquid enters on the side of the vane, forcing the vane to rotate to the barrier. The single-vane unit produce the rotation of approximately 280° .

Double-Vane Rotation Motor

In the double-vane unit, the pressurised fluid enters on one side of a vane and is ported through the shaft to the corresponding side of the other vane, as shown in Fig (b) . A rotation of about 100° can be obtained with the double-vane unit.

Analysis of Torque Capacity in a Single-Vane Type Limited Rotation Motor

The torque producing capacity of a single-vane type limited rotation motion can be determined as below.

Let T = Torque developing capacity in N-m,
 F = Hydraulic force acting on vane in N,

P = Hydraulic pressure in N/m^2 ,

A = Surface area of vane in contact with liquid in m^2 ,

R_R = Outer radius of rotor in m,

R_V = Outer radius of vane in m, and

L = Width of vane in m.

$$\text{Area of vane surface, } A = (R_V - R_R) L$$

$$\begin{aligned}\text{The hydraulic force acting on the vane, } F &= \left\{ \begin{array}{l} \text{Hydraulic} \\ \text{pressure} \end{array} \right\} \times \left\{ \begin{array}{l} \text{Vane} \\ \text{surface area} \end{array} \right\} \\ &= P \times A = P (R_V - R_R) L\end{aligned}$$

We know that the torque developing capacity,

$$\begin{aligned}T &= \text{Vane force} \times \text{Mean radius of the vane} \\ &= [P (R_V - R_R) L] \left(\frac{R_V + R_R}{2} \right)\end{aligned}$$

or

$$T = \frac{P L}{2} (R_V^2 - R_R^2) L$$

We also know that,

$$\text{Volumetric displacement, } V_D = \pi (R_V^2 - R_R^2) L$$

Combining equations (6.8) and (6.9), we get

$$T = \frac{P \cdot V_D}{2\pi}$$

HYDRAULIC MOTOR PERFORMANCE

Like in hydraulic pumps, the performance of hydraulic motor is also evaluated by using volumetric, mechanical, and overall efficiencies

a. Volumetric Efficiency(η_{vol})

The volumetric efficiency of a hydraulic motor is the inverse of that for a pump. Mathematically,

$$\eta_{vol} = \frac{\text{Theoretical flow rate motor should consume}}{\text{Actual flow rate consumed by motor}} \times 100 = \frac{Q_T}{Q_A} \times 100$$

b. Mechanical Efficiency(η_{mech})

The mechanical efficiency of a hydraulic motor is the inverse of that for a pump. Mathematically,

$$\eta_{mech} = \frac{\text{Actual torque delivered by motor}}{\text{Torque motor should theoretically deliver}} \times 100 = \frac{T_A}{T_T} \times 100$$

where $T_A = \frac{\text{Actual power delivered by motor (watts)}}{\text{Angular speed of motor shaft (rad/s)}} = \frac{P}{\omega}$, and

$$T_T = \frac{V_D (m^3/rev) \times P (N/m^2)}{2\pi}$$

c. Overall Efficiency(η_o)

The overall efficiency of the hydraulic motor is the product of the volumetric and mechanical efficiencies, mathematically.

$$\eta_o = \eta_{vol} \times \eta_{mech}$$

Combining equations (6.11), (6.12), (6.13), and (6.14), we get

$$\eta_o = \frac{T_A (N\cdot m) \times \omega (rad/s)}{P (N/m^2) \times Q_A (m^3/s)} \times 100$$

Note The actual power delivered to a motor by the fluid is called by the term '*hydraulic power*'. Similarly, the actual power delivered to a load by a motor via a rotating shaft is called '*brake power*'.



✓ Theoretical learning Activity

- ✓ ask trainees to discussion on pneumatic/ hydraulic equipment
- ✓ Brainstorming on pneumatic/ hydraulic equipment



Practical learning Activity

- ✓ Practical exercises on identification of pneumatic/ hydraulic equipment



Points to Remember (Take home message)

the vast majority of pneumatic systems use compressed atmospheric air as the workingmedium

Reference:

Hydraulic, valves, pumps and accumulators, Q.S. Khan 2. Festo, hydraulics basic level textbook, D. Merkle, B.Schrader, M.Thomes, 2003 3. Basic pneumatics, Jay F.Hooper, 2003



Learning outcome 1.2 formative assessment

Written assessment

Question 1

What is a hydraulic cylinder used for, and what are some common features of a hydraulic cylinder?

Answer:

A hydraulic cylinder is a mechanical device that is used to convert hydraulic pressure into linear force and motion. It is commonly used in hydraulic systems to power machinery and equipment, such as construction equipment, manufacturing machines, and transportation vehicles. Some common features of a hydraulic cylinder include a piston, cylinder barrel, rod, seals, and mounting options.

Question 2

What is a pneumatic actuator used for, and what are some common types of pneumatic actuators?

Answer:

A pneumatic actuator is a device that uses compressed air to create mechanical motion. It is commonly used in pneumatic systems to control the movement of valves, dampers, and other mechanical components. Some common types of pneumatic actuators include diaphragm actuators, piston actuators, and rotary actuators. Diaphragm actuators are used for linear motion, while piston actuators are used for higher force applications. Rotary actuators are used for rotating or swiveling motion, such as controlling the position of a valve or a robotic arm

Question 3. Choose correct answers:

ii) What is a common type of hydraulic fitting used to connect hoses or pipes in a hydraulic system?

- A) Compression fitting
- B) Flare fitting
- C) Quick disconnect fitting
- D) JIC fitting

Answer: D) JIC fitting

ii) Which of the following is a common type of pneumatic valve used to control the flow of compressed air in a pneumatic system?

- A) Relief valve
- B) Check valve
- C) Solenoid valve
- D) Needle valve

Answer: C) Solenoid valve

Practical assessment

- Assessment tools
 - ✓ Assay
 - ✓ Task to be performed
 - ✓ Observation checklist

References:

Learning outcome 1.3: Arrange materials and tools into the working area



Duration: 3.hrs



Learning outcome 1.3, objectives:

By the end of the learning outcome, the trainees will be able to:

1. Select tools and materials needed for Pneumatic and Hydraulic system installation
2. Dispose Pneumatic and Hydraulic systems materials, tools and instruments in the installation area
3. To arrange tools and materials in the working area



Resources

Equipment	Tools	Materials
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Compressor - Hydraulic pumps - Hoses and tubing - Valves	Books - Internet - Manual - - Measurement instruments - Electromechanical tool kit -	Installation material and accessories
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Advance preparation:

- . Material must be available at the workplace



Indicative content 1.3.1: Selection of tools and materials

needed for Pneumatic and Hydraulic System installation

- Arrange materials and tools into the working area

Selection of tools and materials needed for Pneumatic and Hydraulic systems' installations

Before you make hydraulic or pneumatic installation you must select all appropriate tools and materials used according to the work to be done then after collect them together.

- ✓  Theoretical learning Activity

- ✓ Ask trainees to brainstorm on arrangement of tools and materials into the working area

- ✓  Practical learning Activity

- ✓ Trainees in pair arrange material and tools according to their use



Points to Remember (Take home message)

Before you make hydraulic or pneumatic installation you must select all appropriate tools and materials used



Indicative content 1.3.2: Disposition of Pneumatic and Hydraulic systems materials, tools and instruments in the installation area

Disposition of Pneumatic and Hydraulic systems materials, tools and instruments in the installation area

During installation of pneumatic and hydraulic system materials must be fixed in proper way, and tools must be used in proper manner and then keep it well after used in tool box.



✓ Theoretical learning Activity

- ✓ Group discussion on disposing of tools and materials into the working area



✓ Practical learning Activity

- ✓ Practical exercises on Selection of tools and materials needed on the workplace



Points to Remember (Take home message)

During installation of pneumatic and hydraulic system materials must be fixed in proper way, and tools must be used in proper manner



Indicative content 1.3.3: Techniques of arrangement of tools and materials in the working area

Techniques of arrangement of tools and materials in the working area

The first you must know what you are going to do, select materials to be used, select tools to be used, fix all materials, connect the circuit, test and operate the system.



✓ Theoretical learning Activity

- ✓ Group discussion on Techniques of arrangement of tools and materials into the working area



✓ Practical learning Activity

Practical exercises on arranging tools and materials needed on the workplace



Points to Remember (Take home message)

The first you must know what you are going to do



Learning outcome 1.3 formative assessment

Written assessment

I .choose correct answers

1. Which of the following is NOT a good practice for arranging materials and tools in a working area?

- a) Group similar tools and materials together
- b) Store frequently used tools and materials within easy reach
- c) Keep the work area cluttered with unnecessary items
- d) Use shelves, cabinets, and other storage options to keep the area organized

Answer: c) Keep the work area cluttered with unnecessary items

2. Why is it important to arrange materials and tools in a working area?

- a) It makes the area look neat and tidy
- b) It helps to prevent accidents and injuries
- c) It makes it easier to find the right tool or material when needed
- d) All of the above

Answer: d) All of the above

Practical assessment

- Assessment tools
 - ✓ Assay
 - ✓ Task to be performed
 - ✓ Observation checklist

References: Hydraulic, valves, pumps and accumulators, Q.S. Khan 2. Festo, hydraulics basic level textbook, D. Merkle, B.Schrader, M.Thomes, 2003 3. Basic pneumatics, Jay F.Hooper, 2003

Learning outcome 1.4: Identify PPE (Personal Protective Equipment)



Duration:hrs



Learning outcome 1.4 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Select safety equipment used for Pneumatic / installations
2. Use safety equipment used for hydraulic and pneumatic systems
3. Handle safety equipment needed for hydraulic and pneumatic installation.



Resources

Equipment	Tools	Materials
- Overcoat and overall - Gloves - Safety shoes - Helmet - Earmuff - Goggles - Nose protection mask -	Cleaning cloth / brush	Books - Internet



Advance preparation:

- . PPE must be available at the workplace



Indicative content 1.4.1: Selection of safety equipment used

for Pneumatic / installations

- **Selection of safety equipment used for Pneumatic / Hydraulic systems' installations:**
 - ✓ As in other installation system like electricity need safety equipment during installation process also hydraulic and pneumatic system need safety equipment when you are install it or when you are in maintenance process.

A. Overcoat and overall

It is clothing that used to protect the personal for the harmful effect, especially works practical works like scientist, electricians, etc.

B. Gloves

Is Personal protective equipment (PPE) that protects the hand or part of the hand from hazards. It can additionally cover part of the forearm and arm.

C. Safety shoes

A pair of safety shoes (also known as safety boots) is personal protective equipment (PPE) for foot protection at workplaces. It prevents from getting foot injuries due to slippery surface, heavy falling or rolling objects, sharp piercing edges, pinch points, rotary machinery, hot objects, loops of ropes under tension, splinters, electricity, chemicals or even bad weather etc.

D. Helmet

Is personal protective devices that protect the head of personal from something which falls during the work.

E. Earmuff

Earmuffs are objects designed to cover a person's ears for hearing protection or for



warmth

F. Goggles

Goggles, or safety glasses, are forms of protective eyewear that usually enclose or protect the area surrounding the eye in order to prevent particulates, water or chemicals from striking the eyes.



G. Cleaning cloth / brush

Are tools used for cleaning dust in hydraulic or pneumatic installation it can be cloths or brush

H. Nose protection mask

It is personal protective equipment (mask) used to isolate nose produced by machines and other devices to the ears.



- ✓ Theoretical learning Activity
- ✓ Ask trainees to brainstorm about Safety equipment within groups



- ✓ Practical learning Activity
- ✓ Practical exercises on the use of Safety equipment



Points to Remember (Take home message)

hydraulic and pneumatic system need safety equipment when you are install it or when you are in maintenance process



Indicative content 1.4.2: Use of safety equipment used for
✓ hydraulic and pneumatic systems

Use of safety equipment used for hydraulic and pneumatic systems

PPE means personal protective equipment or equipment you use to guarantee your (own) safety.

Use PPE always and anywhere where necessary. Observe the instructions for use, maintain them well and check regularly if they still offer sufficient protection. But when do you use what type of protection?

These 7 tips will help you on your way.

1. SAFETY FOR THE HEAD



Wearing a **helmet** offers protection and can prevent head injuries. Select a sturdy helmet that is adapted to the working conditions. These days you can find many elegant designs and you can choose extra options such as an adjustable interior harness and comfortable sweatbands.

2. PROTECT YOUR EYES



The eyes are the most complex and fragile parts of our body. Each day, more than 600 people worldwide sustain eye injuries during their work. Thanks to a good pair of **safety glasses**, these injuries could be prevented. Do you come into contact with bright light or infrared radiation? Then **welding goggles or a shield** offer the ideal protection

3. HEARING PROTECTION



Do you work in an environment with high sound levels? In that case it is very important to consider hearing protection. **Earplugs** are very comfortable, but earmuffs are convenient on the work floor as you can quickly put these on or take them off.

4. MAINTAIN A GOOD RESPIRATION



Wearing a **mask** at work is no luxury, definitely not when coming into contact with hazardous materials. 15% of the employees within the EU inhale vapors, smoke, powder or dust while performing their job. **Dustmasks** offer protection against fine dust and other dangerous particles. If the materials are truly toxic, use a **full-face mask**. This adheres tightly to the face, to protect the nose and mouth against harmful pollution.

5. PROTECT YOUR HANDS WITH THE RIGHT GLOVES



Hands and fingers are often injured, so it is vital to protect them properly. Depending on the sector you work in, you can choose from gloves for **different applications**:

- protection against vibrations
- protection against cuts by sharp materials
- protection against cold or heat
- protection against bacteriological risks
- Protection against splashes from diluted chemicals.

6. PROTECTION FOR THE FEET



Even your feet need solid protection. **Safety shoes** (type Sb, S1, S2 or S3) and **boots** (type S4 or S5) are the ideal solution to protect the feet against heavy weights. An **antiskid sole** is useful when working in a damp environment, definitely if you know that 16,2% of all industrial accidents are caused by tripping or sliding. On slippery surfaces, such as snow and ice, **shoe claws** are recommended. Special socks can provide extra comfort

1. WEAR THE CORRECT WORK CLOTHING



Preventing accidents is crucial in a crowded workshop. That is why a good visibility at work is a must:

a **high-visibility jacket and pants made of a strong fabric** can help prevent accidents. Just like the handprotection, there are versions for different applications.

Summary of PPE



- **Selection of safety equipment used for Pneumatic / Hydraulic systems' installations:**
 - ✓ As in other installation system like electricity need safety equipment during installation process also hydraulic and pneumatic system need safety equipment when you are install it or when you are in maintenance process.
 - I. Overcoat and overall

It is clothing that used to protect the personal for the harmful effect,

especially works practical workslike scientist, electricians, etc.

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M. Earmuff

Earmuffs are objects designed to cover a person's ears for hearing protection or for warmth



N. Goggles

Goggles, or safety glasses, are forms of protective eyewear that usually enclose or protect the area surrounding the eye in order to prevent particulates, water or chemicals from striking the eyes.



O. Cleaning cloth / brush

Are tools used for cleaning dust in hydraulic or pneumatic installation it can be cloths or brush

P. Nose protection mask

It is personal protective equipment (mask) used to isolate nose produced by machines and other devices to the ears.



- ✓  Theoretical learning Activity

- ✓ Ask trainees to brainstorm about Safety equipment within groups

- ✓  Practical learning Activity
- ✓ Practical exercises on the use of Safety equipment



Points to Remember (Take home message)

Use PPE always and anywhere where necessary. Observe the instructions for use, maintain them well and check regularly if they still offer sufficient protection



Indicative content 1.4.3: Handling of safety equipment needed for hydraulic and pneumatic installation

Handling of safety equipment needed for hydraulic and pneumatic installation

We offer how you can use safety equipment properly during installation of hydraulic and pneumatic system without ignore any one safety procedure.



Theoretical learning Activity

- ✓ ask trainees to Brainstorm on Safety equipment within groups)



✓ Practical learning Activity

- ✓ Practical exercises on the use of Safety equipment



Points to Remember (Take home message)

use safety equipment properly during installation of hydraulic and pneumatic system without ignore any one safety procedure

Reference:

Hydraulic, valves, pumps and accumulators, Q.S. Khan 2. Festo, hydraulics basic level textbook, D. Merkle, B.Schrader, M.Thomes, 2003 3. Basic pneumatics, Jay F.Hooper, 2003



Learning outcome 1 formative assessment

Written assessment

I.

Question 1: What is Personal Protective Equipment (PPE)?

Answer 1: Personal Protective Equipment (PPE) refers to any equipment or clothing worn by an individual to protect them from hazards that may cause injury or illness in the workplace. PPE includes items such as gloves, safety glasses, respirators, hard hats, and safety shoes.

Question 2: What are some examples of PPE?

Answer 2: There are many different types of PPE, including:

- Eye protection (safety glasses, goggles, face shields)
- Hearing protection (earplugs, earmuffs)
- Respiratory protection (respirators, masks)
- Hand protection (gloves)
- Foot protection (safety shoes, boots)
- Head protection (hard hats)
- Body protection (safety vests, aprons, coveralls)
- Fall protection (harnesses, lanyards)

The type of PPE required will depend on the hazards present in the workplace, and it's important to select the appropriate PPE and ensure it is worn correctly to effectively protect against the identified hazards.

II. Choose correct answer

Question 1: Which of the following is an example of Personal Protective Equipment (PPE)?

- A) Fire extinguisher
- B) First aid kit
- C) Safety glasses
- D) Hazardous materials sign

Answer 1: C) Safety glasses. Safety glasses are an example of PPE that protects the eyes from hazards such as flying debris or splashing chemicals. A fire extinguisher, first aid kit, and hazardous materials sign are not examples of PPE.

Question 2: Which of the following is NOT a type of PPE?

- A) Gloves
- B) Hard hats
- C) Cones
- D) Respirators

Answer 2: C) Cones. Cones are not a type of PPE, but they can be used to mark off hazardous areas or create a barrier to prevent access to a hazard. Gloves, hard hats, and respirators are all examples of PPE that protect against hazards in the workplace.

Reference:

Hydraulic, valves, pumps and accumulators, Q.S. Khan 2. Festo, hydraulics basic level textbook, D. Merkle, B.Schrader, M.Thomes, 2003 3. Basic pneumatics, Jay F.Hooper, 2003

Learning outcome 1.5 Prepare the pipe way**Duration: 3 hrs****Learning outcome 1 objectives:**

By the end of the learning outcome, the trainees will be able to:

1. Identify technique of preparation of pipe way
2. Identify methods of tracing pipe ways
3. Identify techniques of drilling holes where necessary

**Resources**

Equipment	Tools	Materials
- Drilling equipment	- Measuring tools/instruments	Installation drawing

**Advance preparation:**

- . Different types of pipes must be available in the workplace
- . Prepare site to be used



Indicative content 1.5.1: Identification of technique of preparation of pipe way

Identify technique of preparation of pipe way

In installation process of hydraulic and pneumatic system we need pipe in order to transmit fluid power which is needed to perform a work so the techniques that followed to prepare the pipe way are:

1. *The first you must measure the length of pipes according to the position component used in installation*
2. *Mark where the pipes can be passed or fixed based on drawing or circuit designed*
3. *Clean the way where the pipes must be passed*
4. *Connect each pipes to its corresponding port*



✓ Theoretical learning Activity

- ✓ Ask learner to discussion on materials/tools to be used in group



✓ Practical learning Activity

- ✓ Trainees in pair perform Practical exercises on the use of drilling tools/equipment



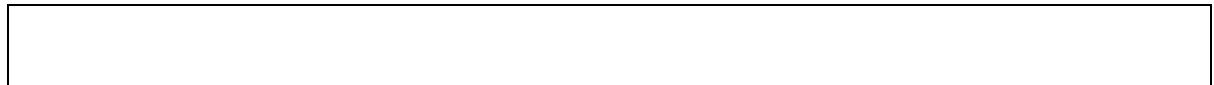
Points to Remember (Take home message)

In installation process of hydraulic and pneumatic system we need pipe in order to transmit fluid



Indicative content 1.5.2: Identification of methods of tracing

- ✓ pipe ways



- **Identify methods of tracing pipe ways**

All method of tracing pipe way depends on how circuit or system can be designed or drawn by designer and the trace where pipes are passed.

lc

✓ Theoretical learning Activity

- ✓ Ask trainees to brainstorm about methods of tracing pipe ways and installation positions



✓ Practical learning Activity

- ✓ Trainees in pair perform pipe tracing



Points to Remember (Take home message)

All method of tracing pipe way depends on how circuit or system can be designed



Indicative content 1.5.3: Identification of techniques of drilling holes

- Identification of techniques of drilling holes where necessary

The techniques used to drill holes where necessary are:

1. *Mark where you want to drill*
2. *select drilling tools, whether power or hand tools*
3. *select drilling bit according to diameter you need and also according to where you want to drill*



Theoretical learning Activity

- ✓ Group discussion on techniques of drilling holes



Practical learning Activity

- ✓ Practical exercises on the use of drilling tools/equipment



Points to Remember (Take home message)

The techniques used to drill holes where necessary are:

Mark where you want to drill ,select drilling tools, weather power or hand tools ,select drilling bit according to diameter you need and also according to where you want to drill



Indicative content 1.5.4: Cleaning the prepared way

Cleaning the prepared way

Before starting installation, you must clean the way or areas where you are going to install or to fix thehydraulic or pneumatic materials



Theoretical learning Activity

- ✓ Brainstorming on different pipe ways and installation positions



Practical learning Activity

- ✓ Each trainees Clean the prepared way



Points to Remember (Take home message)

Before starting installation, you must clean the way or areas where you are going to install



Learning outcome 1.5 formative assessment

Written assessment

Question 1: What is meant by preparing the pipe way?

Answer 1: Preparing the pipe way refers to the process of creating a clear and safe path for pipes to be installed or repaired. This may involve removing obstructions, leveling the ground, and excavating trenches or holes for the pipes to be laid.

Question 2: Why is it important to prepare the pipe way before installing pipes?

Answer 2: It is important to prepare the pipe way before installing pipes for several reasons. First, a clear and safe path ensures that the installation or repair work can be completed efficiently and effectively, without unnecessary delays or hazards. Second, preparing the pipe way can help to prevent damage to the pipes during installation or repair. Third, a well-prepared pipe way can make it easier to access and maintain the pipes in the future, which can help to extend their lifespan and reduce the need for costly repairs or replacement.

Question 1: It is not necessary to prepare the pipe way before installing or repairing pipes.

Answer 1: **False.**

Question 2: Preparing the pipe way can help to prevent damage to the pipes during installation or repair.

Answer 2: **True.**

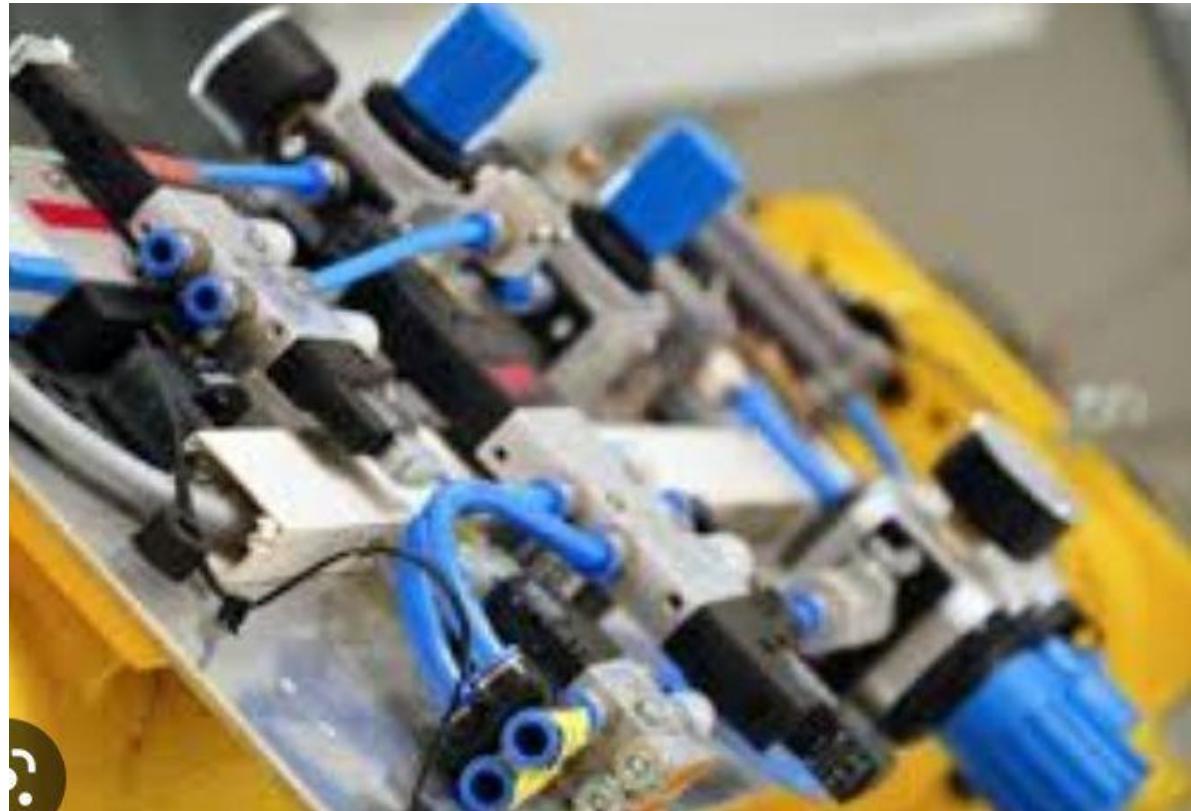
Practical assessment

- Assessment tools
 - ✓ Assay
 - ✓ Task to be performed
 - ✓ Observation checklist

References:

Hydraulic, valves, pumps and accumulators, Q.S. Khan 2. Festo, hydraulics basic level textbook, D. Merkle, B.Schrader, M.Thomes, 2003 3. Basic pneumatics, Jay F.Hooper, 2003

Learning Unit 2: Lay down pneumatic/hydraulic circuit devices



STRUCTURE OF LEARNING UNIT 2

Learning outcomes:

- 2.1 Identify equipment and accessories
- 2.2. Fix hydraulic/pneumatic Energy source production units
- 2.3. Install pipes and fittings
- 2.4. Connect hydraulic/pneumatic components

Learning outcome 2.1 Identify equipment and accessories



Duration: 3 hrs



Learning outcome 2.1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Review on types of equipment used in installation of pneumatic/ hydraulic systems
2. Review on types of accessories used in installation of pneumatic/ hydraulic systems
3. Identify Installation requirements for different installation of pneumatic/ hydraulic equipment



Resources

Equipment	Tools	Materials
Air compressor		Books
Hydraulic pump		Internet
Hoses and Fittings		pneumatic/ hydraulic drawings
Hydraulic Flanges,		
Valves		Manual
Electrical motors Reservoir /Tank		Magazine
Hydraulic and Pneumatic cylinders and pistons		



Advance preparation:

- . Pneumatic/Hydraulic equipment and accessories must be available at the workplace



Indicative content 2.1.1: Review on types of equipment used in installation of pneumatic/ hydraulic systems

Main components of Pneumatic system

- Prime mover (Electric motor)
- Compressor
- Directional control valve
- Air service unit (Filter, Regulator & Lubricator)
- Pneumatic actuator

Main components of hydraulic system

- Prime mover (Electric motor)
- Hydraulic pump
- Directional control valve
- Air service unit (Filter, Regulator & Lubricator)
- Hydraulic actuator
- Reservoir



✓ Theoretical learning Activity

- ✓ ask trainees to brainstorm about pneumatic/ hydraulic equipment and accessories

✓



✓ Practical learning Activity

✓ NA



Points to Remember (Take home message)

Main components of Pneumatic system

Prime mover (Electric motor),Compressor,Directional control valve, Air service unit (Filter, Regulator & Lubricator),Pneumatic actuator

Main components of hydraulic system

Prime mover (Electric motor),Hydraulic pump,Directional control valve,Air service unit (Filter, Regulator & Lubricator), Hydraulic actuator,Reservoir



Indicative content 2.1.2: Review on types of accessories used in installation of pneumatic/ hydraulic systems

types of accessories used in installation of pneumatic/ hydraulic systems

Pneumatic accessories keep their function to connect different parts,to tranfer the air pressure power or to lower the noise from the pneumatic system,so that the pneumatic systems can work smoothly and noiselessly.

Accessories :

Pump/motor adapter,driver couplings, resvoirs, breathes,sight level guage, pressure gauges,etc



✓ Theoretical learning Activity

- ✓ Ask trainee to Brainstorm on pneumatic/ hydraulic equipment and accessories



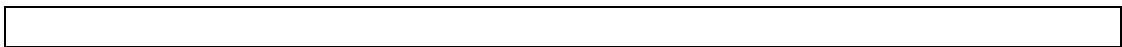
✓ Practical learning Activity

- ✓ NA



Points to Remember (Take home message)

Pneumatic accessories keep their function to connect different parts,to tranfer the air pressure power or to lower the noise from the pneumatic system



Indicative content 2.1.3: Installation requirements for different installation of pneumatic/ hydraulic equipment

Installation requirements for different installation of pneumatic/ hydraulic equipment

Most pneumatic system rely on a constant supply of compressed air to make them work



Theoretical learning Activity

- ✓ Group discussion on Installation requirements



- ✓ Practical learning Activity

- ✓ NA



Points to Remember (Take home message)

Most pneumatic system rely on a constant supply of compressed air to make them work

✓

Reference:

Hydraulic, valves, pumps and accumulators, Q.S. Khan 2. Festo, hydraulics basic level textbook, D. Merkle, B.Schrader, M.Thomes, 2003 3. Basic pneumatics, Jay F.Hooper, 2003

Q1. Give and explain at least five examples of hydraulic equipment

Answers

Hydraulic and Pneumatic Cylinders: These are mechanical devices that use hydraulic or pneumatic pressure to generate force and movement. They can be used to lift, push, pull, or move heavy loads in industrial applications.

Hydraulic and Pneumatic Pumps: These are devices that use hydraulic or pneumatic pressure to transfer fluid or gas from one place to another. They are used to create pressure in the hydraulic or pneumatic system and provide power to the system components.

Valves: These are mechanical devices that control the flow of fluid or gas in the hydraulic or pneumatic system. They can be used to regulate pressure, direction, or flow rate of the fluid or gas.

Fittings and Connectors: These are components that are used to connect different parts of the hydraulic or pneumatic system. They are available in various sizes, shapes, and materials to suit different applications.

Filters and Regulators: These are accessories that are used to maintain the quality and performance of the hydraulic or pneumatic system. Filters are used to remove contaminants from the fluid or gas, while regulators are used to control pressure levels within the system

Question 3 choose correct answer

i)What is the function of hydraulic and pneumatic cylinders in an industrial setting?

- A) To control the flow of fluid or gas
- B) To filter contaminants from the fluid or gas
- C) To generate force and movement
- D) To connect different parts of the system

Answer : C) To generate force and movement. Hydraulic and pneumatic cylinders are used to create mechanical force and movement in industrial applications.

ii)What is the purpose of a filter in a hydraulic or pneumatic system?

- A) To regulate pressure levels
- B) To control the direction of fluid or gas flow
- C) To connect different parts of the system
- D) To remove contaminants from the fluid or gas

Answer D) To remove contaminants from the fluid or gas. Filters are used to remove dirt, debris, and other contaminants from the hydraulic or pneumatic fluid or gas to prevent damage to the system components and maintain performance.

Learning outcome 2.2 : Fix hydraulic/pneumatic Energy source production units



Duration: 6 hrs



Learning outcome 2.2 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Preparation of basis for hydraulic and pneumatic production units
2. Types of units producing pneumatic/ hydraulic Energy
3. Methods of fixing hydraulics/ pneumatic Energy sources production units



Resources

Equipment	Tools	Materials
- Air compressor- Hydraulic pump - Electrical motors - Hydraulic and Pneumatic Reservoir & System Accessories - Accumulator - Pneumatic and Hydraulic Motors	- Electro-mechanical toolkit - Plumber toolkit - Hand Electrical drilling machines	Books - Internet - Manual- Oils

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Advance preparation:

- . Teacher must provide video for demonstration
- Tools and materials of pneumatic/hydraulic system must be available at the workplace



Indicative content 2.2.1: Preparation of basis for hydraulic and pneumatic production units

Preparation of basis for hydraulic and pneumatic production units

A hydraulic power unit (sometimes referred to as a hydraulic power pack) is a self-contained system that generally includes a motor, a fluid reservoir, and a pump. It works to apply the hydraulic pressure needed to drive motors, cylinders, and other complementary parts of a given hydraulic system. A hydraulic system employs enclosed fluid to transfer energy from one source to another, and subsequently create rotary motion, linear motion, or force. The power unit/pack provides the power needed for this transfer of fluid.

Pneumatic service units, normally consisting of filter regulator and fog lubricator, are intended for cleaning compressed air for workshop purposes from liquid and solid contamination, for pressure regulation and for providing a fine oil spray for the lubrication for cylinders, valves, pneumatic tools etc. When used correctly and in accordance with the respective operating condition, they maintain the performance level of pneumatic plant and increase its service life.

Pressure regulator System pressure in a compressed air installation fluctuates according to the size of the compressor (e.g. 6-10 or 10-16 bar, etc.). Pressure regulators reduce this fluctuating system pressure(upstream pressure) to the desired working pressure (downstream pressure) and maintain it constant.

Pressure setting Pull the adjusting knob, or release the lock nut (regulator unlocked) then, by tuning the knob, adjust the pressure regulator to the desired pressure, finally press the adjusting knob, or set the lock nut (regulator locked) down to fix the unit set at the desired pressure.

Lubricator The compressed air is enriched with a fine oil mist by the fog lubricator so that in this state it thus effects continuous and reliable lubrication of the pneumatically controlled compressed air tools, cylinders, valves, etc.

Filter Compressed air contains water condensate scale, rust particles etc., which attack pneumatically, controlled and actuated tools such as pneumatic cylinders, valves, etc. and which thus have disturbing effect on their function. For this reason the purification of compressed air is an indispensable necessity and is undertaken with the aid of filters.



Theoretical learning Activity

- ✓ Brainstorming on pneumatic/ hydraulic Energy production unit



Practical learning Activity

- ✓ Practical exercises on identification of pneumatic/ hydraulic Energy production units



Points to Remember (Take home message)

A hydraulic power unit (sometimes referred to as a hydraulic power pack) is a self-contained system that generally includes a motor, a fluid reservoir, and a pump.



Indicative content 2.2.2: Types of units producing pneumatic/ hydraulic Energy

Types of units producing pneumatic/ hydraulic Energy

A. Pump

A pump is a device that converts the mechanical energy into hydraulic energy for fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into different groups according to the mode of movement of the fluid.

Classification of pumps

Pumps can be classified as:

- ❖ Rotodynamic pump: Dynamic action of the fluid movement is due to

the mechanical energy imparted into the system by a rotating element.

- ❖ Reciprocating pump: The liquid is trapped in a cylinder by suction and then pushed against pressure using mechanical energy.
- ❖ Rotary positive displacement pump: The liquid is trapped in a volume and pushed out against pressure in a rotating environment.

Rotodynamic pumps, that is, centrifugal and axial flow pumps, can be operated at high speeds often directly coupled to electric motors. These pumps can handle small as well as very large volumes. They can handle corrosive and viscous fluids and even slurries. The overall efficiency is high for these pumps compared to other types of pumps. Hence, these pumps are the most popular pumps. Rotodynamic pumps can be of radial flow, mixed flow, and axial flow type according to the flow direction. Radial flow or purely centrifugal pumps generally handle lower volumes at higher pressures. Mixed flow pumps handle comparatively larger volumes at medium pressures. Axial flow pumps can handle very large volumes, but the pressure against which these pumps operate is very limited. The overall efficiency of these three types of pumps will depend on the flow and specific speed.

❖ Centrifugal pump

In a centrifugal pump, energy is imparted to the fluid by the centrifugal action of moving blades, that is, impeller vanes from the inner radius to the outer radius. The main components of centrifugal pumps are impeller, casing, and rotating shaft with gland and packing. Additionally, a suction pipe with a one-way valve (foot valve) and a delivery pipe with a delivery valve complete the system.

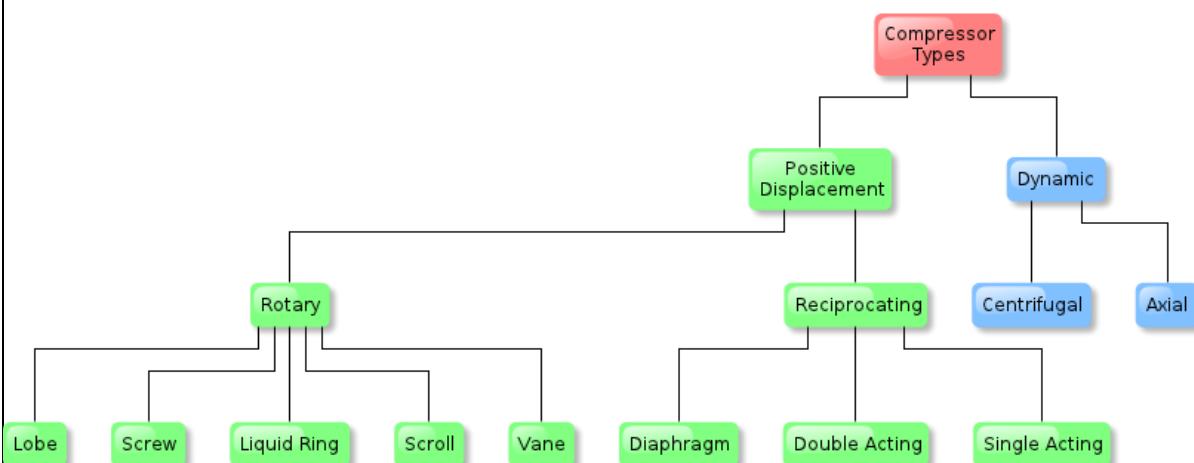
The liquid enters the eye of the impeller axially due to the suction created by the impeller motion. The impeller blades guide the fluid and impart momentum to the fluid, which increases the total head (or pressure) of the fluid, causing the fluid to flow out. The casing is a simple volute type or a diffuser. The volute is a spiral casing of gradually increasing cross-section. A part of the kinetic energy in the fluid is converted to pressure in the casing.

Gland and packing or so-called stuffing box is used to leakage along the driving shaft. By the use of the volute casing or diffuser the kinetic head can be recovered

as useful static head of the centrifugal pump unit.

B. Compressor

A compressor is a mechanical device that increases the pressure of a gas by reducing its volume. An aircompressor is a specific type of gas compressor. Compressors are similar to pumps: both increase the pressure on a fluid and both can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the volume of a gas. Liquids are relatively incompressible; while some can be compressed, the main action of a pump is to pressurize and transport liquids.



❖ Positive displacement

A positive displacement compressor is the system which compresses the air by the displacement of a mechanical linkage reducing the volume (since the reduction in volume due to a piston in thermodynamics is considered as positive displacement of the piston

- Reciprocating compressor

Reciprocating compressors use pistons driven by a crankshaft. They can be either stationary or portable, can be single or multi-staged, and can be driven by electric motors or internal combustion engines. Small reciprocating compressors from 5 to 30 horsepower (HP) are commonly seen in automotive applications and are typically for intermittent duty

An ionic liquid piston compressor, ionic compressor or ionic liquid piston pump is a hydrogen compressor based on an ionic liquid piston instead of a metal piston as in a piston-metal diaphragm compressor.

- Rotary screw compressors use two meshed rotating positive-displacement helical screws to force the gas into a smaller space. These are usually used for continuous operation in commercial and industrial applications and may be either stationary or portable.
- Rotary vane compressors consist of a rotor with a number of blades inserted in radial slots in the rotor. The rotor is mounted offset in a larger housing that is either circular or a more complex shape. As the rotor turns, blades slide in and out of the slots keeping contact with the outer wall of the housing.

The Rolling piston in a rolling piston style compressor plays the part of a partition between the vane and the rotor. Rolling piston forces gas against a stationary vane.

- A scroll compressor, also known as scroll pump and scroll vacuum pump, uses two interleaved spiral-like vanes to pump or compress fluids such as liquids and gases.
- A diaphragm compressor (also known as a membrane compressor) is a variant of the conventional reciprocating compressor. The compression of gas occurs by the movement of a flexible membrane, instead of an intake element. The back and forth movement of the membrane is driven by a rod and a crankshaft mechanism. Only the membrane and the compressor box come in contact with the gas being compressed

❖ Dynamic

Dynamic compressors depend upon the inertia and momentum of a fluid.

- Air bubble compressor also known as a trompe. A mixture of air and water generated through turbulence is allowed to fall into a subterranean chamber where the air separates from the water. The weight of falling water compresses the air in the top of the chamber.
- Centrifugal compressors use a rotating disk or impeller in a shaped housing to force the gas to the rim of the impeller, increasing the velocity of the gas. A diffuser (divergent duct) section converts the velocity energy to pressure energy.
- Diagonal or mixed-flow compressors are similar to centrifugal compressors, but have a radial and axial velocity component at the exit from the rotor. The

diffuser is often used to turn diagonal flow to an axial rather than radial direction.

- Axial compressors are dynamic rotating compressors that use arrays of fan-like airfoils to progressively compress a fluid. They are used where high flow rates or a compact design are required.



Theoretical learning Activity

- ✓ Group discussion on pneumatic/ hydraulic Energy production units



Practical learning Activity

- ✓ NA



Points to Remember (Take home message)

A pump is a device that converts the mechanical energy into hydraulic energy for fluids (liquids or gases), or sometimes slurries, by mechanical action



Indicative content 2.2.3: Methods of fixing hydraulics/ pneumatic Energy sources production units

Methods of fixing hydraulics/ pneumatic Energy sources production units

(Require a video to demonstrate Methods of fixing hydraulics/ pneumatic Energy sources production units)



✓ Theoretical learning Activity

- ✓ trainees makes a Physical demonstration on pneumatic/ hydraulic Energy production units



✓ Practical learning Activity

- ✓ Practical exercises on fixing hydraulics/ pneumatic Energy sources production units



Points to Remember (Take home message)

Four basic component of pneumatic/hydraulic system

Reservoir/receiver,pump/compressor,valve,cylinder

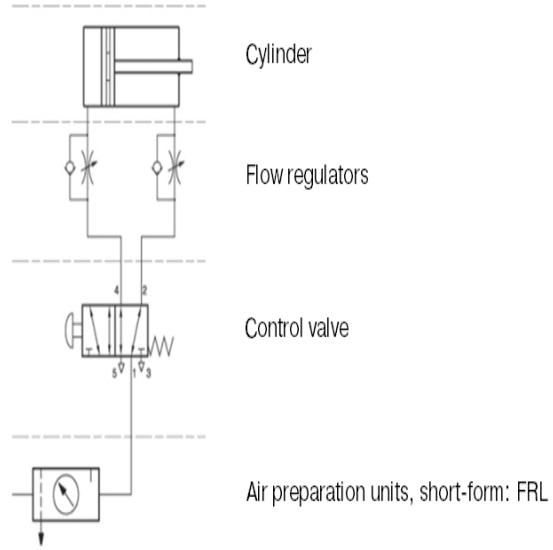
Reference:

Hydraulic, valves, pumps and accumulators, Q.S. Khan 2. Festo, hydraulics basic level textbook, D. Merkle, B.Schrader, M.Thomes, 2003 3. Basic pneumatics, Jay F.Hooper, 2003

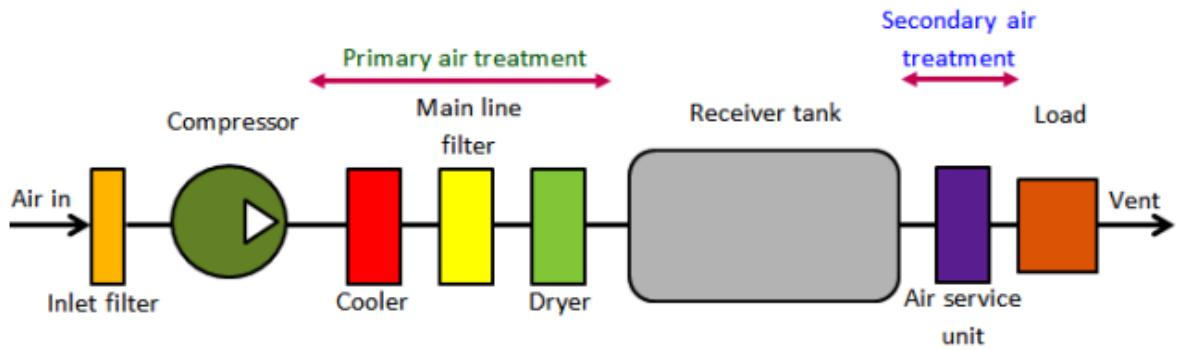
Q1.With the following elements connect them to make a circuit **(4marks)**

Cylinder, flow regulators, control valve, air preparation

Answer.



Q2: Observe the figure below and explain its working principle**(3marks)**



Answers

In the first stage, the large sized particles are prevented from entering the compressor by an intake filter. The air leaving the compressor may be humid and may be at high temperature. The air from the compressor is treated in the second stage. In this stage temperature of the compressed air is lowered using a cooler and the air is dried using a dryer. Also an inline filter is provided to remove any contaminant particles present. This treatment is called primary air treatment. In the third stage which is the secondary air treatment process, further filtering is carried out. A lubricator introduces a fine mist of oil into the compressed air. This will help in lubrication of the moving components of the system to which the compressed air will be applied.

Learning outcome 2.3 Install pipes and fittings



Duration: 5 hrs



Learning outcome 2.3 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify Types of pipes and fittings used in pneumatic and hydraulic system
2. Identify and select pipeline accessories
3. Apply Techniques of installation of pipeline in hydraulic/pneumatic systems



Resources

Equipment	Tools	Materials
-Hoses and Fittings -Couplings	Pliers- Screw drivers- wrench keys- Plumber tools	Books -Internet- pneumatic/ hydraulic drawings - Manual/Magazine- Flow sensors



Advance preparation:

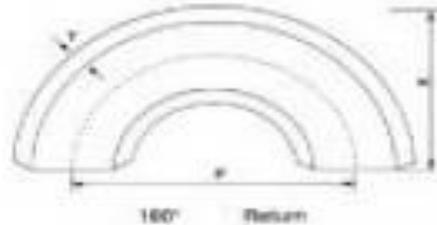
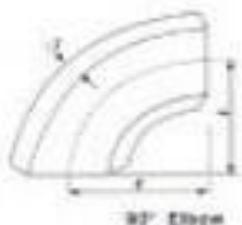
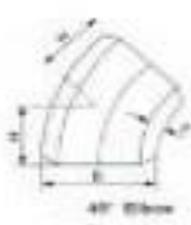
- . Workplace must be prepared
- Pipes and fitting must be available
- All trainee must have Drawings



Indicative content 2.3.1: Types of pipes and fittings used in pneumatic and hydraulic system

Types of pipes and fittings used in pneumatic and hydraulic system

1. **Rigid pipes** are sufficiently strong (both within the pipe wall and joints) to withstand most anticipated live and dead loads. A pipe's ability to resist imposed loads is improved by "better" embedment conditions.
2. **Flexible pipes** rely upon their deformation of the pipe from imposed loads to mobilize the support of embedment materials on both sides of the pipe. Their primary structural function is distributing the imposed vertical loads to the surrounding soil. Some standards define a flexible pipe as one that can deflect more than 2% without cracking. Only a small portion of imposed loads are actually carried by the flexible cracking.
3. **Gaskets:** Gaskets are used for sealing of flange joints. In general, gaskets should not be reused. Various types of gaskets are available depending upon their construction, materials, and features.
4. **Pipe Fittings:** hydraulic and pneumatic fittings have different shapes which allow rigid straight pipe to change both direction and diameter.
5. **Elbows:** Elbows are used to change the angle or direction of the pipe run. The most common elbows come in 90 degrees and 45 degree turns.



Street elbows:

One end of the fitting has male threads and the other end has female threads.

Street elbows are common in galvanized steel and copper pipe.



6. **Tee or T-fittings:** They allow for branch lines and they are shaped like the letter T. DWV tees are known as waste or sanitary Ts.



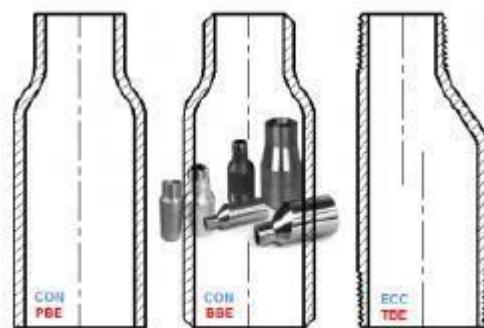
7. **Wyes:** Pronounced like the letter "Y" and used primarily to gain inside access to DWV systems.



8. **Couplings:** Couplings are used to join two straight pieces of pipe of the same diameter



9. **Reducers:** Reducers are used to join pipe of different diameters. Galvanized steel reducers are called bell reducers because they look like a bell.

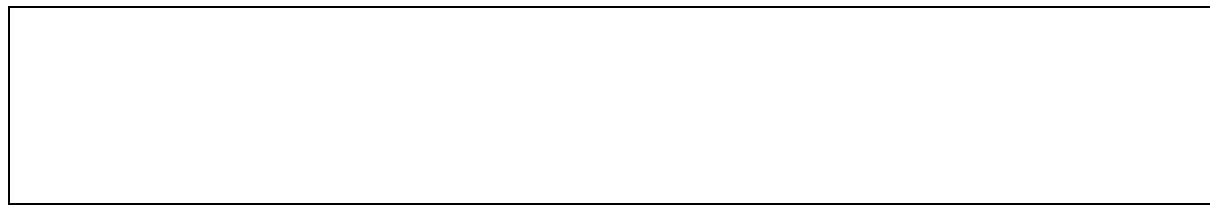


10. **Unions:** Unions are used to join pieces of pipe where pipes cannot be turned or when a piece of equipment may have to be removed for maintenance or replacement.



11. **Adaptor fittings:** Adaptor fittings are used to change the end of a non-threaded pipe to male or female threads as needed. Adaptors are commonly used in copper and plastic plumbing jobs.





✓  Theoretical learning Activity

- ✓ ask trainees to brainstorm about Types of pipes and fittings used in pneumatic and hydraulic system **within groups**



✓ Practical learning Activity

- ✓ Practical exercises on identification of pneumatic/ hydraulic Energy production units



Points to Remember (Take home message)

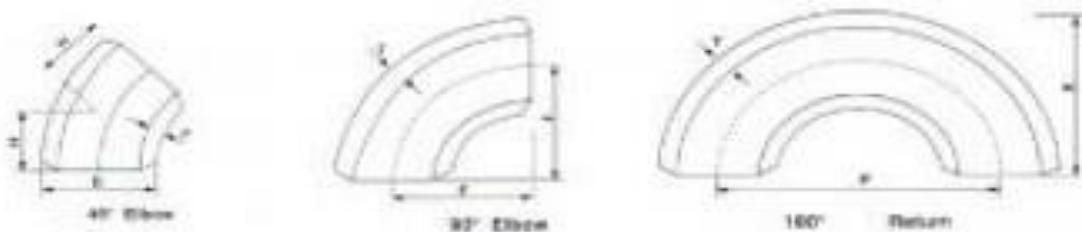
Fittings provide the essential link between tubes, hoses and other components in a pneumatic/hydraulic system



Indicative content 2.3.2: Identification and selection of pipeline accessories

Types of pipes and fittings used in pneumatic and hydraulic system

12. Rigid pipes are sufficiently strong (both within the pipe wall and joints) to withstand most anticipated live and dead loads. A pipe's ability to resist imposed loads is improved by "better" embedment conditions.
13. Flexible pipes rely upon their deformation of the pipe from imposed loads to mobilize the support of embedment materials on both sides of the pipe. Their primary structural function is distributing the imposed vertical loads to the surrounding soil. Some standards define a flexible pipe as one that can deflect more than 2% without cracking. Only a small portion of imposed loads are actually carried by the flexible cracking.
14. Gaskets: Gaskets are used for sealing of flange joints. In general, gaskets should not be reused. Various types of gaskets are available depending upon their construction, materials, and features.
15. Pipe Fittings: hydraulic and pneumatic fittings have different shapes which allow rigid straight pipe to change both direction and diameter.
16. Elbows: Elbows are used to change the angle or direction of the pipe run. The most common elbows come in 90 degrees and 45 degree turns.



Street elbows:

One end of the fitting has male threads and the other end has female threads.

Street elbows are common in galvanized steel and copper pipe.



17. Tee or T-fittings: They allow for branch lines and they are shaped like the letter T. DWV tees are known as waste or sanitary Ts.



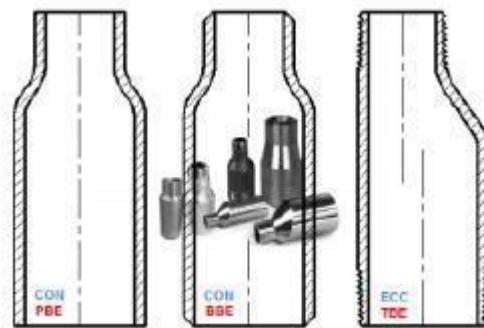
18. Wyes: Pronounced like the letter "Y" and used primarily to gain inside access to DWV systems.



19. Couplings: Couplings are used to join two straight pieces of pipe of the same diameter



20. Reducers: Reducers are used to join pipe of different diameters. Galvanized steel reducers are called bell reducers because they look like a bell.

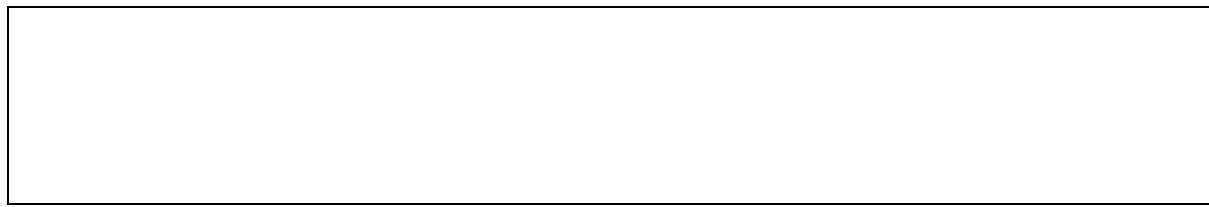


21. Unions: Unions are used to join pieces of pipe where pipes cannot be turned or when a piece of equipment may have to be removed for maintenance or replacement.



22. Adaptor fittings: Adaptor fittings are used to change the end of a non-threaded pipe to male or female threads as needed. Adaptors are commonly used in copper and plastic plumbing jobs.





✓  Theoretical learning Activity

- ✓ ask trainees to brainstorm about Types of pipes and fittings used in pneumatic and hydraulic system **within groups**



✓ Practical learning Activity

- ✓ Practical exercises on identification of pneumatic/ hydraulic Energy production units



Points to Remember (Take home message)

Fittings provide the essential link between tubes, hoses and other components in a pneumatic/hydraulic system

Reference: Hydraulic, valves, pumps and accumulators, Q.S. Khan 2. Festo, hydraulics basic level textbook, D. Merkle, B.Schrader, M.Thomes, 2003 3. Basic pneumatics, Jay F.Hooper, 2003



Learning outcome 2.3 formative assessment

Written assessment

Q1. Discuss on the preparation of pipe while working in pneumatic/hydraulic system installation

Answers

Pneumatic/hydraulic pipe provides transportation for fluid from one component to another

When choosing a pipe consider the pressure rating, temperature range, cover material and bend diameter. While working and commissioning the pneumatic/hydraulic you have to

- Install
- Rinsing, filling and air bleeding
- Cold commissioning, testing for pressure and tightness
- Warm commissioning, testing and adjustment at the highest load and at a minimum and maximum speeds and power
- Final checking, general inspection and release of the system

Q2. What are main properties of pipes in hydraulic system?

Answers

- **Material:** Pipes used in hydraulic systems are typically made of steel, stainless steel, or other high-strength materials that can withstand high pressures and resist corrosion.
- **Size:** The size of the pipe used in a hydraulic system depends on the flow rate and pressure of the fluid being transported. Smaller pipes are used for lower flow rates and pressures, while larger pipes are needed for higher flow rates and pressures.

- Wall thickness: The wall thickness of the pipe is an important factor in determining its strength and ability to withstand pressure. Thicker walls are needed for higher-pressure applications.
- Flexibility: Pipes used in hydraulic systems must be able to bend and flex to some extent without breaking or leaking. This is particularly important in systems where the pipes are subject to vibration or other forms of movement.
- Resistance to abrasion: Hydraulic fluids can be abrasive, so pipes used in hydraulic systems should be able to withstand wear and tear from the fluid flowing through them.
- Temperature resistance: Hydraulic fluids can also be hot or cold, so pipes used in hydraulic systems must be able to withstand a wide range of temperatures without cracking or becoming brittle.
- Compatibility: The pipe material must be compatible with the hydraulic fluid being used in the system to prevent chemical reactions that could damage the pipe or the fluid.

Reference:

Hydraulic, valves, pumps and accumulators, Q.S. Khan 2. Festo, hydraulics basic level textbook, D. Merkle, B.Schrader, M.Thomes, 2003 3. Basic pneumatics, Jay F.Hooper, 2003

Learning outcome 2.4: Connect hydraulic/pneumatic components



Duration: 6 hrs



Learning outcome 2.4 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Arrangement hydraulic/pneumatic component
2. Types of tools
3. Mounting of pneumatic/hydraulic components



Resources

Equipment	Tools	Materials
- Compressor - Hydraulic pumps - Hoses and tubing - Flanges - Valves - Air compressor - Hydraulic pump, - Valves - Electrical motor	Measurement instruments - Electromechanical tool kit - Installation material and accessories	Books - Internet - Magazine - Manual



Advance preparation:

- . Arrange tools and material to be used for Mounting of pneumatic/hydraulic components



Indicative content 2.4.1: Arrangement of hydraulic/pneumatic component

Arrangement of hydraulic/pneumatic component

As another system's component arranged before making installation also in hydraulic and pneumatics' component must be arranged when you are going to install the hydraulic or pneumatic system

Types of tools

- Electromechanical tool kit

Are set that hold all those tools that can be used in mechanical and electrical work

This kit includes the most complete selection of fastener tools we offer. Everything from cushion grip screwdrivers, fixed handle nut drivers, combination wrenches and socket set are included to make any install or repair go quicker and easier.

- Plumber tool kit

It is a set or bag that hold tools used to perform work related with plumbing such as, Allen wrench, tape measure, plier, etc.

- Couplings

A coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power.



✓ Theoretical learning Activity

- ✓ Brainstorming on Arrangement of hydraulic/pneumatic component
- ✓ Group discussion on Arrangement of hydraulic/pneumatic component



✓ Practical learning Activity

- ✓ Ask Trainees to arrange hydraulic/pneumatic component according to their use



Points to Remember (Take home message)

hydraulic and pneumatics' component must be arranged when you are going to install the hydraulic or pneumatic system



Indicative content 2.4.2: Types of tools

Types of tools

- Electromechanical tool kit

Are sets that hold all those tools that can be used in mechanical and electrical work

This kit includes the most complete selection of fastener tools we offer. Everything from cushion grip screwdrivers, fixed handle nut drivers, combination wrenches and socket sets are included to make any installation or repair go quicker and easier.

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It is a set or bag that holds tools used to perform work related with plumbing such as, Allen wrench, tape measure, plier, etc.

- Couplings

A coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power.



- ✓ Theoretical learning Activity
- ✓ Ask trainee to Brainstorm about tool used for Pneumatic and Hydraulic components



- ✓ Practical learning Activity

- ✓ Trainees in pair perform any task using required tools



Points to Remember (Take home message)

screwdrivers, fixed handle nut drivers, combination wrenches and socket set are included to make any installor repair go quicker and easier



Indicative content 2.4.3: Mounting of pneumatic/hydraulic components

Mounting of pneumatic/hydraulic components

Component used in pneumatic and hydraulic system must be fixed or mounted appropriately with safe



- ✓ Theoretical learning Activity
- ✓ ask trainees in groups to discuss on connection of Pneumatic and Hydraulic components

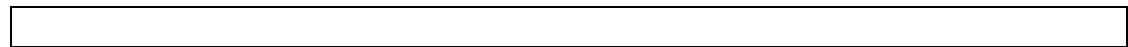


- ✓ Practical learning Activity
 - ✓ Trainees in pair perform connection of Pneumatic and Hydraulic components



Points to Remember (Take home message)

Component used in pneumatic and hydraulic system must be fixed or mounted appropriately with safe



Reference:

Hydraulic, valves, pumps and accumulators, Q.S. Khan 2. Festo, hydraulics basic level textbook, D. Merkle, B.Schrader, M.Thomes, 2003 3. Basic pneumatics, Jay F.Hooper, 2003



Learning outcome 1 formative assessment

Written assessment

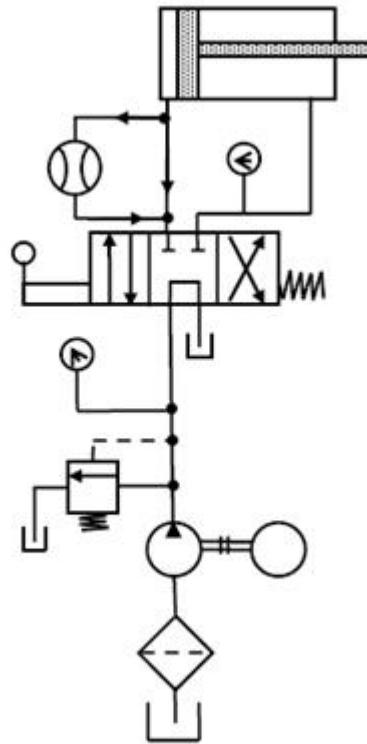
- Assessment tools

01. Draw a hydraulic circuit with the following situation

1. When the 4/3 valve is in its neutral position (tandem design), the cylinder is hydraulically locked and the pump is unloaded back to the tank.
2. When the 4/3 valve is actuated into the flow path, the cylinder is extended against its load as oil flows from port P through port A. Oil in the rod end of the cylinder is free to flow back to the tank through the four-way valve from port B through port T.
3. When the 4/3 valve is actuated into the right-envelope configuration, the cylinder retracts as oil flows from port P through port B. Oil in the blank end is returned to the tank via the flow path from port A to port T.

At the ends of the stroke, there is no system demand for oil. Thus, the pump flow goes through the relief valve at its pressure level setting unless the four-way valve is deactivated.

Answers



Q2. Give different process used for Connect hydraulic/pneumatic components

Answers

One common process for connecting hydraulic and pneumatic components is called "

- "Flaring". Flaring involves using a special tool to form a cone-shaped flare on the end of a tube or pipe. The flare is then connected to a fitting that has a matching cone-shaped seat. The two parts are then tightened together to form a seal.

Another process for connecting hydraulic and pneumatic components is called "

- "Swaging". Swaging involves using a tool to compress and deform the end of a tube or pipe to form a tight seal with a fitting. This process is commonly used for high-pressure applications.

Other processes for connecting hydraulic and pneumatic components include

- Welding, brazing, and threading. Welding involves melting and fusing the two components together using heat, while brazing involves melting a filler metal that joins the components together. Threading involves cutting threads onto the end of a tube or pipe and then screwing it into a matching fitting.

Practical assessment

- Assessment tools
 - ✓ Assay
 - ✓ Task to be performed
 - ✓ Observation checklist

References:

Learning Unit 3: Test and commission



STRUCTURE OF LEARNING UNIT

Learning outcomes:

- 3.1 Prepare the test protocol
- 3.2. Identify testing instruments
- 3.3. Test the installation
- 3.4. Carry out the commissioning of the installation

Learning outcome 3.1 Prepare the test protocol



Duration: 5 hrs



Learning outcome 3.1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify required tests for hydraulic/pneumatic systems
2. Hoses, tubing and fittings: proof pressure, burst, impulse endurance
3. Pumps/compressors, motors: performance and durability
4. System simulation: field duty cycles, accelerated testing, failure analysis
5. System evaluation: on-vehicle performance, prototype testing, efficiency studies, lubrication studies
6. Reservoir/ tanks: proof pressure, burst, impulse endurance
7. Description of different steps for each test
8. Writing of the test protocol



Resources

Equipment	Tools	Materials
- Compressor - Hydraulic pumps - Hoses and tubing - Flanges - Valves - Air compressor - Hydraulic pump, - Valves - Electrical motor	Plier-wrench-mechanical tool kit	Books - Internet - Pneumatic/ hydraulic symbols drawings - Manual

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Advance preparation:

Provide a sample of a written test protocol

- The circuit to be test must be instelled before



Indicative content 3.1.1: Identify required tests for hydraulic/pneumatic systems

Test plans, also called test protocol, are formal documents that typically outline requirements, activities, resources, documentation and schedule to be completed. Some form of test plan should be developed prior to any test.

The key reasons for developing test plans are:

- Preparation: To assure that all reasonable aspects of running a test have been

considered.

- Communication and Training: To train those who need to assist with the test.
- Effectiveness: To provide a mechanism for outlining test needs, limitations (listing assumptions), and justification for purposes of setting expectations, acquiring resources, investigating unexpected results, assuring normalcy and effectiveness.
- Legal and Regulatory Prudence: To enable replication and protection of discoveries made, to mitigate potential litigation costs from use of those discoveries, and to help provide evidence to show regulatory bodies of efficacy. It is easy to see how test plans are an important and sensible part of performing an experiment. They save time and money, assist in getting the best results and can facilitate speedy test report writing.

Identify required tests for hydraulic/pneumatic systems:

For Actuators: proof pressure, burst, piston drag, cyclic (stroke) endurance, impulse endurance
For Valves: performance and durability

➤ Oil Coolers / Heat Exchangers: pressure drop, pressure, burst and/or shock
Pressure drop is defined as the difference in total pressure between two points of a fluid carrying network. A pressure drop occurs when frictional forces, caused by the resistance to flow, act on a fluid as it flows through the tube.

- Accumulators (piston, bladder, & diaphragm): proof pressure, burst, impulse endurance, performance
- Hydraulic/ Pneumatic Cylinder/Actuators rod seals and wipers: endurance per each oil category
- Hoses, tubing and fittings: proof pressure, burst, impulse endurance
- ✓ Pumps/compressors, motors: performance and durability



✓ Theoretical learning Activity

- ✓ Ask trainees to brainstorm about the test protocol in pneumatic/ hydraulic systems



Practical learning Activity

- ✓ Trainees in pair perform a test protocol



Points to Remember (Take home message)

Test plans, also called test protocol, are formal documents that typically outline requirements, activities, resources, documentation and schedule to be completed



Learning outcome 3.1 formative assessment

Q1. Discuss the required tests for hydraulic/pneumatic systems

- Actuators: proof pressure, burst, piston drag, cyclic (stroke) endurance, impulse endurance
- Valves: performance and durability
- Oil Coolers / Heat Exchangers: pressure drop, pressure, burst and/or shock
- Accumulators (piston, bladder, & diaphragm): proof pressure, burst, impulse endurance, performance
- Hydraulic/ Pneumatic Cylinder/Actuators rod seals and wipers: endurance per each oil category
- Hoses, tubing and fittings: proof pressure, burst, impulse endurance
- Pumps/compressors, motors: performance and durability
- Hoses, tubing and fittings: proof pressure, burst, impulse endurance
- Pumps/compressors, motors: performance and durability

- System simulation: field duty cycles

Learning outcome 3.2 Identify testing instruments



Duration: 5 hrs



Learning outcome 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Perform Pressure testing for hydraulic/pneumatic systems
2. Perform Flow testing
3. Perform Temperature and moisture testing
4. Identify Different methods of performing test in hydraulics and pneumatics systems



Resources

Equipment	Tools	Materials
Flow Meters - Flow sensors - Pressure switches, - Temperature transducers - Pressure gauge	- Hygrometer - Electromechanical tool kit	Books- Internet - Manual - Hydraulic/pneumatic



Advance preparation:

- . Testing instrument must be available at the workplace
- . Circuit to test must be installed before testing



Indicative content 3.2.1: Identify testing instruments

Identify testing instruments

- System simulation: field duty cycles, accelerated testing, failure analysis
- System evaluation: on-vehicle performance, prototype testing, efficiency studies, lubrication studies
- Reservoir/ tanks: proof pressure, burst, impulse endurance
- Writing of the test protocol

After conducting all test required you must write test protocol or test plan

- Pressure testing

Pressure switch

A pressure switch is a form of switch that closes an electrical contact when a certain set fluid pressure has been reached on its input. The switch may be designed to make contact either on pressure rise or on pressure fall. Pressure switches are widely used in industry to automatically supervise and control systems that use pressurized fluids.

Pressure gauge

Pressure gauge, instrument for measuring the condition of a fluid (liquid or gas) that is specified by the force that the fluid would exert.

- Flow testing

Flow sensors

These types of devices are going to be able to measure the flow rate, often for a fluid. These sensors are usually a part of a flow meter, which will be able to record the flow rate.

Hydraulic/pneumatic Flow Meters

A flow meter is a device used to measure the volume or mass of a gas or liquid. Flow meters are referred to by many names, such as flow gauge, flow indicator, liquid meter, flow rate sensor, etc.

- ✓ Temperature and moisture testing

➤ Thermometer

A thermometer is a device that measures temperature or a temperature gradient.

➤ Hygrometer

A hygrometer is an instrument used to measure the amount of humidity and water vapor in the atmosphere, in soil, or in confined spaces. Humidity measurement instruments usually rely on measurements of some other quantity such as temperature, pressure, mass, a mechanical or electrical change in a substance as moisture is absorbed.



✓ Theoretical learning Activity

- ✓ Ask trainees to brainstorm about instrumentation to be used in installation
- ✓ Group discussion on instruments to be used during installation



✓ Practical learning Activity

- ✓ Practical exercises on identification of instrument to be used in installation



Points to Remember (Take home message)

After conducting all test required you must write test protocol or test plan

Q1. State and explain at least 5 testing instrument

Answers

- Pressure Gauges: Pressure gauges are used to measure the pressure of hydraulic and pneumatic fluids. They typically consist of a dial that displays the pressure and a sensor that measures the pressure and sends a signal to the gauge.
- Flow Meters: Flow meters are used to measure the flow rate of hydraulic and pneumatic fluids. They can be used to monitor the performance of pumps, valves, and other components, and to ensure that the system is operating efficiently.
- Leakage Testers: Leakage testers are used to detect leaks in hydraulic and pneumatic systems. They can be used to identify leaks in pipes, fittings, valves, and other components, and to ensure that the system is operating safely and efficiently.
- Tension Meters: Tension meters are used to measure the tension or force in hydraulic and pneumatic hoses and cables. They can be used to ensure that hoses and cables are installed correctly and are not over-stressed, which can lead to failure and safety hazards.
- Temperature Sensors: Temperature sensors are used to measure the temperature of hydraulic and pneumatic fluids. They can be used to monitor the performance of cooling systems, to ensure that fluids are not overheating, and to detect potential problems before they cause damage to the system.

Learning outcome 3.3 Test the installation



Duration: 5 hrs



Learning outcome 3.3 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Checking the compliance of installation with pneumatic/ hydraulic drawings
2. Apply Safety requirement for pressure testing in pneumatic and hydraulic systems
3. Test Components/devices and connectors failure
4. Fillind up the test report/protocol



Resources

Equipment	Tools	Materials
Hygrometer- Thermometer	Electromechanical tool kit	Books - Internet - Manual



Advance preparation:

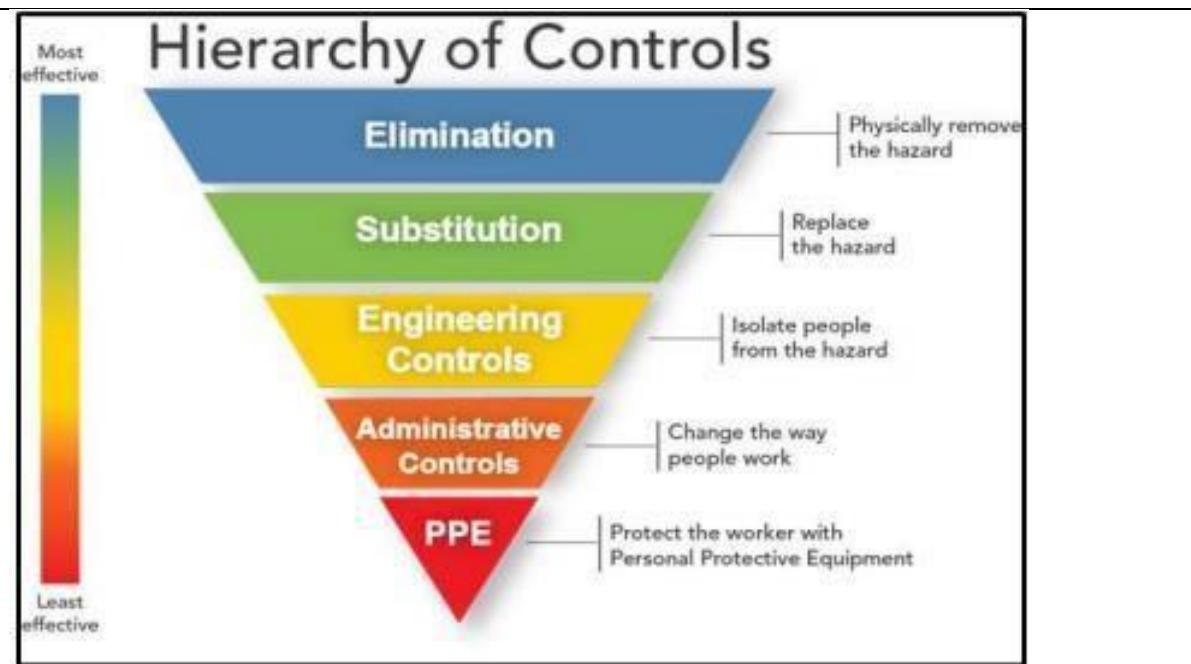
- . Testing instrument must be available at the workplace
- . Circuit to test must be installed before testing



Indicative content 3.3.1: Test the installation

Test the installation

- Checking of the compliance of installation with pneumatic/ hydraulic drawings After making installation you must check if your pneumatic or hydraulic system have the ability to act according to an order, or request that you need
- Safety requirement for pressure testing in pneumatic and hydraulic systems HAZARD ASSESSMENT AND CONTROL 2.1. When developing the test procedure, assess all procedure-specific hazards which may harm life, property or the environment and employ the National Institute for Occupational Safety and Health's Hierarchy of Controls to eliminate or manage each hazard, as shown below in the following flow chart



✓ **Test of Components/devices and connectors failure**

Test all components or devices connected in pneumatic or hydraulic circuit and connectors for making sure if each component or devices work properly without to fail

- Supply (pump/compressor) pressure

Before supplying the pressure in all hydraulic and pneumatic system you must check if the pressure of the pump or compressor is available and much with the required pressure.

✓ **Identification of state of valves /actuators/fittings**

Identify if, for example DCV is normally closed or normally open, also check if the actuators must able to operate when it is controlled, and fitting must be checked whether it is done correctly

- Test hose failure

Test if the hose can withstand the fluid pressure.

- Filling up of the test report/protocol

After finish all required test you fill up the test

report / or test protocol

Learning Outcome 3.4:

Carry out the commissioning of the installation

- Commissioning procedures

1. Analysis of the test results

When you are conducting commissioning you must analyse the result that you have.

2. Comparison of the test results with technical specifications

Then after analyzing the result you have you must compare that result that taken

3. Running of the hydraulic/pneumatic system and ensure it operates efficiently and effectivelyRun your system to be sure that if it is operating efficiently and effectively and accurately

4. Acceptance/recommendation of the hydraulic/pneumatic system

By observing weather your system is running/ operating efficiently and effectively you must accept thesystem to be used



✓ **Theoretical learning Activity**

✓ Group discussion on different types of tests

✓ Physical demonstration on testing of the hydraulic / pneumatics



✓ **Practical learning Activity**

✓ Practical exercises on faults diagnostic in hydraulic / pneumatics installations



Points to Remember (Take home message)

Test all components or devices connected in pneumatic or hydraulic circuit and connectors for making sure if each component or devices work properly without to fail



Learning outcome 3.3 formative assessment

Q1.What are the Safety requirements for pressure testing in pneumatic and hydraulic systems?

Answer:

- Wear personal protective equipment
- Not exceed maximum allowable testing pressure
- Examinations for leakage
- Heat treatment
- Repairs or additional after leaks testing
- Identify piping system pressure.
- Testing pressure shall not be less than 1.5 times of design pressure

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Learning Unit 4: Clean the workplace



STRUCTURE OF LEARNING UNIT

Learning outcomes:

1.1 Collect tools and equipment

- 1.2. Arrange non-used materials(consumables)
- 1.3. Clean tools and working area
- 1.4. Manage waste materials

Learning outcome 4.1 Collect tools and equipment



Duration: 3 hrs



Learning outcome 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify different tools/equipment used for cleaning
2. Identify Method of collecting tools and equipment used in hydraulic and pneumatic systems
3. Arrange tools/equipment according to their use



Resources

Equipment	Tools	Materials
- Lubricants - Blower machine - Hoses	Electromechanical tool kit - Plumber tool kit	Books - Internet - Manual - Sponge -- Brushes

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Advance preparation:

- . Cleaning material, tools and equipment must be available in the workshop



Indicative content 4.1.1: Identification of different tools/equipment used for cleaning

Tools/equipment used for cleaning

1. Brushes for cleaning sharp edges

Brushes for cleaning where we have sharp edges that can cut your hands.

2. Lubricants

Using lubricant for cleaning where we have bearings

3. Blower machines

Air blower machine is a simple and effective electrical device used in homes and industries to blow away dust from every nook and corner



4. Sponge

A sponge is a tool or cleaning aid made of soft, porous material. Typically used for cleaning impervious surfaces, sponges are especially good at absorbing water and water-based solutions, using sponge for cleaning hydraulic component





✓ Theoretical learning Activity

- ✓ Brainstorming on different tools/equipment used for cleaning
- ✓ Group discussion on different tools/equipment used for cleaning



✓ Practical learning Activity

- ✓ Each Trainee collect tools used for cleaning



Points to Remember (Take home message)

sharp edges, bearings, dust must be cleaned

Reference:

Angliss, W. (2019). Manual document used for cleaning workplace. In W. Angliss, *Manual document used for cleaning workplace* (p. 82).

CORP, S. E. (2006). 0505V BAR COMPRESSOR. In S. E. CORP, *SERVICE MANUAL* (p. 35).

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Learning outcome 4.1 formative assessment

LU4.1. Collect tools and equipment

Question1: What are some important factors to consider when collecting tools and equipment for a project?

Answer: When collecting tools and equipment for a project, there are several important factors to consider. First and foremost, you'll want to make sure that you have all of the tools and equipment necessary to complete the project. This means taking the time to carefully review the project plans and make a list of all the required tools and equipment.

Learning outcome 4.2: Arrange non-used materials(consumables)



Duration: 3.hrs



Learning outcome 4.2 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Select area for storing non consumable and non-used materials
2. Prioritize tools/materials and equipment according to their nature
3. Discard unused tools and equipment
4. Apply Disposal of waste materials.



Resources

Equipment	Tools	Materials
- Lubricants - Blower machine - Hoses - Recycle bin	- Brushes-Sponge - Electromechanical tool kit - Plumber tool kit -	Books - Internet - Manual



Advance preparation:

- . Cleaning material, tools and equipment must be available in the workshop



Indicative content 4.2.1: Selection of area for storing non-consumable and non-used materials

Selection of area for storing non-consumable and non-used materials

All those non-used materials or non- consumable materials must be stored according to their nature and stored in good area in order to protect them.



Theoretical learning Activity

- ✓ Brainstorming on Selection of area for storing non-consumable and non-used materials
- ✓ Group discussion on Selection of area for storing non-consumable and non-used materials



Practical learning Activity

- ✓ NA



Points to Remember (Take home message)

All those non-used materials or non- consumable materials must be stored according to their nature and stored in good area in order to protect them



Indicative content 4.2.2: Prioritize tools/materials and equipment according to their nature

Prioritize tools/materials and equipment according to their nature

In arrangement process tools, materials, and equipment are arranged according to their function prioritizing which one you need before others on the working area.

➡ Discard unused tools and equipment

Remove away tools and equipment which is not in service in order to differentiate with those working properly.

➡ Disposal of waste materials:

Prepare where the waste materials must be disposed/stored in order to protect personal and environment ➡ Lubricants

The lubricants can be used for cleaning your tools, lubricating the systems etc.



Theoretical learning Activity

- ✓ Ask trainees to brainstorm about Prioritize tools/materials and equipment according to their nature
- ✓ Group discussion on Prioritize tools/materials and equipment according to their nature



Practical learning Activity

- ✓ Trainees in groups Prioritize tools/materials and equipment according to their nature



Points to Remember (Take home message)

In arrangement process tools, materials, and equipment are arranged according to their function prioritizewhich one you need before others on the working area

Reference: Angliss, W. (2019). Manual document used for cleaning workplace. In W. Angliss, *Manual document used for cleaning workplace* (p. 82).
CORP, S. E. (2006). 0505V BAR COMPRESSOR. In S. E. CORP, *SERVICE MANUAL* (p. 35).
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Learning outcome 4.2 formative assessment

Question 1: Which of the following is the best way to arrange non-used materials (consumables) for a project?

- A) In a random order on a shelf
- B) In labeled containers on a shelf
- C) In a pile on the floor
- D) Scattered throughout the workspace

Answer: B) In labeled containers on a shelf. This allows for easy identification of materials and keeps them organized and easy to access.

Question 2: Why is it important to arrange non-used materials (consumables) before starting a project?

- A) It makes the workspace look neater

- B) It saves time by making materials easier to find
- C) It makes it easier to throw away excess materials
- D) It's not important to arrange materials beforehand

Answer: B) It saves time by making materials easier to find. When materials are arranged and labeled, it reduces the time spent searching for the correct materials during the project

Learning outcome 4.3 Clean tools and working area



Duration: 4 hrs



Learning outcome 4.3 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Apply Different methods of cleaning tools and equipment used in pneumatic/hydraulic installation
2. Apply Different methods of cleaning the working area in pneumatic/hydraulic installation
3. Disposal of waste materials according to their nature.



Resources

Equipment	Tools	Materials
<ul style="list-style-type: none"> - coolant - Hoses - Overcoat and overall - Gloves/ Helmet - Safety shoes - Earmuff/Goggles - Nose protection mask 	<ul style="list-style-type: none"> Electromechanical tool kit - Plumber tool kit 	<ul style="list-style-type: none"> Books - Internet - Manual - Lubricating oil- Cooling water- Cleaning cloth / Brush



Advance preparation:

- . Tools and area to be cleaned must be available



Indicative content 4.3.1: Clean tools and working area

Different methods of cleaning tools and equipment used in pneumatic/hydraulic installation:

- ✓ Air blowing
- ✓ Water
- ✓ Different detergents

Cleaning agent that helps to remove dirt and grease from porous surfaces (such as fabrics clothes, non- treated wood) and/ or non- porous surfaces (such us metals, plastics, treated wood). All detergents are made principally of soaps or surfactants.



Indicative content 4.3.2: Different methods of cleaning the working area in pneumatic/hydraulic installation

- Different methods of cleaning the working area in pneumatic/hydraulic installation:

- ✓ Air blowing

Air blower machine is a simple and effective electrical device used in homes and industries to blow away dust from every nook and corner

- ✓ Lubricating oil

Lubricating oil cleaning tools that is used to install the pneumatic/ hydraulic system

- ✓ Water

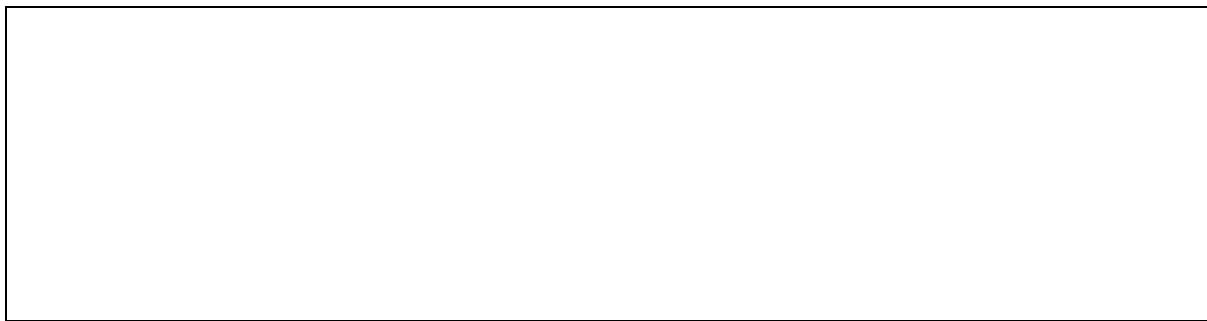
Water used for cleaning the working place after completing to make installation, and cleaning materials if it is applicable.

- ✓ Different detergents

Cleaning agent that helps to remove dirt and grease from porous surfaces (such as fabrics clothes, non- treated wood) and/ or non- porous surfaces (such us metals, plastics, treated wood). All detergents are made principally of soaps or surfactants.

- Disposal of waste materials according to their nature

Waste Materials must be disposed according to their nature because their property is different, so dispose on different area.



Theoretical learning Activity

- ✓ Group discussion on waste management of materials used in pneumatic and hydraulic



Practical learning Activity

- ✓ Practical exercises on waste management of materials



Points to Remember (Take home message)

Waste Materials must be disposed according to their nature because their property is different



Learning outcome 4.3 formative assessment

Question 1: True or False: It's not necessary to clean tools and working areas after each use.

Answer: False

Question 2: True or False: Cleaning tools and working areas can help prevent the spread of germs.

Answer: True

Question 3: True or False: It's okay to store tools and equipment without cleaning them first.

Answer: False

Learning outcome 4.4: Manage waste materials



Duration: 5 hrs



Learning outcome 4.4 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Arrange waste materials according to their nature
2. Dispose waste materials



Resources

Equipment	Tools	Materials
- Overcoat and overall - Gloves - Safety shoes - Helmet, Earmuff - Goggles - Nose protection mask	Cleaning cloth / brush - Recycle bin	books – Internet



Advance preparation:

- .Provide different waste to be disposed
- .The place to dispose waste must be available



Indicative content 4.4.1: Arrangement of waste materials

- ✓ **Arrangement of waste materials according to their nature**
What is waste?
Waste is any scrap materials, effluent or unwanted surplus substance and any substance which require to be disposed of as being broken, worn out, contaminated or otherwise spoiled.
There are four categories of potential waste.
 - Worn but functioning
 - Useable otherwise than by means of specialized waste recovery
 - Useable only by specialized waste recovery establishments
 - Unwanted , and which requires collection

Waste management or waste disposal is all the activities and actions required to manage waste from its inception to its final disposal. This includes amongst other things, Collection, transport, treatment and disposal of waste together with monitoring and regulations.



- Waste Hierarchy

The Waste Hierarchy must be considered when deciding what the best option is to manage a waste stream. This is a mandatory requirement of the Waste (England & Wales) Regulations 2011. It places more emphasis on waste prevention, and requires organisations to consider preparing waste for reuse, then opportunities for recycling, before options such as energy recovery. By law, we need to apply the Waste Hierarchy to ensure we minimise the impacts of our waste activities.

WASTE HIERARCHY



Figure: Waste Hierarchy Triangle

The Regulations stipulate that materials such as paper, metal, plastic and glass must be collected separately if it is necessary to encourage high quality of the recycling of the material.

- ✓  Theoretical learning Activity
- ✓ Brainstorming on waste management of materials used in pneumatic and hydraulic
- ✓ Group discussion on waste management of materials used in pneumatic

and hydraulic  Practical learning Activity

- ✓ Physical demonstration waste management of materials used in pneumatic and hydraulic
- ✓ Practical exercises on waste management of materials



Points to Remember (Take home message)

Waste is any scrap materials, effluent or unwanted surplus substance and any substance which require to be disposed of as being broken, worn out, contaminated or otherwise spoiled



Indicative content 4.4.2: Disposal of waste materials

Disposal of waste materials

The waste materials must be disposed in waste bin in order to protect environment, human hazard. Waste Segregation and Disposal

All waste prior to reuse, recycling or disposal should be held in secure, designated areas. All waste must be pre-treated (where required), segregated, clearly labelled and held in areas to prevent escape. Storage facilities for waste must be:

- ✓ Safe and secure from unauthorised entry
- ✓ Robust
- ✓ Covered and locked





lc

Theoretical learning Activity

- ✓ Brainstorming on waste management of materials used in pneumatic and hydraulic
- ✓ Group discussion on waste management of materials used in pneumatic



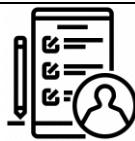
and hydraulic Practical learning Activity

- ✓ Physical demonstration waste management of materials used in pneumatic and hydraulic
- ✓ Practical exercises on waste management of materials



Points to Remember (Take home message)

The waste materials must be disposed in waste bin in order to protect environment, human hazard. Waste Segregation and Disposal



Learning outcome 4.4 formative assessment

Question 1: Which of the following is NOT an example of hazardous waste?

- A) Batteries
- B) Paints

C) Old clothes

D) Chemicals

Answer: C) Old clothes. While old clothes can be donated or recycled, they are not considered hazardous waste.

Question 2: Which of the following is the best way to dispose of hazardous waste? A) Throwing it in the trash B) Pouring it down the drain C) Taking it to a hazardous waste facility D) Burning it in a fire pit

Answer: C) Taking it to a hazardous waste facility. Hazardous waste requires special handling and should not be disposed of in the regular trash or down the drain.

Question 3: Which of the following is an example of a recyclable material?

A) Plastic bags

B) Food waste

C) Tissues

D) Styrofoam

Answer: A) Plastic bags. Plastic bags can be recycled and reused, whereas food waste, tissues, and Styrofoam cannot be recycled.

Question 4: Why is it important to manage waste materials properly?

A) To reduce environmental pollution

B) To save money on trash bags

C) To create a clutter-free workspace

D) To increase the amount of waste produced

Answer: A) To reduce environmental pollution. Managing waste materials properly helps to prevent pollution of the environment and can help to conserve natural resources

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