UNIT I

FLUID POWER PRINCIPLES AND FUNDEMENTALS

HYDRAULIC SYSTEMS

The extensive use of hydraulics to transmit power is due to the fact that a properly constructed hydraulic system possesses a number of favorable characteristics:

- A hydraulic system eliminates the need for complicated systems using gears, cams, and levers.
- Motion can be transmitted without the slack inherent in the use of solid machine parts.
- The fluids used are not subject to breakage as are mechanical parts.
- Hydraulic system mechanisms are not subjected to great wear.

If the system is well adapted to the work it is required to perform and is not misused, it can provide smooth, flexible, uniform action free of vibration and unaffected by variation of load. Hydraulic systems can provide widely variable motions in both rotary and straight-line transmission of power. The need for control by hand can be minimized. In addition, they are economical to operate.

Basic Principles of Hydraulics

The basic principles of hydraulics are few and simple:

- Liquids have no shape of their own.
- Liquids will **NOT** compress.
- Liquids transmit applied pressure in all directions.
- Liquids provide great increase in work force.

Pascal's Law

The foundation of modern hydraulics was established when Blaise Pascal, a French scientist, discovered the fundamental law for the science of hydraulics. Pascal's law states that pressure applied to a confined liquid is ***transmitted*** undiminished in all directions and acts with equal force on all equal areas, at right angles to those areas. According to Pascal's law, any force applied to a confined fluid i s transmitted in al l directions throughout the fluid regardless of the shape of the container. Consider t he effect of this in the systems shown in *Figure*. If there is ***resistance*** on the output piston (*View A*, piston 2) and the input piston is pushed downward, a pressure is created through the fluid which act s equally at right angles to surfaces in al l parts of the container.

Pressure

Pressure (P) is the amount of push or pull (force) applied to each unit area of the surface and is expressed in pounds per square inch (psi) or grams per square centimeter (gm/cm2). Pressure may be exerted in one direction, in several directions, or in all directions.

Force

Force (F) means a total push or pull. It is push or pull exerted against the total area of a particular surface and is expressed in pounds or grams.

Area

Area (A) represents the surface area acted upon by the hydraulic force.

Computing Force, Pressure, and Area

The formula used to compute force, pressure, and area in a hydraulic system can be described by force equals pressure times area and is written as: F=PxA.

Pressure equals force divided by area. By rearranging the above formula, this statement may be condensed into the following: P=F divided by A or P=F/A.

Since the area equals force divided by pressure, the formula for area is written as follows: A=F/P.

If the force is 100 pounds and the area of the input piston is 10 square inches, then pressure in the fluid is 10 psi (100 ÷ 10). It must be emphasized that this fluid pressure cannot be created without resistance to flow, which, in this case, is provided by the 100- pound force acting against the top of the output piston 2. This pressure acts on piston 2, so for each square inch of its area, it is pushed upward with the force of 10 pounds. In this case, a fluid column of a uniform cross section is used so the area of output piston 2 is the same as input piston 1, or 10 square inches; therefore, the upward force on output piston 2 is 100 pounds, the same as was applied to input piston 1. All that was accomplished in this system was to transmit the 100-pound force around a bend; however, this principle underlies practically all mechanical applications of fluid power.

Incompressibility and Expansion of Liquids

For all practical purposes, fluids are incompressible. Under extremely high pressures, the volume of a fluid can be decreased somewhat, though the decrease is so slight that it is considered to be negligible except by design engineers.

Liquids expand and contract because of temperature changes. When liquid in a closed container is subjected to high temperatures, it expands, and this exerts pressure on the walls of the container; therefore, it is necessary that pressure-relief mechanisms and expansion chambers be incorporated into hydraulic systems. Without these precautionary measures, the expanding fluid could exert enough pressure to ***rupture*** the system.

Transmission of Forces through Liquids

When the end of a solid bar is struck, the main force of the blow is carried straight through the bar to the other end (*Figure 9-2, View A*). This happens because the bar is rigid. The direction of the blow almost entirely determines the direction of the transmitted force. The more rigid the bar, the less force is lost inside the bar or transmitted outward at right angles to the direction of the blow.

When a force is applied to the end of a column of confined liquid (*Figure, View B*), it is transmitted straight through the other end and is also undiminished in every direction throughout the column—forward, backward, and sideways—so that the containing vessel is literally filled with pressure.

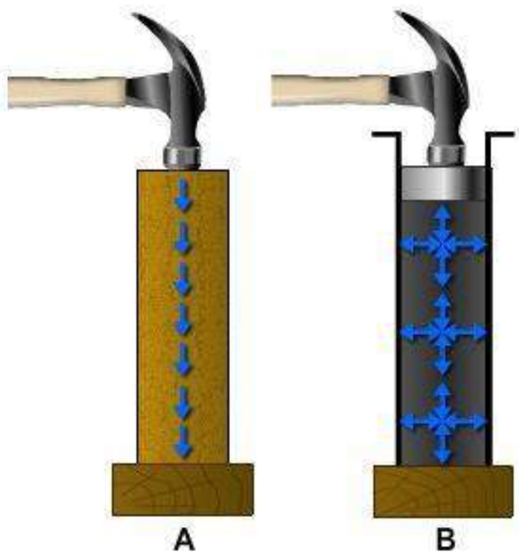


Figure . Transmission of force.

flat hose takes on a circular cross section when it is filled with water under pressure. The outward push of the water is equal in every direction.

Multiplication of Forces

Some hydraulic systems are used to multiply force. In *Figure*, notice that piston 1 is smaller than piston 2. Assume that the area of the input piston 1 is 2 square inches. With a resistant force on piston 2, a downward force of 20 pounds acting on piston 1 creates 10 psi (20 ÷ 2) in the fluid. Although this force is much smaller than the applied forces in *Figure*, the pressure is the same because the force is concentrated on a relatively small area. This pressure of 10 psi acts on all parts of the fluid container, including the bottom of output piston 2; therefore, the upward force on output piston 2 is 10 pounds for each of its 20 square inches of area, or 200 pounds (10 x 20). In this case, the original force has been multiplied tenfold while using the same.

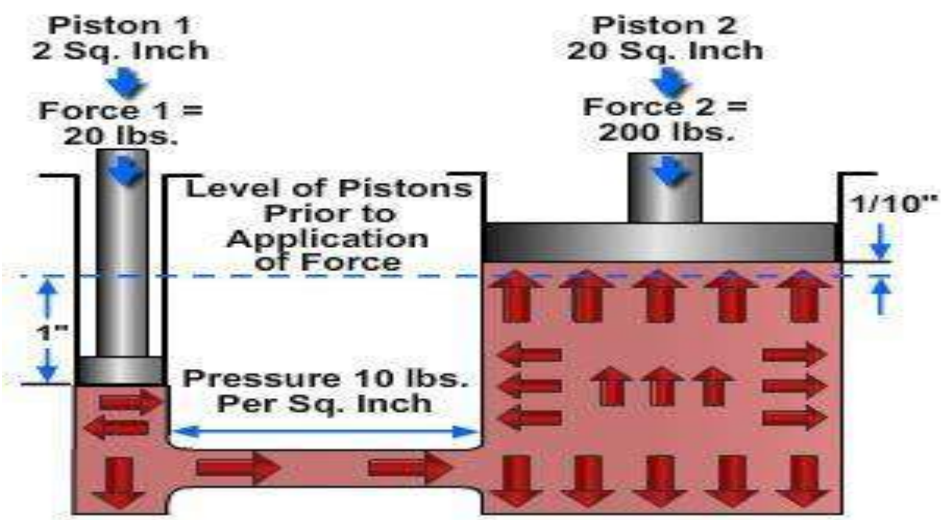


Figure. Multiplication of force in a hydraulic system.

pressure in the fluid as before. In any system with these dimensions, the ratio of output force to input force is always 10 to 1 regardless of the applied force; for example, if the applied force of input piston 1 is 50 pounds, the pressure in the system is increased to 25 psi. This will support a resistant force of 500 pounds on output piston 2. The system works the same in reverse. Consider piston 2 as the input and piston 1 as the output; then the output force will always be one tenth of the input force. Therefore, the first basic rule for two pistons used in a fluid power system is the force acting on each is directly proportional to its area, and the magnitude of each force is the product of the pressure and its area.

Types of Hydraulic Fluids

There have been many liquids tested for use in hydraulic systems. Currently liquids being tested include mineral oil, water, phosphate ester, water based ethylene glycol compounds, and silicone fluids. The three most common types of hydraulic fluids are petroleum-based, synthetic fire-resistant, and water based fire-resistant.

Petroleum-Based Fluids

The most common hydraulic fluids used in hydraulic systems are the petroleum-based oils. These fluids contain additives to protect the fluid from oxidation, to protect the metals from corrosion, to reduce the tendency of the fluid to foam, and to improve the viscosity.

Synthetic Fire-Resistant Fluids

Petroleum-based oils contain most of the desired traits of a hydraulic fluid. However, they are flammable under normal conditions and can become explosive when subjected to high pressures and a source of flame or high temperatures. Nonflammable synthetic liquids have been developed for use in hydraulic systems where fire hazards exist. These synthetic fire-resistant fluids are phosphate ester fire-resistant fluid, silicone synthetic fire-resistant fluid, and the lightweight synthetic fire-resistant fluid.

Hydraulic System Components

An arrangement of interconnected components is required to transmit and control power through pressurized fluid. Such an arrangement is commonly referred to as a system.

The number and arrangement of the components vary from system to system, depending on application. In many applications, one main system supplies power to several subsystems, which are commonly referred to as circuits. The complete system may be a small compact unit; more often, however, the components are located at widely separated points for convenient control.

The basic components of a fluid power system are essentially the same, regardless of whether the system uses hydraulic or pneumatic medium. The basic components are as follows:

- Reservoir
- Pumps
- Strainers and filters
- Valve Types
- Actuators
- Motors
- Accumulators
- Oil Cooler
- Cooling Fan
- Tubing, Piping, and Hose

- Connectors and fittings
- Sealing materials and devices

Several applications of fluid power require only a simple system, that is, a system which uses only a few components in addition to the basic components.

Reservoir

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

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

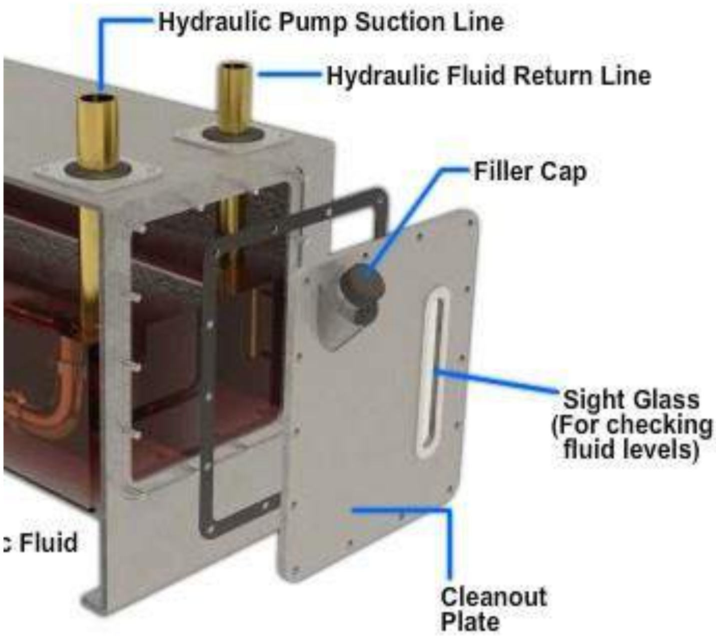


Figure. Typical hydraulic reservoir.

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.
Reservoirs used on CESE may vary considerably from that shown in *Figure*; however, manufacturers retain many of the noted features as possible depending on design limits and use.

FLUID POWER: It may be defined as the technology that deals with the generation, control and transmission of power using pressurized fluids

TYPES OF FLUID SYSTEMS:

Fluid Transport systems: The objective of the fluid transport systems is to transport fluids from one place to another place to achieve some useful purpose

Fluid Power systems: The Fluid power system is primarily designed to perform work. That is these systems use pressurized fluids to produce some useful mechanical movements to accomplish the desired work.

Method of transmitting power:

- Electrical power transmission
- Mechanical power transmission
- Fluid power transmission
  - Hydraulic power transmission
  - Pneumatic power transmission

ADVANTAGES OF FLUID POWER:

1. Easy and Accuracy to Control With the use of simple levels and push buttons, the fluid power system can facilitate easy starting, stopping, speeding up or slowing down and positioning forces that provide any desired power
2. Multiplication of small forces to achieve greater forces for performing work
3. It easily provides infinite and step less variable speed control which is difficult to obtain from other drives
4. Accuracy in controlling small or large forces with instant reversal is possible with hydraulic systems
5. Constant force is possible in fluid power system regardless of special motion requirements. Whether the work output moves a few millimeters or several meters per minute.
6. As the medium of power transmission is fluid, it is not subjected to any breakage of parts as in

mechanical transmission.

7. The parts of hydraulic system are lubricated with the hydraulic liquid itself.
8. Overloads can easily controlled by using relief valves than is possible with overload devices on the other systems. Air equipments reduces the danger of fire and explosion hazard in industries such as painting and mining.
9. Because of the simplicity and compactness the cost is relatively low for the power transmitted.
10. No need of lubrication

DISADVANTAGES:

1. Leakage of oil or compressed air
2. Busting of oil lines, air tanks
3. More noise in operation

APPLICATIONS OF FLUID POWER:

1. **Agriculture:** Tractors and farm equipments like ploughs, mowers, chemical sprayers, fertilizer spreaders, hay balers
2. **Automation:** Automated transfer machines
3. **Aviation:** Fluid power equipments like landing wheels on aeroplane and helicopter, aircraft trolleys, aircraft engine test beds.
4. **Building Industry:** For metering and mixing of concrete ingredients from hopper.
5. **Construction Equipment:** Earthmoving equipments like excavators, bucket loaders, dozers, crawlers, post hole diggers and road graders.
6. **Defense :** Missile-launch systems and Navigation controls
7. **Entertainment:** Amusement park entertainment rides like roller coasters
8. **Fabrication Industry:** Hand tools like pneumatic drills, grinders, bores, riveting machines, nut runners
9. **Food and Beverage:** All types of food processing equipment, wrapping, bottling
10. **Foundry:** Full and semi automatic molding machines, tilting of furnaces, die casting machines
11. **Glass Industry:** Vacuum suction cups for handling
12. **Material Handling:** Jacks, Hoists, Cranes, Forklift, Conveyor system

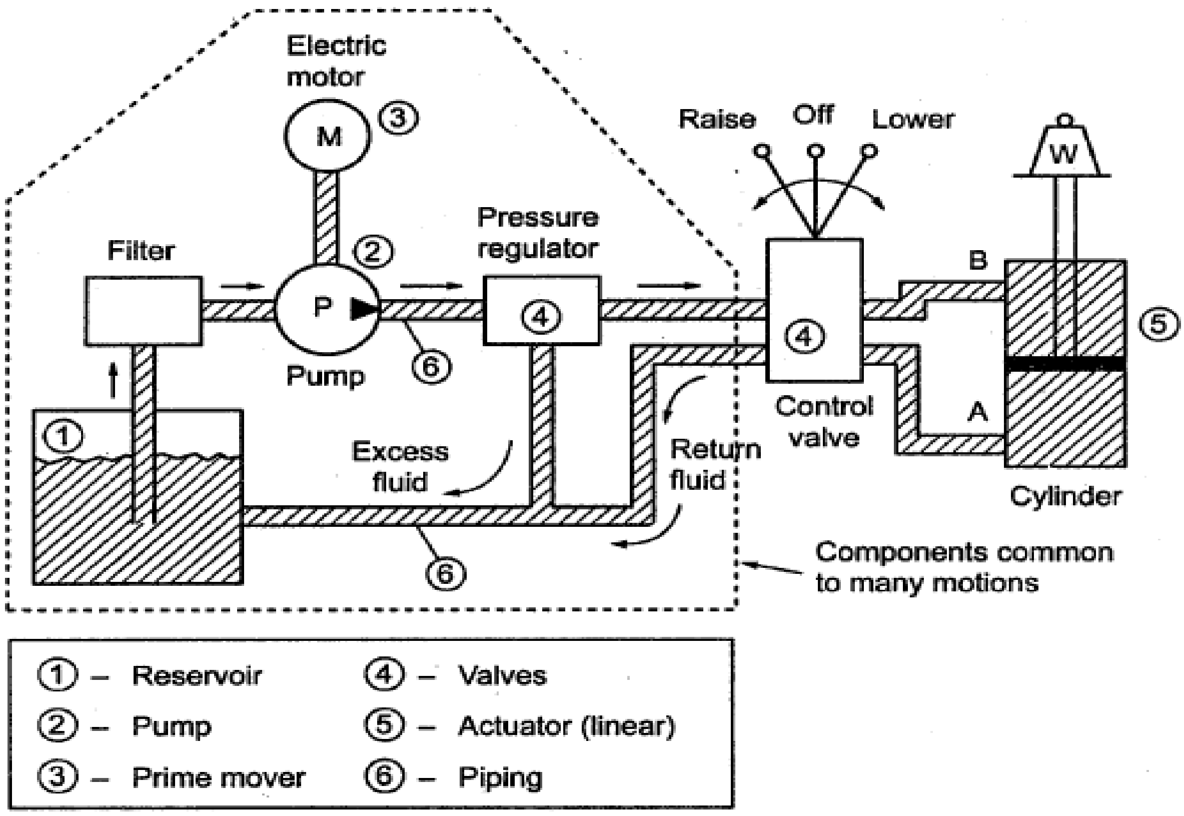
HYDRAULIC SYSTEM:

An electric motor drives the hydraulic pump so that the fluid is pumped from the tank at the required pressure. The fluid circulated into the system should be clean to reduce the wear of the pump and cylinder; hence a filter is used immediate to the storage tank. Since the pump delivers constant volume of fluid for each revolution of the shaft the fluid pressure rises indefinitely until a pipe or pump itself fails. To avoid this some kind of pressure regulators is used to spill out the excess fluid back to the tank. Cylinder movement is controlled by a 3 position change over control valve. One side of the valve is connected to a pressurized fluid line and the fluid retrieval line and other side of the valve is connected to port A and port B of the cylinder. Since the hydraulic circuit is a closed one, the liquid transferred from the storage tank to one side of the piston, and the fluid at the other side of the piston is retrieved back to the tank.

Raise: To lift the weight, the pressurized fluid line has to be connected to port A and the retrieval line has to be connected to the port B, by moving the valve position to "raise".

Lower: To bring down the weight, the pressurized fluid line has to be connected to port B and the retrieval fluid line has to be connected to port A, by moving the valve position to "lower".

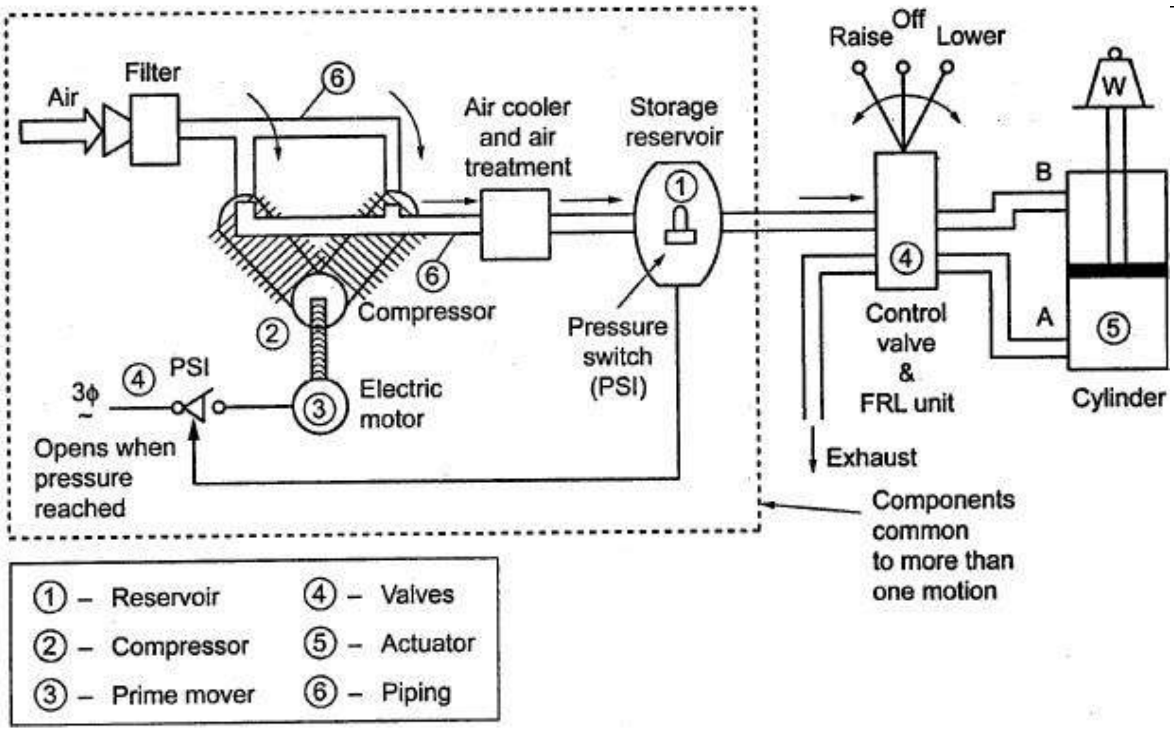
Off: The weight can be stopped at a particular position by moving the valve position to off. This disconnects the port A and port B from the pressurized line and the retrieval line which locks the fluid in the cylinder.



General arrangement of a hydraulic system

PNEUMATIC POWER SYSTEM:

Air is drawn from the atmosphere through the air filter and raised to the required pressure by an air compressor. Air contains significant amount of water vapour and also the air temperature is raised considerably by the compressor. So the air must be cooled before using it in the system, which results in condensation. The compressed air is stored in the reservoir which has water outlet at the bottom of the reservoir and a pressure switch to control the pressure of the compressed air. Pressure switch stops the motor when the required pressure is attained and starts the motor when the pressure falls down the mark. The cylinder movement is controlled by the pneumatic valve. One side of the pneumatic valve is connected to the compressed air line and silencers for the exhaust air and the other side of the valve is connected to port A and port B of the cylinder.



Raise: To lift the weight, the compressed air line has to be connected to port A and the port B is connected to the exhaust air line by moving the valve position to raise.

Lower: To bring down the weight, the compressed air line is connected to port B and the port A is connected to exhaust air line by moving the valve position to lower.

Off: The weight can be stopped at a particular position by moving the valve position to off. This disconnects the port A and port B from the pressurized line and the retrieval line which locks the air in the cylinder.

COMPARISON BETWEEN HYDRAULIC, PNEUMATIC AND ELECTRO MECHANICAL POWER SYSTEM

Hydraulic System	**Pneumatic System**	**Electro-Mechanical System**
Pressurized Liquid is used	Compressed Air is used	Energy is transmitted through mechanical components
Energy stored in Accumulator	Energy stored in Tank	Energy stored in Batteries
Hydraulic Valves are used	Pneumatic Valves are used	Variable Frequency drives
Transmission through Hydraulic cylinders, Actuators	Transmission through Pneumatic cylinders, Actuators	Transmission through Mechanical components like Gears, Cams

Hydraulic System	**Pneumatic System**	**Electro-Mechanical System**
Flow rate is 2 to 6 m/s	Flow rate is 20-40 m/s	Excellent with minimum loss
More Precision	Less Precision	More Precision
Large force can be generated	Limited force can be achieved	Large force can be realized but poor in efficiency
Medium Cost	High cost	Low Cost
Dangerous and fire hazardous because of leakage	Noisy	Easy to work

FUNCTIONS OF FLUIDS IN A FLUID POWER SYSTEM:

- Transfer fluid power efficiently
- Lubricate the moving parts
- Absorb, Carry and Transfer heat generated within the system
- Be compatible with hydraulic components
- Remain stable against physical and chemical changes

VARIOUS HYDRAULIC FLUIDS:

1. **Water:** The least expensive hydraulic fluid is water. Water is treated with chemicals before being used in a fluid power system. This treatment removes undesirable contaminates.

Advantages: Inexpensive, Readily available, Fire resistance

Disadvantage: No lubricity, Corrosive, Temperature limitations

2. **Petroleum Oils:** These are the most common among the hydraulic fluids which are used in a wide range of hydraulic applications. The characteristic of petroleum based hydraulic oils are controlled by the type of crude oil used. Naphthenic oils have low viscosity index so it is unsuitable where the oil temperatures vary too widely. The aromatics have a higher presence of benzene and they are more compatible with moderate temperature variation. Paraffinic oils have a high viscosity index and they are more suitable for the system where the temperature varies greatly.

Advantages: Excellent lubricity, Reasonable cost, Non-corrosive

Disadvantage: Tendency to oxidize rapidly, Not fire resistance

3. **Water Glycols:** These are solutions contains 35 to 55% water, glycol and water soluble thickener to improve viscosity. Additives are also added to improve anticorrosion, anti wear and lubricity properties.

Advantages: Better fire resistance, Less expensive, Compatible with most pipe compounds and seals

Disadvantage: Low viscosity, Poor corrosion resistance, not suitable for high loads.

4. **Water Oil Emulsions:** These are water-oil mixtures. They are of two types oil-in-water emulsions or water-in-oil emulsions. The oil-in-water emulsion has water as the continuous base and the oil is present in lesser amounts as the dispersed media. In the water-in-oil emulsion, the oil is in continuous phase and water is the dispersed media.

Advantages: High viscosity index, Oxidation stability, Film strength

Disadvantage: Depletion of water due to evaporation decreases fire resistance, Demulsification may be problem with water-in-oil emulsions.

5. **Phosphate Ester:** It results from the incorporation of phosphorus into organic molecules. They have high thermal stability. They serve as an excellent detergent and prevent building up of sludge.

Advantages: Excellent fire resistance, Good lubricity, Non corrosive

Disadvantage: Not compatible with many plastics and elastomers, Expensive

PROPERTIES OF FLUIDS:

1. Viscosity: It is a measure of the fluid's internal resistance offered to flow. Viscosity is the most important factor from the stand point of flow. If the viscosity of the hydraulic oil is higher than recommended, the system will be affected in the following manner.

1. The viscous oil may not be able to pass through the pipes.
2. The working temperature will increases because there will be internal friction.
3. The consumption of power will increase

If the viscosity of the oil is lesser than recommended then,

1. The internal and external leakage will increase
2. It cannot lubricate properly and will lead to rapid wear of the moving parts.

2. Viscosity Index: This value shows how temperature affects the viscosity of oil. The viscosity of the oil decreases with increase in temperature and vice versa. The rate of change of viscosity with temperature is indicated on an arbitrary scale called viscosity index (VI). The lower the viscosity index, the greater the variation in viscosity with changes in temperature and vice versa.

3. Oxidation Stability: The most important property of an hydraulic oil is its oxidation stability. Oxidation is caused by a chemical reaction between the oxygen of the dissolved air and the oil. The oxidation of the oil creates impurities like sludge, insoluble gum and soluble acidic products. The soluble acidic products cause corrosion and insoluble products make the operation sluggish.

4. Demulsibility: The ability of a hydraulic fluid to separate rapidly from moisture and successfully resist emulsification is known as Demulsibility. If oil emulsifies with water the emulsion will promote the destruction of lubricating value and sealant properties. Highly refined oils are basically water resistance by nature.

5. Lubricity: Wear results in increase clearance which leads to all sorts of operational difficulties including fall of efficiency. At the time of selecting a hydraulic oil care must be taken to select one which will be able to lubricate the moving parts efficiently.

6. Rust Prevention: The moisture entering into the hydraulic system with air causes the parts made ferrous materials to rust. This rust if passed through the precision made pumps and valves may scratch the nicely polished surfaces. So additives named inhibitors are added to the oil to keep the moisture away from the surface.

7. Pour Point: The temperature at which oil will clot is referred to as the pour point i.e. the lowest temperature at which the oil is able to flow easily. It is of great importance in cold countries where the system is exposed to very low temperature.

8. Flash Point and Fire Point: Flash point is the temperature at which a liquid gives off vapour in sufficient quantity to ignite momentarily or flash when a flame is applied. The minimum temperature at which the hydraulic fluid will catch fire and continue burning is called fire point.

9. Neutralization Number: The neutralization number is a measure of the acidity or alkalinity of a hydraulic fluid. This is referred to as the PH value of the fluid. High acidity causes the oxidation rate in an oil to increase rapidly.

10. Density: It is that quantity of matter contained in unit volume of the substance.

11. Compressibility: All fluids are compressible to some extent. Compressibility of a liquid causes the liquid to act much like a stiff spring. The coefficient of compressibility is the fractional change in a unit volume of liquid per unit change of pressure.

REQUIRED QUALITIES OF GOOD HYDRAULIC OIL:

1. Stable viscosity characteristics
2. Good lubricity
3. Compatibility with system materials
4. Stable physical and chemical properties
5. Good heat dissipation capability
6. High bulk modulus and degree of incompressibility
7. Good flammability
8. Low volatility
9. Good demulsibility
10. Better fire resistance

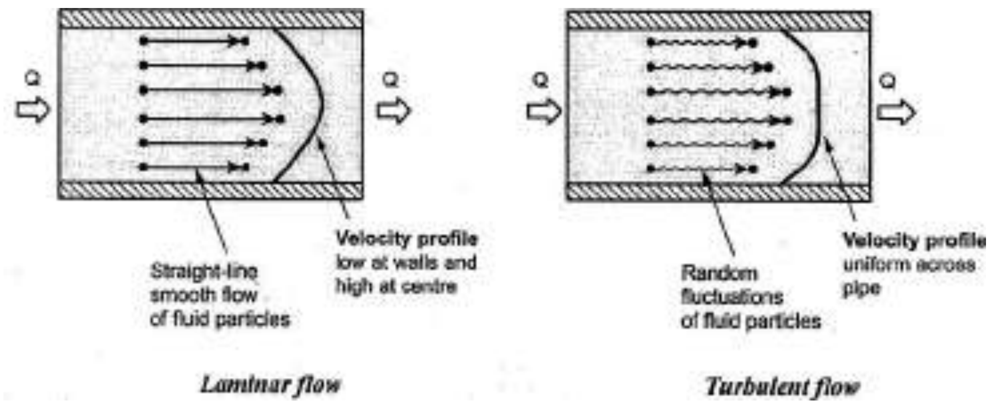
11. Non toxicity and good oxidation stability
12. Better rust and corrosion prevent qualities
13. Ready availability and inexpensive

FLUID FLOW:

Laminar Flow: It is one in which paths taken by the individual partials do not cross one another and moves along well defined paths. The laminar flow is characterized by the fluid flowing in smooth layers of lamina. This type of flow is also known as streamline or viscous flow because the particles of fluid moving in an orderly manner and retaining the same relative positions in successive cross sections.

Examples:

1. Flow of oil in measuring instruments
2. Flow of blood in veins and arteries



Turbulent Flow: It is that flow in which fluid particles move in a zigzag way. It is characterized by continues small fluctuations in the magnitude and direction of the velocity of the fluid particles. It causes more resistance to flow, Greater energy loss and increase fluid temperature due to greater energy loss.

Examples: High velocity flow in a pipe of large size.

REYNOLDS NUMBER:

Osborne Reynolds in 1883 conducted experiments to ascertain the conditions under which a flow through pipe is laminar or turbulent. He applied the dimensional analysis on variables and introduced a dimensionless number called Reynolds number Re. It is given by the following equation to determine whether the flow is laminar or turbulent.

$$\text{Re} = \frac{\rho V D}{\mu} = \frac{VD}{\nu}$$

ρ = Density of fluid kg/m^3)

V = Velocity of Flow (m/sec)

D = Inside diameter of pipe (m)

υ = Kinematic viscosity of fluid(m^2/sec)

μ = absolute viscosity of fluid (Ns/m²)

Experiments showed that the flow is laminar when Reynolds number (Re) is less than 2000 and turbulent for Re greater than 4000. And for 4000 < Re < 2000 then the flow is in transition from laminar to turbulent. It is always desirable to maintain laminar flow in hydraulic system because the chaotic turbulent flow causes more energy loss.

DARCY – WEISBACH EQUATION:

The energy loss due to friction in a hydraulic system results in a loss of potential energy. This potential energy loss leads to a pressure drop or head loss in the system. Pressure or head loss due to friction in pipes carrying fluids are derived using the Darcy-Weisbach Equation.

$$H_L = f\left(\frac{L}{D}\right)\left(\frac{V^2}{g}\right)$$

H_L – Head Loss,
V – Velocity of Flow
f - Friction Factor,
g – Acceleration due to gravity
D – Inner Diameter,
L - Length of pipe

During laminar flow the friction is relatively independent of the surface conditions of the inside diameter of the pipe.

The friction factor 'f' for laminar flow can be found by the equation

But in turbulent flow friction factor depends on both the Reynolds

$$f = \frac{64}{Re} \text{ when } Re < 2000$$

number and roughness of the pipe. An American engineer L.F.Moody documented the experimental and theoretical investigation on the laws of friction in pipe flow in form of a diagram.

LOSSES IN VALVES AND FITTINGS:

Pressure drops are also due to valves, expansions, contractions, bends, elbows, tees and pipe fittings. The losses in valves and fittings in hydraulic systems are frequently computed in terms of equivalent length of hydraulic tube. Equivalent lengths can then be substituted in Darcy-Weisbach equation to solve for total pressure loss in the system. The formula for computing equivalent length is

$$\text{Equivalent length } Le = \frac{KD}{f}$$

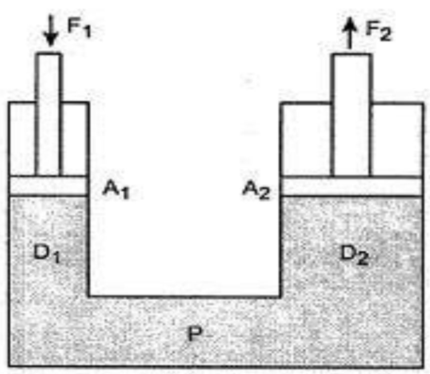
k= Factor for valve and fittings

Valve and Fitting	K Factor
Globe Valve Full open Half open	10 12.5
Gate Valve Full open Half open	0.19 4.5
Check Valve Poppet Type Ball type	3.0 4.0
Return Bend	2.2
Standard Tee	1.8
Standard Elbow	0.9
45º Elbow	0.42

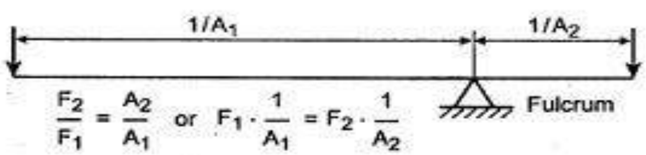
PASCAL'S LAW :

This law states that the pressure generated at any point in a confined fluid acts equally in all directions.

Consider two oil containers both in cylindrical form and connected together contain some oil, as shown Both the cylinders have a piston having different diameters says D_1 and D_2 respectively, where D_1 is smaller than D_2.



Principle of Bramah's press



A hydraulic lever

If a force F_1 is applied to the small-diameter piston, then this will produce an oil pressure P_1 at the bottom of the piston 1. Now this pressure is transmitted through the oil to the large-diameter piston 2. Because the piston 2 has a larger area (A_2), the pressure at the bottom of the piston 2 will be P_2. Now this pressure P_2 will push up the piston 2 to create an output force F_2.

We know that according to Pascal's law, $P_1 = P_2$

or $$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

or $$\boxed{\frac{F_2}{F_1} = \frac{A_2}{A_1}}$$

where A_1 = Area of the smaller piston $= \frac{\pi}{4} D_1^2$, and

A_2 = Area of the larger piston $= \frac{\pi}{4} D_2^2$.

CONTINUITY EQUATION: It states that if no fluid is added or removed from the pipe in any length then the mass passing across different sections shall be same.

$$A_1 V_1 = A_2 V_2$$

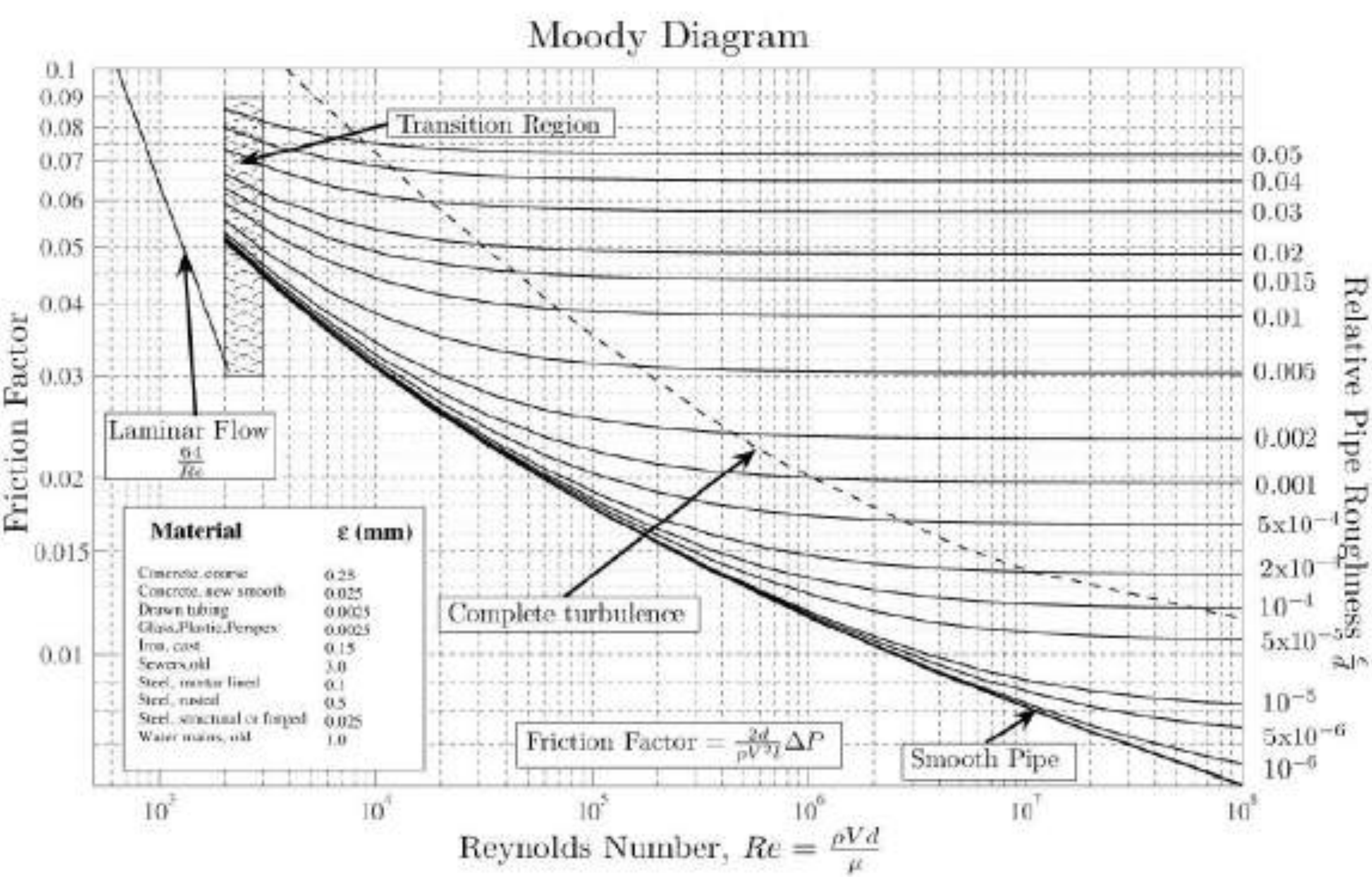
BERNOULLI'S EQUATION: It states that in a ideal incompressible fluid when the flow is steady and continuous the sum of potential energy, kinetic energy and pressure energy is constant across all cross sections of the pipe.

$$Z_1 + \frac{V_1^2}{2g} + \frac{P_1}{w} = Z_2 + \frac{V_2^2}{2g} + \frac{P_2}{w}$$

FRICTIONAL LOSSES IN TURBELENT FLOW

 Due to random and fluctuating movement of fluid particles, the friction factor for turbulent flow cannot be represented in simple formula as in case of laminar flow. For turbulent flow, experiments have shown that the friction factor is a function of not only the Reynolds's number but also the relative roughness of the pipe.

 The relative roughness is defined as the pipe inside surface roughness (ε) divided by the diameter (D), which can be determined with the help of moody's diagram.



Relative Roughness = ε / D

LOSSES IN VALVES AND FITTINGS

- In addition to losses due to friction in pipes, there also energy losses in valves and fittings such as tees, elbows, and bends. For many fluid power applications, the majority of energy losses occur in these valves and fittings where there is a change in the cross section of the flow path and change in the direction of flow.

Fig. Valves and Fittings

Experiments have shown that head losses in valves and fittings are proportional to the square of the velocity of the fluid.

$$H_L = K(V^2/2g)$$

The constant of proportionality (K) is called the K factor (also called loss coefficient) of the valve or fitting. The table given below shows typical K-factor values for several common types of valves and fittings.

VALVE OR FITTING K FACTOR:

VALVE OR FITTING	K FACTOR
Globe valve: WIDE OPEN **½ OPEN**	10.0 12.5
Globe valve: WIDE OPEN **3/4 OPEN** **½ OPEN** **¼ OPEN**	0.19 0.90 4.5 24.0
RETURN BEND	2.2
STANDARD TEE	1.8
STANDARD ELBOW	0.9
45^{O} ELBOW	0.42
90^{O} ELBOW	0.75
BALL CHECK VALVE	4.0

Example 1

The kinematic viscosity of a hydraulic fluid is 0.0001 m^2/s. If it is flowing in a 20-mm diameter commercial steel pipe, find the friction factor in each case:

(a) The velocity is 2 m/s.
(b) The velocity is 10 m/s.

Example 2

The kinematic viscosity of a hydraulic fluid is 0.0001 m2/s. If it is flowing in a 30-mm diameter pipe at a velocity of 6 m/s, find the head loss due to friction in units of bars for a 100-m smooth pipe. The oil has a specific gravity of 0.90.

(Hint: Pressure drop $p=\rho g H_L$)

Example 1

The kinematic viscosity of a hydraulic fluid is 0.0001 m /s. If it is flowing in a 20-mm diameter commercial steel pipe, find the friction factor in each case:

(a) The velocity is 2 m/s.

(b) The velocity is 10 m/s.

Solution:

a) If the velocity is 2 m/s, then

$$Re = \frac{vD\rho}{\mu} = \frac{vD}{\mu/\rho} = \frac{vD}{\nu} = \frac{2\times 0.02}{0.0001} = 400$$

The flow is laminar. Now

$$f = \frac{64}{Re} = \frac{64}{400} = 0.16$$

(b) If the velocity is 10 m/s, then

$$Re = \frac{vD\rho}{\mu} = \frac{vD}{\mu/\rho} = \frac{vD}{\nu} = \frac{10\times 0.02}{0.0001} = 2000$$

$$f = \frac{64}{Re} = \frac{64}{2000} = 0.032$$

Example 2

The kinematic viscosity of a hydraulic fluid is 0.0001 m /s. If it is flowing in a 30-mm diameter pipe at a velocity of 6 m/s, find the head loss due to friction in units of bars for a 100-m smooth pipe. The oil has a specific gravity of 0.90. 2

Solution: We have

$$\mathrm{Re} = \frac{vD\rho}{\mu} = \frac{vD}{\mu/\rho} = \frac{vD}{\nu} = \frac{6\times 0.03}{0.0001} = 1800$$

We can express the head loss in bar as

$$H_L = \frac{64}{\mathrm{Re}}\left(\frac{L}{D}\right)\left(\frac{v^2}{2g}\right)$$

$$= \frac{64}{1800}\left(\frac{100}{0.030}\right)\left(\frac{6^2}{2\times 9.81}\right)$$

$$= 217.5\ \mathrm{m}$$

Hence,

Pressure drop $p = \rho g H_L$

$$= 1000\ \mathrm{kg/m^3} \times 0.90 \times 9.81\ \mathrm{m/s^2} \times 217.5$$

$$= 1.92\ \mathrm{MN/m^2}$$

$$= 1.92\ \mathrm{MPa}$$

$$= 19.2\ \mathrm{bar}$$

Example 3

For the system shown in Fig., the following data are applicable:

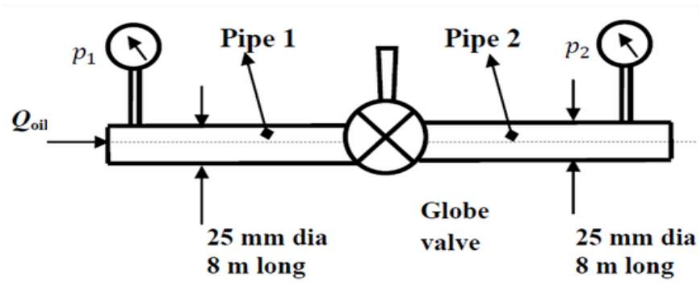
Pipe 1: length = 8m, ID = 25mm

Pipe 2: length =8m, ID = 25mm

The globe valve is 25mm in size and is wide open.

SG =0.90, kinematic viscosity $\nu = 0.0001$ m^2 /s and Q =0.0025 m^3 /s

Find pressure drop in units of bars.



Solution: The velocity can be calculated as

$$v = \frac{Q\,(\text{m}^3/\text{s})}{A\,(\text{m}^2)} = \frac{0.0025}{\dfrac{\pi(0.025^2)}{4}} = 5.09\,\text{m/s}$$

$$\text{Re} = \frac{vD}{\nu} = \frac{5.09 \times 0.025}{0.0001} \cong 1272$$

So the flow is laminar. Now friction factor is

$$f = \frac{64}{\text{Re}} = \frac{64}{1272} = 0.0503$$

Also, head loss is

$$H_\text{L} = \frac{f\,L_\text{p}}{D_\text{p}} \times \frac{v^2}{2g}$$

Now

$$L_\text{p} = 8 + 8 + \left(\frac{KD}{f}\right)_{\text{std elbow}} = 16 + \left(\frac{10 \times 0.025}{0.0503}\right) = 21\,\text{m}$$

$K = 10$ for globe valve (fully open). So

$$H_\text{L} = \frac{0.0503 \times 21}{0.025} \times \frac{5.09^2}{2 \times 9.81} = 55.8 \text{ m of oil}$$

Now

$$\frac{\Delta p}{\gamma} = H_\text{L}$$

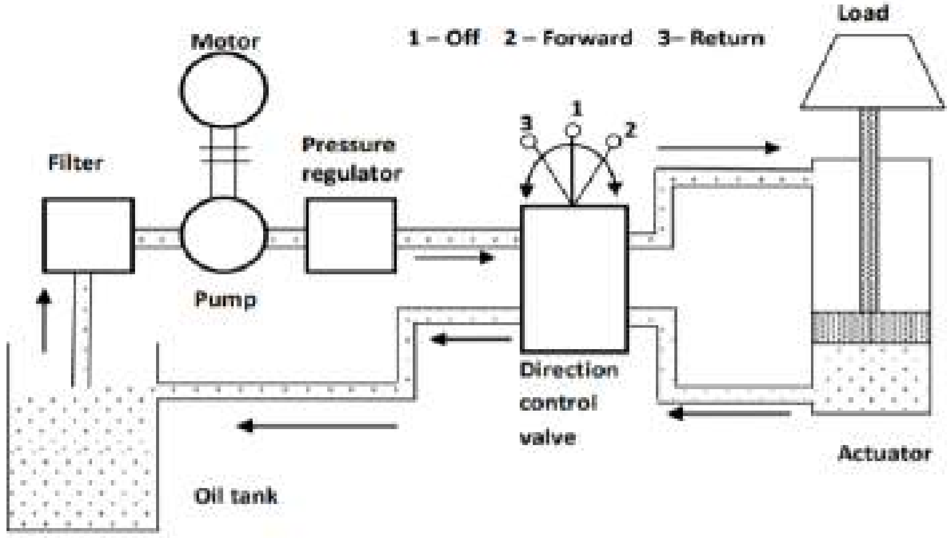
$$\Rightarrow \quad = \gamma H_\text{L}$$

$$\Delta p = (1000 \times 0.9 \times 9.81) \times 55.8$$

$$= 493000\,\text{N/m}^2$$

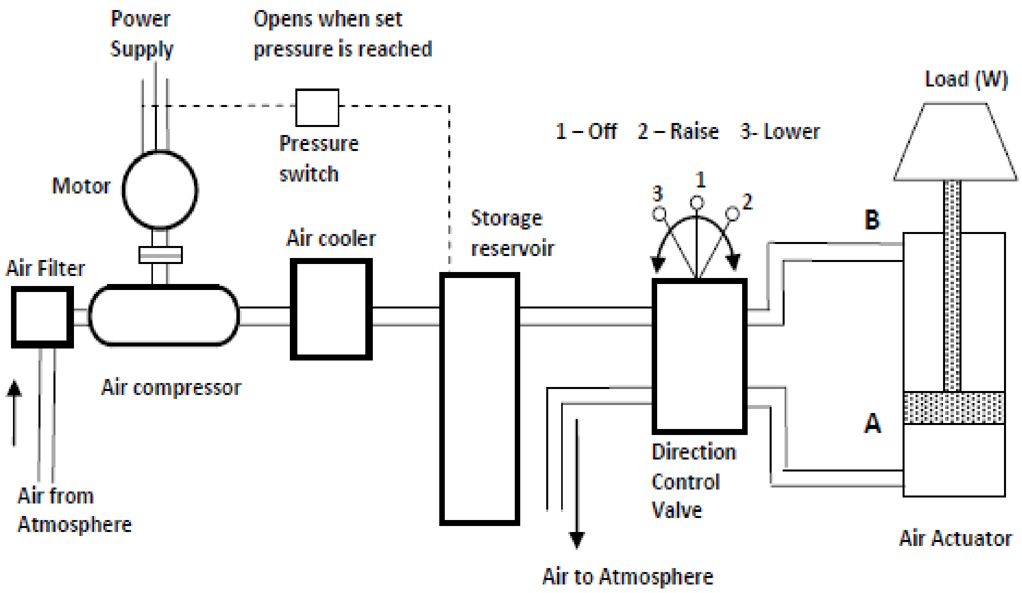
So $= -4.93$ bar

HYDRAULIC POWER PACK



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. 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. Valves are used to control the direction, pressure and flow rate of a fluid flowing through the circuit. External power supply (motor) is required to drive the pump. Reservoir is used to hold the hydraulic liquid, usually hydraulic oil. Piping system carries the hydraulic oil from one place to another. Filters are used to remove any foreign particles so as keep the fluid system clean and efficient, as well as avoid damage to the actuator and valves. Pressure regulator regulates (i.e., maintains) the required level of pressure in the hydraulic fluid.

PNEUMATIC POWER PACK



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

TYPES OF PUMPS

There are two basic types of pumps.

- Non-Positive Displacement Pump
- Positive Displacement Pump

1. Non-Positive Displacement Pump - Centrifugal Pump

This pump design is used mainly for fluid transfer in systems where the only resistance found is created by the weight of the fluid itself and friction.

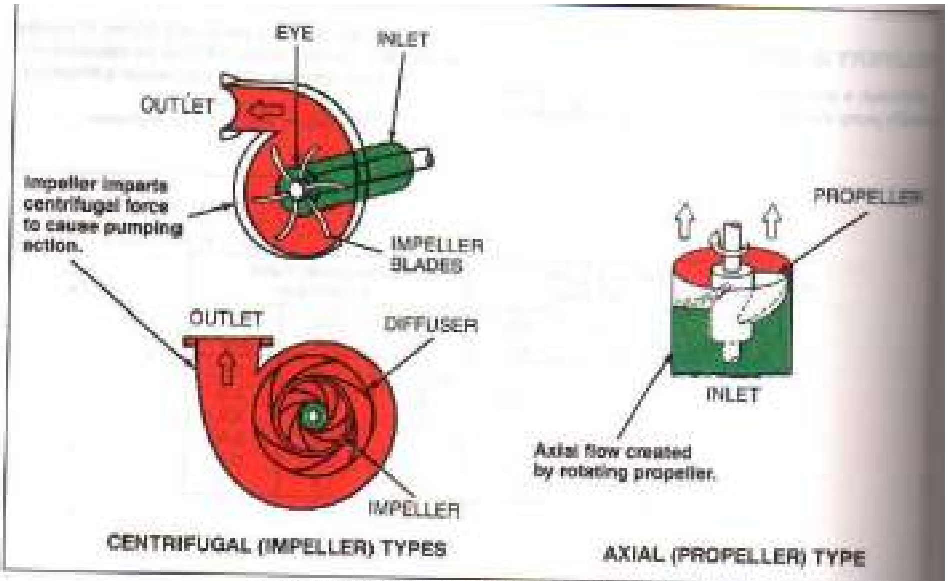


Figure 17-2. Nonpositive displacement pumps.

Most non-positive displacement pumps. (Figure 17-2) operate by centrifugal force. Fluids entering the center of the pump housing are thrown to the outside by means of a rapidly driven impeller. There is no positive seal between the inlet and outlet ports, and pressure capabilities a function of drive speed.

Although it provides a smooth, continuous flow, the output from this type of pump is reduced as resistance is increased.

In fact, it is possible to completely block off the outlet while the pump is running. For this and other reasons, non-positive displacement pumps are seldom used in power hydraulic systems today.

These properties make it a more likely choice for a water pump in a car engine, dishwasher or washing machine. It could also be used as a supercharge pump for a positive displacement pump.

2. Positive Displacement Pump

The positive displacement pump is most commonly used in industrial hydraulic systems. A positive displacement pump delivers to the system, a specific amount of fluid per stroke, revolution, or cycle. This type of pump is classified as fixed or variable displacement.

Fixed displacement pumps have a displacement which cannot be changed without replacing certain components. With some, however, it is possible to vary the size of the pumping chamber (and the displacement) by using external controls. These pumps are known as variable displacement pumps.

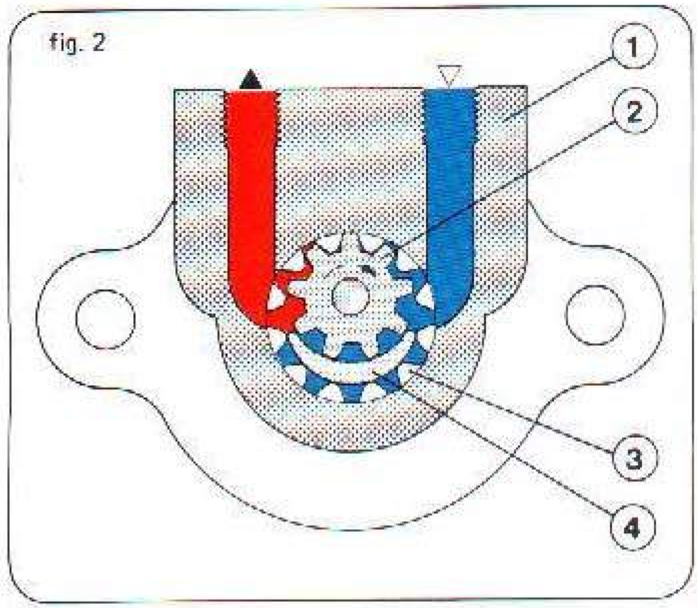
Certain vane pumps and piston units can be varied from maximum to zero delivery. Some are capable of reversing their flow as the control crosses a center or neutral position.

The pressure is determined by the workload, and except for leakage losses, the output is independent of outlet pressure. This makes the positive displacement pump more appropriate for use in the transmission of power.

The three best-known positive displacement pumps: gear pumps, vane pumps, and piston pumps.

2.1 GEAR PUMP WITH INTERNAL GEARING

Gear pump with internal gearing (fig. 2)



It comprises mainly a housing (1), in which a pair of gears run with such low axial and radial play, that the unit is practically oil-tight.

The suction side (blue) is connected to the tank. The pressure side (red) is connected to the hydraulic system.

The inner gear 2 is driven in the direction of the arrow, and takes external gear 3 along with it in the same direction.

The rotary movement causes the gears to separate, so that the gear spaces are free.

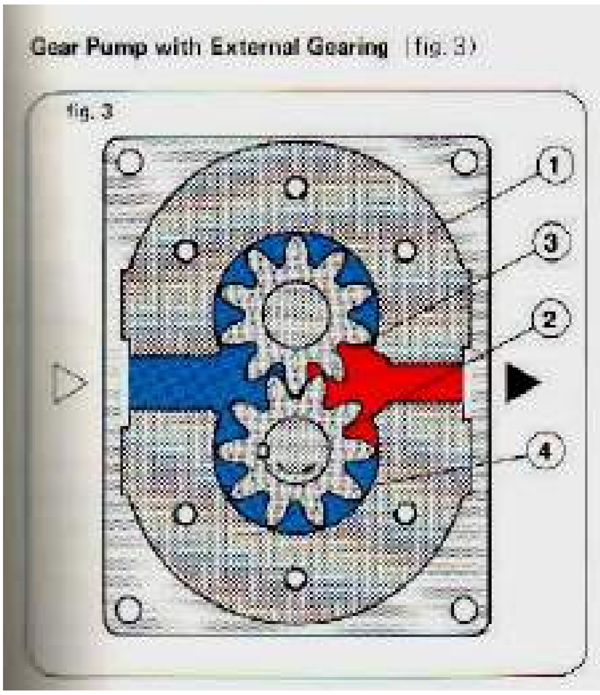
The negative pressure caused by this and the atmospheric pressure on the fluid level in the tank cause fluid to run from the tank to the pump. One generally says “the pump sucks”.

The fluid fills the gear spaces, which form closed chambers with the housing and the crescent 4, during further movement, and is pushed to the pressure side (red).

The gears then interlock once more and push the fluid from the gear chambers.

2.2 GEAR PUMP WITH EXTERNAL GEARING

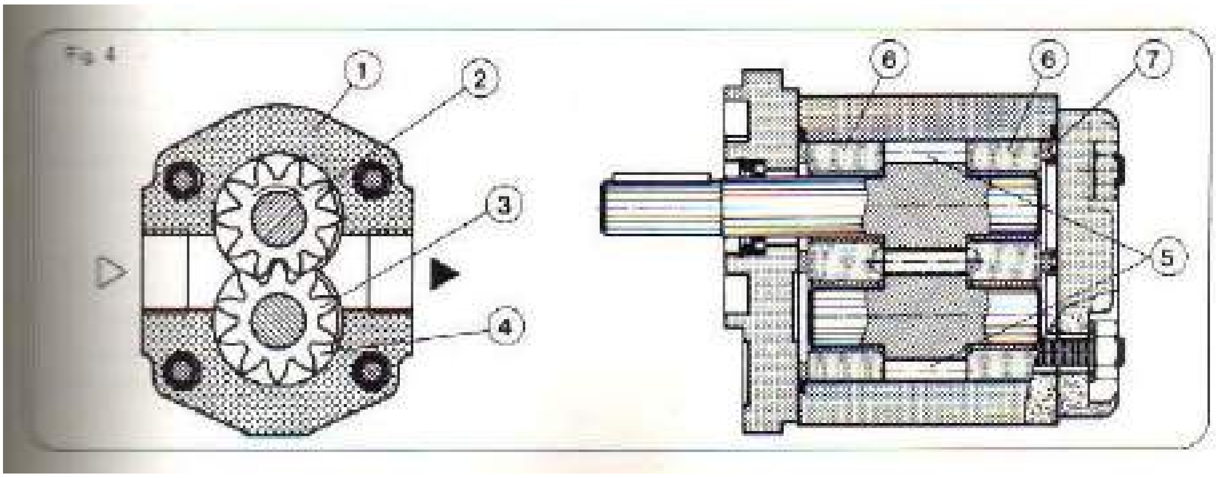
The gears which would come into contact with one another prevent return flow from the pressure chamber to the suction chamber.



In this case, 2 external gears would come into contact with one another. Gear 2 is driven in the direction of the arrow, and causes gear 3 to move with it in the opposite direction. The suction process is identical to that previously described for the internally geared pump.

The fluid in gear chambers 4 is pushed round the outside and out of the gear spaces on the pressure side (red).

It can easily be seen from the sectional drawing that the gears close the spaces before these are completely empty.



Without unloading in the remaining chambers, very high pressure would occur, which would result in hard pulsating running of the pump.

For this reason, unloading bores are arranged at this position on the side of the bearing blocks. The so called “compressed fluid “ is thus fed into the pressure chamber.

A further point worthy of note is the side tolerance play between gears 5 and bearing blocks 6. fig. 4

It tolerance play too great	low friction
	high leakage
If tolerance play too low	high friction
	high leakage

If the tolerance play is designed as a fixed aperature, leakage increases along with wear. The volumetric loss also increases with increasing operating pressure.

This pump design incorporates a hydrostatic bearing balance. The bearing blocks are pushed on to the gears by cams 7, which are affected by system pressure.

Tolerance play therefore adjusts itself according to the system pressure. This results in a high degree of efficiency, independent of speed and pressure.

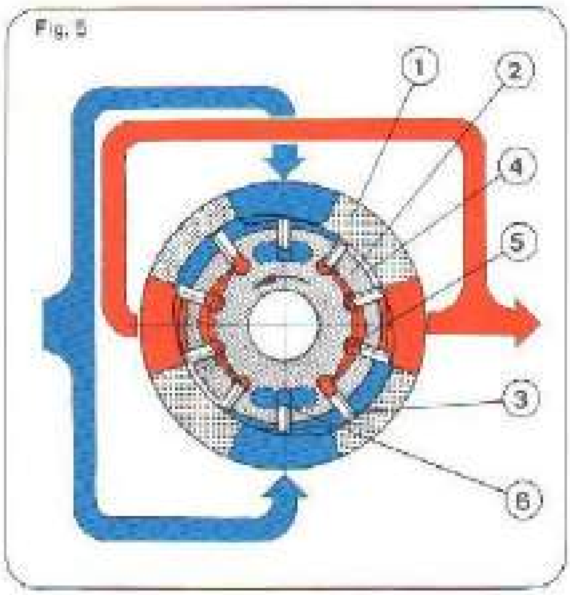
Important technical details

displacement volume	3.5 – 100 cc/rev.
operating pressure	up to 250 bar.

2.3 VANE PUMPS WITH FIXED DISPLACEMENT VOLUME

2.3.1 Single Pump

Cam 1 has an internal running surface on double eccentric design. The rotor is in drive part. On its circumference, two vanes 3 (double vanes, which can be pushed against each other are fitted in radially arranged grooves.



The vane pump comprises mainly the housing, cam 1 and rotor 2 with the vanes 3.

When the rotor is turned, the centrifugal force and the system pressure being one against each and radially moveable vanes towards the outside. They lie with their external edge to the inner running area of the cam.

The cells (transporting chambers are formed by 2 pairs of vanes, the rotor one cam and control discuss arranged on the side.

Supply (suction side, blue and system pressure side red) of the fluid take place by means of the control discs (not shown)

To make things easier to understand external supply and drain are shown in the drawing (Fig.5).

For flow delivery, the rotor is moved in one direction of the arrow. Near the suction line above and below), the vanes 4 are still too small if the rotor is turned further, the vanes increase and fill up with oil. When these cells have reached their maximum size (largest distance from the internal running space to the center point of the motor, they are separated from the suction side by means of control discs. They are then connected to the pressure side.

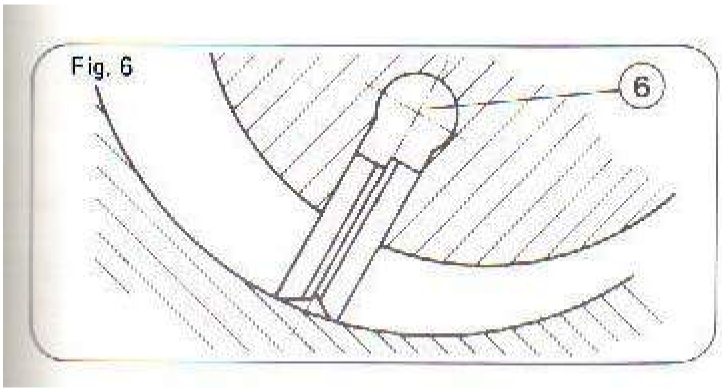
The vanes are pushed into groves by the form of the cam curve. The vane volume decrease once more. The fluid is thus pushed to the pressure port.

As the cam curve is designed as double eccentric, each vane is involved in the delivery process twice per revolution.

At the same time, two suction chamber and two pressure chambers lie opposite each other, whereby the drive shaft is hydraulic unloaded.

The pressure is applied to the back of vanes 5.

Better sealing is thus achieved in addition to the double seal lands.



However, a friction may not be too great, both vanes in a motor grove have chamfers opposite each other (fig.6)

The chamfers on the vanes cause a pressure balance between running and return side. The rolling surface of vanes remains as contact surface for the pressure. Higher contact pressure is not necessary on such suction side. The backs of the vanes are thus unloaded to tank.

2.3.2 DOUBLE PUMP ASSEMBLIES

Vane Pumps with fixed displacement volume

Double pumps (figures 17.20) provide a single power source capable of serving two separate hydraulic circuits or providing greater volume through combined delivery. Most double pumps have a co on inlet in a center housing. The outlet for one unit, usually the larger of the two is the shaft end body. The second outlet is in the cover. Some types of double pumps have separate inlets, although they can be mounted in multiples. Both kinds need only one drive motor, however, double pumps that have separate inlets require separate piping.

Cartridge construction for double pumps is essentially the same as in single unit, making numerous combinations of sizes and displacements possible

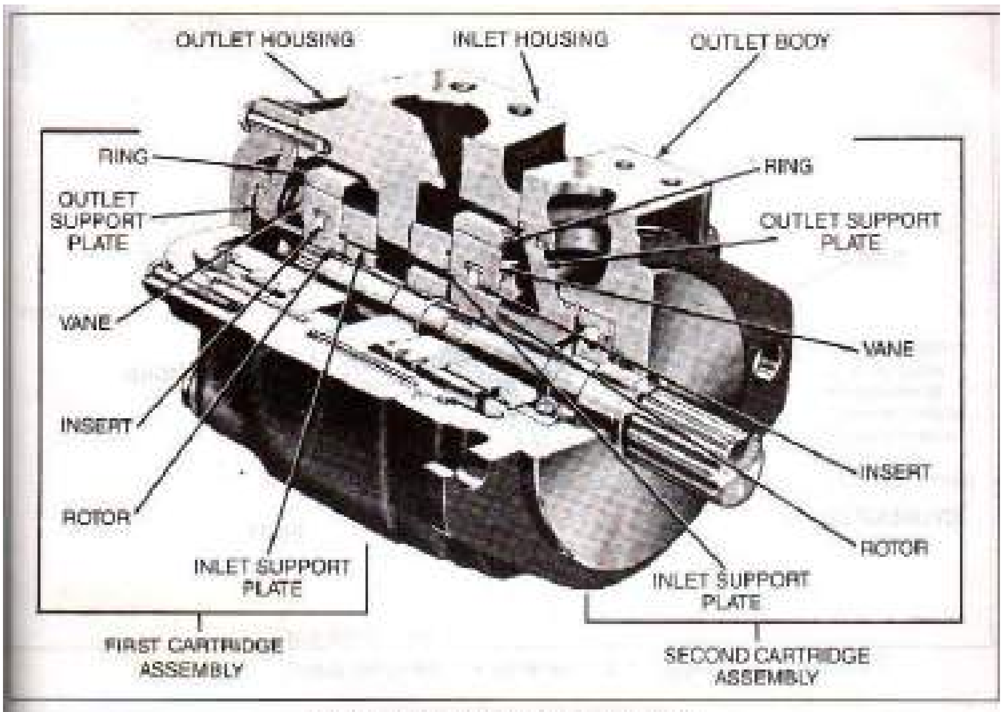
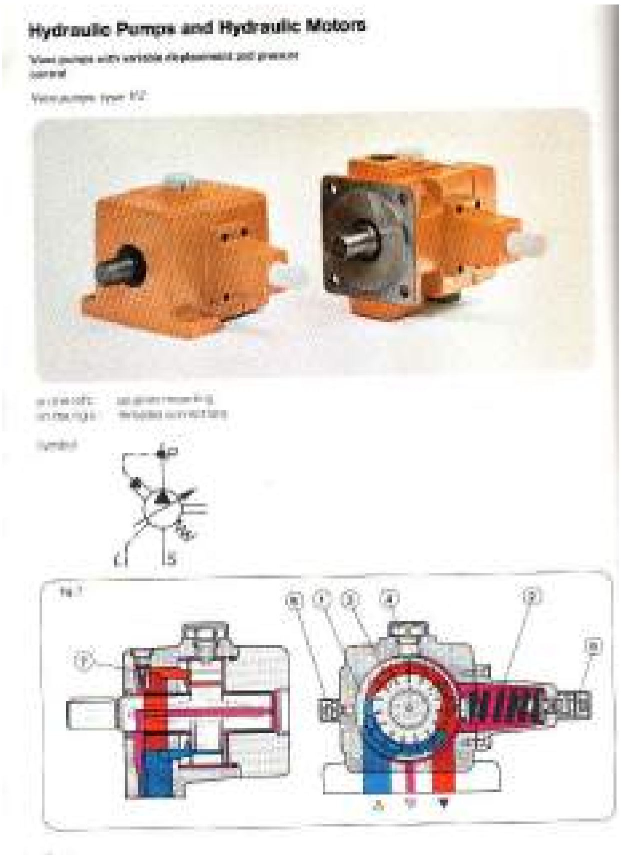


Figure 17-20. Double pump construction.

2.4 VANE PUMPS WITH VARIABLE DISPLACEMENT AND PRESSURE CONTROL



With this type of pump, the displacement volume can be adjusted as the set maximum operating pressure.

The delivery process follows the principle as described for fixed displacement pump V2.

In this case, however, the cam is a circular concentric. A spring 2 pushes the cam into its eccentric outlet position towards the motor.

The maximum eccentric and thus the maximum displacement volume can be set by means of the screw 5. The spring force can also be adjusted by means of adjustment.

There is tangential adjustments of the cam by means of height adjustment screw 4.

The pressure which builds up due to working resistance)e.g. at the user, cylinder with load) affects the internal running surface of the cam on the pressure side. this results in a horizontal force component which operates towards the spring (fig.8)

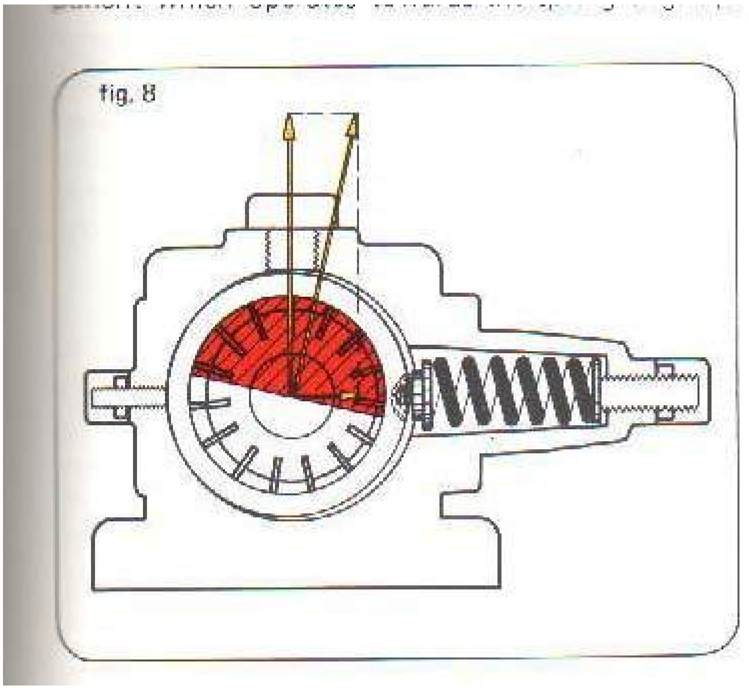


fig. 8

If the pressure force exceeds the set spring force (equivalent to certain pressure), the cam ring moves from eccentric towards zero position. The eccentric decreases.

The delivery flow adjusts itself to the level required by the user.

If no fluid is taken by the user and the set pressure is thus reached, the pump regulates flow to almost zero, operating pressure is maintained and only the leakage oil replaced, Because of this, loss of power and heating of the fluid is kept to a minimum.

When the initial spring tension is achieved, the cam ring moves. Flow decreases are maintained.

The gradient of the performance curve depends on the spring characteristics whereby the gradient with a certain spring and different pressure varies.

To improve the sensitivity of response, the pump can be fitted with 4 different springs corresponding to 4 pressure ratings.

Fig.7 also show the bleed valve 7 fitted as standard commissioning is made easier by automatic bleeding.

The valve poppet is pushed back by spring the valve open. The valve remains open as long as air escapes during start up. If fluid flow through the valve, the poppet is pushed against the spring and the connection closed hermetically.

Important technical data

displacement volume upto 47cc rev.

(4 sizes)

operating pressure upto 100 bar.

2.5 PISTON PUMPS

- All piston pumps operate on the principle that a piston reciprocating in a bore will draw fluid in as it is retracted and expel it as it moves forward.
- The two basic designs are radial and axial, both available as fixed – or variable-displacement models.
- A radial pump has the pistons arranged radially in a cylinder block (Figure 17-21), while the pistons in the axial units are parallel to each other and to the axis of the cylinder block (Figure 17-22).
- Axial piston pumps may be further divided into in-line (swash plate) and bent-axis types.

Operating Characteristics

- Piston pumps are highly efficient units, available in a wide range of capacities.
- They are capable of operating in the medium – to high – pressure range (200 bar to 500 bar), with some going much higher.
- Because of their closely fitted parts and finely machined surfaces, cleanliness and good quality fluids are vital to long service life.

2.5.1 Radial Piston Pumps

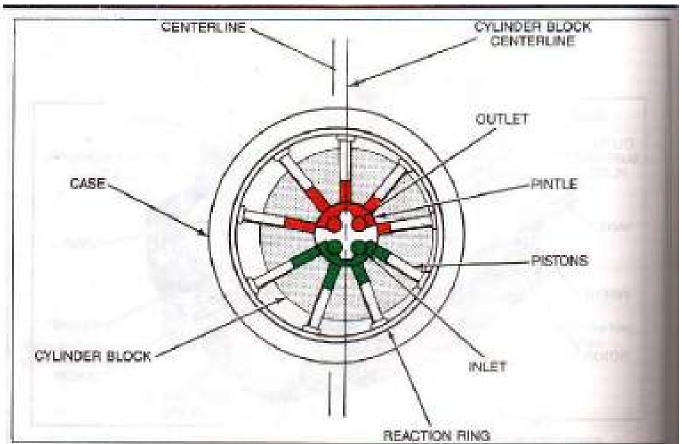


Figure 17-21. Operation of radial piston pump.

- In a radial pump, they cylinder block rotates on a stationary pintle inside a circular reaction ring or rotor.
- As the block rotates, centrifugal force, charging pressure, or some form of mechanical action causes the pistons to follow the inner surface of the ring, which is offset from the centerline of the cylinder block.
- Porting in the pintle permits the pistons to take in fluid as they move outward and discharge it as they move in.

- Pump displacement is determined by the size and number of pistons (there may be more than one bank in a single cylinder block) and the length of their stroke.
- In some models, the displacement can be varied by moving the reaction ring to increase or decrease piston travel.
- Several types of external controls are available for this purpose.

2.5.2 Axial Piston Pumps

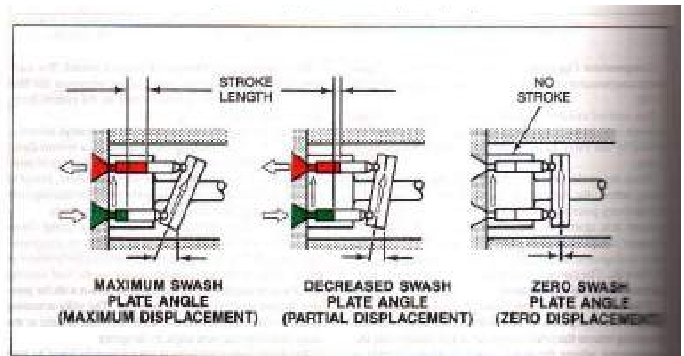


Figure 17-22. Variation in pump displacement.

- In axial piston pumps, the pistons reciprocate parallel to the axis of rotation of the cylinder block. The simplest type of axial piston pump is the swash plate in-line design (Figure 17-23).
- The cylinder block in this pump is turned by the drive shaft. Pistons fitted to bores in the cylinder block are connected through piston shoes and a shoe plate, so that the shoes bear against an angled swash plate.
- As the block turns (Figure 17-24), the piston shoes follow the swash plate, causing the pistons to reciprocate. The ports are arranged in the valve plate so that the pistons pass the inlet as they are pulled out and pass the outlet as they are forced back in.
- Like radial piston pumps, the displacement of axial piston pumps is determined by the size and number of pistons, as well as the stroke length. Stroke length is determined by the angle of the swash plate.

2.5.3 Variable displacement pumps

- In variable displacement models of the in-line pump, the swash plate is installed in a movable yoke (Figure 17-25).

  "Pivoting" the yoke on pintles changes the swash plate angle to increase or decrease the piston stroke (Figure 17-22). The yoke can be positioned by any of several means, including manual control, servo control, pressure compensator control, and load sensing and pressure limiter control.

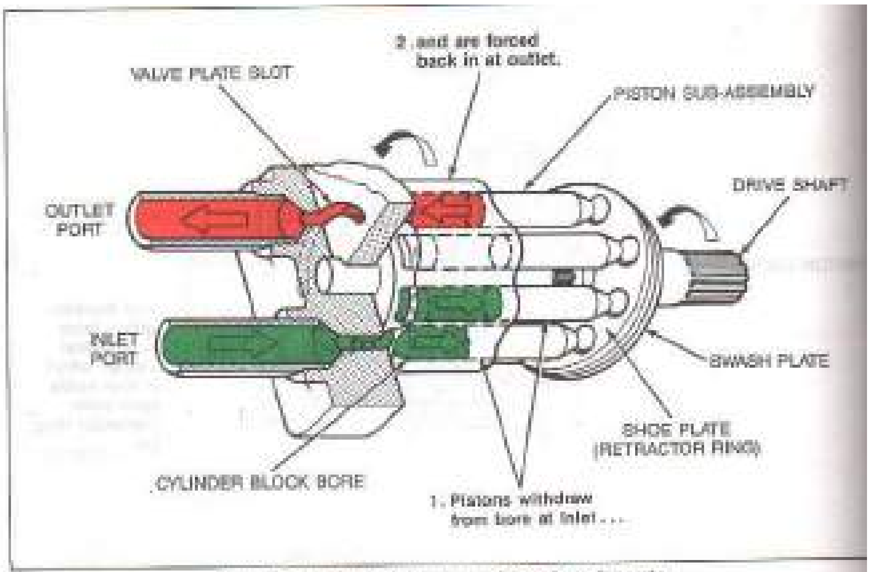
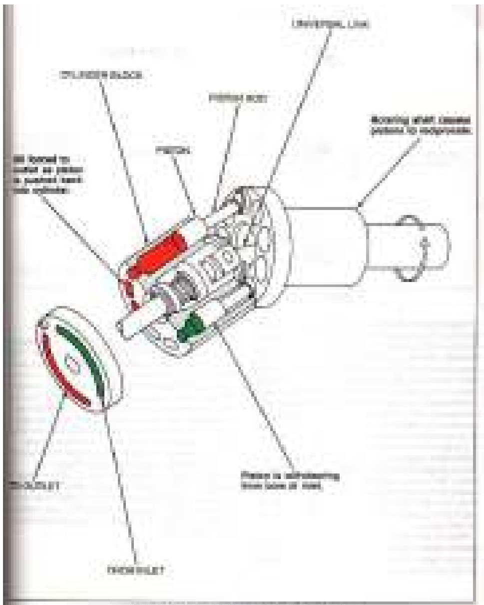


Figure 17-24. Swash plate causes pistons to reciprocate.

2.5.4 Bent-Axis Piston Pumps



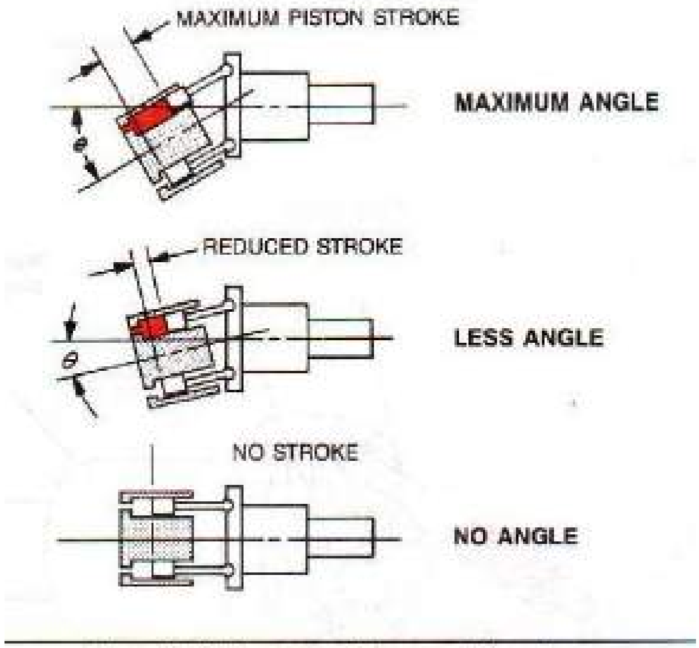


Figure 17-30. Displacement changes with angle.

In a bent-axis piston pump, the cylinder block turns with the drive shaft, but at an offset angle. The piston rods are attached to the drive shaft flange by ball joints and are forced in and out of their bores as the distance between the drive shaft flange and cylinder block changes (Figure 17-29). A universal link keys the cylinder block to the drive shaft to maintain alignment and assure that they turn together. The link does not transmit force, except to accelerate and decelerate the cylinder block and to overcome resistance of the block revolving in the oil-filled housing.

The displacement of this pump varies between 0 to 30 degrees, depending on the offset angle (Figure 17-30).

SUMMARY

Gear pumps and vane pumps are used in low and medium pressure industrial applications. Piston pumps specifically are used in medium and high pressure industrial applications. In short, pump is the heart of any hydraulic system.

REVIEW QUESTIONS:

1. What is the difference between positive and non-positive displacement pumps?
2. Indicate the different types of positive displacement pumps.
3. Are gear pumps fixed or variable type? Justify.
4. Explain the working of fixed displacement vane pump.
5. Explain briefly the working of variable displacement vane pump.

REFERENCE

1. 'Power Hydraulics', Michael J. Pinches and John G. Ashby.
2. Manuals of reputed Hydraulic product manufacturers.

SUBJECT: AXIAL PISTON PUMPS

ABOUT THE SESSION

This session dwells on types and operations of axial piston pumps, focusing on special features.

INTRODUCTION

In Axial Piston pumps, piston reciprocates either parallel to axis or inclined to axis of rotation of cylinder block.

TABLE OF CONTENTS

OBJECTIVES:

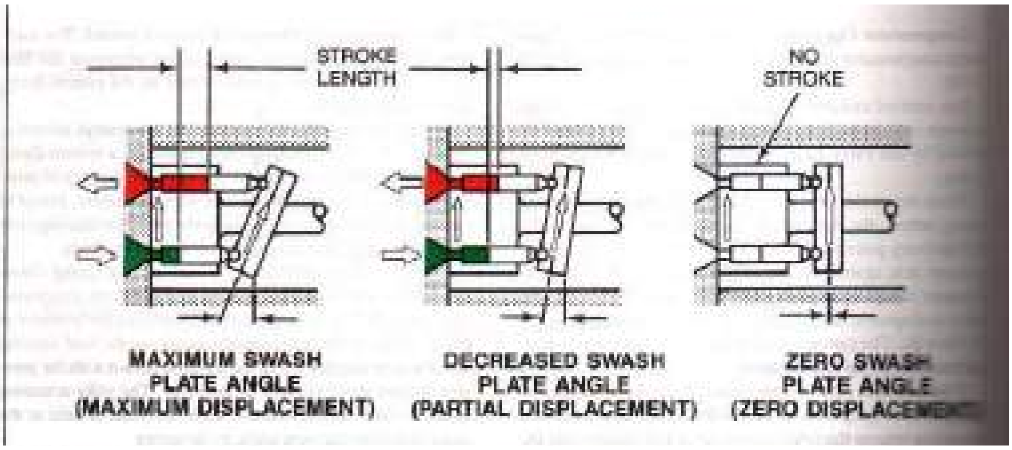
To understand in depth the function and operations of

(i) fixed and variable displacement inline axial piston pump.

(ii) fixed and variable displacement bent axis piston pump.

PRINCIPLE OF OPERATION

In axial piston pumps, the pistons reciprocate parallel to the axis of rotation of the cylinder block. The simplest type of axial piston pump is the swash plate in-line design.



In a bent-axis piston pump, the cylinder block turns with the drive shaft, but at an offset angle. The piston rods are attached to the drive shaft flange by ball joints and are forced in and out of their bores as the distance between the drive shaft flange and cylinder block changes.

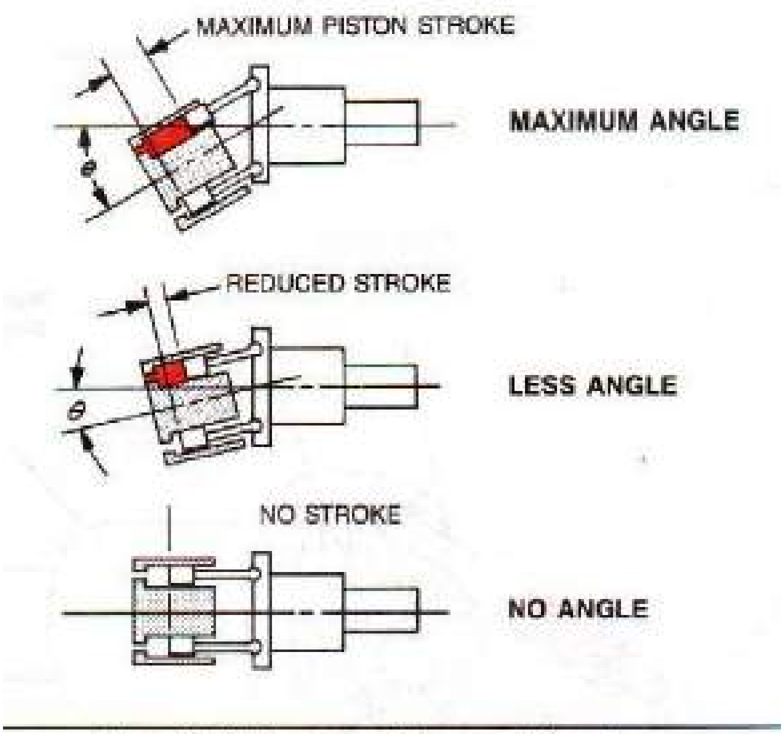
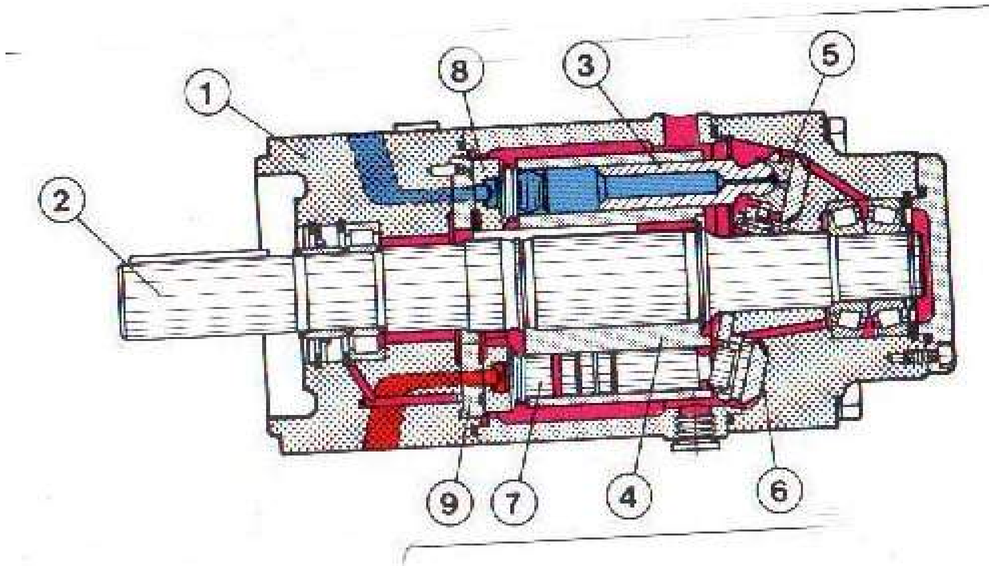


Figure 17-30. Displacement changes with angle.

2.1 Swashplate Design with Fixed Displacement



Nine pistons 3 are arranged in a circle, parallel to the drive shaft 2, in a fixed housing 1. They run in a cylinder drum 4, which is connected rigidly to the drive shaft by means of a key. The piston ends are designed as universal joints and fitted in slipper pads.

These are held on a 15 sloping surface 6 by thrust and retaining washers.

The sloping surface is part of the housing on fixed displacement units, and the slope is thus fixed.

When the drive shaft 2 is rotated (pump operation), the cylinder drum 4, collar bushes 7, cylinder cap n8, as well as piston 3 and slipper pad 5 also rotate. As the pistons are held on the sloping surface by means of the slipper pads, a piston stroke occurs in the cylinder drum when the drive shaft is turned.

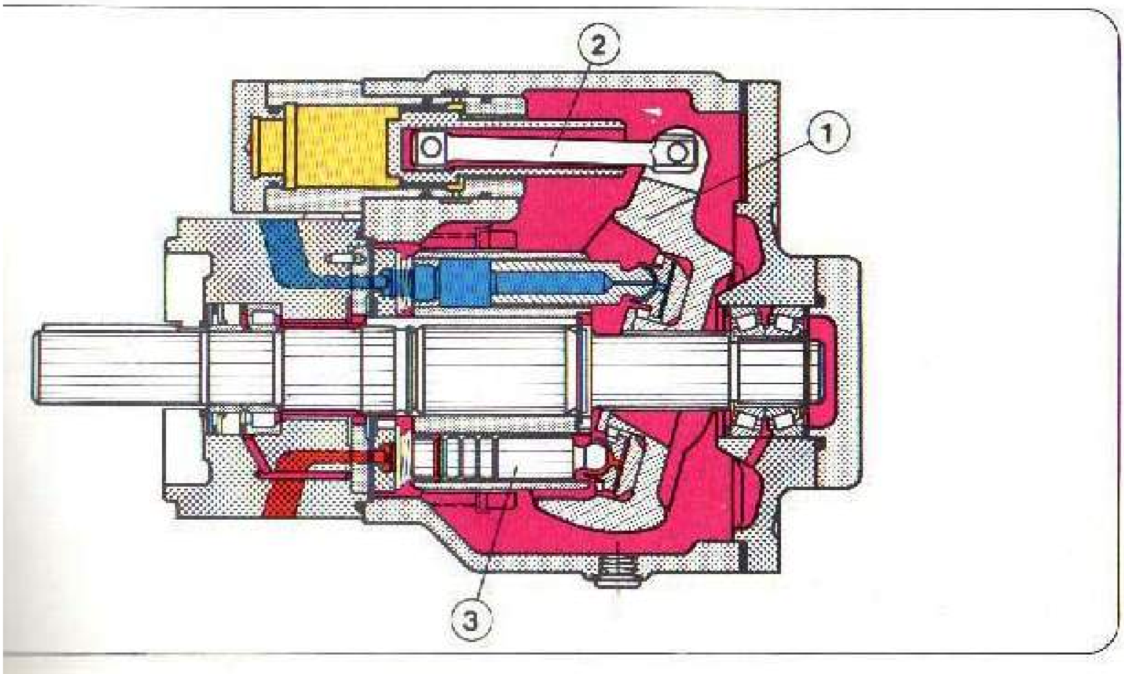
The control and thus the supply and drain of the oil is by means of two kidneys shaped grooves in the control plate 9, which is connected rigidly to the housing.

The pistons which move out of the cylinder drum are connected with the tank side (blue) by means of the control grooves, and draw in fluid. The other pistons are connected to the pressure side (red) by means of the other control groove and push fluid by means of their stroke into the cylinder drum to the pressure port. One piston is always in the change over range from suction to pressure side or vice versa.

Pressure fluid reaches the slipper bearing by means of a bore in the piston, and forms a pressure balance field there.

2.2 Swashplate Design with Variable Displacement

Fig. 17.



On the model with variable stroke displacement, the sloping plane is to a certain extent a disc and no longer part of the housing.

The sloping plate 1 can move. It can be swiveled by means of an adjustment mechanism 2 through an angle of 15 to center position. The pistons 3 carry out a certain stroke, related to the slope position, i.e., the swash angle. The stroke is the determining factor for the displacement volume. The piston stroke increases with increasing angle.

If the disc is in center position while the speed remains unchanged, then the flow direction changes smoothly.

Design Characteristics of an Axial Unit in Swash plate Design (Type A1)

9 pistons/slipper pads

level control surface

through shaft

swash range from 0 up to 15

short oil line.

Special Characteristics:

- short swash times
- low weight
- good flow characteristics in zero position range

- compact
- second shaft extension possible, and thus additional pumps can be fitted.
- well suited for reversing operation of large moment of inertia.

2.3 Compensator Operation: Operation of the in-line pump compensator control is shown schematically in Figure 17-26.

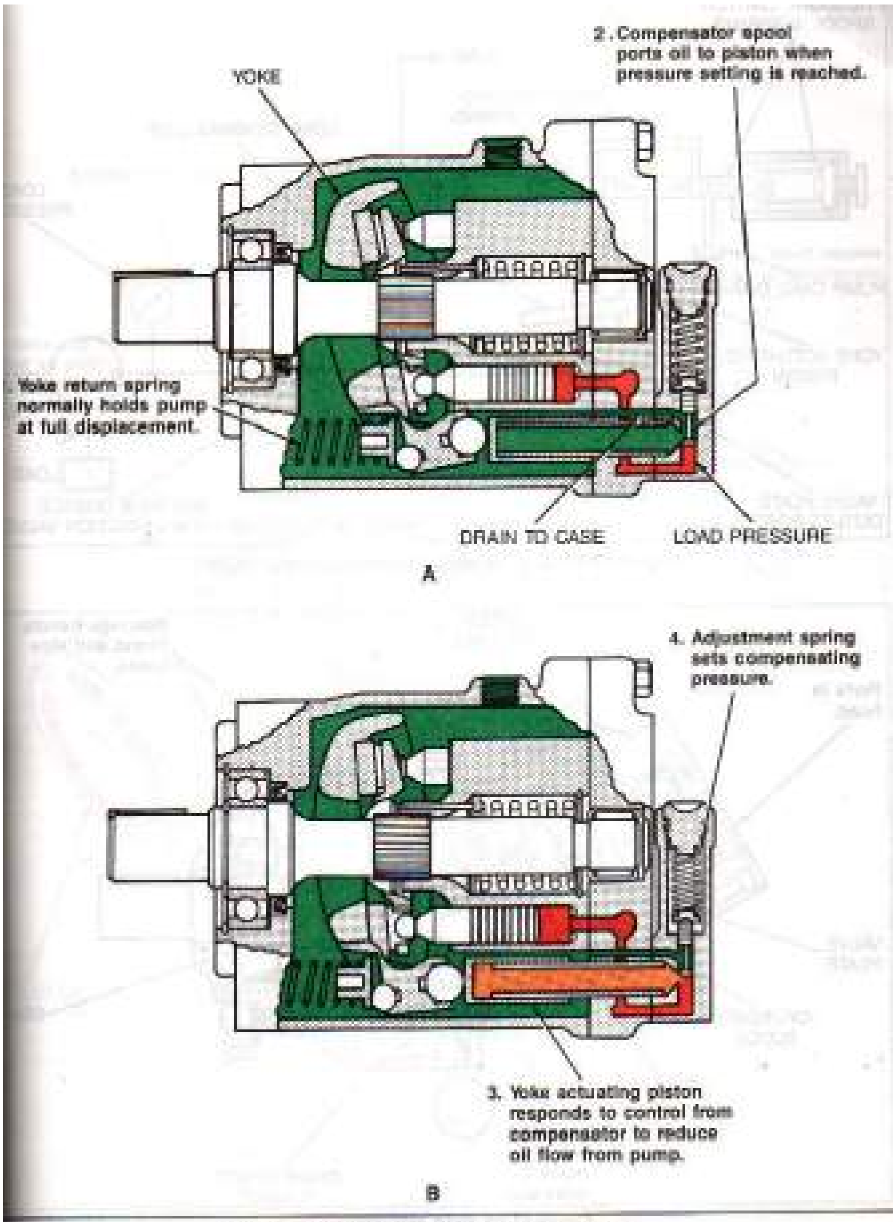


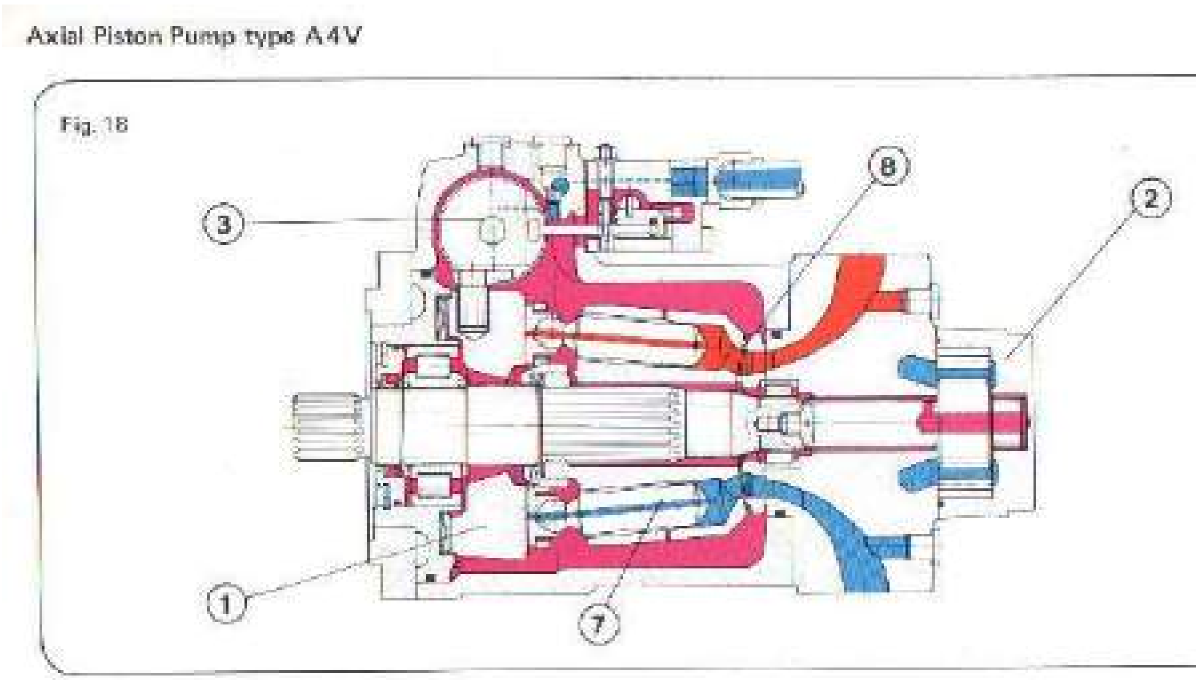
Figure 17-26. Pressure compensator operation.

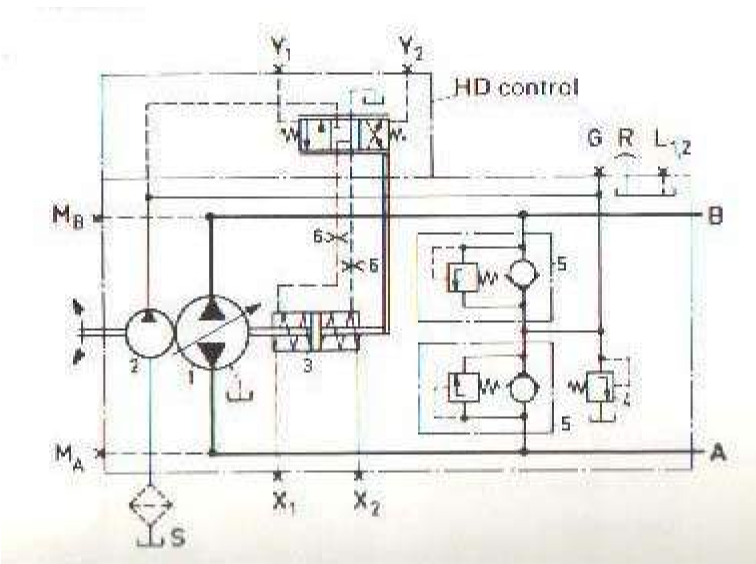
The control consists of a compensator valve balanced between load pressure and the force of a spring, a piston controlled by the valve to move the yoke, and a yoke return spring.

- When the outlet pressure is less than the compensator spring setting, the yoke return spring moves the yoke to the full delivery position (Figure 17-26), View A).
- Increasing pressure acts against the end of the valve spool.
- When the pressure is high enough to overcome the valve spring. the spool is displaced and oil enters the yoke piston (Figure 17-26 View B). The piston is forced by the oil under pressure to decrease the pump displacement.
- If the pressure falls off, the spool moves back, oil is discharged from the piston to the inside of the pump case, and the spring returns the yoke to a greater angle.
- In this way, the compensator adjusts the pump output to whatever level is required to develop and maintain the present pressure.
- Avoiding relief valve operation at full pump volume during holding or clamping prevents excess power loss.

2.4 Axial Piston Pump type A4V – Closed loop type

Fig 18





Connection

A, B working lines

G pressure port for auxiliary circuits

L1 leakage oil or oil filing

L 2 leakage oil or oil drain

M A measuring point working line A

M B measuring point working line B

R bleed port

S suction port for boost oil

X 1 x2 ports for control pressures

Y 1 Y2 remote control ports (e.g. hand pilot valve)

The axial piston variable displacement pump in swashplate design 1 is a primary unit ready for fitting; it incorporates auxiliary pump 2 for boost and pilot oil supply adjustment unit 3, combined feed and pressure relief valves, and boost pressure relief valve.

One difference from the models already described is the tapered piston arrangement 7. With increasing speed, it increases the forces to retain the contact between the swashplate and the pistons. Also there is a spherical control surface 8 (advantage; self centering).

This variable displacement pump is designed for closed circuit and works in boosted operation, i.e. the fluid returning from the user is fed back to the pump under boost pressure. Leakage losses are replaced by the auxiliary pump.

Auxiliary pump 2 serves as a boost and control pump.

A boost pressure relief valve 4 is available to limit the maximum boost pressure.

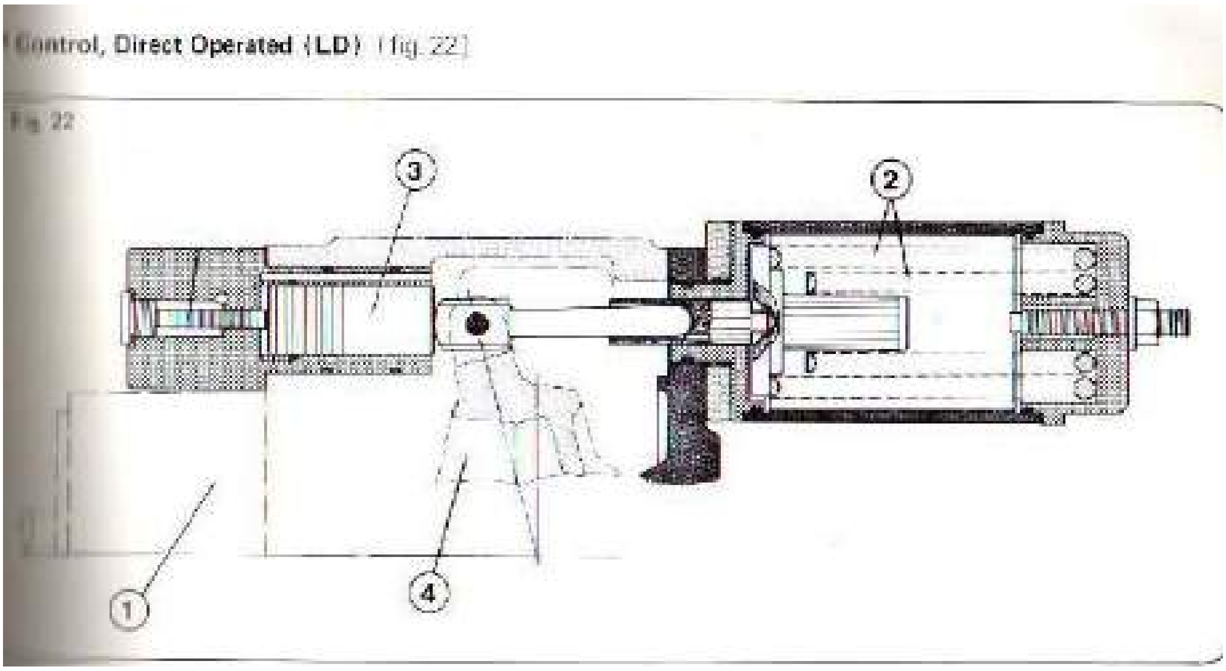
Two built-in pressure relief valves 5 limit the pressure affecting the high pressure side and protect the unit from overloading.

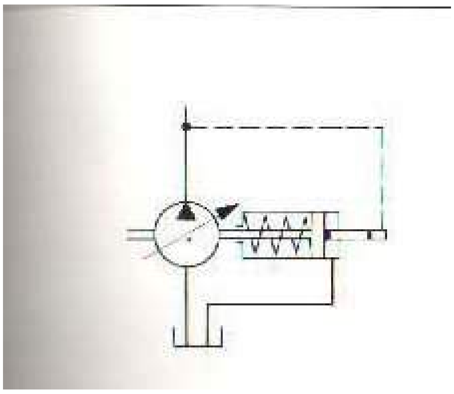
The orifices 6 serve to set the stroke adjustment time.

2.5 Different types of Control.

HP Control, Direct Operated (LD)

(fig. 22)





The direct operated HP control is flanged on to the rear of the axial piston unit1. It comprises a spring assembly 2, against which a piston 3 affected by system pressure works.

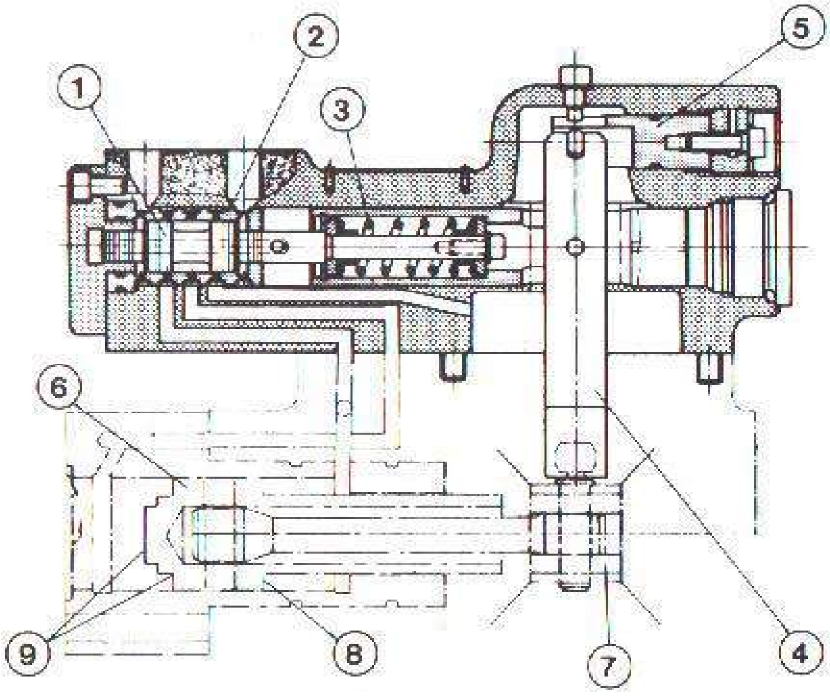
The spring assembly presses the swashplate 4 in the direction of the increased flow.

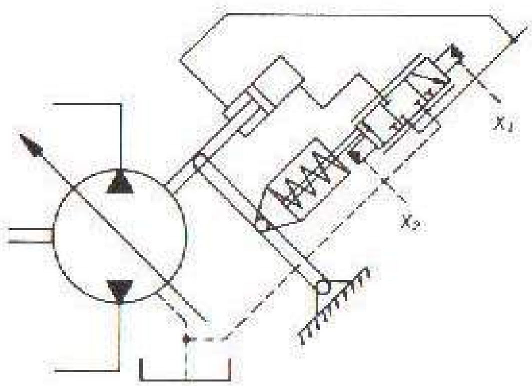
With fixed drive speed, the HP control prevents the given drive power being exceeded by causing a decrease in flow with increase of operating pressure, so that the product of flow and pressure remains constant.

2.6 Hydraulic Control, Pressure Related (HD)

Hydraulic Pumps and Hydraulic Motors

Fig. 23





Important Technical Data for Axial Piston Units:

Adjustment of the stroke volume of the axial piston unit proportional to a pilot pressure is possible using this control.

The control comprises the pilot piston 1, control sleeve 2, measuring spring 3 and return lever 4, also a device 5 for setting the zero position (fig. 23).

Adjustment piston 6 is connected to the pump by means of a piston rod and the swashplate 7. The pilot piston is encased in the control bush and works against a pressure spring. This measuring spring forms the connection to the return lever, which pivots on the swashplate. The annulus area 8 of the adjustment piston is always affected by adjustment pressure. Pressuring of the piston area 9 is controlled by means of pilot piston 1.

If pilot pressure affects the right annulus area of the pilot spool, this is then pushed to the left against the force of the measuring spring, causing the adjustment piston cross area to be connected to the annulus area.

The adjustment spool moves to the right, until the force of the measuring spring corresponds to the hydraulic force at the pilot piston, and this is thus pushed into zero position once again.

If pilot pressure affects the left annulus area of the pilot piston, then this is pushed to the right against the measuring spring and the gross piston area of the adjustment piston is connected to the outlet. The adjustment piston them moves to the left, until there is a balance between the hydraulic force at the pilot piston and the measuring spring force, and the pilot piston is in zero position once again.

The direction of flow of the pump reverses, as opposed to the process first described. A control pressure pump with b60 bar pressure is necessary for the control.

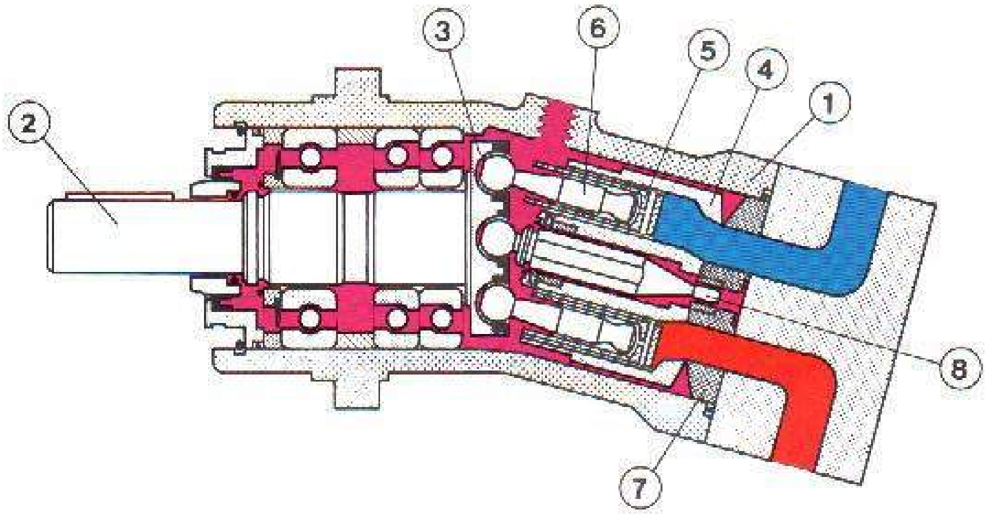
3.0 BENT AXIS PISTON PUMPS

3.1 Bent Axis Design with Fixed Displacement

(fig. 19)

Type A2F

Fig. 19



Drive shaft 2, cam plate 3, cylinder 4 with piston 5 and connecting rod 6, also control plate 7 are fitted (in the fixed housing 1. The cam plate is vertical to the drive shaft. The cylinder with seven piston and connecting rods is at an angle of 25 to the shaft axis. The cam plate is linked to the cylinder by means of the piston rods. The cylinder rests on the central pin 8.

When the drive shaft 2 is rotated in pump operation, cylinder 4 also rotates by means of the connecting rods 6 and the pistons 5. As the pistons are held at the cam plate by means of the connecting rods, a piston stroke occurs in the cylinder drum when the drive shaft is rotated. The control plate has two kidney shaped grooves for supply (blue) and drain (red) of the pressure fluid.

In order to bring the cylinder drum on to the control surface of the control plate (also called port plate) without mechanical guides, this is designed spherically.

The drive to the pistons and cylinder is transmitted through the connecting rods, whereby the drag load (friction and inertia forces) do not impose side loading in the cylinders.

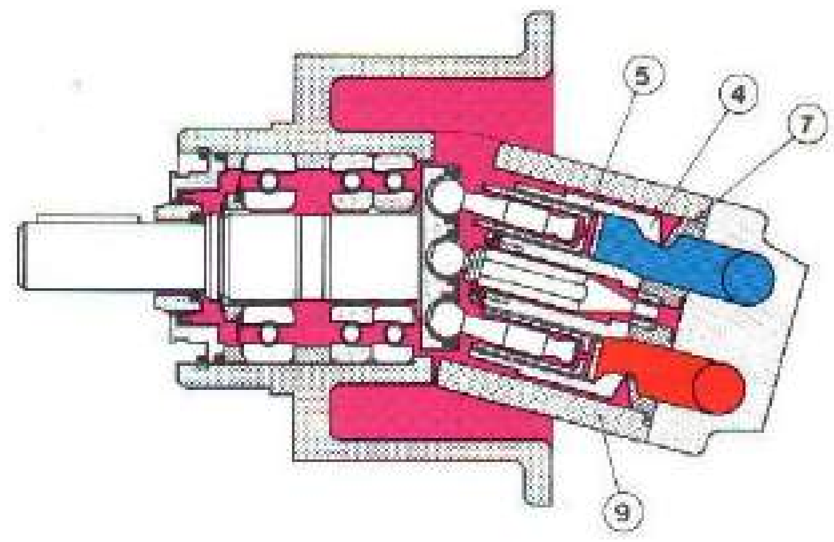
Transverse forces at the cylinder drum are absorbed by the center pin.

3.2 Bent Axis Principle with Variable Displacement (fig.20)

25V

The section shows an axial piston unit type A2V.

Fig. 20



On the version with variable displacement, cylinder drums 4 with pistons 5, port plate 7 and housing are arranged, so that they can move.

The angle to the shaft axis can be altered between 25.

The pistons carry out a certain stroke in the cylinder dependent on this tilt angle. The stroke and thus the displacement volume increases as the till angle increases. With the bent axis principle, the flow direction changes smoothly, when the body is swashed over zero position and the torque remains unchanged. If the tilt angle is zero, the displacement volume is zero.

SUMMARY

Axial piston pumps find application in medium and high pressure application.

- With special features, these pumps become power saving unit and reduces system heating.

REVIEW QUESTIONS

- What types of pumps are available in a Variable Displacement pump.
- What are two ways of positioning a yoke in a variable displacement in line pump.
- How can displacement be varied in an axial piston pump.
- What causes pistons to reciprocate in an axial piston pump? In a bent axis pump.
- What is meant by pressure compensator in an axial piston pump and how it works.

REFERENCE

3. ‘Power Hydraulics’, Michael J. Pinches and John G. Ashby.
4. Manuals of reputed Hydraulic product manufacturers.

SUBJECT: HYDRAULIC MOTORS

ABOUT THE SESSION

This session deals with various types of Hydraulic motors, its functions and operations.

INTRODUCTION

Motor is the name usually given to a rotary hydraulic actuator. Motors very closely resemble pumps in construction. Instead of pushing on the fluid as the pump does, as output members in the hydraulic system, they are pushed by the fluid and develop torque and continuous rotating motion. Since both inlet and outlet ports may at times be pressurized, most hydraulic motors are externally drained.

TABLE OF CONTENTS

OBJECTIVES:

To understand in depth the function and operations of

(i) Gear motors

(ii) Vane motors

(iii) Piston motors

  a. Inline Axial motors
  b. Bent Axis motors
  c. Radial motors

PRINCIPLE OF OPERATION

All hydraulic motors have several factors in common. Each type must have a surface area acted upon by a pressure differential. This surface is rectangular in gear, vane, and rotary abutment motors and circular in radial and axial piston motors. The surface area in each kind of motor is mechanically connected to an output shaft from which the mechanical energy is coupled to the equipment driven by the motor. Finally, the porting of the pressure fluid to the pressure surface must be timed in each type of hydraulic motor in order to sustain continuous rotation.

The maximum performance of a motor in terms of pressure, flow, torque output, speed, efficiency, expected life and physical configuration is determined by the:

- Ability of the pressure surfaces to withstand hydraulic force.
- Leakage characteristics
- Efficiency of the means used to connect the pressure surface and the output shaft.

2.0 MOTOR RATINGS

Hydraulic motors are rated according to displacement (size), torque capacity, speed, and maximum pressure limitations.

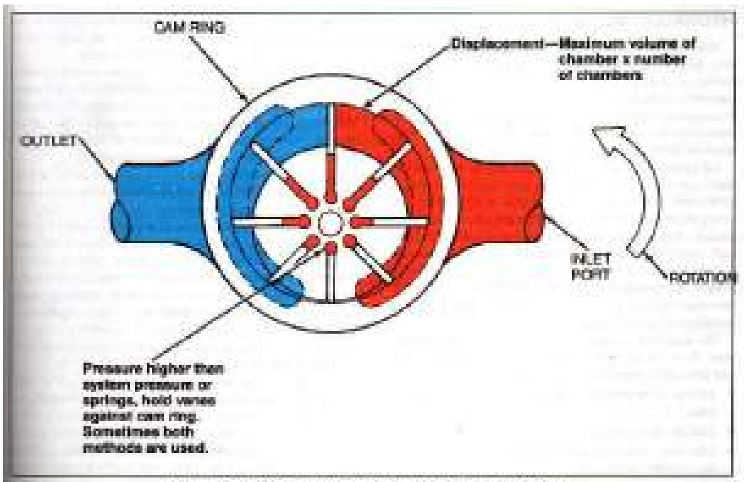


Figure 7-17. Motor displacement is capacity per revolution.

Displacement. Displacement is the amount of fluid required to turn the motor output shaft one revolution. Figure 7-17 shows that displacement is equal to the fluid capacity of one motor chamber multiplied by the number of chambers the motor contains. Motor displacement is expressed in cubic inches per revolution (cu.in./rev).

Displacement of hydraulic motors may be fixed or variable. With input flow and operating pressure constant, the fixed-displacement motor provides constant torque and constant speed. Under the same conditions, the variable displacement motor provides variable torque and variable speed.

Torque. Torque is the force component of the motor's output. It is defined as a turning or twisting effort. Motion is not required to have torque, but motion will result if the torque is sufficient to overcome friction and resistance of the load.

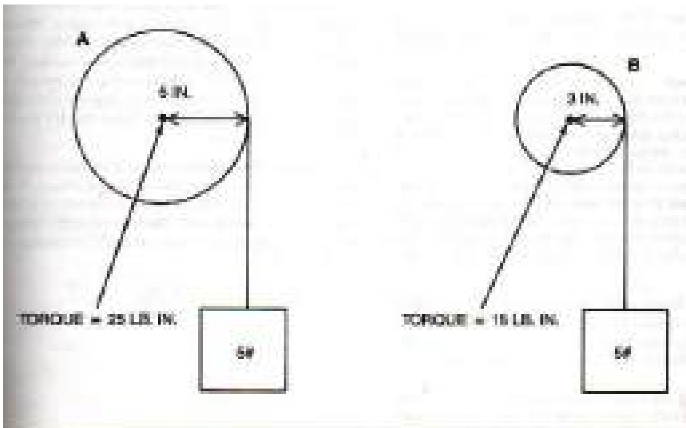


Figure 7-18. Torque equals load multiplied by radius.

Figure 7-18 illustrates typical torque requirements for raising a load with a pulley. Note that the torque is always present at the driveshaft, bus is equal to the load multiplied by the radius A given load will improve less torque on the shaft if the radius is decreased. However, the larger radius will move the load faster for a given shaft speed.

Torque output is expressed inch-pounds or foot-pounds, and is a function of system pressure and motor displacement. Motor torque figures are usually given for a specific pressure differential, or pressure drop across the motor. Theoretical figures indicate the torque available at the motor shaft assuming the motor is 100 percent efficient.

Breakaway torque is the torque required to get a non-moving load turning. More torque is required to start a load moving than to keep it moving.

Running torque can refer to a motor's load or to the motor. When it is used with reference to a load, it indicates the torque required to keep the load turning. When it refers to the motor, running torque indicates the actual torque which a motor can develop to keep a load turning. Running torque takes into account a motor's inefficiency and is expressed as a percentage of theoretical torque. The running torque of common gear, vane, and piston motors is approximately 90 percent of theoretical.

Starting torque refers to the capability of a hydraulic motor. It indicates the amount of torque which a motor can develop to start a load turning. In some cases, this is much less than a motor's running torque. Starting torque is also expressed as a percentage of theoretical torque. Starting torque for common gear, vane, and piston motors ranges between 60 to 90 percent of theoretical.

Mechanical efficiency is the ratio of actual torque delivered to theoretical torque.

Speed. Motor speed is a function of motor displacement and the volume of fluid delivered to the motor. Maximum motor speed is the speed at a specific inlet pressure which the motor can sustain for a limited time without damage. Minimum motor speed is the slowest, continuous, smooth rotational speed of the motor output shaft. Slippage is the leakage across the motor, or the fluid that moves through the motor without doing any work.

Pressure. Pressure required in a hydraulic motor depends on the torque load and the displacement. A large displacement motor will develop a given torque with less pressure than a smaller unit. The size and torque rating of a motor usually is expressed in Kg meter.

CHANGE	**SPEED**	**EFFECT ON OPERATING PRESSURE**	**TORQUE AVAILABLE**
INCREASE PRESSURE SETTING	NO EFFECT	NO EFFECT	INCREASES
DECREASE PRESSURE SETTING	NO EFFECT	NO EFFECT	DECREASES
INCREASE FLOW	INCREASES	NO EFFECT	NO EFFECT
DECREASE FLOW	DECREASES	NO EFFECT	NO EFFECT

INCREASE DISPLACEMENT(SIZE)	DECREASES	DECREASES	INCREASES
DECREASE DISPLACEMENT(SIZE)	INCREASES	INCREASES	DECREASES

Summary of effects of application changes on motor operations.

3.0 TYPES OF HYDRAULIC MOTORS

There are a variety of hydraulic motors used in industrial applications. The type

of motor that is used depends on the demands of each individual application. the following motors are reviewed in this chapter:

- Gear Motors – external
- Vane Motors – including unbalanced, balanced, fixed, variable and cartridge (high performance) types.
- Piston Motors – including in-line, bent-axis, and radial motors (fixed, variable and cam type)

3.1 Gear motors: external gear

External Gear Motor. External gear motors consist of a pair of matched gears enclosed in one housing (Figure 7-20). Both gears have the same tooth form and are driven by fluid under pressure. One gear is connected to an output shaft, the other is an idler.

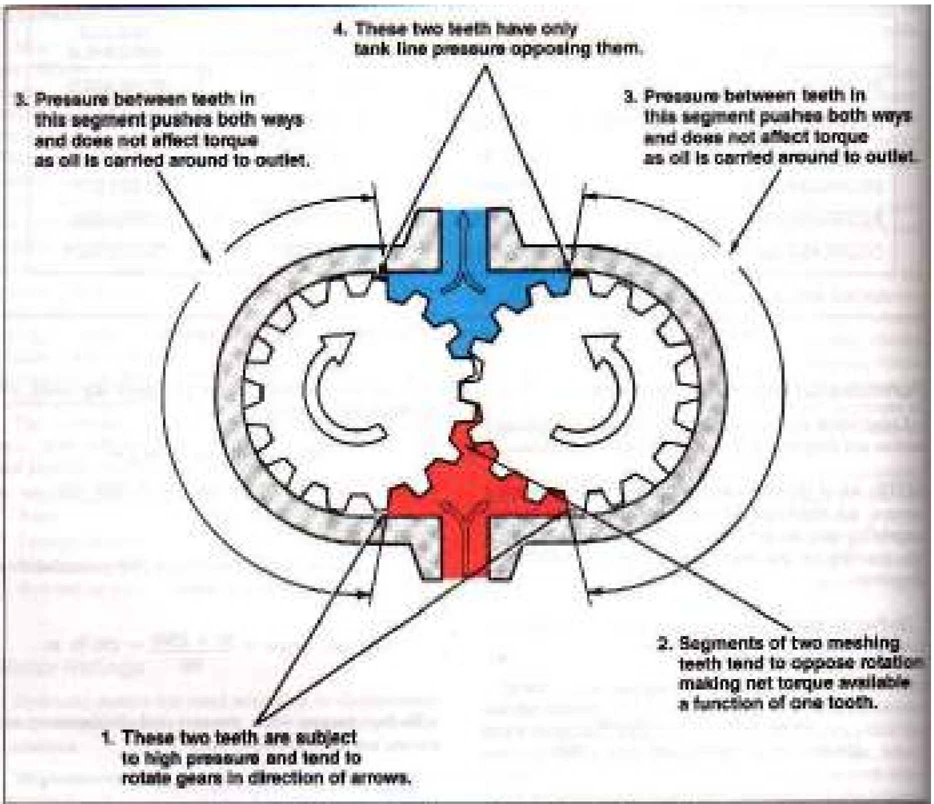


Figure 7-20. Torque development in an external gear motor.

Fluid pressure enters the housing on one side at a point where the gears mesh and forces the gears to rotate, as fluid at high pressure follows the path of least resistance around the periphery of the housing (colored portion of the figure). The fluid exits, at low pressure, at the opposite side of the motor.

Note that torque developed is a function of hydraulic imbalance of only one tooth of one gear at a time; the other gear and teeth are hydraulic balanced.

Close tolerances between gears and housing help control fluid leakage and increase volumetric efficiency. Wear plates on the sides of the gears keep the gears from moving axially and also help control leakage.

3.2 Vane Motors

In a vane motor, torque is developed by pressure on exposed surfaces of rectangular vanes which slide in and out of slots in a rotor splined to the driveshaft (Figure 7-24A). As the rotor turns, the vanes follow the surface of a cam ring, forming sealed chambers which carry the fluid from the inlet to the outlet.

3.2.1 Balanced Design

In the balanced design shown in Figure 7-24B, the system working pressure at the inlet and the tank line pressure at the outlet are both forces in the system. These opposing pressures are directed to two interconnected chambers within the motor located 180 degrees apart. Any side loads which are generated oppose and cancel each other. The majority of vane motors used in industrial systems are the balanced design.

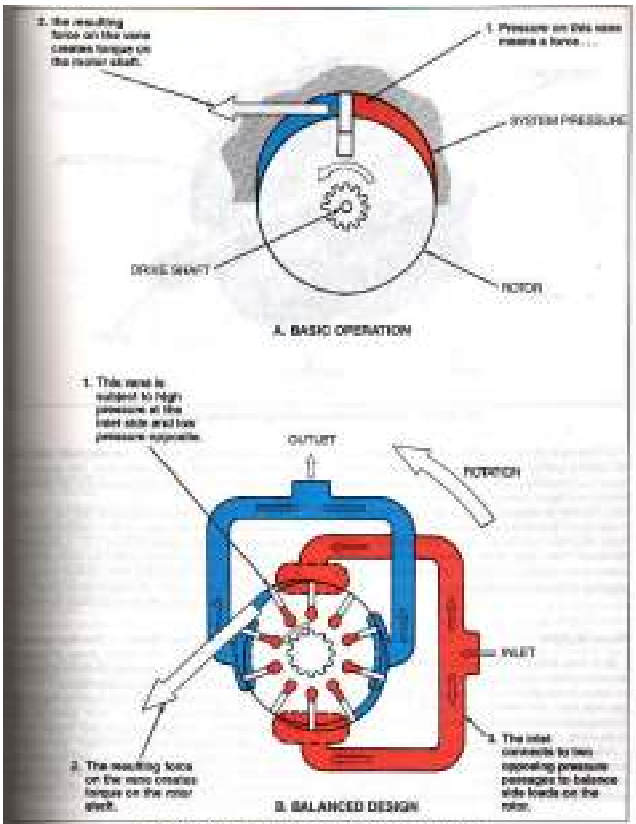


Figure 7-24. Torque development in a balanced vane motor.

There are various design modifications that can be made to vane motors. A vane motor with a unidirectional or non-reversible design is shown in Figure 7-25. A check valve in the inlet port assures pressure to hold the vanes extended, eliminating the need for rocker arms, shuttle valves, or an external pressure source. One application might be a fan drive or similar device which would rotate in only one direction.

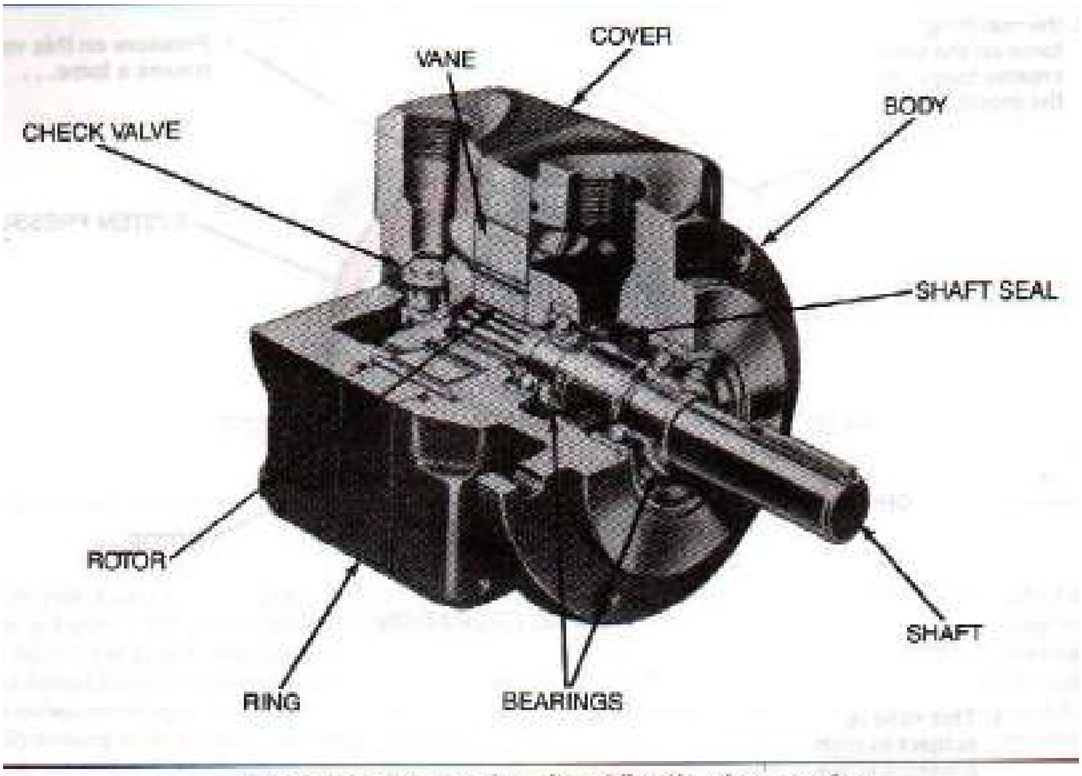


Figure 7-25. Construction of a unidirectional vane motor.

3.2.2 High Performance Vane Motors

The high performance vane motor (Figure 7-26) is a later design of balanced vane motor. It operates under the same principles to generate torque but has significant changes in construction.

In this design, the vanes are held out against the ring by coil springs. The entire assembly or ring, rotor, vanes and side plates is removable and replaceable as a unit (Figure 7-27). In fact, preassembled and tested “cartridges” are available for field replacement. These motors also are reversible by reversing flow to and from the ports. Both side plates function alternately as pressure plates (Figure 7-28), depending on the direction of flow.

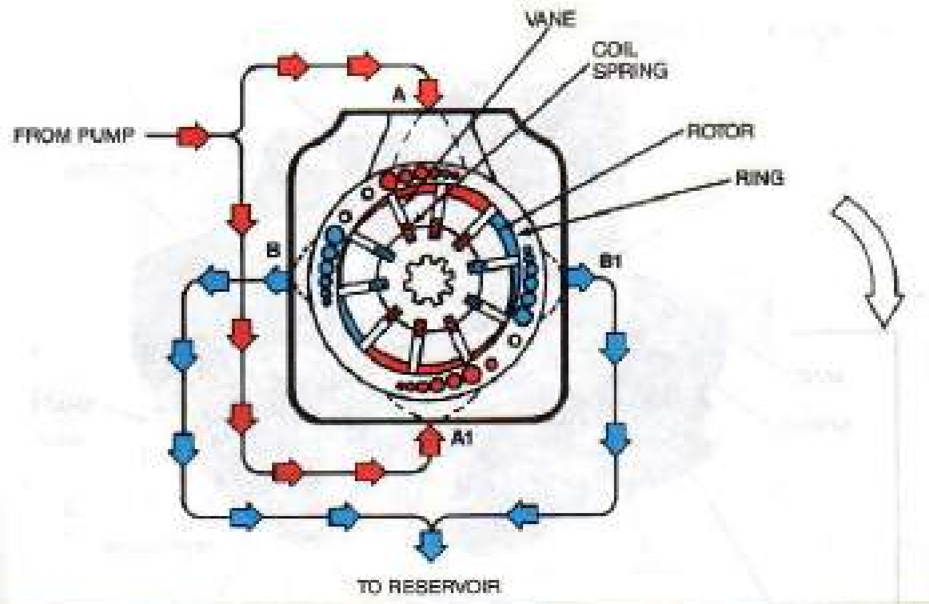


Figure 7-26. Operation of a high performance vane motor.

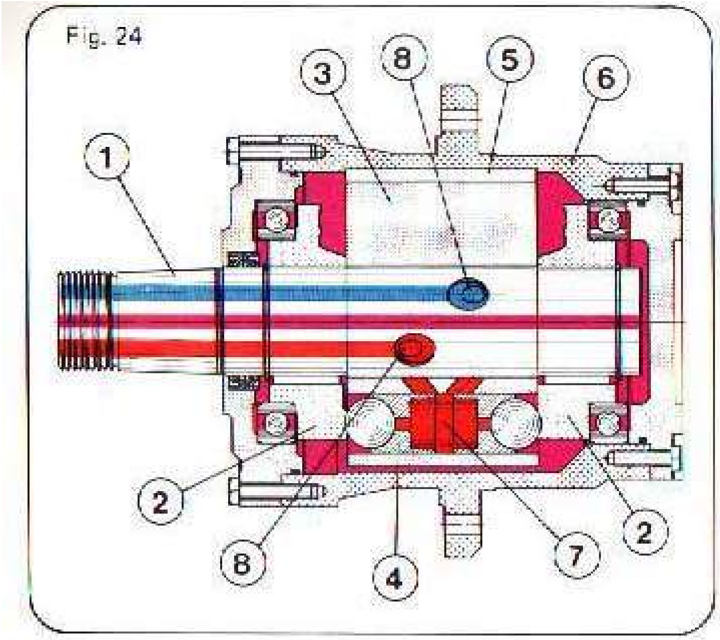
3.3 Piston Motor

There are varieties of piston motor designs currently available. The demands of each industrial application determine the correct selection of a piston motor type. Information on the in-line piston motor, radial piston motor, and the bent-axis piston motor is covered in this section.

Piston motors are probably the most efficient of the three types of hydraulic motors discussed and are usually capable of the highest speeds and pressures. In aerospace applications in particular, they are used because of their high power to weight ratio. In-line motors, because of their simple construction and resultant lower costs, are finding many applications on machine tools and mobile equipment.

3.3.1 Inline Axial Piston Motor

The motor comprises a fixed shaft 1, two cam plates 2 fitted on both shaft ends, and the rotor/piston arrangement 3 (fig. 24)



The rotor between the two plates, with, according to motor type, 5,8 or 9 bores fitted with 2 piston/ball combinations 4 lying opposite one another in each bore, is connected with the external housing 6 by means of key 5.

Rotor 3 and housing 6 can rotate round the fixed shaft 1. This movement is brought about by alternately pressuring the cylinder chambers 7.

The contra-rotating stroke movement of the piston/ball combination us changed to a rotary movement by its contact with the cam plates. Oil supply (red) and oil drain (blue) are by means of the fixed shaft in the motor.

The control is by means of radial bores 8, arranged correspondingly in the shaft (pintel valve).

The motor can be reversed, even during operation, by changing direction of the oil supply and drain.

The piston/ball combination is radially arranged on this slow-speed motor.

The motor comprises a housing with flange for power take-off, the radial cam plates 2 integrated in the housing, and the mounting flange 3 with shaft 4.

3.3.2 Bent Axis Motor

This motor was designed specially for hydraulic drive with secondary control adjustment.

A complete adjustment device for a maximum swash angle range of 7 to 25 is fitted.

A lens shaped port plate 1 is fitted in place of the port plate shown in fig. 20. This is designed in such a way that it can be moved in a circular track.

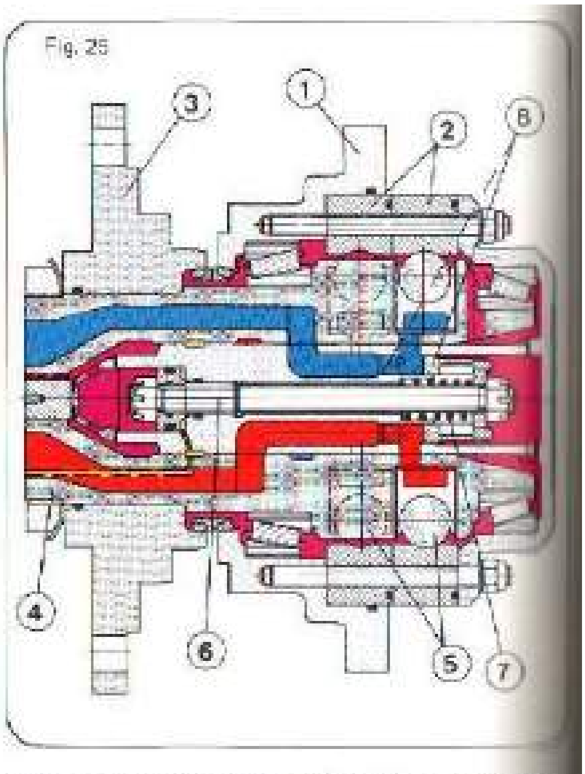
Adjustment is by means of an adjustment piston 2 via a pin 3, which engages on the rear face of the port plate.

Control of adjustment piston 2 is by means of control piston 4, which is operated by pressuring or by a control solenoid depending on the method of control selected. A separate pilot oil pump is not necessary, as the highest operating pressure at any time is drawn as adjustment oil from parts A or B (not shown in fig.).

In order to guarantee that the adjustment functions perfectly, the high pressure and thus simultaneously perfectly, the high pressure and thus simultaneously the adjustment oil pressure must be at least 15 bar.

3.3.3 Radial Piston Motor

It can be switched to half displacement (fig. 25), in which 2 x 6 piston/ball combinations 5 and also the reversal unit 6 are fitted.



Radial Piston Motor Type RH 800, can be switc
to half displacement (Fig. 25)

Supply and drain of the fluid is by means of the fixed shaft. Pressure affects the pistons and thus these are pushed with the ball on to the externally arranged track and cause the housing to rotate.

The twelve pistons are arranged in 2 rows of six. When pressure affects the annulus area (yellow) of the reversal unit 6, this is pushed to the left against the spring, by means of an external signal.

Control components in Hydraulic system

One of the most important functions in any fluid power system is control. If control components are not properly selected, the entire system will fail to deliver the required output. Elements for the control of energy and other control in fluid power system are generally called **"Valves"**. It is important to know the primary function and operation of the various types of control components. This type of knowledge is not only required for a good functioning system, but it also leads to the discovery of innovative ways to improve a fluid power system for a given application. The selection of these control components not only involves the type, but also the size, the actuating method and remote control capability. There are 3 basic types of valves.

1. Directional control valves 2. Pressure control valves 3. Flow control valves.

Basic Consideration for the flow and pressure are controlled by using the principle of orifice flow. The major factors that affect the valve performances are:

i) Rate of opening the orifice. ii) Size of the orifice. iii) Designed characteristics of orifice

. iv) Direction of opening. v) Sequences of opening the orifices in a multi orifice valve.

Directional control valves are essentially used for distribution of energy in a fluid power system. They establish the path through which a fluid traverses a given circuit. For example they control the direction of motion of a hydraulic cylinder or motor. These valves are used to control the start, stop and change in direction of flow of pressurized fluid.

Pressure may gradually buildup due to decrease in fluid demand or due to sudden surge as valves opens or closes. Pressure control valves protect the system against such overpressure. Pressure relief valve, pressure reducing, sequence, unloading and counterbalance valve are different types of pressure control valves.

In addition, fluid flow rate must be controlled in various lines of a hydraulic circuit. For example, the control of actuator speeds depends on flow rates. This type of control is accomplished through the use of flow control valves.

DIRECTION CONTROL VALVES:

Direction control valves determine the path through which a fluid traverses a given circuit. For example, they establish the direction of motion of a hydraulic cylinder or motor. The control of the fluid path is accomplished primarily by check valves, shuttle valves and two-way, three-way and four-way direction control valves.Any valve contains ports that are external openings through which fluid can enter and leave via connecting pipelines. The number of ports on a direction control valve (DCV) is identified using the term way. Thus for example, a valve with four ports is a four- way valve. Directional-control valves also control flow direction. However, they vary considerably in physical characteristics and operation.

The valves may be a **Poppet type**, in which a piston or ball moves on and off a seat, Rotary-spool type, in which a spool rotates about its axis. **Sliding-spool type**, in which a spool slides axially in a bore. In this type, a spool is often classified according to the flow conditions created when it is in the normal or neutral position.

Directional-control valves may also be classified according to the method used to actuate the valve element.A poppet-type valve is usually hydraulically operated. A **rotary-spool type** may be manually (lever or plunger action), mechanically (cam or trip action), or electrically (solenoid action) operated.A sliding-spool type may be manually, mechanically, electrically, or hydraulically operated, or it may be operated in combination.

Directional-control valves may also be classified according to the number of positions of the valve elements or the total number of flow paths provided in the extreme position. For example, a three-position, four-way valve has two extreme positions and a center or neutral position. In each of the two extreme positions, there are two flow paths, making a total of four flow paths.

Directional control valves can be classified in a number of ways:

1. <u>According to type of construction</u> :
   - Poppet valves
   - Spool valves
2. <u>According to number of working ports</u> :
   - Two- way valves
   - Three – way valves
   - Four- way valves.
3. <u>According to number of Switching position</u>:
   - Two – position
   - Three - position
4. <u>According to Actuating mechanism</u>:
   - Manual actuation
   - Mechanical actuation
   - Solenoid (Electrical) actuation
   - Hydraulic (Pilot) actuation
   - Pneumatic actuation
   - Indirect actuation

The designation of the directional control valve refers to the number of working ports and the number of switching positions.

Thus a valve with 2 service ports and 2 switching positions is designated as 2 / 2 way valve.

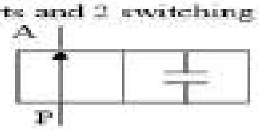


Fig . <u>2 /2 valve symbol</u>

A valve with 3 service ports and 2 position is designated as 2 / 3 way valve.

Fig <u>2 / 3 valve symbol</u>

A valve with 4 service ports and 2 position is designated as 2 / 4 valve.

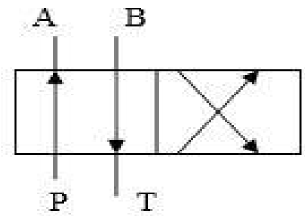


Fig 4.3. 2 / 4 valve symbol

A valve with 4 Service ports and 3 Switching position is designated as 3 / 4 way valve. Fig 4 shows an example of open centered position.

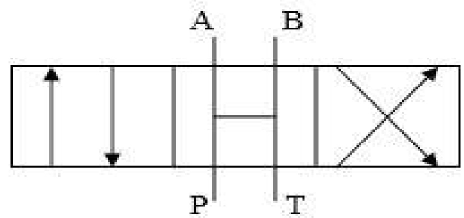


Fig 3/ 4 valve symbol :

Spool positions as well as their corresponding actuating elements are labelled with numbers 1, 2 as shown in figure 5. A valve with 2 spool position is shown and also a valve with 3 spool positions. In directional control valves with 3 spool position, the central position is the neutral position (**or** mid position **or** zero **or** null position).

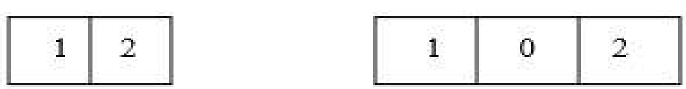
The **neutral** position is the position in which the moving parts are assumed to be inactive, but affected by a force (e.g. spring)

The ports are designated as follows:

P = Pressure Port (Pump Port)

T = Tank Port

A , B = User Ports



2- Position valve 3- Position valve

Fig Basic symbol for directional control valves

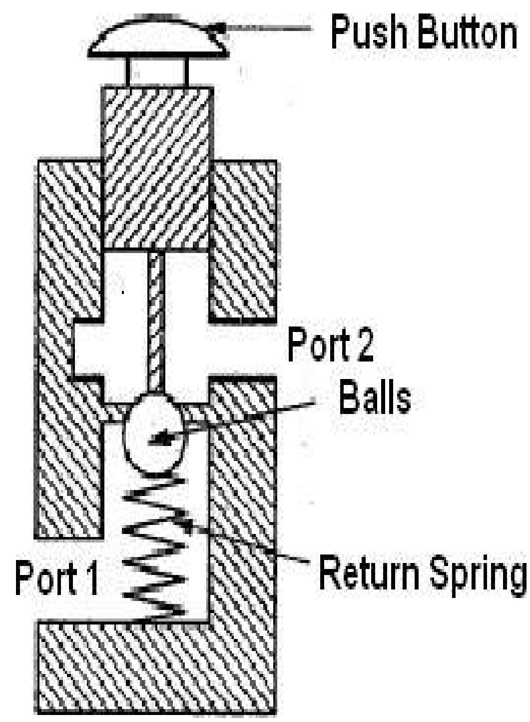
Observe that the graphical symbol shows only one tank port T even though the physical design may have two since it is only concerned with the function of a component and not its internal design. The tank port is the port of the valve that is piped back to the hydraulic oil tank. Therefore, each tank port provides the same function. The spool valve working ports are inlet from the pump, outlets to the cylinder, and exhaust to tank. These ports are generally identified as follows : P = pressure ; A or B = actuator and T = tank.

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

1. .Poppet or Seat Valves
2. Sliding Spool Valves
3. Rotary Spool Valves

POPPET OR SEAT VALVES:

The Figure shows the construction of the poppet valve. Normally this valve is in the closed condition and hence there is no connection between port 1 and port 2. In poppet valves, balls are used in conjunction with valves seats to control the flow.

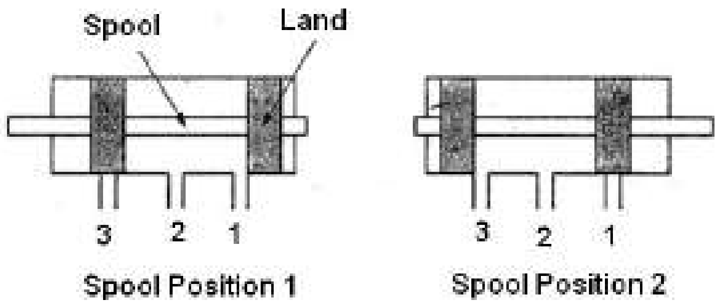


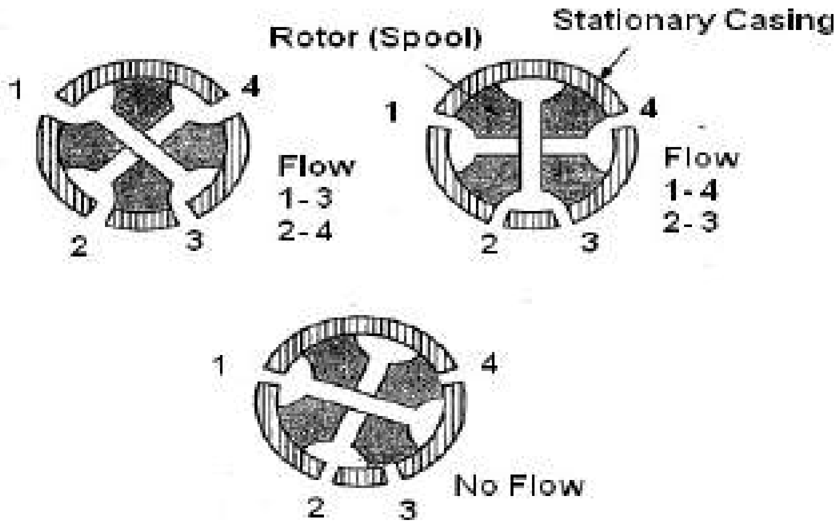
When the push button is depressed the ball is pushed out of its seats and hence the flow is permitted from port1 to port2. When the push button is released spring and fluid pressure force the ball back up against its seat and so closes off the flow.

These types of valves are simple in design and less expensive. The force required to operate the poppet valves are more, so they are suitable mostly for low pressure applications.

SLIDING SPOOL VALVES:

These types of valves are most frequently used in hydraulic system. A spool moves horizontally within the valve body to control the flow. The raised areas called lands block or open portto give the required operation. In first position the port 1 and port 2 is opened and port 3 is blocked so the flow is permitted between ports 1 and 2. In the second position the ports 2 and 3 are open and port 1 is blocked so the flow is permitted between 2 and 3.





By using this type of valves different operations can be achieved with a common body and different spool. It is used for high pressure applications.

ROTARY SPOOL VALVES

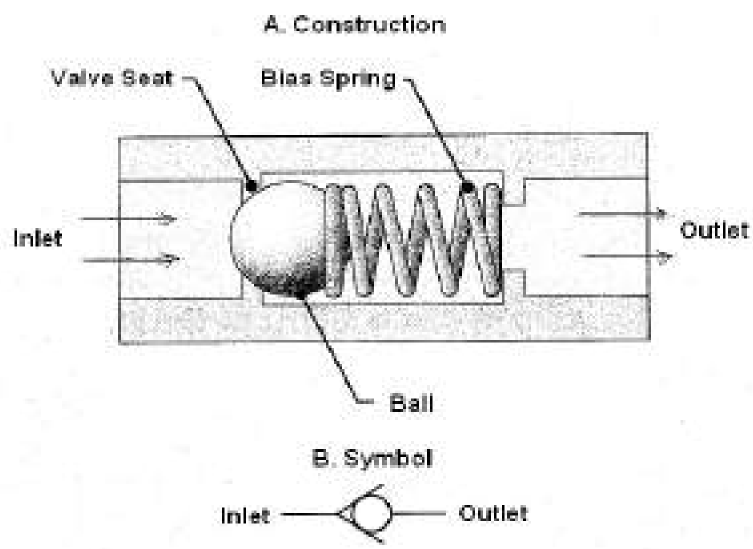
These valves have a rotating spool which engages with ports in the valve casing to give the required operation. The Figure shows the cut section of a rotary spool valve. When the spool rotates, it opens and closes ports to allows and prevent the fluid flow through it. There are four ports 1, 2, 3, and 4. In the first position there is flow between 1 and 3, 2 and 4. In second position flow between 2 and 3, 1 and 4. In third position all the ports are blocked by the spool and there is no flow.

DIRECTION CONTROL VALVES

These valves are used to control the direction of flow in a hydraulic circuit. According to the construction of internal moving parts it is classified as poppet type and sliding spool type. It may be further classified as one way, two way, three way and four way valves, depending upon the number of port connections available. On the basis of actuating devices, it can be classified as manually operated, mechanically operated, solenoid operated and pilot operated.

CHECK VALVES

The simplest direction control valve is a check valve. It allows flow in one direction and blocks flow in the opposite direction. It consists of a ball with a light bias spring that holds the ball against the valve seat. Flow coming into the inlet pushes the ball off the seat against the light force of the spring and continues to the outlet.

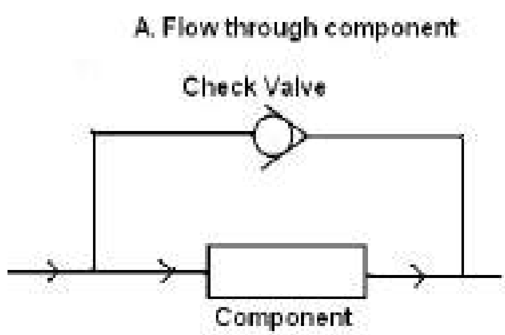


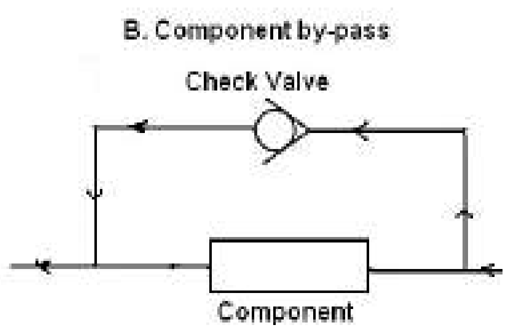
Application of Check Valve

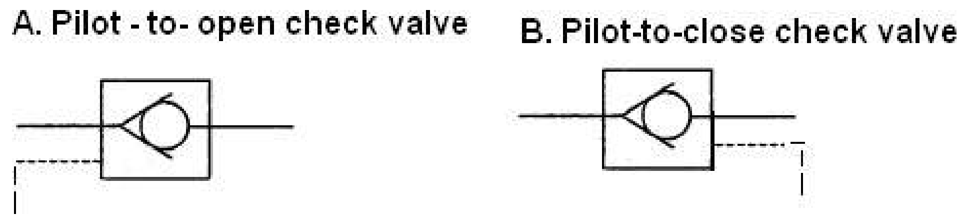
If flow tries to comes in from left it cannot pass through the check valve. It is therefore forced to go through the component. When the flow comes in from the right, however the flow goes through the check valve and the component is bypassed. This occurs because the check valve is designed to have less resistance to flow than the component in this direction.

PILOT OPERATED CHECK VALVE

One commonly used type is the pilot to open check valve. Pilot lines are hydraulic lines that are used for control purposes. They typically send system pressure to component, so that the component can react to pressure changes. The free flow in the normal direction from a port A to port   B is achieved in a usual manner. But the reverse flow is blocked as the fluid pressure pushes the poppet into the closed position. In order to permit the fluid flow in the reverse direction that is 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 reversed direction is also obtained.   The purpose of the drain port in the circuit is to prevent oil from creating a pressure building in the bottom of the pilot piston. The pilot lines are shown in dashed lines.



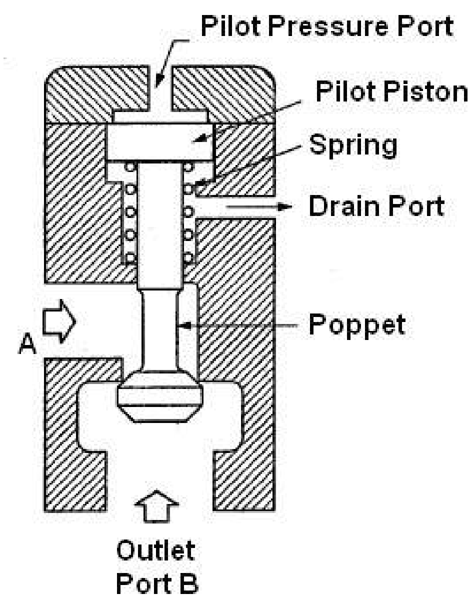


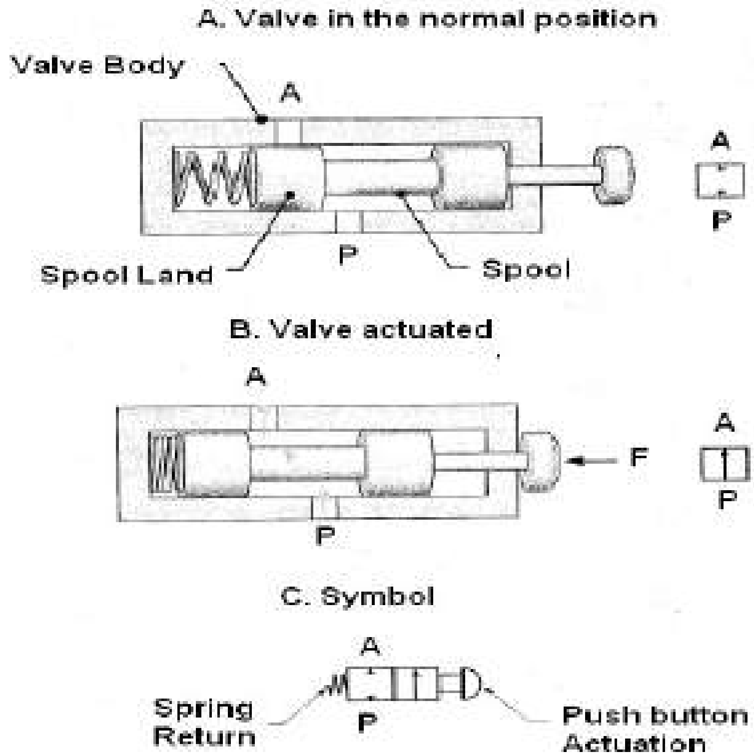


Symbols for Pilot Operated Check Valve

TWO WAY DIRECTIONAL CONTROL VALVE

A spool valve consists of a cylindrical spool that slides back and forth inside the valve body to either connect or block flow between ports. The larger diameter portion of the spool, the land, blocks flow by covering a port. This particular valve has two ports, labeled P and A. P is connected to the pump line and A is the outlet to the system. position, the going to the outlet port A.



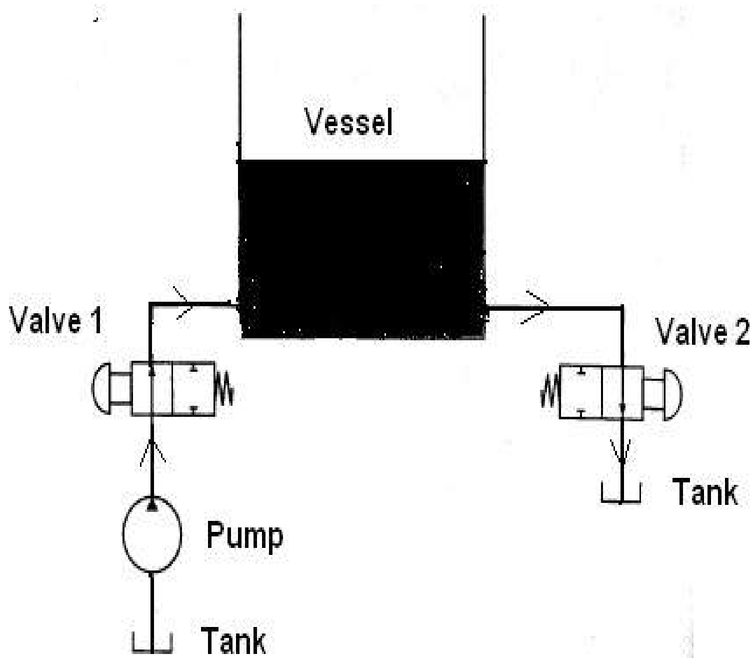


Two way, Two position normally closed DCV

'Figure B' shows the valve in its actuated state and its corresponding symbol. The valve is shifted into this position by applying a force to overcome the resistance of the spring. In this position, the flow is allowed to go to the outlet port around the smaller diameter portion of the spool. The complete symbol for this valve is shown in 'Figure C'. The symbol has two blocks, one for each position of the valve. Valves may have more than two positions. The spring is on the closed position side of the symbol, which indicates that it is a normally closed valve. The symbol for the method of actuation is shown on the opposite side of the valve. In this case, the valve is push button actuated. Thus, the graphic symbol in 'Figure C' represents a two way, two positions, normally closed DCV with push button actuation and spring return.

The below Figure shows the example of an application for a two way valve. Here pair of two way valves is used to fill and drain a vessel.

Although two tanks are shown in this schematic, there may in fact be only one tank in the actual system. When valve1 and valve2 are in the closed position then the line from pump and tank are blocked to hold the fluid in the vessel. When the valve1 is shifted to the open position and valve 2 remains closed. This will fill the vessel.



Application of Two way DCV valves

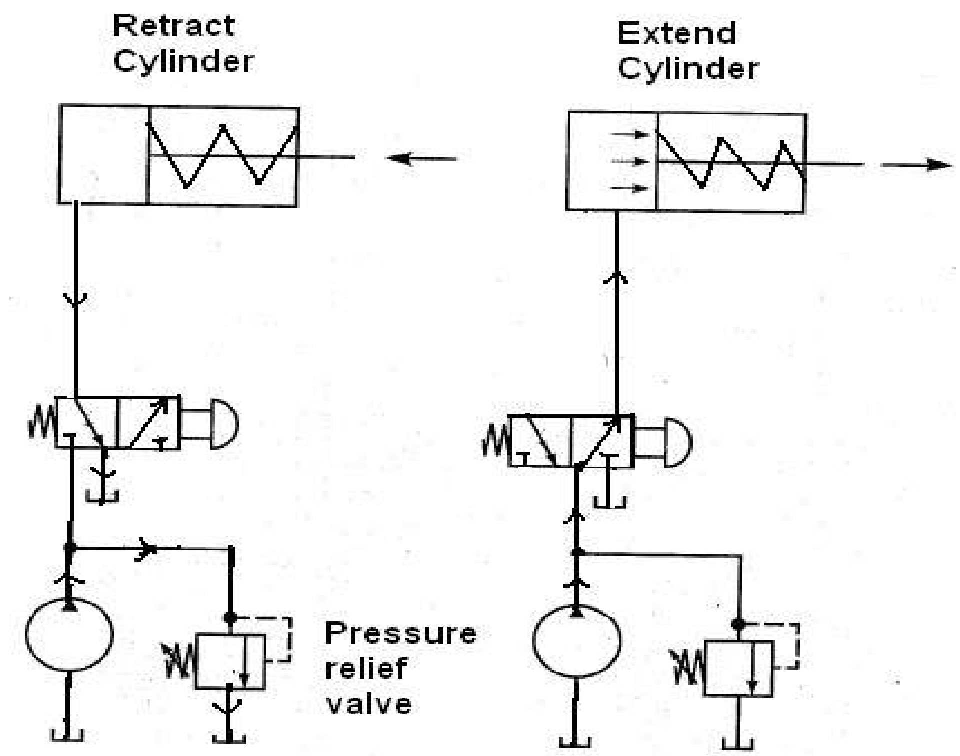
When valve2 is shifted to the open position and valve2 remains closed. This will drain the vessel. The above figure shows that valve1 and valve2 are in open position so that fluid is filled and drain from the vessel. There are other types of construction for two way valves in addition to the spool type are ball valves and gate valves.

THREE WAY DIRECTION CONTROL VALVES

As discussed earlier two way valves are used to start and stop fluid flow in a particular line.

They can either allow or block flow from a pump to an oulet line for example. Three way valves also either block or alow flow from an inlet to an outlet.They also allow the outlet to flow back to the tank when the pump flow in the tank when the pump flow is blocked ,while a 2 way does not.A three way valve have three way valve have three ports a pressure inlet port (P), an outlet to the sytem (A), and a return to the tank (T). In its normal position, just as with the two way DCV, the valve is held in position with spring. In the normal position 'Figure A' the pressure port (P) is blocked and the outlet (A) is connected with the tank (T). This depressurizes or vents the outlet port. In the actuated position the pressure port is connected with the outlet and the tank port is blocked. This sends flow and pressure to the system. The spring is shown on the normal side of the valve symbol and the actuation type is shown in opposite side by push button. The symbol indicates that this is a three way two position normally closed DCV with push button and spring return.

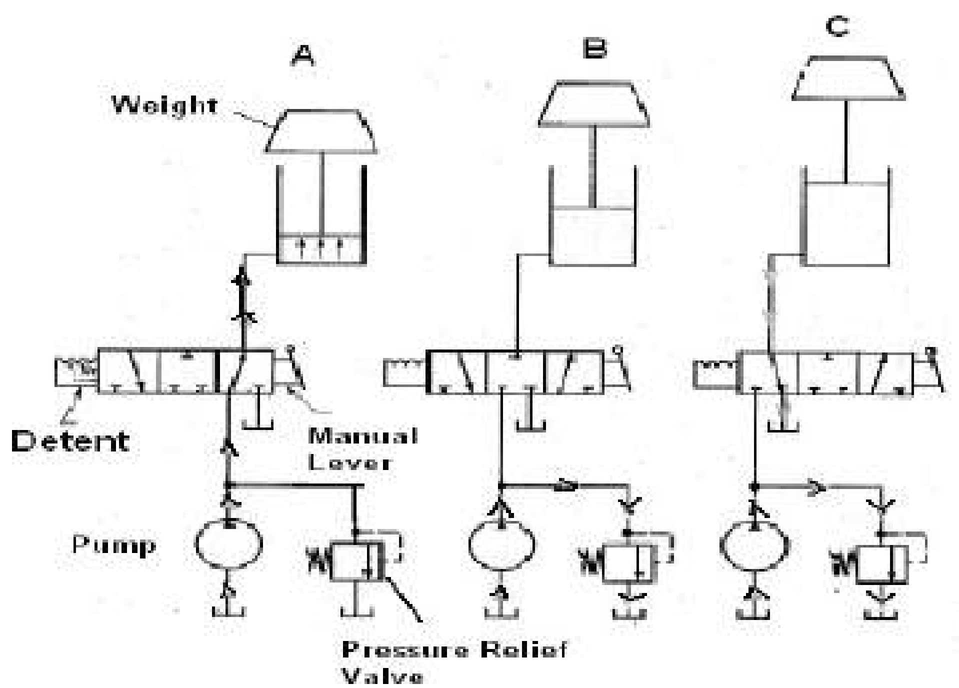
The most common application for a three way valve in a hydraulic circuit is to control a single acting cylinder. Part A shows the valve in normal position in which pressure port is blocked and the outlet is return to the tank. This allows the force of the spring to act on the



Application of Three Way Two Position DCV

piston and retract the cylinder. The cylinder will remain retracted as long as the valve is in this position. In part B the valve is shifted so that the pressure port is connected to the outlet and the tank port is blocked. This applies pump flow and pressure to the piston and extends the cylinder against the relatively light force of the spring. A two way valve could not be used in this application. It would not allow the cylinder to retract when it is in the closed position because the closed position of a two way does not have a return to the tank. A pressure relief valve, a device that limits the maximum pressure in a hydraulic circuit, is included in the previous circuit. These valves are required components in every hydraulic system. The importance of the pressure relief valves are discussed in upcoming topics.

The next figure shows application of three way three position DCV using gravity return type single acting cylinder. A third valve position called neutral may be desirable for this application. This position shown as the center position in the symbol blocks all the three ports. This holds the cylinder in a mid-stroke position because the hydraulic fluid, which is relatively incompressible, is trapped between the valve and the cylinder. Many cylinder applications require this feature. This introduces another type of actuation manual lever and detent. A detent is a mechanism that holds the valve in any position into which it is shifted. Detented valves have no normal position because they will remain indefinitely in the last position indicated.



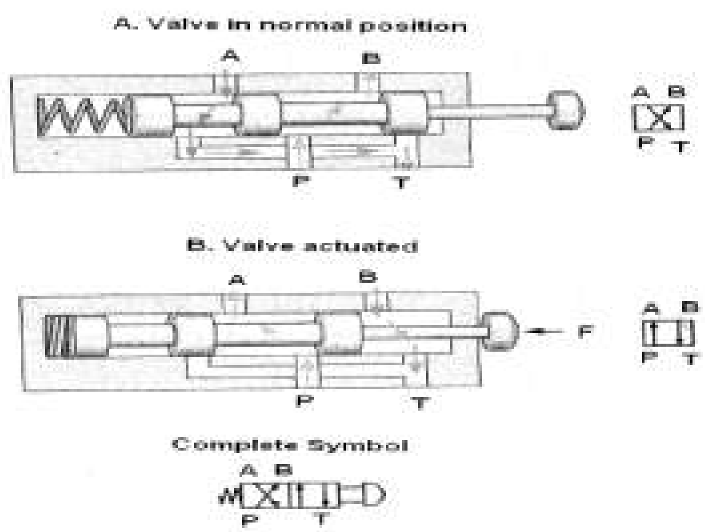
Application of Three way three position DCV

(A) Extend Cylinder (B) Hold Cylinder (C) Retract Cylinder

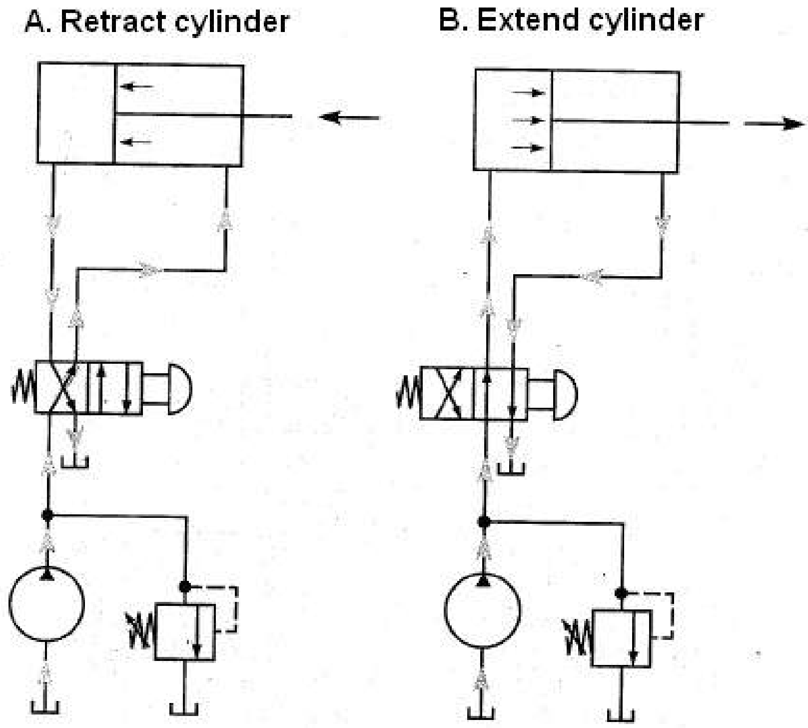
FOUR WAY DIRECTIONAL CONTROL VALVES

Four way valves are the most commonly used directional control valves in hydraulic circuits because they are capable of controlling double acting cylinders and bidirectional motors. Figure shows the operation of a typical four way, two positions DCV. A four way has four ports, usually labeled P, T, A and B. P is the pressure inlet and T is the return to tank. A and B are outlets to the system. In the normal position, pump flow is sent to outlet B and outlet A is connected to the tank. In the actuated position, pump flow is sent to port A and port B is connected to the tank. Four way DCV control two flows of fluid at the same time, while two way and three way DCV control only one flow at the time.

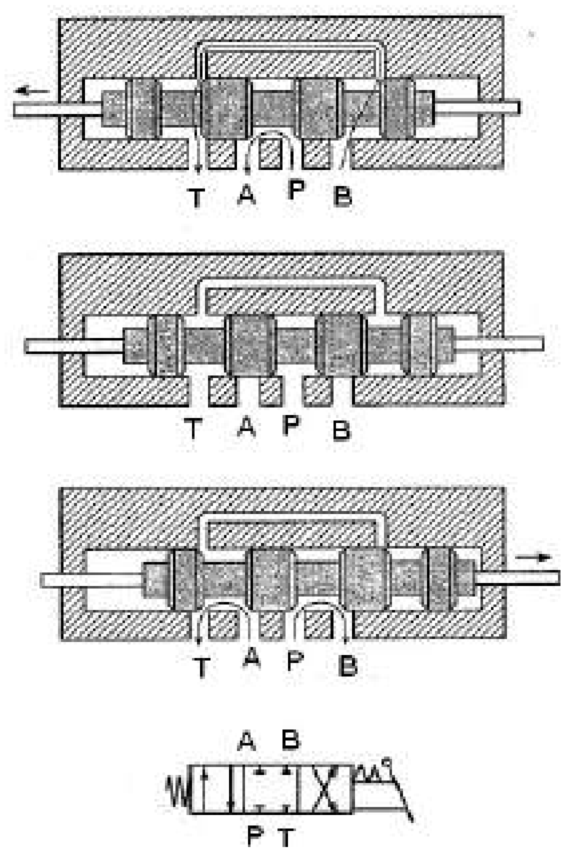
The most common application for a four way DCV is to control a double acting cylinder as shown in below Figure. When the valve is in the normal position, the pump line is connected to the rod end of the cylinder and the blind end is connected to the tank . The cylinder will therefore retracted, the pump flow will go over the pressure relief valve back to the tank, as it must whenever the pump flow cannot go to the system. In Figure B, the pump line is connected to the blind end of the cylinder and the rod end is connected to the tank. This will cause the cylinder to extend. When the cylinder is fully extended, pump flow will again go over the pressure relief valve to the tank.



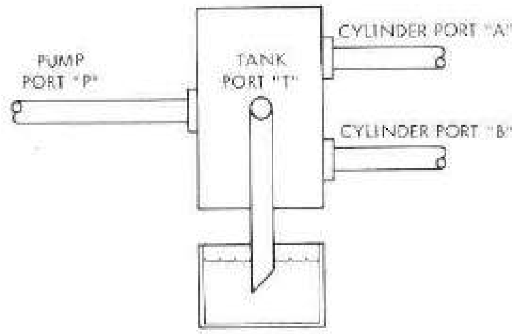
Four way, Two position DCV



Application of Four way, Two position DCV



Four way, Three position DCV



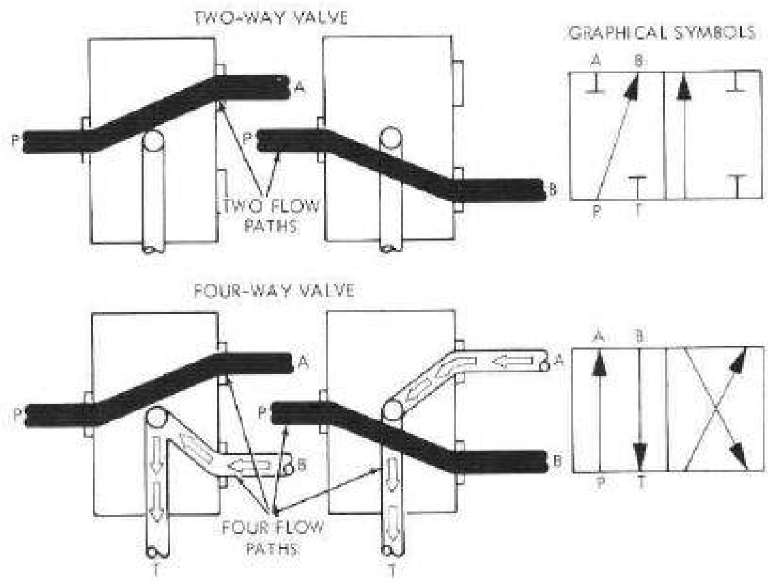
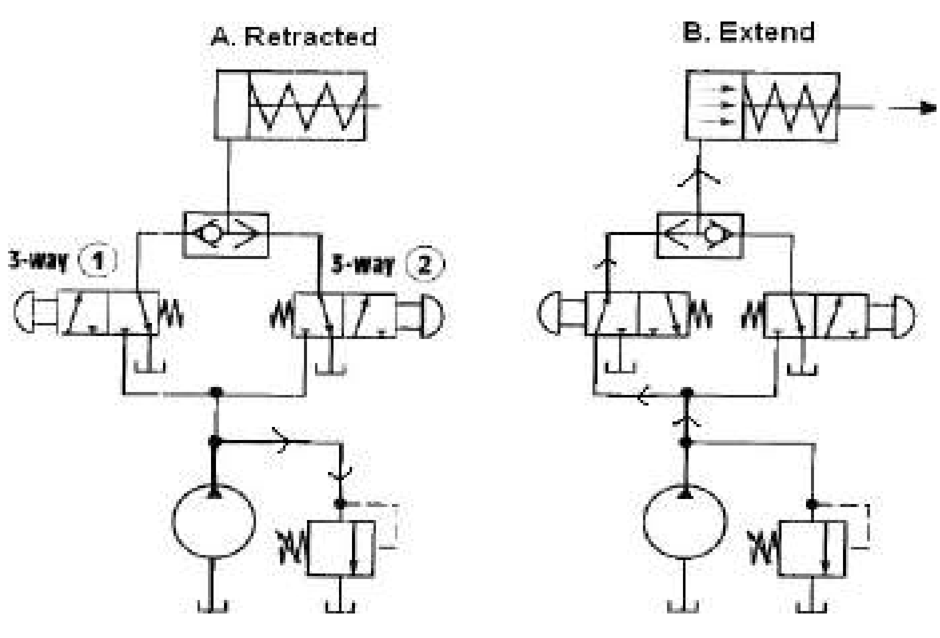
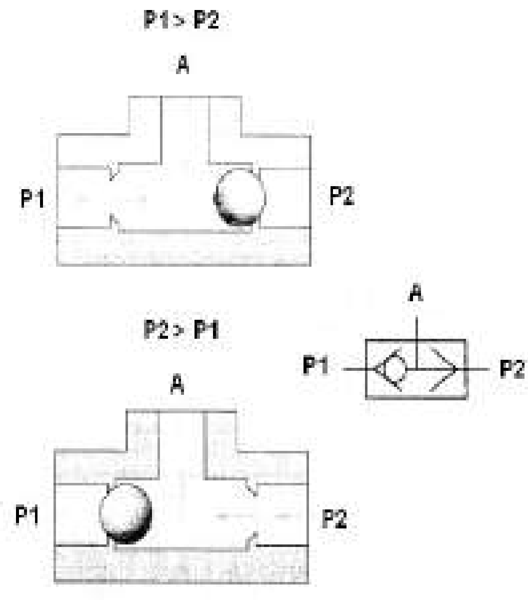


Figure Two-way and four-way directional control valves. (*Courtesy of Sperry Vickers, Sperry Rand Corp., Troy, Michigan.*)

SHUTTLE VALVES

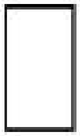
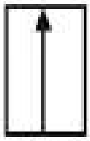
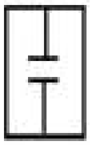
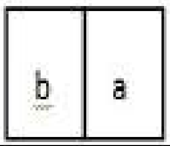
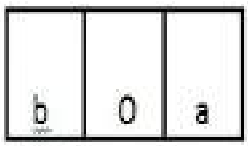


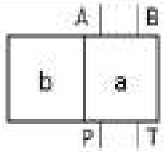
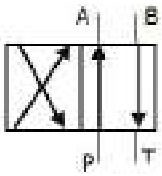
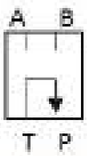
Shuttle Valve Circuit

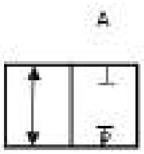
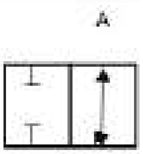


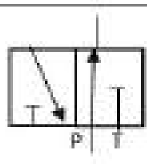
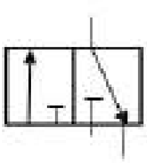
These valves allow two alternate flow sources to be connected to one branch circuit. They have two inlets (P1 and P2) and one outlet (A). Outlet A received flow from whichever inlet is at a higher pressure. If the Pressure at P1 is grater than that at P2, the ball slides to the right and allows P1 to send flow to outlet A. If the pressure at P2 is grater than at P1, the ball slides to the left and P2 supplies flow to outlet A. The Figure shows a circuit that utilizes a shuttle valve. This circuit allows either of two three way buttons to operate a single acting cylinder. 'Figure A' shows both three ways in their normal position. The cylinder is vented to the tank and will remain retracted under the force of the spring. In 'Figure B' three way number 1 is shifted and pump flow is sent to the cylinder through the path shown.

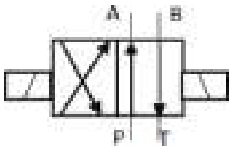
DIRECTIONAL CONTROL VALVE SYMBOLS

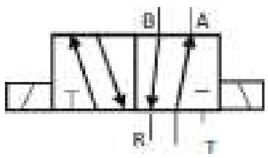
	Each individual switching portion is shown in a square
	Flow path is indicated by means of arrow within a square
	Closed position
	Two-position valve
	Three-position valve

	Ports added to the two-position valve
	Two flow paths
	Two ports are connected, two ports are closed

2/2-way valve: 2-ports and 2-position DCV	
	Normally closed position: P is not connected to A. When the valve is not actuated, the way is closed.
	Normally open position: P is connected to A. When the valve is not actuated, the way is open.

3/2 way valve : 3ports and 2 position DCV	
	Normally open position: P is connected to A. When the valve is not actuated, the way is open.
	Normally open position: P is connected to A. When the valve is actuated, the way is closed

4/2-wax- a-ah-e — 4-port a•d 2-pu inoo DCs”	
	P is connected to A B is connected to T
B	Position 2: P iS connected to B A is connected to T

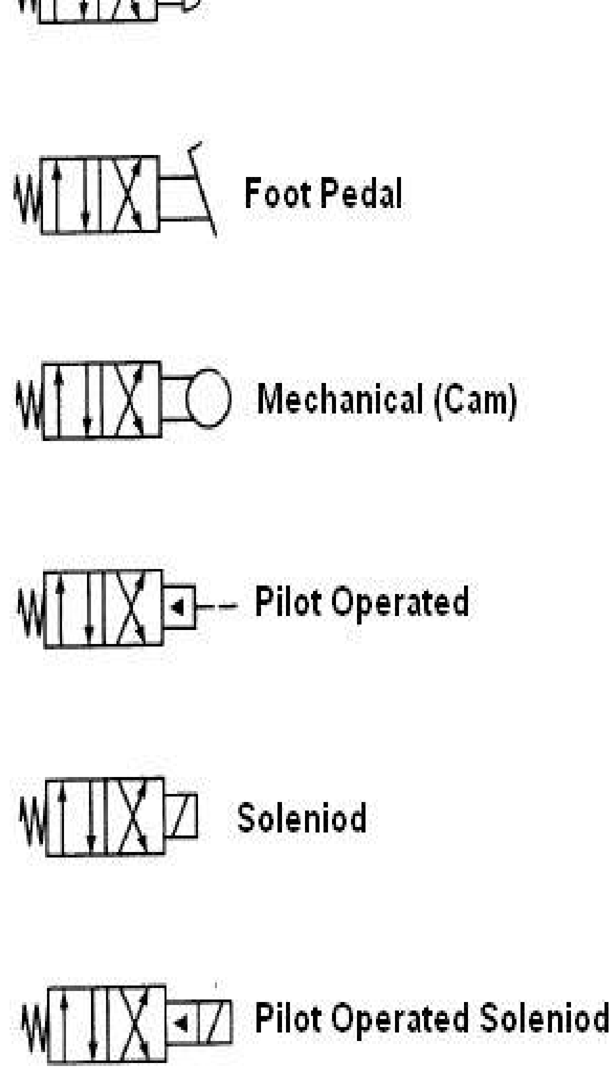
5/2-way valve – 5-port and 2-position DCA’	
	Normal position: his connected to B A is connected to R

DIRECTIONAL CONTROL VALVE ACTUATION

Various methods used to shift the valve are shown in Figure. All shown controlling a spring return four way two position valve. Manual lever is a popular method of actuation for DCVs used in mobile equipment applications such as back hoes, bulldozers and farm equipment. Push button actuation is more prevalent in industrial applications.

Foot pedal actuatio, which could be used in an application in which hands free shifting of the DCV is required.Cam actuated valves shift when depressed by aome mechanical components of the machine.

. Pilot operated valves are shifted with system pressure. As stated earlier, pilot operated check valves use system pressure to hold a check valve open or closed when pressure is applied to the pilot line. Solenoid actuated DCV valves are shifted using electrical current, which induces a magnetic force that shifts the valve spool. Solenoid valves are widely used in industrial applications on electronically controlled machinery. The pilot operated solenoid valves are essentially two valves in one package. The solenoid is used to actuate a small pilot DCV, which in turn uses the pressure of the system to shift the main valve. This method of actuation is necessary on large valves that operate in systems at high pressures. They are necessary because the solenoid alone cannot generate enough force to shift a large valve against a high pressure. The solenoid can, however, generate enough force to shift the small pilot valve, which can then use the pressure the system to shift the main valve.



PRESSURE CONTROL VALVES

The force of a cylinder is proportional to the pressure in a system and the area over which the pressure is applied. Controlling the pressure level in a circuit will therefore allow us to control the output force of a cylinder pressure control valves control the max pressure level and also protect the circuit from excessive pressure, which could damage components and possibly cause serious injury. Some types of pressure control valves simply react to pressure changes rather than control the pressure.

PRESSURE RELIEF VALVES

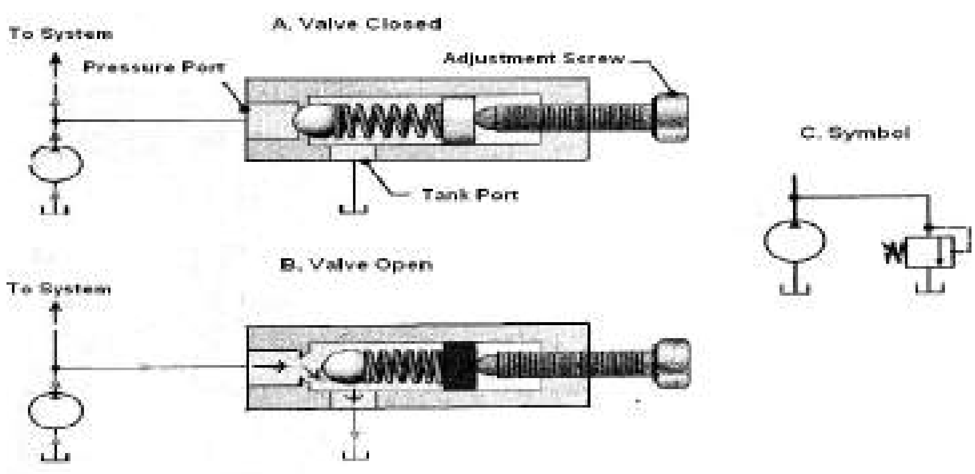
Pressure relief valves limit the max pressure in a hydraulic circuit by providing an alternate path for fluid flow when the pressure reaches a preset level.

The basic types are

1. Direct acting pressure relief valve
2. Pilot operated pressure relief valve

DIRECT ACTING PRESSURE RELIEF VALVES

All relief valves have a pressure port that is connected to the pump line and a tank port that is connected to the tank. The Figure shows the direct acting press relief valve, a ball or poppet is subjected to pump pressure on one side and the force of a spring on the other. When the pressure in the system creates a force on the ball that is less than the spring force, it remains on its seat and the pump flow will go to the systems as shown in Fig. A. When the pressure is high enough to create a force greater than the spring force, the ball will move off its seat and allow pump flow to go back to the tank through the relief as shown in Fig. B. The pressure at which the relief valve opens can be adjusted by changing the amount of spring compression, which changes the amount of force applied to the ball on the spring side.

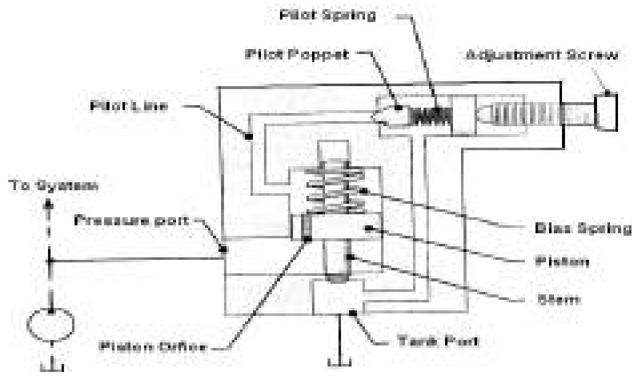


Direct Acting Pressure Relief Valve

This is accomplished with an adjustment screw or knob. This type of relief valve is called direct acting because the ball is directly exposed to pump pressure. The graphic symbol for an adjustable pressure relief valve, along with a pump is shown in Fig. C. The symbol shows that the valve is normally closed on one side of the valve; pressure is fed in to try to open the valve, while on the other side the spring is trying to keep it closed. The arrow through the spring signifies that it is adjustable, allowing adjustment of the pressure level at which the relief valve opens.

PILOT OPERATED PRESSURE RELIEF VALVE

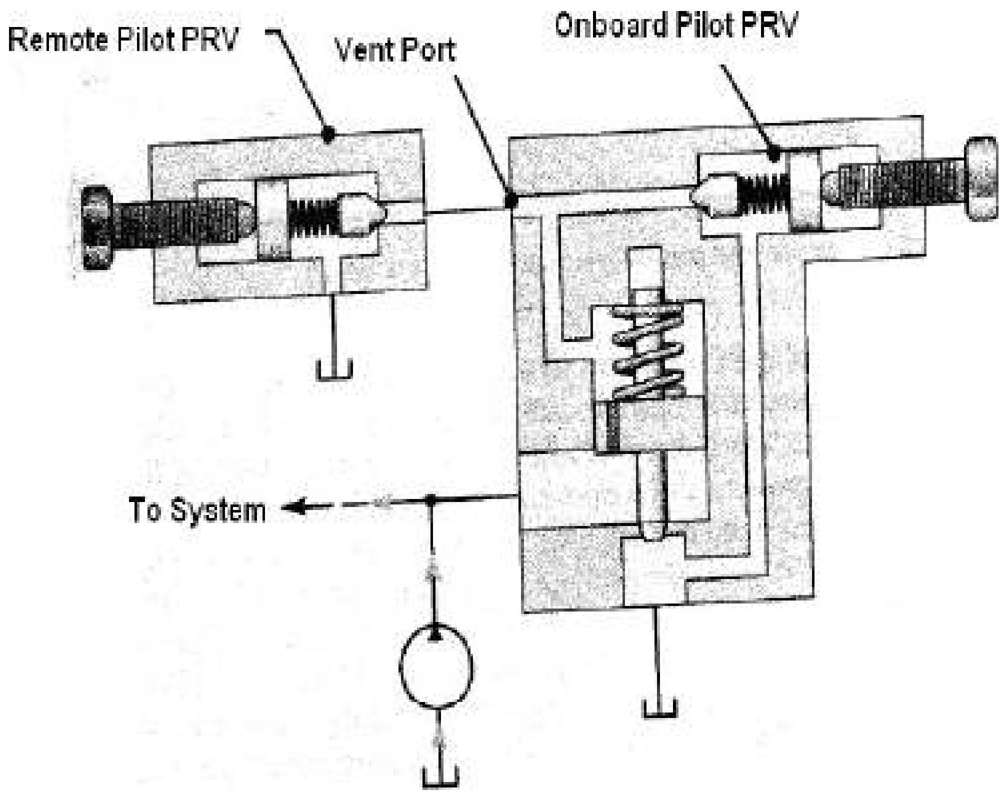
The Figure A, B shows the pilot operated pressure relief valve, rather than a direct acting relief valve, is used to control the maximum pressure. A pilot operated relief valve consists of a small pilot relief valve and a main relief valve. It operates in a two stage process. First the pilot relief valve opens when a preset maximum pressure is reached, which then causes the main relief valve to open. Just like the direct acting type, the pilot operated type has a pressure port that is connected into the pump line and a tank port that is connected to tank.



Pilot Operated Pressure Relief Valve – A - Closed and B =Open

The pilot relief is usually a poppet type. The main relief consists of a piston and stem. The main relief piston has a hole called the orifice drilled through it. This allows pressure to be applied to the top side of the piston, as well as the bottom side. The piston has equal areas exposed to pressure on the top and bottom and is therefore balanced it will have equal force on each side. It will remain stationary in the closed position. The piston has a light bias spring to ensure that it will stay closed. When the pressure is less that the relief valve setting, the pump flow goes to the system. The pressure is also applied to the pilot poppet through the pilot line. If the pressure in the system becomes high enough, it will move the pilot poppet off its seat. A small amount of flow begins to go through the pilot line back to tank. Once flow begins through the piston orifice and pilot line, a pressure drop is induced across the piston due to the restriction of the piston orifice. This pressure drop then causes the piston and stem to lift off its seat and the flow goes directly from the pressure port to the tank.

The symbol for the pilot operated relief valve is the same as that used for the direct acting relief valve. The advantages are usually smaller than a direct acting type for the same flow and pressure ratings. They also generally have a wider range for the maximum pressure setting. Another advantage is that they can be operated remotely. This is achieved by connecting a direct acting relief valve to the vent port of the pilot operated relief valve as shown in Figure C. Notice that the vent port is connected into the pilot line. The direct acting relief valve, called the remote in this arrangement, acts as a second pilot relief valve. Flow can now go back to tank through either the onboard pilot or the remote pilot. Whichever pilot is set to a lower pressure will cause the relief valve to open. Flow through either pilot will cause the main poppet to lift off its seat and allow full flow back to the tank. The advantage of this type of arrangement is that the on board pilot can be set to the absolute maximum pressure that the circuit is designed for, while the remote can be set for a



C - Pilot Operated Pressure Relief Valve with Remote Control

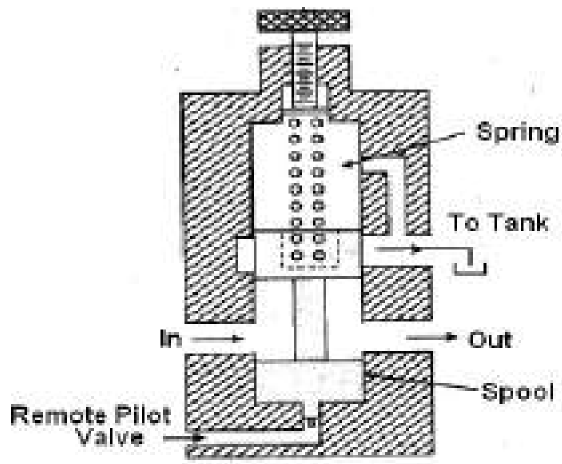
Lower pressure dictated by the current operating parameters. This method of pressure control has two key advantages

1. The on board pilot can be made in accessible so that if the machine operator were to inadvertently set the pressure of the remote too high, the pressure would never rise above the absolute maximum setting determined by the on board pilot.
2. The remote pilot can be located away from the circuit in a safe location that is easily accessible to the operator. In the symbol the lines associated with the remote are dashed because they are control pilot lines.

The pressure at which the relief valve begins to open is known as the cracking pressure. At this pressure, the poppet just begins to lift off its seat and some of the pump flow begins to go through the relief valve back to the tank. The rest of the flow goes to the system. The pressure at which the relief valve is completely open is known as the full flow pressure. The difference between the cracking pressure and the full flow pressure is often called the pressure over ride in manufacture's literature.

UNLOADING VALVES

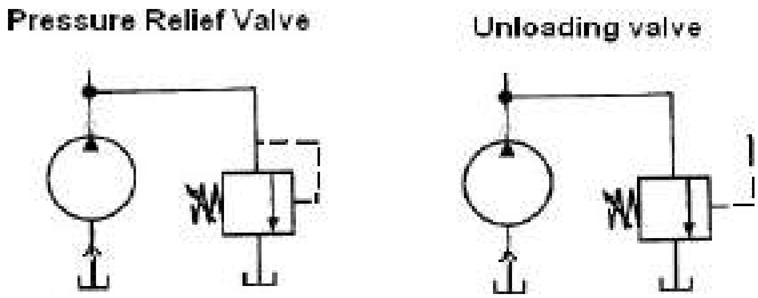
In the case of pressure relief valve, the pump delivers full pump flow at the pressure relief valve setting and thus operates at maximum horse power conditions.



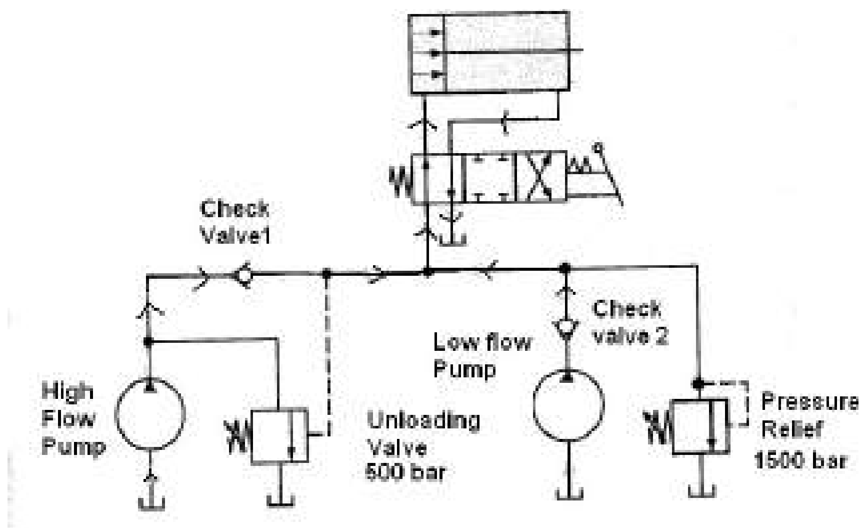
Unloading Valve

The 'In' port of the unloading valve is connected to the line which is to be unloaded. The pilot port is connected to the line which is supposed to send the pressure impulse for unloading the valve. As soon as the system pressure reaches the setting pressure which is available at the pilot port, it lifts the spool against the spring force. The valve is held open by pilot pressure and the delivery from the pump starts going into the reservoir. When the pilot pressure is released, the spool is moved down by the spring and the flow is directed through the valve into the circuit. The unloading valve is useful to control the amount of flow at any given time in systems having more than one fixed delivery pump.

The symbol for each is shown in 'Figure A' for comparison. Both send flow back to the tank when a preset pressure is reached. However, an unloading valve reads the pressure in an external line, rather than in its own line, as indicated by the dashed pilot lines. 'Figure B' shows the application for an unloading valve. This circuit can be used in an application in which high flow (speed) and low pressure (force) is required for a part of the cylinder stroke's while low flow and high pressure are required for the rest for example a metal stamping machine.



A - Symbol Comparison

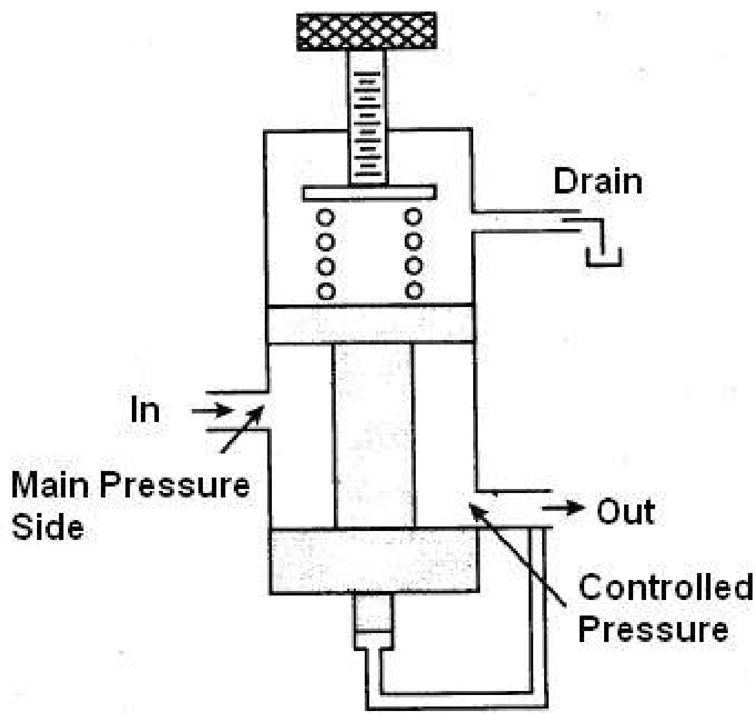


B - Unloading Valve Circuit

In this machine it may be desirable for the cylinder to move into position very quickly, and then slow down when it reaches the work piece. The first part of the cycle requires only minimal pressure because the only resistance is the flow resistance of the components and the friction of the cylinder. The second part of the cycle requires high pressure because the cylinder is deforming the metal. This circuit supplies the cylinder with from both the high flow pump and the low flow pump when the pressure is below 500 bar. When the pressure reaches 500 bar, the unloading valve opens and unloads the high flow pump back to tank at low pressure. Only the low flow pump supplies the cylinder with flow at pressure from 500 bar to 1500 bar. If the pressure reaches 1500 bar, flow from the low flow pump is forced over the relief valve at this pressure. Check valve 1 isolates the high flow pump from the system pressure while it is being unloaded. Check valve 2 prevents the flow the high flow pump from flowing into the low flow pump line. This would reverse the low flow pump, which would cause damage to the power unit.

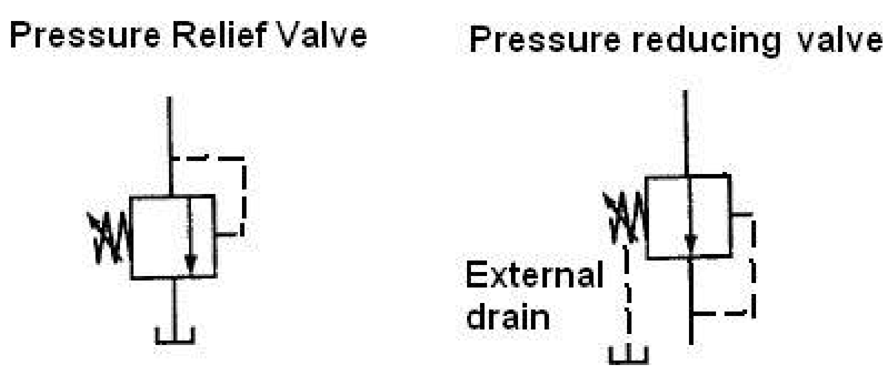
PRESSURE REDUCING VALVE

This type of valve is used to maintain reduced pressure in specified locations of hydraulic systems. It is normally an open valve. It is actuated by down stream pressure and tends to close as this pressure reaches the valve setting. The figure shows the construction of the valve. This valve is one which uses a spring loaded spool to control the down stream pressure. If down stream pressure is below the valve pressure, fluid will flow freely from the inlet to the out let. When the outlet pressure increases the valve setting, the spool moves to partially block the outlet port. If the valve is closed completely by the spool, it could cause the down stream pressure to build above the valve setting. To avoid this, a drain line is provided to drain the fluid to the tank.



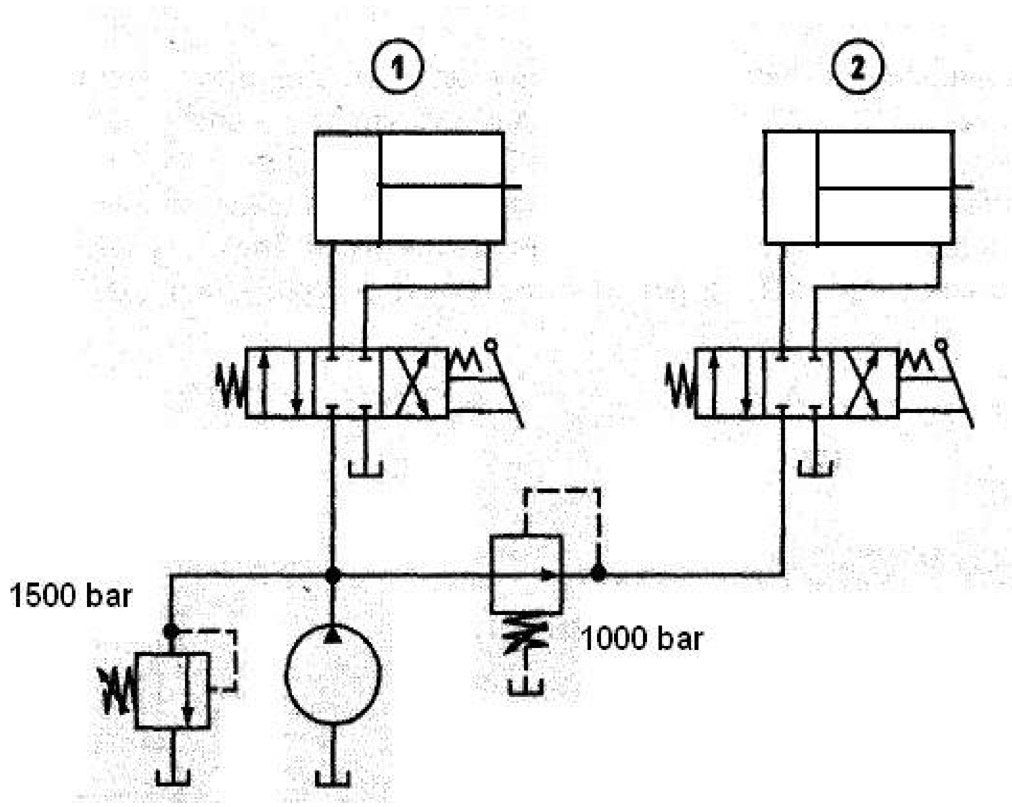
Pressure Reducing Valve

The below Figure compares the symbol for a relief valve and a reducing valve. The reducing valve is normally open, while relief valve is normally closed.



Symbol Comparison

The reducing valve reads the pressure down stream while the relief valve reads the pressure upstream. The reducing valve has an external drain line, while a relief valve does not. When a valve has an external drain, a line must be connected from the valves drain port to the tank. Drain lines, like pilot lines are shown as dashed lines.



Pressure Reducing Valve Application

The above figure shows an application for a pressure reducing valve. Here, two cylinders are connected in parallel. The circuit is designed to operate at a maximum pressure of 1500 bar, which is determined by the relief valve setting. This is the maximum pressure that cylinder will see. For a reason determined by the function of the machine, cylinder 2 is limited to a maximum pressure of 1000 bar. This is accomplished by placing a pressure reducing valve in the circuit in the location as shown.

If the pressure in the circuit rises above 1000 bar, the pressure reducing valve will close partially to create a pressure drop across the valve. The valve then maintains the pressure drop so that outlet pressure is not allowed to rise above 1500 bar setting. The disadvantage of this method of pressure control is that the pressure drop across the reducing valve represents lost energy that is converted to heat. If the pressure setting of the reducing valve is set very low relative to the pressure in the rest of the system, the pressure drop will be very high, resulting in excessive heating of the fluid. When the hydraulic fluid becomes too hot, its viscosity reduces, causing increased component wear.

SEQUENCE VALVES

When the operation of two hydraulic cylinders is required to be performed in sequence by using a single direction valve, a special valve is required for this purpose and it is known as the sequence valve.

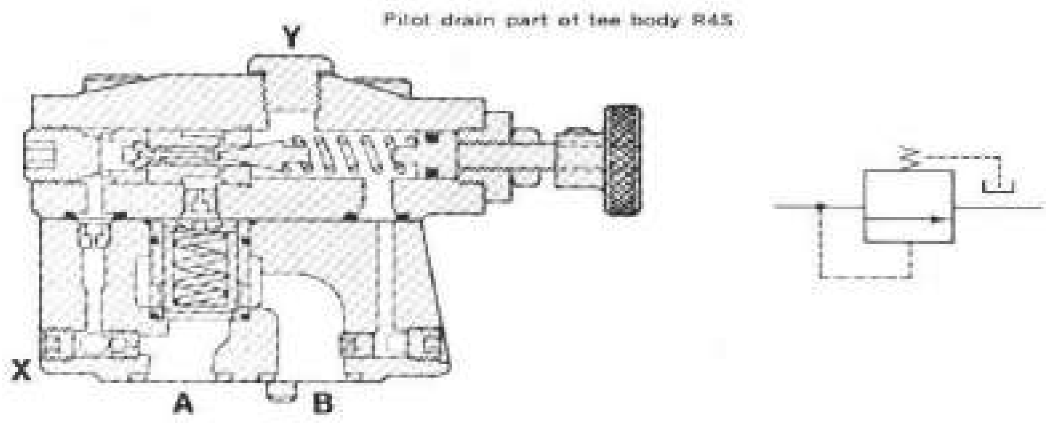
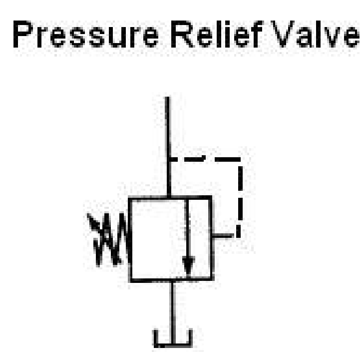
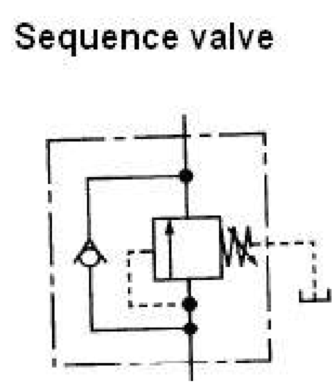


Figure Schematic of sequence valve. *(Courtesy of Abex Corp., Denison Division, Columbus, Ohio.)*

The sequence Valve is to direct flow in a predetermined of sequence .The sequence valve operates on the principle that when system pressure overcomes the spring setting,the valve spool moves up allowing flow to the secondarhy port that is connected with the second operating hydraulic cylinder. The figure shows the symbol comparison of pressure relief valve and sequence Valve. Instead of sending flow back to the tank, however, a sequence valve allows flow to a branch circuit when a preset pressure is reached. The check valve allows the sequence valve to be by passed in the reverse direction The component enclosure line indicates that the check is an integral part of the component. The sequence valve has an external drain line, therefore a line must be connected from the sequence valves drain port to the tank.





The below figure shows the circuit of tube bending machines uses sequence valve for clamping and bending tubes in sequence. As per the required sequence first the work piece has to be clamped, then bend to required shape, bending cylinder retract and clamping cylinder retract to unclamp the work piece. In this circuit, the bending cylinder will extend only after the clamp cylinder is fully extended and the clamp cylinder will retract only after the bending cylinder is fully retracted.

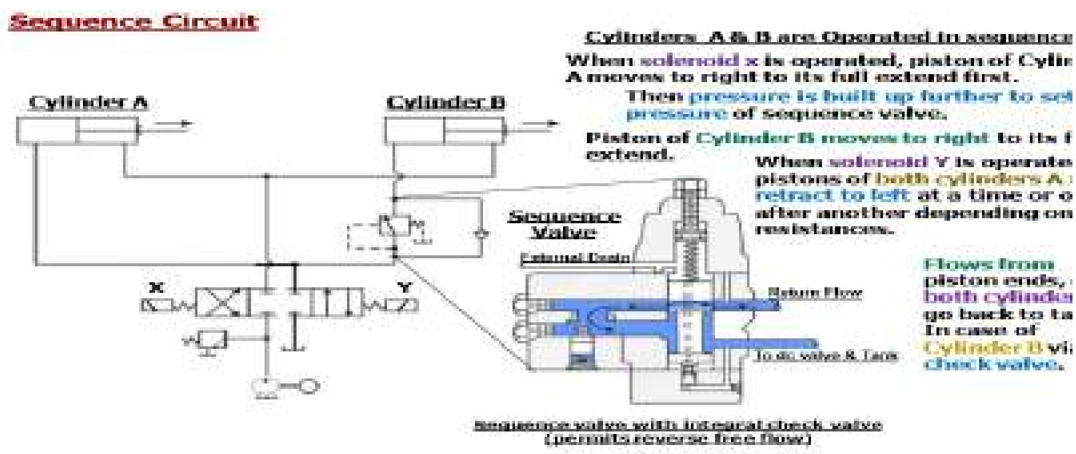
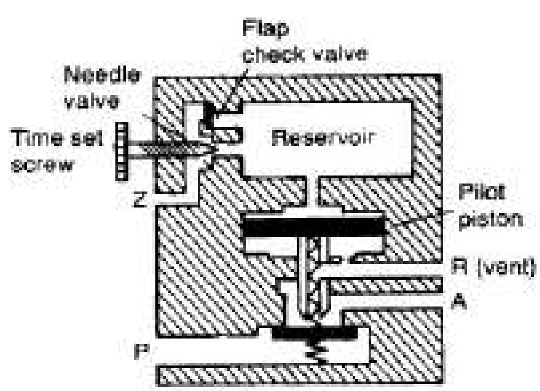


Fig Sequence Circuit

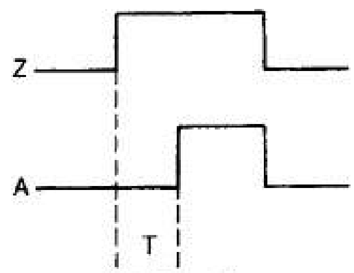
TIME DELAY VALVES

Pneumatic time delay valves are used to delay operations where time-based sequences are required. Fig shows construction of a typical valve. This is similar in construction to a 3/2 way pilot-operated valve, but the space above the main valve is comparatively large and pilot air is only allowed in via a flow reducing needle valve. There is thus a time delay between application of pilot pressure to port Z and the valve operation, as shown by the timing diagram in Figure 4.28b. The time delay is adjusted by the needle valve setting. The built-in check valve causes the reservoir space above the valve to vent quickly when pressure at Z is removed to give no delay off.

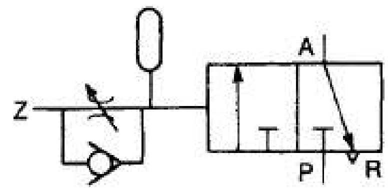
The valve shown in Fig is a normally-closed delay-on valve. Many other time delay valves (delay-off, delay on/off, normally- open) can be obtained. All use the basic principle of the air reservoir and needle valve. The symbol of a normally-dosed time delay valve is in Fig



(a) Construction



(b) Operation



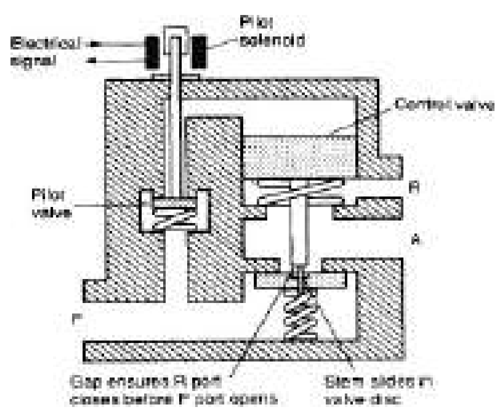
(c) Symbol

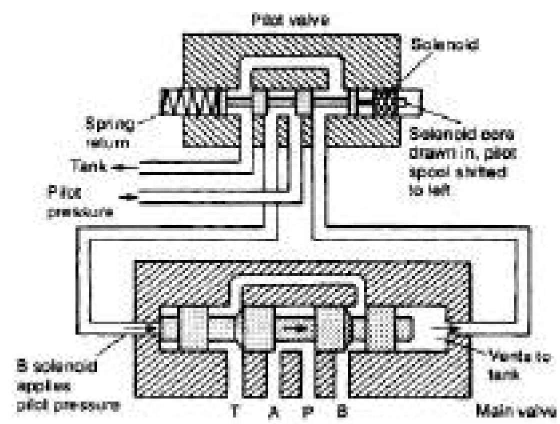
Fig b Pneumatic time delay valve

FLOW CONTROL VALVES

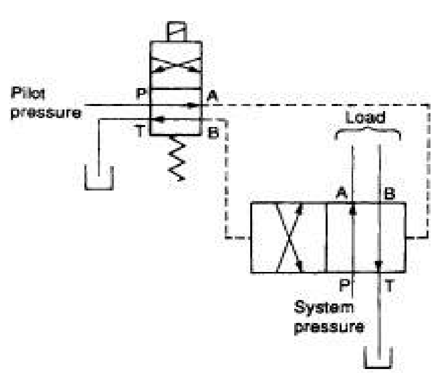
CHECK VALVES

Check valves only allow flow in one direction and, as such, are similar in operation to electronic diodes. The simplest construction is the ball and seat arrangement of the valve in Fig, commonly used in pneumatic systems. The right angle construction in Fig is better suited to the higher pressures of a hydraulic system. Free flow direction is normally marked with an arrow on the valve casing. A check valve is represented by the graphic symbols in Fig. The symbol in Fig is rather complex and the simpler symbol in Fig is more commonly used.





(a) Construction: power applied to solenoid has moved pilot spool to left. This applies pilot pressure to left hand end of main spool, shifting spool to right and connecting P & B ports



(b) Symbol

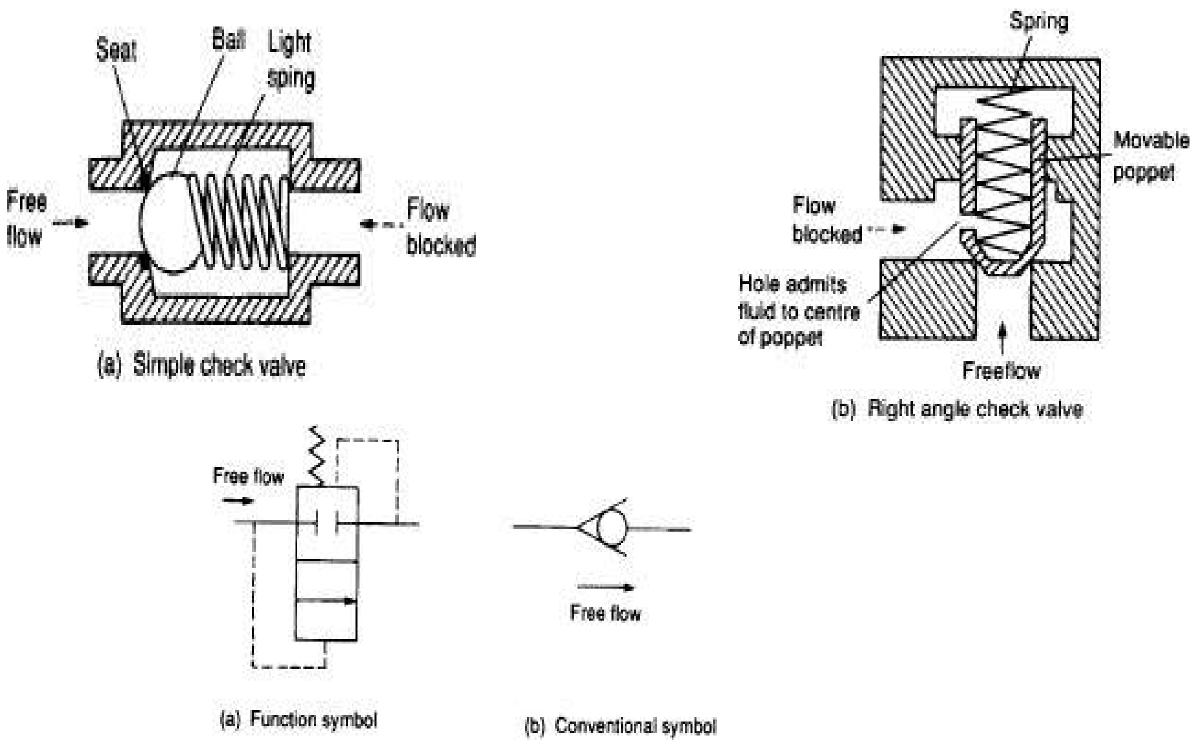


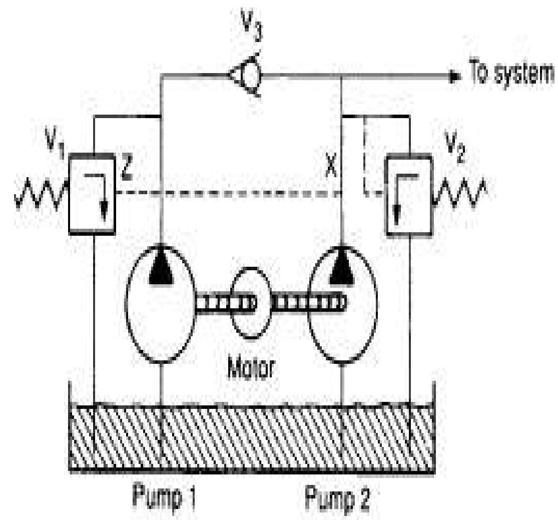
Fig Check valve symbols

The Diagrams illustrates several common applications of check valves. Fig shows a combination pump, used where an application requires large volume and low pressure, or low volume and high pressure. A typical case is a clamp required to engage quickly (high volume and low pressure) then grip (minimal volume but high pressure). Pump 1 is the high volume and low pressure pump, and pump 2 the high pressure pump. In high volume mode both pumps deliver to the system, pump 1 delivering through the check valve V 3. When high pressure is required, line pressure at X rises operating unloading valve V 1 via pilot port Z taking pump 1 off load. Pump 2 delivers the required pressure set by relief valve V 2,with the check valve preventing fluid leaking back to pump 1 and V1.Fig shows a hydraulic circuit with a pressure storage device called an accumulator (described in a later chapter). Here a check valve allows the pump to unload via the pressure regulating valve, while still maintaining system pressure from the accumulator.

A spring-operated check valve requires a small pressure to open (called the cracking pressure) and acts to some extent like a low pressure relief valve. This characteristic can be used to advantage. In Fig pilot pressure is derived before a check valve, and in Fig a check valve is used to protect a blocked filter by diverting flow around the filter when pressure rises. A check valve is also included in the tank return to prevent fluid being sucked out of the tank when the pump is turned off.

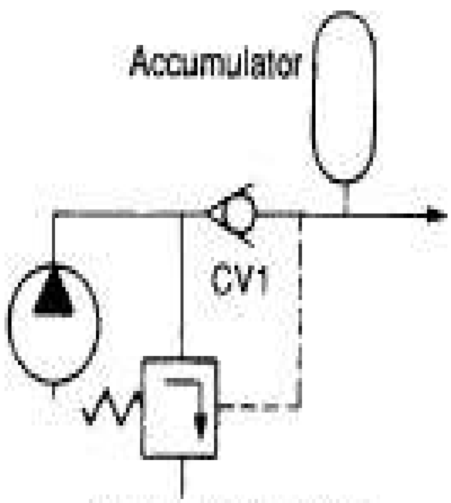
PILOT-OPERATED CHECK VALVES

The cylinder in the system in Fig should, theoretically, hold position when the control valve is in its centre, off, position. In practice, the cylinder will tend to creep because of leakage in the control valve. Check valves have excellent sealage in the closed position, but a simple check valve cannot be used in the system in Fig because flow is required in both directions. A pilot-operated check is similar to a basic check valve but can be held open permanently by application of an external pilot pressure signal. There are two basic forms ofpilot-operated check valves as Shown in Figure.

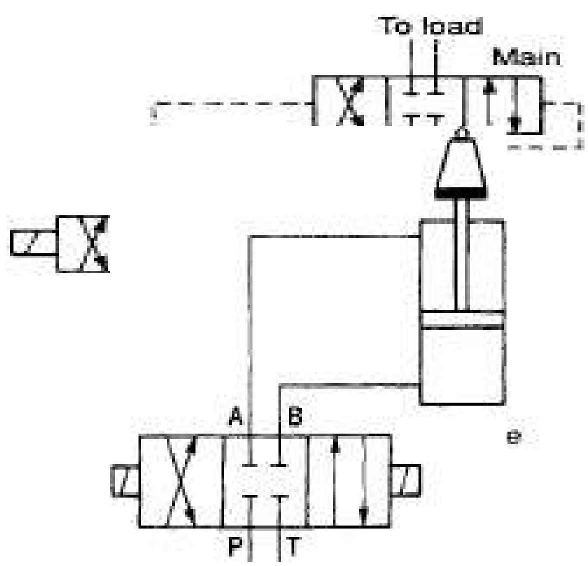


(a) Combination pump

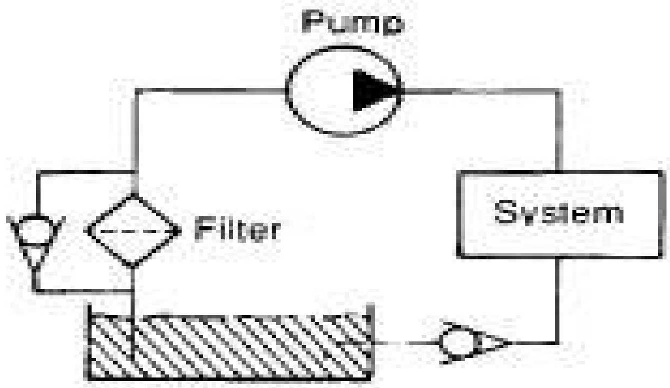
They operate in a similar manner to basic check valves, but with pilot pressure directly opening the valves. In the 4C valve shown in Fig inlet pressure assists the pilot. The symbol of a pilot-operated check valve is shown in Fig The cylinder application of Figure (a) is redrawn with



(b) An accumulator

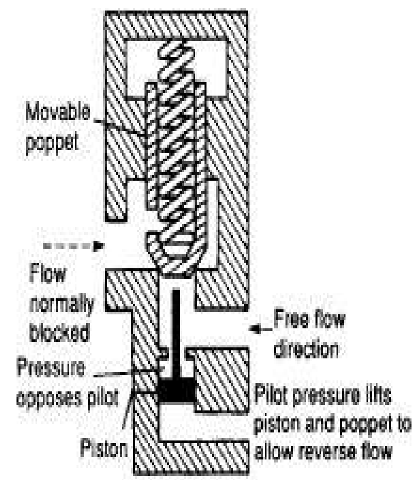


pilotoperated check valves in Fig The pilot lines are connected to the pressure line feeding the other side of the cylinder. For any cylinder movement, one check valve is held open by flow (operating as a normal check valve) and the other is held open by pilot pressure. For no required movement, both check valves are closed and the cylinder is locked in position.



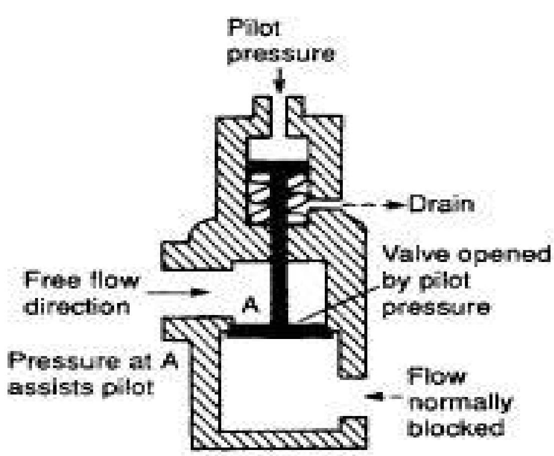
(d) Blocked filter protection and suction blocking

Fig System requiring a check valve. In the off position the load 'creeps'

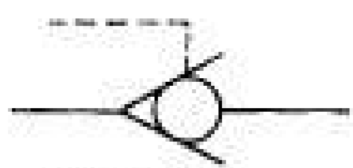


(a) 4C check valve

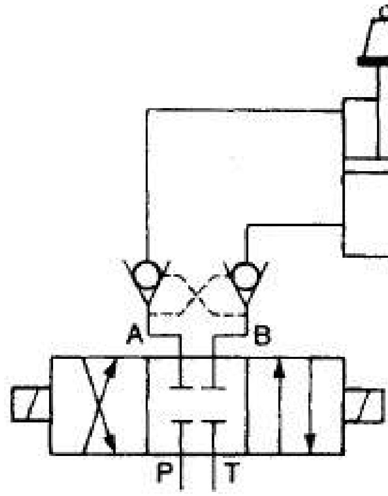
A restriction check valve (often called a throttle relief valve in pneumatics) allows full flow in one direction and a reduced flow in the other direction. Figure 4.24a shows a simple hydraulic valve and Figure 4.24b a pneumatic valve. In both, a needle valve sets restricted flow to the required valve. The symbol of a restriction check valve is shown in Fig shows a typical application in which the cylinder extends at full speed until a limit switch makes, then extend further at low speed. Retraction is at full speed. A restriction check valve V2 is fitted in one leg of the cylinder. With the cylinder retracted, limit-operated valve V3 is open allow-ing free flow of fluid from the cylinder as it extends. When the striker plate on the cylinder ram hits the limit, valve V3 closes and flow out of the cylinder is now restricted by the needle valve setting of valve V2. In the reverse direction, the check valve on valve V2 opens giving full speed of retraction.



(b) 2C check valve



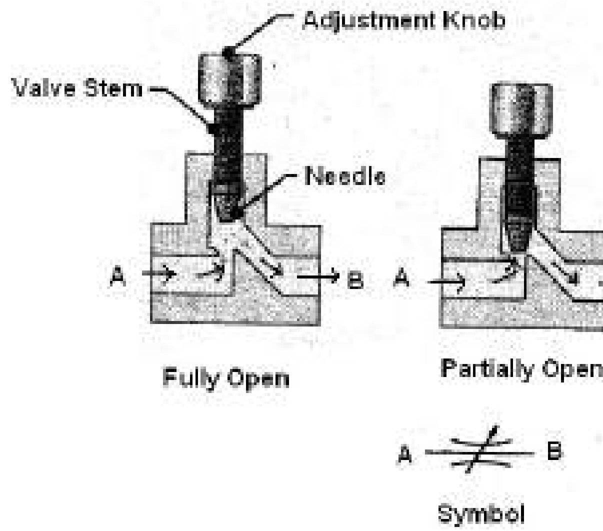
(c) Symbol



(d) Pilot check valves with lifting cylinder

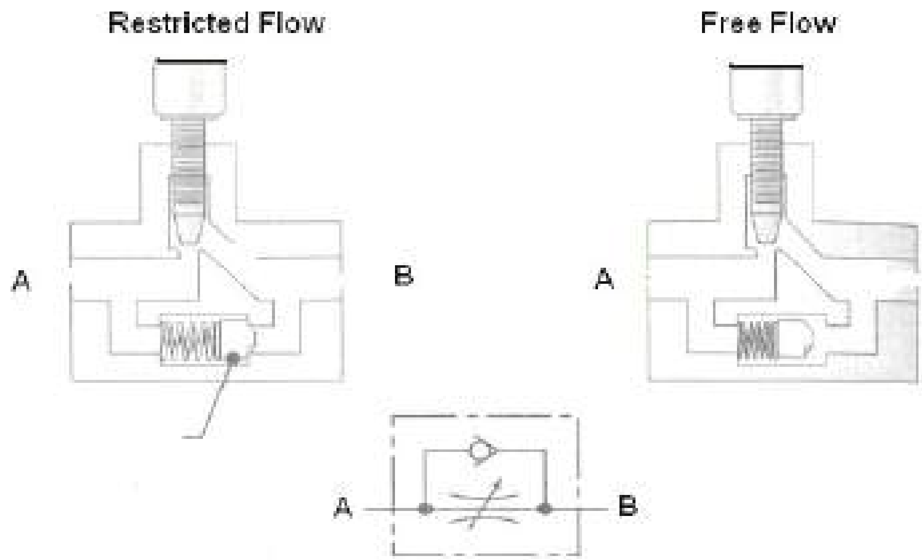
NEEDLE VALVE

The simplest type of flow control valve is needle valve as shown in Figure.



Needle Valve

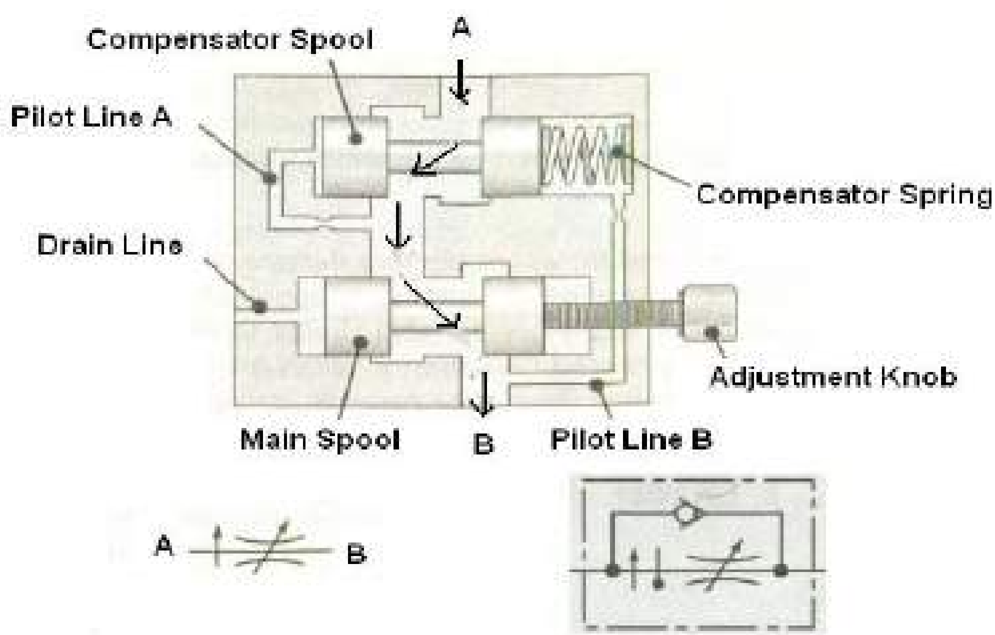
This valve is basically just an adjustable orifice than can be closed to reduce the flow rate in a circuit. The orifice size is adjustment by turning the adjustment knob, which raises or lowers the valve stem and needle. The first figure shows the valve fully open, allowing nearly unrestricted flow. The valve is partially closed and is restricting the flow in the next figure. In the last figure, the valve is completely closed and is therefore allowing no flow. The symbol for a needle valve is shown in D. Needle valves are often used as manual shut-off in applications that require good metering characteristics. In most fluid applications, a needle valve with an integral check valve is used to control the flow rate as shown in below Figure. Part A shows the flow going through the valve from A to B. In this direction, it cannot go through the check and must therefore go through the restriction. In part B, the flow is coming from the opposite direction B to A and can pass through the check valve. The flow is virtually unrestricted in this direction. This flow control valve therefore only controls the flow rate from A to B. From B to A, the flow is uncontrolled because the restriction is by passed through the check.



Needle Valve with Integral Check Valve

PRESSURE COMPENSATED FLOW CONTROL VALVE

The flow control valves blocks the flow in term there is a pressure drop across the valve. This pressure drop affects the motion of the actuators and also increases the temperature of the fluid. To eliminate the above problems pressure compensated flow control valve is designed as shown in below Figure .

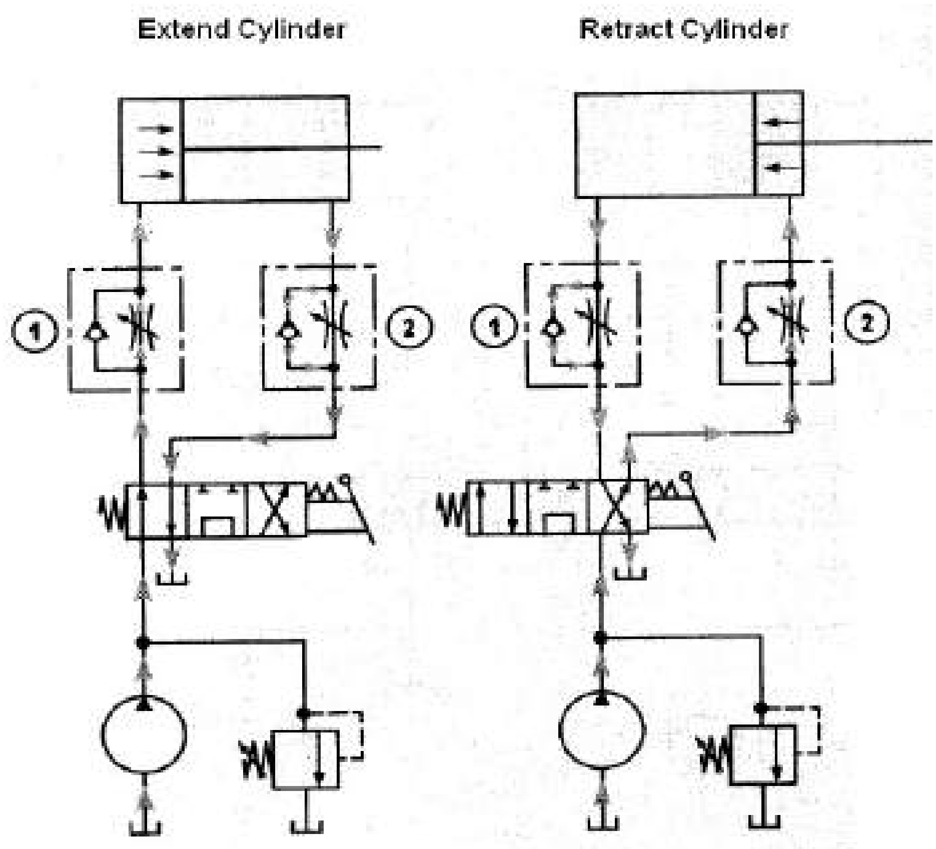


Pressure Compensated Flow Control Valve

This type of flow control valves automatically adjusts the size of the orifice in response to changes in system pressure. It accomplishes this through the use of a spring loaded compensator spool that reduces the size of the orifice when the upstream pressure increases relative to the downstream pressure. Once the valve is set, the pressure compensator will act to keep the pressure drop across the valve nearly constant. This in turn keeps the flow rate through the valve nearly constant. This valve consists primarily of a main spool and a compensator spool. The adjustment knob controls the main spool's position, which controls the orifice size at the outlet. The pressure upstream of (before) the main spool is ported to the left side of the compensator spool through pilot line A. Pressure downstream of (after) the main spool is ported to the right side of the compensator spool through pilot line B. The compensator spring bases the compensator spool to the fully open position. If the pressure upstream of the main spool increases too much relative to the downstream pressure (ie the pressure drop becomes too high), the compensator spool will move to the right against the force of the spring. Thos acts to keep the pressure drop across the main spool and consequently the flow rate nearly constant.

METER-IN FLOW CONTROL

A cylinder with meter-in flow control of the extend stroke is shown is below Figure.

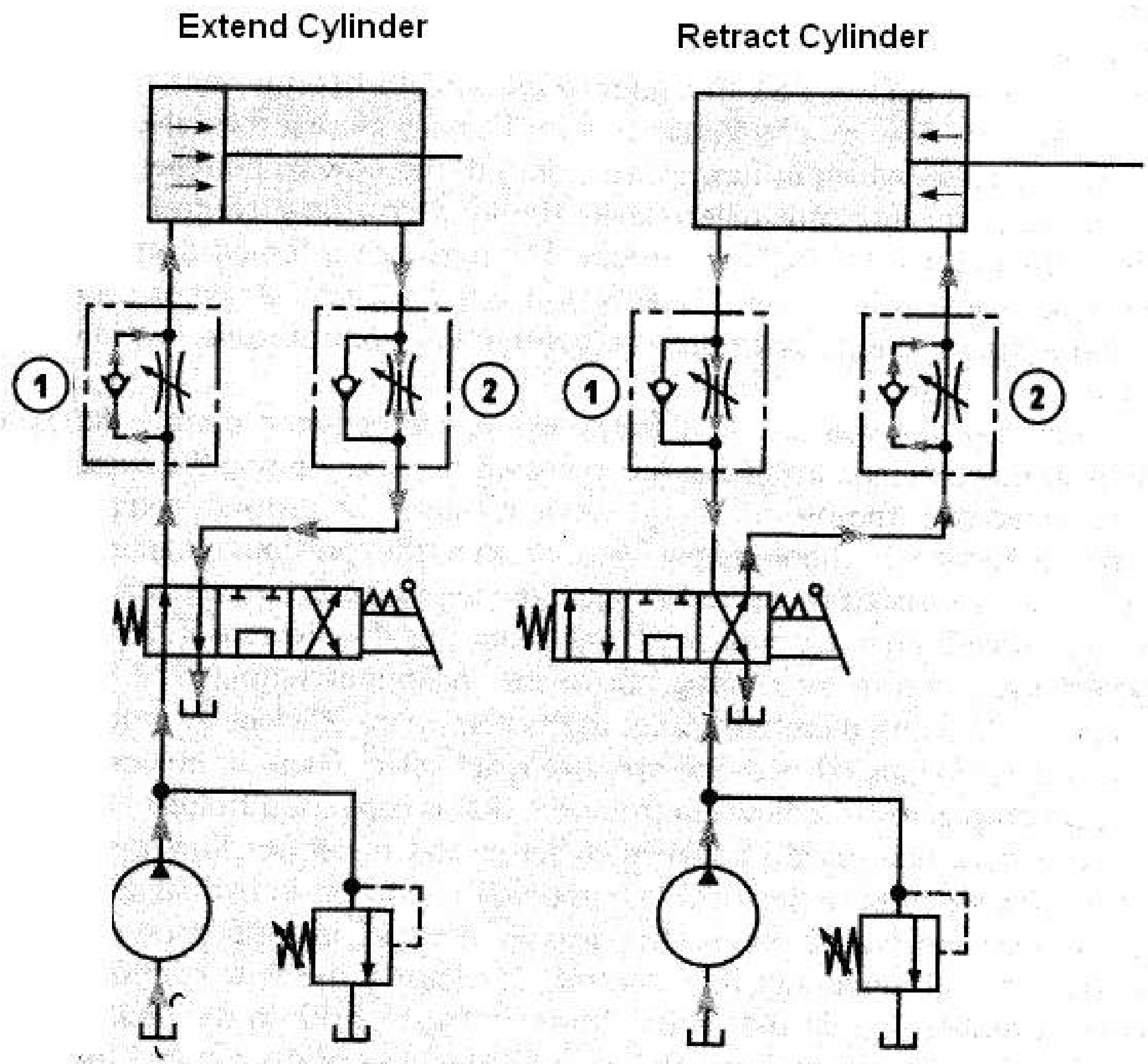


Cylinders with Meter-In Flow Control

When the cylinder is extending, the flow coming from the pump cannot pass through the check valve and is forced to go through the metering orifice (part A). When the cylinder is retracting, the needle valve is being by passed through the check (part B). The net result is that the flow control valve is controlling the extend speed, while the retract speed of the cylinder is uncontrolled. It is common to control only the working stroke of a cylinder, while allowing the return stroke move at full speed.

METER-OUT FLOW CONTROL

The Figure shows a cylinder with meter-out flow control of the extend stroke.

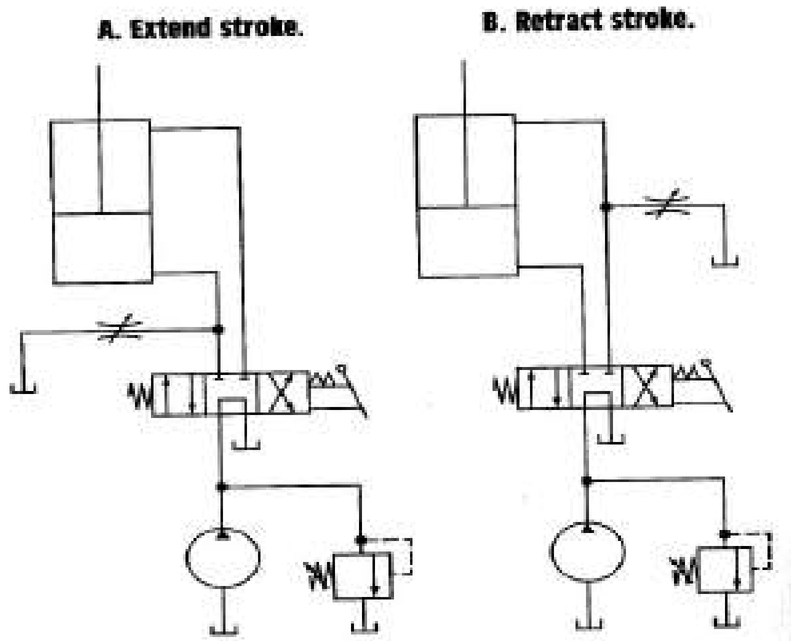


Cylinders with Meter-Out Flow Control

The flow control valve in this circuit is placed in the rod end line. When the cylinder is extending, the flow coming from the cylinder cannot pass through the check and is forced to go through the metering orifice (part A). When the cylinder is retracting, the metering orifice is being by passed through the check (part B). The net result is the same as with the previous circuit. The extend speed is controlled, while the retract speed is uncontrolled. However, in this circuit we control the flow rate act of the cylinder, while in the previous circuit we controlled the flow rate into the cylinder.

BLEED-OFF CONTROL VALVE

In addition to meter-in and meter-out flow control, there is a less commonly used flow control configuration known as bleed-off.



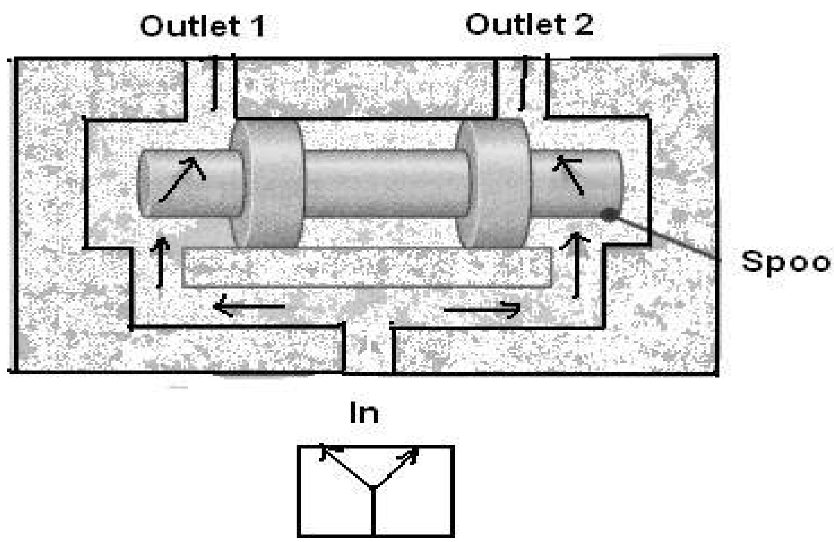
Cylinders with Bleed- Off Control

In this type of flow control, an additional line is run through a flow control back to the tank. To slow down the actuator, some of the flow is bled off through this line, thereby reducing the flow to the actuator 'Figure A' shows bleed off control of the extend stroke, 'Figure B' shows control of the retract stroke. Note that the operation of a bleed-off flow control valve is opposite to a meter-in or meter-out flow control valve. Opening a bleed-off flow control valve slows down an actuator, while opening a meter-in or meter-out flow control valve increases actuator speed.

FLOW DIVIDER

Flow dividers divide the flow from a pump into two or more streams of equal flow rates. They maintain equal flow rates in the branch circuits even if the pressures in the branches are not equal. Without flow divider, the flow from the pump would follow the path of least resistance.

There are two commonly used flow divider designs balanced spool and rotary. The Figure shows a simplified cut away of a balanced spool flow divider. The spool is free to slide back and forth in the housing and will naturally assume a position so that the pressure on either side of the spool will be equal. The spool is therefore pressure balanced. For example if the pressure at outlet 1 was greater than the pressure at outlet 2, the spool would slide to the right to partially cover outlet 2. By partially restricting the more lightly loaded outlet, the flow divider adds more resistance to this path. This acts to equalize the resistance of each path. The rotary flow divider is basically two gear pumps are in one housing whose inlets are joined together as shown in Figure.Their shafts are also coupled together so that must turn at the same speed.Because they are forced to turn at the same speed,they will supply equal flow to their outlets when placed in a pump line.



Balanced Spool Flow Divider

UNIT - III DESIGN OF HYDRAULIC CIRCUITS 9

1. Accessories - Pressure Switches and Electrical switches – Applications.
2. Accessories - Limit switches and Relays – Applications.
3. Types of Accumulators and its Applications.
4. Design of Hydraulic circuits - Reciprocation, Speed control- meter-in & meter-out circuits
5. Design of Hydraulic circuits - Sequence, Synchronization, Regenerative, Pump Unloading-Double pump circuits.
6. Pressure Intensifier and Air-over oil system
7. Hydrostatic transmission
8. Electro hydraulic circuits and

   Mechanical Hydraulic servo systems

ELECTRICAL COMPONENTS

There are five basic types of electric switches used in electrically controlled fluid power circuits:

1. Push-button,
2. Limit switch,
3. Pressure switch,
4. Temperature switch, and
5. Relay switches.

1. Push-button switches.

Push-button switches. By the use of a simple push-button switch, an operator can cause sophisticated equipment to begin performing complex operations. These push-button switches are used mainly for starting and stopping the operation of machinery as well as providing for manual override when an emergency arises.

Four common types of pushbutton switches.

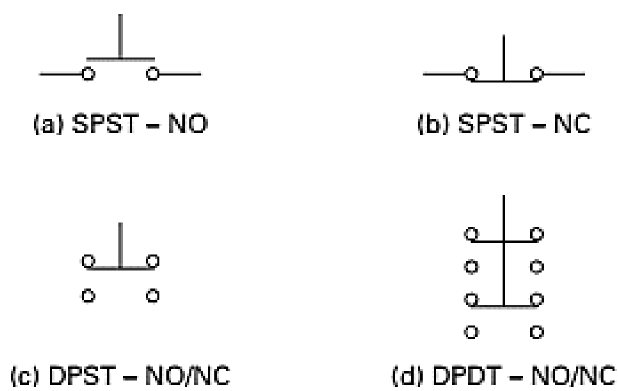


Figure (a) and (b) show the single-pole, single-throw type. These single-circuit switches can be wired either normally open or closed.

Figure (c) depicts the double-pole, single-throw type. This double-contact type has one normally open and one normally closed pair of contacts. Depressing the push button opens the normally closed pair and closes the normally open pair of contacts.

Figure (d) illustrates the double-pole, double-throw arrangement. This switch has two pairs of normally open and two pairs of normally closed contacts to allow the inverting of two circuits with one input.

2. Limit switches

Limit switches open and close circuits when they are actuated either at the end of the retraction or extension strokes of hydraulic or pneumatic cylinders. Figure shows a hydraulic cylinder that incorporates its own limit switches (one at each end of the cylinder). Either switch can be wired normally open or normally closed.

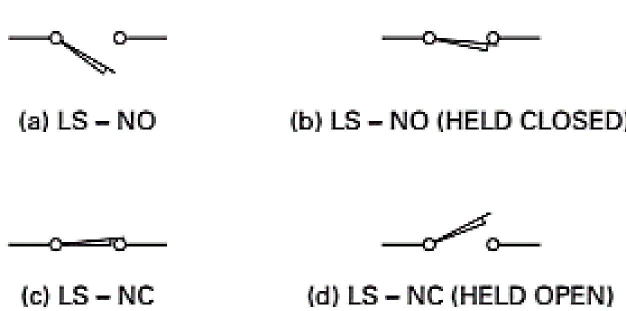
The limit switch on the cap end of the cylinder is actuated by an internal cam when the rod is fully retracted. The cam contacts the limit switch about 3/16 in from the end of the stroke. At the end of the cylinder stroke, the cam has moved the plunger and stem of the limit switch about 1/16 in for complete actuation. The limit switch on the head end of the cylinder is similarly actuated. Since these limit switches are built into the cylinder end plates, they are not susceptible to accidental movement, which can cause them to malfunction.

Basically, limit switches perform the same functions as push-button switches.

The difference is that they are mechanically actuated rather than manually actuated.

Figure (a) shows a normally open limit switch, which is abbreviated LS-NO.

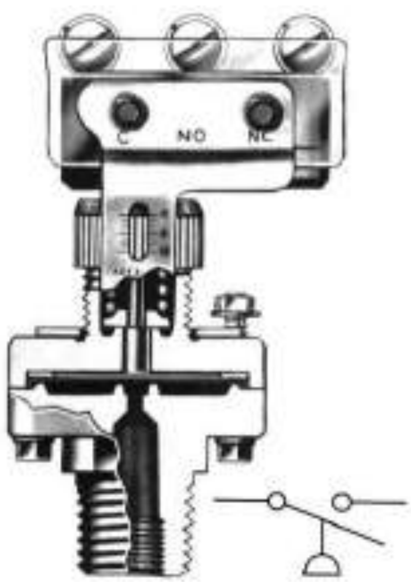
Figure (b) shows a normally open switch that is held closed.

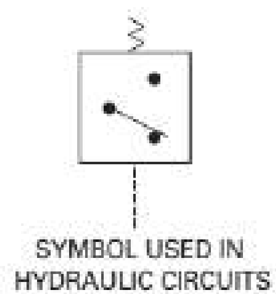


In Figure (c) we see the normally closed type, whereas
Figure (d) depicts a normally closed type that is held open.
There are a large number of different operators available for limit switches. Among these are cams, levers, rollers, and plungers. However, the symbols used for limit switches do not indicate the type of operator used.

3. Pressure switches.

Pressure switches open or close their contacts based on system pressure. They generally have a high-pressure setting and a low-pressure setting. For example, it may be necessary to start or stop a pump to maintain a given pressure. The low-pressure setting would start the pump, and the high-pressure setting would stop it. Figure shows a pressure switch that can be wired either normally open (NO) or normally closed (NC), as marked on the screw terminals.
Pressure switches have three electrical terminals: C (Common), NC (normally closed), and NO (normally open). When wiring in a switch, only two terminals are used. The common terminal is always used, plus either the NC or NO terminal depending on whether the switch is to operate as a normally open or normally closed switch. In Figure 15-2, observe the front scale that is used for visual check of the pressure setting, which is made by the self-locking, adjusting screw located behind the scale. Figure also gives the graphic symbol used to represent a pressure switch in hydraulic circuits as well as the graphic symbol used in electrical circuits.

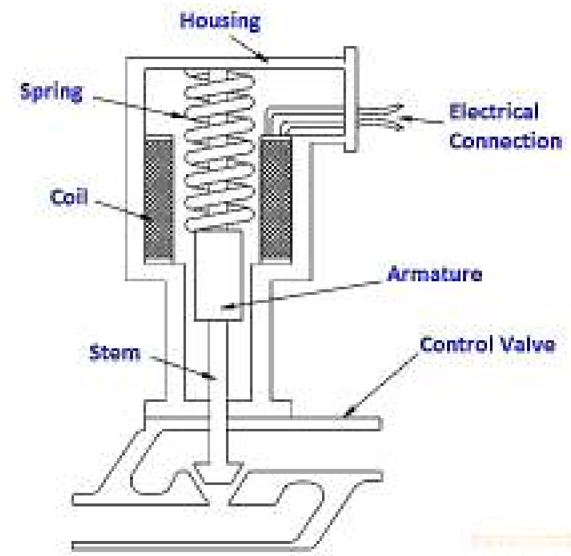




(a) PS – NO (b) PS – NC

The symbols used for pressure switches are given in Figure. Figure (a) gives the normally open type, whereas Figure (b) depicts the normally closed symbol.

Solenoids.

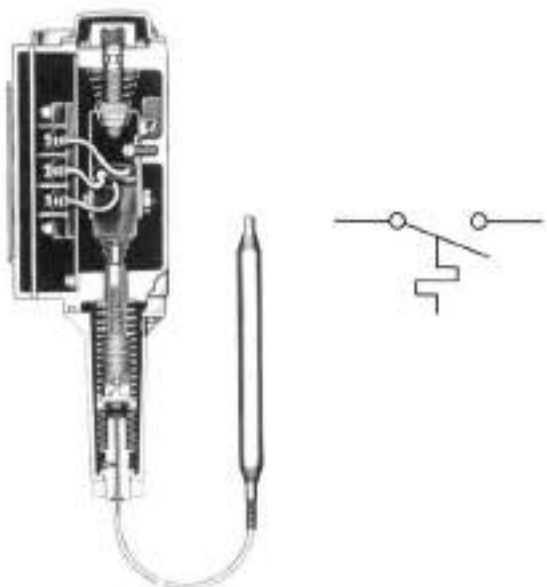


Solenoids are electromagnets that provide a push or pull force to operate fluid power valves remotely. When a solenoid (an electric coil wrapped around an armature) is energized, the magnetic force created causes the armature to shift the spool of the valve containing the solenoid.

The symbol used to represent a solenoid, which is used to actuate valves, is shown in Figure (a) and (b) gives the symbol used to represent indicator lamps. An indicator lamp is often used to show the state of a specific circuit component. For example, indicator lamps are used to determine which solenoid operator of a directional control valve is energized. They are also used to indicate whether a hydraulic cylinder is extending or retracting. An indicator lamp wired across each valve solenoid provides the troubleshooter with a quick means of pinpointing trouble in case of an electrical malfunction. If they are mounted on an operator's display panel, they should be mounted in the same order as they are actuated. Since indicator lamps are not a functional part of the electrical system, their inclusion in the ladder diagram is left to the discretion of the designer.

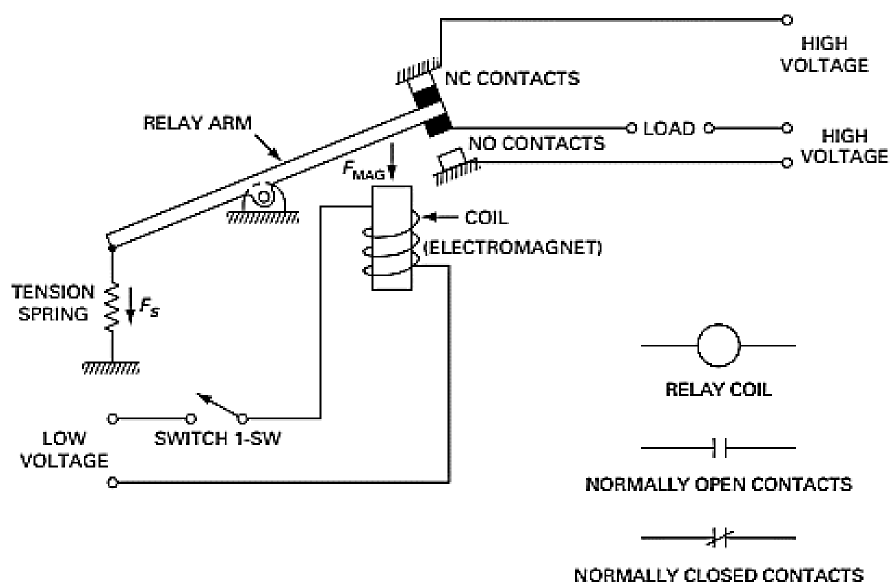
4. Temperature switches.

Figure shows a temperature switch, which is an instrument that automatically senses a change in temperature and opens or closes an electrical switch when a predetermined temperature is reached. This switch can be wired either normally open or normally closed. Note that at its upper end there is an adjustment screw to change the actuation point. The capillary tube (which comes in standard lengths of 6 or 12 ft) and bulb permit remote temperature sensing. Thus, the actual temperature switch can be located at a substantial distance from the oil whose temperature is to be sensed. Temperature switches can be used to protect a fluid power system from serious damage when a component such as a pump or strainer or cooler begins to malfunction. The resulting excessive buildup in oil temperature is sensed by the temperature switch, which shuts off the entire system. This permits troubleshooting of the system to repair or replace the faulty component. This type of switch is depicted symbolically in Figure. Figure (a) gives the symbol for a normally open type, whereas Figure (b) provides the normally closed symbol.



(a) TS – NO   (b) TS – NC

5. Electrical relays.

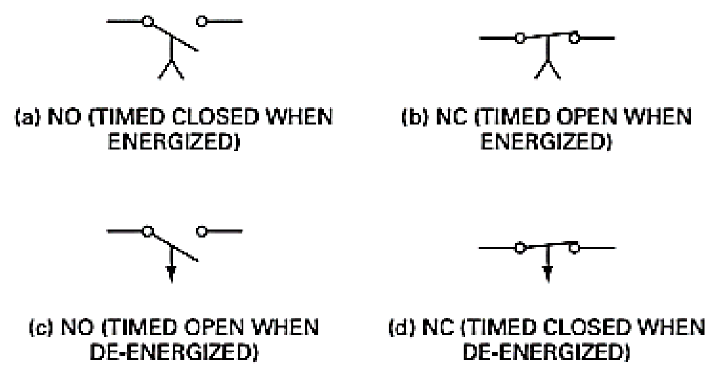


Relays are switches whose contacts open or close when their corresponding coils are energized. These relays are commonly used for the energizing and de-energizing of solenoids because they operate at a high current level. In this way a manually actuated switch can be operated at low voltage levels to protect the operator. This low-voltage circuit can be used to energize relay coils that control high-voltage contacts used to open and close circuits containing the solenoids. The use of relays also provides interlock capability, which prevents the accidental energizing of two solenoids at the opposite ends of a valve spool. This safety feature can, therefore, prevent the burnout of one or both of these solenoids.

A relay is an electrically actuated switch. As shown schematically in Figure (a), when switch 1-SW is closed, the coil (electromagnet) is energized. This pulls on the spring-loaded relay arm to open the upper set of normally closed contacts and close the lower set of normally open contacts. Figure (b) shows the symbol.

Electrical Timers.

Time delay devices are used to control the time duration of a working cycle. In this way a dwell can be provided where needed. For example, a dwell can be applied to a drilling machine operation, which allows the drill to pause for a predetermined time at the end of the stroke to clean out the hole. Most timers can be adjusted to give a specified dwell to accommodate changes in feed rates and other system variables.



Timers are used in electrical control circuits when a time delay from the instant of actuation to the closing of contacts is required. Figure (a) shows the symbol for the normally open switch that is time closed when energized. This type is one that is normally open but that when energized closes after a predetermined time interval. Figure (b) gives the normally closed switch that is time opened when energized. Figure (c) depicts the normally open type that is timed when de-energized. Thus, it is normally open, and when the signal to close is removed (de-energized), it reopens after a predetermined time interval. Figure (d) gives the symbol for the normally closed type that is time closed when de-energized.

Applications

Control of hydraulic cylinder using single limit switch.

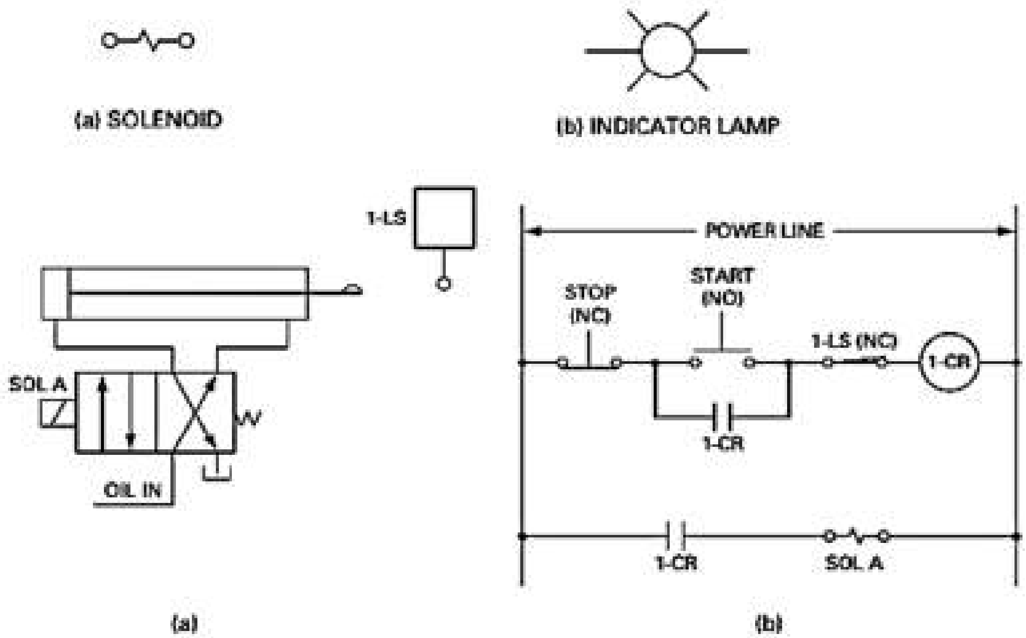


Figure shows a system that uses a single solenoid valve and a single limit switch to control a double-acting hydraulic cylinder. Figure (a) gives the hydraulic circuit in which the limit switch is labeled 1-LS and the solenoid is labeled SOL A. This method of labeling is required since many systems require more than one limit switch or solenoid.

In Figure(b) we see the electrical diagram that shows the use of one relay with a coil designated as 1-CR and two separate, normally open sets of contacts labeled 1-CR (NO).

The limit switch is labeled 1-LS (NC), and also included are one normally closed and one normally open push-button switch labeled STOP and START, respectively. This electrical diagram is called a “ladder diagram” because of its resemblance to a ladder. The two vertical electric power supply lines are called “legs” and the horizontal lines containing electrical components are called “rungs.”

When the START button is pressed momentarily, the cylinder extends because coil 1-CR is energized, which closes both sets of contacts of 1-CR.

Thus, the upper 1-CR set of contacts serves to keep coil 1-CR energized even though the START button is released.

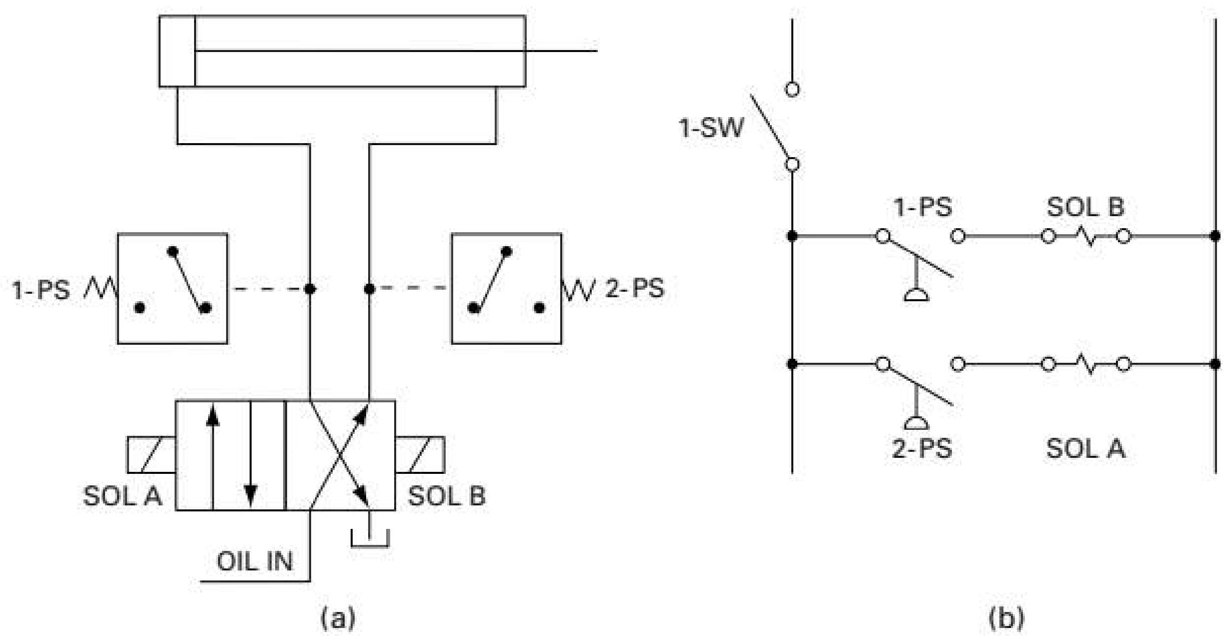
The lower set of contacts closes to energize solenoid A to extend the cylinder. When 1-LS is actuated by the piston rod cam, it opens to de-energize coil 1-CR.

This reopens the contacts of 1-CR to de-energize solenoid A.

Thus, the valve returns to its spring-offset mode and the cylinder retracts. This closes the contacts of 1-LS, but coil 1-CR is not energized because the contacts of 1-CR and the START button have returned to their normally open position.

The cylinder stops at the end of the retraction stroke, but the cycle is repeated each time the START button is momentarily pressed. The STOP button is actually a panic button. When it is momentarily pressed, it will immediately stop the extension stroke and fully retract the cylinder.

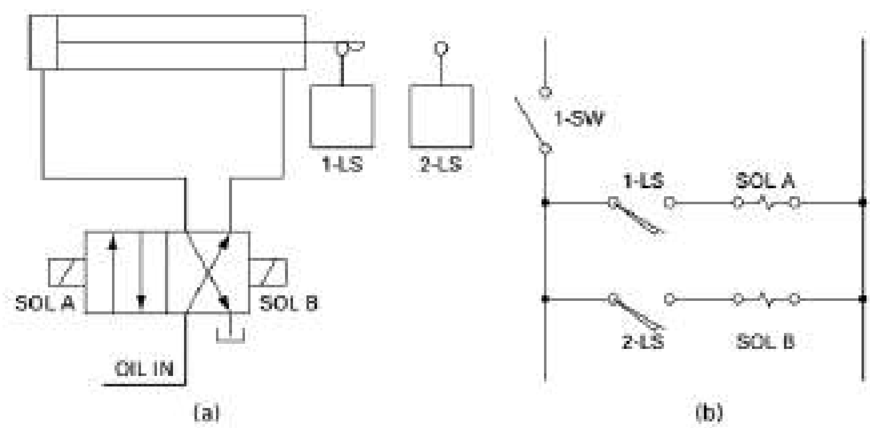
Reciprocation of a Cylinder Using Pressure Or Limit Switches



In Figure, we see how pressure switches can be substituted for limit switches to control the operation of a double-acting hydraulic cylinder. Each of the two pressure switches has a set of normally open contacts. When switch 1-SW is closed, the cylinder reciprocates continuously until 1-SW is opened. The sequence of operation is as follows, assuming solenoid A was last energized: The pump is turned on, and oil flows through the valve and into the blank end of the cylinder.

When the cylinder has fully extended, the pressure builds up to actuate pressure switch 1-PS. This energizes SOL B to switch the valve. Oil then flows to the rod end of the cylinder. On full retraction, the pressure builds up to actuate 2-PS. In the meantime, 1-PS has been deactuated to de-energize SOL B. The closing of the contacts of 2-PS energizes SOL A to begin once again the extending stroke of the cylinder. Figure, gives the exact same control capability except each pressure switch is replaced by a normally open limit switch as illustrated. Observe that switches are always shown in their unactuated mode in the electrical circuits.

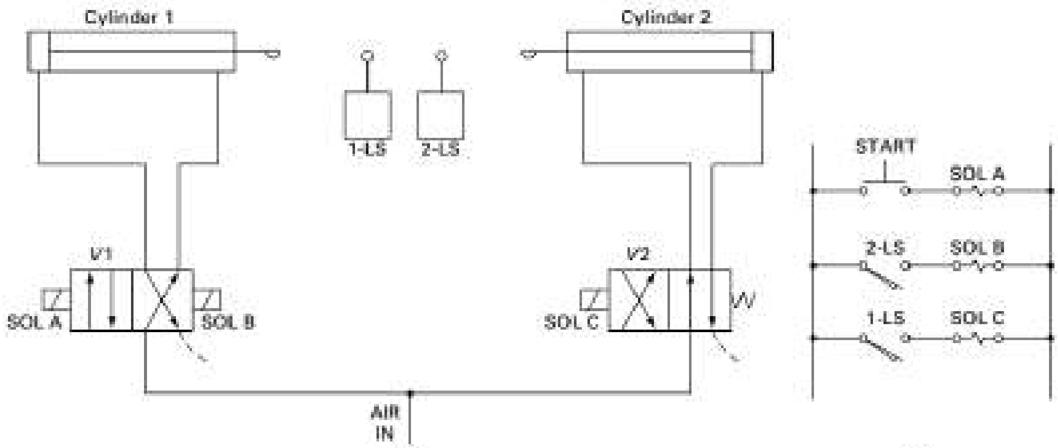
Reciprocation of a Cylinder Using Limit Switches



DUAL-CYLINDER SEQUENCE CIRCUITS

Figure, shows a circuit that provides a cycle sequence of two pneumatic cylinders. When the start button is momentarily pressed, SOL A is momentarily energized to shift valve V1, which extends cylinder 1. When 1-LS is actuated, SOL C is energized, which shifts valve V2 into its left flow path mode. This extends cylinder 2 until it actuates 2-LS. As a result, SOL B is energized to shift valve V1 into its right flow path mode. As cylinder 1 begins to retract, it deactuates 1-LS, which de-energizes SOL C. This puts valve V2 into its spring-offset mode, and cylinders 1 and 2 retract together. The complete cycle sequence established by the momentary pressing of the start button is as follows:

1. Cylinder 1 extends.
2. Cylinder 2 extends.
3. Both cylinders retract.
4. Cycle is ended.

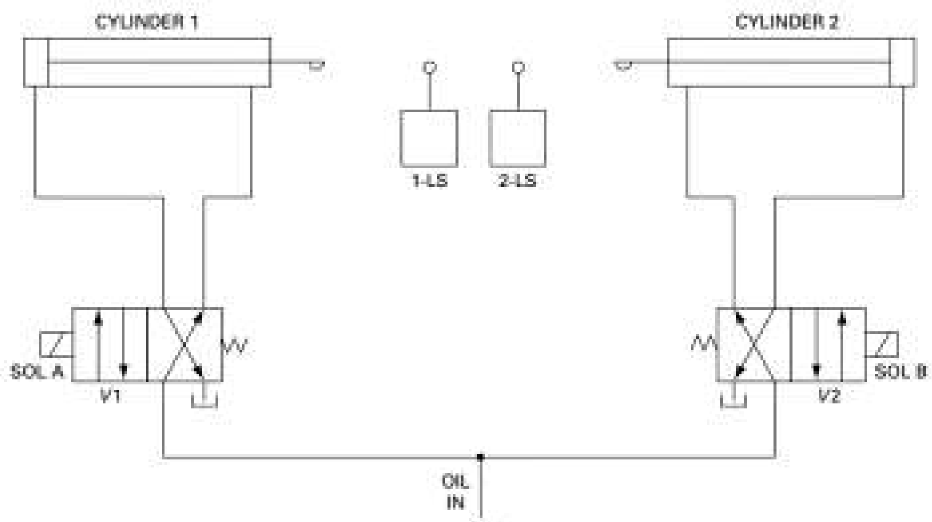


(a) (b)

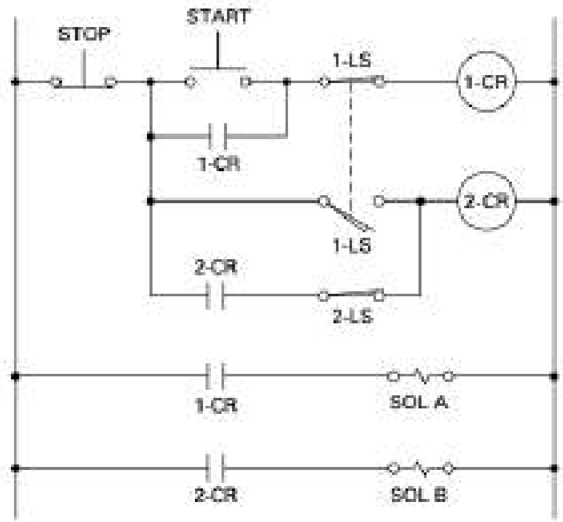
A second dual-cylinder sequencing circuit is depicted in Figure below. The operation is as follows: When the START button is depressed momentarily, SOL A is energized to allow flow through valve V1 to extend cylinder 1. Actuation of 1-LS de-energizes SOL A and energizes SOL B.

Note that limit switch 1-LS is a double pole, single-throw type. Its actuation opens the holding circuit for relay 1-CR and simultaneously closes the holding circuit for relay 2-CR. This returns valve V1 to its spring-offset mode and switches valve V2 into its solenoid-actuated mode. As a result, cylinder 1 retracts while cylinder 2 extends. When 2-LS is actuated, SOL B is de-energized to return valve V2 back to its spring-offset mode to retract cylinder 2. The STOP button is used to retract both cylinders instantly. The complete cycle initiated by the START button is as follows:

1. Cylinder 1 extends.
2. Cylinder 2 extends while cylinder 1 retracts.
3. Cylinder 2 retracts.
4. Cycle is ended.



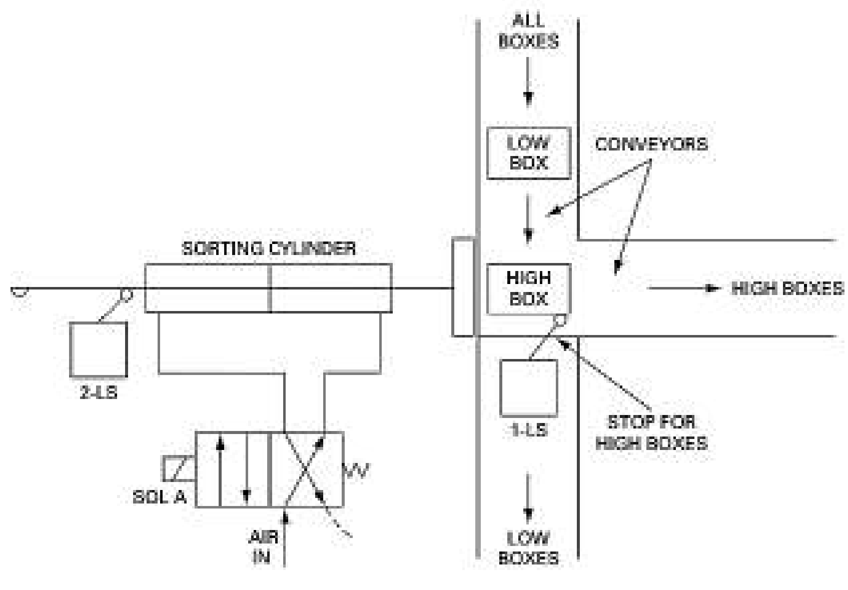
(a)



(b)

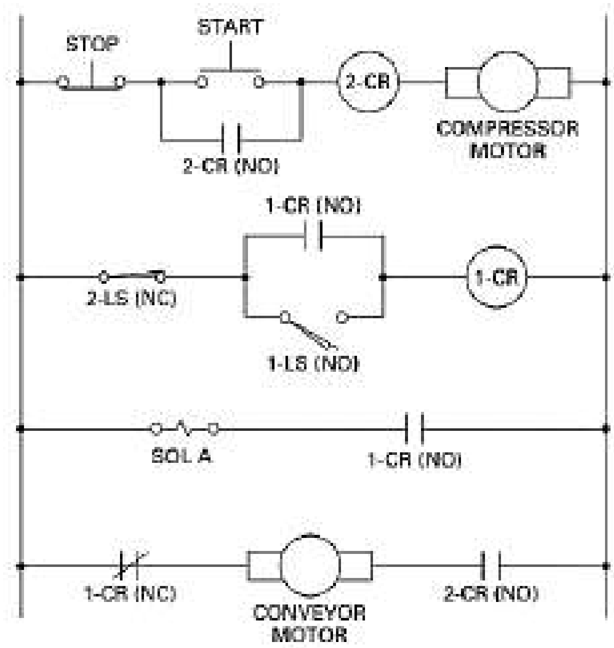
BOX-SORTING SYSTEM

An electropneumatic system for sorting two different-sized boxes moving on a conveyor is presented in Figure. Low boxes are allowed to continue on the same conveyor, but high boxes are pushed on to a second conveyor by a pneumatic cylinder. The operation is as follows: When the START button is momentarily depressed, coil 2-CR is energized to close its two normally open sets of contacts. This turns on the compressor and conveyor motors.



(a)

When a high box actuates 1-LS, coil 1-CR is energized. This closes the 1-CR (NO) contacts and opens the 1-CR (NC) contacts. Thus, the conveyor motor stops, and SOL A is energized. Air then flows through the solenoid-actuated valve to extend the sorting cylinder to the right to begin pushing the high box onto the second conveyor. As 1-LS becomes deactuated, it does not deenergize coil 1-CR because contact set 1-CR (NO) is in its closed position.



(b)

After the high box has been completely positioned onto the second conveyor, 2-LS is actuated. This de-energizes coil 1-CR and SOL A. The valve returns to its spring-offset mode, which retracts the cylinder to the left. It also returns contact set 1-CR (NC) to its normally closed position to turn the conveyor motor back on to continue the flow of boxes. When the next high box actuates 1-LS, the cycle is repeated. Depressing the STOP button momentarily turns off the compressor and conveyor motors because this causes coil 2-CR to become de-energized. The production line can be put back into operation by the use of the START button.

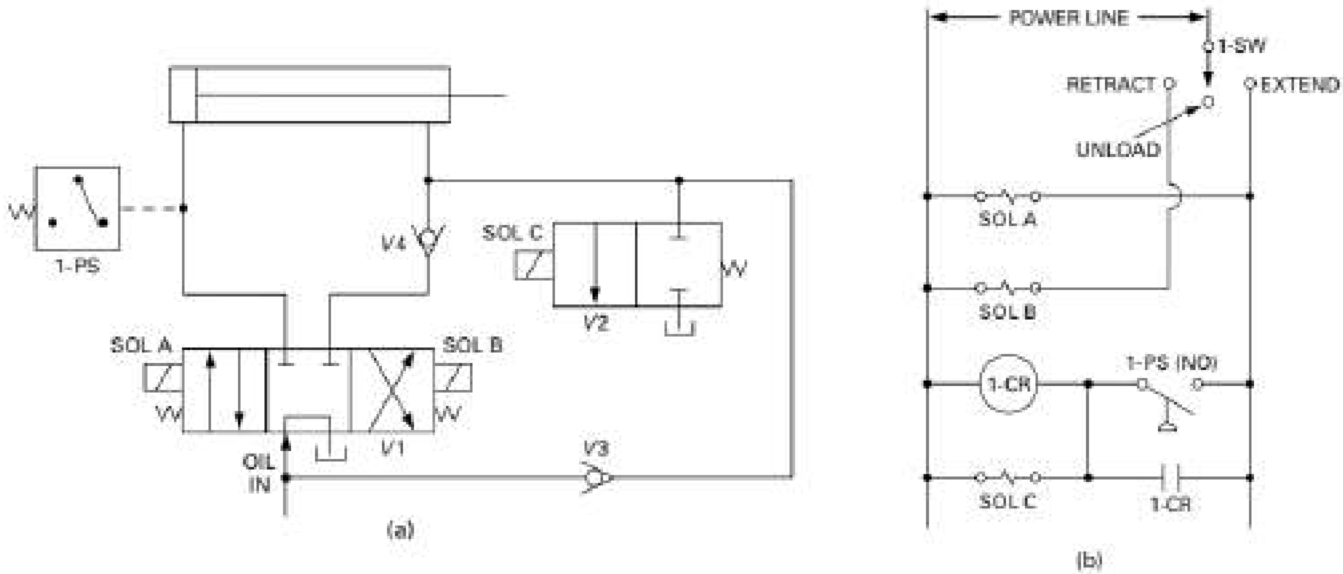
ELECTRICAL CONTROL OF REGENERATIVE CIRCUIT

Figure shows a circuit that provides for the electrical control of a regenerative cylinder. The operation is as follows: Switch 1-SW is manually placed into the extend position. This energizes SOL A, which causes the cylinder to extend. Oil from the rod end passes through check valve V3 to join the incoming oil from the pump to provide rapid cylinder extension.

When the cylinder starts to pick up its intended load, oil pressure builds up to actuate normally open pressure switch 1-PS. As a result, coil 1-CR and SOL C become energized.

This vents rod oil directly back to the oil tank through valve V2. Thus, the cylinder extends slowly as it drives its load. Relay contacts 1-CR hold SOL C energized during the slow extension movement of the cylinder to prevent any fluttering of the pressure switch. This would occur because fluid pressure drops at the blank end of the cylinder when the regeneration cycle is ended. This can cause the pressure switch to oscillate as it energizes and de-energizes SOL C. In this design, the pressure switch is bypassed during the cylinder's slow-speed extension cycle. When switch 1-SW is placed into the retract position, SOL B becomes energized while the relay coil and SOL C become de-energized.

Therefore, the cylinder retracts in a normal fashion to its fully retracted position. When the operator puts switch 1-SW into the unload position, all the solenoids and the relay coil are de-energized. This puts valve V1 in its spring centered position to unload the pump.



COUNTING, TIMING, AND RECIPROCATION OF HYDRAULIC CYLINDER

Figure shows an electrohydraulic system that possesses the following operating features:

1. A momentary push button starts a cycle in which a hydraulic cylinder is continuously reciprocated.

2. A second momentary push button stops the cylinder motion immediately, regardless of the direction of motion. It also unloads the pump.

3. If the START button is depressed after the operation has been terminated by the STOP button, the cylinder will continue to move in the same direction.

4. An electrical counter is used to count the number of cylinder strokes delivered from the time the START button is depressed until the operation is halted via the STOP button. The counter registers an integer increase in value each time an electrical pulse is received and removed.

5. An electrical timer is included in the system to time how long the system has been

operating since the START button was depressed. The timer runs as long as a voltage exists across its terminals. The timer runs only while the cylinder is reciprocating.

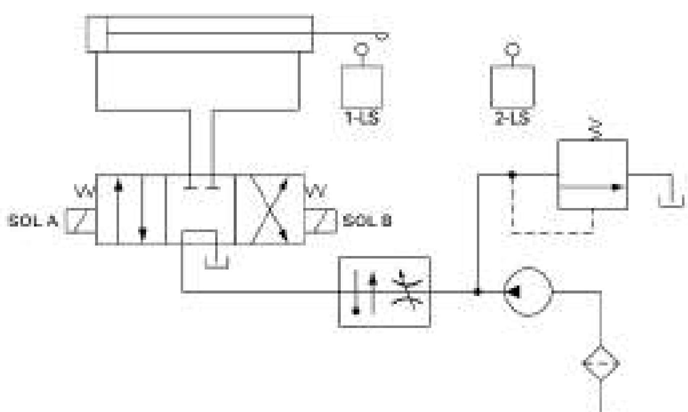
6. Two lamps (L1 and L2) are wired into the electric circuit to indicate whether the cylinder is extending or retracting. When L1 is ON, the cylinder is extending, and when L2 is ON, the cylinder is retracting.

7. The cylinder speed is controlled by the pressure- and temperature-compensated flow control valve.

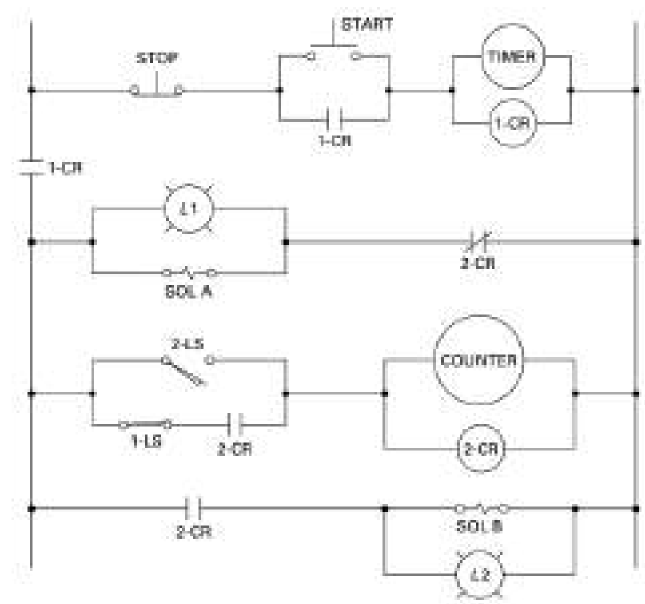
Note that the resistive components (lamps, solenoids, coils, timer, and counter) are connected in parallel in the same branch to allow the full-line voltage to be impressed across each resistive component.

It should be noted that switches (including relay contacts) are essentially zero-resistance components.

Therefore, a line that contains only switches will result in a short and thus should be avoided.



(a)



(b)

ACCUMULATORS

An accumulator is a device that stores potential energy by means of either gravity, mechanical springs, or compressed gases. The stored potential energy in the accumulator is a quick secondary source of fluid power capable of doing useful work as required by the system.

There are three basic types of accumulators used in hydraulic systems.

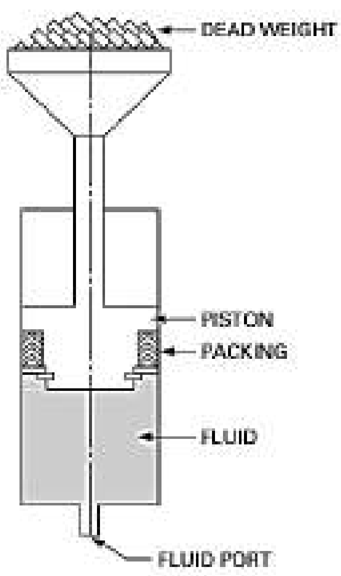
1. Weight-loaded or gravity type,
2. Spring-loaded type,
3. Gas-loaded type:
    a. Nonseparator type
    b. Separator type
        i. Piston type
        ii. Diaphragm type
        iii. Bladder type

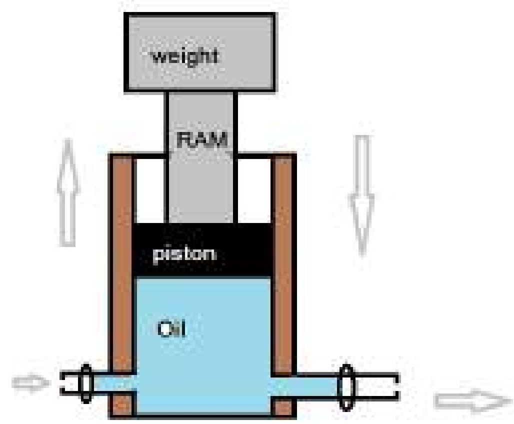
Weight-Loaded Accumulator

The weight-loaded accumulator is historically the oldest. This type consists of a vertical, heavy-wall steel cylinder, which incorporates a piston with packings to prevent leakage.

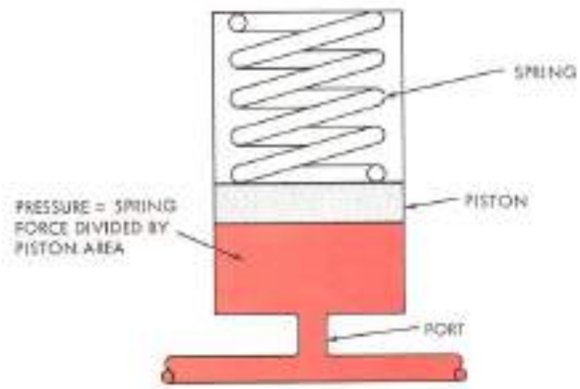
A deadweight is attached to the top of the piston. The force of gravity of the deadweight provides the potential energy in the accumulator. This type of accumulator creates a constant fluid pressure throughout the full volume output of the unit regardless of the rate and quantity of output. In the other types of accumulators, the fluid output pressure decreases as a function of the volume output of the accumulator.

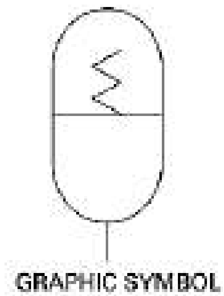
The main disadvantage of this type of accumulator is its extremely large size and heavy weight, which makes it unsuitable for mobile equipment.

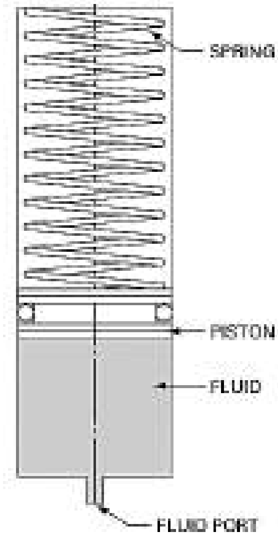




Spring-Loaded Accumulator







A spring-loaded accumulator is similar to the weight-loaded type except that the piston is preloaded with a spring. The compressed spring is the source of energy that acts against the piston, forcing the fluid into the hydraulic system to drive an actuator. The pressure generated by this type of accumulator depends on the size and preloading of the spring.

In addition, the pressure exerted on the fluid is not a constant. The spring-loaded accumulator typically delivers a relatively small volume of oil at low pressures. Thus, they tend to be heavy and large for high-pressure, large-volume systems. This type of accumulator should not be used for applications requiring high cycle rates because the spring will fatigue, resulting in an inoperative accumulator.

Gas-Loaded Accumulators

Gas-loaded accumulators (hydropneumatic accumulators) have been found to be more practical than the weight-and spring-loaded types. This type operates in accordance with Boyle's law of gases, which states that for a constant temperature process, the pressure of a gas varies inversely with its volume. Thus, for example, the gas volume of the accumulator would be cut in half if the pressure were doubled.

The compressibility of gases accounts for the storage of potential energy. This energy forces the oil out of the accumulator when the gas expands due to the reduction of system pressure when, for example, an actuator rapidly moves a load.

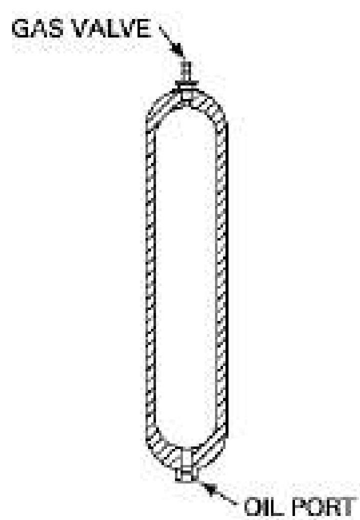
Nitrogen is the gas used in accumulators because (unlike air) it contains no moisture. In addition, nitrogen is an inert gas and thus will not support combustion.

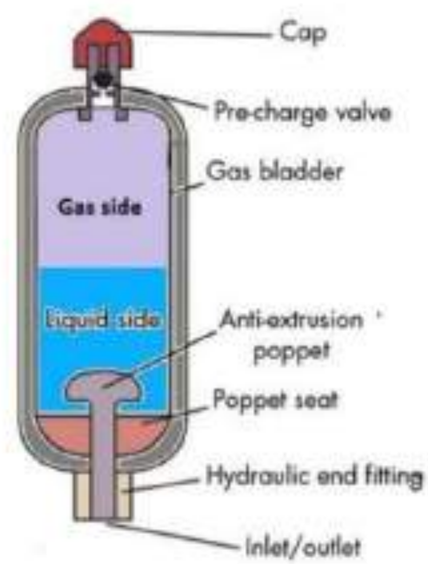
Gas-loaded accumulators fall into two main categories:

1. Nonseparator type
2. Separator type

Nonseparator-Type Accumulator:

The nonseparator type of accumulator consists of a fully enclosed shell containing an oil port on the bottom and a gas charging valve on the top. The gas is confined in the top and the oil at the bottom of the shell. There is no physical separator between the gas and oil, and thus the gas pushes directly on the oil. The main advantage of this type is its ability to handle large volumes of oil. The main disadvantage is absorption of the gas in the oil due to the lack of a separator. This type must be installed vertically to keep the gas confined at the top of the shell. This type is not recommended for use with high-speed pumps because the entrapped gas in the oil could cause cavitation and damage to the pump. Absorption of gas in the oil also makes the oil compressible, resulting in spongy operation of the hydraulic actuators.





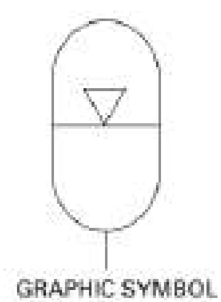
Separator-Type Accumulator.

The commonly accepted design of gas-loaded accumulators is the separator type. In this type there is a physical barrier between the gas and the oil. This barrier effectively uses the compressibility of the gas. The three major classifications of the separator accumulator are

1. Piston type
2. Diaphragm type
3. Bladder type

Piston Accumulator.

The piston type of accumulator consists of a cylinder containing a freely floating piston with proper seals. The piston serves as the barrier between the gas and oil. A threaded lock ring provides a safety feature, which prevents the operator from disassembling the unit while it is precharged. The main disadvantages of the piston types of accumulator are that they are expensive to manufacture and have practical size limitations. Piston and seal friction may also be a problem in low-pressure systems. Also, appreciable leakage tend to occur over a long period, requiring frequent precharging. Piston accumulators should not be used as pressure pulsation dampeners or shock absorbers because of the inertia of the piston and the friction of the seals. The principal advantage of the piston accumulator is its ability to handle very high or low temperature system fluids through the use of compatible O-ring seals.

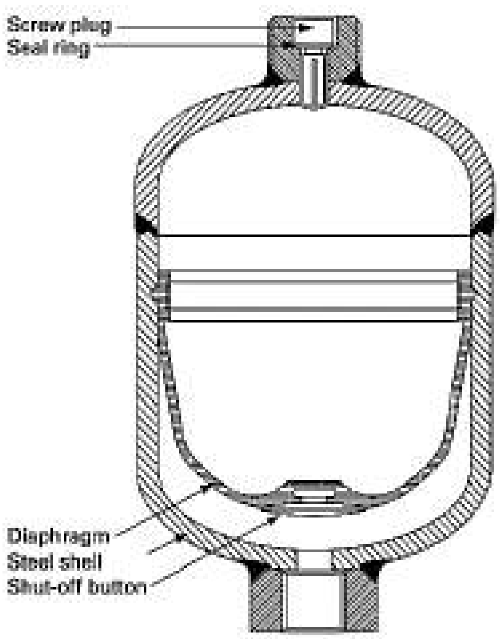


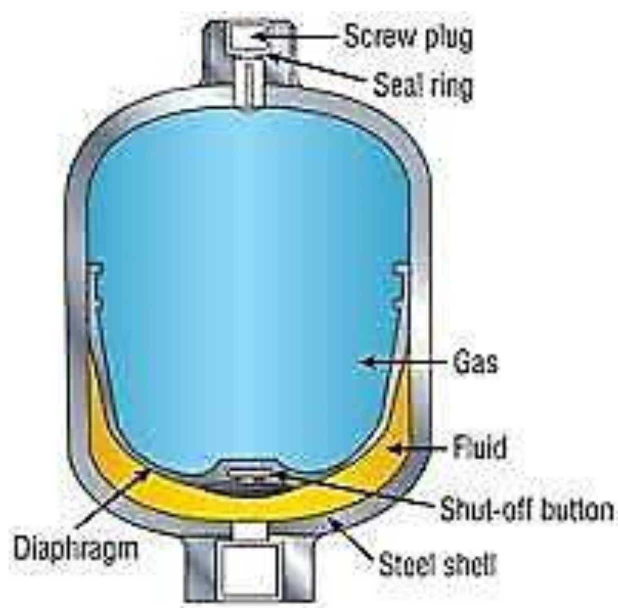
Diaphragm Accumulator.

The diaphragm-type accumulator consists of a diaphragm, secured in the shell, which serves as an elastic barrier between the oil and gas. A shutoff button, which is secured at the base of the diaphragm, covers the inlet of the line connection when the diaphragm is fully stretched. This prevents the diaphragm from being pressed into the opening during the precharge period.

On the gas side, the screw plug allows control of the charge pressure and charging of the accumulator by means of a charging device. The hydraulic pump delivers oil into the accumulator and deforms the diaphragm. As the pressure increases, the volume of gas decreases, thus storing energy. In the reverse case, where additional oil is required in the circuit, it comes from the accumulator as the pressure drops in the system by a corresponding amount.

The primary advantage of this type of accumulator is its small weight-to-volume ratio, which makes it suitable almost exclusively for airborne applications.

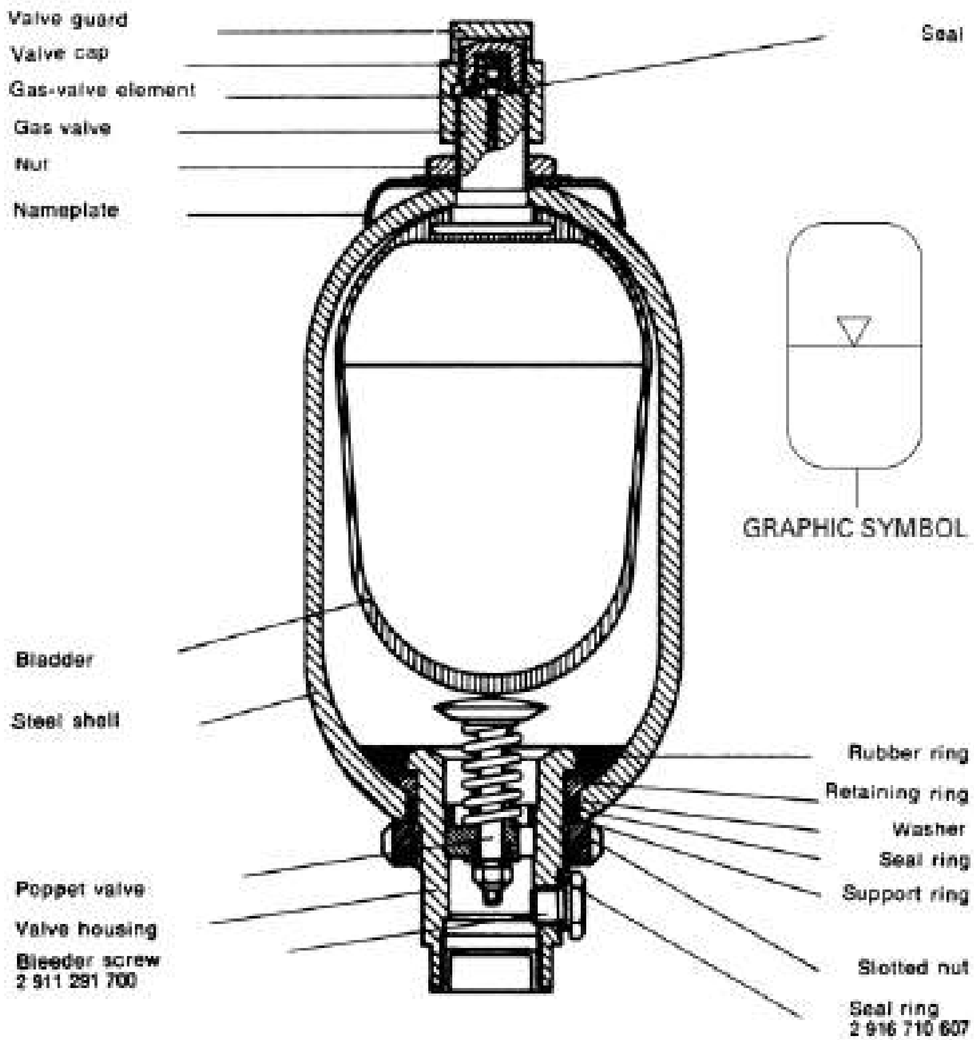




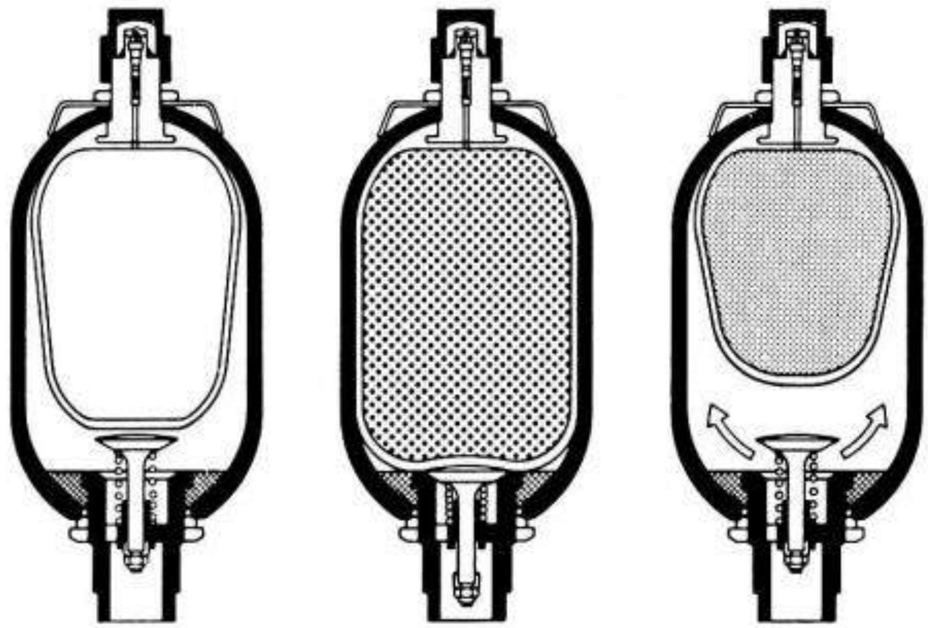
Bladder Accumulator.

A bladder-type accumulator contains an elastic barrier (bladder) between the oil and gas. The bladder is fitted in the accumulator by means of a vulcanized gas-valve element and can be installed or removed through the shell opening at the poppet valve. The poppet valve closes the inlet when the accumulator bladder is fully expanded. This prevents the bladder from being pressed into the opening.

The greatest advantage of this type of accumulator is the positive sealing between the gas and oil chambers. The lightweight bladder provides quick response for pressure regulating, pump pulsation, and shock-dampening applications. The hydraulic pump delivers oil into the accumulator and deforms the bladder. As the pressure increases, the volume of gas decreases, thus storing energy. In the reverse case, where additional oil is required in the circuit, it comes from the accumulator as pressure drops in the system by a corresponding amount.



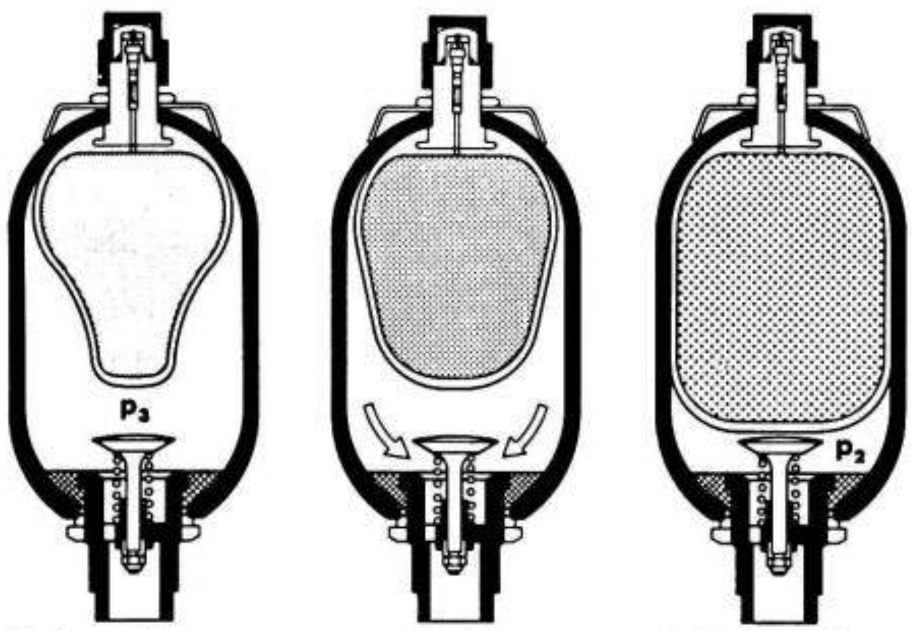
Operation of Bladder Accumulator.



a) without nitrogen charge

b) with nitrogen, charged to pre-charge pressure p_1

c) inlet of fluid for storage



d) charged to maximum operating pressure p_3

e) discharge of fluid

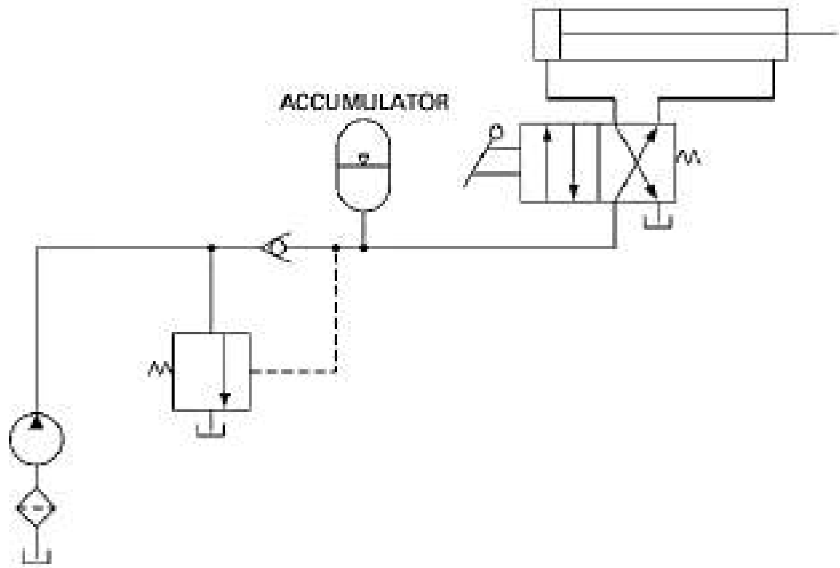
f) discharged to minimum operating pressure p_2

APPLICATIONS OF ACCUMULATORS

There are four basic applications where accumulators are used in hydraulic systems.

1. An auxiliary power source
2. A leakage compensator
3. An emergency power source
4. A hydraulic shock absorber

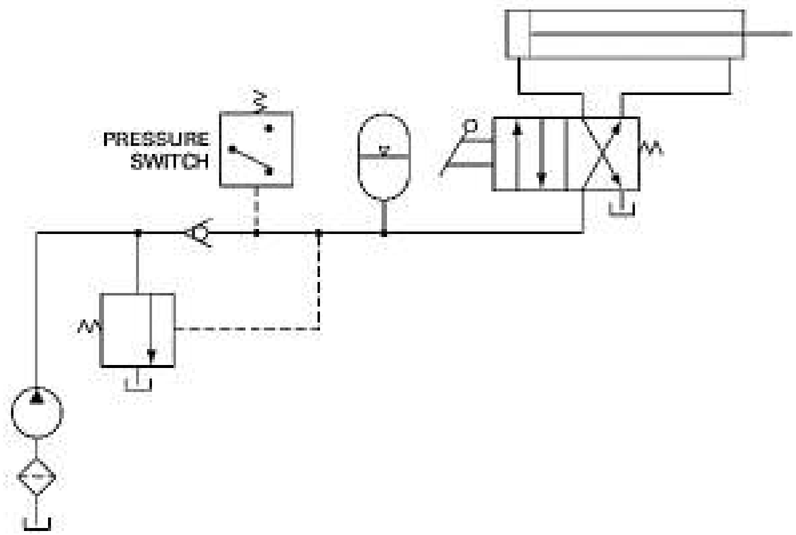
Accumulator as an Auxiliary Power Source



One of the most common applications of accumulators is as an auxiliary power source. The purpose of the accumulator in this application is to store oil delivered by the pump during a portion of the work cycle.

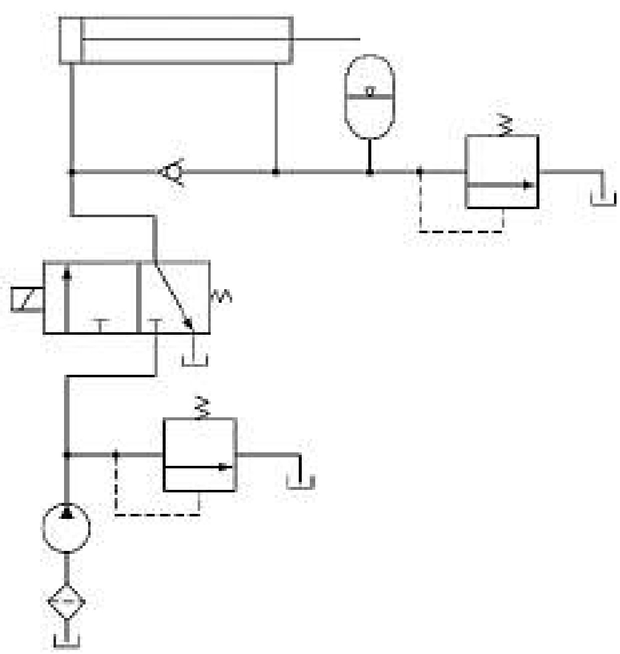
The accumulator then releases this stored oil on demand to complete the cycle, thereby serving as a secondary power source to assist the pump. In such a system where intermittent operations are performed, the use of an accumulator results in being able to use a smaller sized pump. This application is depicted in Figure in which a four-way valve is used in conjunction with an accumulator. When the four-way valve is manually actuated, oil flows from the accumulator to the blank end of the cylinder. This extends the piston until it reaches the end of its stroke. While the desired operation is occurring (the cylinder is in the fully extended position), the accumulator is being charged by the pump. The four-way valve is then deactivated for the retraction of the cylinder. Oil flows from the pump and accumulator to retract the cylinder rapidly. The accumulator size is selected to supply adequate oil during the retraction stroke.

Accumulator as a Leakage Compensator



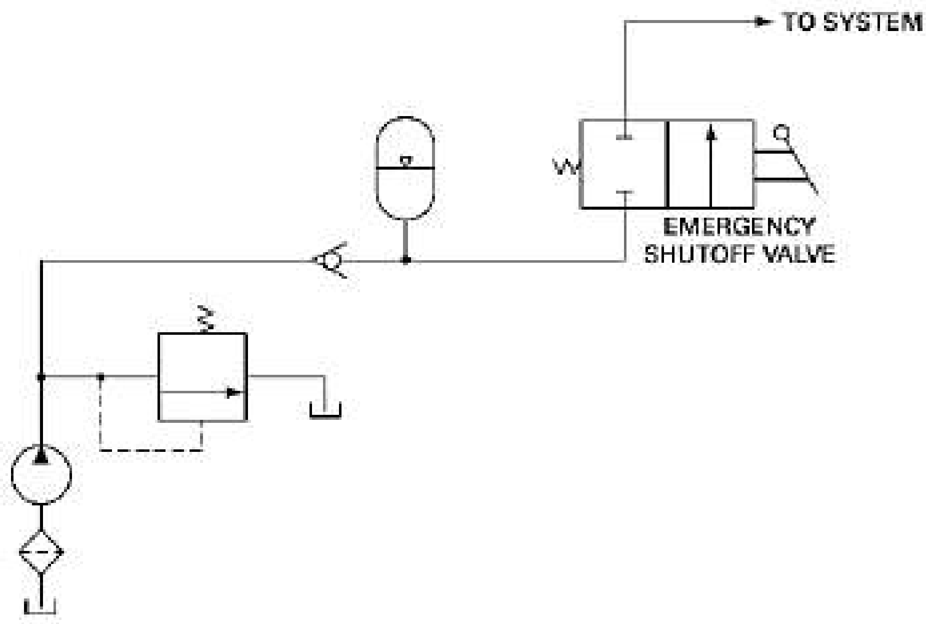
A second application for accumulators is as a compensator for internal or external leakage during an extended period of time during which the system is pressurized but not in operation. As shown in Figure, for this application the pump charges the accumulator and system until the maximum pressure setting on the pressure switch is obtained. The contacts on the pressure switch then open to automatically stop the electric motor that drives the pump. The accumulator then supplies leakage oil to the system during a long period. Finally, when system pressure drops to the minimum pressure setting of the pressure switch, it closes the electrical circuit of the pump motor (not shown) until the system has been recharged. The use of an accumulator as a leakage compensator saves electrical power and reduces heat in the system.

Accumulator as an Emergency Power Source



In some hydraulic systems, safety dictates that a cylinder be retracted even though the normal supply of oil pressure is lost due to a pump or electrical power failure. Such an application requires the use of an accumulator as an emergency power source. In this circuit, a solenoid-actuated, three-way valve is used in conjunction with the accumulator. When the three-way valve is energized, oil flows to the blank end of the cylinder and also through the check valve into the accumulator and rod end of the cylinder. The accumulator charges as the cylinder extends. If the pump fails due to an electrical failure, the solenoid will de-energize, shifting the valve to its spring-offset mode. Then the oil stored under pressure is forced from the accumulator to the rod end of the cylinder. This retracts the cylinder to its starting position.

Accumulator as a Hydraulic Shock Absorber



One of the most important industrial applications of accumulators is the elimination or reduction of high-pressure pulsations or hydraulic shock. Hydraulic shock (or water hammer, as it is frequently called) is caused by the sudden stoppage or deceleration of a hydraulic fluid flowing at relatively high velocity in a pipeline. One example where this occurs is in the case of a rapidly closing valve. This creates a compression wave where the rapidly closing valve is located. This compression wave travels at the speed of sound upstream to the end of the pipe and back again to the closed valve, causing an increase in the line pressure. This wave travels back and forth along the entire pipe length until its energy is finally dissipated by friction. The resulting rapid pressure pulsations or high-pressure surges may cause damage to the hydraulic system components. If an accumulator is installed near the rapidly closing valve, the pressure pulsations or high pressure surges are suppressed.

HYDRAULIC CIRCUITS

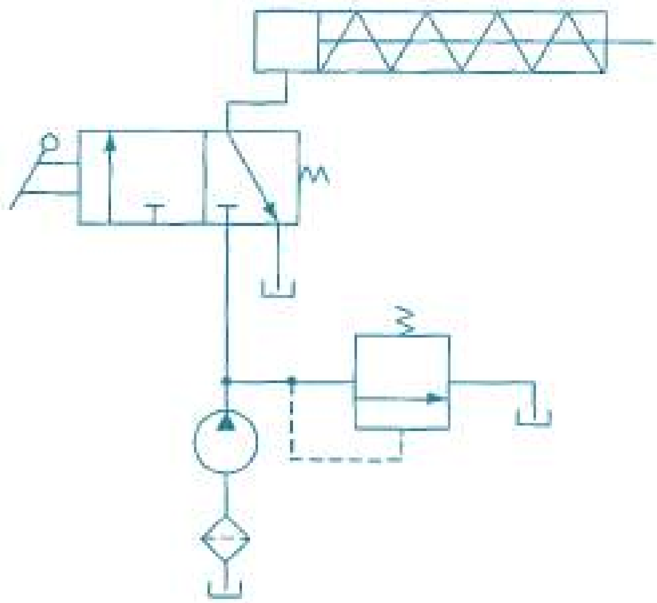
Definition of Hydraulic Circuits

A hydraulic circuit is a group of components such as pumps, actuators, control valves, and conductors arranged so that they will perform a useful task.

Important considerations when analyzing or designing hydraulic circuits:

1. Safety of operation
2. Performance of desired function
3. Efficiency of operation

CONTROL OF A SINGLE-ACTING HYDRAULIC CYLINDER



What are the components of the circuit?

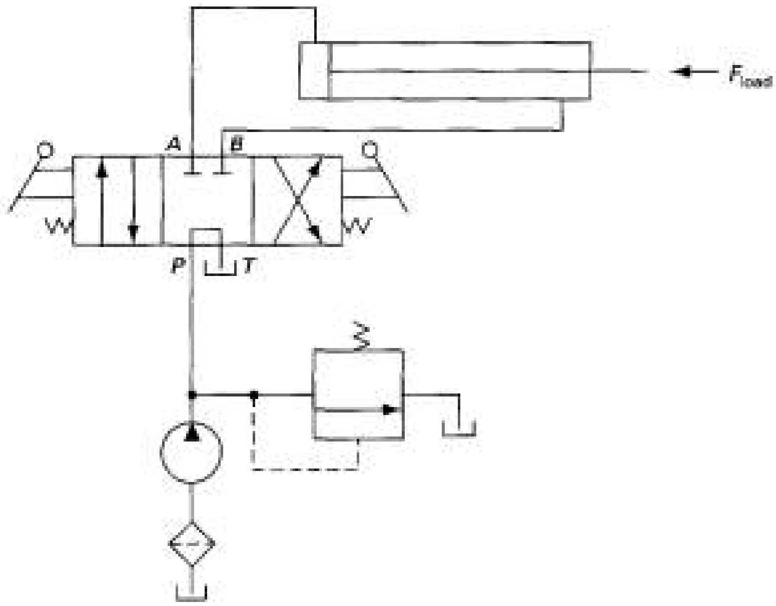
1. 2/3, manually actuated, spring-offset directional control valve (DCV)
2. Pump
3. Filter
4. Tank
5. Pressure relief valve.

Operation

In the spring-offset mode, full pump flow goes to the tank via the pressure relief valve. The spring in the rod end of the cylinder retracts the piston as oil from the blank end drains back to the tank. When the valve is manually actuated into its left envelope flow path configuration, pump flow extends the cylinder.

At full extension, pump flow goes through the relief valve. Deactivation of the DCV allows the cylinder to retract as the DCV shifts into its spring-offset mode.

CONTROL OF A DOUBLE-ACTING HYDRAULIC CYLINDER



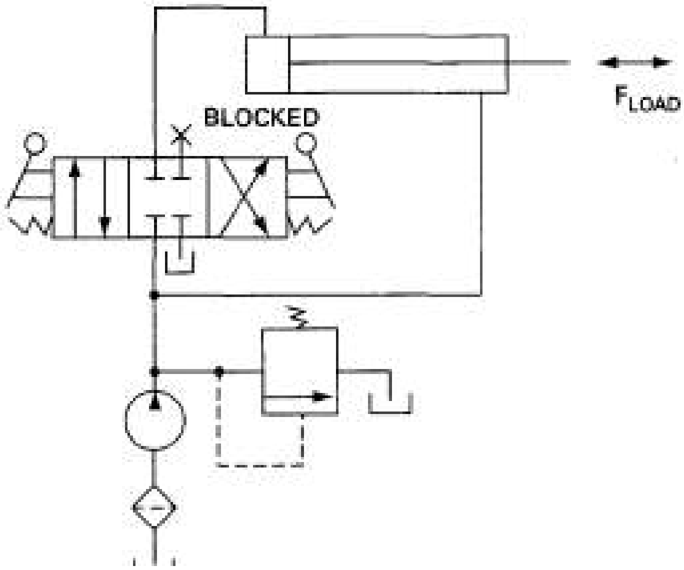
When the four-way valve is in its tandem design, the cylinder is hydraulically locked. Also, the pump is unloaded back to the tank at essentially atmospheric pressure.

When the four-way valve is actuated into the flow path configuration of the left envelope, the cylinder is extended against its load force Fload as oil flows from port P through port A. Also, oil in the rod end of the cylinder is free to flow back to the tank via the four-way valve from port B through port T. Note that the cylinder could not extend if this oil were not allowed to leave the rod end of the cylinder.

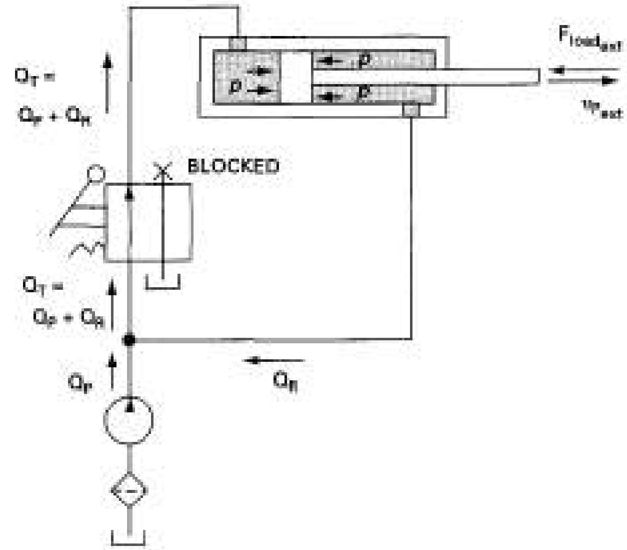
When the four way valve is deactivated, the spring-centered envelope prevails, and the cylinder once again hydraulically locked. When the four valve is actuated into the right envelope configuration, the cylinder retracts as oil flows from port P through port B. Oil in the blank end is returned to the 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. In any event, the system is protected from any cylinder overloads.

REGENERATIVE CYLINDER CIRCUIT

It is used to speed up the extending speed of a double-acting hydraulic cylinder.



Complete circuit.



Partial circuit showing flow paths during cylinder extension stroke.

A regenerative circuit that is used to speed up the extending speed of a double-acting hydraulic cylinder. Note that the pipelines to both ends of the hydraulic cylinder are connected in parallel and that one of the ports of the four-way valve is blocked. A common method used to block a valve port is to simply screw a threaded plug into the port opening. The operation of the cylinder during the retraction stroke is the same as that of a regular double-acting cylinder.

Fluid flows through the DCV via the right envelope during retraction. In this mode, fluid from the pump bypasses the DCV and enters the rod end of the cylinder. Fluid in the blank end drains back to the tank through the DCV as the cylinder retracts.

When the DCV is shifted into its left envelope configuration, the cylinder extends. The speed of extension is greater than that for a regular double-acting cylinder because flow from the rod end (QR) regenerates with the pump flow (QP) to provide a total flow rate (QT), which is greater than the pump flow rate to the blank end of the cylinder. The total flow rate (QT) entering the blank end of the cylinder equals the pump flow rate (Q) plus the regenerative flow rate (QR) coming from the rod end of the cylinder:

$$Q_T = Q_P + Q_R \quad \Rightarrow \quad Q_P = Q_T - Q_R$$

$$Q_P = A_p v_{p_{ext}} - (A_p - A_r) v_{p_{ext}}$$

$$v_{p_{ext}} = \frac{Q_P}{A_r}$$

a small rod area produces a large extending speed.

Ratio of Extending and Retracting Speeds

When extending and retracting speeds are equal

Extending speed of the piston, $v_{p_{ext}} = \frac{Q_P}{A_r}$

We know that the retracting speed (V_p) equals the pump flow rate divided by the difference of the piston and rod areas:

$$v_{p_{ret}} = \frac{Q_P}{A_p - A_r}$$

The Ratio $\frac{v_{p_{ext}}}{v_{p_{ret}}} = \frac{A_p}{A_r} - 1$

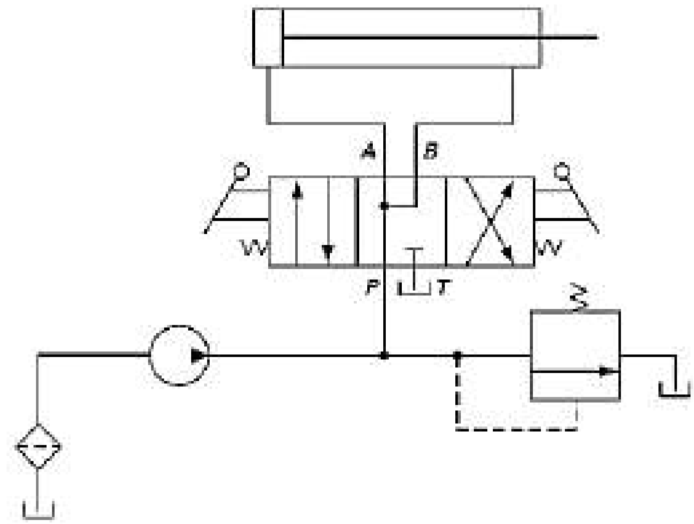
Speed Equality Condition: When the piston area equals two times the rod area, the greater the ratio of piston area to rod area, the greater the ratio of extending speed to retracting speed.

Load-Carrying Capacity During Extension $F_{load_{ext}} = pA_r$

The load-carrying capacity of a regenerative cylinder during extension is less than that obtained from a regular double-acting cylinder.

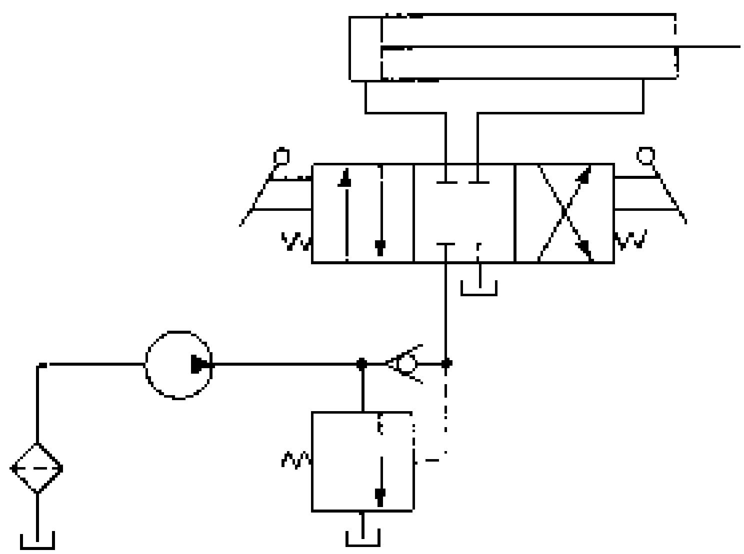
The load-carrying capacity (Fload) for a regenerative cylinder during extension equals the pressure times the piston rod area rather than the pressure times piston area.

Drilling Machine Application



An application using a four-way valve having a spring centered design with a closed tank port and a pressure port open to outlet ports A and B. The application is for a drilling machine, where the following operations take place: The spring-centered position gives rapid spindle advance (extension). The left envelope mode gives slow feed (extension) when the drill starts to cut into the workpiece. The right envelope mode retracts the piston.

PUMP-UNLOADING CIRCUIT

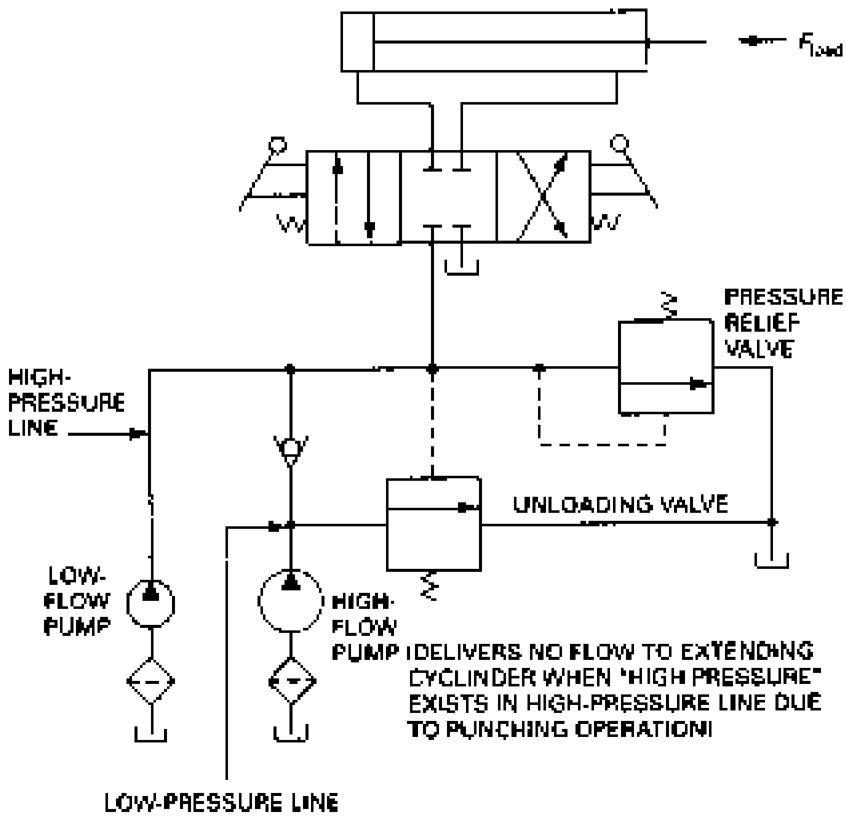


An unloading valve is used to unload a pump.

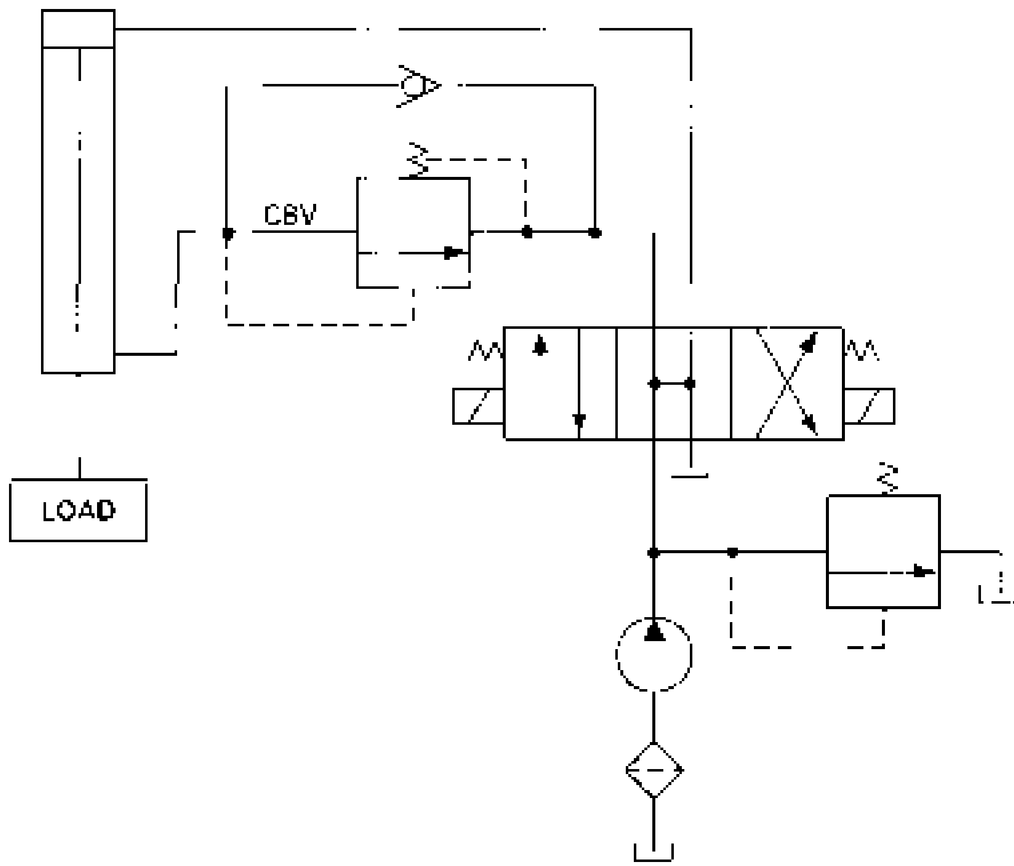
The unloading valve opens when the cylinder reaches the end of its extension stroke because the check valve keeps high-pressure oil in the pilot line of the unloading valve. When the DCV is shifted to retract the cylinder, the motion of the piston reduces the pressure in the pilot line of the unloading valve. This resets the unloading valve until the cylinder is fully retracted, at which point the unloading valve unloads the pump. The unloading valve unloads the pump at the ends of the extending and retraction strokes as well as in the spring-centered position of the DCV.

DOUBLE-PUMP HYDRAULIC SYSTEM

The circuit uses a high-pressure, low-flow pump in conjunction with a low-pressure, high-flow pump. A typical application is a sheet metal punch press in which the hydraulic ram (cylinder) must extend rapidly over a great distance with very low pressure but high flow-rate requirements. This rapid extension of the cylinder occurs under no external load as the punching tool (connected to the end of the cylinder piston rod) approaches the sheet metal strip to be punched.



COUNTERBALANCE VALVE APPLICATION

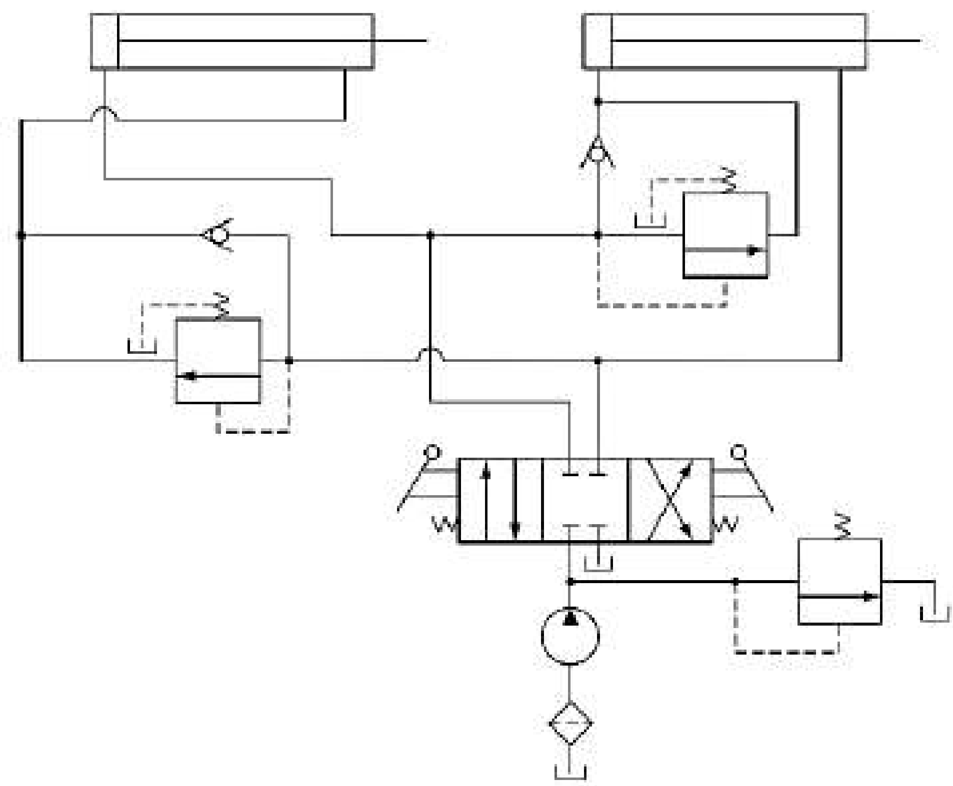


Purpose of Counter Balance (back-pressure) Valve (CBV) is to keep a vertically mounted hydraulic cylinder in the upward position while the pump is idling. The counterbalance valve (CBV) is set to open at somewhat above the pressure required to prevent. The vertical cylinder from descending due to the weight of its load. This permits the cylinder to be forced downward when pressure is applied on the top. The open-center directional control valve unloads the pump.

The DCV is a solenoid-actuated, spring-centered valve with an open-center flow path configuration.

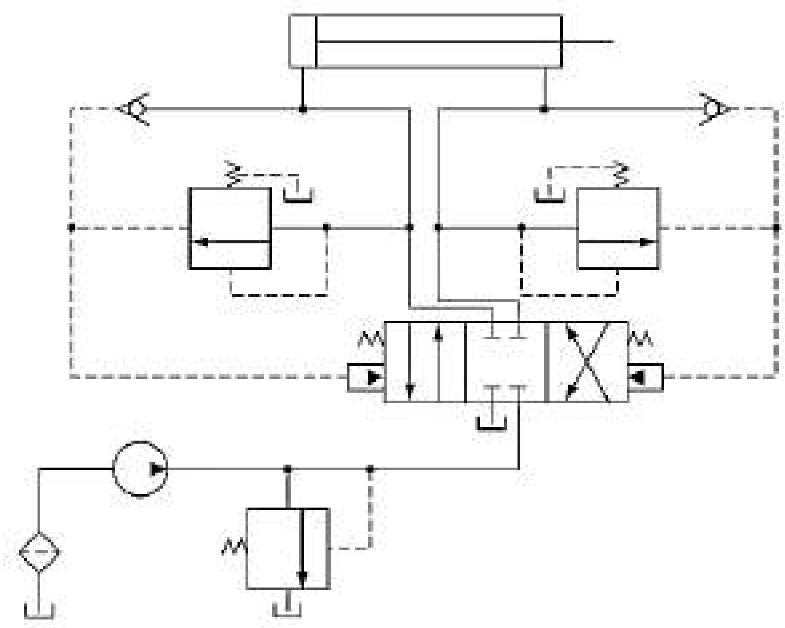
HYDRAULIC CYLINDER SEQUENCING CIRCUITS

A sequence valve causes operations in a hydraulic circuit to behave sequentially. Figure is an example where two sequence valves are used to control the sequence of operations of two double-acting cylinders. When the DCV is shifted into its left envelope mode, the left cylinder extends completely, and then the right cylinder extends. If the DCV is then shifted into its right envelope mode, the right cylinder retracts fully, and then the left cylinder retracts. This sequence of cylinder operation is controlled by the sequence valves. The spring-centered position of the DCV locks both cylinders in place. One application of this circuit is a production operation. For example, the left cylinder could extend and clamp a workpiece via a power vise jaw. Then the right cylinder extends to drive a spindle to drill a hole in the workpiece. The right cylinder then retracts the drill spindle, and then the left cylinder retracts to release the workpiece for removal. Obviously these machining operations must occur in the proper sequence as established by the sequence valves in the circuit.



AUTOMATIC CYLINDER RECIPROCATING SYSTEM

Figure shows a circuit that produces continuous reciprocation of a hydraulic cylinder. This is accomplished by using two sequence valves, each of which senses a stroke completion by the corresponding buildup of pressure. Each check valve and corresponding pilot line prevents shifting of the four-way valve until the particular stroke of the cylinder has been completed. The check valves are needed to allow pilot oil to leave either end of the DCV while pilot pressure is applied to the opposite end. This permits the spool of the DCV to shift as required.



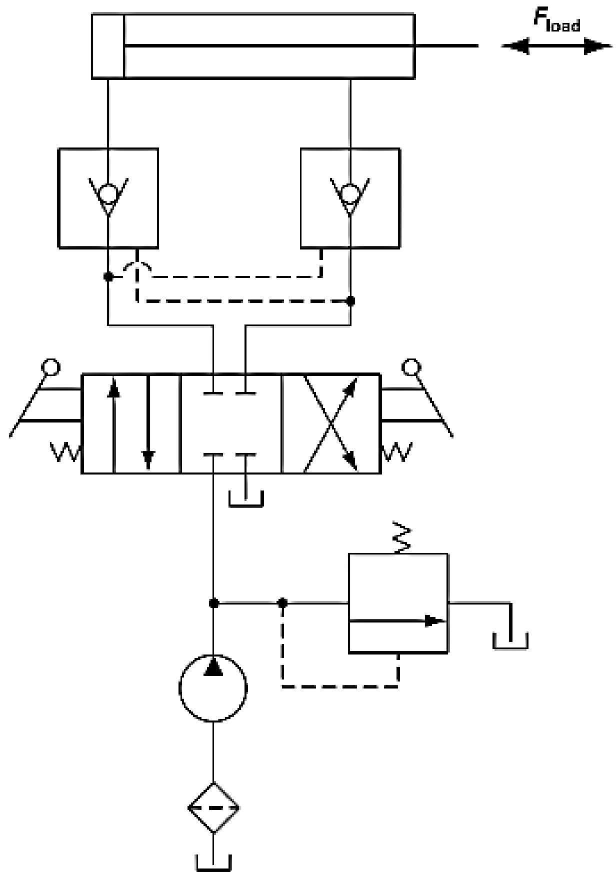
LOCKED CYLINDER USING PILOT CHECK VALVES

In many cylinder applications, it is necessary to lock the cylinder so that its piston cannot be moved due to an external force acting on the piston rod. One method for locking a cylinder in this fashion is by using pilot check valves.

The cylinder can be extended and retracted as normally done by the action of the directional control valve.

If regular check valves were used, the cylinder could not be extended or retracted by the action of the DCV.

An external force, acting on the piston rod, will not move the piston in either direction because reverse flow through either pilot check valve is not permitted under these conditions.

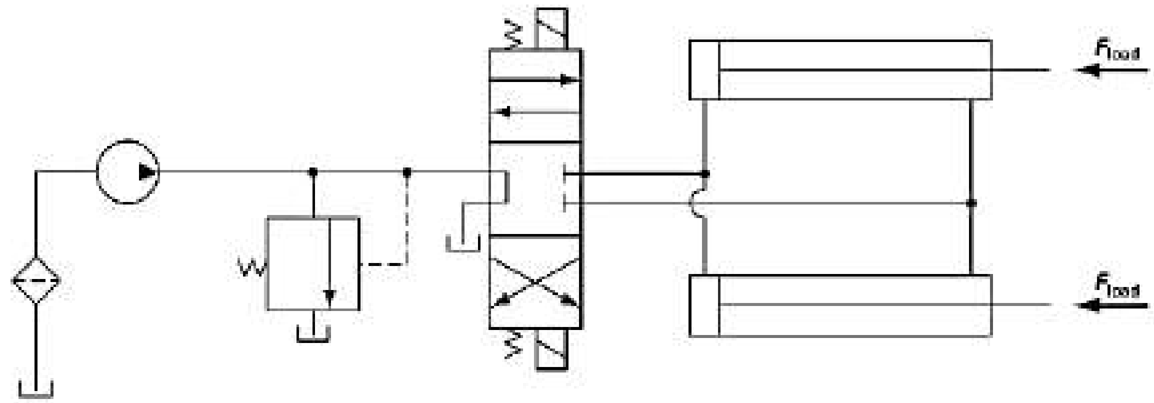


CYLINDER SYNCHRONIZING CIRCUITS

Cylinders Connected in Parallel

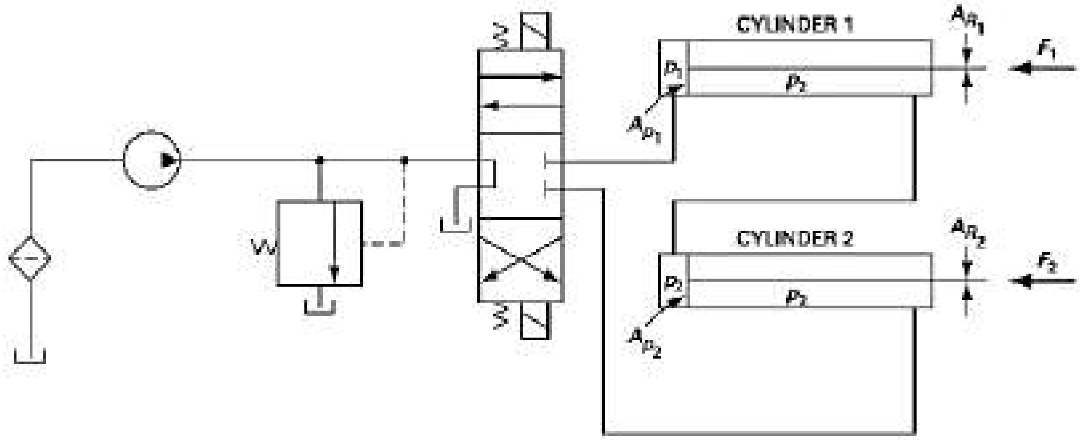
Figure shows two identical cylinders can be synchronized by piping them in parallel. However, even if the two cylinders are identical, it would be necessary for the loads on the cylinders to be identical in order for them to extend in exact synchronization. If the loads are not exactly identical (as is always the case), the cylinder with the smaller load would extend first because it would move at a lower pressure level.

After this cylinder has fully completed its stroke, the system pressure will increase to the higher level required to extend the cylinder with the greater load. It should be pointed out that no two cylinders are really identical. For example, differences in packing friction will vary from cylinder to cylinder. This alone would prevent cylinder synchronization for the circuit.



Cylinders Connected in Series

The circuit of Figure shows that hooking two cylinders in series is a simple way to synchronize the two cylinders. For example, during the extending stroke of the cylinders, fluid from the pump is delivered to the blank end of cylinder 1 via the flow path shown in the upper envelope of the DCV. As cylinder 1 extends, fluid from its rod end is delivered to the blank end of cylinder 2. Note that both ends of cylinders and the entire pipeline between the cylinders is filled with fluid. Fluid returns to the oil tank from the rod end of cylinder 2, as it extends, via the DCV. For the two cylinders to be synchronized, the piston area of cylinder 2 must equal the difference between the areas of the piston and rod for cylinder 1. This can be shown by applying the continuity equation which states that the rate at which fluid leaves the rod end of cylinder 1 must equal the rate at which fluid enters cylinder 2. Thus, we have for a hydraulic fluid Qout(cyl1) = Qin(cyl2)



It should be noted that the pump must be capable of delivering a pressure equal to that required for the piston of cylinder 1 by itself to overcome the loads acting on both extending cylinders. This is shown as follows, noting that the pressures are equal at the blank end of cylinder 2 and at the rod end of cylinder 1 per Pascal's law.

Speed control

The operational speed of an actuator is determined by the fluid flow rate and the actuator area (for a cylinder) or the displacement (for a motor). The physical dimensions are generally fixed for an actuator, so speed is controlled by adjusting the fluid flow to (or restricting flow from) the actuator. Rotary actuator speed can also be controlled by altering swash plate angle. Speed control of a hydraulic cylinder is accomplished using a flow control valve. A flow control valve regulate the speed of the cylinder by controlling the flow rate to and of the actuator. There are 3 types of speed control:

- Meter- in circuit (Primary control)
- Meter-out circuit (Secondary control)
- Bleed - off circuit (By pass control)

Speed control - Meter – in Circuit :

In this type of speed control, the flow control valve is placed between the pump and the actuator. Thereby, it controls the amount of fluid going into the actuator.

C = Double acting cylinder;

P = Pump ;

T = Tank ;

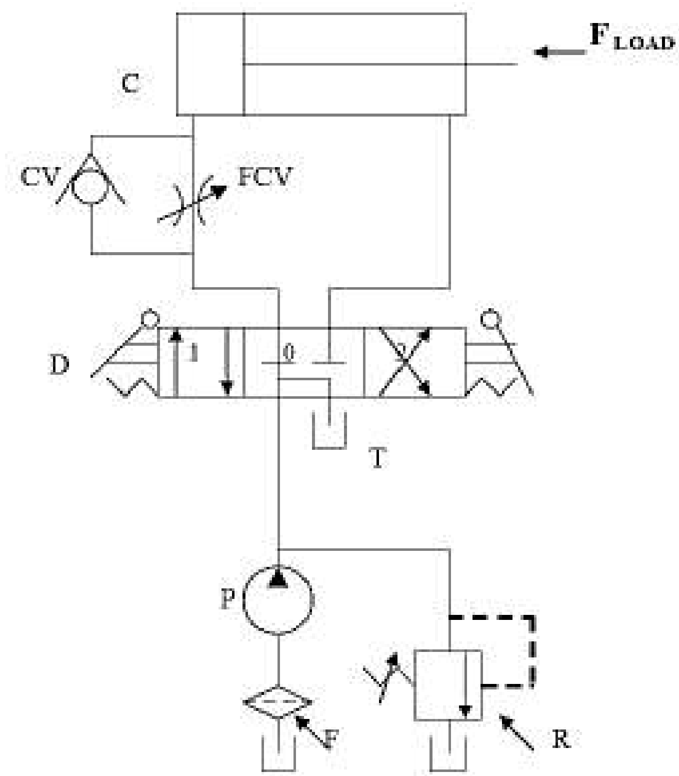
F = Filter;

R = Relief Valve;

CV = Check Valve ;

FCV = Flow control Valve

D=3-position, 4way, Tandem center, Manually operated, Spring Centered DCV



Speed control - Meter – out Circuit:

In this type of speed control, the flow control valve is placed between the actuator and the tank. Thereby, it controls the amount of fluid going out of the actuator.

C = Double acting cylinder ;

P = Pump ;

T = Tank ;

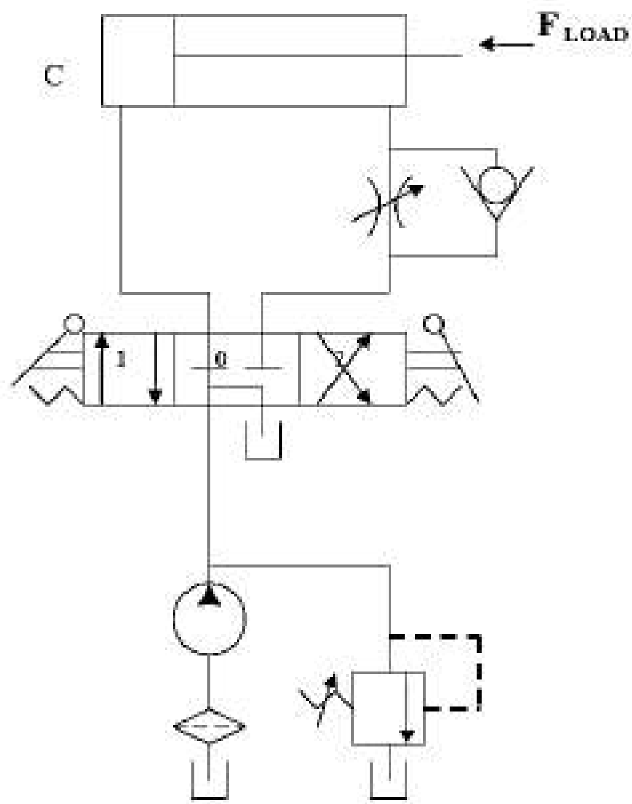
F = Filter;

R = Relief Valve;

CV = Check Valve ;

FCV = Flow control Valve

D=3-position, 4way, Tandem center, Manually operated, Spring Centered DCV



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

Speed control - Bleed – off Circuit

In this type of speed control, the flow control valve is placed between the pressure line and return line. Thereby, it controls the fluid by bleeding off the excess not needed by the working cylinder.

C = Double acting cylinder ;

P = Pump ;

T = Tank ;

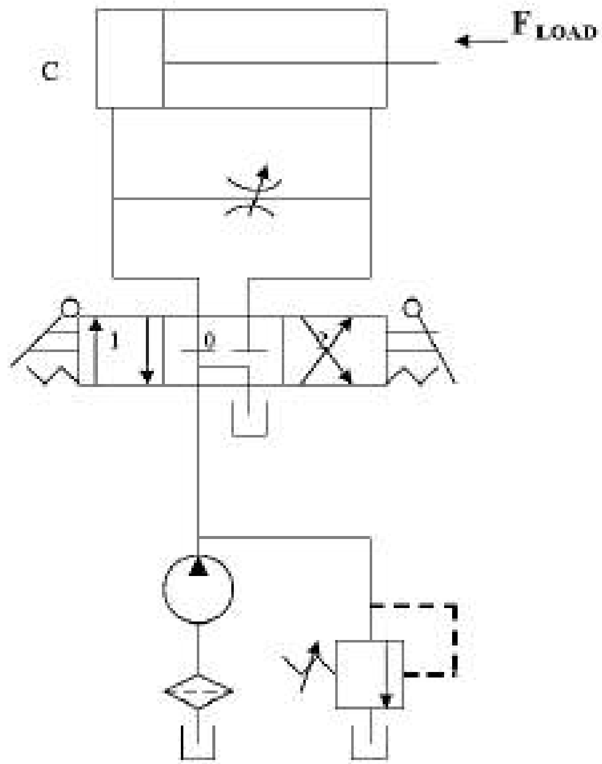
F = Filter;

R = Relief Valve;

CV = Check Valve ;

FCV = Flow control Valve

D=3-position, 4way, Tandem center, Manually operated, Spring Centered DCV



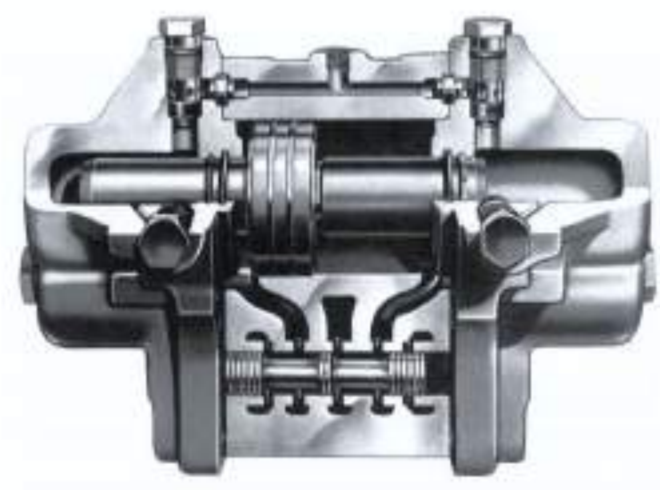
This type of flow control is much more efficient than the inlet restricting type for meter-in, because the bypass feature allows fluid to be exhausted to the tank at just slightly higher pressure than that necessary to do the work. With the meter-in type, pump delivery not used would discharge over the main relief valve at maximum pressure.

PRESSURE INTENSIFIERS or PRESSURE BOOSTER

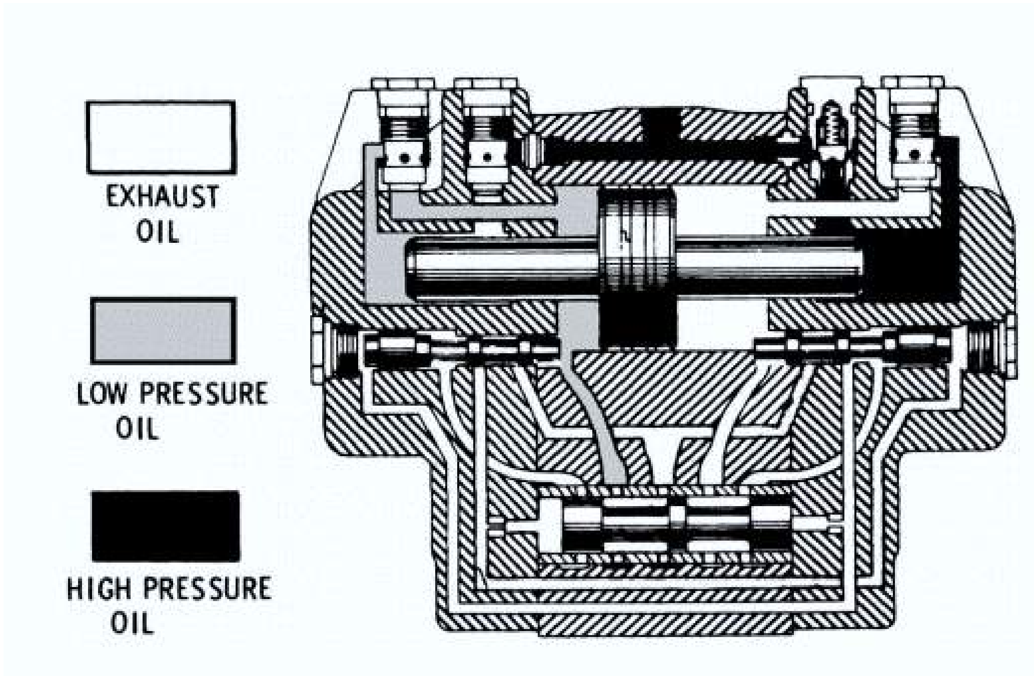
Although a pump is the primary power source for a hydraulic system, auxiliary units are frequently employed for special purposes. One such auxiliary unit is the pressure intensifier or booster. It is used to increase the pressure in a hydraulic system to a value above the pump discharge pressure. It accepts a high-volume flow at relatively low pump pressure and converts a portion of this flow to high pressure. The internal construction consists of an automatically reciprocating large piston that has two small rod ends. This piston has its large area (total area of piston) exposed to pressure from a low-pressure pump.

The force of the low-pressure oil moves the piston and causes the small area of the piston rod to force the oil out at intensified high pressure.

This device is symmetrical about a vertical centerline. Thus, as the large piston reciprocates, the left- and right-hand halves of the unit duplicate each other during each stroke of the large piston. The increase in pressure is in direct proportion to the ratio of the large piston area and the rod area. The volume output is inversely proportional to this same ratio.



Oil flow paths of pressure intensifier.



$$\frac{\text{high discharge pressure}}{\text{low inlet pressure}} = \frac{\text{area of piston}}{\text{area of rod}} = \frac{\text{high inlet flow rate}}{\text{low discharge flow rate}}$$

Racine pressure intensifiers are available with area ratios of 3:1, 5:1, and 7:1, developing pressures to 5000 psi and flows to 7 gpm.

There are many applications for pressure intensifiers, such as the elimination of a high-pressure/low-flow pump used in conjunction with a low-pressure/high-flow pump. In an application such as a punch press, it is necessary to extend a hydraulic cylinder rapidly using little pressure to get the ram near the sheet metal strip as quickly as possible. Then the cylinder must exert a large force using only a small flow rate. The large force is needed to punch the workpiece from the sheet metal strip. Since the strip is thin, only a small flow rate is required to perform the punching operation in a short time.

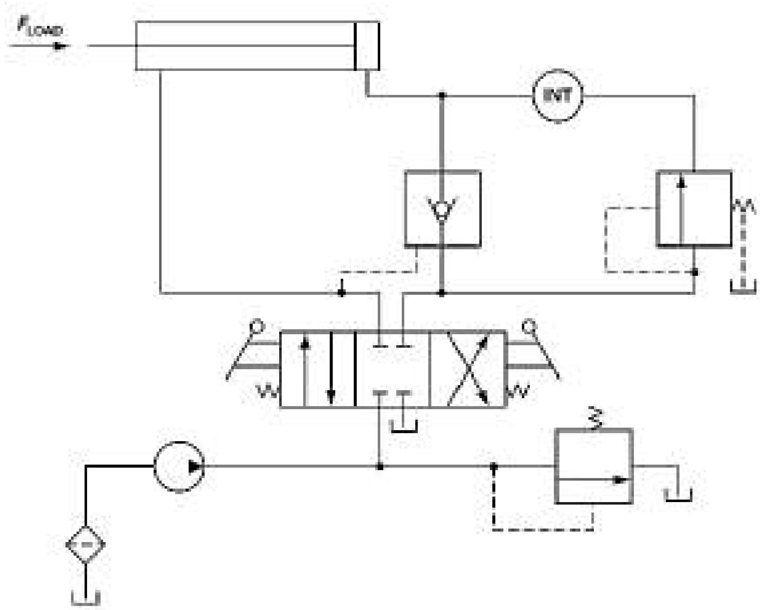
The use of the pressure intensifier results in a significant cost savings in this application, because it replaces the expensive high-pressure pump that would normally be required.

Pressure Intensifier Circuit

Figure gives the circuit for a punch press application where a pressure intensifier is used to eliminate the need for a high-pressure/low-flow pump. This circuit also includes a pilot check valve and sequence valve.

The operation is as follows: When the pressure in the cylinder reaches the sequence valve pressure setting, the intensifier starts to operate. The high-pressure output of the intensifier closes the pilot check valve and pressurizes the blank end of the cylinder to perform the punching operation.

A pilot check valve is used instead of a regular check valve to permit retraction of the cylinder. Very high pressures can be supplied by a pressure intensifier operating on a low-pressure pump. The intensifier should be installed near the cylinder to keep the high-pressure lines as short as possible.



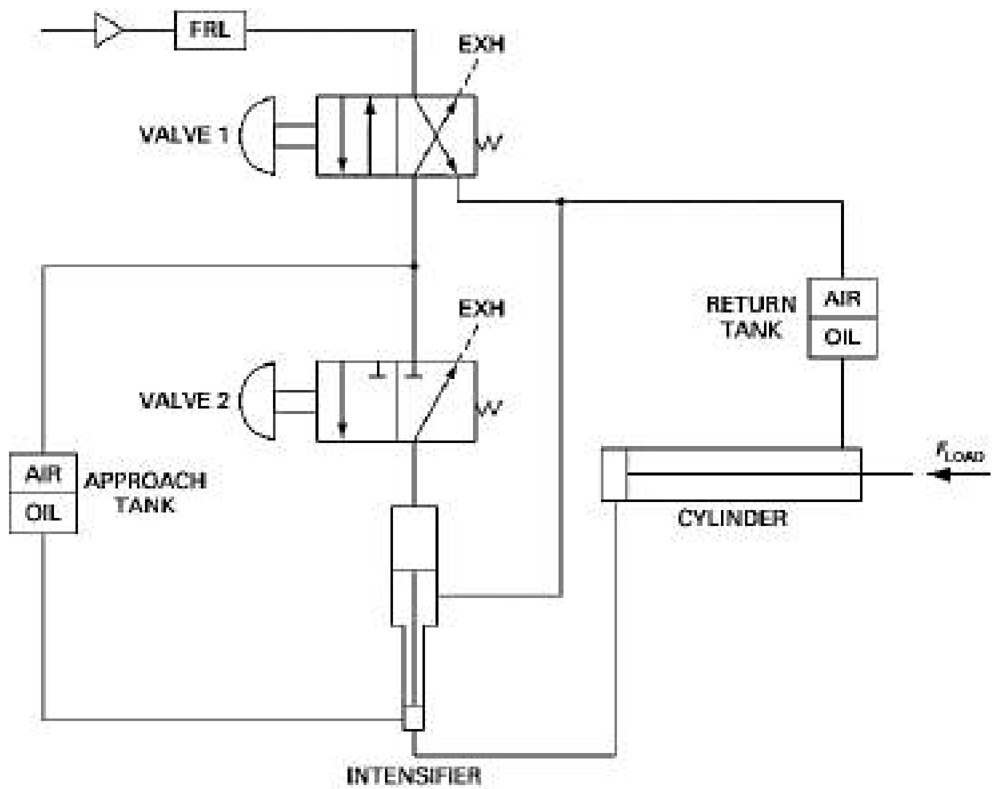
Air-over-Oil Intensifier System

An air-over-oil intensifier circuit drives a cylinder over a large distance at low pressure and then over a small distance at high pressure. Shop air can be used to extend and retract the cylinder during the low-pressure portion of the cycle.

The system operates as follows: Valve 1 extends and retracts the cylinder using shop air at approximately 80 psi. Valve 2 applies air pressure to the top end of the hydraulic intensifier. This produces high hydraulic pressure at the bottom end of the intensifier. Actuation of valve 1 directs air to the approach tank.

This forces oil at 80 psi through the bottom of the intensifier to the blank end of the cylinder. When the cylinder experiences its load (such as the punching operation in a punch press), valve 2 is actuated, which sends shop air to the top end of the intensifier. The high-pressure oil cannot return to the approach tank because this port is blocked off by the downward motion of the intensifier piston. Thus, the cylinder receives high-pressure oil at the blank end to overcome the load. When valve 2 is released, the shop air is blocked, and the top end of the intensifier is vented to the atmosphere. This terminates the high-pressure portion of the cycle. When valve 1 is released, the air in the approach tank is vented, and shop air is directed to the return tank.

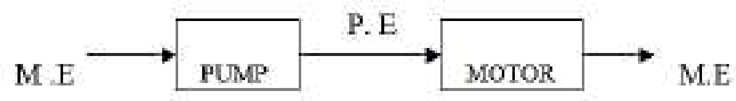
This delivers oil at shop pressure to the rod end of the cylinder, causing it to retract. Oil enters the bottom end of the intensifier and flows back to the approach tank. This completes the entire cycle. Figure also shows an air-oil intensifier and its graphic symbol. This type of intensifier is capable of producing output hydraulic pressures up to 3000 psi.


FRL
EXH
VALVE 1
EXH
VALVE 2
RETURN TANK
AIR
OIL
AIR
OIL
APPROACH TANK
F_{LOAD}
CYLINDER
INTENSIFIER

ANSI SYMBOL

Hydrostatic Transmission (HST):

These are special cases of energy transmission system. It consists of a drive with hydraulic energy as input. Hydraulic motor convert hydraulic energy to mechanical energy. Hydrostatic transmission is a whole unit in which pumps and motors are designed to match (the speed torque characteristics) to get optimum transmission. The HST can be open or closed circuit.

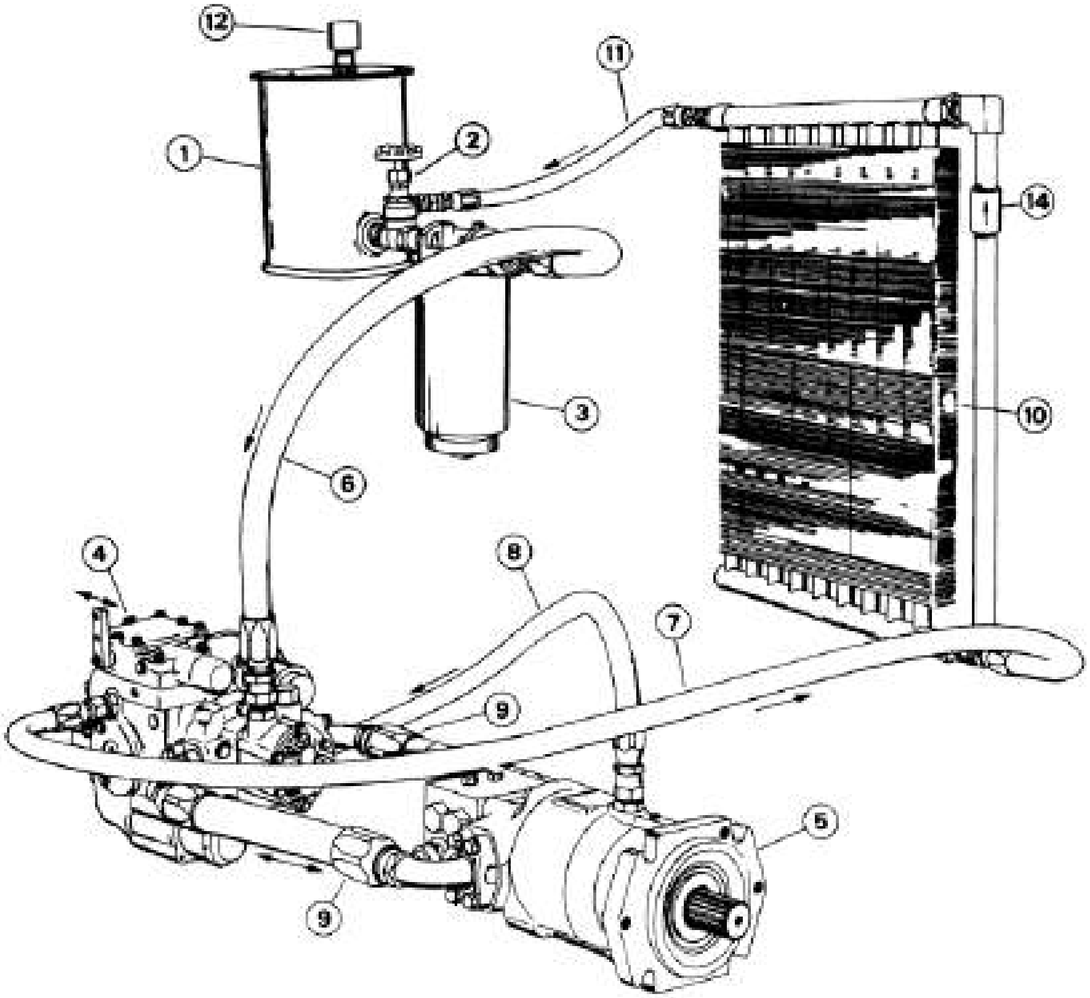


A system consisting of a hydraulic pump, a hydraulic motor, and appropriate valves and pipes can be used to provide adjustable-speed drives for many practical applications. Such a system is called a hydrostatic transmission. There must, of course, be a prime mover such as an electric motor or gasoline engine. Applications in existence include tractors, rollers, front-end loaders, hoes, and lift trucks. Some of the advantages of hydrostatic transmissions are the following:

- Infinitely variable speed and torque in either direction and over the full speed and torque ranges
- Extremely high power-to-weight ratio
- Ability to be stalled without damage
- Low inertia of rotating members, permitting fast starting and stopping with smoothness and precision
- Flexibility and simplicity of design

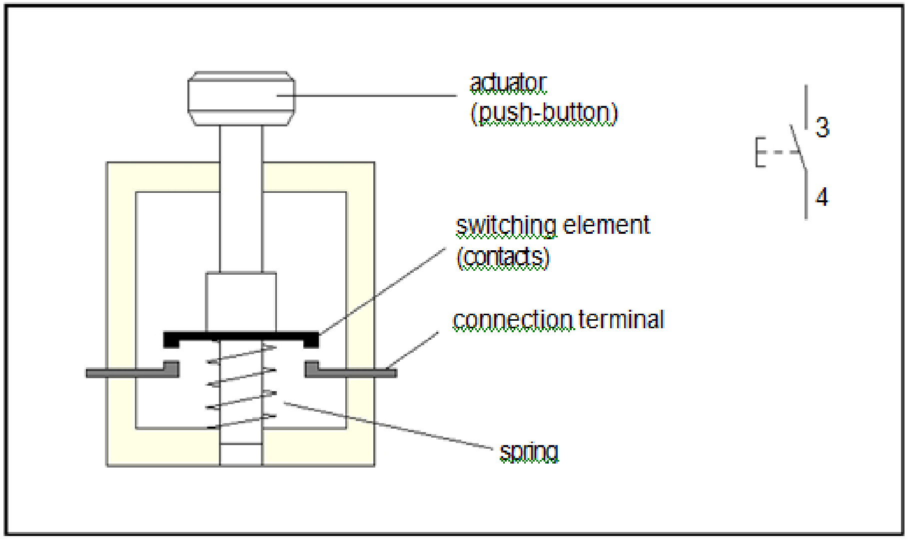
Figure shows a heavy-duty hydrostatic transmission system which uses a variable displacement piston pump and a fixed displacement piston motor. Both pump and motor are of the swash plate in-line piston design. This type of hydrostatic transmission is expressly designed for application in the agricultural, construction, materials handling, garden tractor, recreational vehicle, and industrial markets. For the transmission, the operator has complete control of the system, with one lever for starting, stopping, forward motion, or reverse motion. Control of the variable displacement pump is the key to controlling the vehicle. Prime mover power is transmitted to the pump. When the operator moves the control lever, the swash plate in the pump is tilted from neutral. When the pump swash plate is tilted, a positive stroke of the pistons occurs. This, in turn, at any given input speed, produces a certain flow from the pump. This flow is transferred through high-pressure lines to the motor. The ratio of the volume of flow from the pump to the displacement of the motor determines the speed at which the motor will run. Moving the control lever to the opposite side of neutral causes the flow through the pump to reverse its direction. This reverses the direction of rotation of the motor. Speed of the output shaft is controlled by adjusting the displacement (flow) of the pump. Load (working pressure) is determined by the external conditions (grade, ground conditions, etc.), and this establishes the demand on the system.

1. Reservoir
2. Shut-off Valve
3. Filter
4. Variable Displacement Pump
5. Fixed Displacement Motor
6. Inlet Line
7. Pump Case Drain Line
8. Motor Case Drain Line
9. High Pressure Lines
10. Heat Exchanger
11. Reservoir Return Line
12. Reservoir Fill Cap or Breather
14. Heat Exchanger By-pass Valve

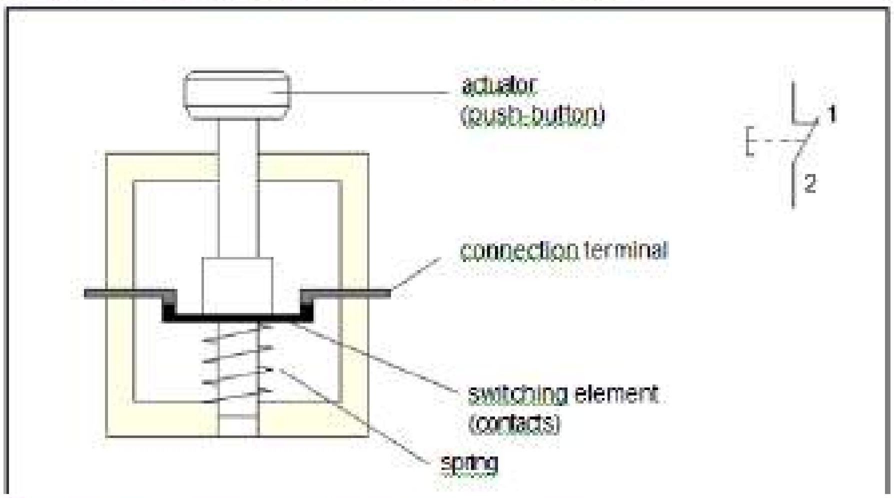

12
11
1
2
14
3
10
6
4
8
7
9
5
9

Electrical Control of hydraulic circuits

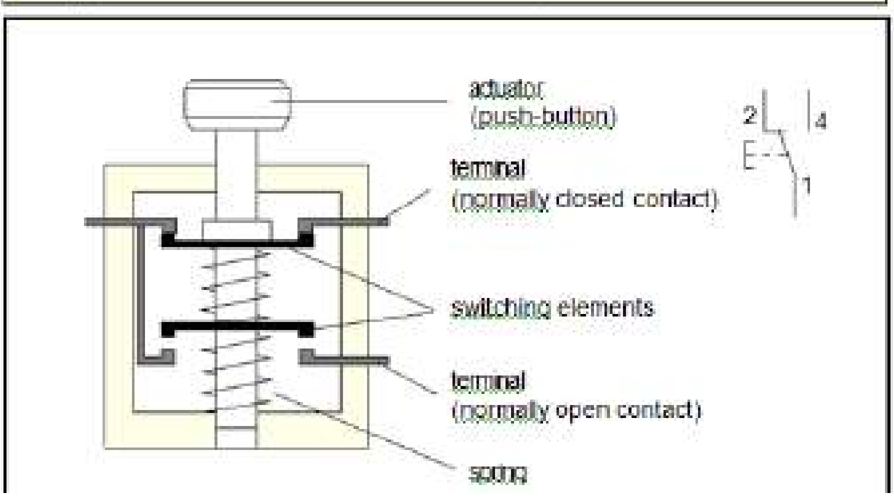
Normally open contact: sectional view and circuit symbol



Normally closed contact: sectional view and circuit symbol



Changeover contact: sectional view and circuit symbol



Electrical Control of hydraulic circuits

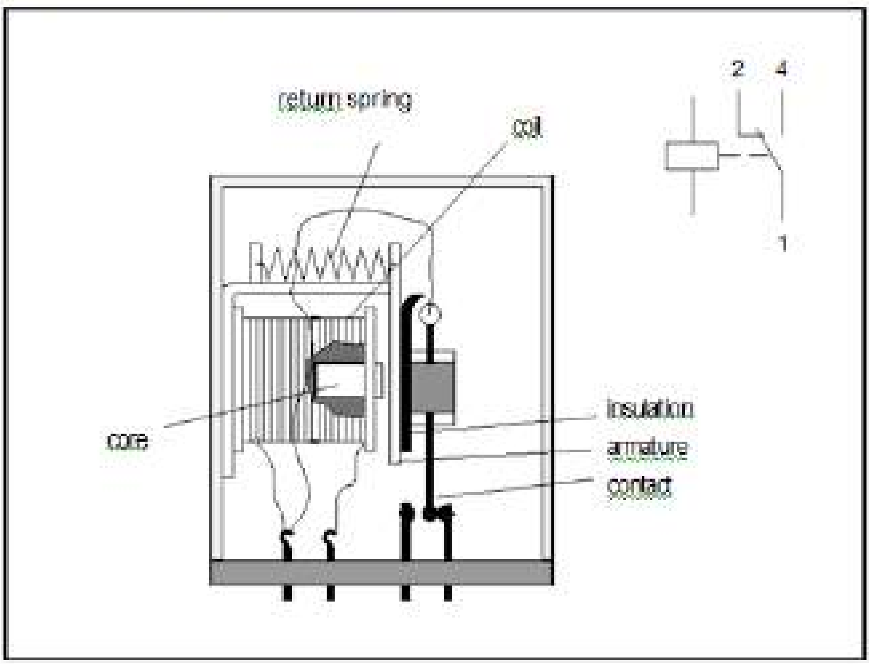
Relays and Relay Contacts

Relays are designated K1, K2, K3 etc.

Coil terminals are designated A1 and A2.

Contacts switched by the relay are also designated K1, K2, resp., etc. in circuits

Relay: sectional view and circuit symbol



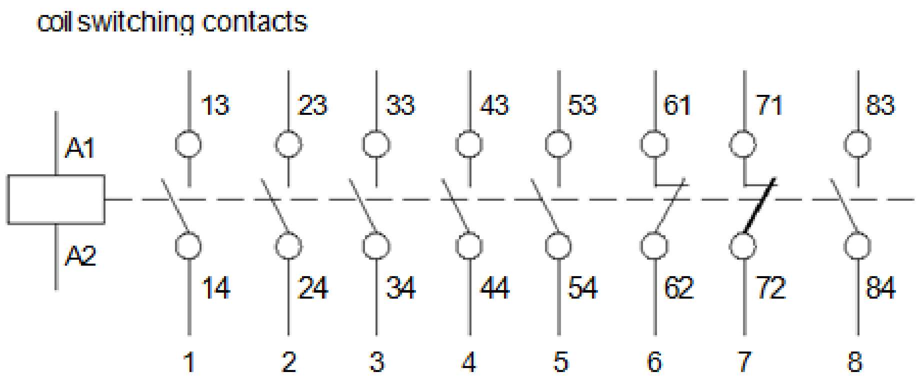
Electrical Control of hydraulic circuits

Terminals of the auxiliary contacts (relay contacts) are designated by two digit numbers:

the first digit is the ordinal(position) number

the second digit is the function number

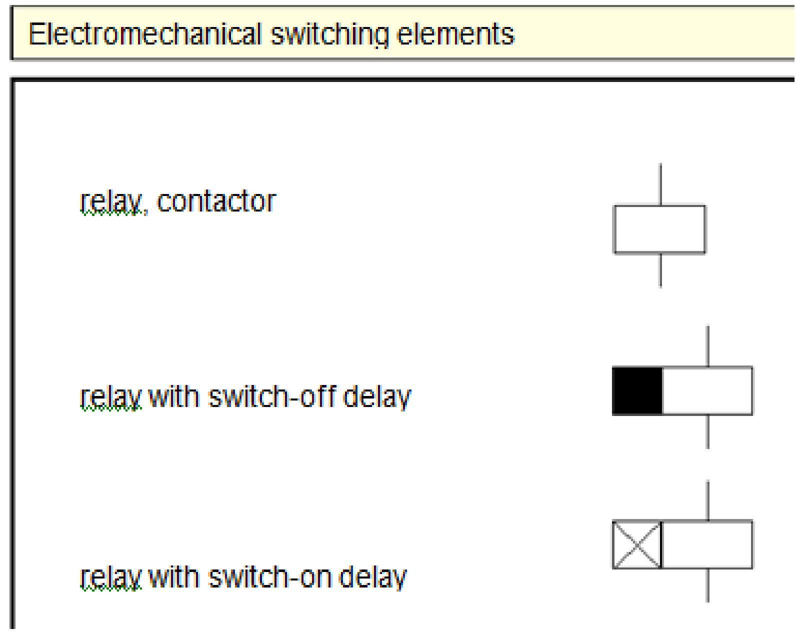
Circuit symbols and terminal designations of a relay



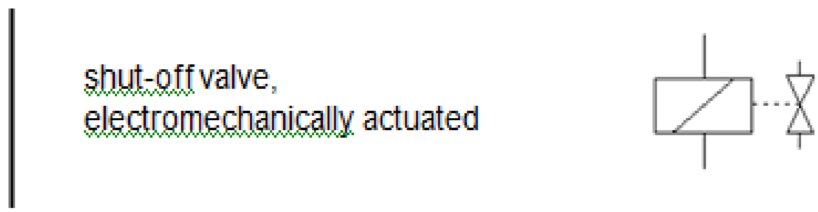
Function numbers for relays

1	2		normally closed contact
3	4		normally open contact
5	6		normally closed contact, time delay
7	8		normally open contact, time delay
1	2	4	changeover contact
5	6	8	changeover contact, time delay

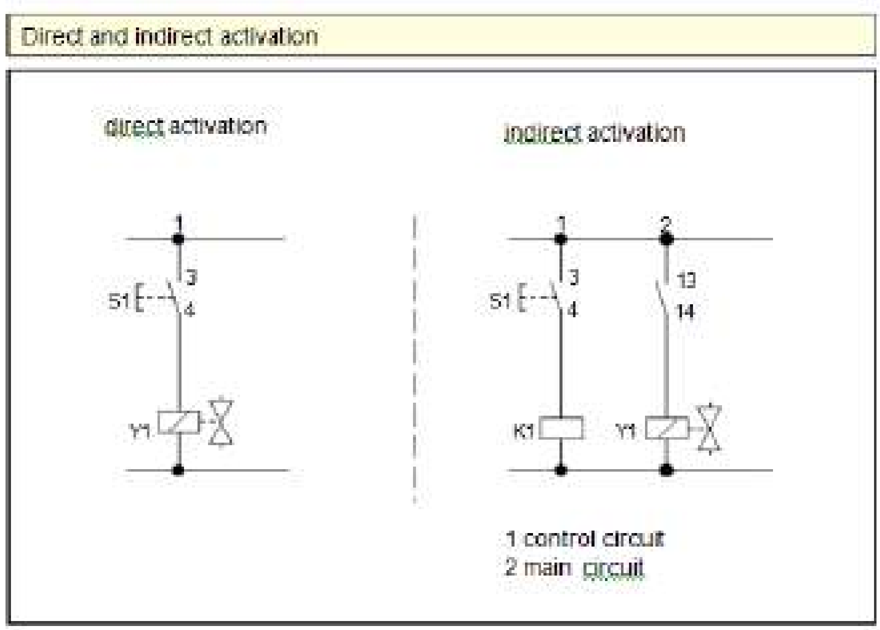
Relay operation types



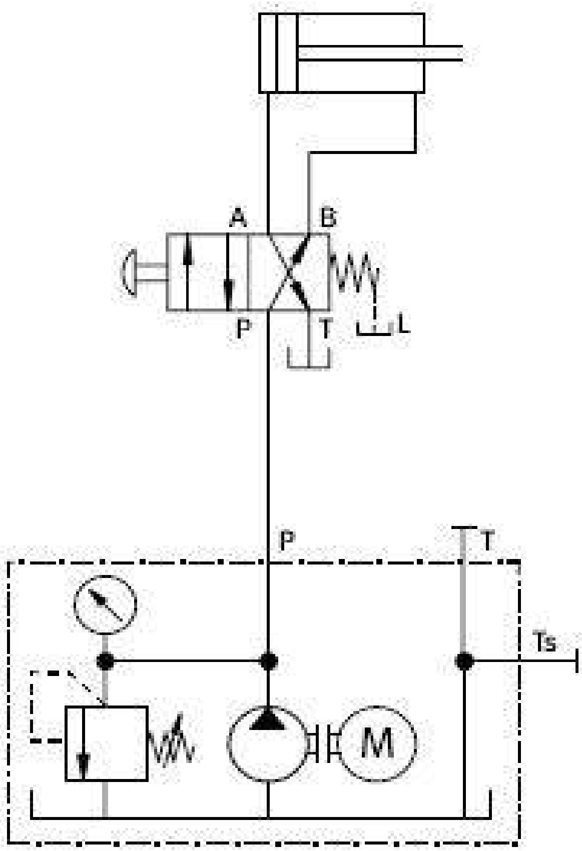
Representation of solenoid operated direction control valve

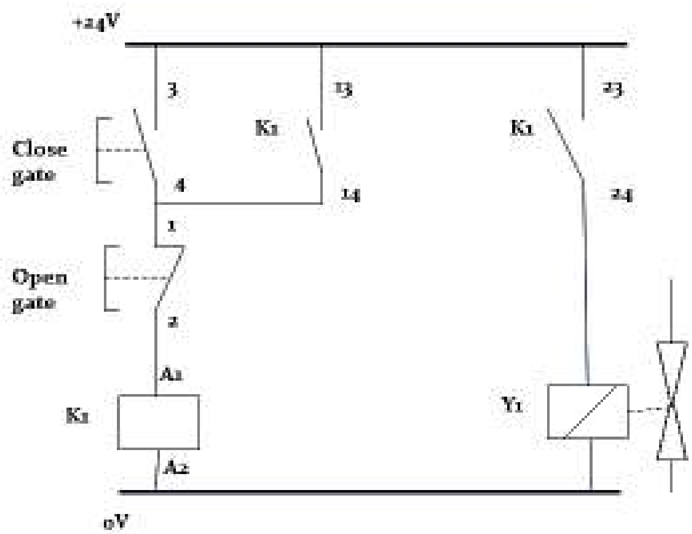


Electrical control circuit illustration



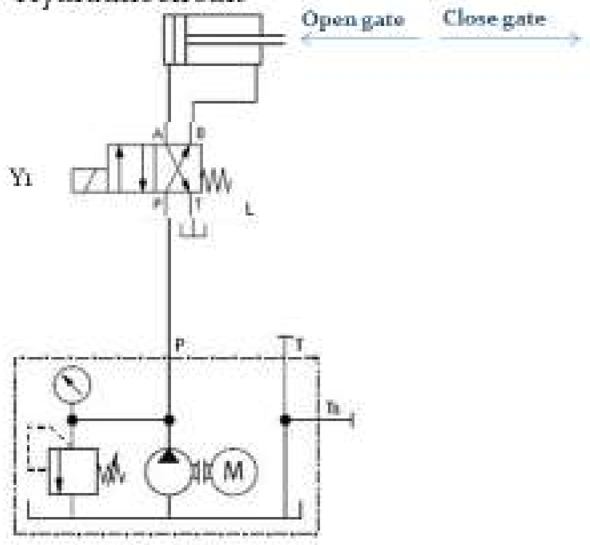
Electro hydraulic circuit for operating a hydropower gate for water intake canal


A
B
P
T
L
P
T
Ts
M

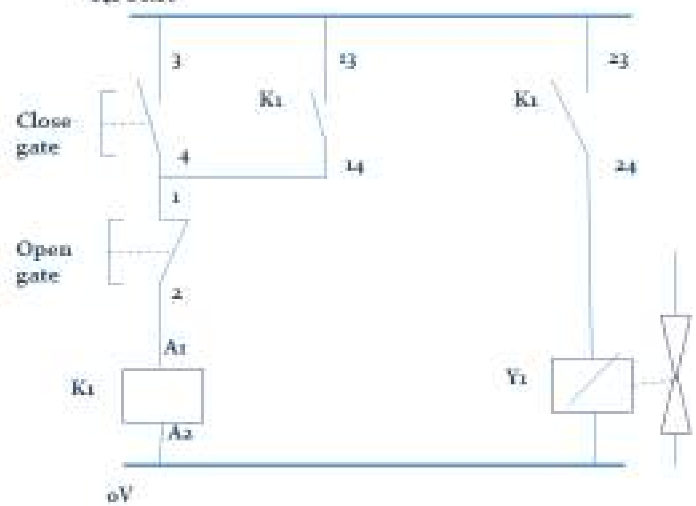

+24V
3
13
23
Close gate
K1
K1
4
14
24
1
Open gate
2
A1
K1
Y1
A2
0V

Exercise: Reproduce and simulate the provided Electro hydraulic circuit for hydropower gate operation using the software and ascertain that the circuit will operate as intended.

- Hydraulic circuit



- Electrical control circuit



Mechanical Hydraulic servo systems

System

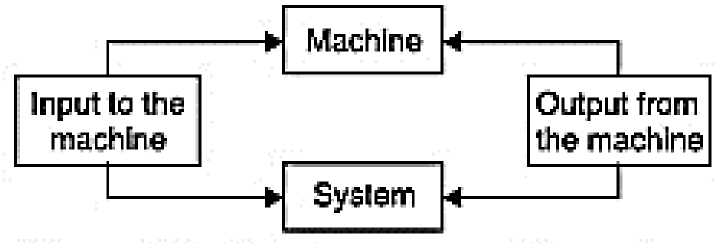
Any working machine can be referred to as a system. The system will have an input and an output. The illustrated system is said to be an open-loop system.

Generally, an operator keeps looking at the output and if necessary, controls or adjusts the machine input so that the output as required can be maintained. Another example of an open-loop system with operator providing the control as a feedback to the input side is that of driving a vehicle. Depending on the traffic, the operator changes the input to the vehicle so that the output of the vehicle such as the speed and the direction change accordingly.

Generally in an open-loop system, the output such as the position, the speed, the pressure, the force or the torque is measured and the operator checks the same with what is needed and accordingly adjusts the input, so that any deviation observed in the measured output is corrected by effecting a change in the input.

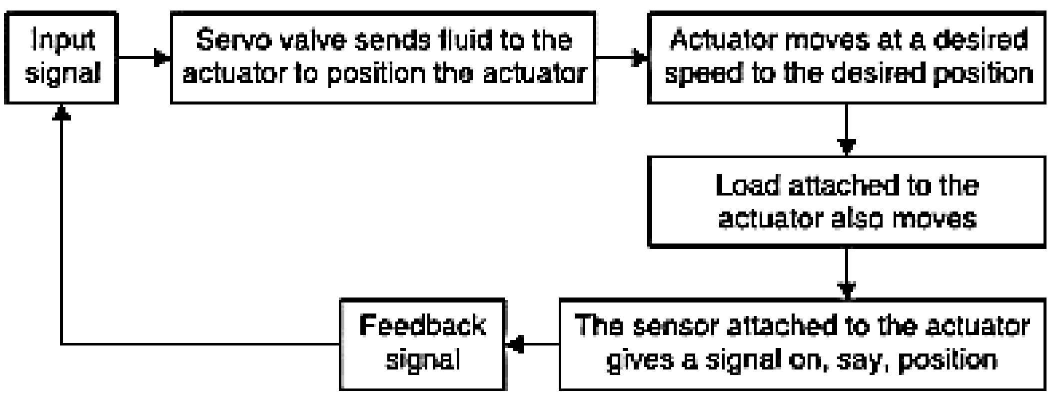
In a closed-loop system the human operator is replaced by the electronic hardware. Many of us are aware that a modern control system include features such as safety against overload, horsepower limiting, over tilt, emergency shutdown, etc. In a simple closed-loop system, the output quantity is measured (say, pressure, position, speed, torque, etc.). It is then compared with the desired specifications of the input and the error (i.e. the difference between the input and the output) is taken as a feedback to the input side. Corresponding to this error the input is changed, so that the error in the output is minimized. For accurate functioning of a closed-loop system, we require a servo system, valves, actuators, pumps, etc. as the hardware components.

Open loop man-machine system



Closed-Loop Control with Servo System In the system

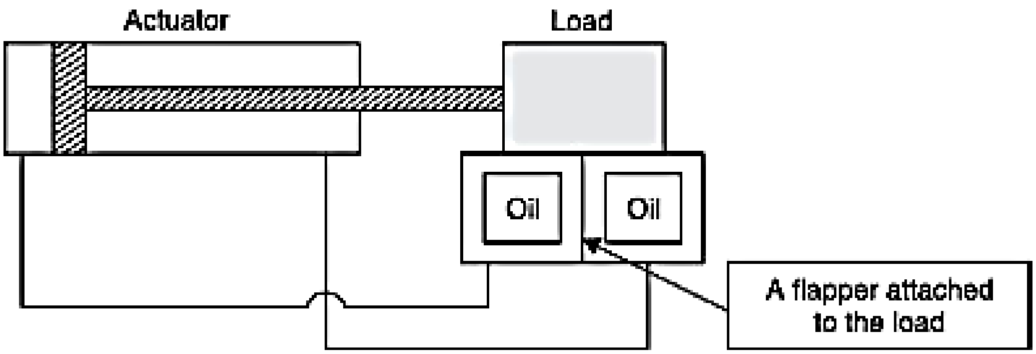
The term servo itself indicates that the valve is capable of receiving a feedback and depending on the set input it can adjust itself, so that the desired output is maintained.



Hydro

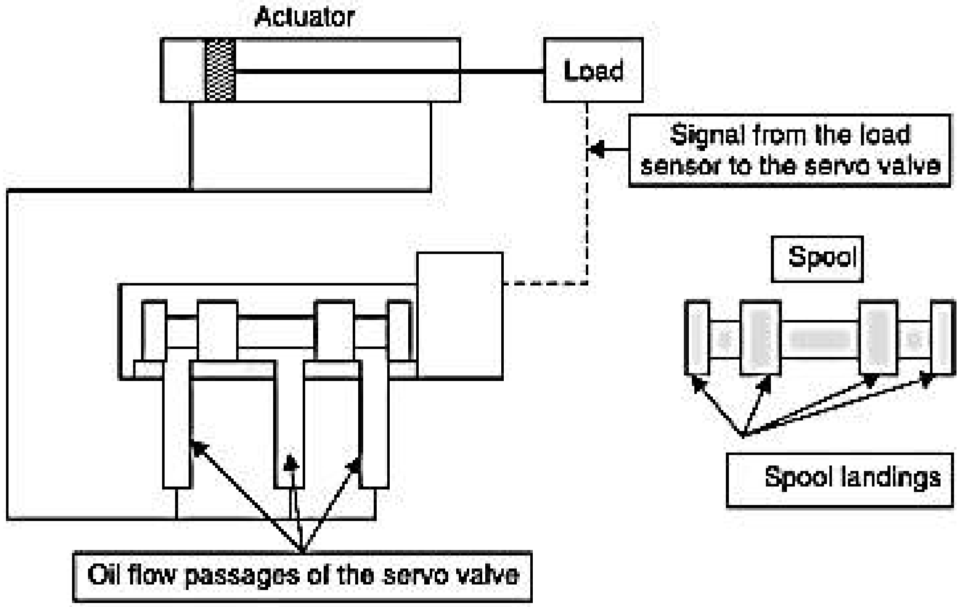
Mechanical Servo System

The concept of a hydromechanical servo system can be understood by the following example. In this example the output of the hydraulic actuator is mechanically linked to the movement of a flapper that displaces fluid (oil) to the actuator and a correction in terms of positioning of the load takes place. That is, the feedback from the output is given to the actuator. In case the load moves to the left from the designated spot, the flapper attached to the load also moves to the left displacing oil and sending the oil to the left (piston side) of the actuator and the actuator moves to the right to correct the output location of the load. The reverse action takes place if the load moves to the right, then, in that case the flapper also moves to the right and the oil is displaced and sent to the rod side of the actuator, and the actuator moves to the left to correct the error. However, the concept explained above is meant to only illustrate as to how a hydromechanical system can work. In practice the flapper is replaced by a proper sizing of the mechanical servo valve with a spool, cylinder, load connections, etc.



Electro Hydraulic Servo Valve System

In an electrohydraulic servo valve, it is the servo valve with a torque motor that receives the signal from the output and correspondingly adjusts the passage restriction to control the flow of oil to the actuator, thereby correcting the actuator position or speed. The signal from a sensor attached to the actuator or the load is taken to the torque motor of the servo valve. The torque motor actually operates the spool of the servo valve. The servo valve then moves the spool in such a way that the passage of the oil to the actuator is altered. It is to be noted that as the spool moves the landing width of the spool either clears the passage of the oil flow or obstructs it partially/ proportionately or fully depending on the signal received. Accordingly, the flow of fluid (oil) to the actuator is controlled and consequently the position of the load.



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Module 6: Pneumatic Systems

Lecture 1

Pneumatic system

Pneumatic technology deals with the study of behavior and applications of compressed air in our daily life in general and manufacturing automation in particular. Pneumatic systems use air as the medium which is abundantly available and can be exhausted into the atmosphere after completion of the assigned task.

1. Basic Components of Pneumatic System:

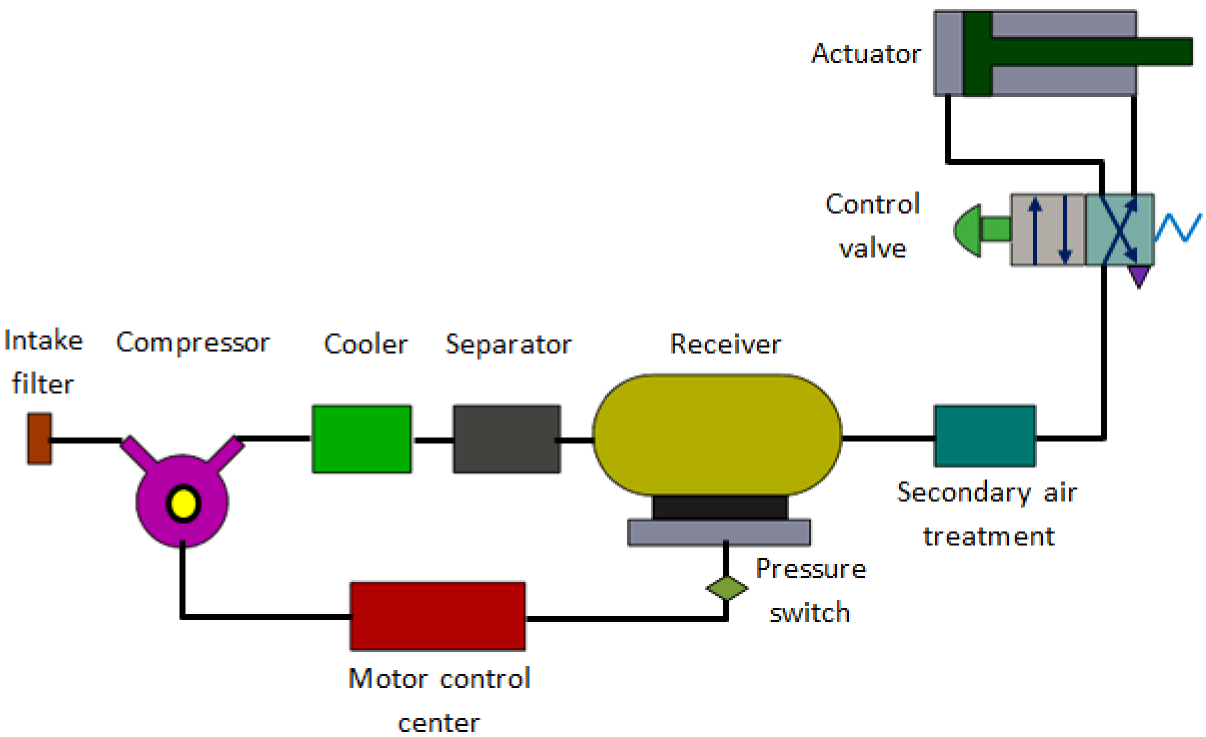


Fig. 6.1.1 Components of a pneumatic system

Important components of a pneumatic system are shown in fig.6.1.1.

a) **Air filters:** These are used to filter out the contaminants from the air.
b) **Compressor:** Compressed air is generated by using air compressors. Air compressors are either diesel or electrically operated. Based on the requirement of compressed air, suitable capacity compressors may be used.
c) **Air cooler:** During compression operation, air temperature increases. Therefore coolers are used to reduce the temperature of the compressed air.
d) **Dryer:** The water vapor or moisture in the air is separated from the air by using a dryer.
e) **Control Valves:** Control valves are used to regulate, control and monitor for control of direction flow, pressure etc.
f) **Air Actuator:** Air cylinders and motors are used to obtain the required movements of mechanical elements of pneumatic system.

g) **Electric Motor:** Transforms electrical energy into mechanical energy. It is used to drive the compressor.
h) **Receiver tank***:* The compressed air coming from the compressor is stored in the air receiver.

These components of the pneumatic system are explained in detail on the next pages.

2. Receiver tank

The air is compressed slowly in the compressor. But since the pneumatic system needs continuous supply of air, this compressed air has to be stored. The compressed air is stored in an air receiver as shown in Figure 6.1.2. The air receiver smoothens the pulsating flow from the compressor. It also helps the air to cool and condense the moisture present. The air receiver should be large enough to hold all the air delivered by the compressor. The pressure in the receiver is held higher than the system operating pressure to compensate pressure loss in the pipes. Also the large surface area of the receiver helps in dissipating the heat from the compressed air. Generally the size of receiver depends on,

- Delivery volume of compressor.
- Air consumption.
- Pipeline network
- Type and nature of on-off regulation
- Permissible pressure difference in the pipelines

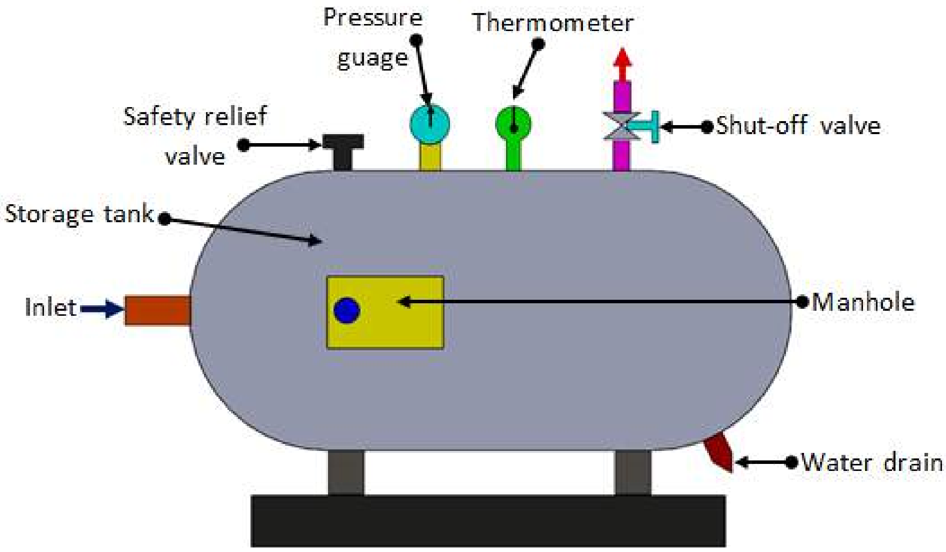


Fig.6.1.2 Air receiver

3. *Compressor:*

It is a mechanical device which converts mechanical energy into fluid energy. The compressor increases the air pressure by reducing its volume which also increases the temperature of the compressed air. The compressor is selected based on the pressure it needs to operate and the delivery volume.

The compressor can be classified into two main types

a. Positive displacement compressors and
b. Dynamic displacement compressor

Positive displacement compressors include piston type, vane type, diaphragm type and screw type.

3.1 Piston compressors

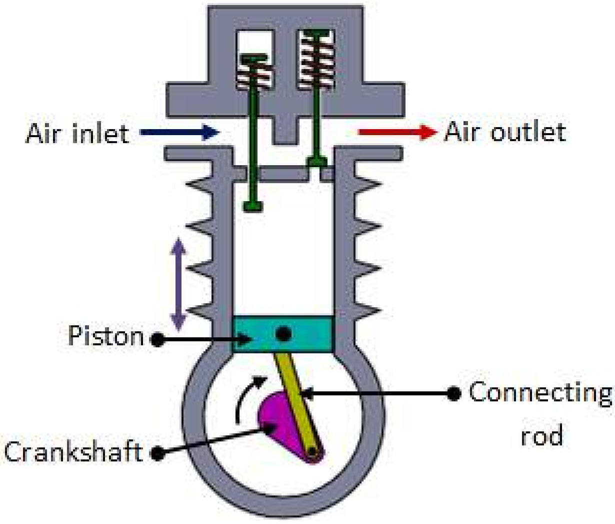


Fig. 6.1.3 Single acting piston compressor

Piston compressors are commonly used in pneumatic systems. The simplest form is single cylinder compressor (Fig. 6.1.3). It produces one pulse of air per piston stroke. As the piston moves down during the inlet stroke the inlet valve opens and air is drawn into the cylinder. As the piston moves up the inlet valve closes and the exhaust valve opens which allows the air to be expelled. The valves are spring loaded. The single cylinder compressor gives significant amount of pressure pulses at the outlet port. The pressure developed is about 3-40 bar.

3.2 Double acting compressor

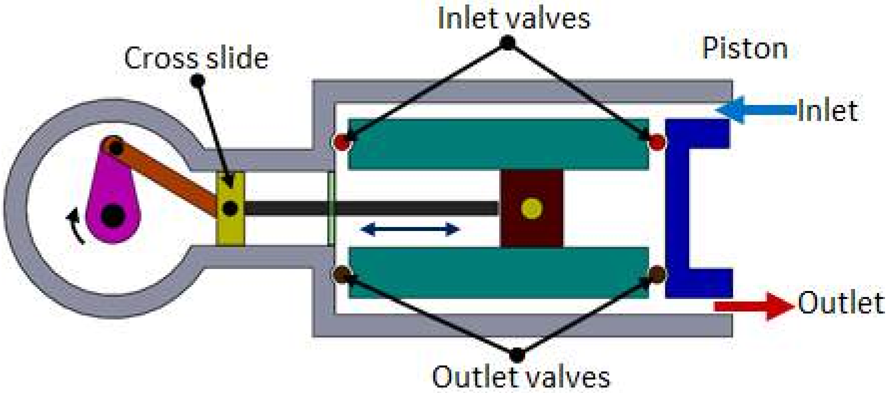


Fig. 6.1.4 Double acting piston compressor

The pulsation of air can be reduced by using double acting compressor as shown in Figure 6.1.4. It has two sets of valves and a crosshead. As the piston moves, the air is compressed on one side whilst on the other side of the piston, the air is sucked in. Due to the reciprocating action of the piston, the air is compressed and delivered twice in one piston stroke. Pressure higher than 30bar can be produced.

3.3 Multistage compressor

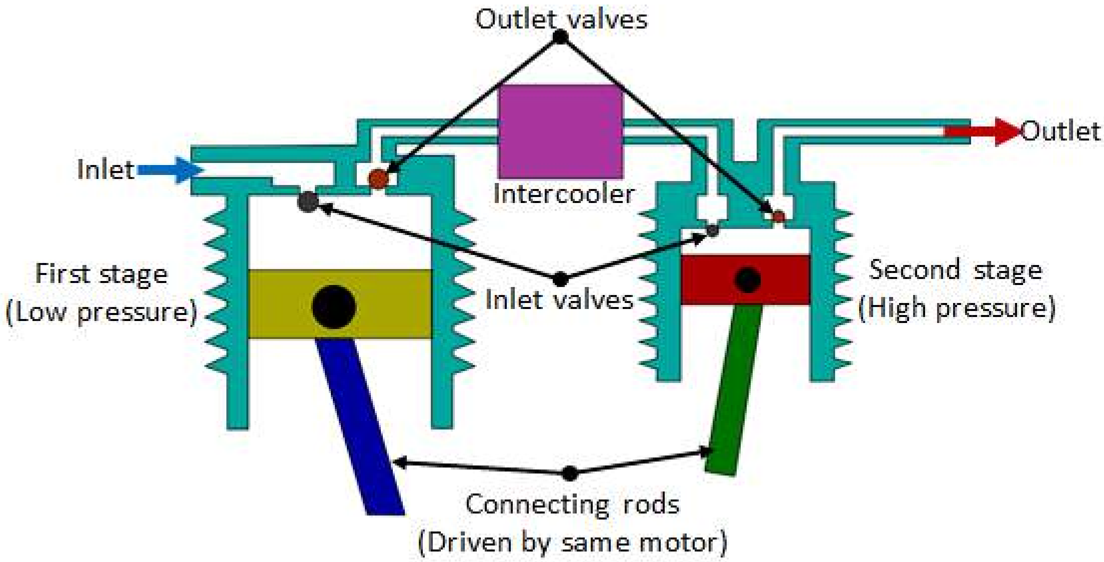


Fig. 6.1.5 Multi-stage compressor

As the pressure of the air increases, its temperature rises. It is essential to reduce the air temperature to avoid damage of compressor and other mechanical elements. The multistage compressor with intercooler in-between is shown in Figure 6.1.5. It is used to reduce the temperature of compressed air during the compression stages. The inter-cooling reduces the volume of air which used to increase due to heat. The compressed air from the first stage enters the intercooler where it is cooled. This air is given as input to the second stage where it is compressed again. The multistage compressor can develop a pressure of around 50bar.

3.4 Combined two stage compressors

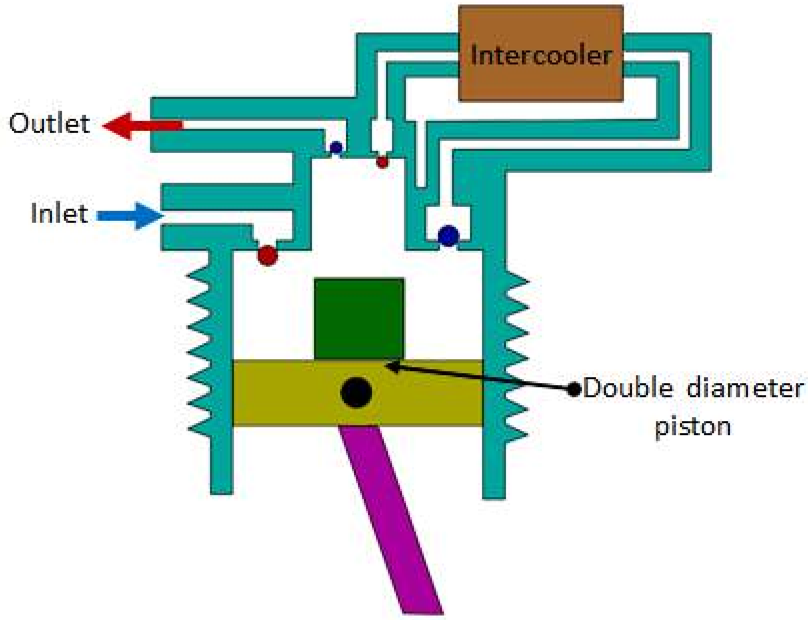


Fig. 6.1.6 Combined to stage compressor

In this type, two-stage compression is carried out by using the same piston (Fig. 6.1.6). Initially when the piston moves down, air is sucked in through the inlet valve. During the compression process, the air moves out of the exhaust valve into the intercooler. As the piston moves further the stepped head provided on the piston moves into the cavity thus causing the compression of air. Then, this is let out by the exhaust port.

1.2 Cooler

As the air is compressed, the temperature of the air increases. Therefore the air needs to be cooled. This is done by using a cooler. It is a type of heat exchanger. There are two types of coolers commonly employed viz. air cooled and water cooled. In the air cooled type, ambient air is used to cool the high temperature compressed air, whereas in the water cooled type, water is used as cooling medium. These are counter flow type coolers where the cooling medium flows in the direction opposite to the compressed air. During cooling, the water vapor present will condense which can be drained away later.

2. Main line filter

These filters are used to remove the water vapors or solid contaminants present in the pneumatic systems main lines. These filters are discussed in detail as follows.

2.1 Air filter and water trap

Air filter and water trap is used to

- prevent any solid contaminants from entering in the system.
- condense and remove water vapor that is present in the compressed air.

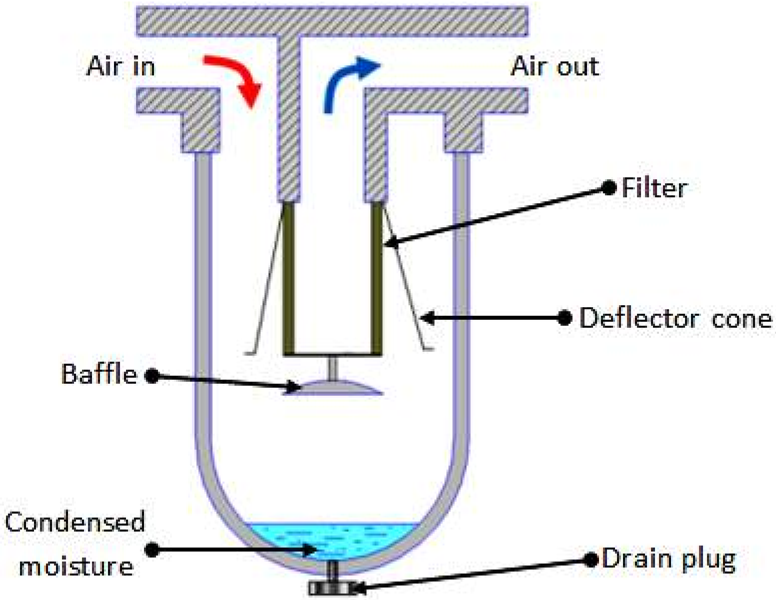


Fig. 6.3.2 Air filter and water trap

The filter cartridge is made of sintered brass. The schematic of the filter is shown in Fig. 6.3.2. The thickness of sintered cartridge provides random zigzag passage for the air to flow-in which helps in arresting the solid particles. The air entering the filter swirls around due to the deflector cone. The centrifugal action causes the large contaminants and water vapor to be flung out, which hit the glass bowl and get collected at the bottom. A baffle plate is provided to prevent the turbulent air from splashing the water into the filter cartridge. At the bottom of the filter bowl there is a drain plug which can be opened manually to drain off the settled water and solid particles.

3. *Lubricators*

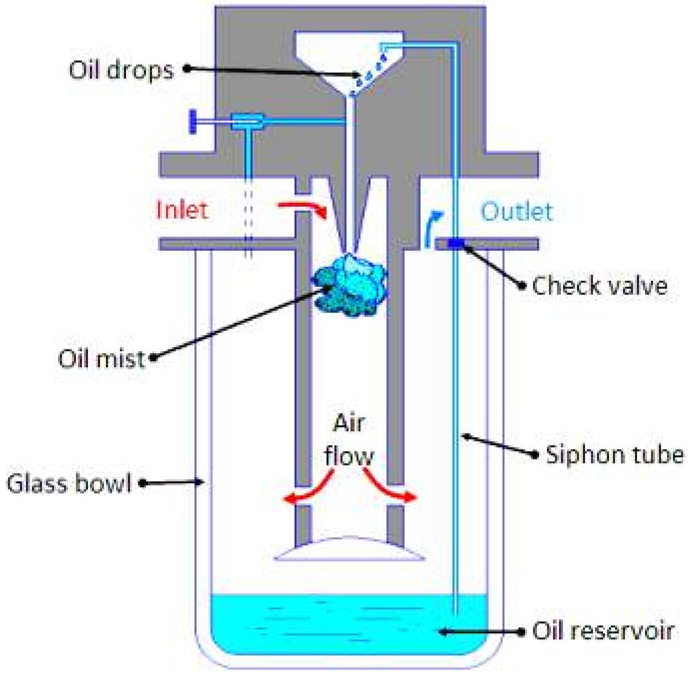


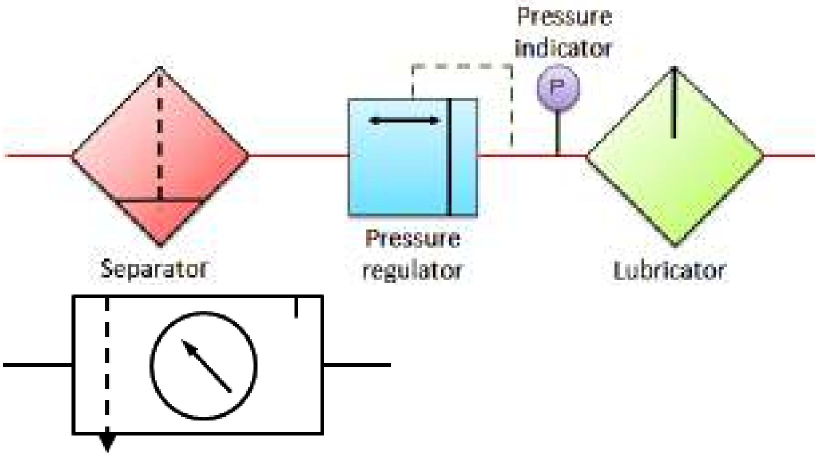
Fig. 6.3.6 Air lubricator

The compressed air is first filtered and then passed through a lubricator in order to form a mist of oil and air to provide lubrication to the mating components. Figure 6.3.6 shows the schematic of a typical lubricator. The principle of working of venturimeter is followed in the operation of lubricator. The compressed air from the dryer enters in the lubricator. Its velocity increases due to a pressure differential between the upper and lower changer (oil reservoir). Due to the low pressure in the upper chamber the oil is pushed into the upper chamber from the oil reservoir through a siphon tube with check valve. The main function of the valve is to control the amount of oil passing through it. The oil drops inside the throttled zone where the velocity of air is much higher and this high velocity air breaks the oil drops into tiny particles. Thus a mist of air and oil is generated. The pressure differential across chambers is adjusted by a needle valve. It is difficult to hold an oil mixed air in the air receiver as oil may settle down. Thus air is lubricated during secondary air treatment process. Low viscosity oil forms better mist than high viscosity oil and hence ensures that oil is always present in the air.

7. *Service units*

During the preparation of compressed air, various processes such as filtration, regulation and lubrication are carried out by individual components. The individual components are: separator/filter, pressure regulator and lubricator.

Preparatory functions can be combined into one unit which is called as 'service unit'. Figure 6.3.10 shows symbolic representation of various processes involved in air preparation and the service unit.



(a) (b)

Fig. 6.3.10 (a) Service unit components (b) Service unit symbol

Module 6: Pneumatic Systems

Lecture 4
Actuators

Actuators are output devices which convert energy from pressurized hydraulic oil or compressed air into the required type of action or motion. In general, hydraulic or pneumatic systems are used for gripping and/or moving operations in industry. These operations are carried out by using actuators.

Actuators can be classified into three types.

1. Linear actuators: These devices convert hydraulic/pneumatic energy into linear motion.
2. Rotary actuators: These devices convert hydraulic/pneumatic energy into rotary motion.
3. Actuators to operate flow control valves: these are used to control the flow and pressure of fluids such as gases, steam or liquid.

The construction of hydraulic and pneumatic linear actuators is similar. However they differ at their operating pressure ranges. Typical pressure of hydraulic cylinders is about 100 bar and of pneumatic system is around 10 bar.

1. Single acting cylinder

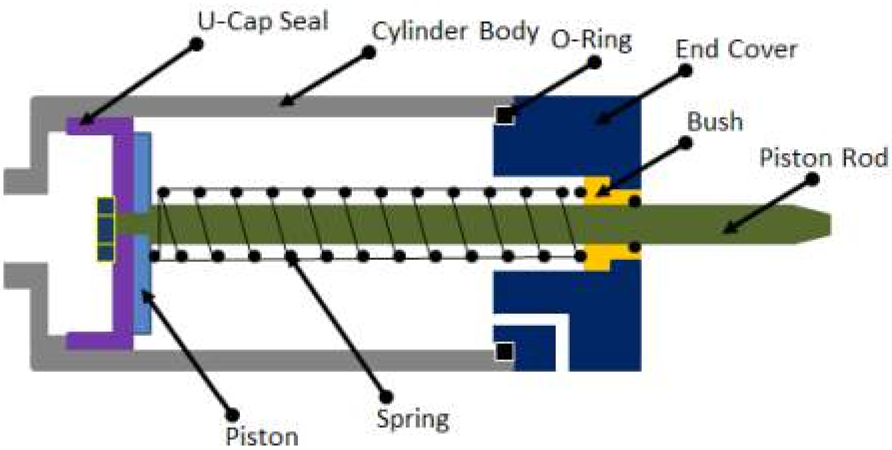


Fig. 6.4.1 Single acting cylinder

These cylinders produce work in one direction of motion hence they are named as single acting cylinders. Figure 6.4.1 shows the construction of a single acting cylinder. The compressed air pushes the piston located in the cylindrical barrel causing the desired motion. The return stroke takes place by the action of a spring. Generally the spring is provided on the rod side of the cylinder.

2. Double acting cylinder

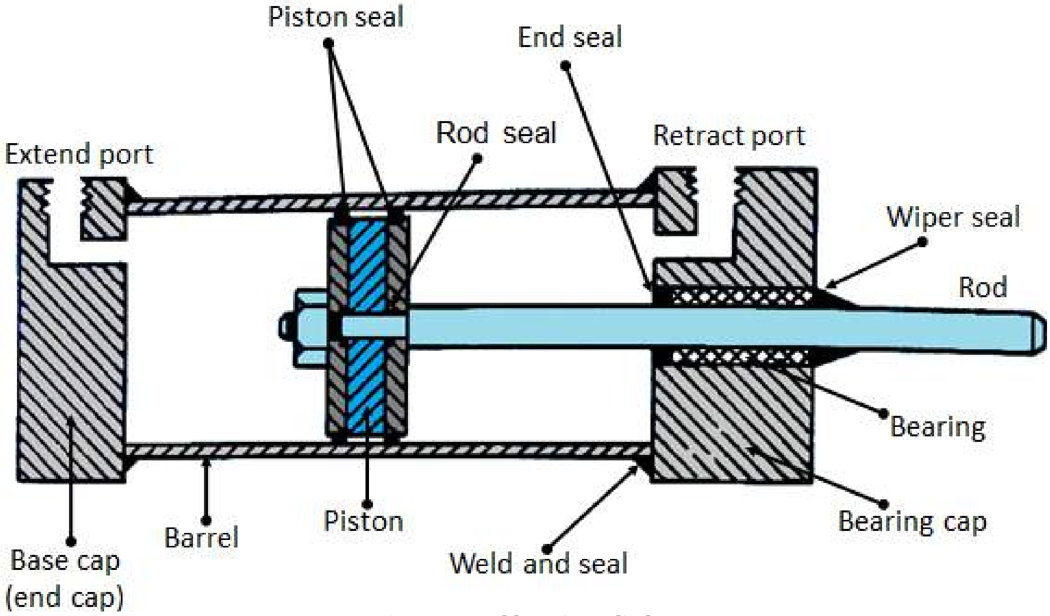


Fig. 6.4.2 Double acting cylinder

The main parts of a hydraulic double acting cylinder are: piston, piston rod, cylinder tube, and end caps. These are shown in Figure 6.4.2. The piston rod is connected to piston head and the other end extends out of the cylinder. The piston divides the cylinder into two chambers namely the rod end side and piston end side. The seals prevent the leakage of oil between these two chambers. The cylindrical tube is fitted with end caps. The pressurized oil, air enters the cylinder chamber through the ports provided. In the rod end cover plate, a wiper seal is provided to prevent the leakage of oil and entry of the contaminants into the cylinder. The combination of wiper seal, bearing and sealing ring is called as cartridge assembly. The end caps may be attached to the tube by threaded connection, welded connection or tie rod connection. The piston seal prevents metal to metal contact and wear of piston head and the tube. These seals are replaceable. End cushioning is also provided to prevent the impact with end caps.

3. Cylinder end cushions

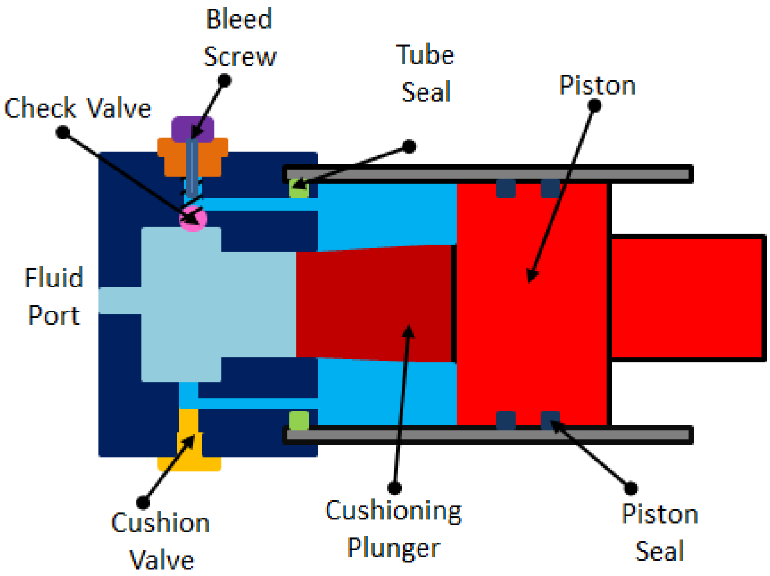


Fig. 6.4.3 Cylinder end cushioning

Double acting cylinders generally contain cylinder cushions at the end of the cylinder to slow down the movement of the piston near the end of the stroke. Figure 6.4.3 shows the construction of actuating cylinder with end cushions. Cushioning arrangement avoids the damage due to the impact occurred when a fast moving piston is stopped by the end caps. Deceleration of the piston starts when the tapered plunger enters the opening in the cap and closes the main fluid exit. This restricts the exhaust flow from the barrel to the port. This throttling causes the initial speed reduction. During the last portion of the stroke the oil has to exhaust through an adjustable opening since main fluid exit closes. Thus the remaining fluid exists through the cushioning valve. Amount of cushioning can be adjusted by means of cushion screw. A check valve is provided to achieve fast break away from the end position during retraction motion. A bleed screw is built into the check valve to remove the air bubbles present in a hydraulic type system.

4. Gear motor: a rotary actuator

Rotary actuators convert energy of pressurized fluid into rotary motion. Rotary actuators are similar to electric motors but are run on hydraulic or pneumatic power.

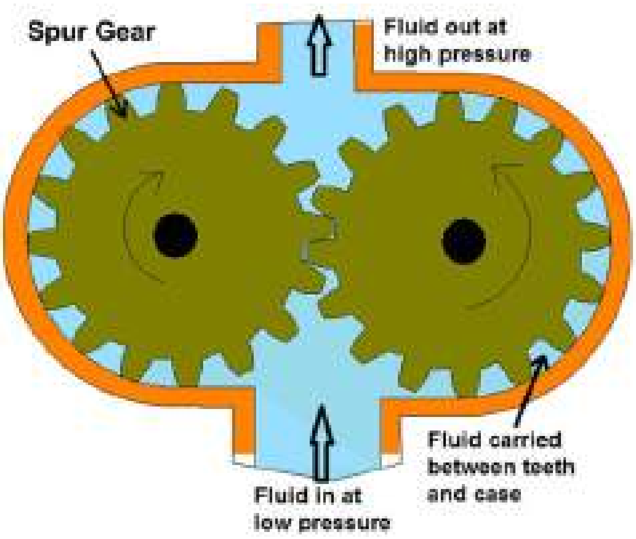


Fig. 6.4.4 Gear motor

It consists of two inter meshing gears inside a housing with one gear attached to the drive shaft. Figure 6.4.4 shows a schematic diagram of Gear motor. The air enters from the inlet, causes the rotation of the meshing gear due to difference in the pressure and produces the torque. The air exists from the exhaust port. Gear motors tend to leak at low speed, hence are generally used for medium speed applications.

5. Vane motor: a rotary actuator

A rotary vane motor consists of a rotor with sliding vanes in the slots provided on the rotor (Fig. 6.4.5). The rotor is placed eccentrically with the housing. Air enters from the inlet port, rotates the rotor and thus torque is produced. Air is then released from the exhaust port (outlet).

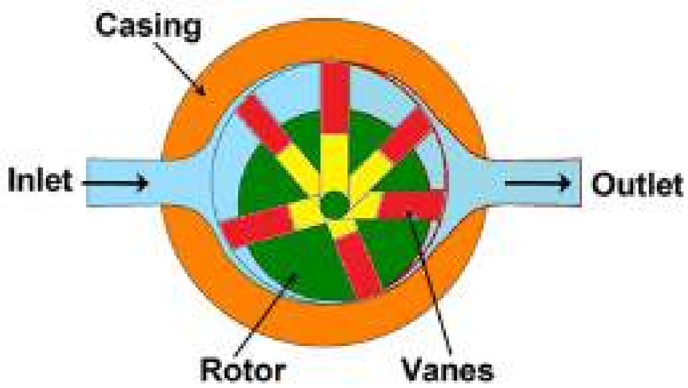


Fig. 6.4.5 Vane motor

Lecture 38

PNEUMATIC CONTROL VLAVES

Learning Objectives

Upon completion of this chapter, Student should be able to

- Define the function of a valve
- Classify the valves
- Identify the DCVs as per ISO designation
- Explain the various types of Directional control valves
- Explain the various method of valve actuation
- Describe the function of various Non return valves
- Understand the working of quick exhaust valves
- Differentiate pressure control valve and sequence valve

1.1 VALVES

Valve are defined as devices to control or regulate the commencement, termination and direction and also the pressure or rate of flow of a fluid under pressure which is delivered by a compressor or vacuum pump or is stored in a vessel.

Values of one sort or another, perform three main function in pneumatic installation

- They control the supply of air to power units, example cylinders
- They provide signal which govern the sequence of operation
- They act as interlock and safety devices

The type of valve used is of little importance in a pneumatic control for most part. What is important is the function that can be initiated with the valves, its mode of actuation and line connection size, the last named characteristics also determining the flow size of the valve. Valves used in pneumatics mainly have a control function that is when they act on some process, operation or quantity to be stopped. A control function requires control energy, it being desirable to achieve the greatest possible effect with the least effort. The form of control energy will be dictated by the valve's mode of actuation and may be manual, mechanical, electrical hydraulic or pneumatic.

Valve available for pneumatic control can be classified into four principal groups according to their function:

1. Direction control valve
2. Non return valves
3. Flow control valves
4. Pressure control valves

1.2 DIRECTION CONTROL VALVES

Pneumatic systems like hydraulic system also require control valves to direct and regulate the flow of fluid from the compressor to the various devices like air actuators and air motors. In order to control the movement of air actuators, compressed air has to be regulated, controlled and reversed with a predetermined sequence. Pressure and flow rates of the compressed air to be controlled to obtain the desired level of force and speed of air actuators.

The function of directional control valve is to control the direction of flow in the pneumatic circuit. DCVs are used to start, stop and regulate the direction of air flow and to help in the distribution of air in the required line.

6.2.1 TYPES OF DIRECTION CONTROL VALVES

Directional valves control the way the air passes and are used principally for controlling commencement, termination and direction of air flow. The different classification scheme of the pneumatic cylinders are given below

1. Based on construction

    i) Poppet or seat valves

    - Ball seat valve
    - Disc seat valve
    - Diaphragm Valves

    ii) Sliding spool valves

    - Longitudinal slide valve
    - Suspended spool valves
    - Rotary spool valves

2. Based on the Number of ports

i) Two way valves

ii) Three way valves

iii) Four way valves

3. Based on methods of actuation

i) Mechanical

ii) Electrical

iii) Pneumatic

4. Based on Size of the port

Size refers to a valve's port size. The port sizes are designated as M5, G1/8, and G1/4 etc. M refer to Metric thread, G refer to British standard pipe (BSP) thread.

5. Based on mounting styles

i) Sub base

ii) Manifold

iii) In-line

iv) Valve island

6.2.1.1 ISO DESIGNATION OF DIRECTION CONTROL VALVES

Valves are represented by symbols because actual construction is quite complex. A symbol specifies function of the valve, method of actuation, no of ports and ways. Pneumatic symbols have been standardised in ISO 1219-1:2006. (Fluid power systems and components – Graphic symbols and circuit diagram). Another standard ISO 1219-2:1995 establishes the rules for drawing diagrams of fluid power systems using symbols from ISO 1219-1. Port designations are described in ISO 5599.

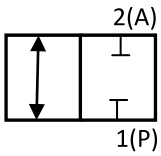
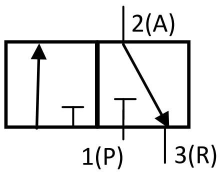
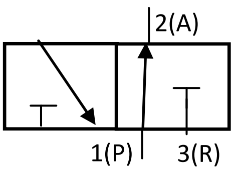
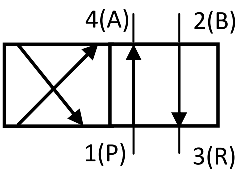
Port markings: As per the ISO 5599, ports are designated using a number system. Earlier, a letter system was used to designate a port. Table 1.1 gives port markings.

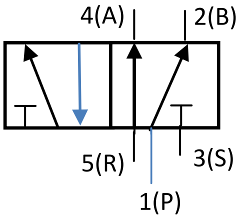
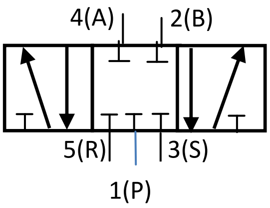
Port	Old (Letter) system	ISO (Number) System	Remarks
Pressure port	P	1	Supply port
Working port	A	2	3/2 DCV
Working ports	A, B	4, 2	4/2 or 5/2 DCV
Exhaust port	R	3	3/2 DCV
Exhaust ports	R, S	5,3	%/2 DCV
Pilot ports	Z or Y	12	Pilot line (flow 1-2)
Pilot ports	Z	14	Pilot line (flow 1-4)
Pilot ports	Z or Y	10	Pilot line (no flow)
Internal pilot ports	Pz, Py	81, 91	Auxiliary pilot line

Table 1.1: Port Markings of Direction Control Valve

Ports and position: DCVs are described by the number of port connections or ways they control. For example: Two way, three – way, four way valves. Table 1 shows the Port markings of DCVs and Table 1.2 shows commonly used DCVs with old and new designations.

Table 1.2: Port designation of DCV

Port and position	
	2/2 Directional control valve Port Positionn
	3/2 Directional control valve (normally closed)
	3/2 Directional control valve (normally open)
	4/2 Directional control valve

	5/2 Directional control valve
	5/3 Directional control valve

1.2.1.2 POPPET DIRECTION CONTROL VALVES

There are two different types of poppet valves, namely ball seat valve and disc seat valve.

A.Ball seat valve.

In a poppet valve, discs, cones or balls are used to control flow. Figure 1.1 shows the construction of a simple 2/2 normally closed valve. If the push button is pressed, ball will lift off from its seat and allows the air to flow from port P to port B. When the push button is released, spring force and air pressure keeps the ball back and closes air flow from port P to port B. Valve position are shown in Figure 1.1(a) 1.1 (b)   1.1(C)

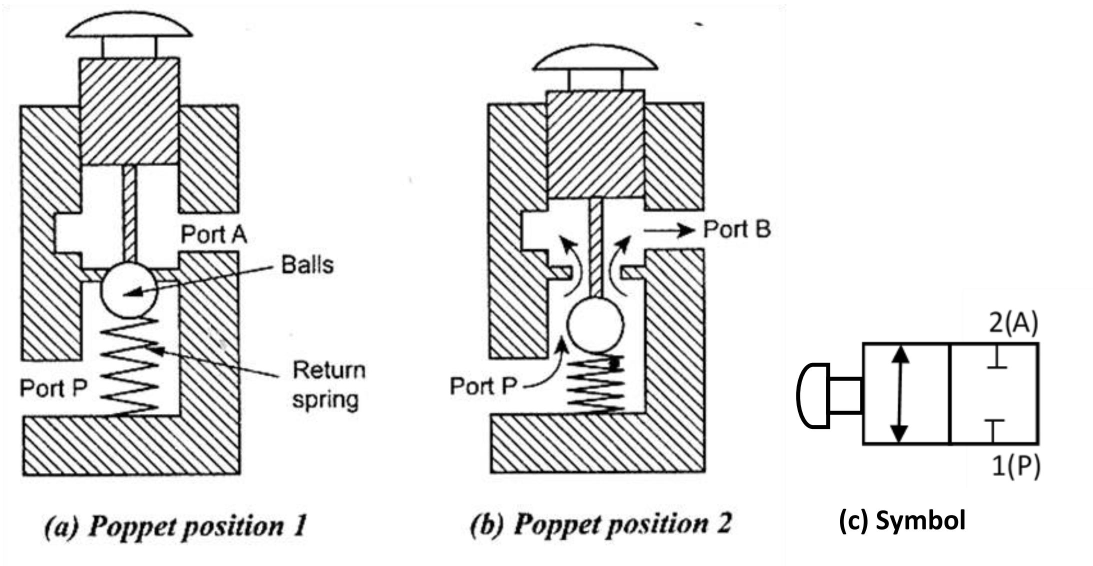


Figure 1.1 Two/Two Ball seat Poppet valve

B. Disc seat poppet valve

Figure 1.2 shows the construction of a disc type 3/2 way DCV. When push button is released, ports 1 and 3 are connected via hollow pushbutton stem. If the push button is pressed, port 3 is first blocked by the moving valve stem and then valve disc is pushed down so as to open the valve thus connecting port 1 and 3. When the push button is released, spring and air pressure from port 1 closes the valve.. Comparison between Ball seat and disc seat valve is given in Table 1.3

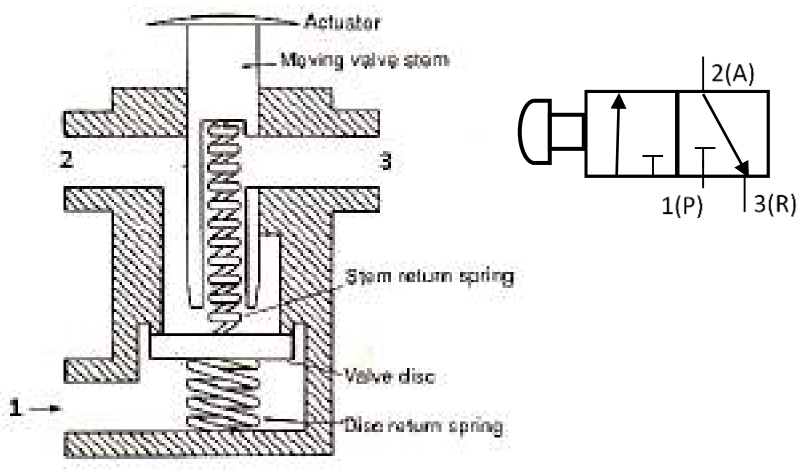


Figure 1.2 Disc seat poppet valve

Advantages of poppet valves are as follows

i) Response of poppet valve is very fast- short stroke to provide maximum flow opening
ii) They give larger opening (larger flow) of valves for a small stroke
iii) The valve seats are usually simple elastic seals so wear is minimum
iv) They are insensitive to dust and dirt and they are robust, seats are self cleaning
v) Maintenance is easy and economical.
vi) They are inexpensive
vii) They give longer service life: short stroke and few wearing parts give minimum wear and maximum life capabilities

Disadvantages of poppet valves are as follows

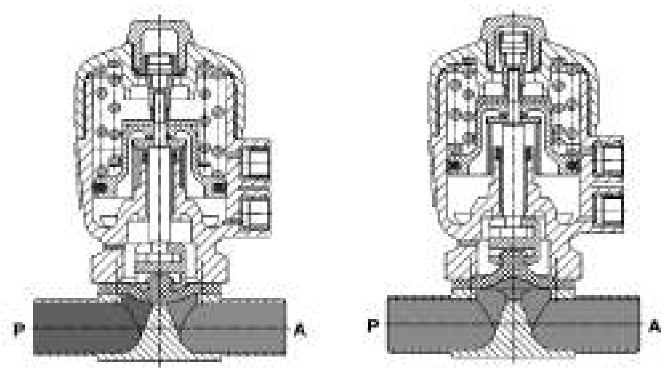
i) The actuating force is relatively high, as it is necessary to overcome the force of the built in reset spring and the air pressure.
ii) They are noisy if flow fluctuation is large.

Table 1.3 Comparison of Ball seat and Disc seat valves

Ball seat valves	***Disc seat valve***
They are inexpensive	Offer large area and lift required is very small
They are relatively small in size	Time response is good
Insensitive to dirt and dust	Insensitive to dirt and dust
Can be operated manually or mechanically	Can be actuated manually , mechanically, electrically or pneumatically

C.Diaphragm valves

The diaphragm between the actuator and valve body hermetically isolates the fluid from the actuator. The valves are maintenance-free and extremely robust and can be retrofitted with a comprehensive range of accessories, e.g. electrical position feedback, stroke limitation or manual override. **Figure 1.4** shows unactuated and actuated position of diaphragm valves.



a) Unactuated b) actuated

Figure 1.4 Diaphragm valve: unactuated position, actuated position

Closed position: When de-energized, the valve is closed by spring action

Open position: If the actuator is pressurized by the control pressure, it simultaneously lifts the control piston and the valve spindle to open the valve.

6.2.1.3 SPOOL DIRECTION CONTROL VALVES

A. Hand operated 3/2 DCV

The cross sectional views of 3/2 DCV (normally closed) based on spool design is shown below. When the valve is not actuated, port 2 and 3 are connected and port 1 is blocked. When the valve is actuated then port 2 and 1 are connected and port 3 is blocked.

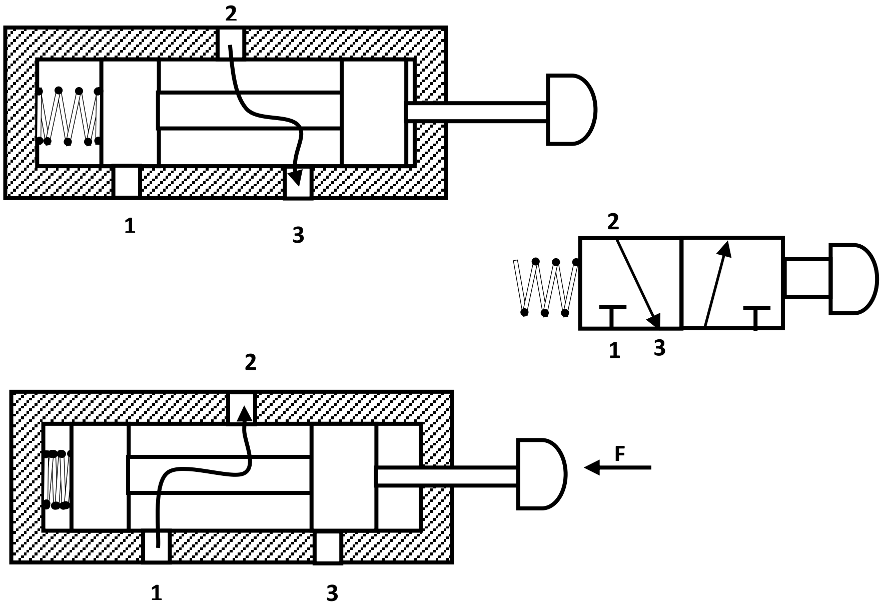


Figure 1.5 3/2 Directional control valve (Normally closed)

Figure 1.5 shows schematic diagram of 3/2 spring operated valve. There are three ports common port, normally open port and normally closed. When the valve is not actuated, there is flow from NO port to common port. When the valve is actuated there is flow from NC to common port.

B.Pneumatically actuated 3/2 DCV

The cross – sectional views of pneumatically actuated NC type 3/2 DCV in normal position and actuated positions are shown in the Figure 1.7

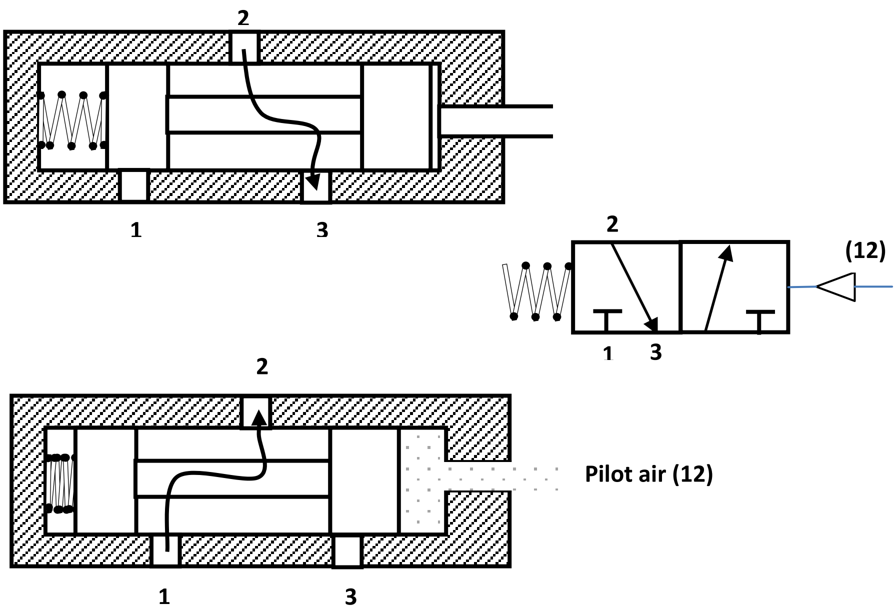


Figure 1.7 3/2 Directional control valve (pneumatically operated)

In normal position, the working port (2) is closed to the pressure port (1) and open to the exhaust port (3). When the compressed air is applied through the pilot port (12), the spool is moved against the spring. In the actuated position, the working port (2) is open to the pressure port(1) and closed to the exhaust port(3). Thus, the application of the compressed air to the port 12 causes the pressure port (1) to be connected to the working port (2).

Pneumatically actuated valves have following advantages

i. Great flexibility for use in simple as well as complex control system
ii. Adaptability for use in safety circuits.
iii. Various control functions can be easily incorporated as and when required
iv. Feedback signals from sensors can be applied conveniently for the purpose of controlling the pilot ports of these main valves. This means existing pneumatically actuated control circuits can be modified easily to incorporate any additional control requirement.

C.Pneumatically actuated 4/2 DCV

The valve shown in Figure 1.9 is a 4/2 way valve pneumatically operated DCV. Switch over is effected by direct application of pressure. If compressed air is applied to pilot spool through control port 12, it connects port 1 with 2 and 4 is exhausted through port 3. If the pilot pressure is applied to port 14, then 1 is connected with 4 and line 2 exhausted through port 3. On disconnecting the compressed air from the control line, the pilot spool remains in its current position until spool receives a signal from the other control side.

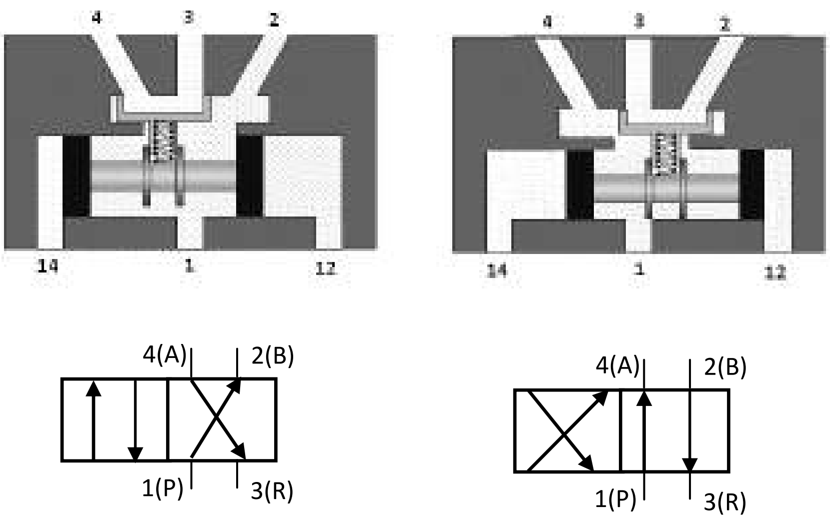


Figure 1.9 Schematic diagram of 4/2 way valve

D. Suspended Disc Direction Control Valves

This valve is quite similar to 4/2 way spool valve. Schematic diagram is shown in Figure 1.11. In this design disc is used instead of a spool. This suspended disc can be moved by pilot pressure or by solenoid or by mechanical means. In this design, main disc connects port 1 to either port 4 or 2. The secondary seat discs seal the exhaust port 3 whichever is not functional. These values are generally provided with manual override to manually move the cylinder.

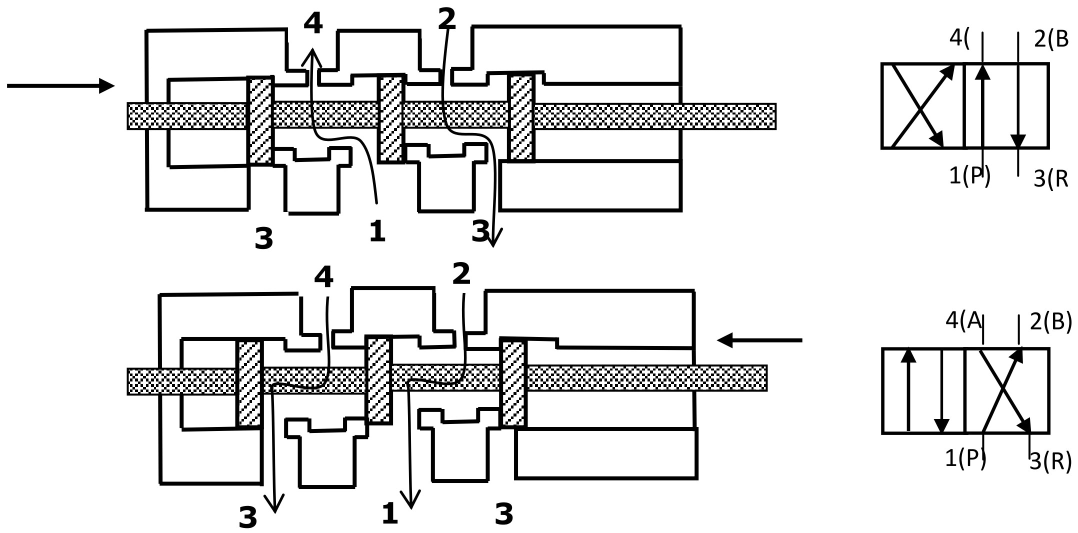


Figure 1.11 4/2 Directional control valve (suspended disc type)

Figure 1.12 below shows 5/2 way valve which uses suspended disk instead of spool. In spool type valve, spool controls the opening and closing of ports. In this type, suspended disc controls the opening and closing of ports. This suspended disc can be moved by pilot pressure at port 14 or port 12. When the pilot pressure acts through port 14. The ports 1 - 2 and 4 - 5 are connected and 3 is blocked. When the air is given to pilot line 12, then 2 - 3 and 4 -1 are connected and 5 is blocked

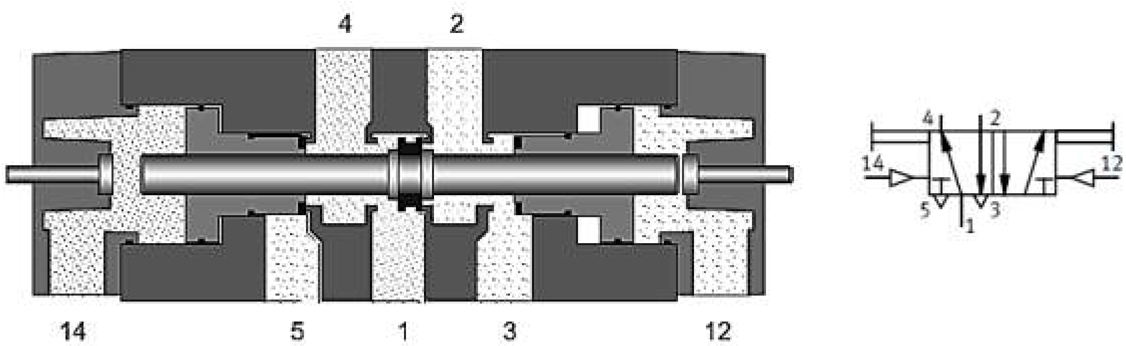


Figure 1.12 5/2 Directional control valve (suspended disc type)

Advantages

i) They have short actuation movement

ii) They are quick to operate because of small switching movement

iii) If signals are applied at both ports, first signal will be dominant

Disadvantages

i) Construction of the valve is complex

ii) Expensive

E.Rotary valves

The rotary spool directional control valve (Figure 1.13) has a round core with one or more passages or recesses in it. The core is mounted within a stationary sleeve. As the core is rotated within the stationary sleeve, the passages or recesses connect or block the ports in the sleeve. The ports in the sleeve are connected to the appropriate lines of the fluid system.

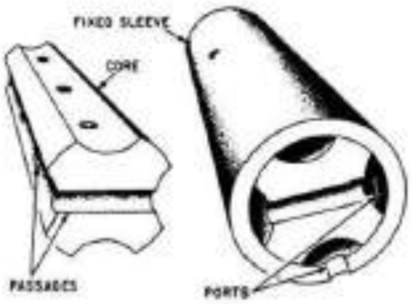


Figure 1.13 Parts of a rotary spool directional control valve.

Figure 1.14 shows the construction of a rotary spool directional control valve. We connect different ports by rotating the handle. By rotating the handle, core gets connected to different holes to give the required configuration of the valve. This type of the valve can be directly mounted on panel using bolt.

Figure 1.15 shows three different position of the core when the handle is rotated. Left most envelope of DCV connects P to B and A to T. Middle envelope of DCV blocks all ports. Right most envelope of DCV connects P to A and T to B.

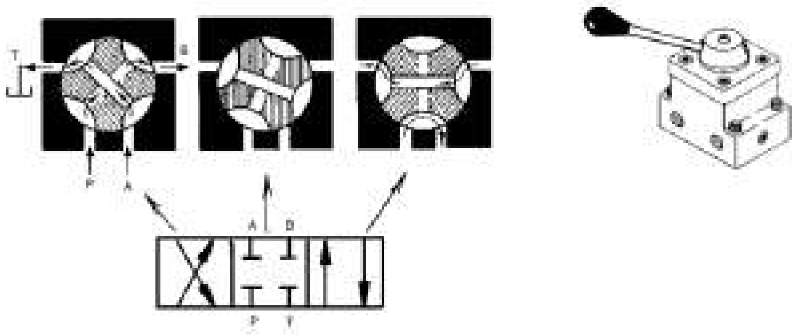
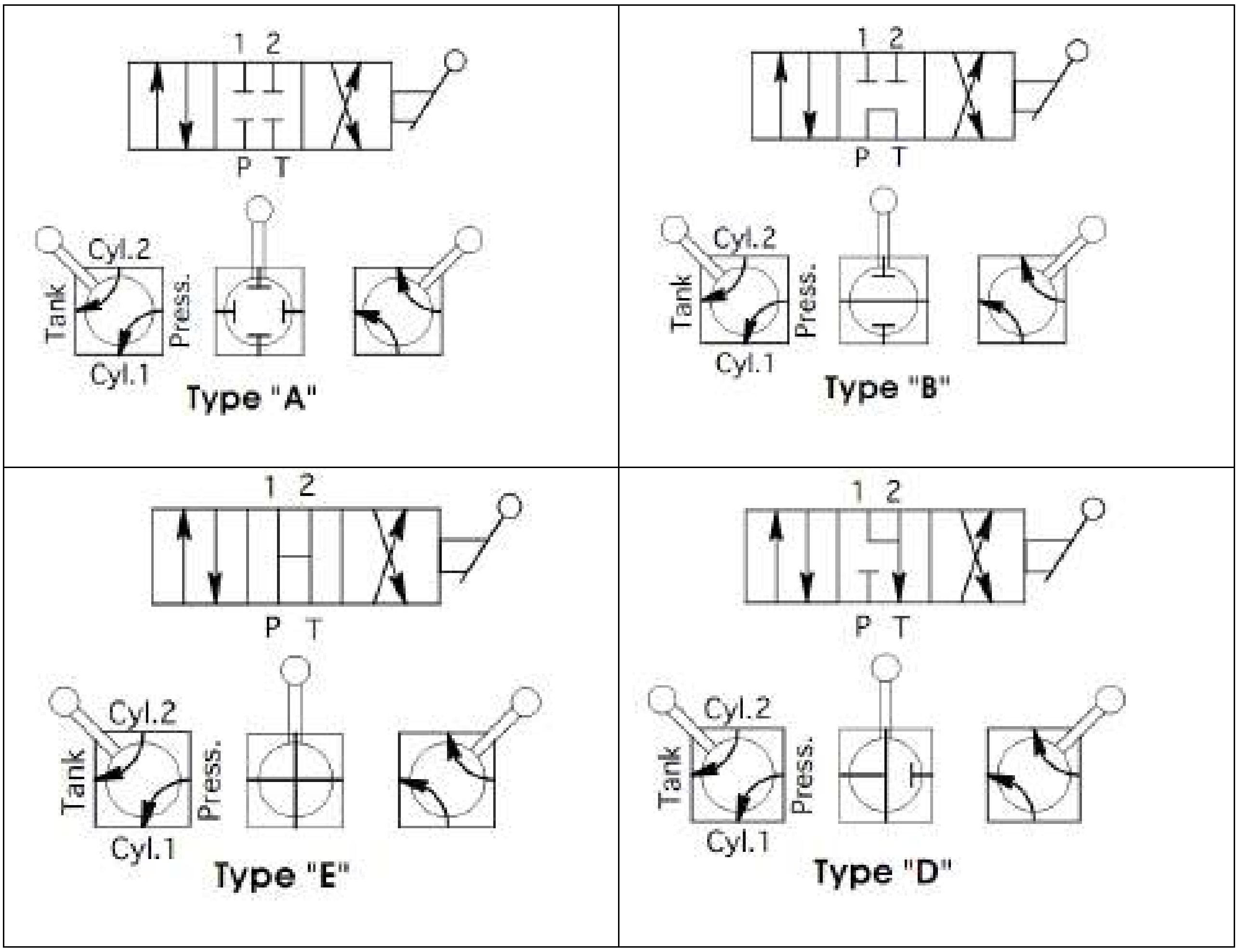


Figure 1.15 Three different positions of 4/3 way rotary spool directional control valve.

Table 1.4 shows schematically the different position of core and sleeve for various middle position of 4/3 way Direction control valve.

Table 1.4 Different position of core and sleeve for various mid position of 4/3 DCV



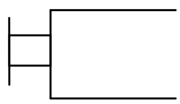
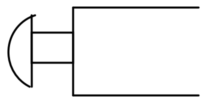
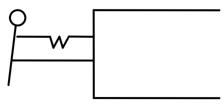
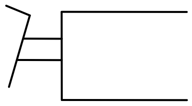
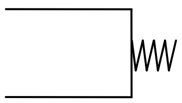
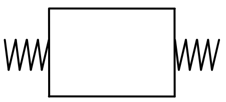
6.2.1.5 METHODS OF ACTUATION.

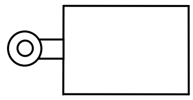
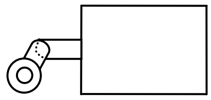
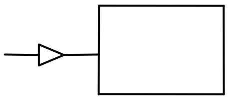
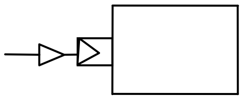
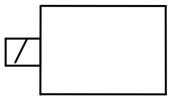
The methods of actuation of pneumatic directional control valves depend upon the requirements of the task. (Table 1.5) The types of actuation vary;

- manually actuated
- mechanically actuated
- pneumatically actuated
- electrical
- combined actuation

The symbols of the methods of actuation are detailed in DIN ISO 1219. When applied to a directional control valve, consideration must be given to the method of initial actuation of the valve and also the method of return actuation. Normally these are two separate methods. They are both shown on the symbol on either side of the position boxes. There may also be additional methods of actuation such as manual overrides, which are separately indicated.

Table 1.5 Methods of actuation

Type of actuation	Type of control	Symbol
Manual	General	
	Pushbutton	
	Detent lever operated	
	Foot pedal	
Mechanical	Spring return	
	Spring centered	

	Roller operated	
	Idle roller	
Pneumatic	Direct	
	Indirect, pilot operated	
Electrical	Single solenoid	
	Double solenoid	
Combined	Double solenoid with pilot operated	

1.2.1.7 BASED ON MOUNTING STYLES

Directional control valves can be mounted in two ways; inline and subplate.

Inline means that there are threaded connections in the valve itself. Fittings are screwed directly into the valve. This method has several disadvantages. Each time the valve is disconnected there is the possibility of damaging the valve by stripping the threads. The threads will also wear each time the unit is disconnected, causing contamination and an increased possibility of leakage. In the subplate method, the bottoms of the valves have unthreaded connections. The valve is then attached to a subplate that has matching connections.

The subplate has the threaded connection to which the fittings are attached. Sealing at the valve /subplate interface is accompanied through the use of o-rings, which fit into small recesses around the DCV ports. The subplate methods results in less leakage, less contamination, and a smaller probability of doing damage to the valve during assembly and disassembly. Valve replacement is simpler and less time – consuming task.

Figure 1.34 Manifold for three valves

1.2.2 NON RETURN VALVES

Non return valves permit flow of air in one direction only, the other direction through the valve being at all times blocked to the air flow. Mostly the valves are designed so that the check is additionally loaded by the downstream air pressure, thus supporting the non-return action.

Among the various types of non-return valves available, those preferentially employed in pneumatic controls are as follows

i) Check valve
ii) Shuttle valve
iii) Restrictor check valve
iv) Quick exhaust valve
v) Two pressure valve

A. Check valve

The simplest type of non-return valve is the check valve (Figure 1.35 (a)) , which completely blocks air flow in one direction while permitting flow in the opposite direction with minimum pressure loss across the valve. As soon as the inlet pressure in the direction of free flow develops a force greater than that of the internal spring, the check is lifted clear of the valve seat. The check in such valve may be plug, ball, plate or diaphragm.

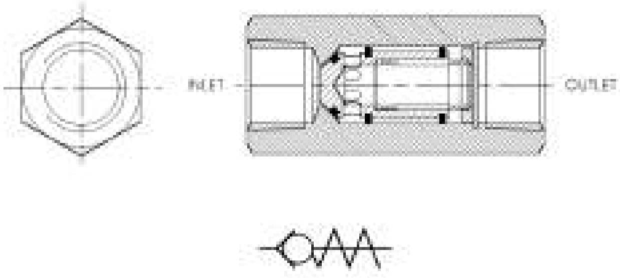


Figure 1.35 Check valve

B. Shuttle valve

It is also known as a double control valve or double check valve. A shuttle valve has two inlets and one outlet. At any one time, flow is shut off in the direction of whichever inlet is unloaded and is open from the loaded inlet to the outlet (Figure 1.36). A shuttle valve may be installed, for example, when a power unit (cylinder) or control unit (valve) is to be actuated from two points, which may be remote from one other.

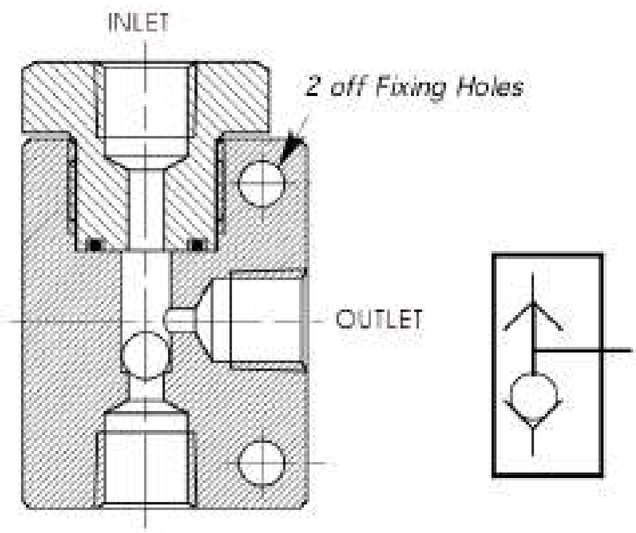


Figure 1.36 Shuttle valve

C. **Restrictor check valve**

It also termed speed control valve for pneumatic applications are actually hybrid type of unit. By reason of their throttling function they are flow control valves and they are indeed used as flow control valves in pneumatics. Incorporation of check function also makes them non –return valves and it is as such that they are generally classified.

Usually the throttle of a restrictor check valve is adjustable so as to permit regulations of air flow through the valve. Throttling function is effective only in one direction of flow, while in the other direction free flow is provided through the check.(Figure 1.37). When restrictor check valves are used to control the speed of pneumatic cylinders, differentiation is made between supply-air and exhaust air-throttling.

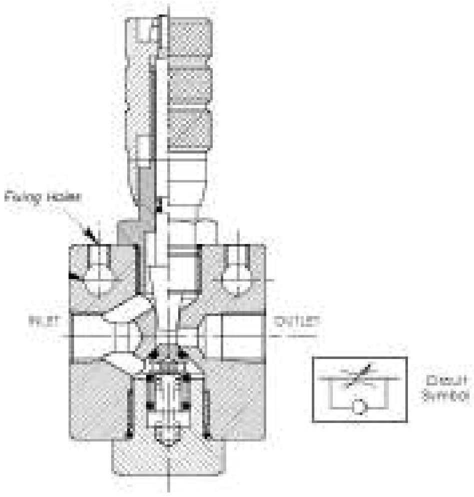


Figure 1.37 Functional diagram of restrictor check valve.

D. Quick Exhaust Valves

A quick exhaust valve is a typical shuttle valve. The quick exhaust valve is used to exhaust the cylinder air quickly to atmosphere. Schematic diagram of quick exhaust valve is shown in Figure 1.38. In many applications especially with single acting cylinders, it is a common practice to increase the piston speed during retraction of the cylinder to save the cycle time. The higher speed of the piston is possible by reducing the resistance to flow of the exhausting air during the motion of cylinder. The resistance can be reduced by expelling the exhausting air to the atmosphere quickly by using Quick exhaust valve.

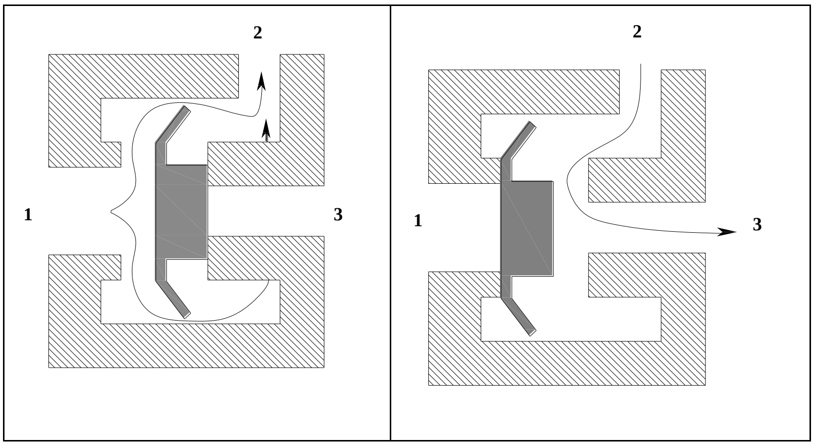


Figure 1.38 Functional diagram of quick exhaust valve.

The construction and operation of a quick exhaust valve is shown in Figure 1.38. It consist of a movable disc (also called flexible ring) and three ports namely, Supply port 1, which is connected to the output of the final control element (Directional control valve). The Output port, 2 of this valve is directly fitted on to the working port of cylinder. The exhaust port, 3 is left open to the atmosphere

Forward Motion: During forward movement of piston, compressed air is directly admitted behind the piston through ports 1 and 2 Port 3 is closed due to the supply pressure acting on the diaphragm. Port 3 is usually provided with a silencer to minimise the noise due to exhaust.

Return Motion: During return movement of piston, exhaust air from cylinder is directly exhausted to atmosphere through opening 3 (usually larger and fitted with silencer) .Port 2 is sealed by the diaphragm. Thus exhaust air is not required to pass through long and narrow passages in the working line and final control valve

Typical applications of quick exhaust valves for single acting and double acting cylinders are shown in Figure 1.39

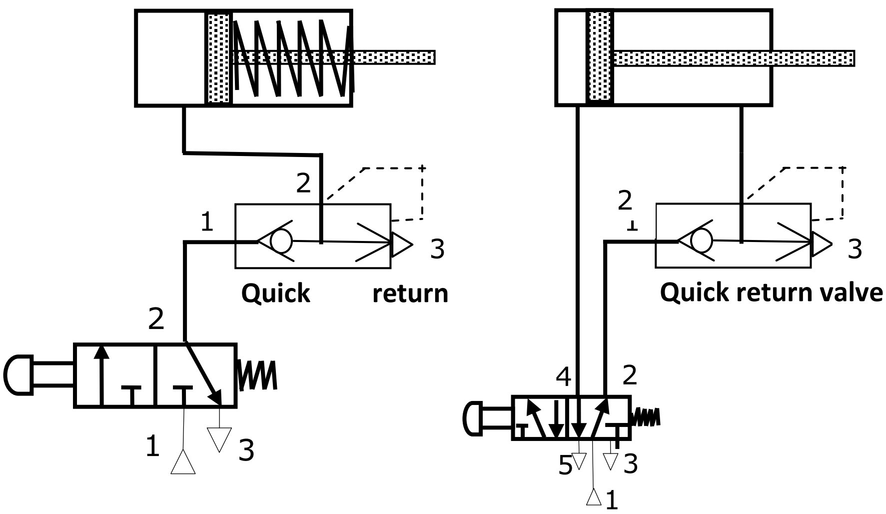


Figure 1.39 Application of quick exhaust valve.

E. Two Pressure Valve

This valve is the pneumatic AND valve. It is also derivate of Non Return Valve. A two pressure valve requires two pressurised inputs to allow an output from itself. The cross sectional views of two pressure valve in two positions are given in Figure 1.40 As shown in the figure, this valve has two inputs 12 and 14 and one output 2. If the compressed air is applied to either 12 or input 14, the spool moves to block the flow, and no signal appears at output 2. If signals are applied to both the inputs 12 and 14, the compressed air flows through the valve, and the signal appears at output 2.

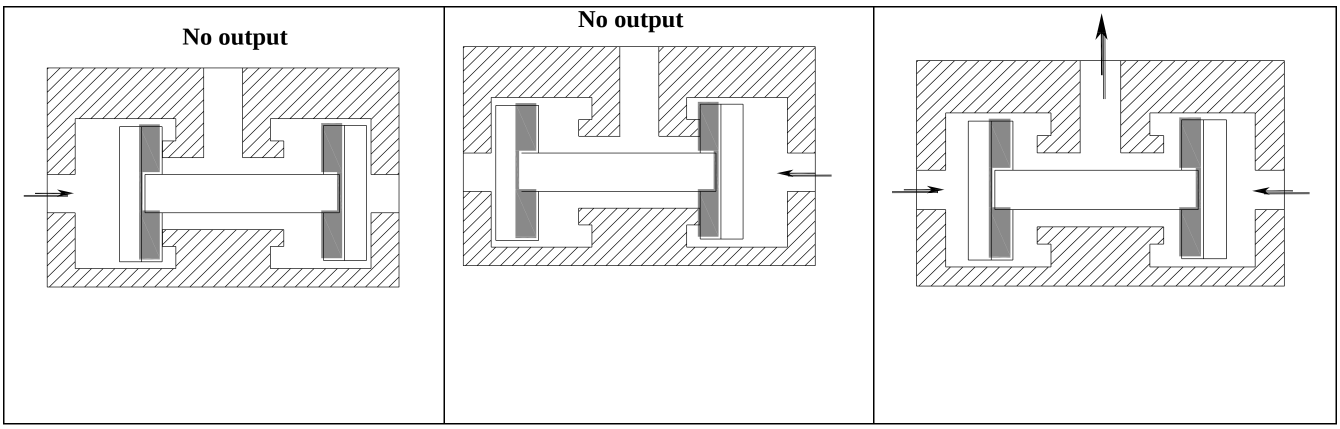


Figure 1.40 Two pressure valve.

1.2.3 FLOW CONTROL VALVES

Function of a flow control valve is self –evident from its name. A flow control valve regulates the rate of air flow. The control action is limited to the air flow passing through the valve when it is open, maintaining a set volume per unit of time. Figure 1.41(a) shows a variable restrictor type flow control valve (manifold type). Figure 1.41(b) shows a variable restriction type flow control valve (inline type). Figure 1.42 shows another design of Flow control valve, in which flow can be set by turning the knob.

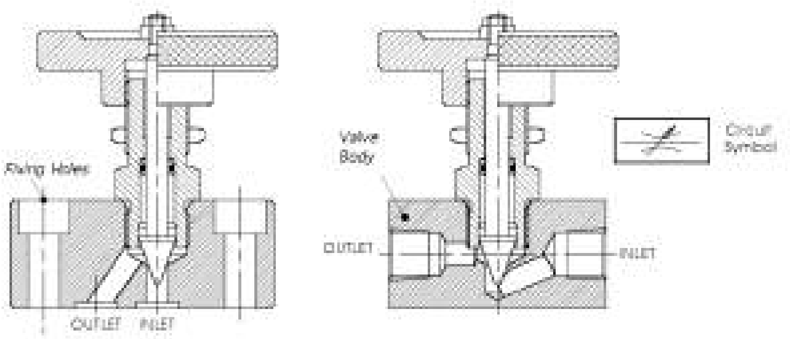


Figure 1.41 Flow control valve a) manifold b) inline

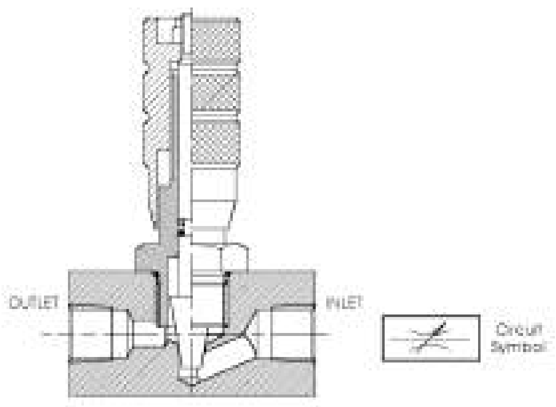


Figure 1.42 Flow control valve (adjustable)

1.2.4 PRESSURE CONTROL VALVE.

Compared with hydraulic systems, few pressure control valves are brought into use in pneumatics. Pressure control valves control the pressure of the air flowing through the valve or confined in the system controlled by the valve.

There are three types of pressure control valves

1. Pressure limiting valve

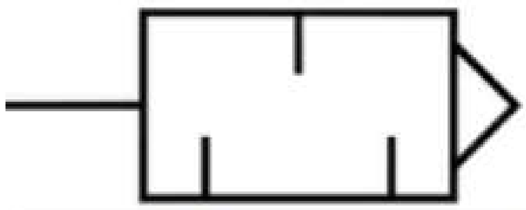
Pneumatic Muffler or Silencer

A pneumatic silencer is used to vent pressurized air to the atmosphere. They are commonly installed on pneumatic 5/2-way solenoid valves, pneumatic cylinders, or fittings. Depending on the flow and pressure of the air coming out of the exhaust port, the pneumatic air exiting the device could produce noise that is potentially harmful to workers in the surrounding environment or cause noise issues in the application (theatre applications). In addition to noise, the exhaust air may emit contaminants during operation. Using a silencer exhaust cleaner can prevent harmful contaminants from entering the environment. Pneumatic air silencers, also commonly called pneumatic mufflers, are a cost-effective and simple solution to reduce noise level and unwanted discharge of contaminants from pneumatics.

Pneumatic muffler examples

Pneumatic silencer symbol

The pneumatic silencer symbol seen in schematics is shown in Figure.



Pneumatic silencer symbol

SERVO VALVES

Servo valves were developed to facilitate the adjustment of fluid flow based on changes in the load motion. Simply put, it is a programmable orifice. In machine motion control, servo systems involve continuous monitoring, feedback and correction.

A servomechanism is defined as an automatic device for controlling a large amount of power by means of a very small amount of power and automatically correcting the performance of a mechanism. The automatic and continuous correction requires return of information from the mechanism– feedback, in other words.

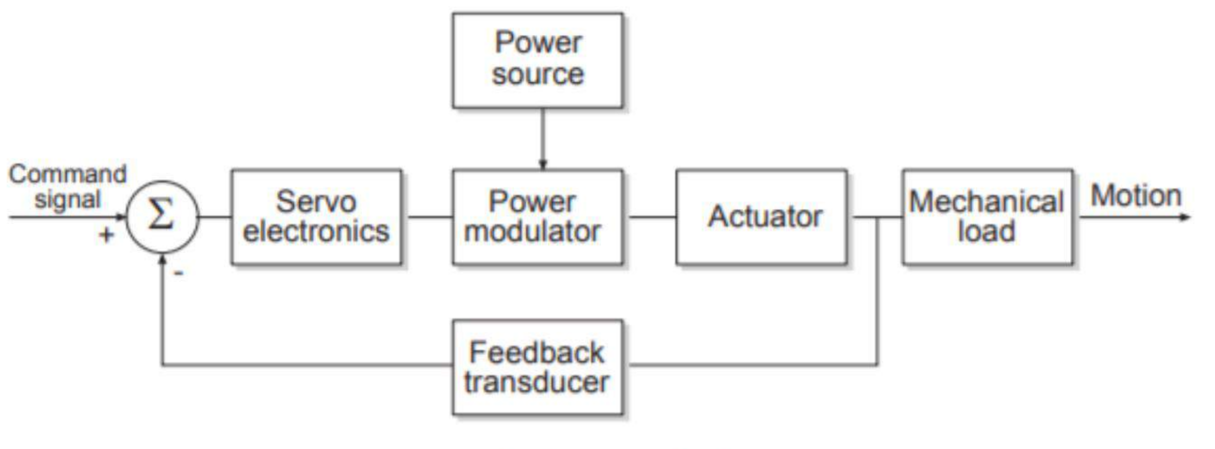


Figure : Basic servomechanism

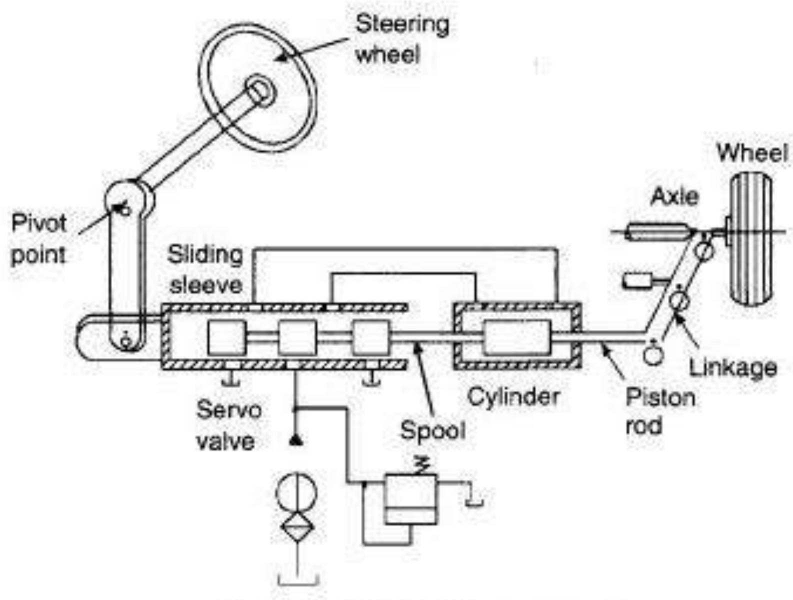
Hydraulic Servo for Steering Mechanism

Figure shows a mechanical hydraulic servo system with automotive power steering, the sequential operation of which occurs as follows:

- The input or command signal is the turning of the steering wheel. This results in movement of the valve sleeve, which ports oil to the actuator (steering cylinder).
- The piston rod moves the wheels through the steering linkage.
- The valve spool is attached to the linkage, thereby moving it.

When the valve spool has moved far enough, it cuts off the oil flow through the cylinder. This stops the motion of the actuator.

It is therefore clear that mechanical feedback re-centers the valve (servo valve) in order to stop motion at the desired point which in turn is determined by the position of the steering wheel. Additional motion of the steering wheel is required to cause further motion of the output wheels.

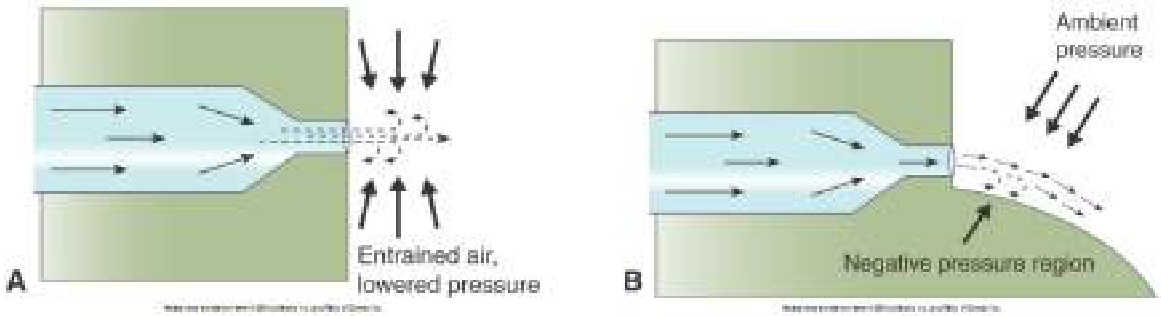


Mechanical hydraulic servo system

Fluidics-Coanda Effect and Fluidic Logic Circuits

Fluidics is the branch of engineering that applies hydordynamic principles in flow circuits for purposes such as switching, pressure and flow sensing, and amplification. Fluidics – no moving parts required for switching, pressure and flow sensing.

Principle of fluidic circuitry is the phenomenon of **wall attachment**, known as the **Coanda Effect.**

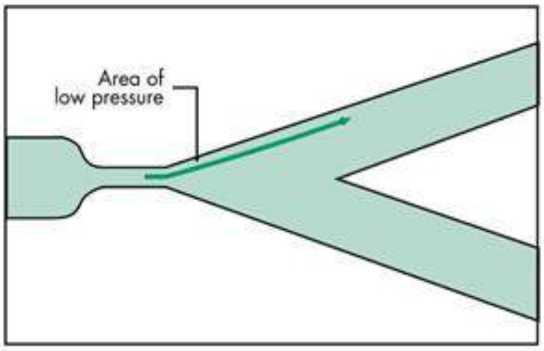


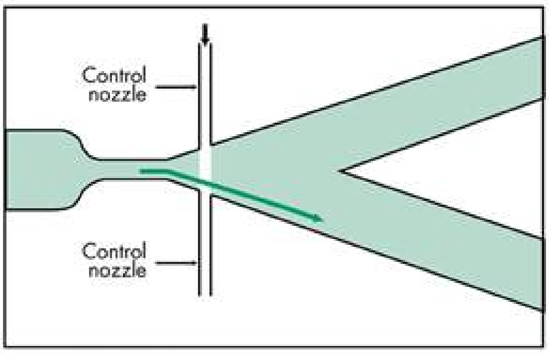
Based on the Bernoulli effect (A) coupled with curved wall on one side of jet (B).

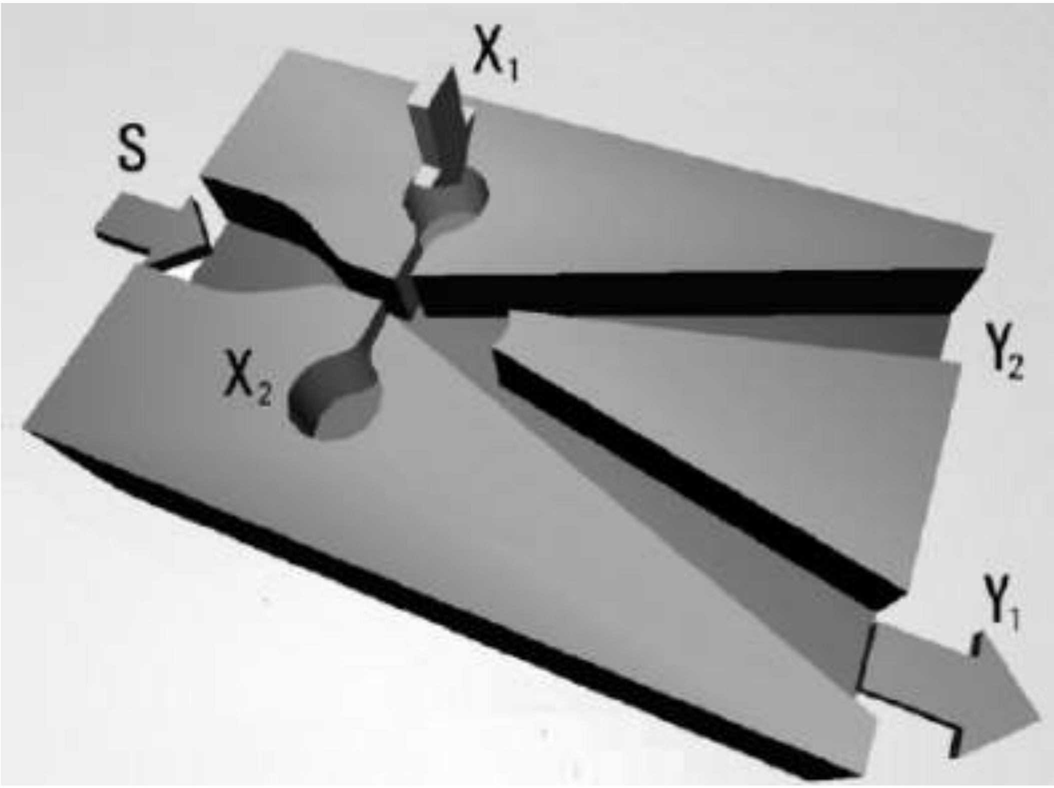
Can actually deflect fluidic stream through a 180o turn by carefully extending the wall contour

Subatmospheric pressure along wall directs flow until interrupted by counterforce (pulse of gas).

Gas flow pathway can be changed by side jets in devices called gates; pulses of air from the side jet cause an increase in pressure at the wall, breaks the attachment and allows the gas stream to attach to the other wall, which will stay adhered to that wall until a pulse of air from below causes it to switch back.





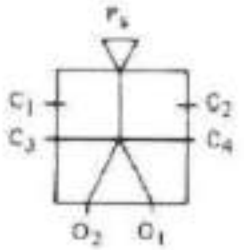


Truth Table:

Sl. No	Input (S)	Control X1	Control X2	Output Y1	Output Y2
1	1	1	0	1	0
2	1	0	0	1	0
3	1	0	1	0	1
4	1	0	0	0	1

1. Basic Flip-Flop

The following figure elucides the basic flip-flop of fluidic device and its truth table.

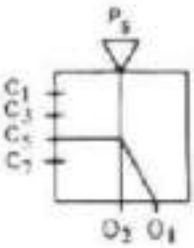


C1	C2	01	02
1	0	1	0
0	0	1	0
0	1	0	1
0	0	0	1

Basic flip-flop with its symbol and truth table.

2. OR/NOR Gate

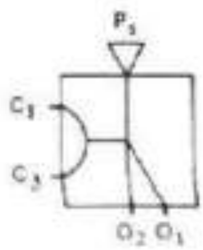
Figure shows an actual OR/NOR gate with its symbol and truth table. Although the truth table shows only control signals *C1* and *C3*, the device actually has two additional control ports, *C5* and *C7*. A control signal at any one or any combination of these ports causes the device to switch to the *O1* output. With all control signals OFF, the output is automatically *O2*.



C1	C3	01	02
0	0	0	1
1	0	1	0
0	1	1	0
1	1	1	0

OR/NOR gate with its symbol and truth table.

3. AND/NAND Gate



C1	C3	01	02
0	0	0	1
1	0	0	1
0	1	0	1
1	1	1	0

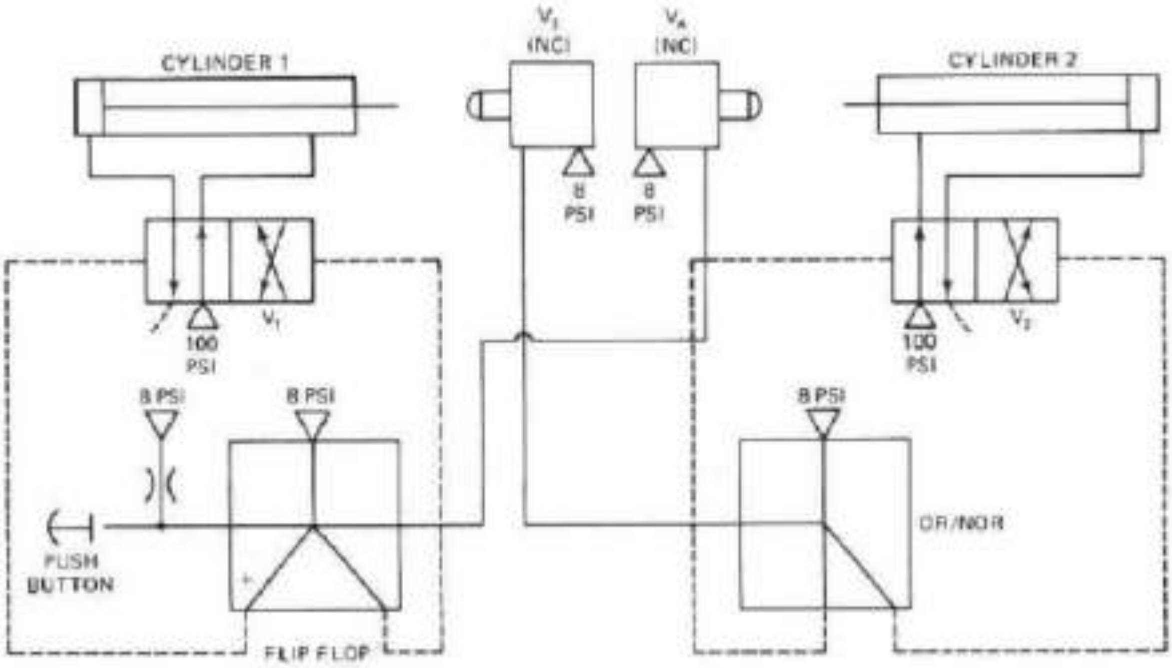
AND/NAND gate with its symbol and truth table

Fluidic Sequencing circuit of two pneumatic cylinders

The sequence control of two air cylinders is accomplished by the circuit given in Fig. . The system consists of two interface valves (*V1* and *V2*), a preferenced flip-flop, an OR/NOR gate, two normally closed (N.C.) air limit switches (*V3* and *V4*), and two pneumatic cylinders. When the push-button valve is momentarily released, the following sequence cycle occurs:

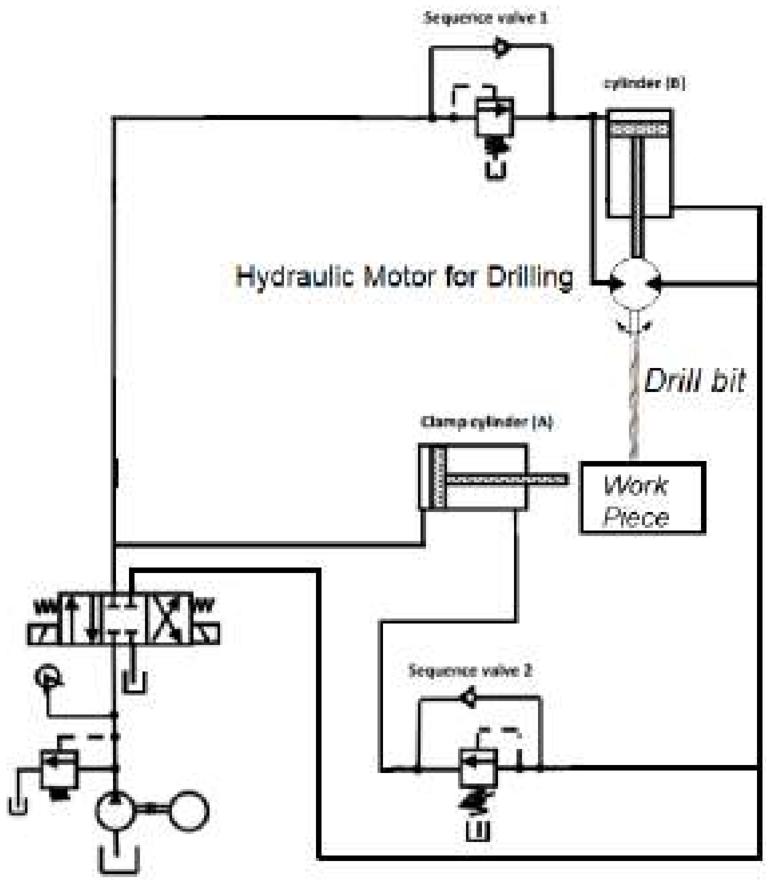
1. Cylinder 1 extends.
2. Cylinder 2 extends.
3. Both cylinders retract together.

The cycle is repeated each time the push button is momentarily pressed. A flip-flop with a start-up preference is used to prevent the cycle from starting automatically as soon as the fluidic and pneumatic air supplies are turned on.



Fluidic sequencing control of two pneumatic cylinders.

1. Hydraulic Circuit for Drilling Operation:

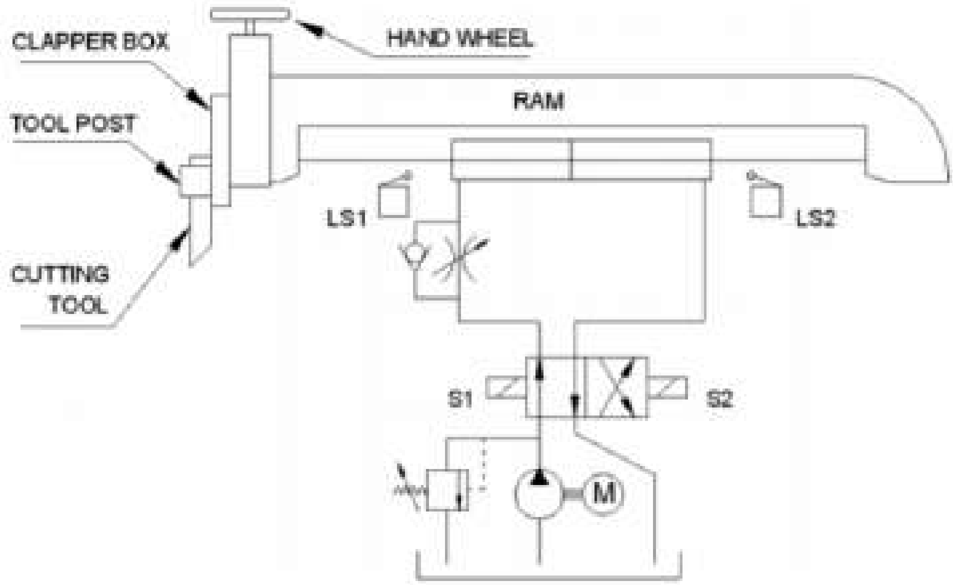


Hydraulic cylinders can be operated sequentially using the sequence valves. Figure shows that two sequence valves are used to sequence the operation of two double-acting cylinders and one hydraulic motor. Clamping cylinder A is used to clamp the workpiece firmly. Hydraulic Motor is used to perform drilling operation using drill bit attached to it. Cylinder B is used to obtain the up and down movement of drill bit.

When the DCV is actuated to its left-envelope mode, the clamping cylinder A extends and clamp the workpiece. Then the sequence valve 1 allows the pressurized liquid to cylinder B and Hydraulic Motor. Hydraulic motor rotates the drill bit in clock wise direction and cylinder B provides the downward motion of drill bit.

When the DCV is actuated to its right-envelope mode, the cylinder (B) retracts fully and the hydraulic motor rotates the drill bit in anticlockwise direction. Once the pressure increases beyond the setting pressure of sequence valve 2, it allows the liquid to clamp cylinder (A) to retract it. This sequence of cylinder operation is controlled by sequence valves. This hydraulic circuit can be used in a production operation such as drilling.

2. Hydraulic Circuit for Shaping Operation:

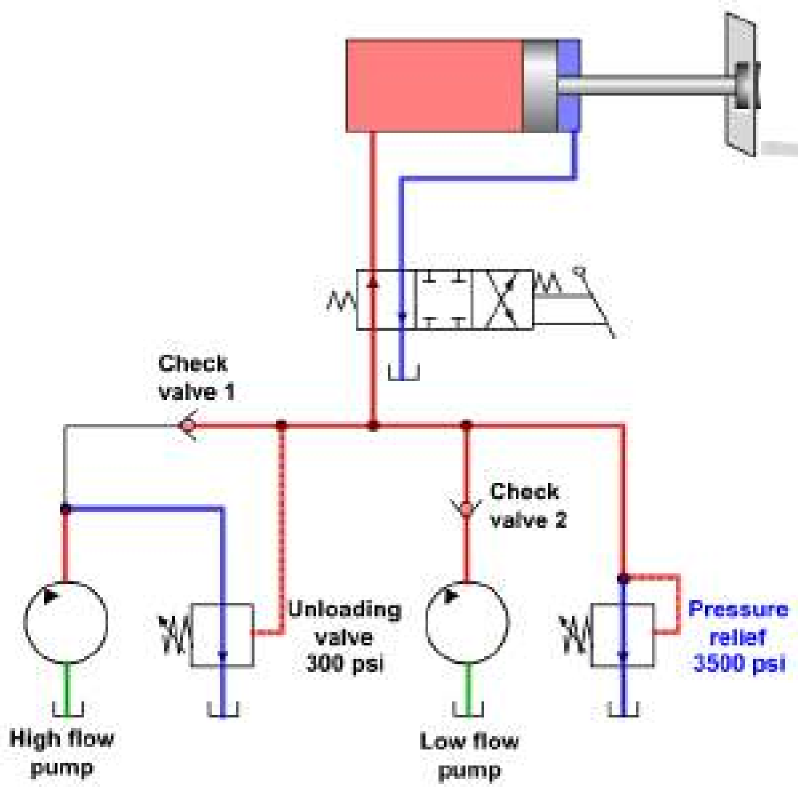


Quick return mechanism is completely replaced by double rod hydraulic cylinder. Other basic components are hydraulic reservoir, pump, pressure relief valve, solenoid operated 4/2 DCV, flow control valve, limit switches.
When the solenoid S2 energized, the DCV shifted to its right mode, then the pressurized liquid supplied to right side of the hydraulic cylinder, which enables the shaping tool take forward stroke for performing shaping operation. At the end of this stroke limit switch LS1 actuated and sends the electrical signal to relay. Relay deenergize the solenoid S2 and energize solenoid S1. Hence the DCV shifted to its left mode, then the pressurized liquid supplied to left side of hydraulic cylinder, which enables the shaping tool take the return stroke. At the end of return stroke, the limit switch LS2 gets actuated and sends the signal to relay for getting forward stoke. This process will takes place continuously until the pump is switch off at the end of shaping operation.

3. Hydraulic Circuit for Punching/Pressing Operation:

The same hydraulic circuit used for punching and pressing operations. Depending upon the type of operation either punching or pressing die is attached to the hydraulic cylinder rod. The basic components are hydraulic reservoir, pump, pressure relief valve, high flow-low pressure pump P1, low flow-high pump P2, two check valves, unloading valve, 4/3 lever operated-spring return DCV and double acting cylinder.

When the prime movers starts, both the pump supplies the pressurized liquid to the hydraulic cylinder, hence the piston along with the punching/pressing die moves rapidly. Once the die touches the workpiece, the pressure in the hydraulic line increases. Increased pressure actuates the unloading valve, which unload the high flow-low pressure pump P1. Now the flow will takes place only from low flow-high pressure pump P2 to carry out the punching/pressing operation.



4. CASCADE Circuit (Pneumatic) for the sequence operations A^+, B^+, B^-, A^-:

The cascade method is simple to apply and results in reliable and easily understood circuits. Steps involved

Step 1:
Each cylinder is given a code letter and the sequence is determined. For example A+, B+, A-, B- etc. '+' and '-' represent extension and retraction of the cylinder respectively.

Step 2:
The sequence is split into minimum number of groups. Care should be taken to see that no letter is repeated within any group. Next the circuit is drawing it up using the following steps.

Step 3:
Each group is assigned a pressure connecting line which must be pressurized only while that particular group is active. So, the number of pressure connecting lines equals the number of groups.

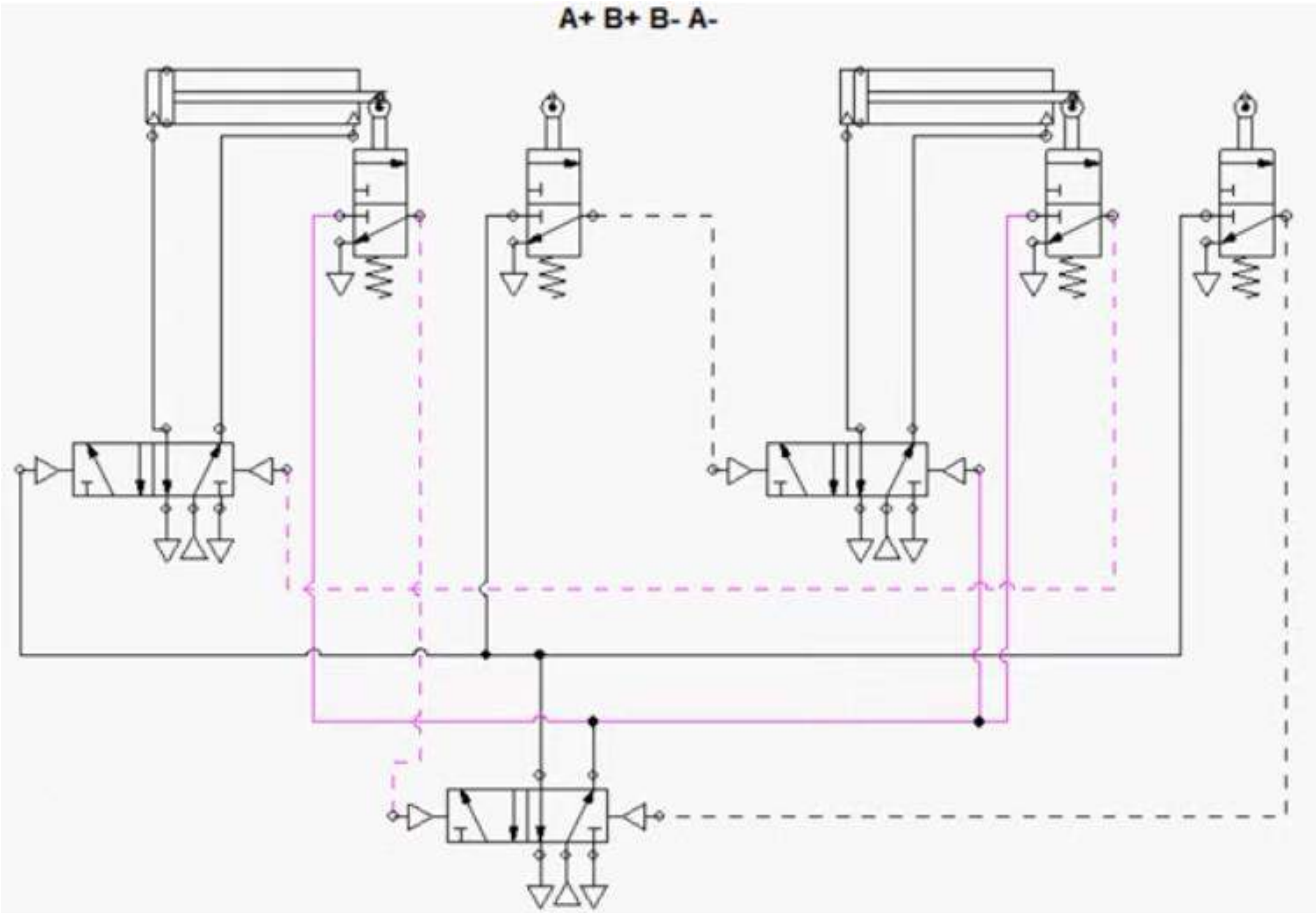
Step 4:
Selecting the valves.
The limit valves are denoted as a0, a1, b0, b1 etc. where the suffix 0 corresponds to valves which are actuated at the end of return stroke and the suffix 1 corresponds to valves which are actuated at the end of forward stroke. Each cylinder requires two limits valves and it equals twice the number of cylinders. Each manifold line supplies air pressure to those limit valves within its particular group.

In order to pressurise the various connecting lines in the proper order, one or more group changing valves or cascade valves (double air piloted of 4/2 DCV or 5/2 DCV) are employed. The number of group valves always equals the number of groups minus one (=number of group – 1).

For each cylinder, a pilot operated direction control valve is selected. The number of cylinders acting valves equals the number of cylinders.

Step 5:
The valves are connected as follows. The output of each limit valve is connected to the pilot input corresponding to the next sequence step with one exception. The limit valve corresponding to the last step of the given group is 'not' connected to the actuating valve of the next cylinder, but rather to the pilot line of a group changing valve so as to pressurize the connecting line of the next group. This connecting line is then connected to the pilot line corresponding to the first step of the next group.

- Two Cylinder Co- Ordinated Motion Control with sequence [A+,B+,B-,A-]
- Signal Groups [a1][b1][b0][a0]-limit switches
- Last signal (a0) + Start signal is used to initiate the motion. This will be input signal to o last stage of cascade.



CASCADE CIRCUIT

Electropneumatic:

ELECTRICAL COMPONENTS

There are five basic types of electric switches used in electrically controlled fluid power circuits: push-button, limit, pressure, temperature, and relay switches.

1. Push-button switches: Figure 13-4 shows the four common types of push-button switches. Figure 13-4(a) and (b) shows the single-pole, single-throw type. These single-circuit switches can be wired either normally open or closed. Figure 13-4(c) depicts the double-pole, single-throw type. This double-contact type has one normally open and one normally closed pair of contacts. Depressing the push button opens the normally closed pair and closes the normally open pair of contacts.

Figure 13-4(d) illustrates the double-pole, double-throw arrangement. This switch has two pairs of normally open and two pairs of normally closed contacts to allow the inverting of two circuits with one input.

2. Limit switches: In Fig. 13-5 we see the various types of limit switches. Basically, limit switches perform the same functions as push-button switches. The difference is that they are mechanically actuated rather than manually. Figure 13-5(a) shows a normally open limit switch, which is abbreviated LS-N.O. Figure 13-5(b) shows a normally open switch that is held closed. In Fig. 13-5(c) we see the

normally closed type, whereas Fig. 13-5(d) depicts a normally closed type that is held open. There are a large number of different operators available for limit switches. Among these are cams, levers, rollers, and plungers. However, the symbols used for limit switches do not indicate the type of operator used.

3. Pressure switches: The symbols used for pressure switches are given in Fig. 13-6. Figure 13-6(a) gives the normally open type, whereas Fig. 13-6(b) depicts the normally closed symbol.

4. Temperature switches: This type of switch is depicted symbolically in Fig. 13-7. Figure 13-7(a) gives the symbol for a normally closed type, whereas Fig. 13-7(b) provides the normally open symbol.

5. Electrical relays: A relay is an electrically actuated switch. As shown schematically in Fig. 13-8(a), when switch 1-SW is closed, the coil (electromagnet) is energized. This pulls on the spring-loaded relay arm to open the upper set of normally closed contacts and close the lower set of normally open contacts. Figure 13-8(b) shows the symbol for the relay coil and the symbols for the normally open and closed contacts.

Timers are used in electrical control circuits when a time delay from the instant of actuation to the closing of contacts is required. Figure 13-9 gives the symbol used for timers. Figure 13-9(a) shows the symbol for the normally open switch that is time closed when energized. This type is one that is normally open but that when energized closes after a predetermined time interval. Figure 13-9(b) gives the normally closed switch that is time opened when energized. Figure 13-9(c) depicts the normally open type that is timed open when de-energized. Thus, it is normally open, and when the signal to close is removed (de-energized), it reopens after a predetermined time interval. Figure 13-9(d) gives the symbol for the normally closed type that is time closed when de-energized.

The symbol used to represent a solenoid, which is used to actuate valves, is shown in Fig. 13-10(a). Figure 13-10(b) gives the symbol used to represent indicator lamps. An indicator lamp is often used to indicate the state of a specific circuit component. For example, indicator lamps are used to determine which solenoid operator of a directional control valve is energized. They are also used to indicate whether a hydraulic cylinder is extending or retracting. An indicator lamp wired across each valve solenoid provides the troubleshooter with a quick means of pinpointing trouble in case of an electrical malfunction. If they are mounted on an operator's display panel, they should be mounted in the same order as they are actuated. Since indicator lamps are not a functional part of the electrical system, their inclusion in the ladder diagram is left to the discretion of the designer.

The remaining portion of this chapter is devoted to discussing a number of basic electrically controlled fluid power systems. In these systems, the standard electrical symbols are combined with ANSI fluid power symbols to indicate the operation of the total system. Fluid power–operated electrical devices such as pressure switches and limit switches are shown on the fluid power circuits to correspond to symbols used in the electrical diagrams.

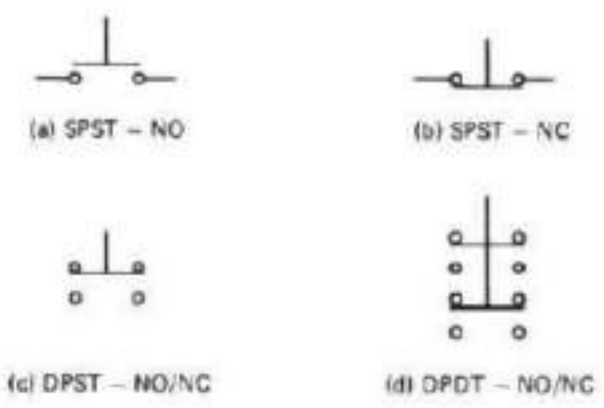


Figure 13-4. Push-button switch symbols. (a) SPST-N.O., (b) SPST-N.C., (c) DPST-N.O./N.C., (d) DPDT-N.O./N.C.

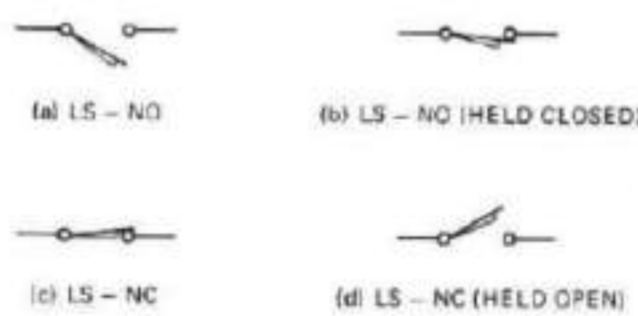
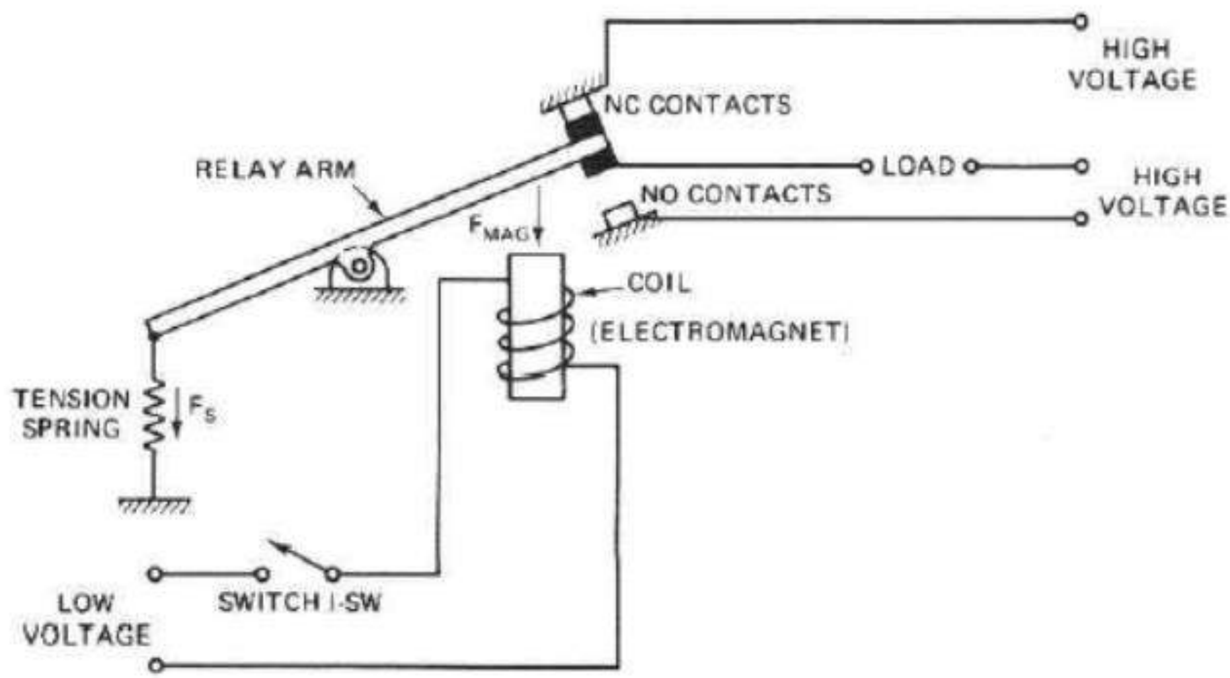


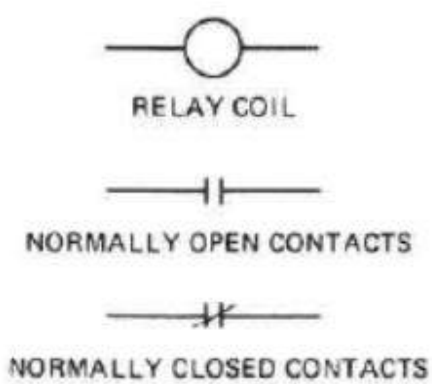
Figure 13-5. Limit switch symbols. (a) LS-N.O., (b) SL-N.O. (held closed), (c) LS-N.C., (d) LS-N.C. (held open).

Figure 13-6. Pressure switch symbols. (a) PS-N.O., (b) PS-N.C.

Figure 13-7. Temperature switch symbols. (a) TS-N.O., (b) TS-N.C.



(a)



(b)

Figure 13-8. Electrical relay.

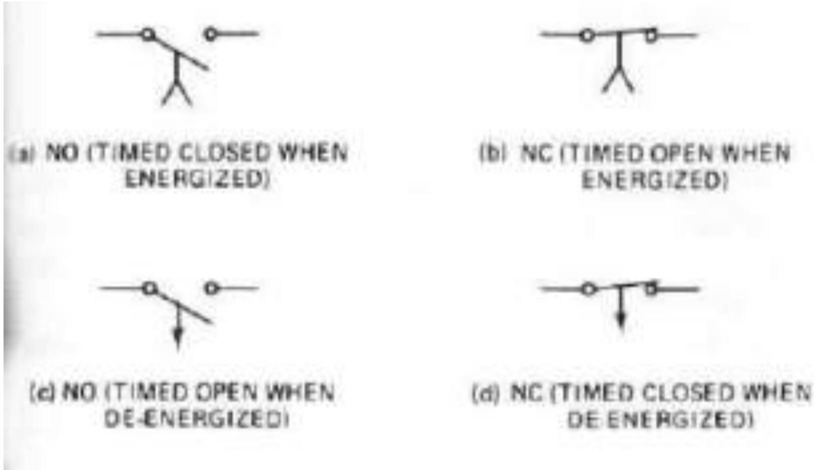


Figure 13-9. Electrical timer symbols. (a) N.O. (timed closed when energized), (b) N.C. (timed open when energized), (c) N.O. (timed open when de-energized), (d) N.C. (timed closed when de-energized)

Figure 13-10. Solenoid and indicator lamp symbols. (a) Solenoid, (b) indicator lamp.

Reciprocation of cylinder using Pressure and Limit switches:

In Fig. 13-12 we see how pressure switches can be substituted for limit switches to control the operation of a double-acting hydraulic cylinder. Each of the two pressure switches has a set of normally open contacts. When switch 1-SW is closed, the cylinder reciprocates continuously until 1-SW is opened. The sequence of

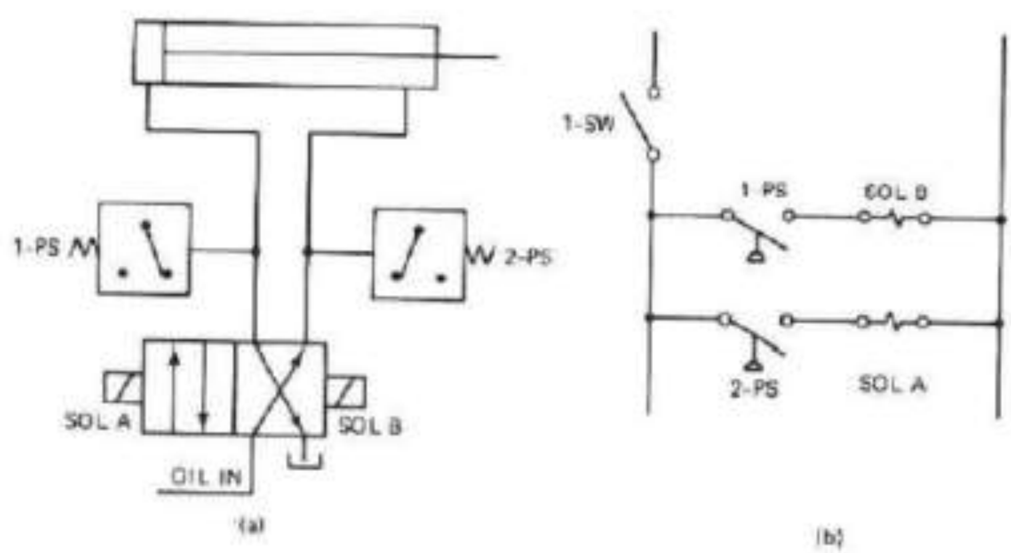


Figure 13-12. Reciprocation of cylinder using pressure switches.

operation is as follows, assuming solenoid A was last energized: The pump is turned on, and oil flows through the valve and into the blank end of the cylinder. When the cylinder has fully extended, the pressure builds up to actuate pressure switch 1-PS. This energizes SOL B to switch the valve. Oil then flows to the rod end of the cylinder. Upon full retraction, the pressure builds up to actuate 2-PS. In the meantime, 1-PS has been deactuated to de-energize SOL B. The closing of the contacts of 2-PS energizes SOL A to begin once again the extending stroke of the cylinder.

Figure 13-13 gives the exact same control capability except each pressure switch is replaced by a normally open limit switch as illustrated. Observe that switches are always shown in their unactuated mode in the electrical circuits.

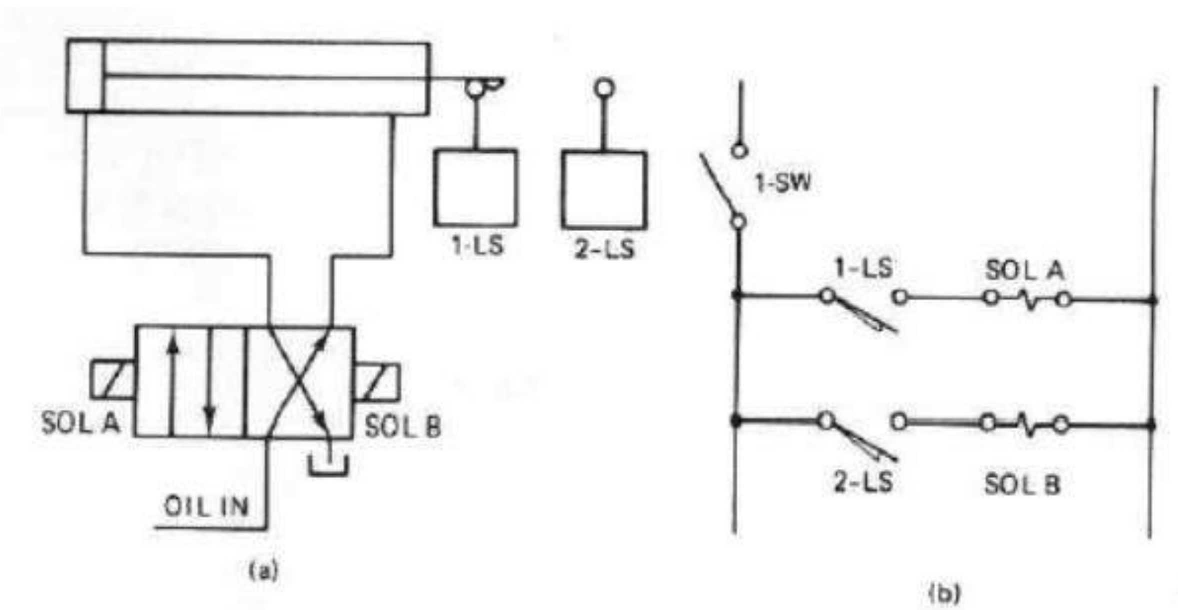


Figure 13-13. Reciprocation of cylinder using limit switches.

Fault finding and maintenance of hydraulic components:

Troubleshooting Steps

A good troubleshooting program should include the following steps.

- Know the System.
  - Study the Hydraulic Schematic.
  - Know what the relief valve settings and pump outputs should be.
- Ask the operator.
  - Ask how did the crane acted when it started to fail or what is unusual about the crane's operation.
  - Ask if any valve setting was changed.
  - Discuss how the crane is being used and when preventive maintenance is being performed; many problems can be traced to abuse of the crane or poor maintenance.
- Operate the Crane.
  - How is the crane's performance? Is any function slow, erratic, or not operating at all?
  - Do the controls feel solid or spongy?
  - Smell any unusual odors? Any signs of smoke?
  - Hear any unusual noises? Where, at what speeds, and during what cycles?
- Inspect the Crane
  - Inspect the entire crane for any signs of trouble.
  - Inspect the hydraulic tank. Is the oil at the proper level? Is the oil foamy or milky? Does the oil smell scorched? Does the oil appear too thin, too thick, or excessively dirty?
  - Is the filter bypassing (clogged with dirt)? If so, replace the element.
  - Feel the tank and the lines. Are they hotter than normal? Are they caked with dirt, mud, or dry oil? Is the paint peeled from any components? Are there kinked or collapsed hoses or tubes?
  - Inspect all lines for oil leaks.
  - Check for air leaks, usually accompanied by a sucking sound.
  - Look closely at each component. Inspect for cracked welds, hairline cracks in housings, and loose mounting bolts or tie bolts.
- List the Problems.
  - Make a list of the problems found while inspecting the crane.
- Reach a Conclusion.
  - Study the list of problems and determine the possible causes using the Troubleshooting List as a guide. *Note* If all of the hydraulic circuits are bad, the problem is in a component common to all circuits, such as the pump. If, on the other hand, only one circuit is bad, concentrate on the parts of that circuit.
- Take Corrective Action.
  - Once the problem has been isolated and the possible cause has been determined, take the necessary corrective action.
  - Fully test the crane before returning it to service.

Troubleshooting List

Hydraulic Oil Condition

- Oil milky or dirty.
  - Water in oil (milky).
  - Filter failure (dirty).
  - Metal particles (mechanical failure).
  - Oil discolored or has burned odor.
  - See *Oil Overheating*.

❑ System Inoperative
■ Power Take-Off (PTO) not engaged. ❑ Engage PTO.
■ No oil in system.
❑ Fill tank to proper level. Check system for leaks. ■ Oil viscosity too high.
❑ Refer to Lubrication Chapter for proper viscosity. ■ Suction line plugged.
❑ Drain oil and clean suction line. Locate source of contamination. ■ Ball valve closed.
❑ Make sure this valve is fully open. ■ Restriction in system.
❑ Oil lines could be dirty or have inner walls that are collapsing and cutting off the oil supply. Clean or replace lines.
■ Air leaks in pump suction line. ❑ Repair or replace suction line.
■ Dirt in pump.
❑ Clean and repair pump. If necessary, drain and flush hydraulic system. Locate source of contamination. ■ Badly worn pump.
❑ Repair or replace pump. ■ Badly worn components.
❑ Examine and test valves, motors, and cylinders for external and internal leaks. If wear is abnormal, locate the cause.
■ Oil leak in pressure lines.
❑ Tighten fittings or replace defective lines.
■ Relief valves improperly adjusted or defective.
❑ Test relief valves to make sure they are opening at specified pressures. Refer to Hydraulic Schematic.
❑ Examine seals for damage that could cause leaks. Clean relief valves and check for broken springs and other possible causes.
■ Pump rotating in wrong direction. *Applies to knockdown units only.* ❑ Reverse to prevent damage.
***Important** Pump rotation must be matched with PTO and transmission.*
■ Operating system under excessive load. ❑ Check Capacity Chart for load limits.
■ Hoses attached improperly.
❑ Attach correctly and tighten securely. ■ Broken PTO.
❑ Replace defective parts. ■ Pump not operating.
❑ Check for broken pump shaft.

System Operates Erratically

■ Air in system.
❑ Examine suction line for leaks. Make sure oil level is correct (leaks on pressure side of system could account for oil loss).
■ Cold oil.
❑ Viscosity of oil may be too high at start-up. Allow oil to warm before operating controls. ■ Components sticking or binding.
❑ Check for dirt or gummy deposits. If dirt is caused by contamination, locate the source. Check for worn parts. ■ Pump damaged.
❑ Check for broken or worn parts. Determine cause of pump damage. ■ Dirt in relief valves.
❑ Clean relief valves.
■ Restriction in suction line.
❑ Suction line could be dirty or have inner walls that are collapsing and cutting off the oil supply. Clean or replace suction line.

System Operates Slowly

▪ Cold oil.
❑ Allow oil to warm before operating controls. ▪ Oil viscosity too high.
❑ Refer to Lubrication Chapter for proper viscosity. ▪ Insufficient drive speed.
❑ Make sure PTO is matched to transmission. Troubleshoot engine. ▪ Low oil supply.
❑ Check tank and add oil if necessary. Check system for leaks that could cause loss of oil. ▪ Air in system.
❑ Check suction line for leaks. ▪ Badly worn pump.
❑ Repair or replace pump. Check for problems causing pump wear such as misalignment or contaminated oil. ▪ Restriction in suction line.
❑ Suction line could be dirty or have inner walls that are collapsing and cutting off the oil supply. Clean or replace suction line.
▪ Ball valve closed.
❑ Make sure this valve is fully open.
▪ Relief valves not properly set or leaking.
❑ Test relief valves to make sure they are opening at specified pressures. Examine valves for damaged seats that could leak.
▪ Badly worn components.
❑ Examine and test valves, motors, and cylinders for external and internal leaks. If wear is abnormal, locate the cause.
▪ Valves plugged.
❑ Clean dirt from components. Clean orifices. Find source of dirt and correct. ▪ Oil leak in pressure lines.
❑ Tighten fittings or replace defective lines. Examine mating surfaces of fittings for irregularities.

Oil Overheating

▪ Operator holds control levers in power position too long, causing relief valve to open. ❑ Return control levers to NEUTRAL position when not in use.
▪ Using incorrect oil.
❑ Drain and refill system with proper oil. See Lubrication Chapter. ▪ Low oil level.
❑ Fill tank to proper level. Look for leaks. ▪ Dirty oil.
❑ Drain and refill with clean oil. Look for source of contamination. ▪ Engine running too fast.
❑ Troubleshoot engine.
▪ Incorrect relief valve pressures.
❑ Check and reset pressures; clean or replace relief valve. ▪ Internal oil leakage.
❑ Examine and test valves, cylinders, and motors for internal leaks. If wear is abnormal, locate the cause. ▪ Restriction in pump suction line.
❑ Clean or replace suction line.
❑ Dented, obstructed or undersized oil lines.
❑ Remove obstructions or replace defective oil lines. ▪ Control valve stuck in partially open position.
❑ Free spool so it returns to NEUTRAL position. ▪ Heat not radiating properly.
❑ Clean dirt and debris from oil cooler, hydraulic tank, oil lines and all other components.
❑ Make sure oil cooler fans are operating properly. The oil cooler fans should turn on when the oil temperature rises above 120°F. Make sure oil is circulating through oil cooler.

Oil Foaming

▪ Low oil level.
❑ Fill tank to proper level. Look for leaks. ▪ Water in oil.
❑ Drain and replace oil.
❑ Wrong kind of oil being used. Drain and refill system with proper oil. See Lubrication Chapter. ▪ Air leak in suction line.
❑ Tighten or replace suction line.
▪ Kink or dent in oil lines (restricts oil flow). ❑ Replace oil lines.
▪ Worn seal around pump shaft.
❑ Clean sealing area and replace seal. Check oil for contamination or pump for misalignment.

Pump Makes Noise

▪ Low oil level.
❑ Fill tank to proper level. Check system for leaks. ▪ Oil viscosity too high.
❑ Drain and refill system with proper oil. See Lubrication Chapter. ▪ Pump speed too fast.
❑ Operate pump at recommended speed. ▪ Suction line plugged or pinched.
❑ Clean or replace suction line. ▪ Ball valve closed.
❑ Make sure this valve is fully open. ▪ Sludge and dirt in pump.
❑ Disassemble and inspect pump and lines. Clean hydraulic system. Determine cause of dirt. ▪ Tank breather plugged.
❑ Replace breather. ▪ Air in oil.
❑ Tighten or replace suction line. Check system for leaks. Replace pump shaft seal. ▪ Worn or scored pump bearings or shafts.
❑ Replace worn parts or complete pump if parts are badly worn or scored. Determine cause of scoring. ▪ Broken or damaged pump parts.
❑ Repair pump. Look for cause of damage like contamination or too much pressure. ▪ Sticking or binding parts.
❑ Repair binding parts. Clean parts and change oil if necessary.

Pump Leaks Oil

▪ Damaged seal around drive shaft.
❑ Replace seal. Trouble may be caused by contaminated oil. Check oil for abrasives and clean entire hydraulic system. Locate source of contamination. Check the pump drive shaft; misalignment could cause the seal to wear. If shaft is not aligned, check the pump for other damage.
▪ Loose or broken pump parts.
❑ Make sure all bolts and fittings are tight. Check gaskets and seals. Examine pump casting for cracks. If pump is cracked, look for a cause like too much pressure or hoses that are attached incorrectly.

Motor Leaks Oil

▪ Damaged seal around drive shaft.
❑ Replace seal. Trouble may be caused by contaminated oil. Check oil for abrasives and clean entire hydraulic system. Locate source of contamination. Check the motor drive shaft; misalignment could cause the seal to wear. If shaft is not aligned, check the motor for other damage.
▪ Loose or broken motor parts.
❑ Make sure all bolts and fittings are tight. Check gaskets and seals.

❑ Examine motor casting for cracks. If motor is cracked, look for a cause like too much pressure or hoses that are attached incorrectly.
■ Back pressure too high.
❑ Check if return filter is bypassing; if so, replace element.

❑ Check for and remove any obstruction in return line.

Valve Sticks or Works Hard

■ Tie bolts too tight on valve stacks.
❑ Use manufacturer's recommendation to adjust tie bolt torque. ■ Valve broken or scored internally.
❑ Repair broken or scored parts. Locate source of contamination that caused scoring.

Valve Leaks Oil (External)

■ Tie bolts too loose on valve stacks.
❑ Use manufacturer's recommendation to adjust tie bolt torque. ■ Worn or damaged O-rings.
❑ Replace O-rings (especially between valve stacks). If contamination has caused O-rings to wear, clean system and look for source of contamination.
■ Broken valve parts.
❑ If valve is cracked, look for a cause such as too much pressure or hoses that are attached incorrectly.

Cylinder Leaks Oil (External)

■ Damaged cylinder barrel.
❑ Replace cylinder barrel. Correct cause of barrel damage. ■ Rod seal leaking.
❑ Replace seal. If contamination has caused seal to wear, look for source. Wear may be caused by external as well as internal contaminants. Check piston rod for scratches or misalignment.
■ Loose parts.
❑ Tighten parts until leakage has stopped. ■ Piston rod damaged.
❑ Check rod for nicks or scratches that could cause seal damage or allow oil leakage. Replace defective rod.

Cylinder Drifts or Will Not Hold Load

Important *See Cylinder Leaks Oil (External).*
■ Excessively worn or damaged piston seals.
❑ Disassemble cylinder and replace faulty parts. ■ Counterbalance valve or check valve stuck open.
❑ Replace valve.

Cylinder Will Not Extend or Not Retract

Important *See System Inoperative.*
■ Counterbalance valve or check valve stuck closed. ❑ Replace valve.

Boom Cannot Be Extended or Lowered

■ LMI function lockout.
❑ See LMI Operating Instructions.

Swing Inoperative or Erratic

Important *See System Inoperative or System Operates Erratically.*

▪ Swing parking brake switch. ❑ Brake not releasing.

❑ Check for a collapsed, restricted, or leaking brake release hose. Clean or replace the hose. *Note* The brake should fully release at 250 psi.

▪ Improper backlash between the swing pinion and the slewing ring gear. ❑ Adjust the backlash between the gears.

▪ Damaged slewing ring bearing. ❑ Replace the slewing ring.

Swing Brake Does Not Hold

▪ Brake return springs broken or brake discs worn or damaged. ❑ Disassemble the brake and replace the faulty parts.

Winch Will Not Lower Load or Lowers Load Erratically ***Important*** *See System Inoperative or System Operates Erratically.*

▪ Brake not releasing.

❑ Check for a collapsed, restricted, or leaking pilot line to the brake. Clean or replace the hose. *Note* The winch brake should fully release at 350 psi to 450 psi.

▪ Counterbalance valve not opening.

❑ Check for a collapsed, restricted, or leaking pilot line to the counterbalance valve. Clean or replace the hose.

Winch Will Not Hold Load in Neutral

▪ Excessive back pressure acting on the brake causing brake to release partially.

❑ Back pressure must not exceed 150 psi. Inspect the return lines between the control valve and tank for restrictions.

▪ Brake return springs broken or brake discs worn or damaged. ❑ Disassemble the winch and replace the faulty brake parts.

▪ Clutch slipping.

❑ Improper oil being used in winch can cause the clutch to slip. Drain the winch and refill with proper oil, see Lubri-cation Chapter.

❑ The clutch may be damaged or worn. Disassemble the winch and replace the clutch.

Winch Will Not Raise Load

Important *See System Inoperative.*

▪ Load too heavy.

❑ Refer to the Capacity Chart for load limits and applicable reeving diagram. ▪ LMI function lockout.

❑ See LMI operating instructions.

Boom Chatters When Extending or Retracting Boom

▪ Boom sections not lubricated.

❑ Lubricate the boom sections as instructed in the Lubrication Chapter. ▪ Slider pads worn or improperly adjusted.

❑ Check the slider pads for wear and proper adjustment.

Boom Does Not Sequence Properly

▪ Crowd rope system improperly adjusted.

❑ Adjust the crowd ropes.

Pneumatic troubleshooting and Maintenance:

The following troubleshooting charts cover common problems with pneumatic equipment including actuators, filters, regulators, lubricators, air valves, directional control valves and air cylinders. These lists are intended as a starting point for troubleshooting since it is impossible to include all possibilities. If one of the following situations exists, work through the source and remedy lists as possible causes. Re-check operation after checking each source before trying another source.

Actuator Moving Abnormally Slow

4 Source/Symptom: Excessive air choke

Possible Problem	Recommended Action
Flow control valve incorrectly adjusted	Readjust the valve.
Plugged air silencer	Replace or clean silencer.
Air leak or squeezed tube	Repair air leak or tube.
Plugged filter	Replace air filter.
Damaged cylinder or seal	Replace cylinder or seal.

5 Source/Symptom: Pressure too low

Possible Problem	Recommended Action
Damaged or incorrectly adjusted pressure regulator valve	Replace regulator or readjust rating as shown in drawing.
Plugged filter	Replace filter.
System leaks	Fix leaks.
Directional or other valve open due to dirt or failed pilot circuit	Locate damaged part and clean or replace it.
Cylinder pipe, piston or seal damaged	Repair or renew damaged parts.

Filter / Regulator / Lubrication Unit

6 Source/Symptom: Air leak at regulator

A continuous air leak from the small vent hole in the regulator bonnet indicates a leaky main bonnet or diagram. Repair parts should be ordered at once and the regulator should be scheduled for repair. Overhaul kits with diaphragm and seals are available for most standard regulators.

IMPORTANT:
Replace a diaphragm or the seals as soon as possible after the leak is discovered. A complete failure of the diaphragm might apply full house pressure to the pneumatic system. This may cause some solenoid valves to shift by themselves, creating a safety hazard to personnel and equipment.

7 Source/Symptom: Pressure problems

If diaphragm is cracked or broken, a high velocity air leak at the vent hole will occur. Replace diaphragm.

8 Source/Symptom: Filter problems

Clean or replace the filter element regularly. When over-contaminated, the filter element will create a pressure drop which may affect system operation.

Drain condensate from the filter bowl before it rises above the baffle. Otherwise, air turbulence may pick up the water and carry it downstream into the pneumatic system. If condensate requires frequent draining, install an automatic drain.

Use filter elements with the appropriate rating to protect cylinder barrels and other smooth surfaces from harmful contaminants.

Directional Control Valve Not Changing Position

9 Source/Symptom: Coil not picking up

Possible Problem	Recommended Action
Electric failure	Fix electric failure and check mechanical spool movement.

10 Source/Symptom: Valve spool stuck

Possible Problem	Recommended Action
Impurities between spool and sleeve	Replace valve.
Valve pilot not working	Replace or clean piloting part.

11 Source/Symptom: Proportional valve not responding

Possible Problem	Recommended Action
Valve not receiving set value from program	Locate and fix electric failure.
Set value received but valve not responding	Replace the proportional valve.

Air Valves

12 Source/Symptom: Low voltage problems

Applying low voltage to an AC solenoid valve will cause the solenoid coil to draw high inrush current continuously and burn out, because there won't be enough magnetic force to seat the armature of the valve. Causes of low voltage include high resistance connections; and low voltage on the control transformer that powers the circuit.

13 Source/Symptom: Voltage transients

Solenoid burnout may be caused by high transient voltages that break down coil insulation, causing short circuits to ground. This problem is most common where solenoids are connected to voltage sources that supply motors and other inductive loads. Switching such loads on and off can cause very high voltage peaks that will be seen by all components in the circuit. The remedy is to isolate solenoid circuits. Use 120-volt control circuits and observe good grounding practices. Electrical filter networks may also be used.

14 Source/Symptom: AC hum

If the solenoid noise level is very high and occurs each time the solenoid is energized, operate the manual override to check to see that the armature is seating. If the noise decreases, it indicates incomplete solenoid motion. Clean all moving parts and check for correct voltage supply.

Extremely loud AC hum can be caused by a broken part within the solenoid. Replace the solenoid.

15 Source/Symptom: Valve spool stuck

The armature may be held unseated because a valve spool won't shift. The solenoid will draw high inrush current for too long a time and burn out.

A metal-to-metal spool-type valve may be varnished in place, or dirt may prevent the spool (and the solenoid armature) from shifting. Repair or replace.

16 Source/Symptom: Temperature problems

Solenoid failure can be expected when a valve is operated above its rated temperature. Insulation may fail, causing shorts to ground or shorts between turns of the coil. If ambient temperatures are too high, consider moving the valve or using a pilot-actuated valve with a remote pilot valve.

Air Cylinders

17 Source/Symptom: Drift

Piston seal leaks can cause a cylinder to drift from its normal position. To check the seal, pressurize one side of the piston and observe leakage from the opposite side. Virtually no air should leak past pistons equipped with soft seals. Replace seals as needed.

Other circuit leaks also can cause a cylinder to drift. Check for leaks through the directional control valve (internally and externally) and in connecting lines. Fix leaks as needed.

18 Source/Symptom: No movement

Possible Problem	Recommended Action
Pressure too low	Check pressure at cylinder to make sure it meets circuit requirements.
Piston seal leak	Operate valve to cycle cylinder. Observe fluid flow at valve exhaust ports at end of cylinder stroke. Replace piston seals if flow is excessive.
Scored cylinder bore	Replace necessary parts. Eliminate contaminants from air supply.

19 Source/Symptom: Erratic movement

Possible Problem	Recommended Action
Load misalignment	Re-align cylinder and load.
Large difference between static and dynamic friction	Install flow control valves to provide back pressure to control stroke.

20 Source/Symptom: Cylinder body seal leak

Possible Problem	Recommended Action
Loose tie rod	Repair or replace.
Excessive pressure	Repair or replace.
Pinched or extruded seal	Repair or replace.
Seal deterioration - soft, gummy	Repair or replace.
Seal deterioration - hard, brittle. Usually due to temperature extremes.	Repair or replace.
Seal deterioration - wear	Repair or replace.

21 Source/Symptom: Rod gland seal leak

Possible Problem	Recommended Action
Torn or worn seal	Examine piston rod for dents, gouges or score marks. Repair or replace. Check gland bearing for wear. Repair or replace.
Pinched or extruded seal	Replace gland seal.
Seal deterioration - soft, gummy	Check compatibility of seals with lubricant. Replace with new seals.
Seal deterioration - hard, brittle. Usually due to temperature extremes.	Replace seals and shield cylinder from temperature extremes.
Seal deterioration - wear	Replace seals.

22 Source/Symptom: Contamination in circuit

Possible Problem	Recommended Action
Sealing compound inside fittings	Protect fittings during storage. Follow proper sealing procedures.

	Disconnect cylinder from circuit and attempt to clear debris from lines by aggressive air blast.
Improperly filtered feed pipes	Evaluate circuit design, consider adding pre-filters.
Burrs inside piping components	Components and/or piping not protected during repairs and/or storage. Disconnect cylinder from pipes and remove burrs. Clear remaining debris from lines with aggressive air blast.
Seals extruding from excessive pressure	Troubleshoot cause for excessive pressure and make changes to prevent. Reseat seals if possible, otherwise clean and reseal.
Generally excessive dirt in circuit	Wipers or boots not used on cylinders where needed. Evaluate circuit design, consider adding wipers or boots to cylinders.

Programmable Logic Controller (PLC)

Programmable logic controller is globally known as ‘Work Horse’ of industrial automation. Its invention was to replace large sequential relay circuits for machine control. PLC’s were first introduced in the late 1960’s. Typically PLC system has basic functional components of processor unit, memory, power supply unit, input or output interface section, communication interface and programming device. Fig shows basic arrangements of PLC.

PLC has four main units:

1. The program memory

It is the memory space where the program instructions for the logical control sequence are Stored.

2. The Data Memory

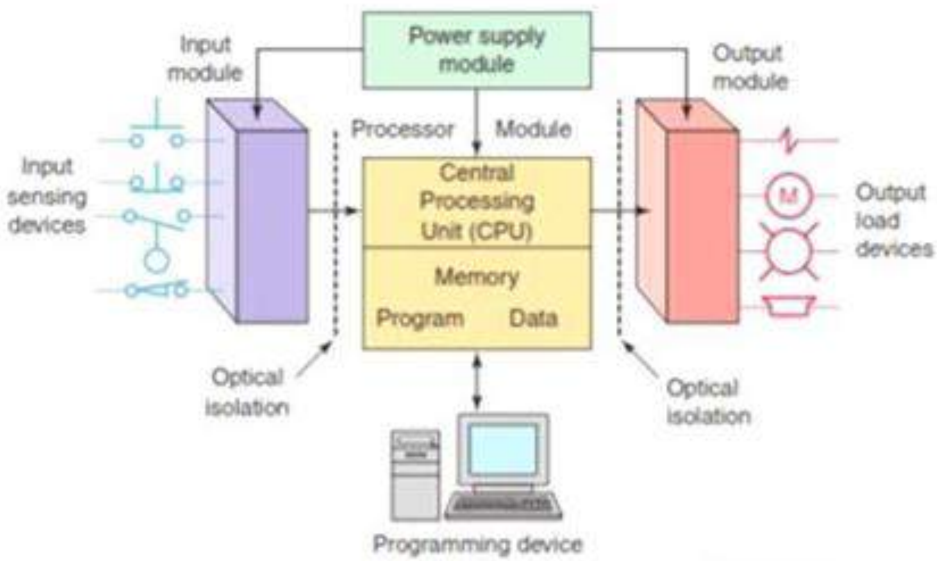
The status of input/outputs likes, switches, previous values of data and other working data is stored.

3. The Input Devices

These are the hardware/software inputs from the field from industrial process. The signals maybe sensors, switches proximity detectors and interlock settings etc. These inputs trigger the sequences in user program as when this switch is hit by incident or accident the whole PLC process is suspended to a halt situation.

4. The output devices

The output ports of a PLC are of the relay type or to isolator with transistor traic types depending on the devices connected to them, which are to be switch on or off. Generally the digital signal from an output channel of a PLC is used to control an actuator, which in turn controls some process. The term actuator is used for the device that transforms the electrical signals into some more powerful action.



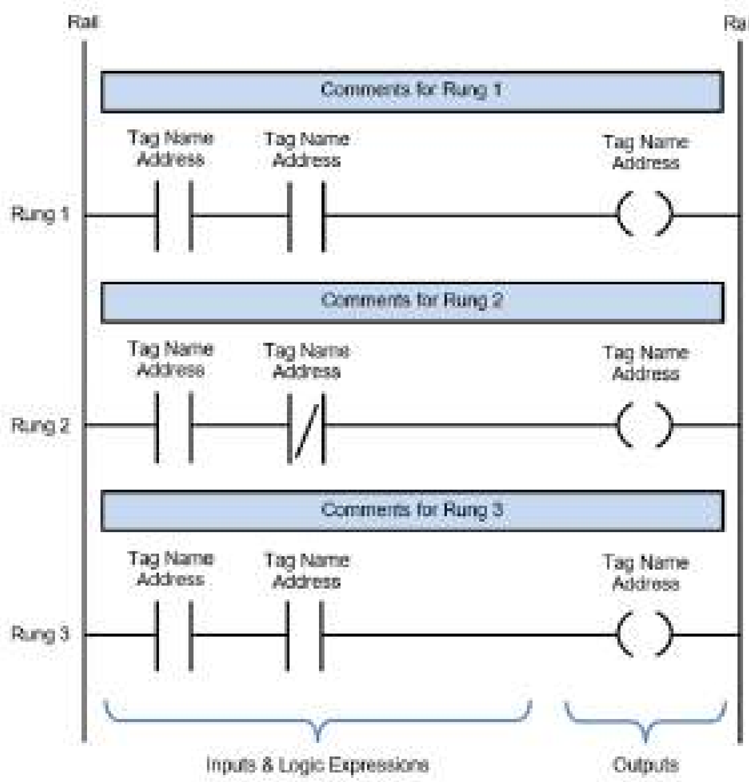
PLC Ladder Logic Programming:

When implementing a ladder logic program in a PLC there are **seven basic parts of a ladder diagram** that critical to know. They are rails, rungs, inputs, outputs, logic expressions, address notation/tag names and comments. Some of these elements are essential and others are optional.

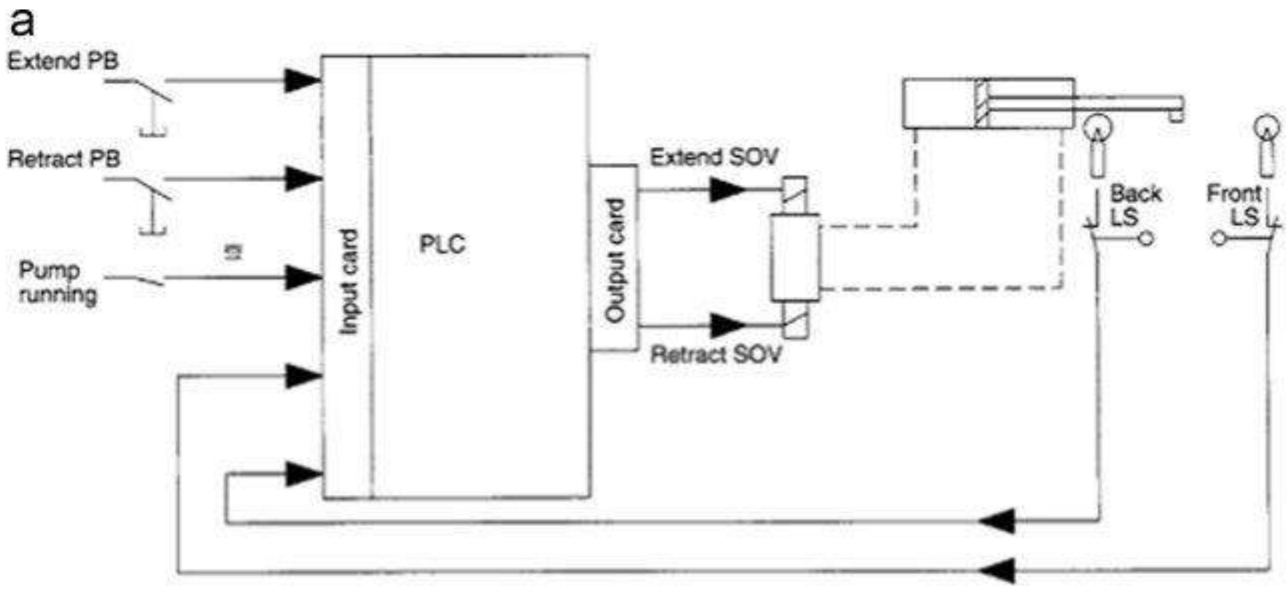
To help understand **how to draw ladder logic diagrams** the seven basic parts of a ladder diagram are detailed below.

1. **Rails** – There are two rails in a ladder diagram which are drawn as vertical lines running down the far most ends of the page. If they were in a relay logic circuit they would represent the active and zero volt connections of the power supply where the power flow goes from the left hand side to the right hand side.
2. **Rungs** – The rungs are drawn as horizontal lines and connect the rails to the logic expressions. If they were in a relay logic circuit they would represent the wires that connect the power supply to the switching and relay components.

3. **Inputs** – The inputs are external control actions such as a push button being pressed or a limit switch being triggered. The inputs are actually hardwired to the PLC terminals and represented in the ladder diagram by a normally open (NO) or normally closed (NC) contact symbol.
4. **Outputs** – The outputs are external devices that being are turned on and off such as an electric motor or a solenoid valve. The outputs are also hardwired to the PLC terminals and are represented in the ladder diagram by a relay coil symbol.
5. **Logic Expressions** – The logic expressions are used in combination with the inputs and outputs to formulate the desired control operations.
6. Address Notation & Tag Names – The address notation describes the input, output and logic expression memory addressing structure of the PLC. The tag names are the descriptions allocated to the addresses.
7. **Comments** – Last but by not least, the comments are an extremely important part of a ladder diagram. Comments are displayed at the start of each rung and are used to describe the logical expressions and control operations that the rung, or groups of rungs, are executing. Understanding ladder diagrams is made a lot easier by using comments.



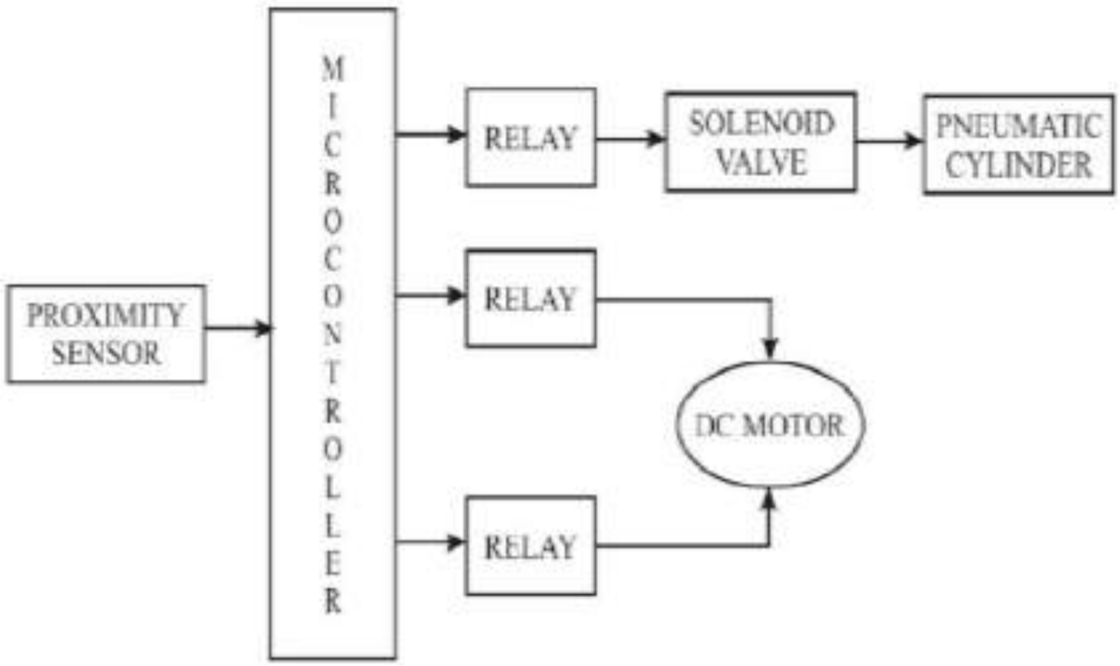
Control of Double Acting Hydraulic Cylinder using PLC



Applications of Microcontroller in Hydraulics and Pneumatics:

A microcontroller is a computer on chip that is, a single integrated circuit containing a core processor, memory unit, and programmable input/output ports. Microcontrollers are versatile and hence used in places where automatic control of products and devices, such as controlling of automobile engine systems, implantable medical devices, remote controls, toys and other embedded systems. The size and cost of employing a microcontroller is very less than that compared to a design that uses microprocessor whose units are separate such as memory, timer, counter and separate input/output devices.

The Programme is written using machine language with the predefined sequences. The control unit of microcontroller execute the programme and makes the motor to operate and thereby opens the solenoid operated directional control valves. A solenoid operated directional control valve is an electro mechanically actuated valve. The control of this valve is done by an electric current through a solenoid. Directional control valve sends the pressurized fluid either to blank end or rod end of the actuator to get either extension or retraction.



Low Cost Automation

Automation means to replace human control through machines and technology. This includes automation in any unit i.e. storage systems, production lines, assembly lines, Software etc. Low Cost Automation (LCA) is defined as technology that creates some degree of automation using existing tools, methods and equipment. Low cost automation involves the introduction of standard equipment, mechanisms and devices to convert manual operations to automatic ones. Investment cost is low, as the term itself implies, and the Return of Investment in terms of improved productivity and better work efficiency is high. LCA may best be paraphrased as "simple automation" Jigs, fixtures, drills etc are the few tools used in LCA.

Fluid power and its scope in low cost automation

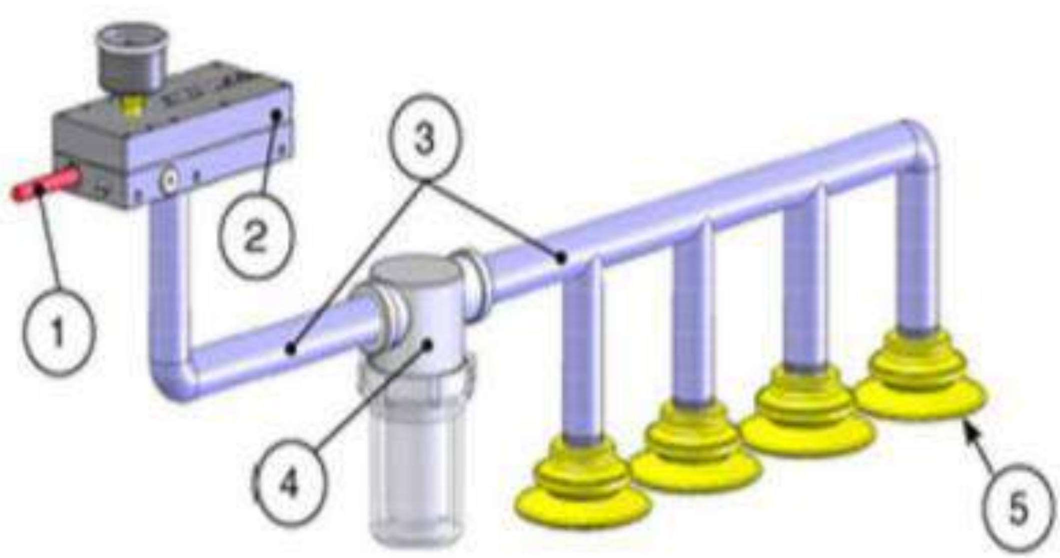
Fluid power means using pressurized gas or liquid in a confined space to control force or to achieve certain movement of the mechanical element. Fluid power consists of pneumatic and hydraulic systems. Pneumatic system makes use of compressed gas for performing the work whereas in hydraulics pressurised liquid, oils, petroleum etc is used for performing the work.

Merits of using fluid power system

- Fluid power is easy to produce, transmit, regulate, control and can be operated easily.
- Low weight to power ratio.
- Multiplication and variation of forces.
- Frictional resistance is less.
- Noise and vibrations produced is minimal.

- We can start, stop, accelerate, decelerate, reverse or position change with great accuracy using simple levers and push buttons.
- Economical
- FPS can be used where safety is of vital importance.

Case study on pneumatic gripper used for Low Cost Automation



The Pneumatic grippers were used which is specifically a type of pneumatic actuator that involves either a parallel or angular motion i.e. the „tooling jaws, fingers or rubber suction diaphragm" that will grip on object. In pneumatic grippers, the vacuum is created in the rubber cups by creating pressure difference with the help of the force from the compressed air by compressor. The gripper is placed directly on a product and with vacuum generation the rubber cups creates sucking action which in turn grip the object firmly and tightly.