Volume 3.

STUDY OF HYDRAULIC VALVES AND PUMPS AND ACCUMULATORS

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Chapter - 9

INTRODUCTION TO HYDRAULIC SYSTEM

So far we studied the design of hydraulic cylinder and press-body, in this section we will study the design of hydraulic system required to operate a hydraulic press.

9.1 Importance of hydraulic knowledge: - A 50 Ton press is available in Rs. 30000/-, in market, at most of the dealer. And on other hand for a reputed manufacturer it is not possible to manufacture similar press even at Rs. 50000/-. It is not because a good manufacturer wants a high profile, but even the raw material cost of good quality 50 Ton press may be costing more than Rs. 50000/-.

A sequence of operation of a press could be achieved in many ways in hydraulics. Even with technically wrong, in-accurate, cheap, undoable old and used valves and pumps or with high quality, correct and efficient valves and pump, or combination of both.

Only after understanding hydraulic principle, its various components, their functioning, we can understand what manufacturer makes and supply. We can also design; do maintenance and servicing of our own equipments. Hence it is important to study various valves, pump, hydraulic principle and other equipments in details.

A Hydraulic System Consist of :-

1. Prime-Mover
2. Pump
3. Pressure Regulating Valve.
4. Direction Control Valves.
5. Supporting Valves. (Flow Control Valve, Check Valve etc.)
6. Standard Accessories.

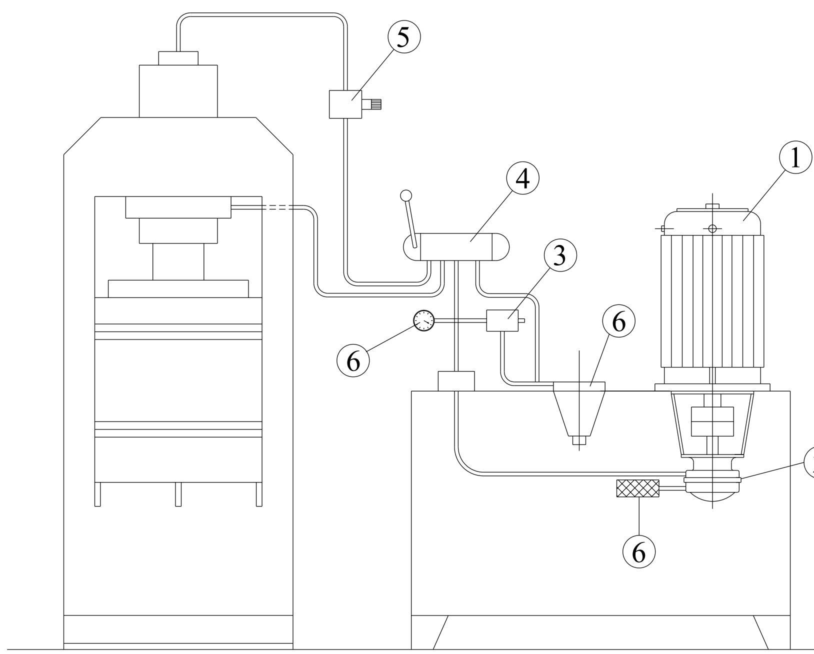


Figure No. 9.1

We will study all the above mentioned components in details in next chapters.

9.2 PRIME-MOVER (MOTOR)

Two types of prime movers are used in hydraulic system.

- Electric Motor
- I. C. Engine

The hydraulic system used in mobile vehicles drives their power from main I. C. Engine of automobile. As well as those hydraulic equipments, which are going to be used at those areas where there is no electricity supply, then in such case also I.C. engine are used to drive the hydraulic pump of hydraulic equipment.

Electric motors are convenient and most commonly used prime-mover in hydraulic system.

Electric Motors :-

1. Standard motors are available in four speeds 750, 1000, 1440, 3000 RPM. In hydraulic generally 1440 RPM is used.
2. Standard motors are available in many classes of insulation. In hydraulic power pack we use ‘F’ class of insulation. Common motor have ‘B’ class insulation, good quality motor ‘E’ grade insulation but ‘F’ grade is best, most reputed manufacturer using ‘F’ grade insulation.
3. In refinery and chemical plant, a small spark in junction box, connection box of motor may cause an explosion or fire. Due to the combustible fumes around. Hence in such atmosphere “Flame and Explosion Proof” electrical items are used. Such items have two metallic casing or enclosure. In one casing main equipment is enclosed and in other enclosure it’s electrical connection is fitted. All incoming and outgoing wires are through special cables and gland. All these arrangement is done so the heated surface and spark do not come in contact with outside combustible atmosphere. And due to residual combustible gases even if an explosion takes place within enclosure of electrical component then it remains confined in enclosure and do not come-out in open atmosphere.

   Electric motor, solenoid valves, limit switch etc. are available in flame and explosion proof grade.

   Hence whenever such requirement of safety arises, only such safe electrical item should be used.
4. Motors are made in many grade of protection against entry of water and dust etc. generally commercial grade of motor are with protection grade of IP44. But better grade protection is IP65 in which case water cannot enter in motor from rear (Fan side)?
5. Nowadays most of the pumps are flange mounted type. If such pumps are coupled to flange of motor through a accurately machined bracket and coupling, then centerline of pump and motor can be accurately controlled. Which increases bearing life of both motor and pump. Hence always try to select flange type motor. In market vertical flange mounted motor, and horizontal foot mounted motor with flange is available. According to requirement they should be selected.
6. At full load and working pressure electric motor should draw only 90% of it full rated current.

7. When a hydraulic system starts and motor is switch on, motor may start with no load on it, or full load on it. In case of no load start equipment, use slip ring type of electric motor, and in full load start type of requirement use squire cage type of electric motor.

8. Up to 15HP and no load start type of requirement DOL starter could be used while above 15HP use star-delta type of motor-starter.

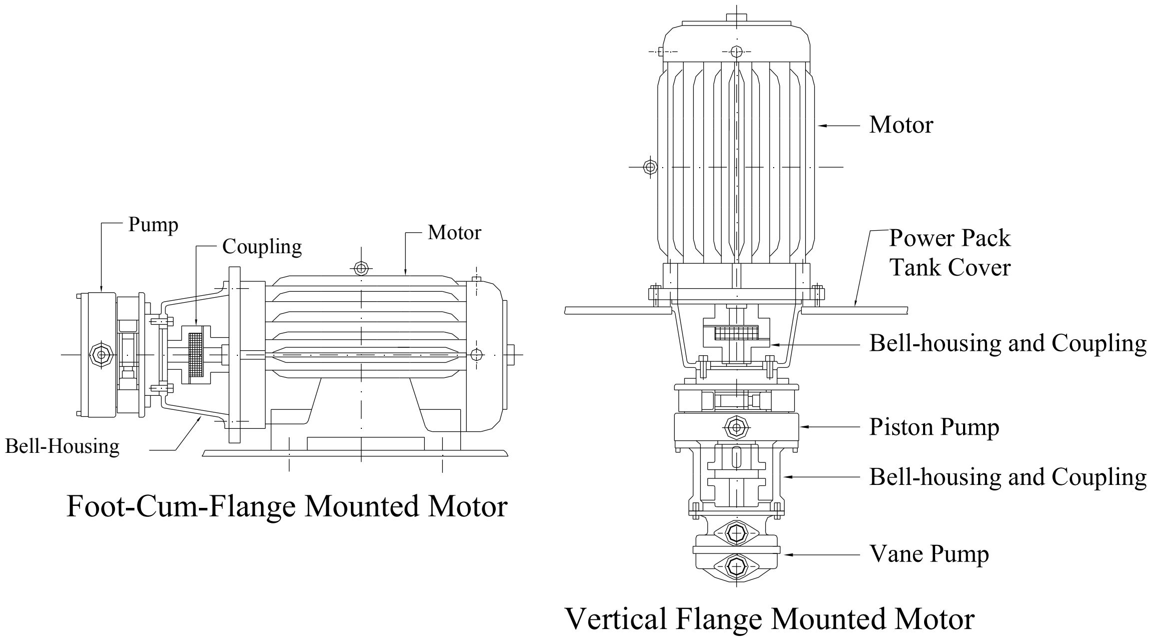


Figure No. 9.2

9.3 PUMP

Hydraulic pump is heart of a hydraulic system. It pumps oil in hydraulic system and converts the mechanical energy of prime-mover into hydraulic energy. (Hydraulic horsepower). Only positive displacement types of pumps are used in high-pressure hydraulic system.

9.3.1 Terms related to pumps: -

A pump is described in following terms.

a) Type of Pump: -

There are three types of pumps namely, vane pump, gear pump and piston pump. These each type of pumps has many verities, which will be discussed later in this chapter.

b) Displacement: -

This is oil discharge of pump per revolution of its shaft. This is generally indicated as Cubic Centimeter per revolution.

c) Delivery: -

This is total discharge of pump at particular RPM of prime mover, and at particular pressure. It is indicated as liters per minute. Delivery of pump changes with RPM of prime-mover and operating pressure, hence it is generally indicated as graph. For example a vane pump of 28 CC per revolution displacement will have 40 LPM discharge at 1440 RPM at 10 kg/cm^2 working pressure, and same pump will have 35 LPM discharge at 1440 RPM and 175 kg/cm^2 working pressure.

d) Pressure Rating: -

Vane pump can operate up to maximum pressure 210 kg/cm^2, Gear pump 250 kg/cm^2, and Piston pump 550kg/cm^2. This is the maximum limit; many manufacturers have much less working pressure. Hence it is indicated with pump, so that it is always operated within safe limit, to avoid any damage to pump.

e) Volumetric Efficiency: -

All pumps give higher or theoretical discharge at low-pressure. And discharge decrease as pressure increase due to internal leakage between various parts of pump.

Efficiency = Actual Output / Theoretical Output.

Higher the efficiency, better the performance and low heat generation and rise in temperature of oil.

9.3.2 General Selection Criteria: -

1. Gear and vane pump are economical than piston pump.

2. Vane pumps are ratd up to 210 kg/cm^2, gear pump up to 250 kg/cm^2, and piston pump as high as 550 kg/cm^2 in India.

3. Vane pump are economical and simple in maintenance and repair. Their discharge capacity can be changed by simply changing cam ring, vanes, pressure-plate etc. all are made from harden alloy steel, hence they are comparatively less susceptible to heat and oil contamination as compared

to other pump. Hence for most moderate pressure and heavy duty operation vane pumps are most suited. Most of the injection mounding machines use vane pump.

4. Gears pumps are made from harden alloy steel gears and aluminum or C.I. casting casing. Pressure is developed between the gear teeth and casing. When gear rotates, due to oil contamination, heat, or pressure surge if pump casing get score or get expanded. Then it cannot be repaired, and pump stops developing pressure. Hence even though gear pump can also be used for moderate pressure and heavy duty operation, but utmost care should be taken to avoid oil contamination, oil heating and pressure surge. Forklift, Hydraulic mobile crane, tractor etc. uses gear pump.

5. There are two types of piston pump available in market. Radial piston pump and Axial piston pump. Both pumps are best suited for high pressure heavy duty work. But basic cost as well as maintenance charges of axial piston pump is much more than radial piston pump in India. In case of radial piston pump one piston or one pumping element can be changed or repaired, which cost 5 to 10% cost of pump may cost. While in axial piston pump it is very difficult to individually repair any piston pumping element, and all the pistons or pumping element has to be replaced which may cost 70% of pump cost.

High capacity best quality radius piston pump are available and used extensively in hydraulic application such as presses, cranes, earth moving vehicle, but ut-most care should be taken to avoid oil contamination, and to protect pump.

Axial piston pump also gives equally best performance as axial piston pump. But radius piston pump have one more advantage. They are available with extended shaft from rear end of pump. Hence in those applications where two pumps are coupled to motor then radius piston pumps best suits to such application. Vertically flange-mounted motor, coupled to axial piston pump through bracket, and axial piston pump coupled to another gear or vane pump from its rear shaft and through mounting bracket is best combination, and widely used in hydraulic presses. (As shown in figure No. 26.1)

Whatever we described above is as per pump made and available in India. In international market situation may differ.

9.3.3 Vane Pumps : -

Vane pump consists of vanes (Blades) which slide in slots in a rotor. Rotor eccentrically rotates in a cam-ring. Vanes, rotor and cam-ring are covered from both sides by pressure plates. When rotor rotates by drive shaft, it throws out vanes (blades) due to centrifugal force against cam ring. Vanes rub against cam-ring under centrifugal force as rotor rotates.

But as rotor is eccentrically located in cam-ring, hence while rubbing against cam-ring blades also reciprocate in and out in slots in rotor. Because of this action the volume between two vanes increase and decrease in one rotation of rotor. When volume between vanes increase, the vacuum get created which suck oil between vanes. And when volume between vanes decreases it push out oil between vanes. This cause the pumping action of vane pump.

To throw out vanes against cam-ring, and to make a leak proof joint between cam-ring and vanes minimum 600 RPM of rotor is required. The schematic diagram of pump is shown in following figure.

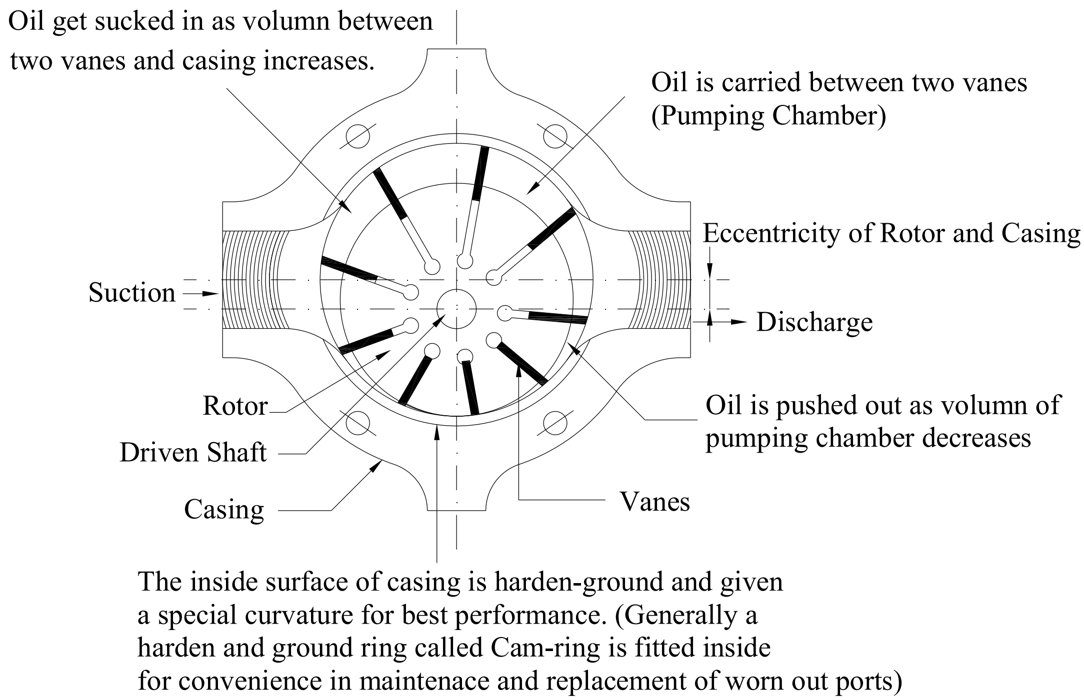


Figure No. 9.3.3

Types of Vane-Pump: -

9.3.4 Types of Vane Pumps: -

There are three types of Vane-pump namely.

a) Fixed displacement vane pump.

b) Variable displacement vane pump.

c) Tendum pump (double pump).

a) Fixed displacement Vane Pump: -

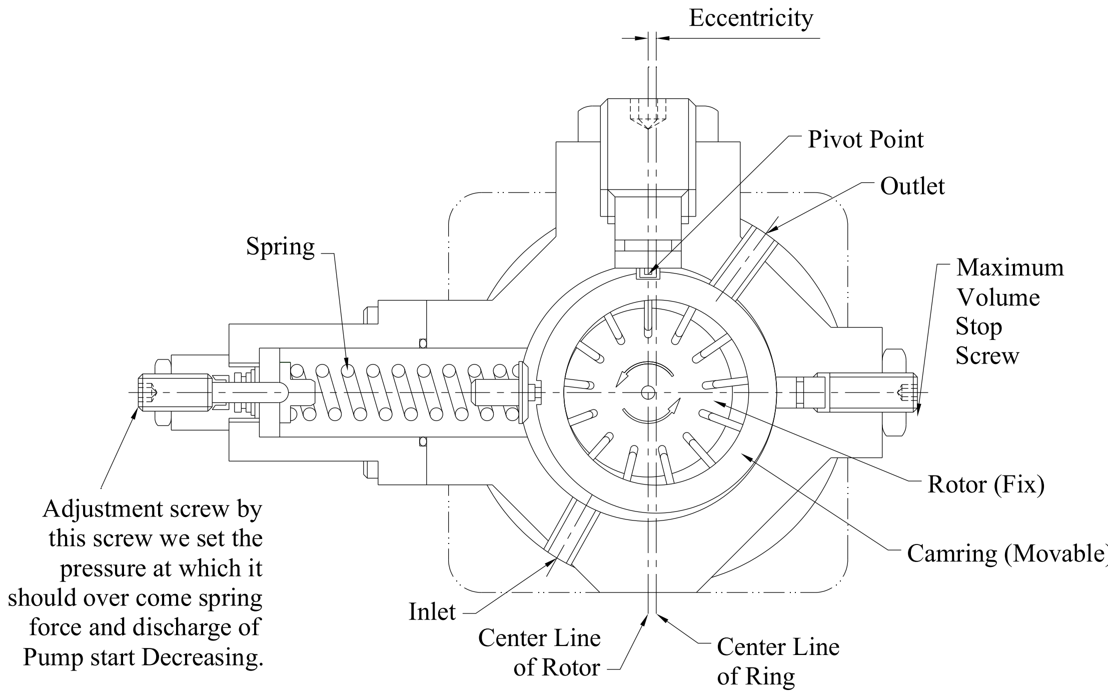
The schematic diagram shown in figure no____ is a fixed displacement vane pump. In this type of pump the eccentricity between pump cam-ring and rotor is fixed and pump discharge always remains same at a particular pressure. Fixed displacement type vane pump is most widely used in industry. For better performance and longer life the rotor is balanced under pressure.

b) Variable displacement Pump: -

In variable displacement the discharge of pump can be changed by varying the eccentricity between rotor and pump cam-ring. As eccentricity increases pump discharge increases. With decrease in eccentricity discharge decreases and oil flow completely stops when rotor becomes concentric to pump cam ring.

In a hydraulic system when it is required that after reaching certain pressure, the discharge of pump should reduce, and should be just sufficient to maintain the required pressure, then variable discharge pump is used. By decreasing pump discharge at high pressure we save the input energy of prime-mover.

In variable discharge pump the cam-ring is hinged at one point, and rotor is fixed. A spring on one side off-center the cam-ring and increases eccentricity between cam-ring and rotor, which results in high discharge. As pressure increases it acts against spring and try to make it concentric with rotor, as eccentricity decrease discharge decreases and when cam-ring and rotor become concentric discharge stops completely. There is a mechanical stopper to avoid complete concentricity and to maintain some minimum oil flow as required by the hydraulic system.



Variable Discharge Vane Pump

Figure No. 9.3.4

a) Tandem Vane-Pump: -

Double pump or duel pump. It is basically two fixed discharge type independent vane pump, combined together. For convenience the drive shaft is made common so that both pumps could be operated with single prime-mover and suction is common, while oil discharge port is separate.

Both pumps have separates rotor and cam-ring, hence accordingly separate discharge capacity. Both can operate two separate systems with independent working pressure setting.

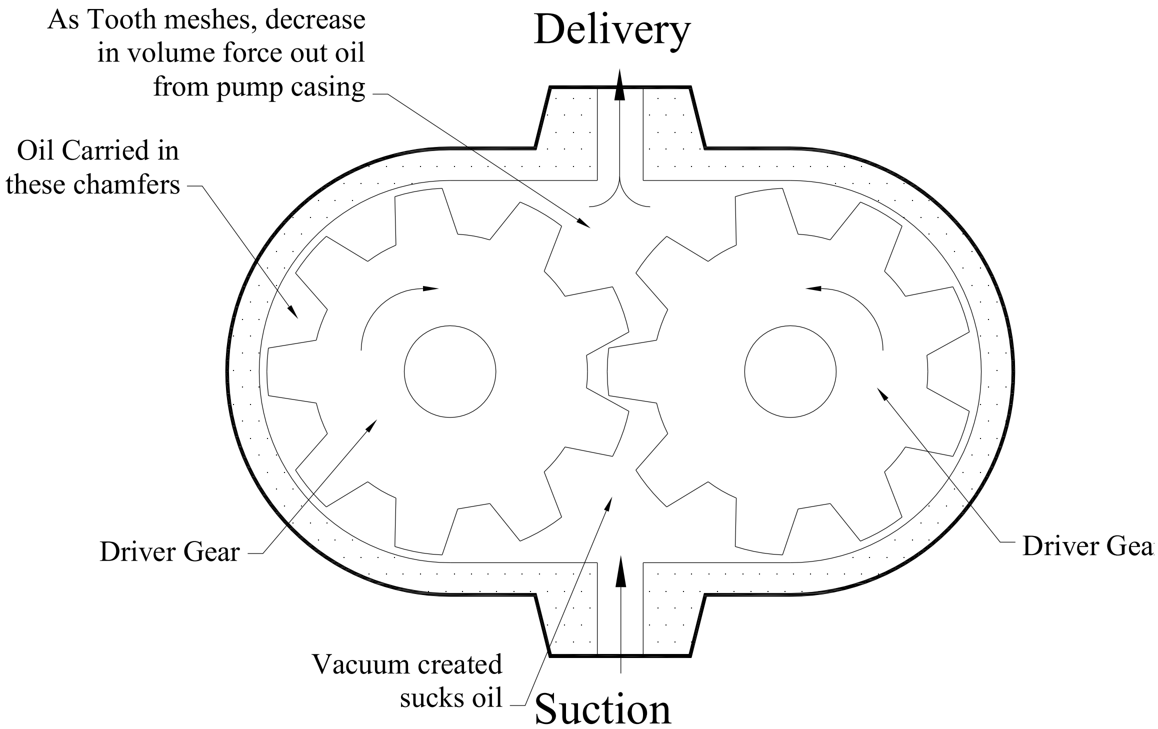
In industry generally these types of pump are used in those applications where combination of low pressure and high discharge pump is required for high approach and return speed of piston rod and low discharge and high pressure is required for their pressing operation.

9.3.5 Gear Pump: -

Gear pump consists of two gears, harden and ground and engaged with each other. They are enclosed by pump casing and side-pressure plates, all fitted with very close tolerance. When gear rotates the side where teeth disengaged create partial vacuum, which sucks oil in pump casing. Oil is carried between gear teeth and casing, and the side where teeth of gears start engaging due to reduction in volume oil is pushed out of pump. This is how gear pump works.

As there is high pressure on one side and low pressure on other side of gears, hence gear pumps are always of unbalance type. And heavy duty bearings are to be used in gear pump.

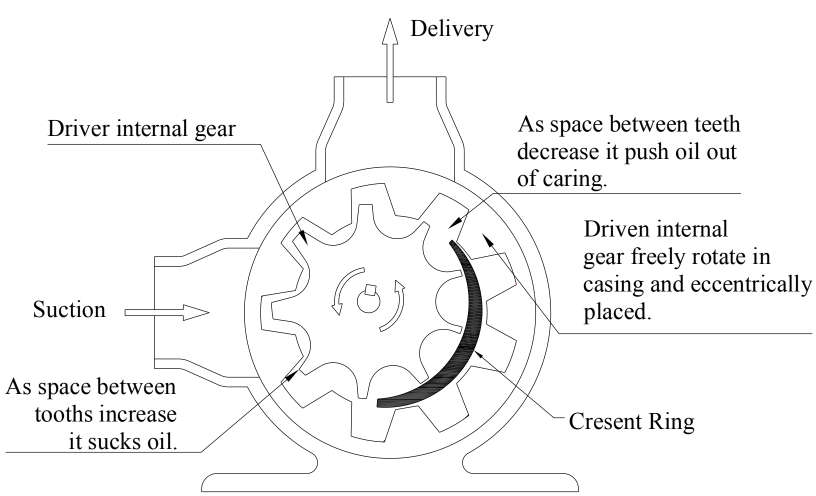
Two, three or four gear pump could be assembled on single shaft, and could be used for independent circuit or could be used collectively.



Gear Pump
Figure No. 9.3.5

a) Internal Gear Pump : -

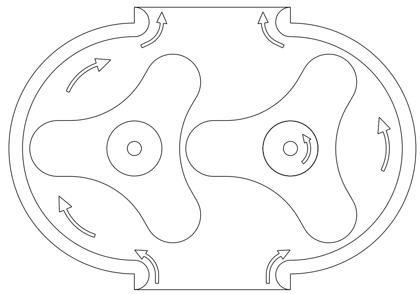
Figure explains the principle of internal gear pump. One driver gear with external teeth rotate inside a internal gear with crescent ring. The engagement and disengagement of teeth causes the oil flow. Advantage of internal gear-pump is its compact size, but it cannot be used above 100 kg/cm^2.



Internal Gear Pump
Figure No. 9.3.5 (a)

b) Lobe Pump :-

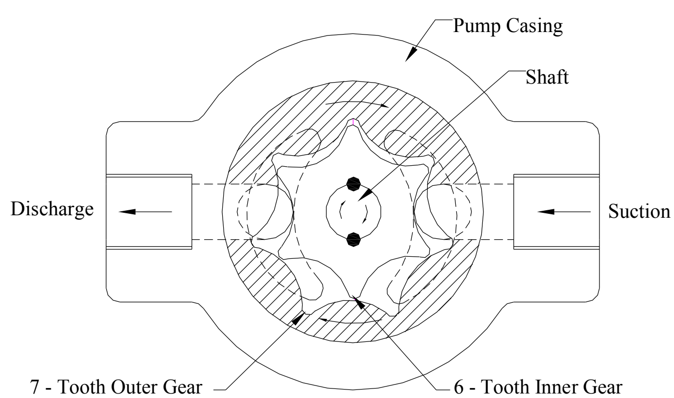
In this type of pump the external gear are replaced by three lobes. This type of pump has more displacement per revolution then same size of gear pump, but the discharge of such pumps are more pulsating and pump is used for low pressure application.



Lobe Pump
Figure No. 9.3.5 (b)

c) Garrotter Pump :-

In this type of pump an external tooth gear driver rotates inside a internal gear. Driver gear has one tooth less than the internal gear. Hence the internal gear rotates slower than driver gear. Teeth of both gear remain in contact with each other. But as the driver gear has one tooth less than the internal gear, hence on one half side the volume increase with rotation of gear hence oil gets sucked and on other side volume between teeth decrease, hence it pumps out oil out of pump casing. This cause pumping action.



Gerotor Pump
Figure No. 9.3.5 (c)

9.3.6 Piston Pump: -

Working Principle of Piston Pump: -

Piston pump consists of number of pumping elements. Each pumping element consists of a small cylinder, a small piston, two non-return valves and a mechanism to generate reciprocating motion between piston and cylinder.

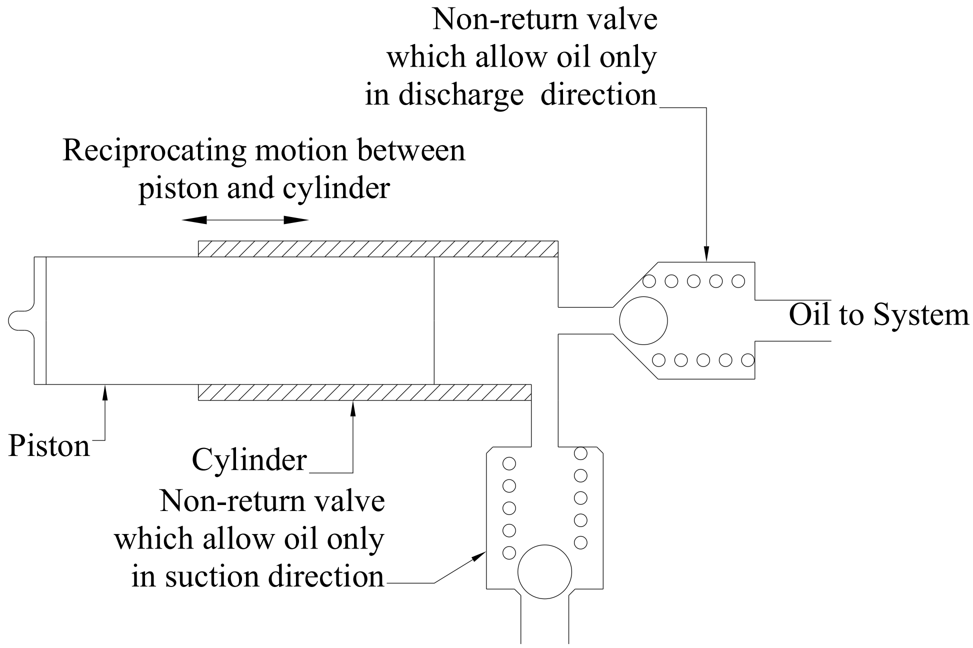


Figure No.9.3.6

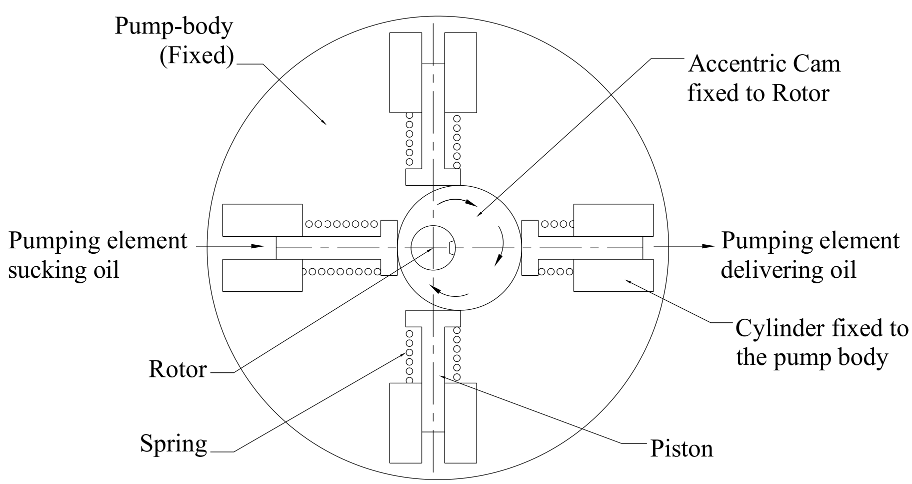
In outward stroke of piston, cylinder sucks fluid, and in inward motion of piston, cylinder delivers fluid. Similar numbers of small pumping units are used in one piston pump. The mechanism to reciprocate piston differs in different type of pump.

Piston pump is available in two types namely.

1. Radial Piston Pump.
2. Axial Piston Pump.

9.3.7 Redial Piston Pump: -

A schematic diagram of radial piston pump is as follow.



Schematic Diagram of
Radial Piston Pump
Figure No. 9.3.7

We have shown four pumping elements in our drawing, while in actual practice radial piston pump consists of 3, 5, or 7 pumping elements.

In redial piston pump the cylinder of pumping element is fixed to main pump-body and piston is forced against rotor by spring, as shown in above sketch. Rotor is placed eccentric to the pump body, hence when it rotates it produces reciprocating motion of piston assemblies. In radial piston pump, piston reciprocates perpendicular to axis of rotor.

9.3.8 Axial Piston Pump: -

In case of axial piston pump, the pumping assemblies have similar cylinder, piston and check valves, but piston reciprocates either parallel or at some angle to pump shaft axis, but not perpendicular to it.

Axial piston pump are of two types namely swash plate type and bent axis type. The principle of operation of these two types of pump is explained in following sketches. Piston pump of both radial piston and axial piston type are available fixed as well as variable displacement type pump.

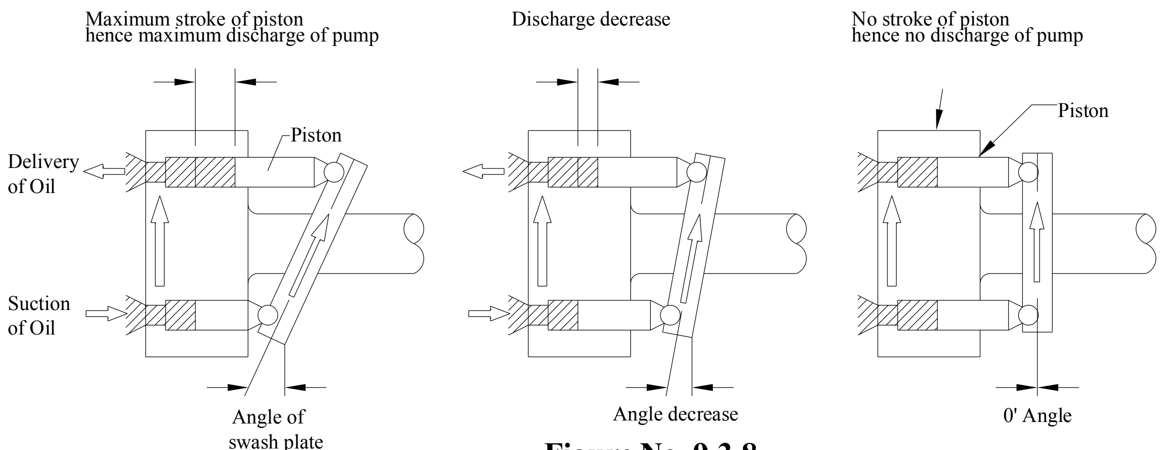


Figure No. 9.3.8

Schematic diagram of Variable displacement Axial Piston Pump. (Bent Axial Type)

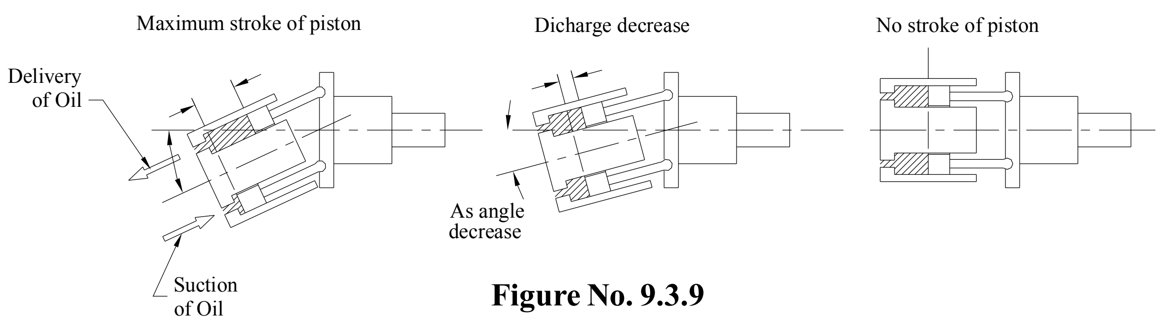


Figure No. 9.3.9

9.4 Pressure Control Valves

Introduction : -

Pump only generates the flow of oil. It does not develop pressure. Pressure gets developed when flow of oil opposed by the some restriction.

If development of pressure is not checked and controlled then pressure may keeps on building up, and may reach beyond the safe limit of hydraulic component, resulting in permanent damage to system or an accident. Hence pressure relief valve is basic and most important part of a hydraulic system.

In addition to controlling maximum pressure, a hydraulic system demand manipulation of pressure and flow of oil in many ways. To fulfill such need various types of hydraulic valves have been developed. In this chapter we will study various types of valves widely used in industry and their working principle

9.4.1 Terms related to Pressure Relief-Valves: -

a. Cracking Pressure :-

The pressure at which the valve just begins to bypass the pressurized fluid to reservoir is called **Cracking-Pressure**. At this pressure the force developed by fluid at ball or poppet (which ever is used) just overcomes the compressive force of spring retaining ball or poppet on valve seat.

Generally screw is provided to vary the spring force, so that the pressure at which valve bypasses the oil can be conveniently adjusted.

b. Full-Flow Pressure :-

As fluid start by-passing through the valve, the poppet gets lifted from it seat. This lifting of poppet cause compression of spring. As spring get compressed its force on poppet increases. Hence to further compress spring and allow more passage to fluid for free flows require more pressure. Hence for full-flow of fluid through relief valve is at much high pressure than cracking pressure. The pressure at which full-flow of pump by-passes to reservoir is called **"Full-Flow Pressure"**. And the difference of **cracking-pressure** and **Full-flow pressure** is called **Pressure Override.**

"Pressure Override" is undesirable and when it is required to minimize pressure override, pilot operated relief valve should be used.

RELIEF VALVES

Relief valve is used to control and regulate the pressure in a hydraulic system. The relief valve could be classified in two categories.

1. Direct Acting Relief Valve.
2. Pilot Operated Relief valve.

9.4.2 Direct Acting Relief Valve: -

It consists of a valve body, poppet, spring and adjusting screw. Refer Fig. No. 28.1 Poppet held on valve seat by spring compression, which is adjusted by screw. When pressure at inlet is insufficient to overcome the force of the spring, the valve remainder on reaching closed. The pre-set pressures reached the oil pressure over came the spring forces and force-off the poppet from its seat and by-passes sits on its seal to tank. And poppet will remain lifted till pressure is above pre-set pressure. As pressure reduces poppet again block by-passing of oil to tank.

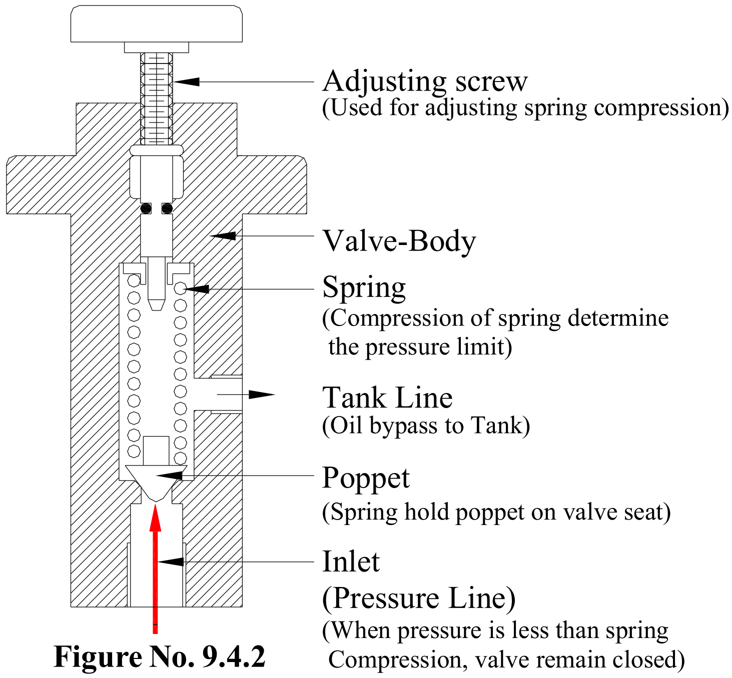


Figure No. 9.4.2

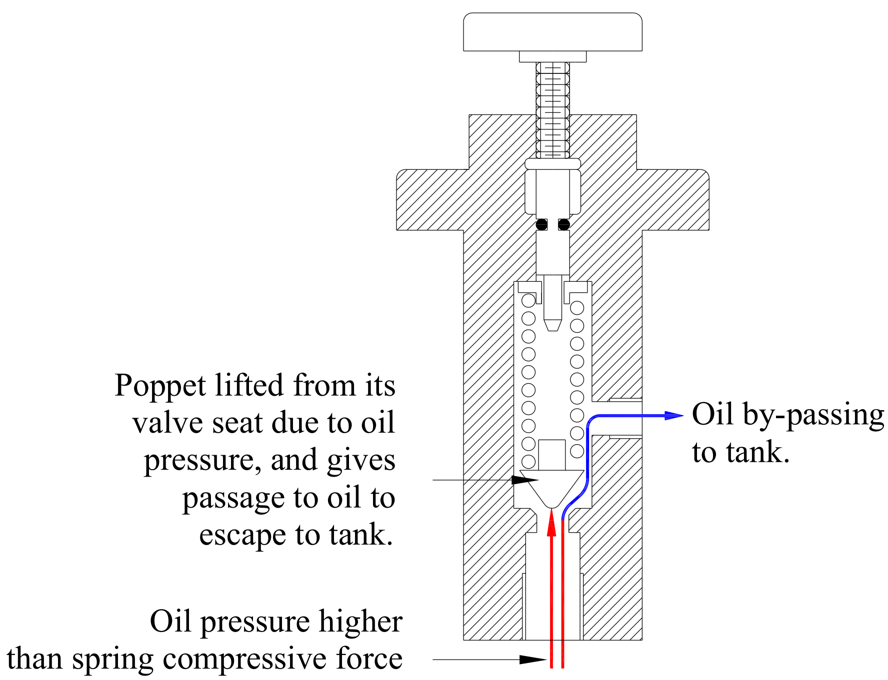


Figure No. 9.4.2
(a)

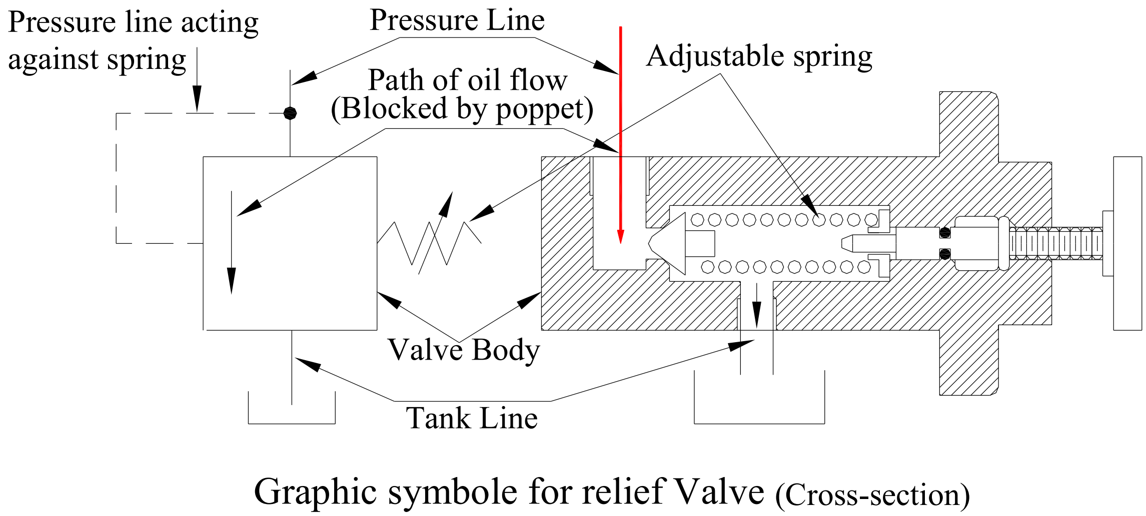


Figure No. 9.4.2

(b)

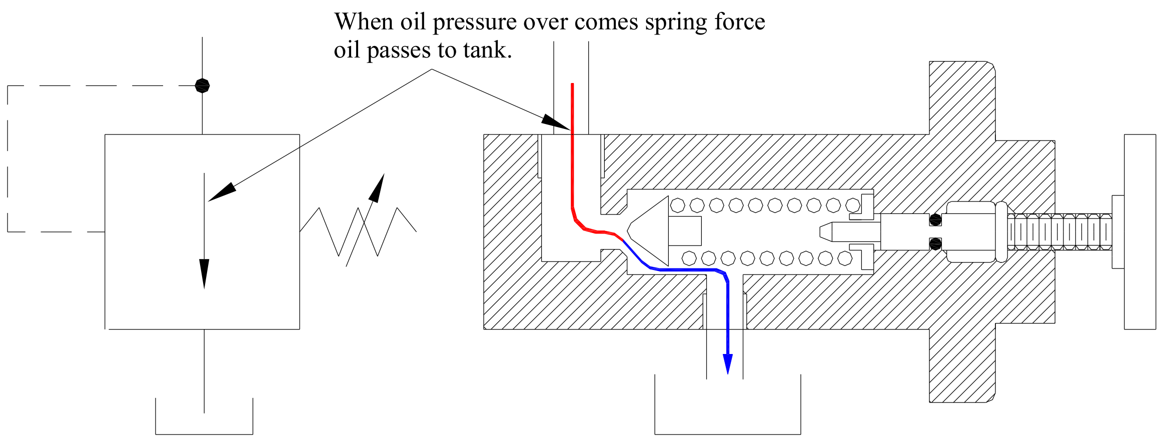


Figure No. 9.4.2

(c)

As oil pressure overcomes spring force, oil passes by to tank. (Second figure is only explanatory drawing. In actual as oil port of pressurized oil is always block in normally operating condition. Hence in hydraulic symbol also the path of oil will always be shown as off-centered and blocked).

9.4.3 Pilot Operated Relief Valve: -

In case of direct acting relief valve the pressurized fluid is stopped by spring loaded poppet against by-passing to the reservoir. While in case of pilot operated relief valve a balanced piston or spool blocks the passage of pressurized fluid against bypassing to reservoir. Excess pressure causes unbalances of the piston, because of which it slides to one side allowing pressurized fluid to by-pass to the reservoir. Refer Fig. No.28.5 & 28.6

Spring, screw and poppet or spool is an inseparable part of all pressure controlling valves. Hence Direction acting relief valve is also an integral part of pilot operated relief valve, in addition to this it also have a chamber which consists of balance piston, as shown in figure. One side chamber of piston is connected to pressure port of direct acting relief valve. And other side of the chamber to the pressure line of pump. Both the chambers are connected by small orifice. Because of which pressure on both the sides are same, and there is no continuous flow of fluid in either side of balance piston across orifice. As pressure increase, the poppets of direct acting relief valve gets lifted and pressurized fluid bypasses to reservoir. This causes a flow of fluid across the orifice, when fluid flow through small orifice, their pressure drops due to throttling. Hence on this side of chamber there is less pressure than pump side. Hence this difference in pressure causes an unbalance force on piston and it slides to low-pressure side. This side shifting of piston opens path to pressurized fluid of pump to bypass to reservoir.

As pressure decreases, poppet of direct acting relief valve again sits on valve seat and blocking the small amount of fluid by-passing to reservoir. Which cause increase of pressure on this side of piston or spool, as when there is no flow across orifice there is no pressure drop, and pressure gets equalized on both side of piston this forces back piston to its original position where it blocks the path of fluid of system to bypass to reservoir.

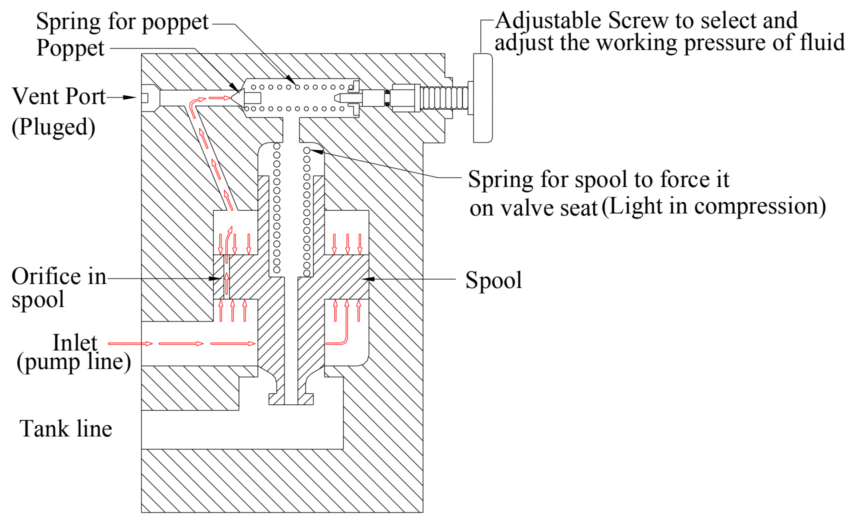


Figure No. 9.4.3

As long as poppet sits on valve seat and there is no flow of fluid across spool through orifice, pressure on both side of spool remains same. Spool remains balanced, and it also remains seated on its valve seat due to spring compression.

Both poppet spring chamber, spool spring chamber are connected to tank through a hole across the spool. Hence any leakage across spool or poppet passes on to tank without disturbing balance of spool.

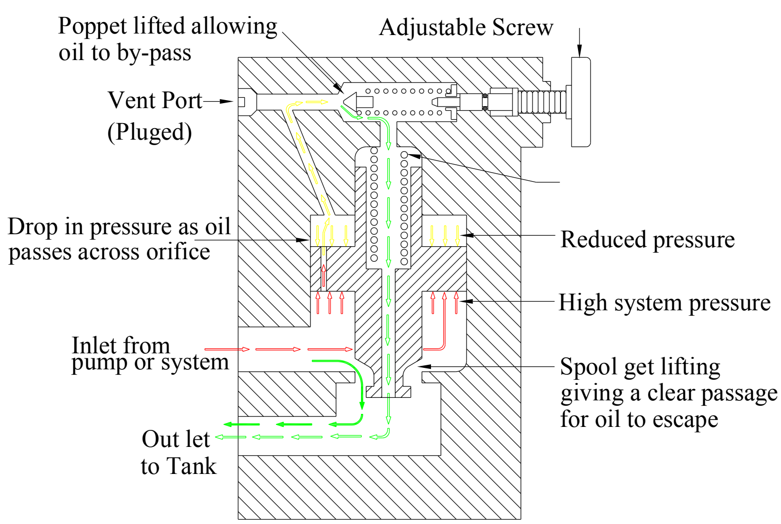


Figure No . 9.4.3
(b)

Application of Pilot operated relief Valve: -

Hydraulic circuits are designed as per the demand and requirement of a system. Hydraulic circuits are very flexible, and same operation could be achieved by using various different types of valves. Additions of valves add cost as well as complication. Hence it will be ideal to achieve requirement of a system using minimum and simple valves.

We will describe some simple arrangement with pilot operated relief valve, which performs useful function and, which avoids complication and addition of many valves in hydraulic system.

9.4.4 Remote Control Pilot Operated relief Valve: -

In a hydraulic press generally power pack is kept on top of hydraulic press or away from working side of operation. Suppose a press requires constant adjustment of pressure, then either operator has to regularly go to power pack for adjustment or relief valve along with its pipe line has to be fitted on control panel. Fitting relief valve on panel is very difficult, as it require large size of piping. As well as adjusting main valve is very risky, as even if by mistake or oversight operator increase pressure beyond safe limit of system, press will get damage. Hence another addition relief valve should be fitted on control panel.

To avoid second full size relief valve and large piping, pilot operated relief valve is modified slightly and with help of a direct acting relief valve, with very small piping like capillary tube, could be used for said purpose. This arrangement is as follow.

Figure – 1

A direct acting relief valve connected to pilot operated relief valve at vent port.

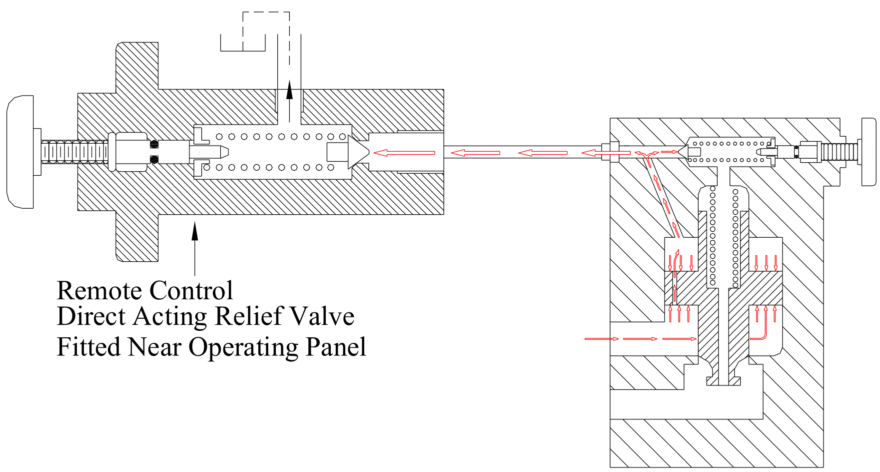


Figure No. 9.4.4

As pressure increases above spring setting of poppet of remote control direct acting relief, poppet gets lifted allowing oil to pass on to tank through separate drain. When there was no flow across orifice in spool, pressure on both side of spool was same. But as oil stars flowing through orifice to pass on to tank through poppet of remote control relief valve, there is a drop of pressure as oil passes through a orifice. Hence pressure on upper side of spool gets reduced. This causes unbalance force on spool and spool gets lifted up. Spring retaining spool on its seat is of very light in tension, hence do not offer any resistance against shifting of spool from its seat, shifting of spool gives a clear path to oil to pass on to tank. Hence pressurized oil starts bypassing to tank. Hence by varying spring tension in direct acting remote control relief valve. We can adjust the pressure of complete system, but only below the setting of main

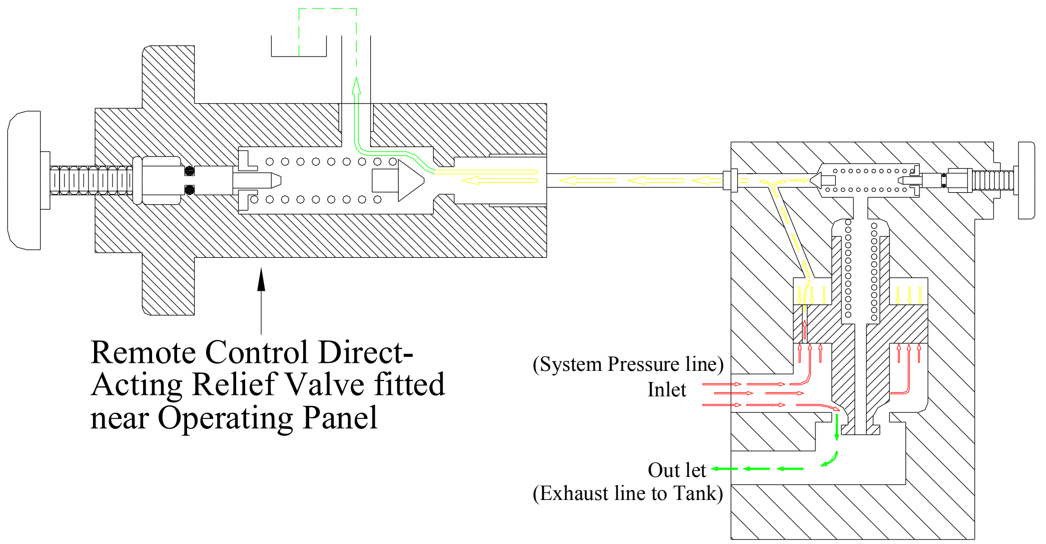


Figure No. 9.4.4 (b)

Advantage of this arrangement is that.

i) Direct acting relief is much economical than pilot operated relief valve.

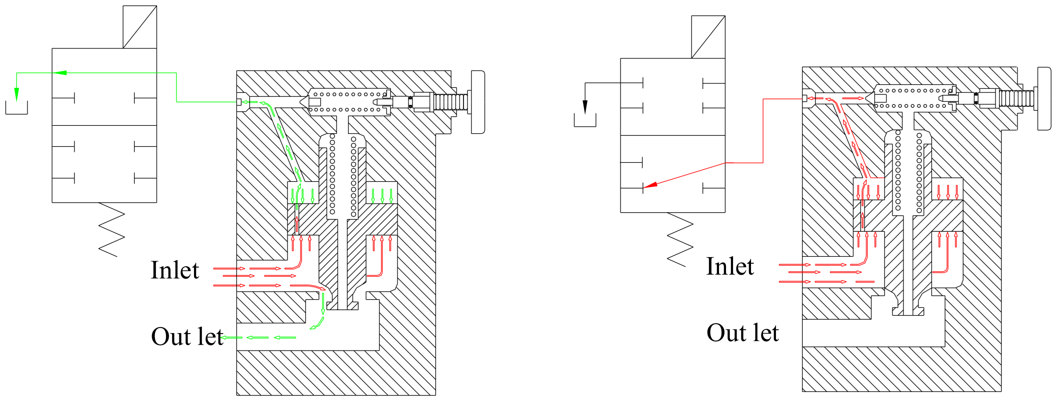
ii) Very small size of piping is required, between remote control direct acting relief valve and pilot operated relief valve.

iii) Even if operator tries to increase pressure above the safe limit of system, he cannot do so, from remote control direct acting relief valve, as main pilot operated relief valve will release oil at its set pressure.

9.4.5 Solenoid Operated Pilot Operated Relief Valve: -

In those hydraulic systems, in which motor-pump should runs continuously. But there should be no pressure in system. And pressure should get developed only when a electric signal is given. In such condition pilot operated relief valve along with a solenoid valve is used to serve the purpose.

Solenoid valve is connected to the vent port of relief valve, which connects vent port of relief valve to tank, when it is not energies. Hence all oil of pump unloads to tank through pilot operated relief valve. As soon as solenoid get electric signal to energies, it blocks the vent port, and oil stop bypassing through relief valve and pressure gets developed. In this condition relief valve will only release oil if pressure increases beyond setting of pilot operated relief valve.



(1) Vent port connected to tank through solenoid valve. Because of which pilot operated relief valve unloading full discharge of pump to tank, and there is no pressure in hydralulic system.

(2) As soon as solenoid valve gets enegied, it block the vent port. And pilot operated relief valve stop by-passing to tank, and pressure get developed in system.

Figure No. 9.4.5

By connecting a suitable solenoid direction control operated valve along with two direct acting relief valve to vent port of pilot operated relief valve. Same relief valve can be used to have three working pressure in a hydraulic system as explained below.

Consider following system.

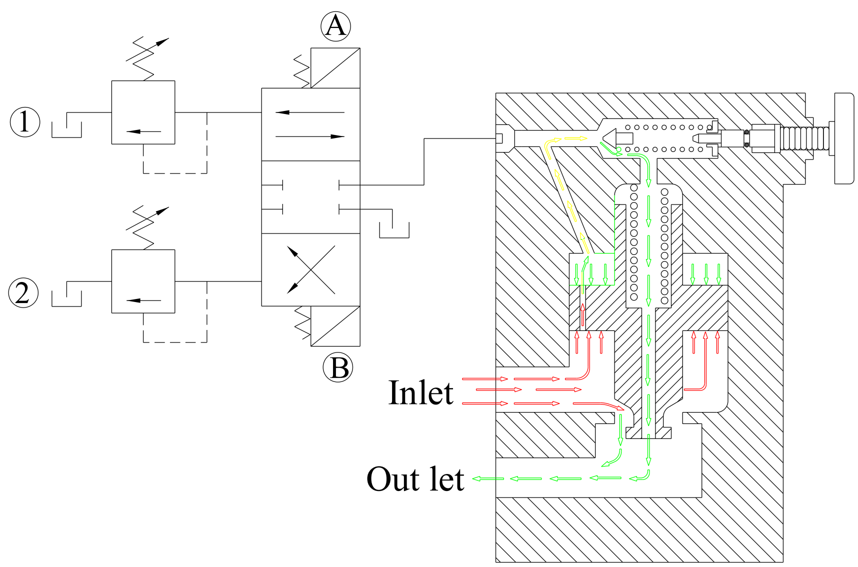


Figure No. 9.4.5
(b)

When solenoid operated direction control valve is not energies and is in neutral position, the pilot operated relief valve will release oil as per its own pressure setting (for example say 200 kg/cm^2). When solenoid (A) of direction control valve is energies, vent port get connected to remote direct acting relief number (1) and pilot operated relief valve will release oil as per pressure setting of remote control direct acting relief valve no. (1). When solenoid (B) of direction control valve get energies it connect remote control direct acting relief valve No. (2) and pilot operated relief valve will release oil as per setting of relief valve No. (2). Hence system can operate at three pressures with this arrangement. Pressure setting of relief valve No. 1 & 2 will be always less than main pilot operated relief valve.

9.4.6 Unloading Relief Valve: -

So for we studied direct acting relief valve and pilot operated relief valve. In pilot operated relief valve using its vent port we studied its three modified application

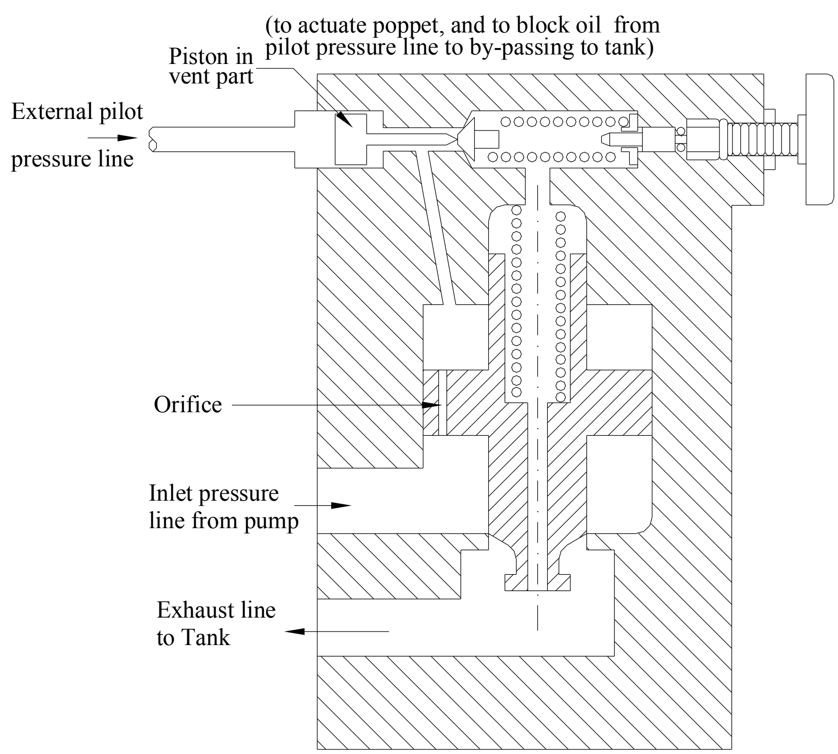
In example of pilot operated relief valve, the basic valve remain same. Only when vent port connected to direct acting relief valve it becomes remote controlled relief valve and when solenoid valve connected to vent it becomes solenoid controlled relief valve.

Pilot operated relief valve has its one more modified category, which is important and most widely used in industry and is called "Unloading Valve". For unloading valve basic pilot operated relief valve is modified slightly and used along with a check valve.

In unloading valve the basic pilot operated relief valve has a small piston in its vent port, which on sensing remote pressure, only lift-up poppet of direct acting relief valve from its valve seat. But piston does not allow oil to pass across it.

Unloading valves are used in a circuit, where two pumps are used. One high flow and low pressure pump and second low flow and high-pressure pump Unloading relief valve is connected to low-pressure pump. After reaching certain required pressure, a pilot pressure from high-pressure pump is used to actual small piston in vent port of unloading valve to by-pass all oil of low-pressure pump to tank.

Second most important application of unloading valve is charging of accumulator. Pump keeps on charging accumulator and when accumulator reaches its full pressure, the piston in vent port of unloading relief valve senses the pressure and unloads full discharge of pump to tank. Till the accumulator remains charged, the pump will be unloaded to tank, and as soon as pressure of accumulator drops pump again starts charging to accumulator.

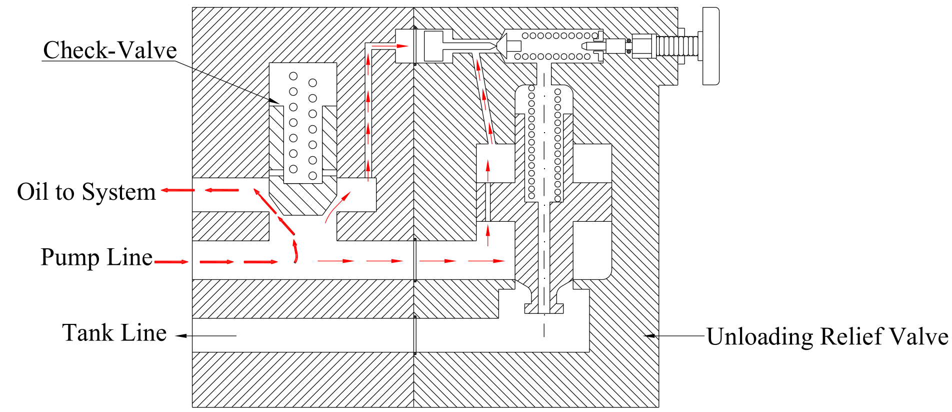


Unloading Relief Valve

Figure No. 9.4.6

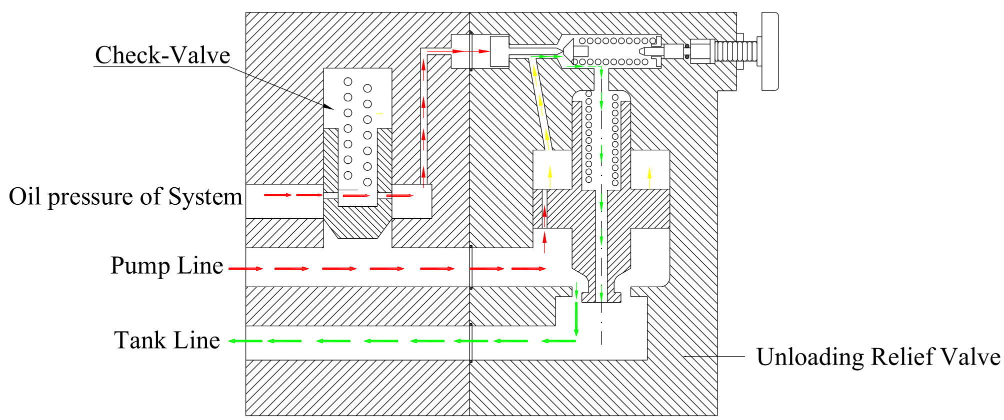
Unloading valve releases pressurized oil from pump to tank when pressure reaches to its set pressure. As well as when it senses pilot pressure from external source. For example if setting of valve is at 200 Bar. Then it will release oil at 200 Bar to tank, even when there is no pressure at pilot line. Also it will release oil to tank when pump or system pressure is below 200 Bar, but vent port sensed pilot pressure above 200 Bar through the piston in vent port.

Unloading valve is always used with a check valve a shown in figure.



Pump supllying oil to system

Figure No. 9.4.6 (a)



Pump getting unloaded to tank.

Figure No. 9.4.6 (b)

9.4.7 Pressure Reducing Valve: -

Consider a hydraulic system in which two working pressures are required in two section or branches of hydraulic circuit. Pressure relief valve only limits or controls the maximum pressure in a system, once pressure relief valve setting reached, it by-passes oil to tank at atmospheric pressure. Said exhausted oil cannot be used to operate another hydraulic system. If two relief valves are provide in a line, the oil will be released from relief valve with minimum setting. Hence using many relief valves at a time in a same fluid line two pressures cannot be achieved in a system at same time. Second alternative is to provide separate pump with separate relief valve. By this method another independent pressure limit can be achieved but at additional higher cost of pump and relief valve.

Hence a special valve is used for such application. It is called "Pressure Reducing Valve". It is similar in construction to direct acting or pilot operated relief valve, but differ slightly in its principle of operation. This valve gives a constant reduced pressure in its secondary side irrespective of pressure in primary side. Only in case in which pressure in primary side is below the required pressure in secondary side, then both side pressure remains equal.

Pressure reducing valve has a special spool. On one side of spool there is springs, which try to shift spool in such a way that oil port at secondary side opens completely. From secondary port small pipe line supply oil below the spool, and any pressure in oil work against the spring and tries to close the oil-port of secondary side.

There is a orifice in spool which allows oil to pass from below the spool from secondary side to the poppet. Which is similar to direct acting relief valve, with separate drain line.

When pressure increases from primary side, upto setting of spring of poppet pressure on both primary and secondary side remain same, but after crossing pressure limit, poppet gets lifted and oil passes to tank. When oil flows through the orifice of spool pressure drops after passing through the orifice. This causes lower pressure on spring side of spool and spool slides against spring to close the secondary side oil port. This closing action of oil port cause throttling of flow of oil of secondary side, which causes pressure drop. The pressure drops to such a extent that spring overcome oil force from its bottom side to spool. And again opens the secondary port and a balance is reached. Because of this action whatever may be the pressure on primary side, due to throttling at secondary port, it will always maintain a constant reduced pressure on secondary side as per the setting of spring tension of poppet.

In reverse flow from secondary to primary if due to any reason, the pressure of secondary side becomes more than primary side, the spool will shift-up and block the port of secondary side and stops the oil flow. Hence a check valve is provided. Which will by-pass blocked oil passage and allow free flow from secondary side to primary side.

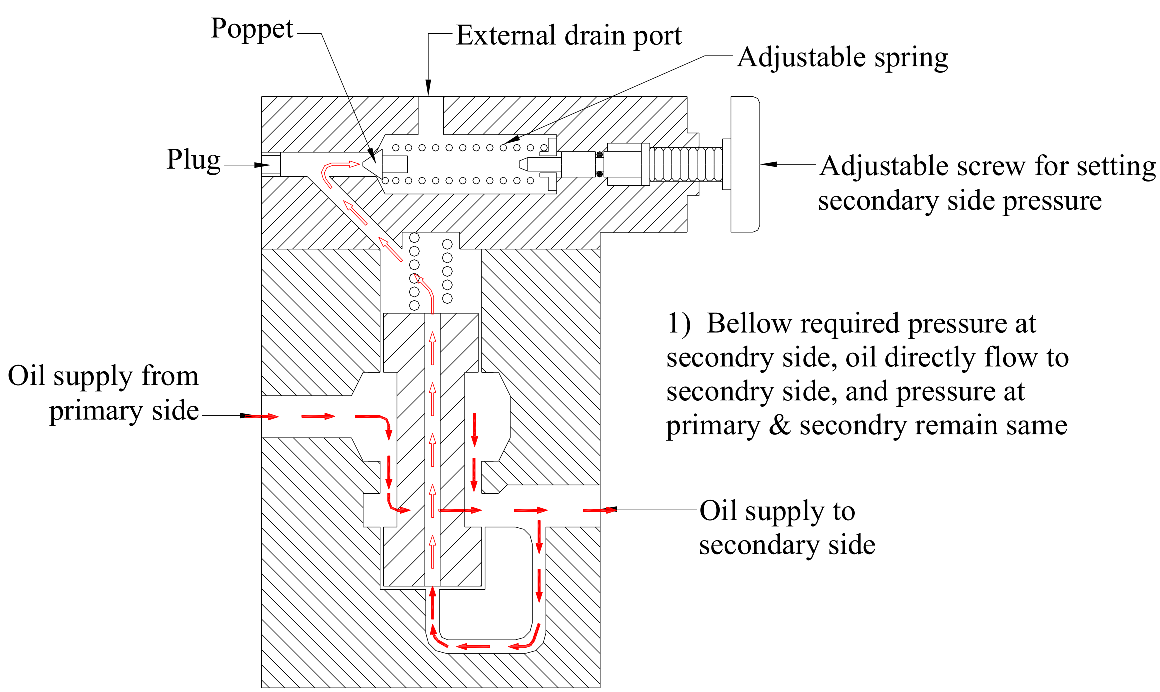


Figure No. 9.4.7

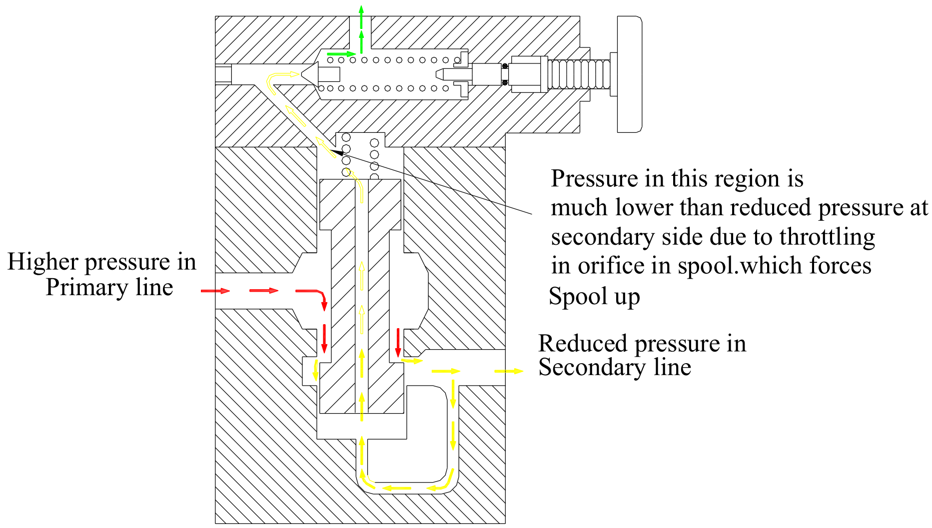


Figure No. 9.4.7 (a)

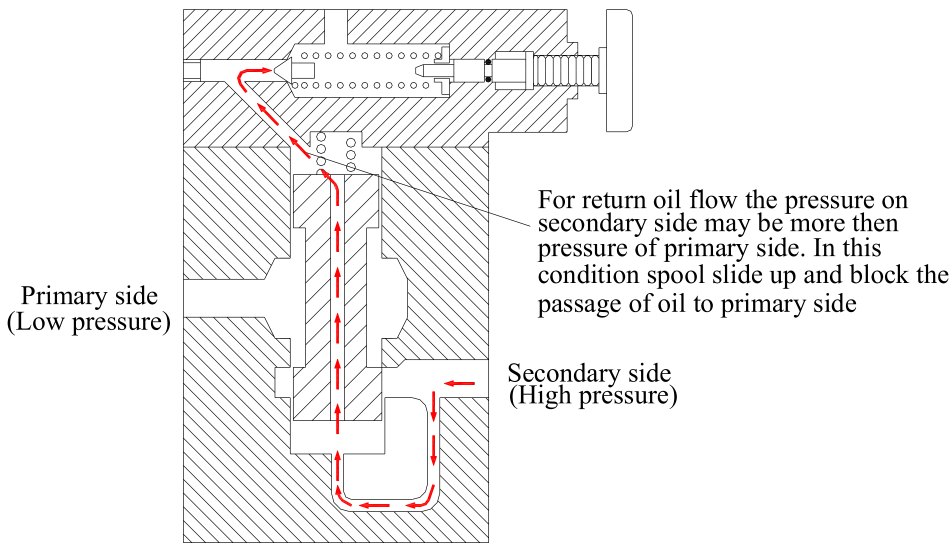


Figure No. 9.4.7 (b)

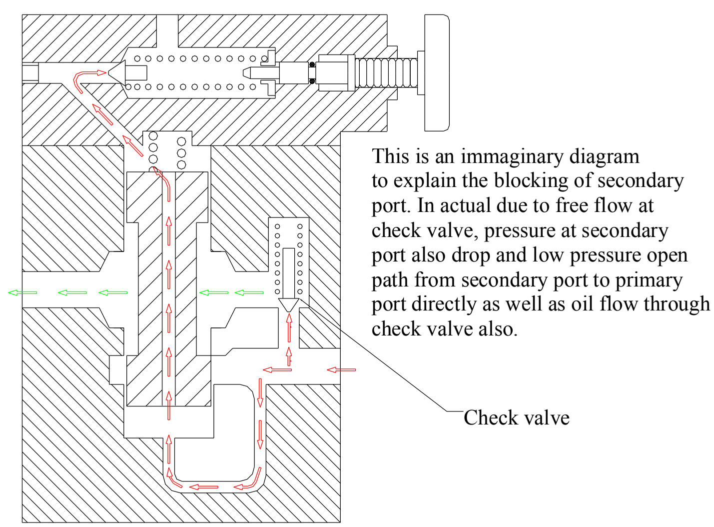


Figure No. 9.4.7 (c)

9.4.8 Sequence valve, counter balance valve, back pressure valve, unloading valve.

A basic direct acting spool-type valve modified in number of ways to get many types of valves of different application. First we will describe the basic valve.

It consists of.

1. Valve body, which is in three pieces.
2. A spool sliding in middle part of valve body.
3. Spool has an orifice along its axis.
4. Small piston fitted in lower part of body.
5. A spring and an adjusting screw fitted in top part of body.
6. A check valve (optional) fitted in middle part of body.

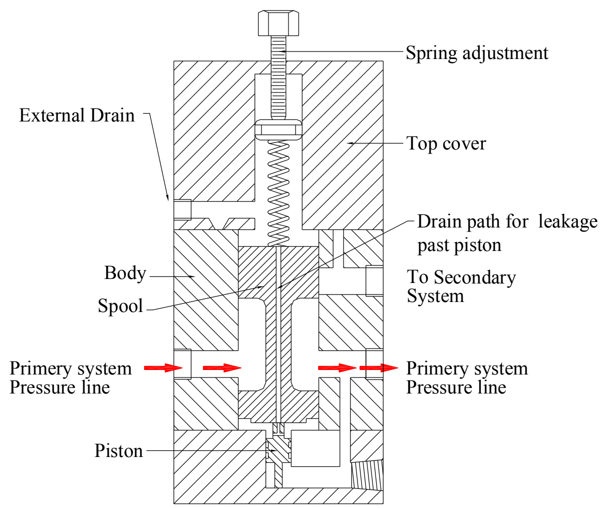


Figure No. 9.4.8

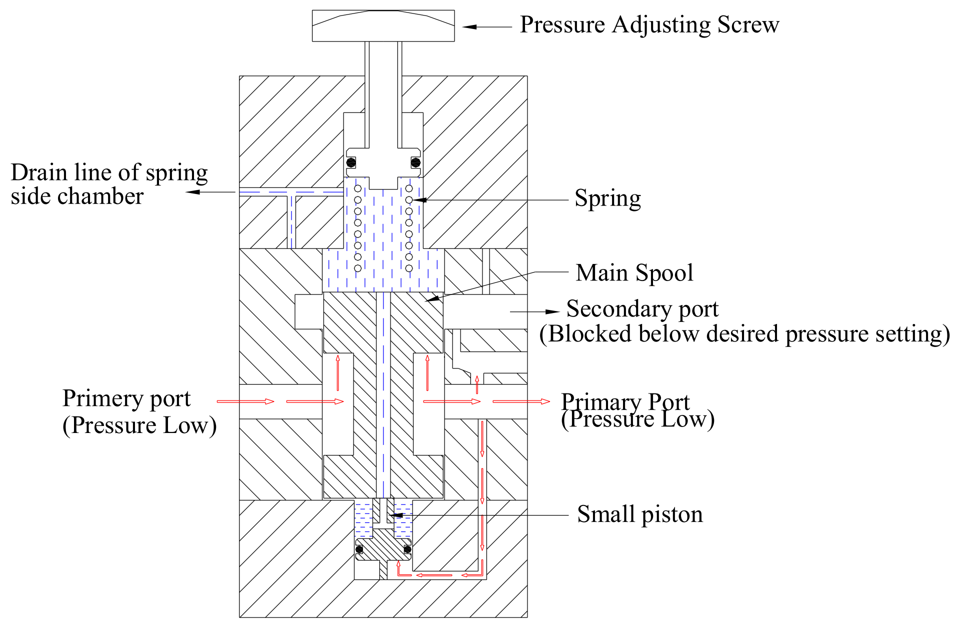
9.4.9 a) Sequence Valve: -

Consider a hydraulic press, which has a main pressing cylinder and an auxiliary cylinder. Auxiliary cylinder is used to clamp the job. Job should be clamped before pressing, hence first auxiliary cylinder should operate then after developing certain pressure main cylinder should operate. Said sequence of operation could be achieved by using two direction control valves. It could also be achieved by a simple sequence valve, which supplies oil to other cylinder only after first cylinder develops some pressure.

Consider figure No.28:15. The spring side oil chamber is connected to the external drain, and bottom side small piston connected to primary side of system pressure line. Hence spring is opposed only by primary pressure. At atmospheric pressure spring shift spool to one side and completely block the oil port of secondary side. When primary side develops pressure, and when this pressure over come the compression of spring, spool slides up to open oil port secondary side. As spring compression is adjustable hence cracking pressure, and secondary pressure could be adjusted and selected.

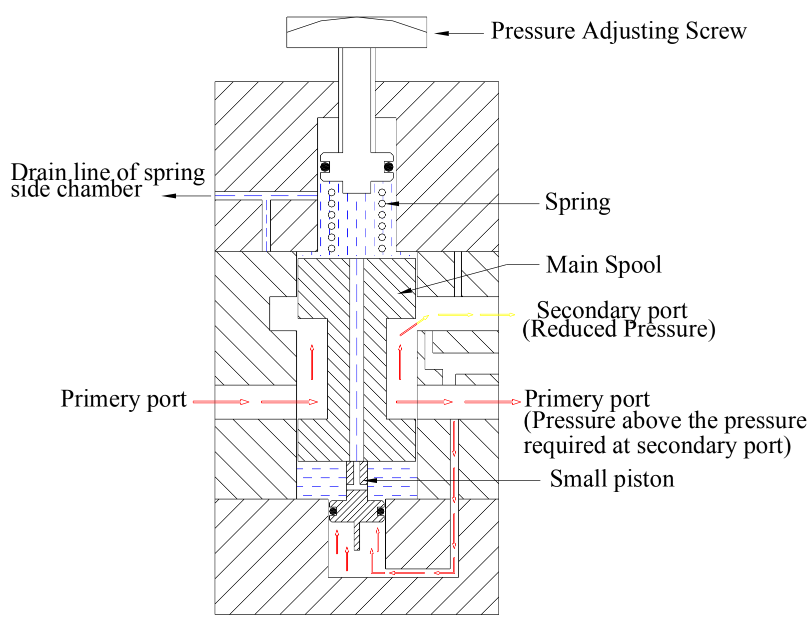
In previous case if clamp cylinder is connected to primary system pressure line and main cylinder to secondary system pressure line then with single direction control valve both the cylinder could be operated at desired sequence and pressure.

As when primary system pressure line reduces below the spring compression setting, the secondary port gets closed, hence in return stroke this valve may not allow oil flow from secondary to primary, hence a check valve is used to by-pass the oil from secondary to primary in return flow, as shown in figure.



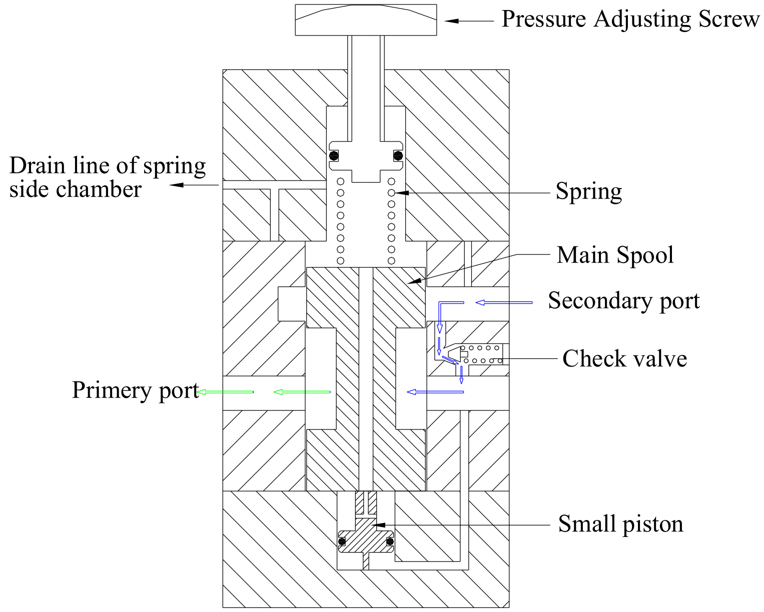
Secondary side pressure line blocked as primary side pressure is below the required

Figure No. 9.4.9 (I)



As primary side pressure risens above spring setting secondary part open slightly

Figure No. 9.4.9 (II)



When secondary side pressure is higher them primary side in return stroke, oil by -passes through ceck valve

Figure No. 9.4.9 III

9.4.9 b) Back Pressure Valve: -

Many hydraulic circuits require continuous backpressure in system. Direct acting spool type valve is one alternation, by using which we can precisely select and adjust the backpressure.

Back-pressure valve is similar to sequence valve in operation with some modification as shown in following fig.

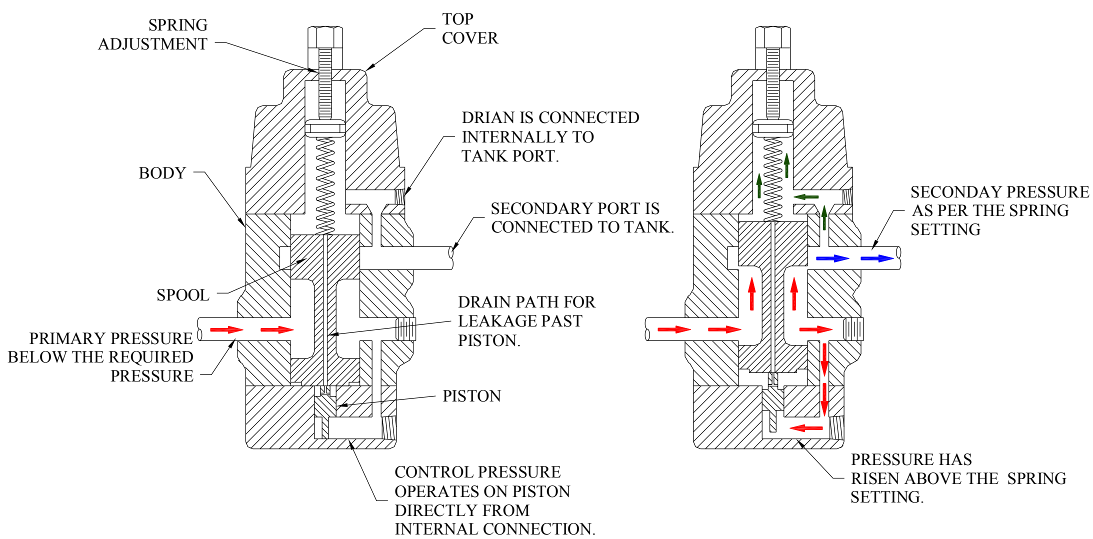


Figure No. 9.4.9 (b)

9.4.9 c) Unloading Valve: -

We have studies unloading valve, which made by modifying pilot operated relief valve. Unloading valve also can be made by modifying direct acting spool-type valve, which is explained by following diagrams.

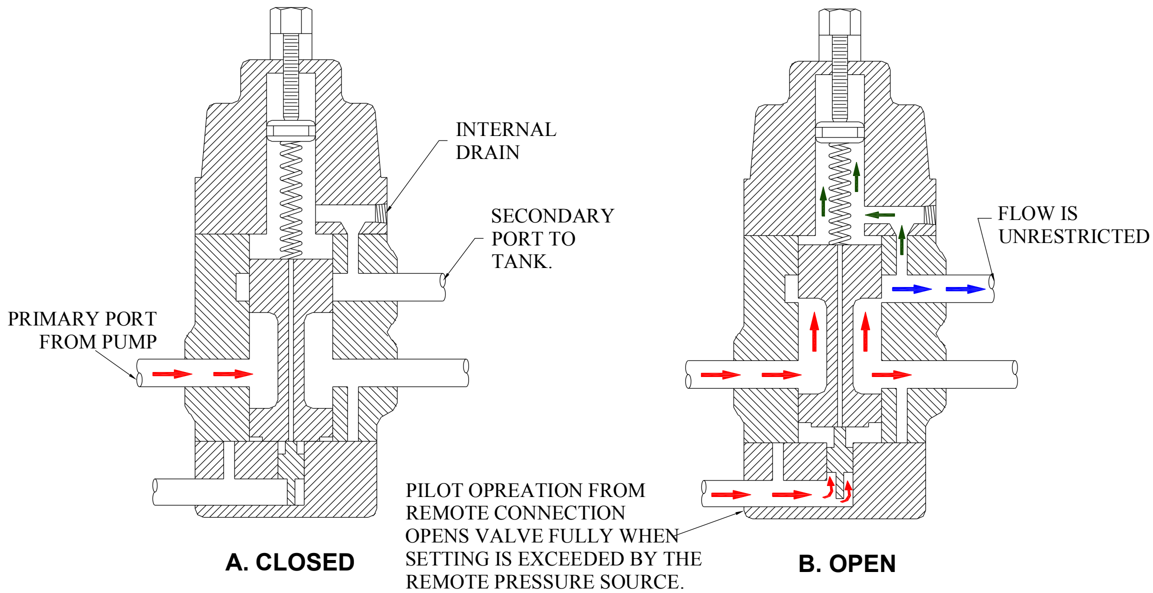
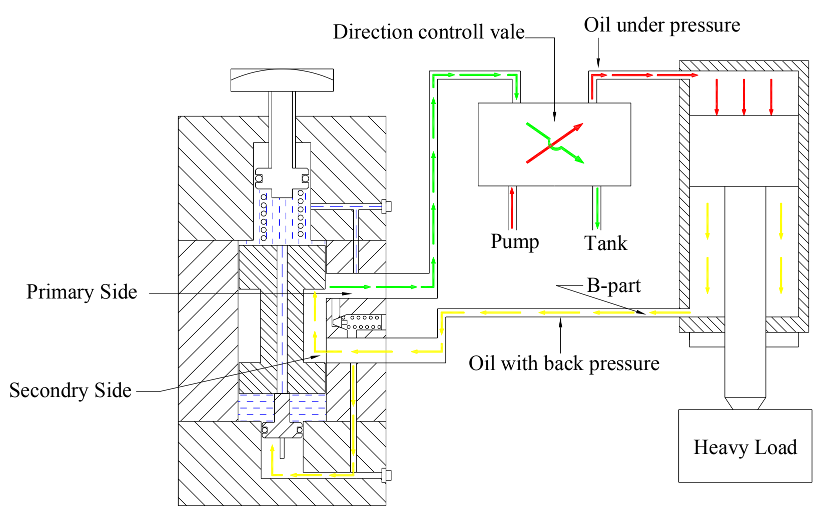


Figure No. 9.4.9 (c)

9.4.9 d) Counter Balance Valve: -

In case of large vertical presses, the piton rods are very heavy, In case of those applications in which heavy loads are attached to piston rod, piston-rod tries to slide-down by its own weight, and forward-speed is un-controlled and faster than what it should be. Because of which upper side of piston may develop vacuum or low-pressure. At low-pressure air gets released from oil and causes spongy and jerky action of piston rod. To avoid this, pressure is developed in exhaust side of piston, so that it supports the piston, and avoids free fall. This controlled exhaust of oil in forward stroke of cylinder is achieved by using a valve called "counter-balance-valve".

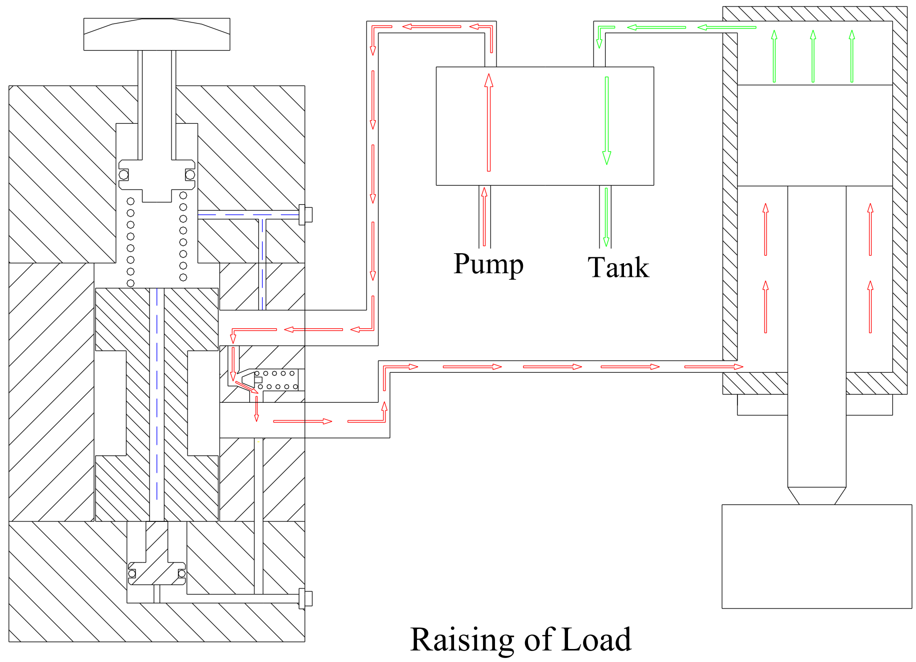


Lowering of Cylinder

Figure No. 9.4.9 (d)

While lowering load, oil coming out from B-port gets resistance from spring, and only developing pressure sufficient to lift the spring oil gets exhausted to tank via primary port and direction control

Counter-balance-valve is a modification of direct-acting spool type valve, and its function is explained by following diagram.



Raising of Load
Figure No. 9.4.9 (e)

9.5 FLOW CONTROL VALVE

Flow control valves are used to control the speed of hydraulic actuator that is hydraulic cylinder and motor. A simple orifice or a needle valve could be used to control the flow of fluid and can be called as "Flow-Control-Valve".

9.5-1 Factor affecting flow: -

Flow across a needle valve depends on three factors.

a. Size of Orifice: - Larger the size of orifice higher is the flow.

b. Temperature: - Higher the temperature, lower viscosity of oil, causes high flow rate across the orifice.

c. Pressure difference across the orifice:- Higher the pressure difference, higher the flow across the orifice. (This means that if pump pressure is constant, and if cylinder operates at low pressure, Then its speed will be higher. And with same pump and pressure if working pressure of cylinder increase, its speed slow downs, because flow across flow-control valve will decrease as pressure difference across orifice decrease.)

9.5-2 Method of using Flow-Control-Valve: -

A control of flow in a circuit can be accomplished in three ways in a hydraulic system. **Meter-in-circuit, meter-out-circuit, Bleed-off-circuit.**

9.5-3 a) Meter-in-circuit: -

In meter-in-circuit we control the flow of oil going into the cylinder. That means we control the supply of oil to the cylinder. This method of control of speed has a disadvantage that it could not control a pulling load precisely.

For example if a system has 10 LPM pump operating at 100 kg/cm^2. And if cylinder should be supplied only 6 LPM oil. Then Flow-control valve adjusted in such a way that only 6 LPM goes to cylinder, and remaining 4 LPM passes to tank through relief valve, at 100 kgcm^2 pressure. Operating pressure at cylinder will depend on the load on cylinder. Suppose cylinder is receiving 6 LPM and it is operating at 500 PSI. If load on cylinder increase and its operating pressure becomes 600 PSI then oil received by cylinder will decrease and will be less than 6 LPM. If operating pressure decrease below 500 PSI cylinder will receive more than 6 LPM and its speed will increase. If there is a pulling load and cylinder pressure is negative, then air-bubble will be released from oil and piston rod will have uncontrolled higher speed.

Hence meter-in-circuit has three main disadvantages.

1. It is not suitable for pulling load.
2. Pump always operates at full rated pressure.
3. Cylinder speed changes with its working pressure. (or loop on cylinder)

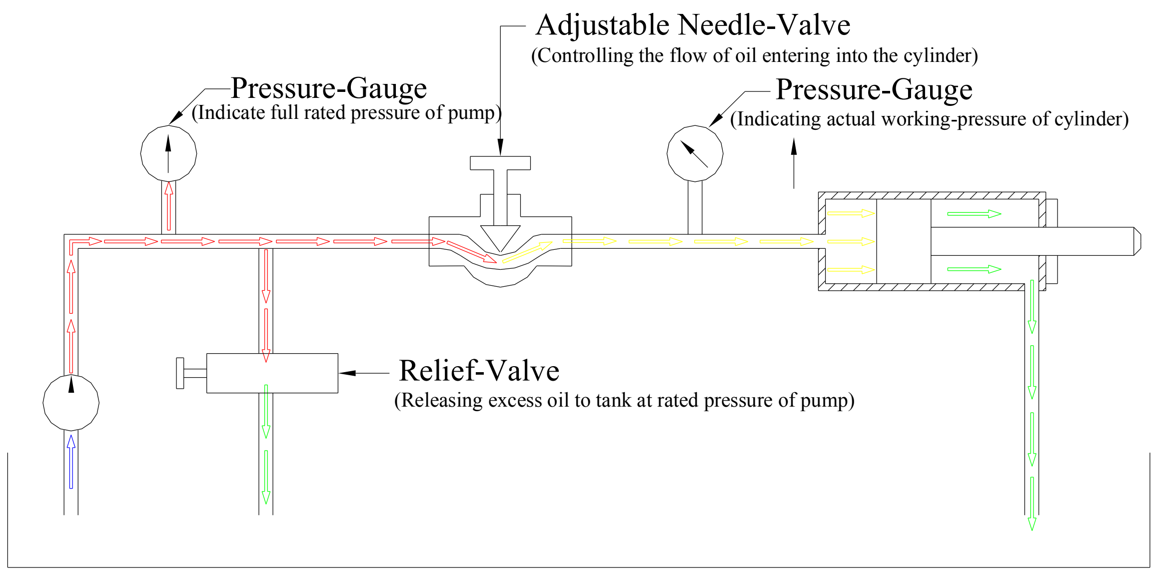


Figure No. 9.5.3 (a)

9.5-3 b) Meter-out-circuit: -

In case of meter-out circuit we control the flow of oil coming out from the cylinder.

In this method.

1. Pump operates at full rates pressure.
2. Cylinder speed changes with its working pressure.
3. At rod-end the pressure may be higher than working pressure of system, due to pressure intensification.

Let us understand pressure intensification,

Cylinder inside diameter = D

Rod diameter = d

Working pressure = P_S

Pressure at rod end = P_R

$\pi/4\ D^2 \times P_S = \pi/4\ (D-d)^2 \times P_R$

As area on $(D-d)^2$ is less than p/4 D^2 hence P_R will be more than P_S.

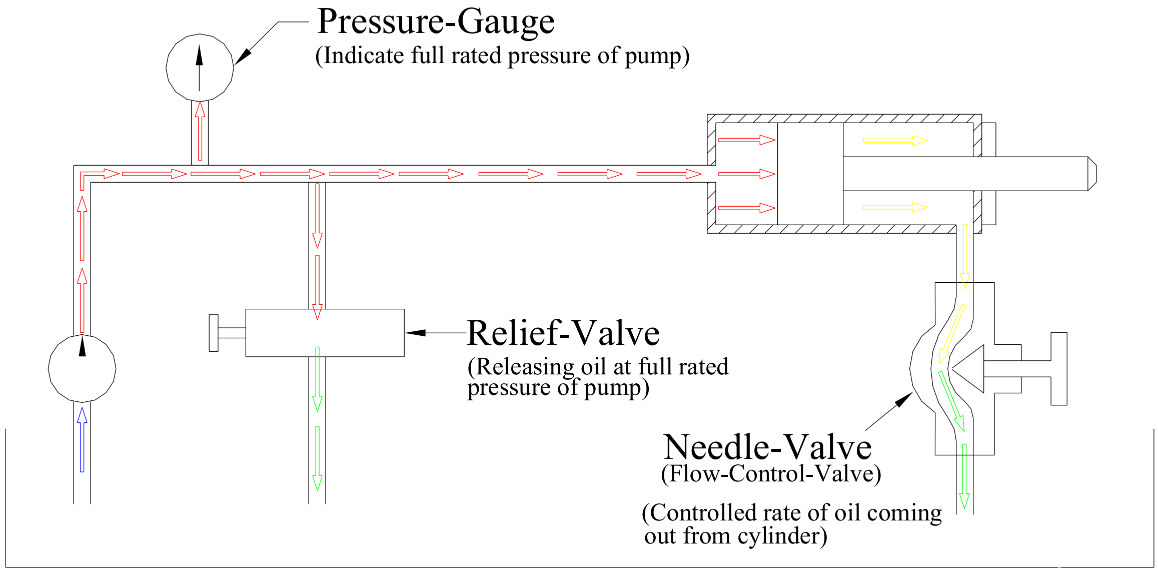


Figure No. 9.5.3 (b)

9.5-3 c) Bleed-off-Circuit: -

In case of bleed-off circuit, we by-pass some of the oil to tank to control the speed of cylinder, as show in the diagram. This system has following features.

1. It cannot control speed of cylinder with pulling load.

2. Speed of cylinder changes with its working pressure. This system has advantage that pump always do not work at full rated pressure.

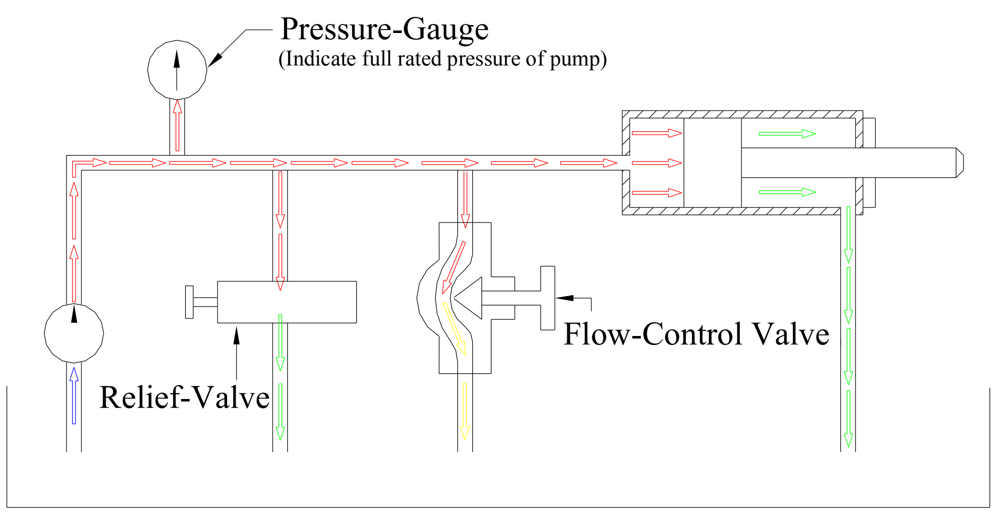


Figure No. 9.5.3 (c)

1. Non-pressure compensated.

2. Pressure compensated.

9.5-4 Non-pressure compensation types are those flow control valve, which control flow by throttling the oil passage, and throttling remains fixed unless it is changed manually. What ever flow passes through the throttle to cylinder at rated working pressure of pump depends on load on cylinder. If load on cylinder is high and it is working at higher pressure, then flow across throttle will be less and cylinder will move at slower speed. And if load on cylinder is low and it is working at lower pressure then flow across throttle will be more and cylinder will move at higher speed.

Hence in case of non-pressure compensated type flow control valve flow across flow control valve do not remain fixed but changes with pressure. A needle valve or a simple orifice is example of non-compensated flow control valve.

9.5-5 Pressure-compensated flow control valve are those control valve in which flow through the valve remain fixed irrespective of the working pressure of pump or actuator (cylinder). If load on cylinder changes and its working pressure changes then also its speed remains same as the oil it receives from flow control valve remains same.

Pressure compensated flow control valves are of two types. Restrictor type flow control valve and bypass type flow control valve.

9.5-6 By-pass type pressure compensated flow control: -

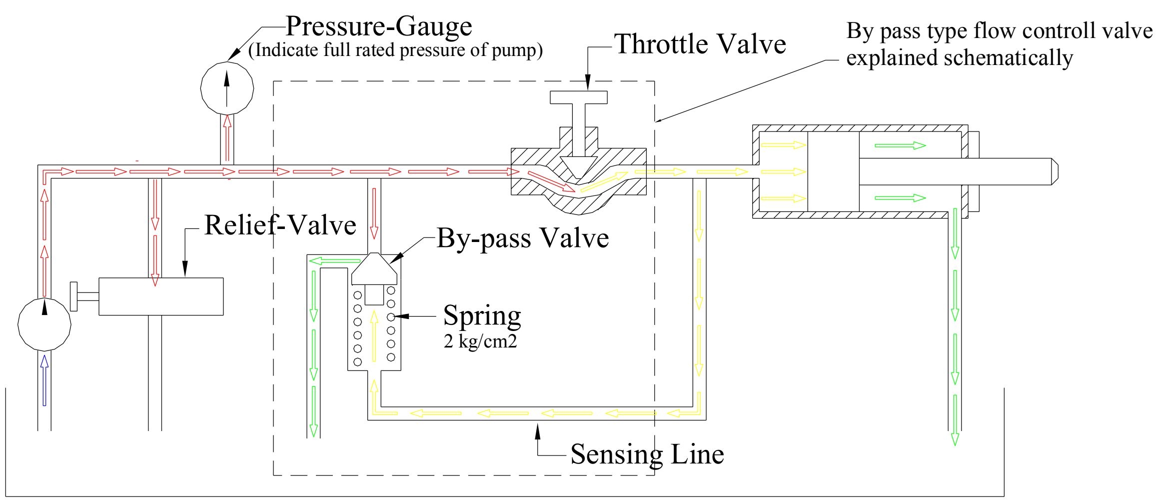


Figure No. 9.5.6

Consider diagram 29.4. A simple bypass valve is connected to the pump line before throttle. It has only a 2 kg/cm^{2}spring. Hence it will allow all oil to bypass at 2 kg/cm^2, which will not serve the purpose. Hence a pilot line is connected to the bypass valve at its spring side. Pilot line is taken after the throttle. These pilot pressures strengthen the spring force. Hence by-pass valve will stop bypassing oil. It will only bypass oil when the pilot pressure it receiving is less than 2 kg/cm^2 from pump pressure.

Let us study the function of this valve.

1. Consider a pump of 12 LPM is supplying oil to a cylinder.

2. A by-pass valve, throttle valve, pilot line (pressure sensing line after throttle), pressure relief valve etc. are connected in circuit as shown in fig No. 29.4.

3. Initially throttle full open, hence cylinder will operate at maximum speed.

4. To control speed we reduce the size of orifice in throttle valve so that less oil passed through orifice. As higher pressure is required to force flow of oil through orifice, hence pressure on pump side increase. This high pressure is more than spring compression of bypass valve and pilot pressure, hence by-pass valve opens and allows some discharge of pump to bypass to tank.

5. As some discharge of pump is directed to tank hence flow across throttle reduces. When flow decreases speed of cylinder decreases.

6. Reduced flows across throttle also brings down the pressure build-up before throttle, as less oil is to be forced across throttle.

7. A equilibrium or balance will reach in which by-pass valve will discharge some amount of oil to tank, so that the balance oil flowing through throttle will undergo pressure drop equal to spring compression. (In present example 2 kg/cm^2. it may change as per valve design).

8. By-pas valve always tries to maintain the pressure drop across throttle equal to spring-compression (2 kg/cm^2.)

9. Consider load on cylinder is increased. This causes increase in working pressure of cylinder side (oil pressure after throttling). As pressure difference across throttle decrease, less oil flow through throttle. When less oil flows throttles, there is further increase in pressure after throttle valve. This higher pressure is sensed in spring side of by-pass valve and it tries to close the bypass. This causes increase in flows through throttle, cylinder also gets high flow. Hence it will not slow down when load increases.

10. Bypass valve will close to only such an extent that the balance oil passing through throttle will have pressure drop equal to spring compression.

11. Now consider there is reduction in load of cylinder. This will cause low working pressure of cylinder. As pressure difference across throttle increase, more oil rushes through throttle, hence there is increase of speed of cylinder. But this high flow of oil through throttle causes more pressure drop across throttle, hence pressure after throttle further decrease, which is sensed in spring side of bypass valve, and it opens and allows more oil to by-pass to tank.

12. When more oil by-pass to tank, flow through throttle decreases. Which cause less pressure drop across throttle. Also cylinder slows down, as it received less oil.

13. By-pass valve will allow only that much oil to by-pass to tank, so that balance oil flow through throttle will under go pressure-drop equal to spring-compression (2kg/cm^2).

14. From above discussion we see, by-pass valve open and close as per the increase or decrease in operating pressure in cylinder, and throttle will under go pressure drop equal to spring compression. And as spring compression is constant, hence flow across throttle will be always constant.

15. Hence a pressure compensated flow control valve, compensate and keeps the total flow across valve constant. Bypass type of valve achieves this property by allowing less or more oil to by-pass to tank, to keep the flow through the valve constant.

This valve only can be used in meter-in-circuit, because excess oil it by passes to tank.

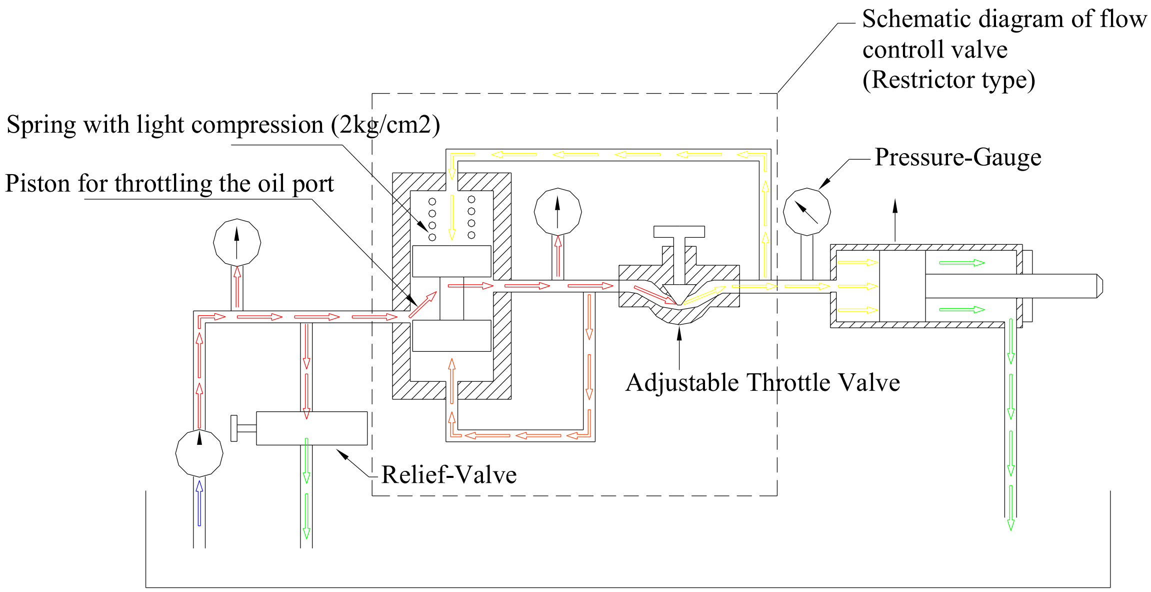


Figure No. 9.5.6 (a)

9.5-7 Pressure-Compensated Flow Control Valve (Restrictor Type): -

Let us study the functioning of restrictor type pressure compensation flow control valve.

1. This type of valve could be used in meter-in, meter-out or bleed-off-circuit.
2. Initially when throttle valve fully open all the oil of pump discharge will go to cylinder.
3. When throttle closes to reduce the flow of oil, pressure build-up at pump and on reaching its rated pressure relief valve opens and by passes balance oil to tank.
4. Suppose only 5 liter out of 12 LPM pump discharge is going to cylinder through valve and remaining 7 liter of pump discharge is going to tank. Now this valve will always maintain 5 LPM flow across this valve irrespective of load on cylinder.
5. Now consider load increases on cylinder, hence its pressure will increase, and it will have tendency to slow down. At this moment spring chamber of valve will sense more pressure and open spool to allow more oil flow.
6. And if load decreases on cylinder, its working pressure will decrease and it will have tendency to move faster. At this moment spring chamber of valve will sense which will piston and try to reduce the oil flow hence cylinder will not move fast.
7. In both the case when spool moves up or down to increase or reduce the flow of oil, an equilibrium or balance will reach in such a way that pressure drop across throttle valve will be just equal to strength of spring (in present case 2 kg/cm^2). And so the flow across throttle will be always same, for a particular setting.
8. Before valve, the pressure in system will be rated pressure of pump (relief valve setting). After throttle the pressure in system will be as per load on cylinder. And pressure between throttle and spool of valve will be cylinder pressure, plus compression of spring.
   For example relief valve is set at 100 kg/cm^2, cylinder is operating at 50 kg/cm^2 the pressure between throttle and spool will be 52 kg/cm^2 (2 kg/cm^{2}is spring strength).

9.5-8 Temperature Compensation: -

As temperature increase, oil become thinner they flow easily, hence for same pressure drop more oil flow through the throttle valve.

Hence any pressure-compensated flow control valve can control and keep constant flow even if load on cylinder changes, but they cannot keep same flow if temperature of oil changes.

Hence temperature compensation is also introduced along pressure compensation in flow control valve, which require precise control of speed.

For temperature compensation special throttle valve is used in which the spool is of cup-shaped with V-notches. It is supported against a aluminum rod by a light spring. As temperature increases, length of aluminum rod increase and it closes the throttle valve slightly. And when temperature decrease it open the valve slightly, hence compensate for the slight variation in flow of oil due to change its viscosity.

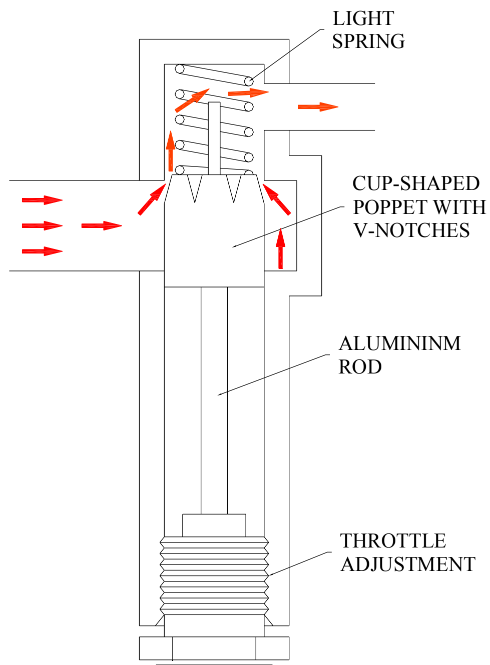


Figure No. 9.5.8

Control of flow may not be desirable in reverse flow for return stroke; hence all the flow control valves are provided a check valve for free reverse flow.

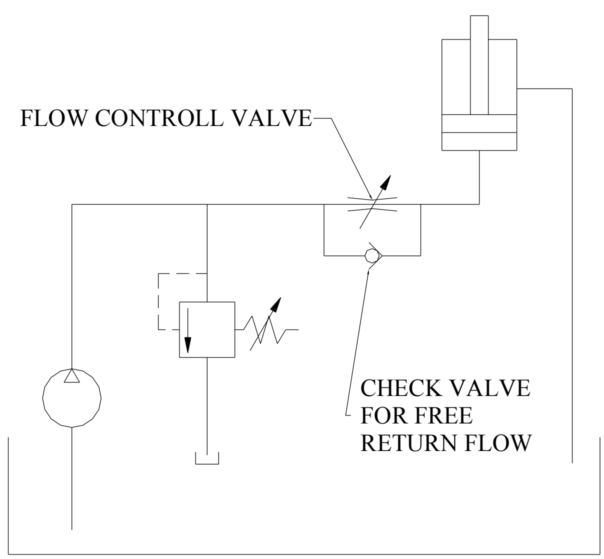


Figure No. 9.5.8 (b)

9.6 DIRECTION CONTROL VALVE

General Description:-

a. Direction control valves are used to start, stop and control the direction of fluid flow.

b. The direction controlling elements in the valve body of direction control valve may be a poppet (piston or ball) a sliding spool or a rotary spool. In industrial hydraulic generally we use sliding spool type direction control valve.

c. Direction control valve may be actuated by manual, electrical, hydraulic, pneumatic, and mechanical activator or combination of these.

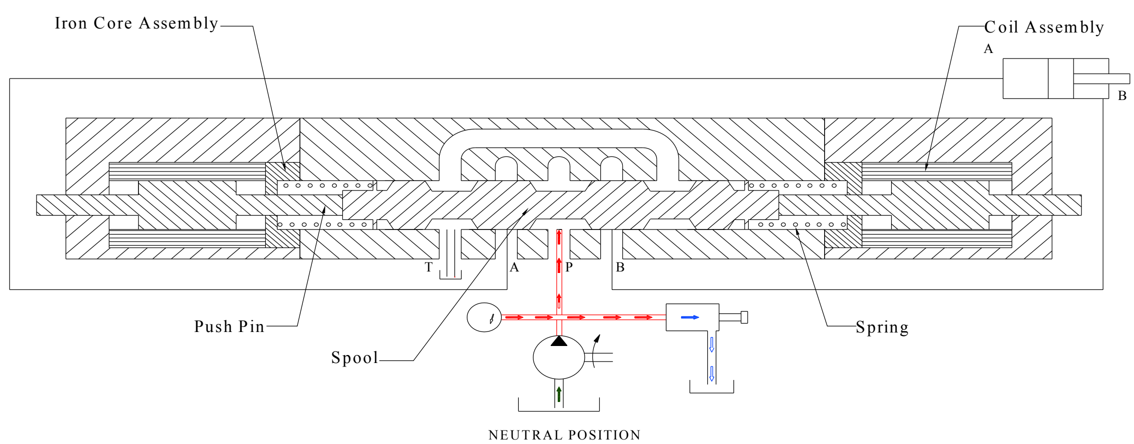
d. Sizes of direction control valves are mostly as per CETOP (European oil hydraulic and pneumatic committee) standard. They have specified five standard mounting patterns, and designated as 3, 5, 7, 8, and 10. Valves made as per CETOP3 handle lowest flow and smallest in size, while valves as per CETOP10 are largest in size. Valves of any manufactures who make valve as per CETOP standard can be replaces by valve of other manufactures, as mounting dimension, oil hole sizes, oil port sizes, flow capacity etc. are all same.

e. Other standards are ISO, NFPA etc. but they also match with CETOP standard. Hence in the world most of the valve of standard companies is interchangeable. Each size of valve 03, 05, etc. specify nominal size of port, flange connection to the valve, mounting patterns, valves flow handling capacity pressure rating etc.

f. A direction control valve could be connected by threading, flange or could be mounted on sub-plate or on manifold block. Valve mounting on manifold block is more common.

Function of Direction Control Valve:-

Let us study the functioning of a direction control valves with help of following diagrams.



Solenoid Operated Direction Control Valve

Figure No. 9.6.1

Direction control valves at central position and in this configuration or type the spool is blocking both the port of cylinder, pump as well as tank and all the flow of oil supplied by pump is returning to tank after passing over relief valves. Pumps continuously run at its rated pressure (setting of pressure relief valve).

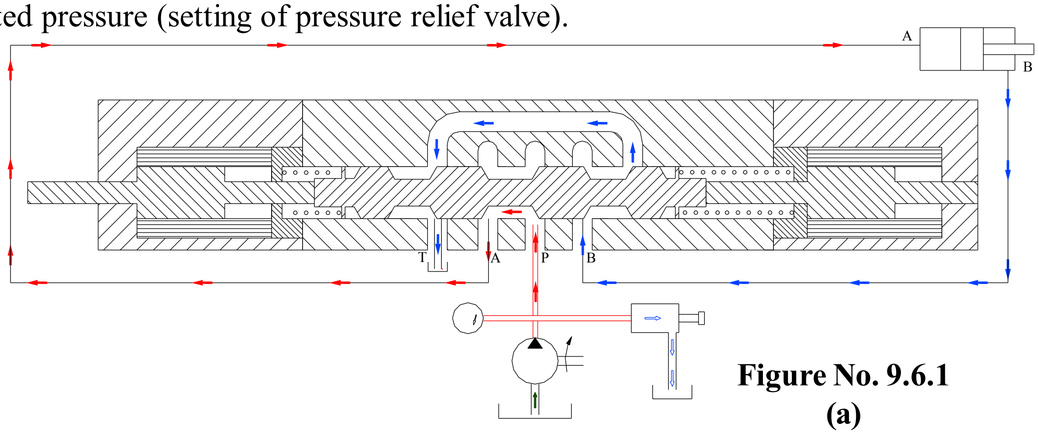


Figure No. 9.6.1
(a)

Spool shifted to other extreme end, and at this position it connects pump to cover end of cylinder, and tank to front end of cylinder. Cylinder takes its forward stroke and oil from front-end returns to tank. Working pressure will be as per pressing load on cylinder.

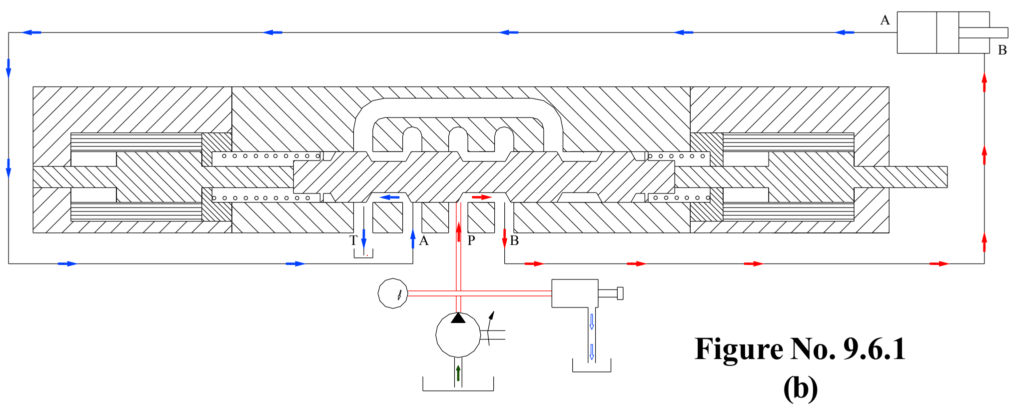


Figure No. 9.6.1
(b)

Spool of direction control valve shifted to one extreme end, because of which a path for oil open between pump to return port-B, of cylinder, and tank to forward port-A, of cylinder. Cylinder starts retracting and oil from cover end of cylinder passes on to tank.

<u>Graphic Symbol: -</u> Graphic symbol of Direction Control Valve is as follow.

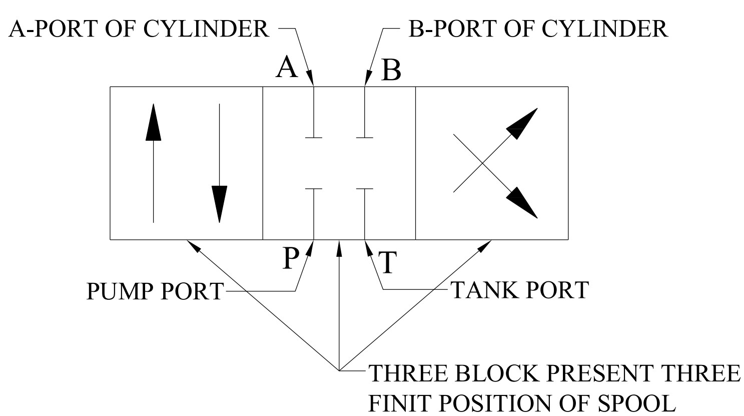


Figure No. 9.6.1
(c)

This diagram indicates at central position all ports will be blocked as we studied in circuit diagram. (30.2) On its one (left) extreme end pump will be connected to port-A and tank is connected to port-B. On its other (right) extreme end pump will be connected to port-B and tank is connected to port-A.

This type of valve is called “Close type three position four-way valve”.

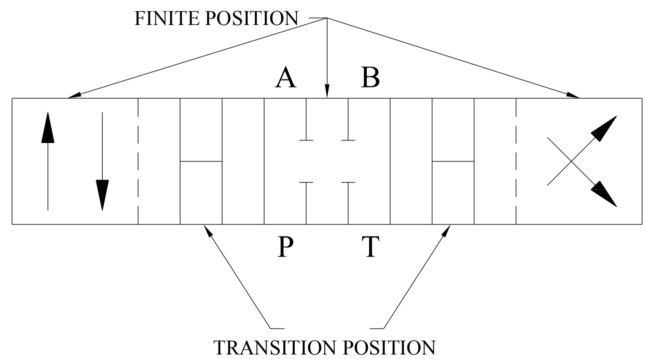


Figure No. 9.6.1 (c)

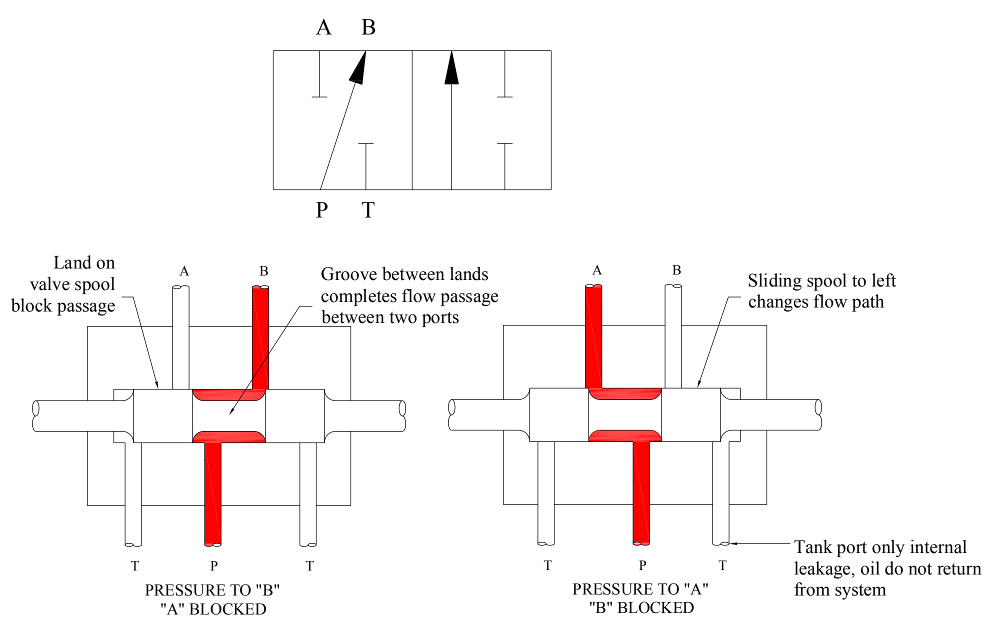
Above graphic symbol is only explanatory. It represents the interconnection of port in transit position. That is how the port will be interconnected when spool is shifting from its one position to other.

9.6-2 SPECIFYING THE DIRECTION CONTROL VALVES :-

What is two-way, four-way valve?

The number of oil ports to and from which fluid flows determines whether a valve is a two-way, three-way or four-way.

In a two-way valve there is one pressure port and two-outlet port. On one position of spool oil from pressure port goes to first outlet and on other position of spool, oil from pressure port goes to other outlet. In two-way valve oil only goes to two outlets, and oil does not return to valve from any of outlet. Hence it is called **“Two-way valve”.**



Two way-two position valve

Figure No. 9.6.2

In case of four-way valves, oil also returns to direction control valve and flows through the tank port to tank. In one position of spool, oil flows from pump to port-A, and port-B to tank, and in other position oil flows from pump to port-B and port-A to tank. The valve discussed earlier (figure 30.2) is a four-way valve.

9.6-3 SPOOL POSITION: -

Direction control valve could be actuated by five means, these are Manual, hydraulically, pneumatically, mechanically and electrically means. But the condition when it is not actuated the spool position is very important. Following are the spool position generally used in industry.

1. Three-Position Spring-Centered Valve:- Three-position spring centered valve return to the central position whenever actuating force is released. (Refer figure No. 30.1).

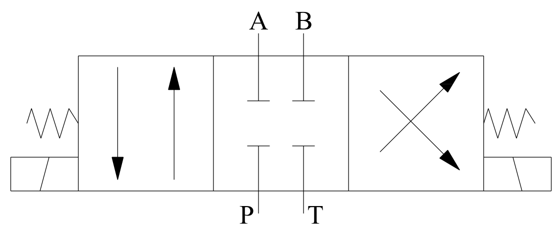


Figure No. 9.6.3 (a)

It has two actuators, one actuator mover spool to one extreme end and other actuator of valve shift spool to other extreme end. And when direction control valve not actuated, spool returns to central position due to spring force.

2. Two-Position Spring Centered Valve: - This is similar to three position, but it has only one actuator, and spool will be in center in neutral position by spring force and shift to only on one side by actuator.

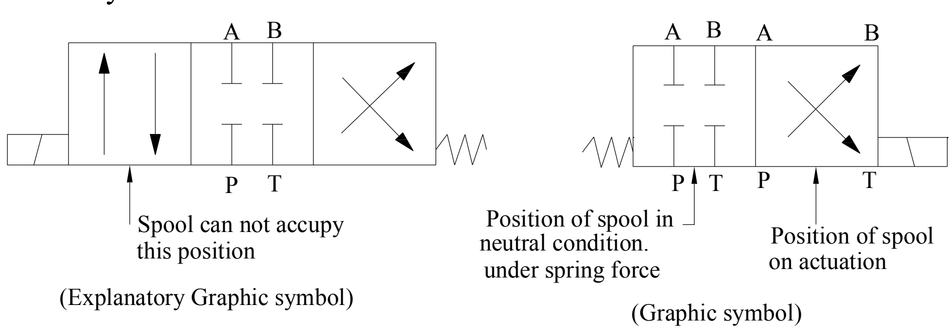


Figure No. 9.6.3 (b)

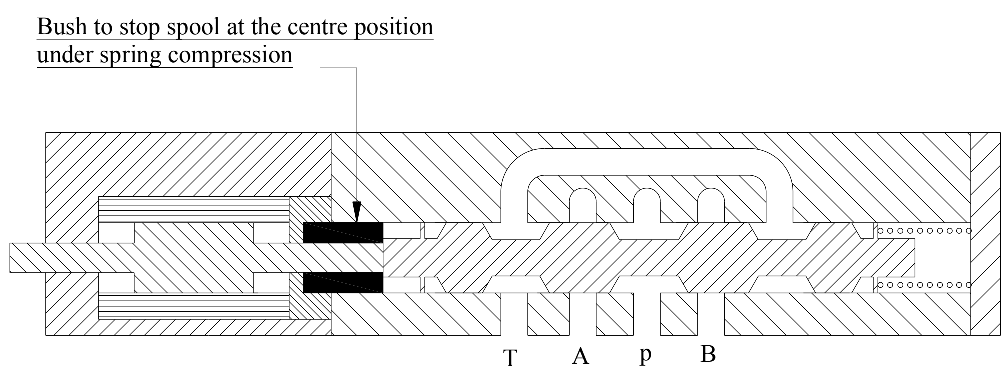


Figure No. 9.6.3 (c)

By actuating solenoid spool will be pushed against spring-to-spring end, and on releasing it will return to center. As on actuator end there is a stopper hence it cannot over travel to actuator end by spring force.

Note: In above symbol, spring or solenoid pushes spool to other end of valve body, but in graphic symbol, the condition of port connection is shown just next to that actuator. For example, in above diagram spring pushes spool to other end and at that end all ports are blocked, so this configuration will be just shown next to spring, and when solenoid energised, it pushes spool to other end where port P is connected to B and A is connected to T. So this configuration will be shown just next to solenoid.

3. Two-Position Spring-Offset: - In this configuration, spring shifts the spool to actuator extreme end, and on actuating spool goes to other extreme end of valve (spring side). Although neutral position is possible, but spool only passes through it, there is no way to accurately keep the spool in central position, neither it is

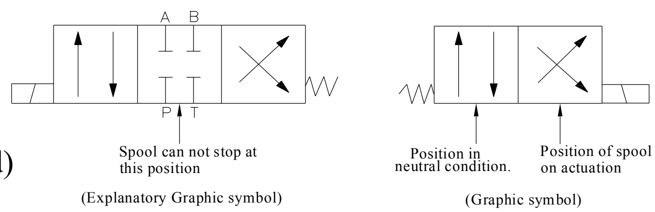


Figure No. 9.6.3 (d)

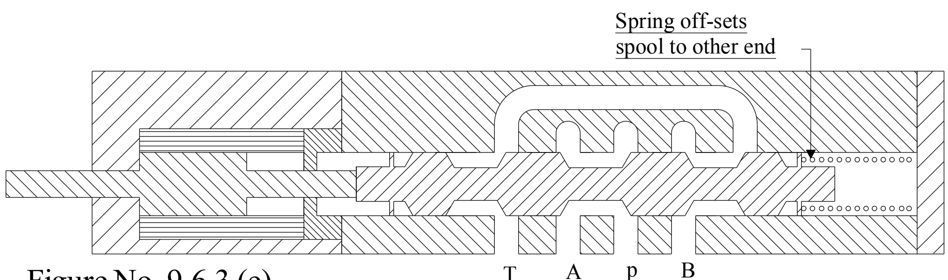


Figure No. 9.6.3 (e)

4. Two Position Actuated to Center: - In this configuration also spring offset spool to actuator extreme end. But when spool actuated it comes center position. It cannot pass on to spring extreme end.

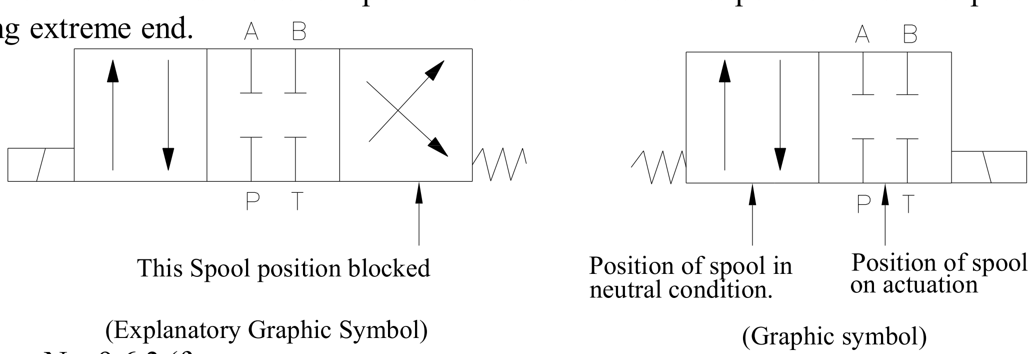


Figure No. 9.6.3 (f)

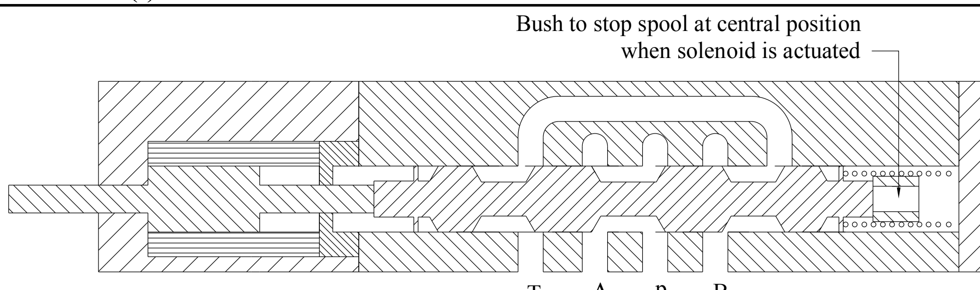


Figure No. 9.6.3 (g)

5. Two Position Detente: - Similar to the three position spring centered valve this valve also have two actuator but without spring. And it has arrangement to keep the spool to its extreme end even when actuator released. Hence when actuator is shifts the spool it remains in same position, do not return to neutral position even when actuation released. And will pass on to other extreme position when other actuator actuated.

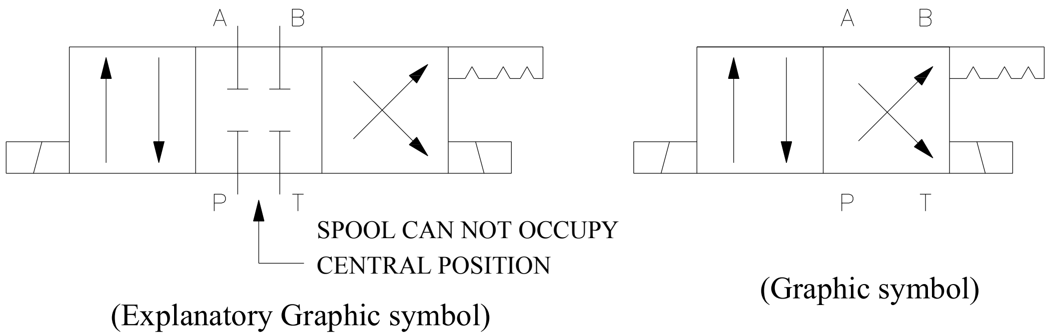


Figure No. 9.6.3 (e)

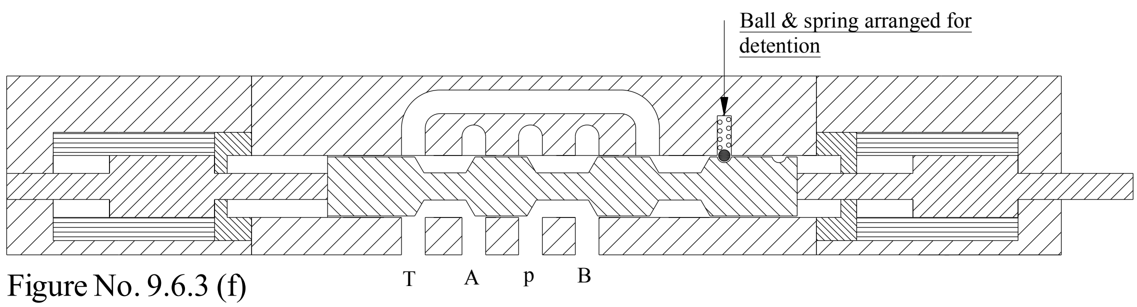


Figure No. 9.6.3 (f)

9.6-4 SPOOL-CENTER CONDITION: -

In most of the standard four-way valves spool provides the same flow pass when shifted to extreme end. That is in one position pump connected to (A port and tank to B- port). And in other position pump to (B) port and tank to (A) port. But in central neutral position it differs. Following types of configuration are more commonly used flow pattern in center position of spool.

1. Open Center Type: - In this type, of all ports are interconnected, hence pump discharge return to tank as well as cylinder port are not under pressure, and connected to tank.

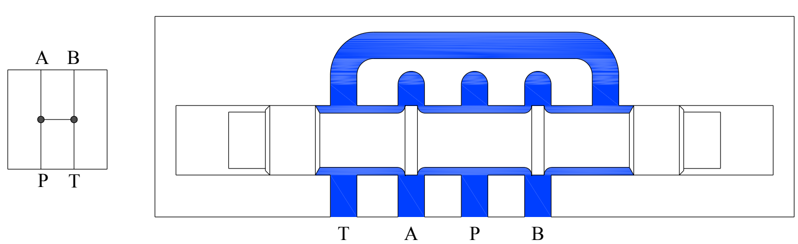


Figure No. 9.6.4 (a)

2. Close-Center Type: - In this type all the ports are blocked. Pump port is blocked hence pressure develops. Oil passes over relief valve or used for operating other valves.

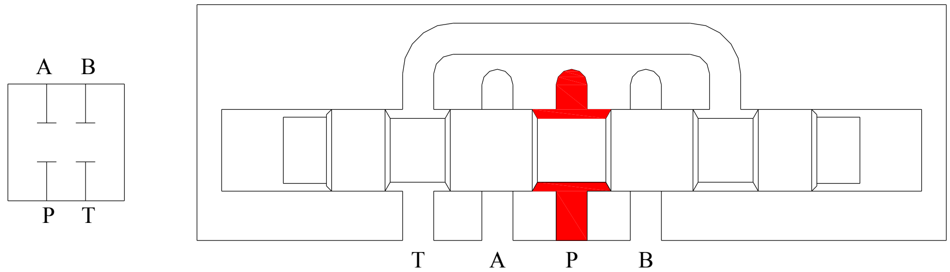


Figure No. 9.6.4 (b)

3. Tandem Type: - In this type both the oil port for cylinders are blocked and pump port is connected to tank. Hence in neutral position cylinder remains locked while pump is unloaded to tank at low pressure. These types of valves could be connected in series.

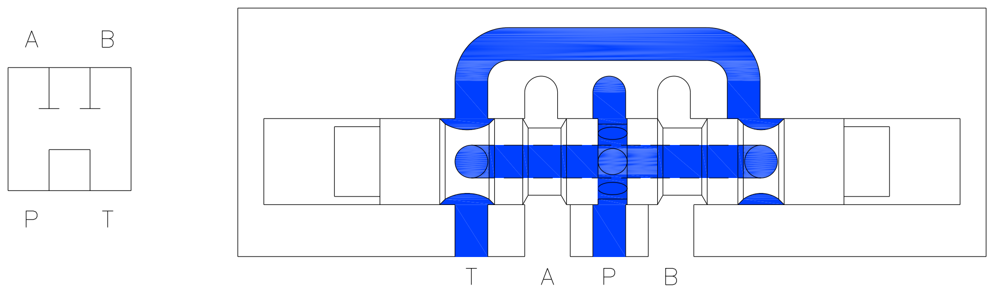


Figure No. 9.6.4 (c)

4. Float Type: - In this type only pump port remain blocked while cylinder and tank port are inter-connected. In two stage direction control valve, the solenoid valve, which operate main valve have this type of spool in center condition.

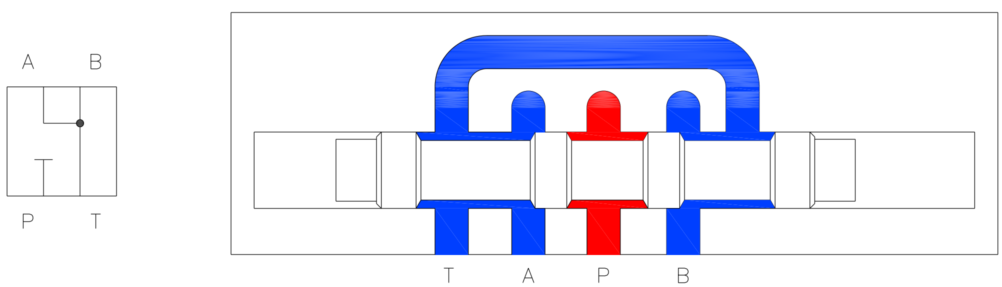


Figure No. 9.6.4 (d)

In addition to above four types, there are so many other types valves manufacture by many manufacturers.

9.6-5 Two Stage Direction Control Valve: -

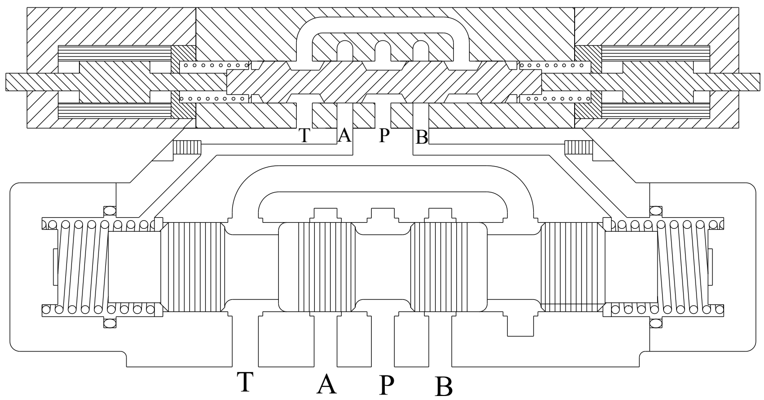
When large volume of fluid is to be controlled then large size of valve requires, with large spool. To actuate large spool, large solenoid is to be used, which requires great amount of electricity, which is not practical. It is more convenient and easy to actuate them by hydraulic means than any other means.

To actuate spool by hydraulically an oil chamber is made on each end-side of spool in valve body. When one side is supplied with pressurized oil other side is connected to tank. This causes shifting of spool. To reverse the direction, oil is supplied to other side, and first pressurized chamber connected to tank.

This supplying oil on both side of spool is carried out by another direction control valve actuated by standard small solenoid and is called pilot valve and mounted directly on the main large direction control valve body.

The small pilot direction control valve is only to actuate the spool hence even a 3 to 4 kg/cm^2 pressure is sufficient for its satisfactory operation. But it can also work up to full rated pressure of system. Pilot valve must have supply of oil under some pressure even when pump is unloaded to tank at atmospheric pressure.

To supply oil under pressure to pilot valve both backpressure is developed in system, and that backpressure is used operates pilot valve or it is supplied oil from other source.



Two Stage Direction Control Valve
Figure No. 9.6.5 (a)

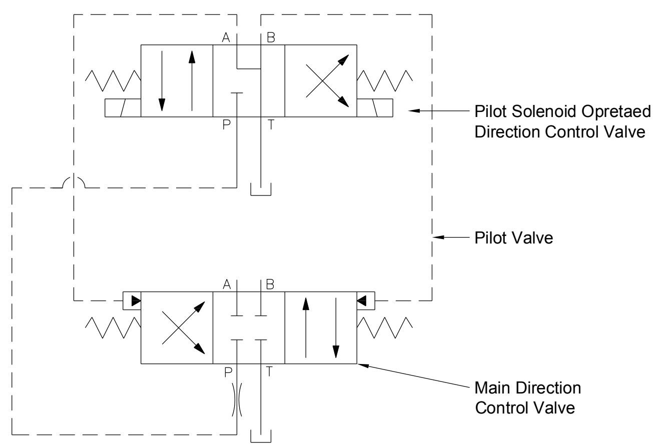


Figure No. 9.6.5 (b)

9.7 CHECK VALVE

Check valve is one-way direction control valve. It allows flow in one direction while blocking flow in other direction.

Check valve consists of a valve body, a ball or a poppet and a light spring, which hold ball or poppet on valve seat. In one direction oil flow lifts the poppet/ball against spring force, and passes to the other side. While in reverses direction ball/poppet sits on valve seat and do not allow the flow of oil.

Check valve in addition to control flow in one direction also used to develop backpressure. If a strong spring is used the oil require some pressure to lift it and by-pass. Hence according to need a spring equivalent to 2, 3 or 5 kg/cm2 or as requirement by the system is used to develop a backpressure in system.

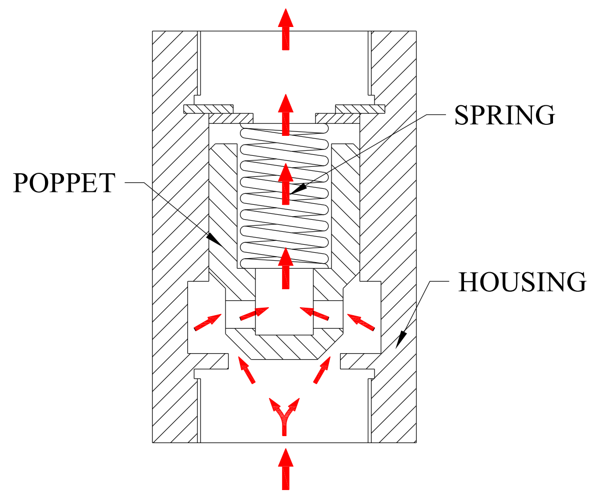


Figure No. 9.7

9.7-1 Pilot Operated Check Valve :-

Pilot operated check valve is similar to simple check valve. But this valve can also allow reverse flow if it is supplied with a pilot pressure to lift the poppet, as shown in the figure.

These types of valves are used to hold and lock the cylinder under pressure. And release the pressure by providing pilot pressure to valve when it is not required.

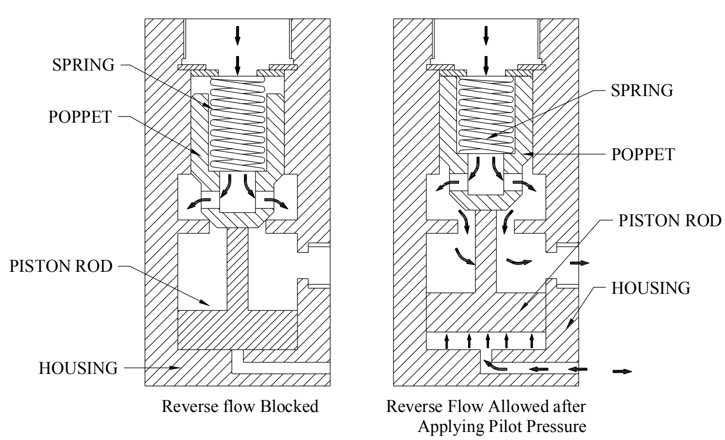


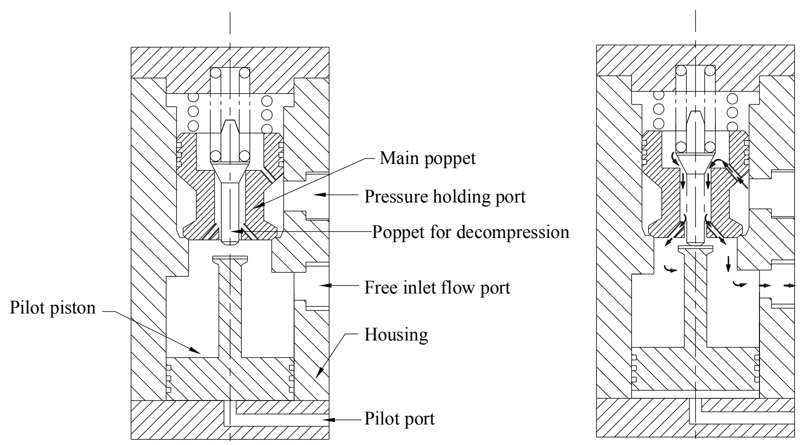
Figure No. 9.7.1 (a)

As pilot operated check valve is used to hold the high-pressure oil locked in cylinder. Suddenly releasing the oil pressure from cylinder will produce a shock and vibration, which are damaging the system.

The high pressure oil in cylinder acts on poppet of pilot operated check valve, a low pilot pressure through the pilot port on pilot piton may not develop sufficient force to lift the poppet from its seat to allow release of high pressure oil from cylinder. Hence for above two reasons it is necessary to first defuse the high pressure locked in cylinder then release oil from cylinder.

For this purpose the poppet of pilot operated check valve is modified. It is made in two stages. That is a small check valve (a poppet and spring arrangement) is fitted in main poppet.

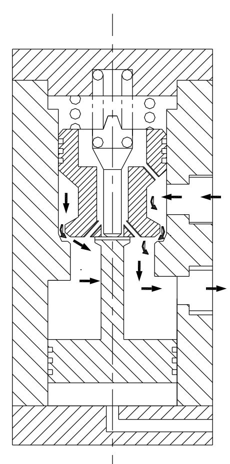
Small puppet required less force to lift it from its seat. Hence when even a low pilot pressure applied, pilot piston first lifts the small poppet, which causes release of small amount of oil slowly. Hence slow drop in pressure locked in cylinder, when pressure drops sufficiently and load on main poppet reduces it also get lifted up and releasing all the oil from cylinder to return to tank.



Pilot Opareted Valve with Reverse flow block

Pilot operated check valve with decompression feature

Figure No. 9.7.1 (b)



Pilot operated check valve full flow in reverse direction

Figure No. 9.7.1 (c)

9.8 TYPES OF CONSTRUCTION OF HYDRAULIC VALVE

Most of the hydraulic valves are available in four types of construction, as follow.

1. Threaded port type construction.
2. Sub-plate mounting type construction.
3. Modular construction type.
4. Cartridge type

To explain above four constructions we will take an example of flow control valve and describe it by sketch in all four constructions.

9.8-1 Threaded port type: - In this type of construction, valves have threaded port, and they are inter connected by piping. This is old design. Piping requires more space. Prone to leakage, require more labour and time for fixing, and they also looks shabby.

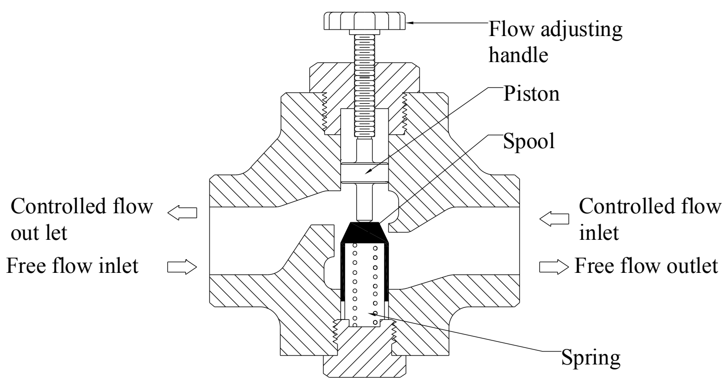
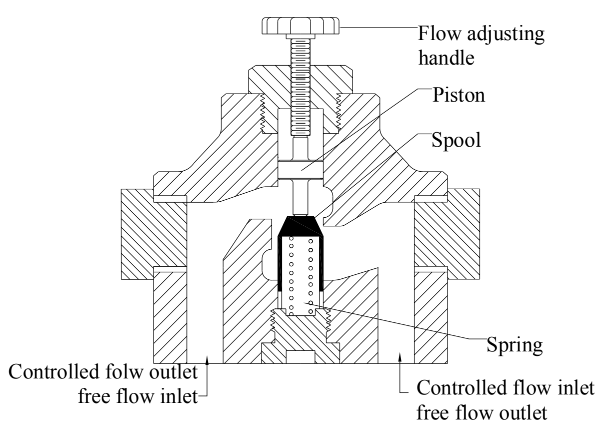


Figure No. 9.8.1

9.8-2 Sub-Plate Mounting type construction: - These types of valves are most widely used. In industry. They are similar to threaded type and differ only in way of mounting. These valves have a flat surface where all the oil ports are provided. They are bolted to manifold at this flat surface. Oil port of valve matches with holes in manifold. Using o-ring at each oil ports prevents oil leakage.



Sub-plate type construction of
flow controll valve

Figure No. 9.8.2

Manufacturing a hydraulic system becomes simplest using such types of valves. But this type of construction has limited flow capacity. As largest type of valve is only as per CETOP-5, hence their maximum flow capacity is only 100 LPM. And best result we get only below 40 LPM and 200 bar working pressure.

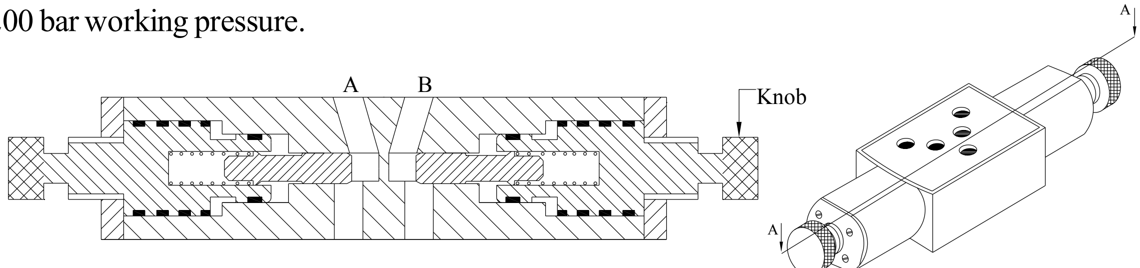


Figure No. 9.8.2 (b)

9.8-3 Cartridge types of construction: - Construction of cartridge types of valve differs from above types of valve construction. Their concept and principle also differs. But they handle maximum flow and quickest in response, and they are also economical if designed for large power pack with two many function and operation. As this is totally new concept, hence to explain it we will study and describe it in detail in next chapter.

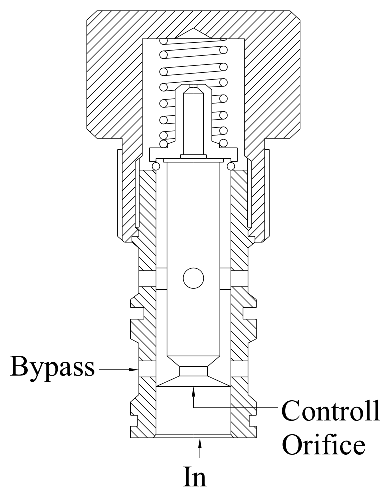


Figure No. 9.8.3

All-the above valve we described are for same purpose that is to control flow. But there is drastic difference in their construction, cost and fixing. Hence all-the valves should be studied thoroughly and then selected and used correctly.

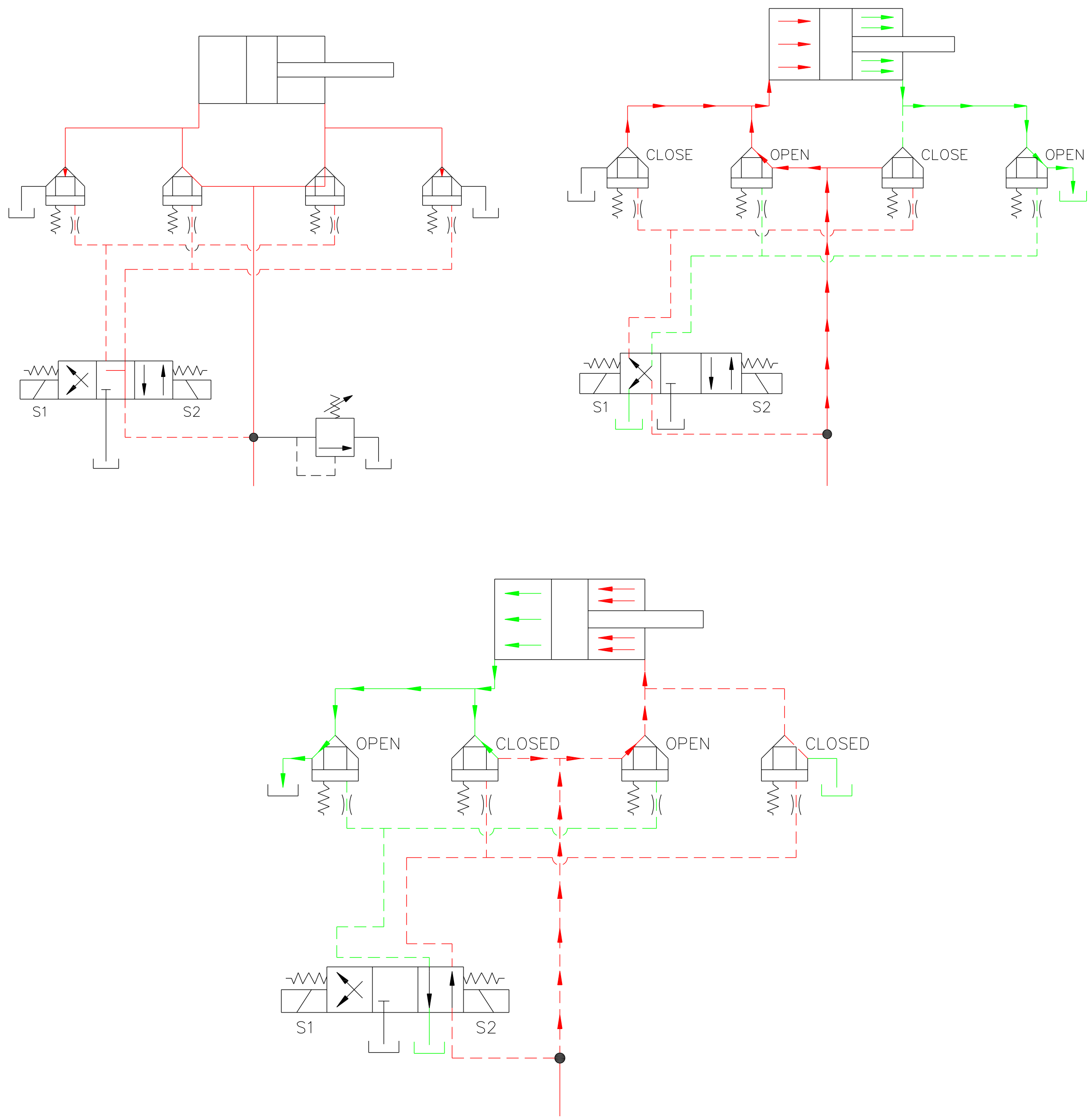


Figure No. 9.8.3 (b)

9.9 UNDERSTANDING THE PRINCIPLE CARTRIDGE VALVE

The cartridge valve is a simple element, which opens or blocks the passage of oil flow. To understand how it is actuated, consider a nail driven through a wooden board.

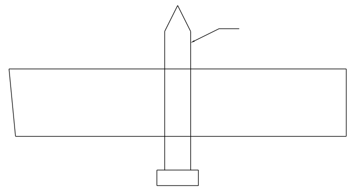


Figure No. 9.9 (a)

To remove it either we will apply load on its pointed edge or by prying under the head

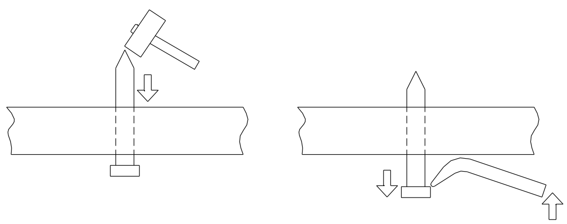


Figure No. 9.9 (b)

And to drive it further in board we will apply load on its lead, which is large in area.

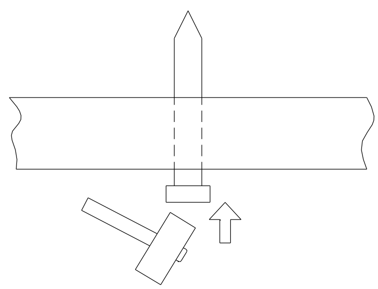


Figure No. 9.9 (c)

Similarly consider a simplified sketch of poppet type slip in cartridge valve. Consists of a poppet and a spring. Spring locate poppet firmly on its seat. To open simple valve poppet should be lifted to lift poppet pressure is to be applied port-A, which will apply pressure on area ($\pi/4 \times d^2$). Poppet also could be lifted by applying pressure in port-B, which will apply pressure in annular area (D^2-d^2) x $\pi/4$.

To close the valve, poppet should be firmly seated on its seat and blocked passage of oil between port-A & B. it could be done by applying pressure at port-X. Pressure will act on area ($D^2 \times \pi/4$). In addition to oil pressure spring force also tries to force poppet on its seat.

One of the most important advantages of cartridge valve is that it handles very large volume of flow when actuated with very small solenoid valve. Now consider how easily and conveniently this simple single cartridge valve can be used as a.

1. Check Valve.
2. Direction Control Valve.
3. Could incorporate acceleration Feature.
4. Could have quick closing feature.
5. Could act as simple flow control features.

Could have pressure-compensated flow. Control feature with addition of another cartridge etc.

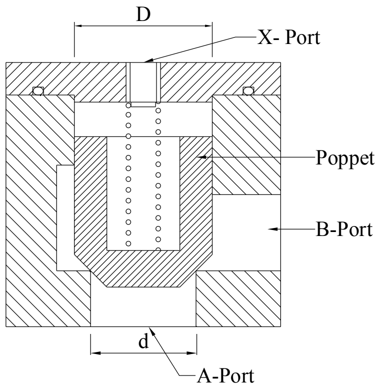


Figure No. 9.9 (d)

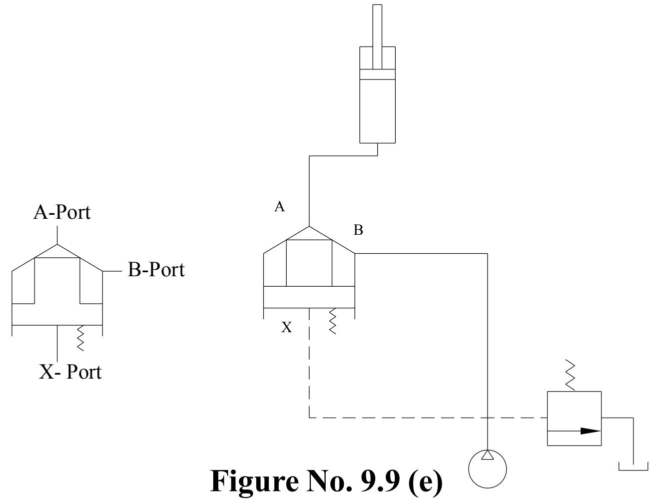


Figure No. 9.9 (e)

9.9-1 Check valve:-

When there is no pressure, the valve is closed by spring force. If there is pressure in A side and no pressure at port-B or X, flow will pass from port-A to B. but flow cannot pass from port-B to A. As port-X is connected to port-X, and poppet is enclosed by spring force as well as force acting on large area. Hence this cartridge valve acts as check valve.

9.9-2 Direction Control Valve: -

To form a direction control valve, which will allow flow from port-B to port-A or stop it, a solenoid valve is added to alternation the signal in the port-X.

When port-X, is connected to pump, through solenoid valve, a check valve is created which will not allow flow from port-A to port-B that is from pump to cylinder. But when port-X is connected to tank by solenoid valve, flow can pass from pump to cylinder. Hence it acts as direction control valve.

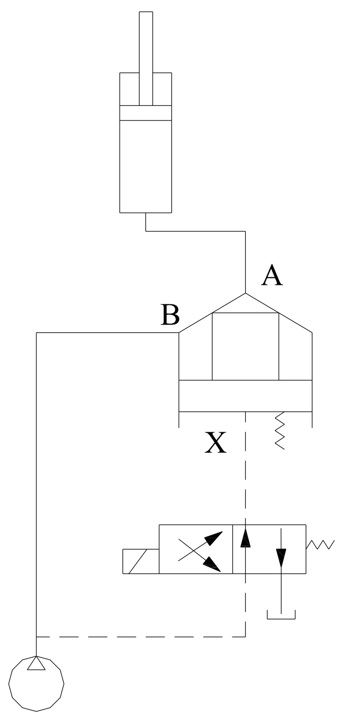


Figure No. 9.9.2

9.9-3 Acceleration Control: -

In previous circuit when port-X is connected to tank pump oil flows to cylinder. Spool solenoid valve shifts in 10-mil/sec Hence cartridge valve open in 10 millisecond and oil rushes in 10 mil/sec to cylinder. This causes a sudden and jerky start of cylinder. For smooth start and acceleration a throttle is added in port-X. Throttle cause slow opening and closing of cartridge valve. Hence cylinder starts and stops slowly.

If the throttle in port-X is of variable type then rate of acceleration and deceleration also could be vary and controlled.

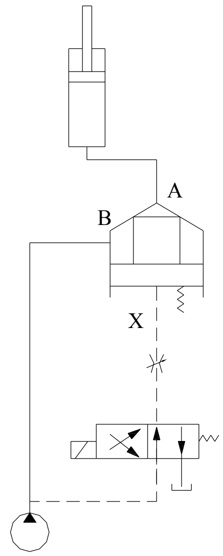


Figure No. 9.9.3

If a quick start or a quick stop of cylinder is required then a check valve is added in parallel to orifice (throttle) in port-X. if check valve allow quick closing of cartridge valve then stopping of cylinder will be sudden and if check valve make cartridge valve to open quickly then starting of cylinder will be quick. Hence as per requirement of system, acceleration of cylinder and their substitute could be selected.

Following figure shows controlled acceleration and quick stopping of cylinder.

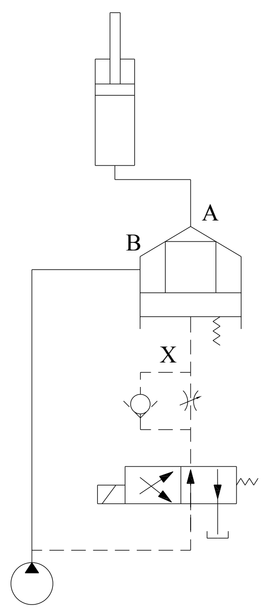


Figure No. 9.9.3 (a)

9.9-4 Flow Control Valve: -

In previous examples once cartridge valve opens it allow full-flow of pump to pass on to cylinder. Hence cylinder always works at its maximum possible speed. Such high speed may not be required and if it is desired to control the speed of cylinder then flow of oil into the cylinder must be throttled.

For this purpose a adjusting screw is provided in cartridge valve which do not allow full opening of cartridge valve. Hence same cartridge valve also starts acting as flow control valve.

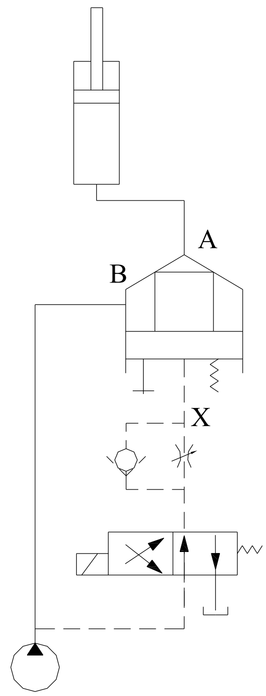


Figure No. 9.9.4

9.9-5 Pressure Compensated Flow Control Valve: -

In previous example by providing adjusting screw and controlling opening of cartridge valve we created a fixed or throttle type flow control valve. By adding one more cartridge valve in following way we create a pressure compensated flow control valve.

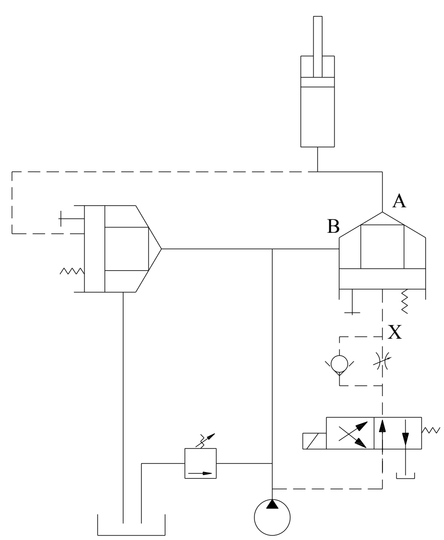


Figure No. 9.9.5

Suppose the second cartridge has spring of 2 kg/cm2 and the port-X1 of second cartridge valve is connected to tank. Then pump will be unloaded to tank at 2 kg/cm2 through second cartridge valve. And if port-X1 is connected to cylinder line then second cartridge will remain close, as closing force is equal to pump pressure plus 2-kg/cm2 spring forces.

When flow of oil in first cartridge valve is throttle speed of cylinder. There will be drop of pressure due to throttling, and pressure at cylinder port will decrease. If pressure drop is more than 2kg/cm^2 then second cartridge valve get opened. As pressure supporting closure of cartridge valve in addition with 2kg/cm^2. Spring becomes less than opening force on second cartridge valve. Hence some oil start by passing through second cartridge valve to tank.

As when less oil passes through first cartridge valve there is less pressure drop, and as pressure at cylinder port increases second cartridge valve starts closing.

This process will keep on hunting and equilibrium will reach when a quality of oil which will cause 2 kg/cm2. While flowing through first cartridge valve after throttle is reached. Hence cylinder will always get fixed amount of flow irrespective of load on it.

From above example we can judge that cartridge valve are simple. By manipulation a cartridge valve is made as check valve, direction control valve, flow control valve with pressure compensation as well as acceleration control etc. these few examples are only to give you idea of its function. But in actual complete circuit of a hydraulic current could be made using cartridge valve, and they have following special advantage.

9.10 ACCUMULATORS

An accumulator is a device which stores energy of fluid (potential energy) in the form of pressure, against the dynamic force, such as lifted weight or gravity, or pressurised gas or mechanical force by spring.

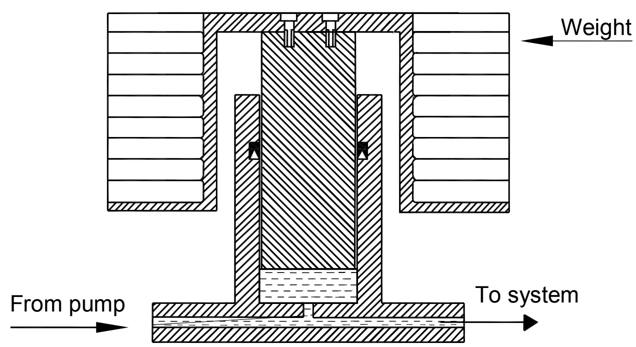
Classification of accumulators:-

On the basis of dynamic force against which they store energy, accumulator could be divided into three catalogues

1) Weight loaded accumulator
2) Spring loaded accumulator
3) Gas-charged accumulator

9.10.1 Weight loaded accumulator:-

Construction of weight loaded accumulator is similar to gravity return single action cylinder with heavy load on it's piston-rod.



Weight Loaded acccumalatar

General formula for loaded accumulator:-

1) Static pressure (P)which accumulator can hold = $\dfrac{\text{Weight}}{\text{effective cross section area of Ram}} = \dfrac{W}{0.7854\ D^2}$

Where D= Ram diameter
W= Loaded weight
L= Length of stroke
P= Pressure

$\frac{\pi}{4}$

2) Capacity of accumulator $= \frac{\pi}{4} \times D^2 \times$ stroke

3) Enery stored $= D^2 \times P\,L$

Hp / hour $= 2.494\ PD^2L \times 10^{-6}$

P= in PSI
D= in inches
L= length of stroke in feet

Advantages:-Weight loaded accumulator delivers fluid at constant pressure throughout it's stroke.

Disadvantages:- It is bulky, and not suitable for mobile hydraulic system. It is sluggish due to inertia of weight. And when weight descends fast and stops suddenly, it generates very high pressure surge (similar to water hammer effect)

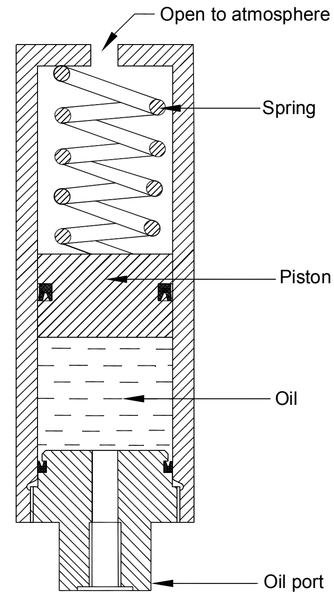
Application :- It is generally used for low pressure and low volume application. Average capacity of weighted loaded accumulator is 5 litre and pressure range as 75 bar. babar.

9.10-2 Spring Loaded Accumulator:-

Spring loaded accumulators are similar in construction to that of weight loaded type of accumulators. But instead of weight, it is preloaded with spring compression. Oil enters in accumulator by further compression spring. When oil required by system, spring forces out oil to system. But as compression of spring changes, its compression force also changes. It is minimum at beginning of compression and maximum at end of compression. Hence pressure of oil supplied by spring loaded accumulators are not at constant pressure.

Spring loaded accumulators are generally used for 5 to 35 bar pressure, and up to 1.5 liter capacity application. High pressure and high volume requires spring of very large size, which are not practical and feasible.

Their response is very fast but these types of accumulators are not used for application of repetitive cycle. As because of high cycle rate, spring will be subjected to fatigue and will lose its elasticity.



Spring-loaded Accumulateor

$$\text{Oil pressure in accumulator} = \frac{\text{Spring force}}{\text{Piston force}}$$

$$\text{Spring force} = \text{Spring constant} \times \text{compression} ....$$

9.10-3 Gas Charged Accumulator:-

• This type is widely used accumulator, in industry. They use compressed gas to give the dynamic force. As they are compressed gas operated, so they are also called hydro-pneumatic accumulators.

These accumulators are designed on basis of Boyle's gas law which states that "for constant temperature process, the pressure of the gas varies inversely with its volume." That means if at a constant temperature if volume of a gas reduced to half, its pressure will get doubled.

This compressibility of gas is used to store potential energy. When system pressure increases, gas get compressed and system pressure increases, compressed gas forces oil out of accumulator into the pipe line of hydraulic system.

Gas charged accumulator consists of a cylinder, a gas volume to fill and locks gas in accumulator and a oil port.

Types of Gas Accumulator :-

Gas type accumulator could be divided in two categories, depending up on the method of which they separate oil and gas. They are as follow:

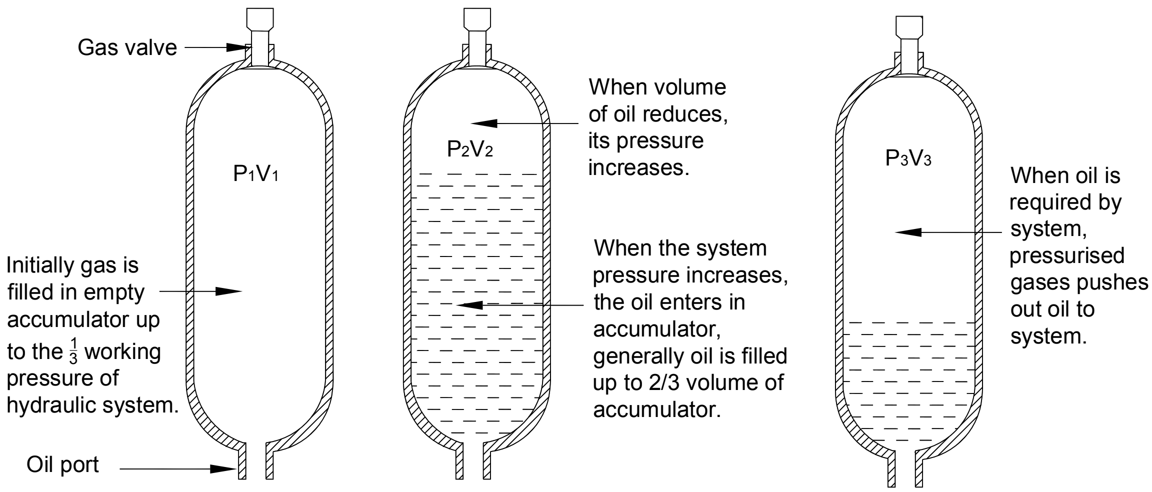
1) Non-separator type
2) Separator type

Non-separator type: - These types of accumulators consist of a shell without any piston or bladder or diaphragm. Gas is directly changed in shell from top side, and oil is pumped-in from bottom side, there is no barrier between gas and oil. When oil pumped-in, it reduces volume of gas, hence its pressure increases. When system requires oil, gas pushes out the oil to system, but as gas expands, pressure reduces. Their working pressure range is between 3 to 50 bars and their response is very fast.

Advantage: - Capacity of this type of accumulator is highest as compared to others. Their capacity is between 35 liters to 5000 liters.

Disadvantages: - As there is no barrier between oil and gas, hence gas gets dissolved in oil, which causes spongy or sluggish response of hydraulic system. If oil drawn more than capacity of accumulator, then gas escape-away from accumulator hence great care has to be taken while using such accumulator.

Usually dry nitrogen or inert gases are used for charging accumulator, Oxygen should never be used because of its decency to burn or explode when compressed with oil (similar to what happens in diesel engine cylinder) And because of this reason air is also not recommended, although it is some time used.



Non-Separator type gas charged accumulator

Separator type accumulator:-

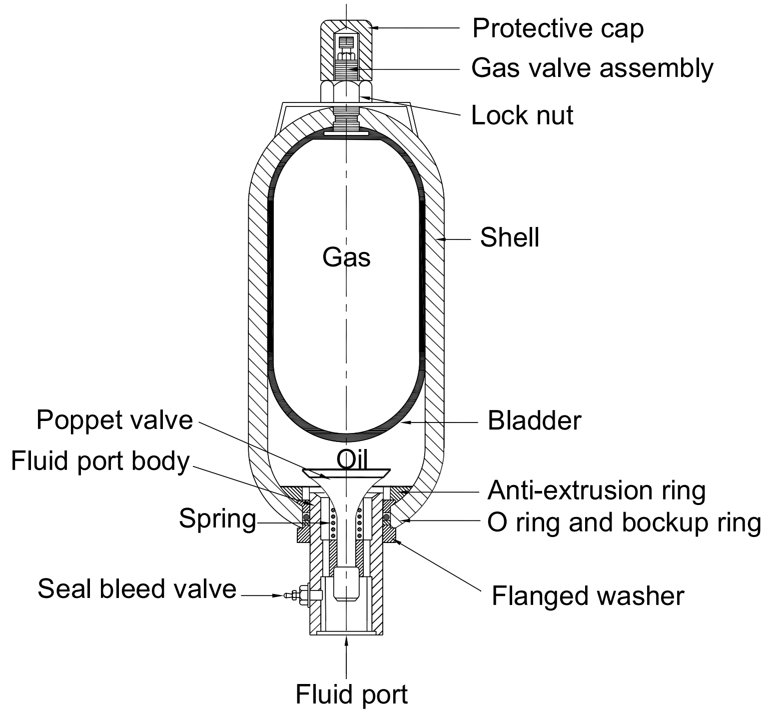
These types of accumulators are most widely used accumulators in industry. In these types, there is a physical barrier between oil and gas. The barrier may be a piston, a bladder or diaphragm.

Bladder type accumulator:- This type of accumulator has an elastic barrier in the form of bladder between oil and gas. Bladder is basically a balloon like thing, made from elastic materials which are compatible with mineral oil. Accumulator has two openings. Bladder is fixed to top opening from where gas is charged. Oil is supplied from bottom openings. Bottom opening also has a normally open type check valve. In normal operation it remains open. But when complete oil gets exhausted, and bladder tries to extrude out from oil port, this valve gets closed, and bladder remains safe from getting extruded and permanently damaged.

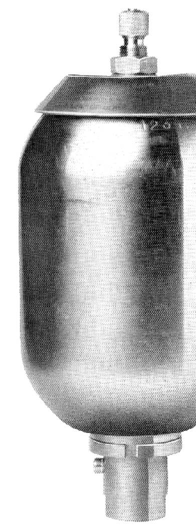
Bladder types of accumulators are available from fraction of a liter to 70 liter capacity. And their optimum operating range is up to 200 bars. But accumulator up to 500 bars also available. Their response is very fast and they can withstand temperature up to 175 ^{0}F.

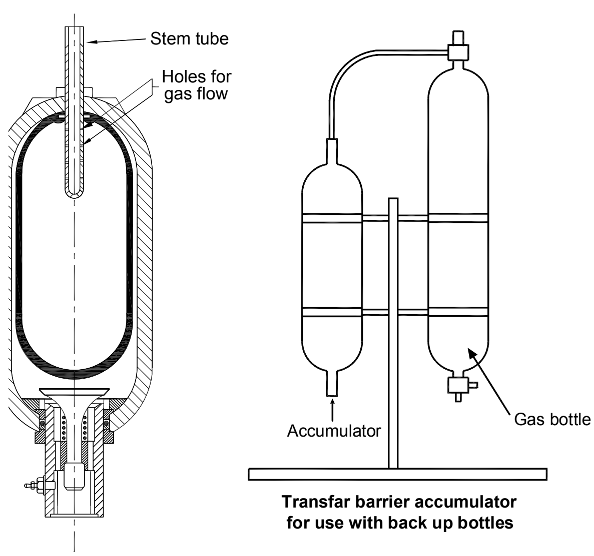
Shell are made from chromium molybdenum steel as per BS 5045 part 1:1982 or 316 grade stainless steel as per CODAP standard. Bladders are made from Nitrile (-20, +100^{o}C temperaturem range), Butyl (-15,+120^{o}C), Fluorocarbon (-220, +120^{o}C), Ethylene prophylene (-20, + 120^{o}C) etc.

(See Diagrams on next page)

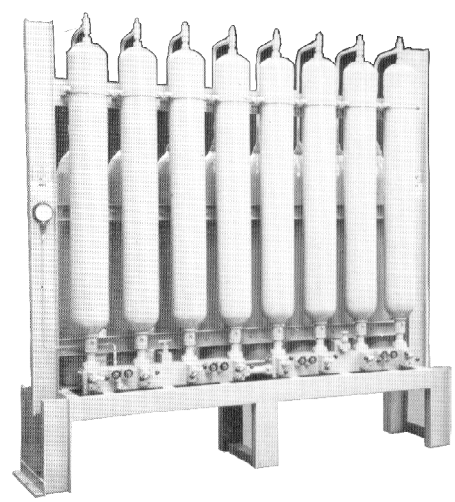


Bladder type Accumulator





Transfar barrier accumulator for use with back up bottles



Transfer barriers accumulators are those in which compressed gas section of accumulator is not locked, but connected to pressurised gas bottles or othersource of pressurised fluid.

Diaphragm type Accumulator: - Diaphragm type accumulators are similar to bladder type accumulator with two following differences:

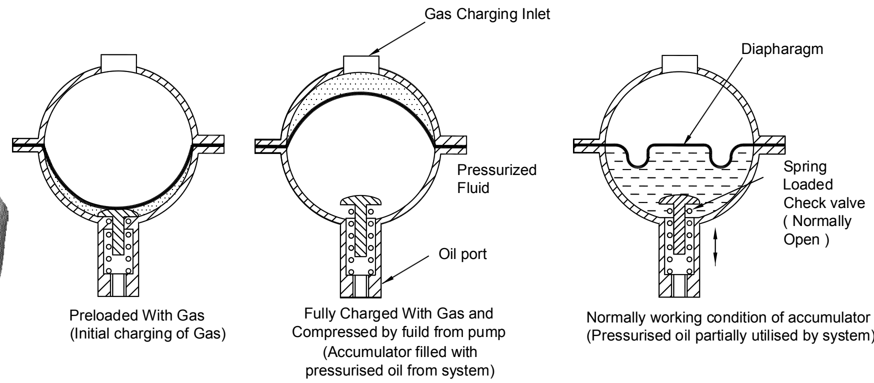
1) Body of diaphragm type accumulators is spherical in shape.
2) They use diaphragm instead of bladder or balloon for separating gas with oil.

Diaphragm type accumulator also has two ports. Top port is for gas from when gas is charged. Bottom port is for oil. Oil port is also fitted with a normally open type non-return volume to avoid extrusion of diaphragm from oil port.

Diaphragm type accumulators are available from 0.07 to 5 liter capacity, and working pressure from 40 to 500 bars.

As gas charged accumulator are charged in empty condition. Charging pressures are 90% of minimum system pressure or ¼ to 1/3 of normal working pressure. For example if its working pressure is 200 bars, the pre-charging gas pressure will be 50 to 70 bars, or if minimum allowable system pressure is 100 bar, then precharge pressure will be 90 bar

Diaphragm or bladder type accumulators are generally used between ¼ to ¾ of their total capacity. If they are used out side this range, then it may cause elastic material to stretch or wrinkle which shortens their life.

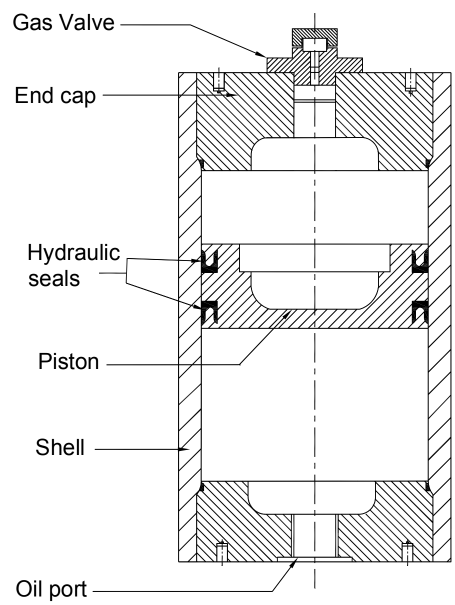


Piston type accumulator:-

In this type the accumulator has a cylinder shell and a freely floating piston with oil seal. Piston prevents mixing of pressurised gas with oil.

Cylinder shell requires honing and anti-corrosive plating, hence this type of accumulator is costly as compared to others. They are made from 15 cc. to 70 liter capacity range. Due to piston seal friction with shell, at low pressure these accumulators do not give quick response.

Due to inertia of piston, there response is not instantaneous, hence not suitable for pulsation damping and shock absorption.



Piston Accumulator

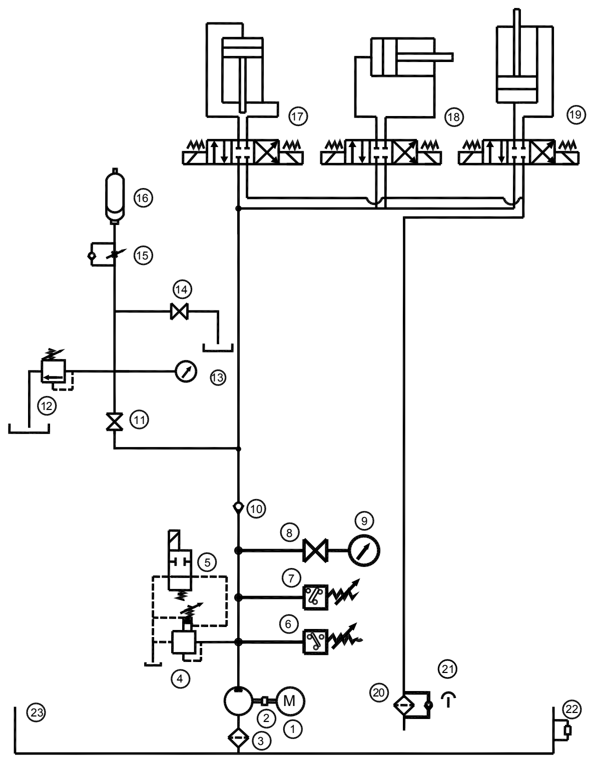
As there is no positive sealing between gas and oil, as in case of bladder or diaphragm type of accumulator, hence gas leaks out in long run.

At very high or low temperature, bladder and diaphragm material loses their mechanical properties. In case of piston type accumulator, piston requires a small size of seal. By using suitable material of seal, which can withstand higher and low temperature, Piston type accumulator could be used for extreme temperature (-04 to 250 F)

This type could be used up to 350 bar pressure.

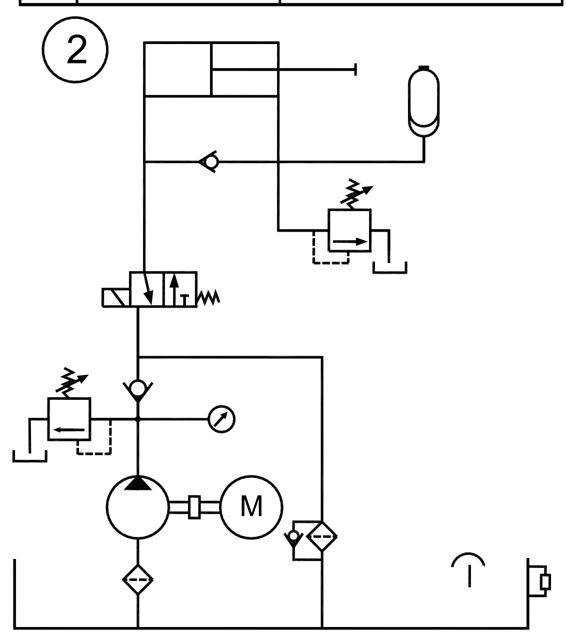
9.10.4. Applicaton of Accumulator:-

1) Reduction of install power:- Accumulator stores energy of fluid (potential energy) in form of pressure when system is running idle or wasting it. And supply it back when system requires it. This reduces the flow rate capacity of the hydraulic pump. This results in reduction of the installed power.



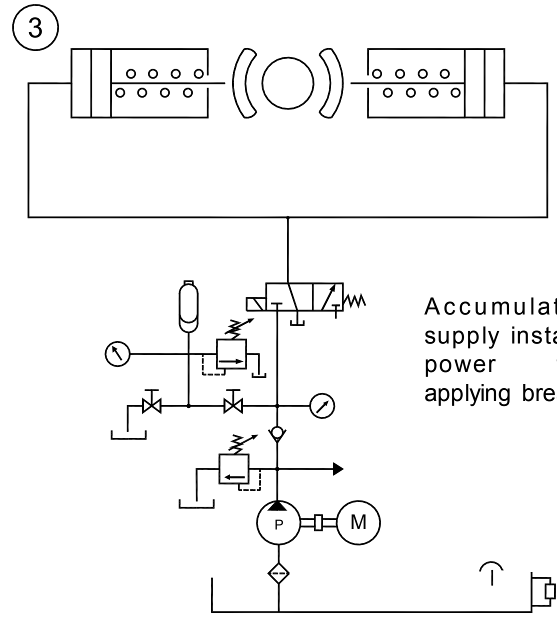
Sr.No.	Components	Functions
1	Motor	Prime mover (motor)
2	Coupling	To connect motor and pump.
3	Pump	To supply oil.
4	Pilot operated relief valve	To regulate pump pressure, and to unload pump flow to tank on receiving signal
5	Solenoid valve	To actuate relief valve[4] for unloading pump[3] flow to tank at minimum pressure
6 7	Pressure switch	To sense minimum and maximum system pressure, and give signal to solenoid volume[5]
8	Needle valve	Pressure gauge isolator
9	Pressure gauge	To read system pressure
10	Check valve	To avoid back flow of accumulator to pump
11	Needle valve	To isolate accumulator from pump
12	Relief valve	To safe guard accumulator against excess pressure
13	Pressure gauge	To read accumulator pressure
14	Needle valve	To empty out accumulator to tank
15	Flow control valve	To control discharge of accumulator oil to system. Without this valve system may operate at very high speed.
16	Accumulator	To store energy
17 18 19	Direction control valve	To actuate number of hydraulic cylinders or actuators.
20	Return line filter	To filter exhaust oil
21	Air-breather	To filter air sucked in tank
22	Oil level indicator.	To check oil level in tank

2) Guaranteeing continuity of energy supply:- Energy stored in an accumulator guarantees the operation of a system for specific time limit, even in case of accidental power failure.



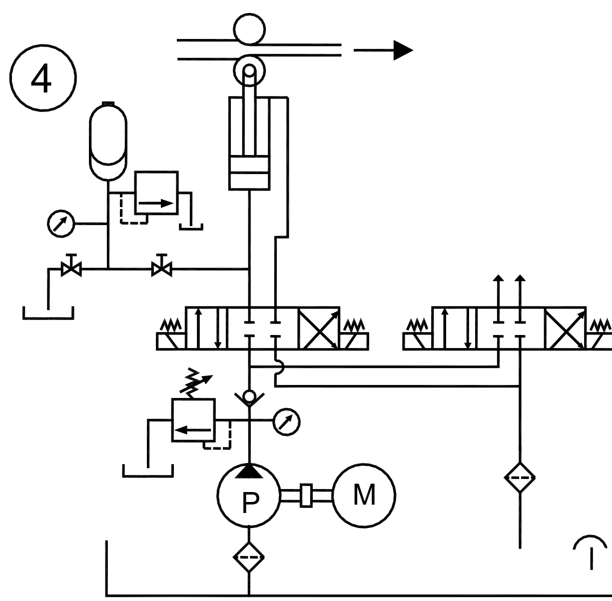
Piston rod is connected to fluid gate of Dam. When ever system switched off purposely or by power failure, piston-rod retracts back and opens the fluid gate

3) Energy and safety:- An accumulator which is kept always in fully charged condition, gives instant power for safety operation, such as breaking, closing or opening of door etc. (Pump take few seconds for developing rated pressure, while accumulator keeps it in ready stock for instant supply.)



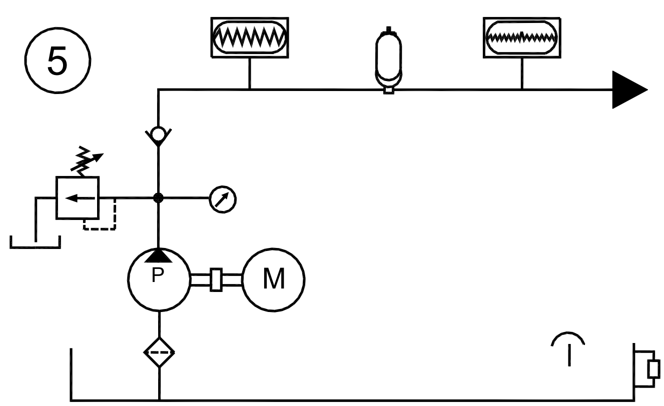
Accumulator supply instant power for applying break.

4) Maintaining pressure :- Many times hydraulic systems are required to hold pressure for very long period of time. Using hydraulic valve such as pilot operated check valve etc. pressure could be locked in system. In such cases, to maintain pressure pump and motor has to be frequency operated to build up and maintain pressure. Pressure also could be maintained more economically by using an accumulator. Accumulator keeps on supply of oil to compensate the lose of oil due to leakage and maintains pressure till itself gets exhausted. (Pressure drop below specified pressure)



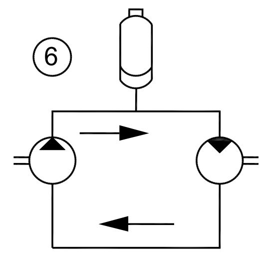
Accumulator supply costant pressure on rolls of rolling machine.

5) Pulsation dampening::- Accumulator absorbs the high pressure pulses, developed by pump, and reduces vibration.

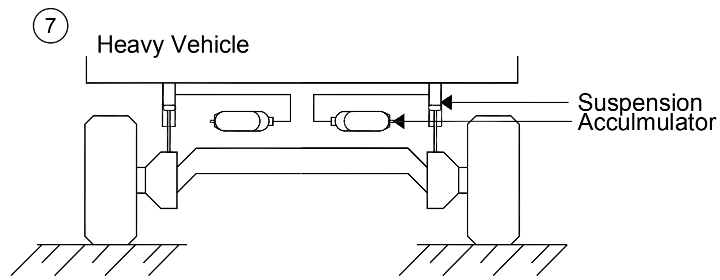


Accumulator dampens the pulse generatd by pump.

6) Compensating Thermal expansion :- In case of closed hydraulic circuit, where there is no reservoir, increase in volume of oil due to thermal expansion, results excessive rise in pressure. If an accumulator used in circuit, then it absorbs the increased volume of oil, and maintains pressure.

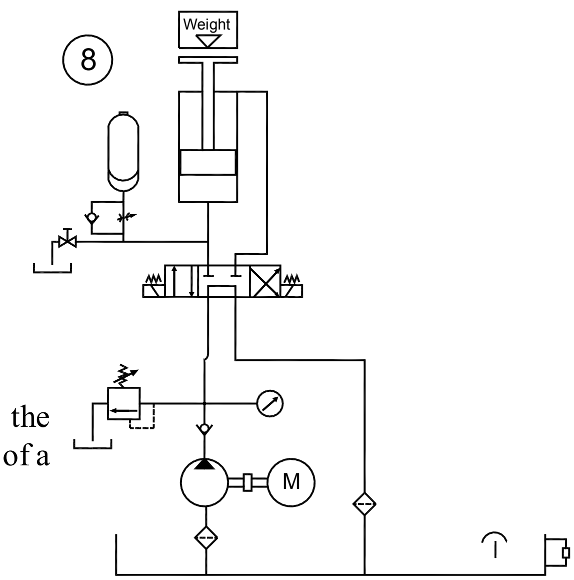


7) Heavy load suspension:- Suspension of heavy vehicle are connected to accumulator to absorb heavy shock and maintain pressure in suspension



8) Shock Absorption:- When a machine part moved by hydraulic, stops suddenly. it generate a shock wave (a peak pressure) in system. An accumulator used in system absorbs such pressure surges. For example: impact test benches, over-head crane etc.

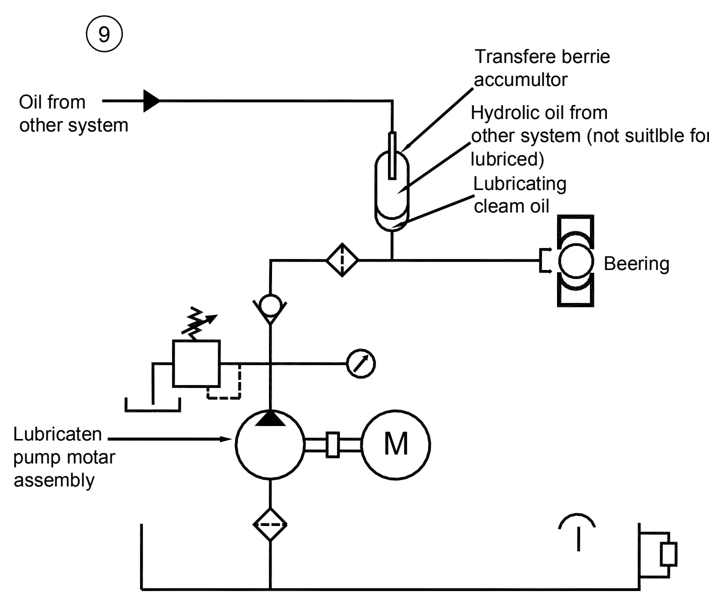
Accumulator connected to cylinder, absorbs the shock generated by impact or sudden stoping of a moving object.



9) Transfer barrier Accumulator:-

By using transfer barrier accumulator, it is possible to transmit completely a pressure developed by a hydraulic or pneumatic system to another circuit containing a different type of fluids without danger of mixing.

When pump of lubrication system fails, some amount of lubricating clean oil could be supplied to bearing by using transfer barrier type accumulator.

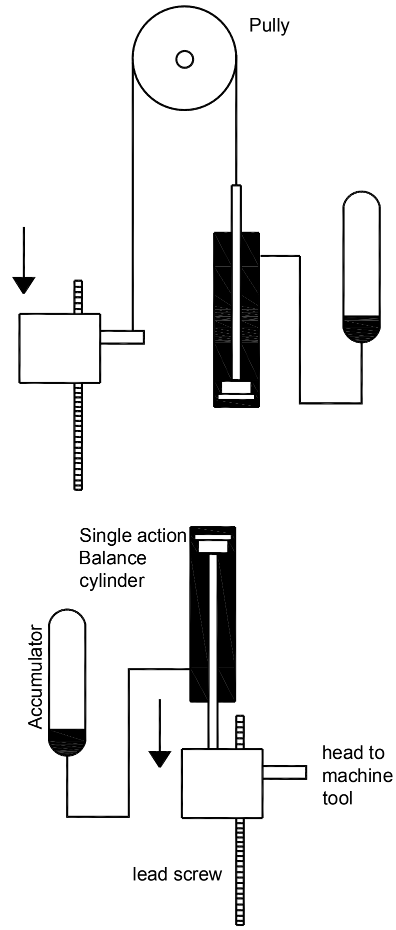


10) Use of accumulator as counterbalance weight:-
Nowadays, an accumulator along with a hydraulic cylinder is used in place of counterbalance weight in machine tool.

This arrangement consist of a single action cylinder connected to an accumulator to form a closed circuit. Piston rod of cylinder is connected to the machine-head or weight to be balanced. Initially accumulator is pre-charged to a pressure slightly below the required balance pressure. The oil side of accumulator, with cylinder in complete retracted position, is charged with oil to a pressure slightly in excess of the balance pressure.

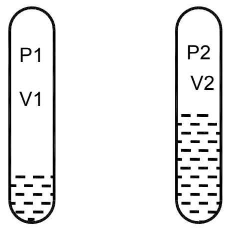
Because of this head is overbalanced in pulled up condition. When head slides down and cylinder takes forward stroke, the displaced oil of cylinder further increases the oil pressure. This overbalance pressure is normally kept to an acceptable limit of about 20% above required pressure.

Accumulator and cylinder arrangement is a component, economical design, with no inertia problem as in case of heavy counterbalance weight. It also could be used along with pulley system where direct fixing of cylinder piston-rod to head is not possible.



9.10.5. Calculation for determining Accumulator capacity:-

- Boyle's gas law is used to determine the parameters and characteristics of these accumulators.
- Boyle's law says that for constant temperature process, the pressure of gas varies inversely with it's volume.

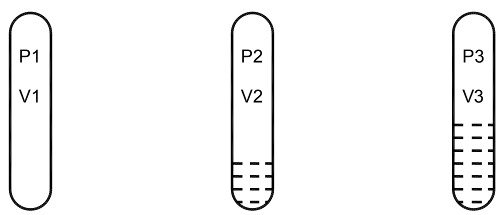


Basic isothermal rotation = PV = constant

$$P_1V_1 = P_2V_2$$

- For Isentropic (non-isothermal) condition
  Basic relation of gas volume and pressure becomes PV^n = constant
- For full adiabatic condition valve of 'n' is considered as 1.4
- For rapid cycling and appreciable heating 'n' is considered as 1.3
- For those condition in which accumulator has sufficient time to dissipate heat and return to normal temperature 'n' is considered as 1.

Calculation for Gas loaded accumulator in service :-



Recharged condition | Minimum fluid level in accumulator | Maximum fluid level in accumulator

P_1 = Pre-charged pressure
V_1 = Accumulator gas volume
P_2, V_2 = Pressure and volume at low fluid level
P_3, V_3 = Pressure and volume at high fluid level.

$$P1\ V1 = P_2 V_2 = P_3 V_3$$

$$V2 = \frac{P_3 V_3}{P_2} = \frac{P_1 V_1}{P_2}$$

$$V3 = \frac{P_1 V_1}{P_3} = \frac{P_2 V_2}{P_3}$$

fluid volume $\quad V_f = V_2 - V_3 = \dfrac{P_1 V_1}{P_2} = \dfrac{P_1 V_1}{P_3}$

$$= P1V1 - \left(\frac{1}{P_2} - \frac{1}{P_3}\right)$$

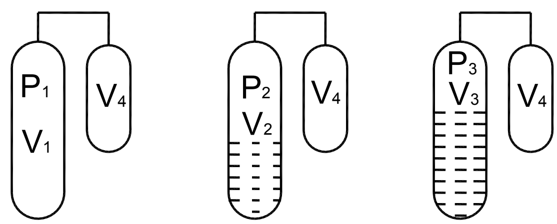
This formula gives the capacity of accumulator (volume of fluid) required for safe moving that is between minimum pressure of system P2 to maximum system pressure P3

$$\text{Precharge pressure P1} = \frac{V_f}{V_1\left(\frac{1}{P_2} - \frac{1}{P_3}\right)}$$

$$P_1 = \frac{V_f\, P_2.P_3}{V_1\,(P_3 - P_2)}$$

- While charging P_1 must not exceed P_2, otherwise in operation P_3 will exceed accumulator bearing capacity.

V_f must not exceed capacity of accumulator, otherwise life of bladder will reduce, gases will leak-out if bladder is not used.
To increase V_1 , a new extra gas bottle could be added in system.



$$P_1(V_1+V_4) \quad = P_2(V_2+V_4) \quad = P_3(V_3+V_4)$$

Accumaltor capacity = $V_f = V_2 - V_3$

$$\text{Pressure pressure } P_1 = \frac{V_f + P_2.P_3}{(V_1+V_4)(P_3+P_2)}$$

- $\frac{V_1}{V_2}$ is known as compression ratio.For gas bottle compression ratio are 1.5:1 to 3 :1

  and for piston type accumulator it is 2:1.

Question :- What size of accumulator is required to store 5 liters of fluid between pressure of 105 and 210 Bar?

Ans:-

<u>Step 1:-</u>

- We assure accumulator capacity as V_1
- We assure initial filling pressure or pre-charge pressure (without pressure) as P_1
- As we know the pre-charge pressure should be 90% of minimum allowable pressure, and minimum allowable pressure is 105.

  Hence pre-charge pressure will be

  $0.9 \times 105 = 94.5$ Bar

Step 2:-

- $P_1V_1^n = P_2V_2^n$
- We assure that accumulator is charged slowly. Hence it has sufficient time to dissipate heat, so the gas is compressed isothermally from pre-charge to system storage pressure (P_3).

For isothermal compression: n = 1

Hence $P_3V_3 = P_1V_1$

$$V3 = \frac{P_1V_1}{P_3} = \frac{94.5\ V_1}{210}$$

$V_3 = 0.45\ V_1$

Step 3:-

- We assure accumulator supplies fluid within very short period of time and do not get time to maintain its temperature. Hence it exhausts adiabatically to minimum system pressure.

Thus $P_3V_3^{\ 1.4} = P_2V_2^{\ 1.4}$

$$V2 = \left(\frac{P_3}{P_2}\right)^{\frac{1}{1.4}} = V_3$$

$$= \left(\frac{210}{105}\right)^{\frac{1}{1.4}} \times - 0.45\ V_1$$

$$= 1.6406 \times 0.45\ V_1$$

$V_2 = 0.7382\ V_1$

Step 4:-

Volume of fluid supplied to system (accumulator capacity) is the volume of gas which pushes it out. Or difference of gas volume at minimum allowable pressure and maximum allowable pressure.

$= V_2 - V_3$

As we require 5 liter fluid to be supplied to system, between minimum and maximum allowable pressure

Thus $.5 = V_2 - V_3$

$= 0.7382V_1 - 0.45\ V_1 = 0.288V_1$

$$V_1 = \frac{5}{0.288} = 17.34 \text{ liters}$$

Case - II:-

- In previous calculation we found out 17.34 liter capacity accumulator is required to supply 5 liter fluid between pressure limits of 105 to 210 bars. And for this parameters accumulator is required to be pre-charged at 94.5 Bar.
- Now suppose in one of our new requirement we calculated following parameters of accumulator. Then how should we select accumulator?
- Calculated parameters are:

1) Accumulator capacity	= 1019 liters
2) Minimum allowable pressure	= 48 Bar
3) Maximum allowable pressure	= 58 Bar
4) Pre-charge pressure	= 43.2 Bar
5) Fluid to be supplied by accumulator	= 110 liters

- One single standard accumulator may not be available in market of 1019 liter capacity. Hence we have to select number of accumulator of smaller size.
- To use minimum accumulator, maximum fluid should be drawn from accumulator. But it cannot exceed 80 of its capacity. Beyond this range bladder will be too much stretched, which will reduce its life.
- To draw more fluid with less pressure difference, additional gas bottles has to be attached to accumulator

Step 1:-

- Arbitrarily we select an accumulator of 50 liter capacity, and we connect three additional gas bottle of 50 liters to accumulator.
- Per set volume of accumulator become
  = Volume of accumulator + Volume of gas bottle.
  = $(50 + 3 \times 50) = 200$ liters
- Total volume required = Volume of each set x number of sets
  $1019 = 200 \times n$

  $$n = \frac{1019}{200} = 5.095$$
- We require more than 5 sets, so we select six sets of accumulator + gas bottle.

Step 2:-

- In this step we check that, fluid from each accumulator should not be drawn or filled more than 80% of its capacity.
- Each set is pre-charged to 43.2 bar.
  $P_1 = 43.2$ bar, $V_1 = 200$ liter

Each set stores fluid isothermally to 58 bars.

$$P_3 = 58 \text{ bar}, \qquad V_3 = \frac{P_1V_1}{P_3} = \frac{43.2 \times 200}{58} = 148.96$$

- Volume of fluid entering or exhausting accumulator $= V_1 - V_2$

  $= 200 - 148.96$

  $= 51.04$

This volume of fluid is more than capacity of accumulator, hence we add one or more sets of accumulator to system.

Step 3:-

- In previous step we used 6 sets of 200 liters capacity that is (50+3x50=200)
- If we require 7 sets of accumulator and gas bottle, then each set may be of less capacity.

$$\frac{\text{Total capacity}}{\text{No of sets}} = \frac{1019}{7} = 145.57 \text{ liters (required capacity of each set)}$$

- If we use one 50 liter capacity accumulator and two gas bottles, then we will have 150 liter capacity.. Hence we can select this combination.

Step 4:-

- Volume per set = (50+50x2) = 150 liters
- For each set pre-charge pressure = P_1 = 43.2 bar

V_1 = 150 liter

P_3 = 58 bars

$$V_3 = \frac{P_1 V_1}{P_3} = 111.72$$

- Volume of oil entering in accumulator while charging is : $V_1 - V_3$ = 150 - 111.72 = 38.28
- As this is less than permitted volume (80 % of basic volume , that is 40 liter) Hence above mentioned combination of one accumulator of 50 liter and two gas bottles of 50 liters each could be selected.

Step 5:-

Some time system requires oil within very short span of time. This determines flow rates of fluid in pipe line. Care should be taken that size of pipe line should be large enough, other wise even after having sufficient capacity, accumulator will not be able to fulfill the requirement of system.

Facts to remember while selecting an accumulator:-

1) Accumulator is a cylindrical structure. Amount of fluid which it can store is called "capacity of accumulator".

2) For satisfactory performance of accumulator, only some percentage of fluid can be used. 100% fluid inside accumulator cannot be drawn or used.

3) Volume of gas inside accumulator is very important factor. Hence the capacity of accumulator should be selected correctly, to store sufficient amount of gas.

As pressure multiplied to volume is constant. With small amount of gas inside accumulator, pressure drops quickly with slight increase in volume of gas. Hence if system works on fixed pressure or in small pressure range, a large volume of gas should be selected.

3) For energy storage application , pre-charge accumulator to 90 % of minimum allowable system pressure. For pulsation dampening pre-charge to 70% of mean pumping pressure. For shock absorption pre-charge to 90% of flow pressure at accumulator position.

Pressure should not be less than 20% maximum system pressure. Always use dry nitrogen gas for accumulator charging. Oxygen should never be used at it explodes on compression with oil.

Reputed manufacturers:

1)

2) Hydac

3)

9.11 Design and Manufacturing of Hydraulic Power Pack Unit

Before designing the power pack unit, we calculate or determine following four parameters.

1.	Prime-mover	: Its type and capacity
2.	Pump	: Its type, discharge capacity, working pressure etc.
3.	Type of hydraulic circuit and Valves	: Type of circuit, type of pipeline and valves etc.
4.	Accessories	: Capacity of oil reservoir, type and capacity of accessories such as filter, air-breather, pressure gauge, etc.

9.11.1 Selecting the Parameter: -

1. Prime mover: -

We have described in chapter-26 of prime mover regarding its type, and selection criteria. We again summarize it. The equations more often use to calculate the capacity of prime mover is.

HP of electric motor = constant x pump discharge x working pressure.

HP = 0.0007 x lpm/3.5 x PSI.

If we know pump discharge and working pressure HP could be calculated.

2. Pump: -

We have discussed in detail in chapter-27 of hydraulic pump, regarding its various type, and its selection criteria. We again summarize it as follow.

a. For very high pressure above 200kg/cm^2. And continuous operation. Piston pump is more suitable.
b. For medium pressure (175kg/cm^2) and continuous operation, and more possibility for contaminated oil, vane pump is more suitable.
c. For medium to low pressure and clean oil, gear pump is suitable, other pump can also be used.
d. Piston pump is costlier than vane pump. And vane pump is costlier than gear pump.
e. Highest flow is possible with vane pump, than gear pump and piston pump.
f. Vane pump is most convenient to repair.

Hence as per the working pressure, discharge capacity, operating situation etc. pump could be selected.

Equation useful to calculate pump is.

1. HP = Constant x Pump Discharge x Working Pressure.
2. Cross-Section Area of Cylinder x Working Speed = Pump Discharge.
3. Pressing capacity of Cylinder=Cross-Sectional Area of Cylinder x Working Pressure.

If we know any two parameters, the third that is pump capacity can be calculated.

3. Reservoir or Tank Capacity: -

We have discussed in detail about reservoir in chapter-33, we again summarize it as follow.

a. Tank capacity could be between 3 to 10 times of the pump discharge capacity.
b. For less frequent operation tank capacity may be between 3 to 5 times of the pump discharge.
c. For more frequent operation tank capacity may be 5 to 7 times and for continuous operation it may be 7 to 10 times more than of pump discharge capacity.

4. Accessories: -

We have discussed, suction filter, return line filter, pressure-line filter, air breather, oil level indicator, drain plug, pressure gauge etc. in previous chapter-33, all these are necessary parts of a power pack unit, and must be selected as per requirement, as discussed earlier.

5. Selection of Types of Valves, and Hydraulic Circuit: -

There are basically four types of valves.

a. Conventional Threaded Type Valves.
b. Conventional Sub-Plate-Mounted Valves.
c. Modular Type Valves.
d. Cartage Type Valves.

Advantage and disadvantage of each above type of valve we summarize them as follow:

a. Threaded Type of Valves: - Required more piping, more joints. Hence more leakages and maintenance. So they should be used when there is no alternative.

b. Conventional Sub-plate Type of Valves: - These valves are best, and available in large range, and capacity. If manifold is designed for them correctly, and they are properly used then they give good performance, minimum leakage, and easy in maintenance.

c. Modular Type Valves: - They are also as good as conventional sub-plate type of valves, but they are not available for large volume. Hence should be used according to flow, and pressure parameter of system. Sub-plate type and modular valves could be used for any kind of hydraulic press and all kind of customer.

d. Cartridge Type of Valves: - These valves have main advantage of quick response, economical for large circuit, and can handle large volume of flow. But require very precise manifold making, good circuit design and very clean oil, and difficult to understand malfunctioning if it occurs. Hence generally cartridge valve is used by a manufacturer with a good team of design engineers. For very precise machine, and for customer who also have good staff of engineers for maintenance.

Hence according to hydraulic machine to be designed and type of customer to whom machine will be supplied valves should be selected.

6. Type of Hydraulic Circuit: -

The purpose of power pack unit is to actuate a cylinder or hydraulic motor. But along with achieving this aim, power pack should also have many features to carry out its function or purpose properly. These features or functions are as follow:

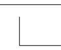
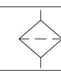
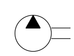
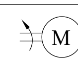
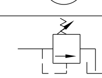
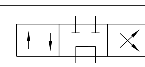
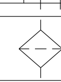
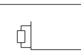
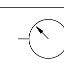
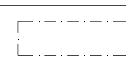
a. Pressure Control.
b. Pressure Holding.
c. Flow Control / Speed Control.
d. Regenerative Circuit.
e. De-compression.
f. Pressure Intensification and

Any as per requirement.

In chapter No.35 we will discuss in detail various type of circuits. In this chapter we will study the assembly of basic components of power pack, such as motor, bell-housing, coupling, pump, manifold, relief valve and hydraulic accessories.

7. Design of a Simplest Power Pack Unit: -

A commonly used power pack consist of:

NO.	NAME	SYMBOL
1.	Oil Reservoir	
2.	Suction Filter	
3.	Pump	
4.	Coupling	
5.	Prime mover/moter	
6.	Pressure relief Valve	
7.	Direction control Valve	
8.	Return line filter	
9.	Air Breather	
10.	Oil Level indicator	
11.	Drain Plug	
12.	Pressure Guage	
13.	Manifold block	

GRAPHIC SYMBOL

Step I :- Assembly of reservoir with accessories.

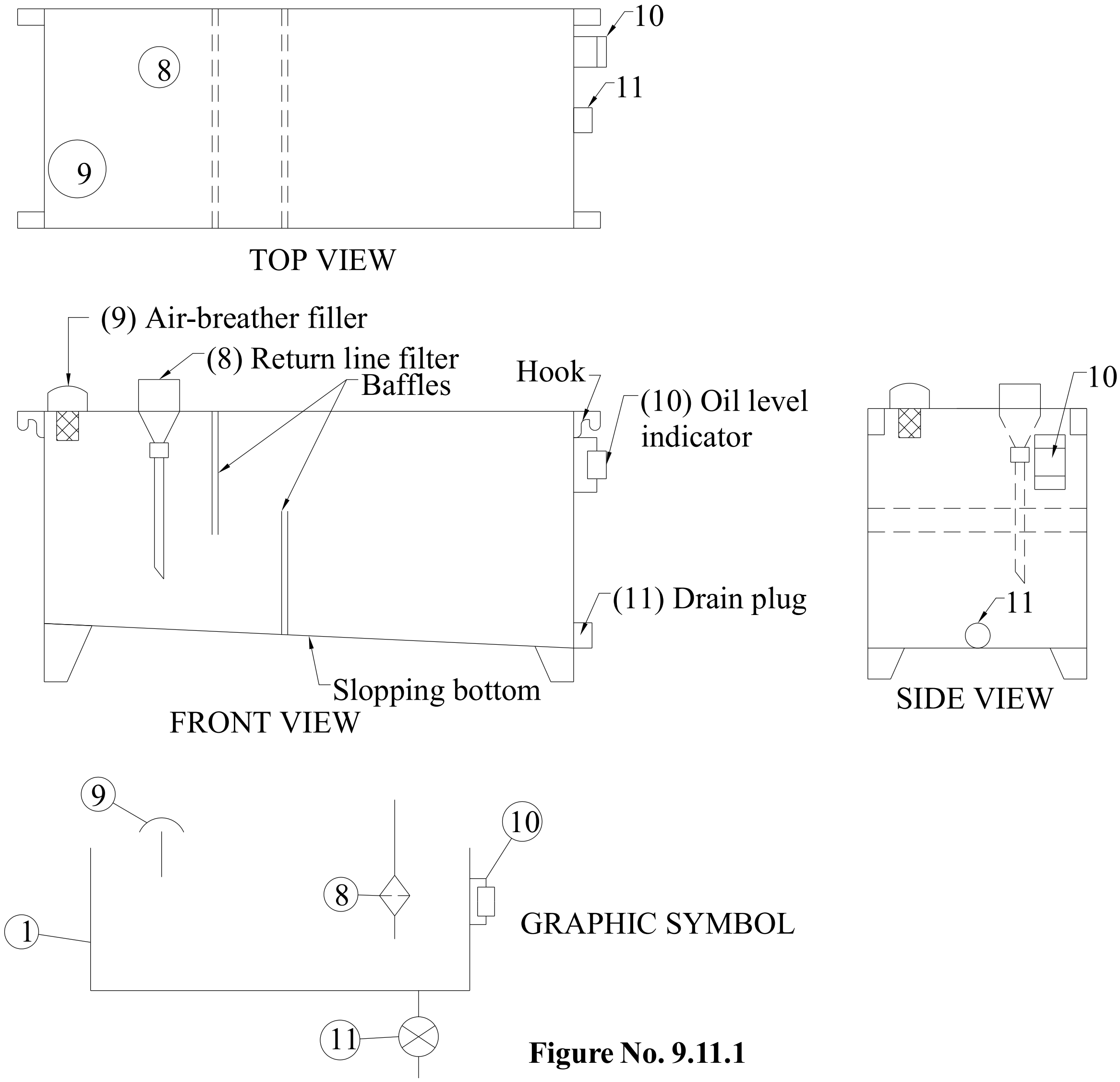


Figure No. 9.11.1

Every reservoir must have.

1. Fabricated oil tank. All welding joints should be tested to check for any welding defects.
2. Bottom of tank should be sloping, where drain plug is provided. This facilitate removal of all contamination settled at bottom, when oil is drained-out.
3. Every tank should be provided with externally visible oil level indicator.
4. Every tank should be provided with air-breather filler assembly and return line filter.
5. Every tank should be provided with lifting hook for easy handling of tank.
6. Every tank should be provided with suction filter and baffle plate to protect pump from sucking heavy or light contamination returning to tank along with exhaust oil.

Above diagram shows all these accessories such as, suction filter, drain plug, oil level indicator, air-breather-cum-filler assembly, return line filter etc. assembled on power pack tank.

<u>Step II</u>: - Fixing of Pumps Bell-housing and Motor.z

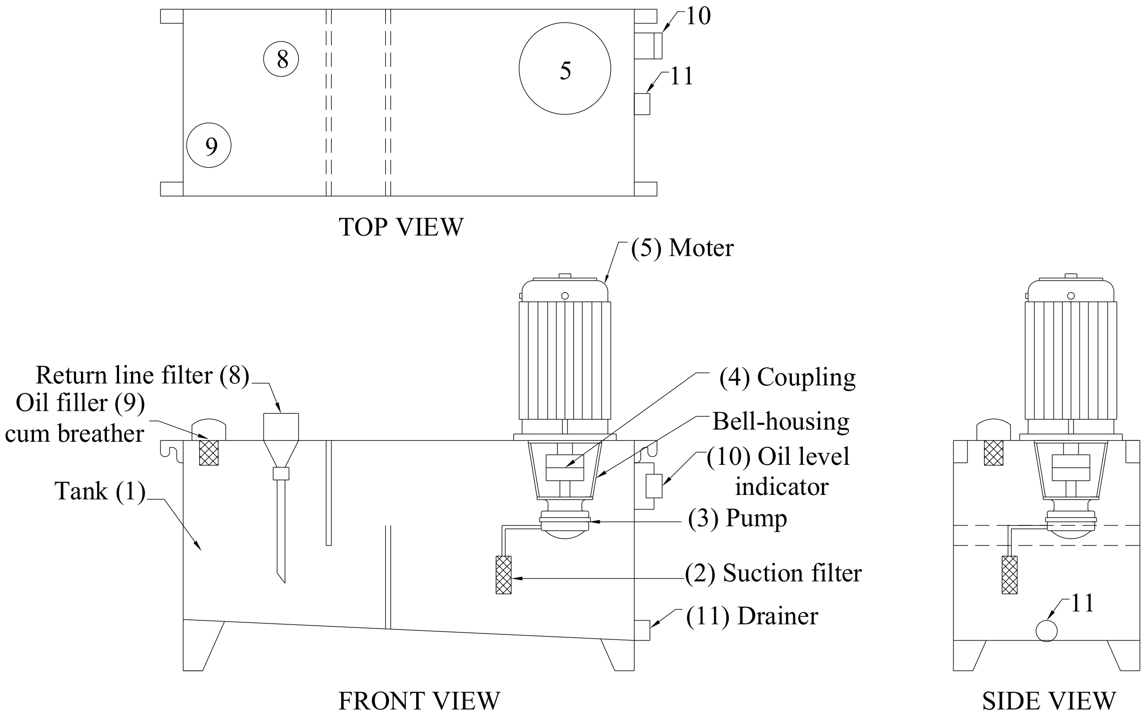
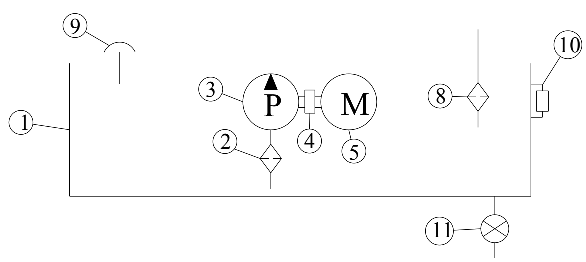


Figure No. 9.11.2



A layout should be made to decide how to fit motor, pump assembly, manifold block, return line filter, air-breather, pressure gauge etc. They should be decided, before fixing of motor-pump assembly. Once layout finalized then motor, pump assembly, and other accessories should be fixed accordingly.

Step III: - Before starting pump, it should be fitted with suction filter. Otherwise pump may even suck large articles such as cotton-waste etc. and may get damaged.

A relief valve must be provided at delivery side of pump to avoid any pressure build-up. A pump operating with out relief valve is bound to cause an accident or damage to system or for itself.

Convenient way to fix values in a power pack is by using a basic base plate or manifold and then fix modular value and sub-plate mounted valves on it.

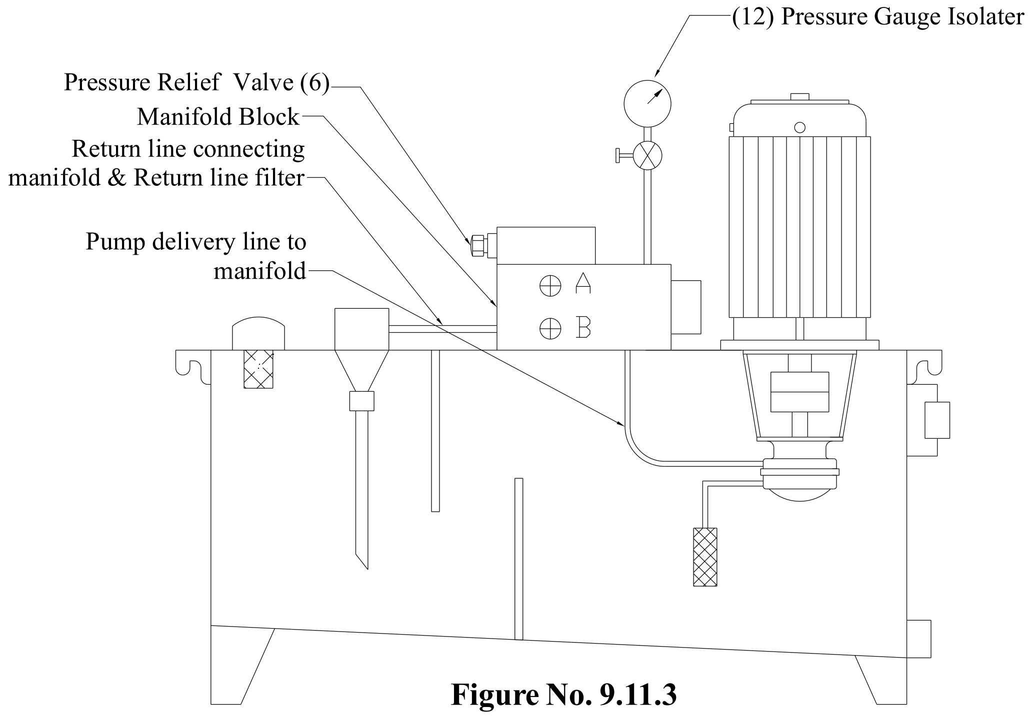
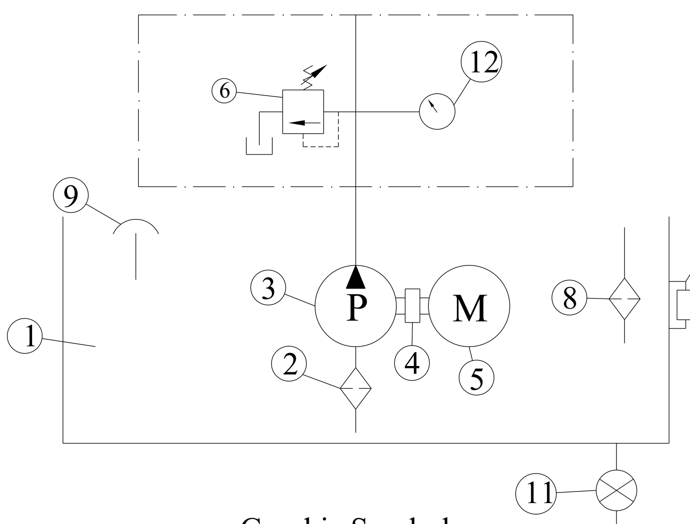


Figure No. 9.11.3

A single manifold block or sub-plate is block which has connection port for connecting pump, exhaust port, and two oil port for cylinder, and on its various ground surface provision to mount the valves.



Graphic Symbol

Step IV: - After providing manifold and relief valve, a direction control valve is fitted on it. Oil is filled through filter upto maximum level of oil level indicator. This completes a simple power pack.

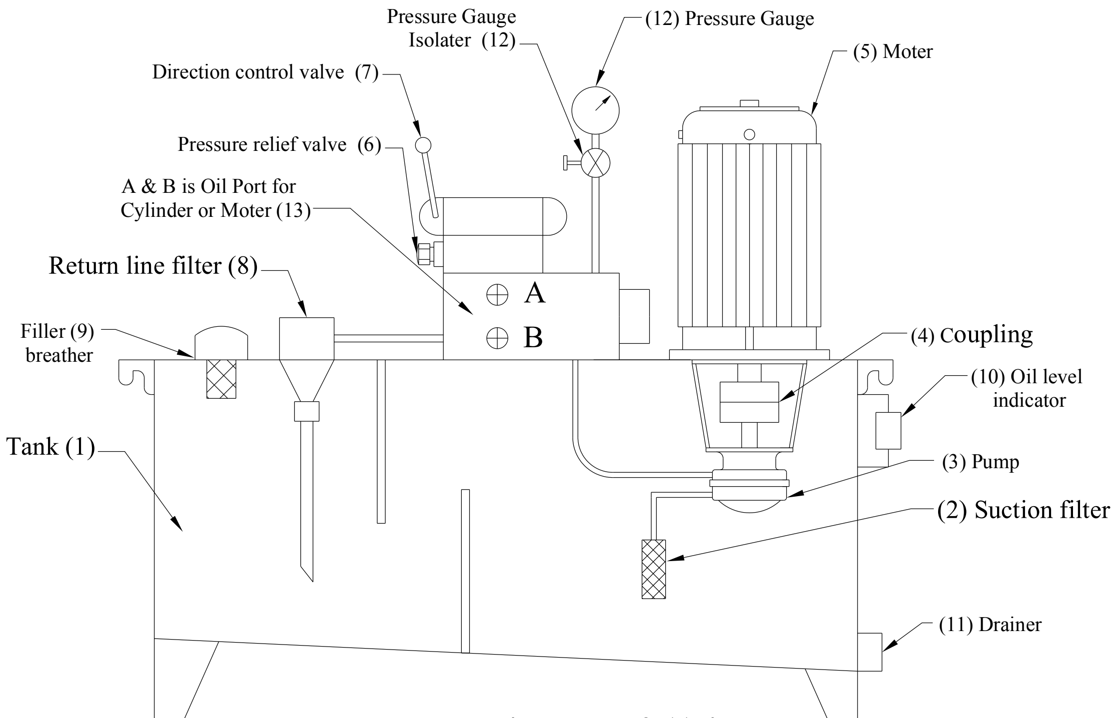


Figure No. 9.11.4

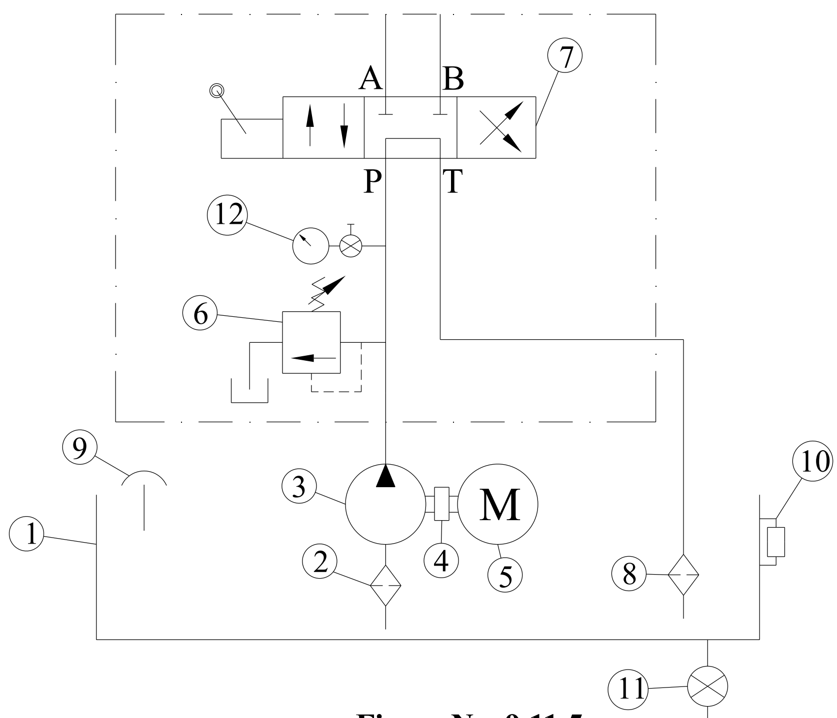


Figure No. 9.11.5

Step V: -

If valve such as flow control valve, pilot operated check valve, relief valve for A port, B port etc. is to be provided then modular valve could be stacked between manifold block and direction control valve. For sub-plate type of valves manifold is to be designed and made for mounting of each type of sub-plate type of valve individually on its various surface.

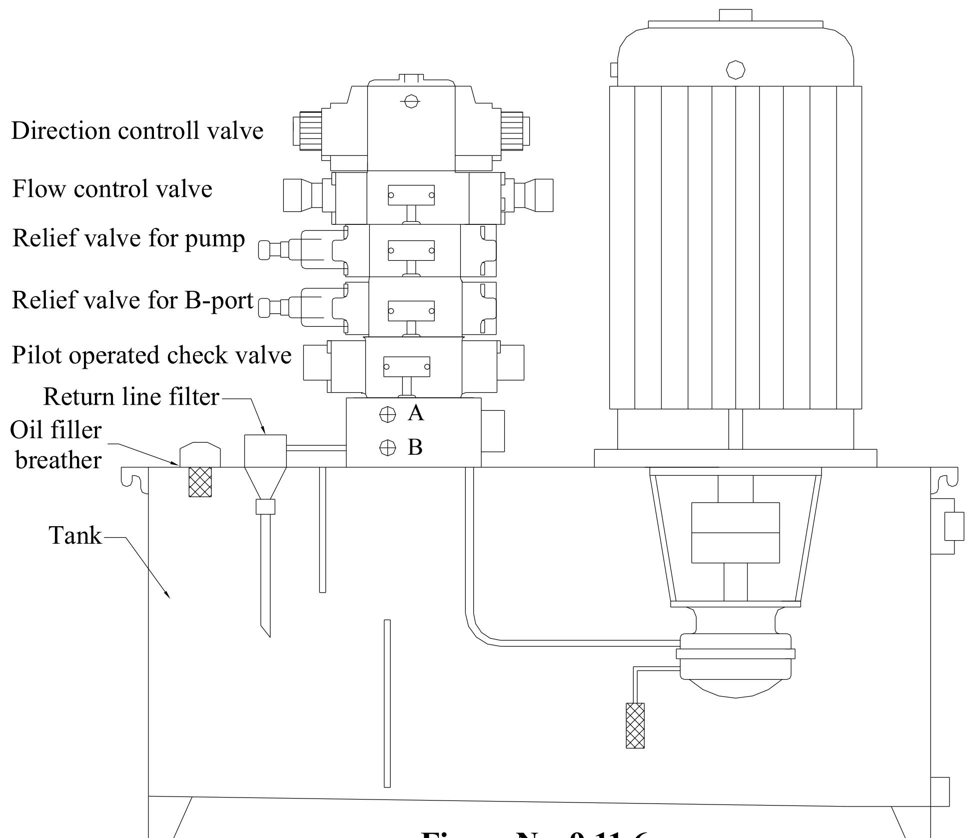
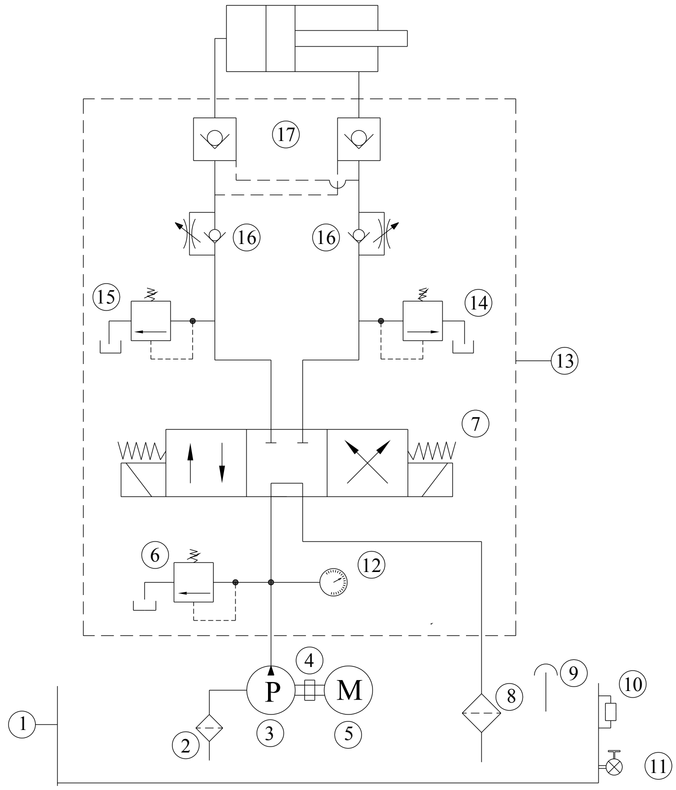


Figure No. 9.11.6

In following example we have added many modular valves such as, flow control valve, pilot operated check valve, pressure relief valve for both A & B port. The valve used in said power pack unit add following feature in power pack.

1. **Direction control valve**, it facilitates to operated cylinder in both direction (Forward and reverse).
2. **Main pressure relief valve**, Pressure of pump could be adjusted.
3. **Pressure relief valve for A & B port**, pressure of forward as well as reverse side of cylinder could be independently changed, selected and controlled (within maximum operating pressure of system).
4. **Flow control valve**, Speed of forward and reverse stroke could be controlled.
5. **Pilot operated check valve,** Pressure on both forward and reverse side of cylinder could be locked and pressure could be held for long time.



HYDRAULIC CIRCUIT DIAGRAM

Figure No. 9.11.7

Bill of Material			
S/R	**Name**	**Model No.**	**Make**
1	Oil Tank	70 Liter Capacity	As per drg.
2	Suction Filter	G–5	Hydax
3	Gear Pump	IP–3020	Dowty
4	Coupling	Haydax-28	Hydax
5	Motor	2HP, 3Ph, 1440RPM, Vertical	Crompton
6	Pressure Relief Valve	DPR-H-06-S-100	Polyhydron
7	Direction Control Valve	4DL-10G-10S	Polyhydron
8	Return Line Filter	RLF-04-25	Hydax
9	Air-Breather	TT-700	Hydax
10	Oil Level Indicator	SG-3	Hydax
11	Drain Plug	¾” BSP (Plug+Nut)	STD.
12	Pressure Gauge	4” dia, bottom, Glycerin, 4000PSI	Any STD.
13	Manifold Block		STD.
14	Pressure Relief Valve	MBB-03-B	Yuken
15	Pressure Relief Valve	MBA-03-A	Yuken
16	Flow Control Valve	TCM-10	Polyhydron
17	Pilot Operated Check Valve	CIM-10	Polyhydron

In above mentioned power pack units, all valves, pump, motor and hydraulic accessories are standard, and their dimensions are available in catalogue. As we have given make and model of each component, hence they could be referred in catalogue. For your convenience we are copying the catalogue in annexure No. ——————

The component, which we have not mentioned in Bill of Material are.

a) Oil Tank.
b) Manifold Block.
c) Hydraulic Fittings.
d) Fasteners.

Manufacturing drawing of tank and tank cover is described in Annexure No. ————. Manufacturing drawing of manifold block is described in Annexure No.————. Detail of fastener is as per table No. —————. Detail of hydraulic fittings is as per table No. —————.