

VALVES

Fluid power systems use different kinds of valves to control the fluid power. These valves are selected considering the type as well as the size, actuating technique, and remote-control capability.

There are three basic types of valves: (1) directional control valves (2) pressure control valves and (3) flow control valves.

Directional control valves (DCV) determine the path through which a fluid flows in a given circuit. They establish the direction of motion of a hydraulic cylinder or motor. Example: check valves, shuttle valves, and two-way, three-way, and four-way directional control valves.

Pressure control valves (PCV) protect the system against overpressure, which may occur due to excessive actuator loads or due to the closing of a valve. Example: pressure relief, pressure reducing, sequence, unloading, and counterbalance valves.

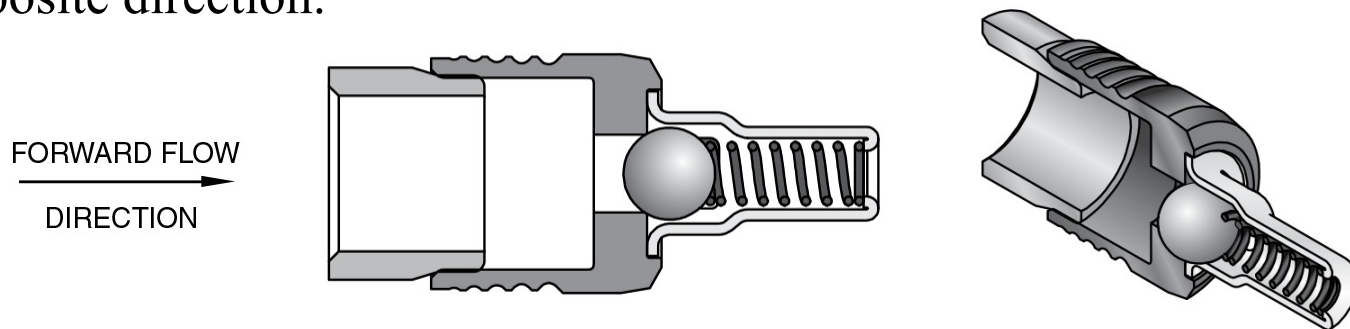
Flow control valves (FCV) are used to control the fluid flow-rate in various lines of a hydraulic circuit. The control of actuator speed depends on flow-rates. Example: Noncompensated flow control valve and Pressure-compensated flow control valve.

DIRECTIONAL CONTROL VALVES

Directional control valves are used to control the direction of flow in a hydraulic circuit. Any valve (regardless of its design) contains ports. **Ports** are external openings through which fluid can enter and leave via connecting pipelines. The number of ports on a directional control valve (DCV) is identified using the term **way**. Thus, for example, a valve with four ports is a four-way valve.

Check Valve

A check valve is a simple two-way valve with two ports. The purpose of a check valve is to permit free flow in one direction and prevent any flow in the opposite direction.



A specially shaped plug element called **poppet** is held onto a seat (a surface surrounding the flow path opening inside the valve body) by a spring. Fluid flows through the valve in the space between the seat and poppet.

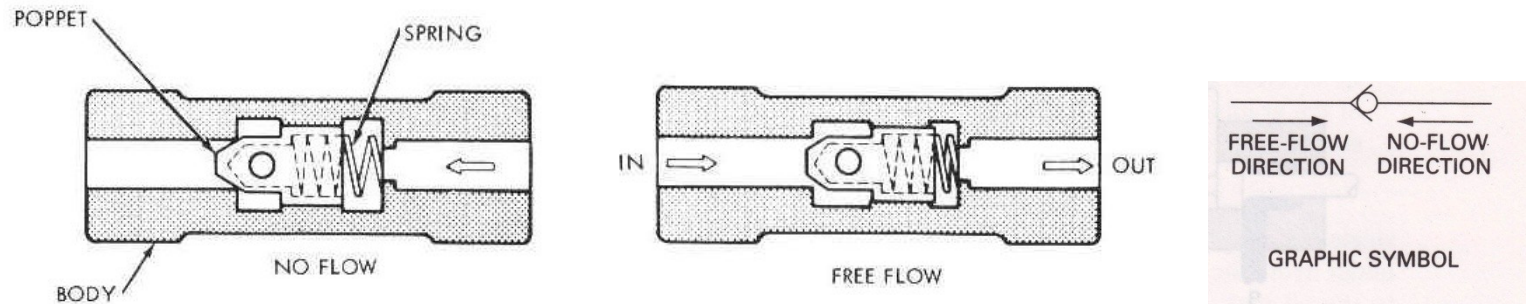


Figure 8-4. Operation of check valve. (Courtesy of Sperry Vickers, Sperry Rand Corp., Troy, Michigan.)

The light spring holds the poppet in the closed position. In the free-flow direction, the fluid pressure overcomes the spring force at some preset pressure.

If flow is attempted in the opposite direction, the fluid pressure pushes the poppet (along with the spring force) in the closed position. Therefore, no flow is permitted. The higher the pressure, the greater will be the force pushing the poppet against its seat. Thus, increased pressure will not result in any tendency to allow flow in the no-flow direction.

Pilot Operated Check Valve

A pilot-operated check valve always permits free-flow in one direction but permits flow in the normally blocked opposite direction only if pilot pressure is applied at the pilot pressure port of the valve.

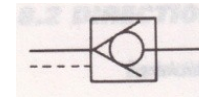
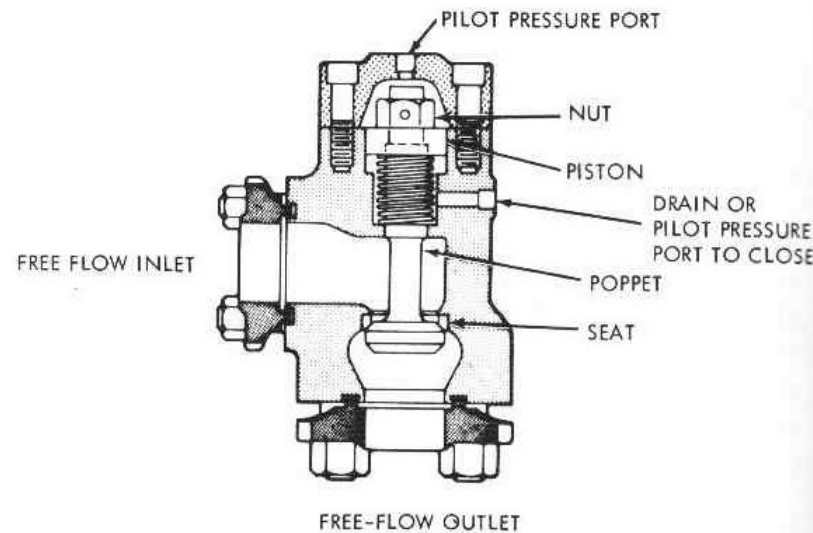


Figure 8-4. Pilot-operated check valve. (Courtesy of Sperry Vickers, Sperry Rand Corp., Troy, Michigan.)

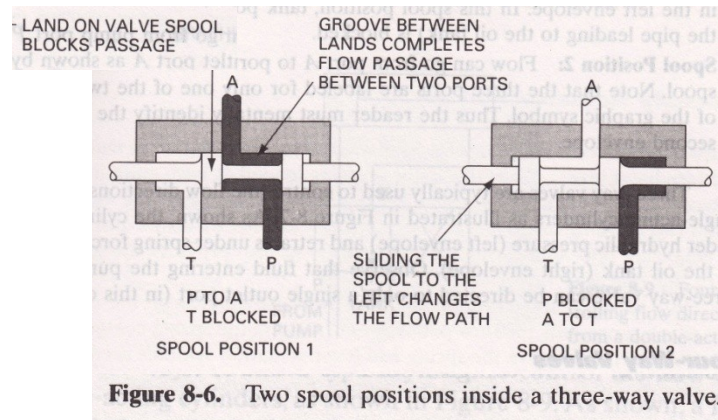
In this design, the check valve poppet has the pilot piston attached to the threaded poppet stem by a nut. The light spring holds the poppet seated in a no-flow condition by pushing against the pilot piston. There is a separate drain port on the bottom side of the piston to prevent oil from creating a pressure buildup.

The dashed line in the graphic symbol represents the pilot pressure line connected to the pilot pressure port of the valve. Pilot check valves are frequently used for locking hydraulic cylinders in position.

Three-Way Valves

Three-way directional control valves contain three ports and are typically of the **spool** design rather than **poppet** design.

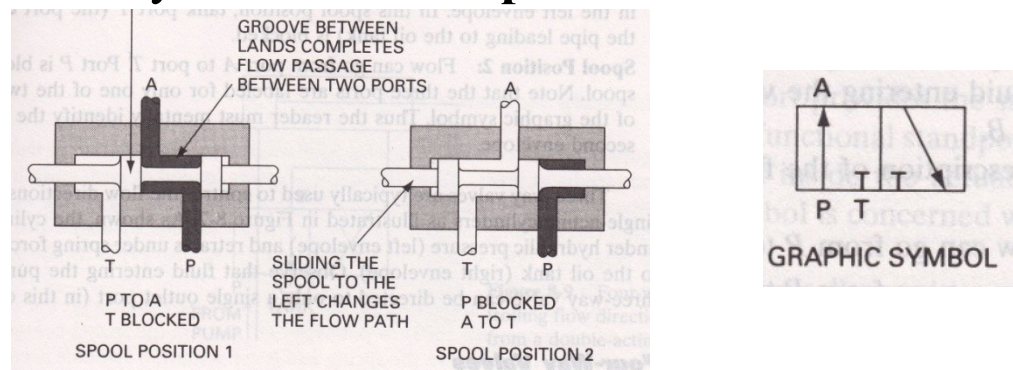
A spool is a circular shaft containing lands that are large diameter sections machined to slide in a very close fitting bore of the valve body. The radial clearance between the land and bore is usually less than 0.001 in. The grooves between the lands provide the flow paths between ports.



These valves are designed to operate with two or three unique positions of the spool. The spool can be positioned manually, mechanically, by using pilot pressure, or by using electrical solenoids.

The Figure shows the flow paths through a three-way valve that uses two positions of the spool.

Such a valve is called a 3-way, 2-position directional control valve. The flow paths are shown in the graphic symbol by two side-by-side rectangles (one for each spool position). In describing the operation of these valves, the rectangles are commonly called “**envelopes**.”

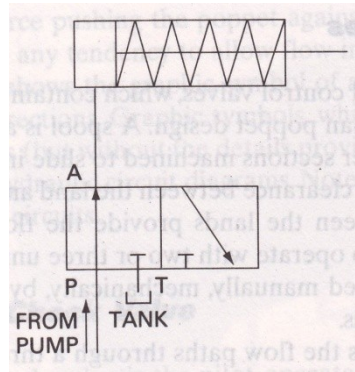


Description of the flow paths through the three-way valve shown above:

Spool Position 1: Flow can go from pump port P (the port connected to the pump discharge pipe) to outlet port A as shown by the straight line and arrow in the left envelope. In this spool position, tank port T (the port connected to the pipe leading to the oil tank) is blocked.

Spool Position 2: Flow can go from port A to port T. Port P is blocked by the spool. Note that the three ports are labeled for only one of the two envelopes of the graphic symbol. The ports on the other envelope follow the same sequence of names.

Three-way valves are typically used to control the flow directions to and from single-acting cylinders. As shown, the cylinder extends under hydraulic pressure (left envelope) and retracts under spring force as oil flows to the oil tank (right envelope).



The fluid entering the pump port of a three-way valve can be directed to only a single outlet port (in this case port A).

Four Way Valves

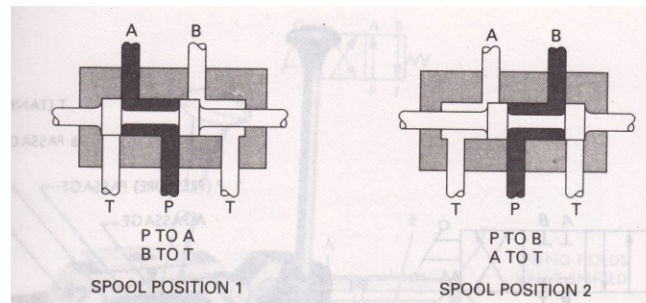
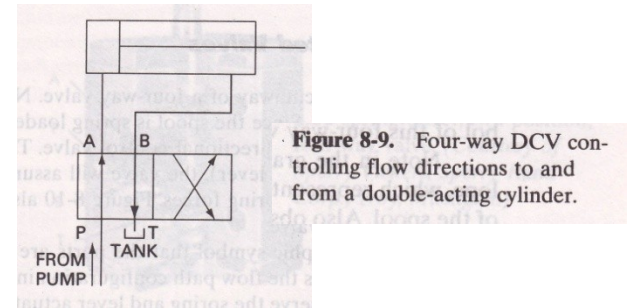
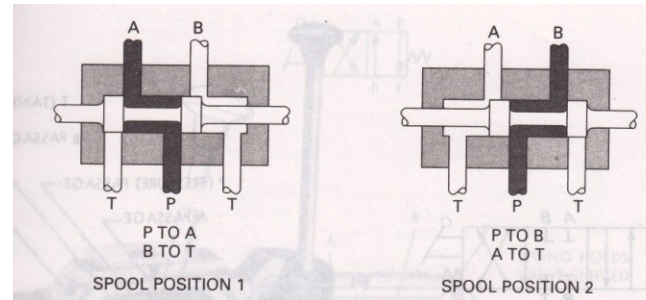
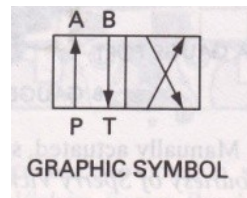


Figure 8-8. Two spool positions inside a four-way valve.

This Figure shows the flow paths through a four-way, two-position directional control valve. Two ports labeled by T in the schematic diagram are functionally one port connected to the oil tank.

Fluid entering the valve at the pump port can be delivered to either outlet port A or B.



Spool Position 1: Flow can go from P to A and B to T.

Spool Position 2: Flow can go from P to B and A to T.

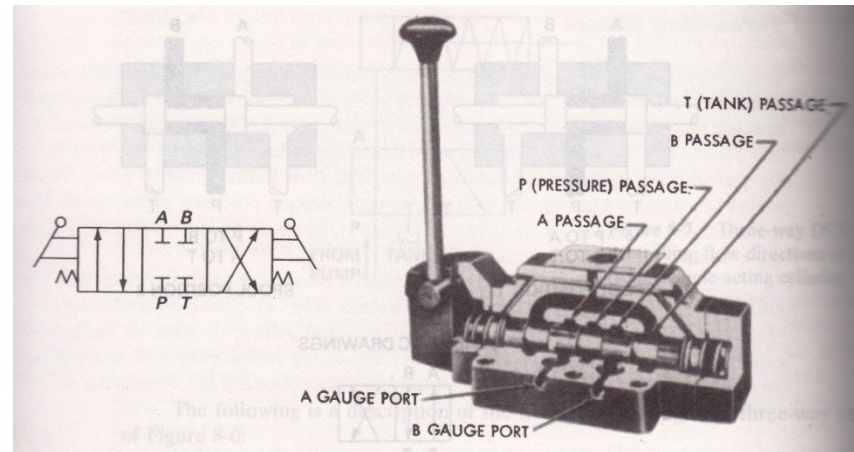
The graphic symbol shows only one tank port T (for a total of four ports) even though the actual valve may have two, as shown in the schematic drawings.

However, each tank port provides the same function, and thus there are only four different ports from a functional standpoint. The two internal flow-to-tank passageways can be combined inside the actual valve to provide a single tank port.

Four-way valves are typically used to control the flow directions to and from double-acting cylinders, as shown above. A four-way valve permits the cylinder to both extend (left envelope) and retract (right envelope) under hydraulic pressure.

Manually Actuated Valves

Figure 8-10. Manually actuated, spring-centered, three-position, four-way valve. (Courtesy of Sperry Vickers, Sperry Rand Corp., Troy, Michigan.)



This figure shows a cutaway of a **manually actuated** (see hand lever) four-way valve. The spool is spring loaded at both ends and is a **spring centered**, three-position directional control valve. Thus, when the valve is unactuated (no hand force on lever), the valve will assume its center position due to the balancing opposing spring forces.

In the graphic symbol, the ports are labeled on the center envelope, which represents the flow path configuration in the spring-centered position of the spool. The spring and lever actuation symbols used at the ends of the right and left envelopes imply a spring-centered and manually actuated valve, respectively. A three-position valve is used when it is necessary to stop or hold a hydraulic actuator at some intermediate position within its entire stroke range.

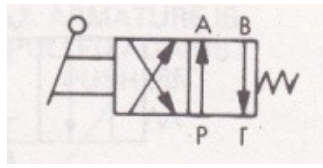
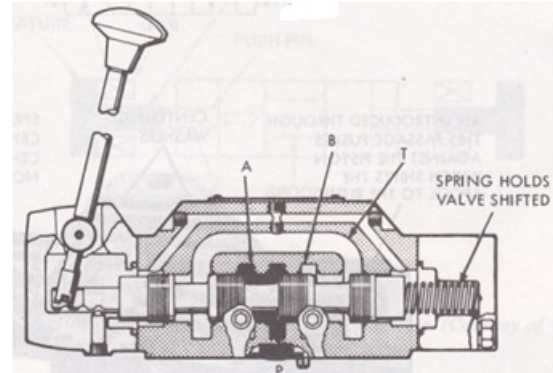


Figure 8-11. Manually actuated two-position, spring-offset, four-way valve. (Courtesy of Sperry Vickers, Sperry Rand Corp., Troy, Michigan.)



In the above figure we see a manually actuated two-position, four-way valve that is **spring offset**. In this case the lever shifts the spool, and the spring returns the spool to its original position when the lever is released. There are only two unique operating positions, as indicated by the graphic symbol. The ports are labeled at the envelope representing the neutral (spring offset or return) or unactuated position of the spool

Mechanically Actuated Valves

Figure 8-12 shows a two-position, four-way, spring offset valve that is mechanically actuated. The spool end containing a roller is typically actuated by a cam-type mechanism. The graphic symbol is the same except that actuation is shown as being mechanical (the circle represents the cam-driven roller) rather than manual.

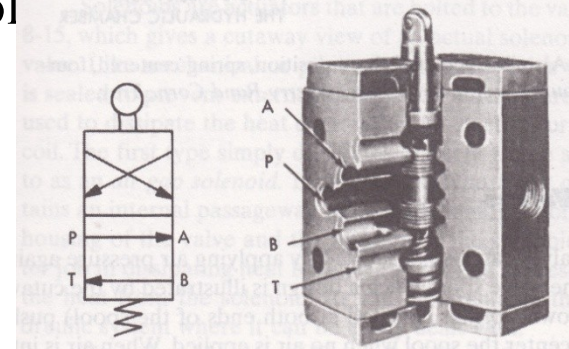


Figure 8-12. Mechanically actuated spring offset, two-position, four-way valve. (Courtesy of Sperry Vickers, Sperry Rand Corp., Troy, Michigan.)

Pilot-Actuated Valves

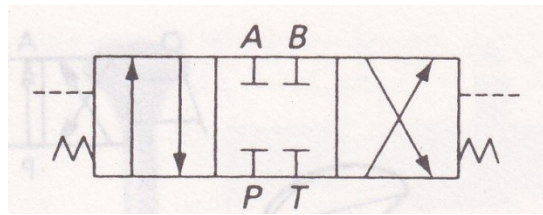
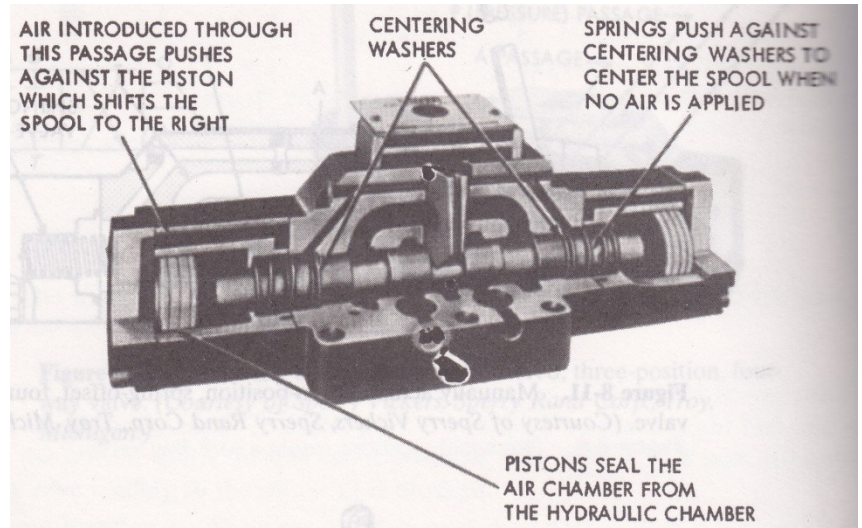


Figure 8-13. Air pilot-actuated three-position, spring-centered, four-way valve. (Courtesy of Sperry Vickers, Sperry Rand Corp., Troy, Michigan.)



Directional control valves can also be shifted by applying air pressure against a piston at either end of the valve spool. Such a design is known as **pilot actuated** and is illustrated by the cutaway view of Figure 8-13.

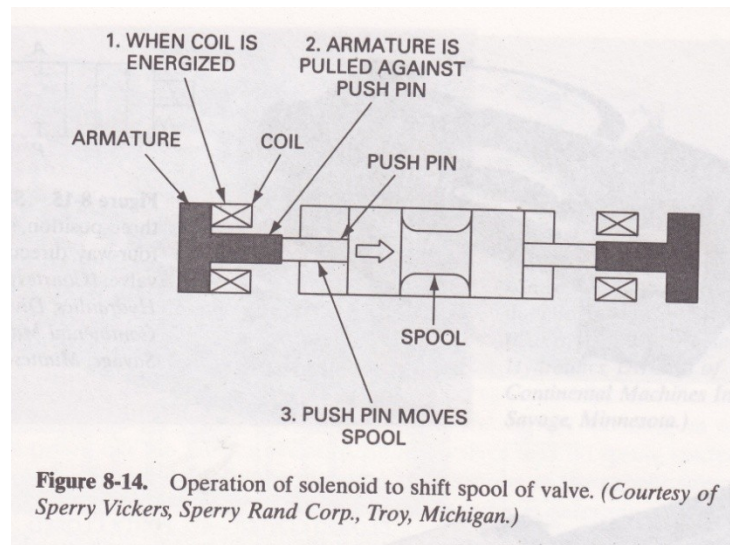
The springs (located at both ends of the spool) push against centering washers to center the spool when no air is applied.

When air is introduced through the left end passage, it shifts the spool to the right. Removal of this left end air supply and introduction of air through the right end passage causes the spool to shift to the left. Therefore, this is a four-way three-position, spring-centered, air pilot-actuated directional control valve. In the graphic symbol, the dashed lines represent pilot pressure lines.

Solenoid-Actuated Valves

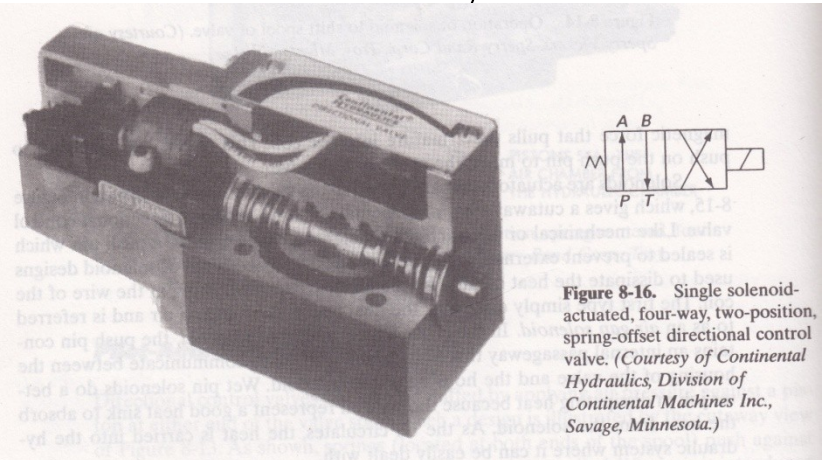
A very common way to actuate a spool valve is by using a solenoid. When the electric coil (solenoid) is energized, it creates a magnetic force that pulls the armature into the coil. This causes the armature to push on the push pin to move the spool of the valve.

Solenoids are actuators that are bolted to the valve housing. Like mechanical or pilot actuators, solenoids work against a push pin, which is sealed to prevent external leakage of oil.



There are two types solenoid designs used to dissipate the heat created by the electric current flowing in the wire of the coil.

The first type simply dissipates the heat to the surrounding-air and is referred to as an **air gap solenoid**. In the second type, a **wet pin solenoid**, the push pin contains an internal passageway that allows tank port oil to communicate between the housing of the valve and the housing of the solenoids. Wet pin solenoids do a better job in dissipating heat because the cool oil represents a good heat sink to absorb the heat from the solenoid. As the oil circulates, the heat is carried into the hydraulic system where it can be easily dealt with.

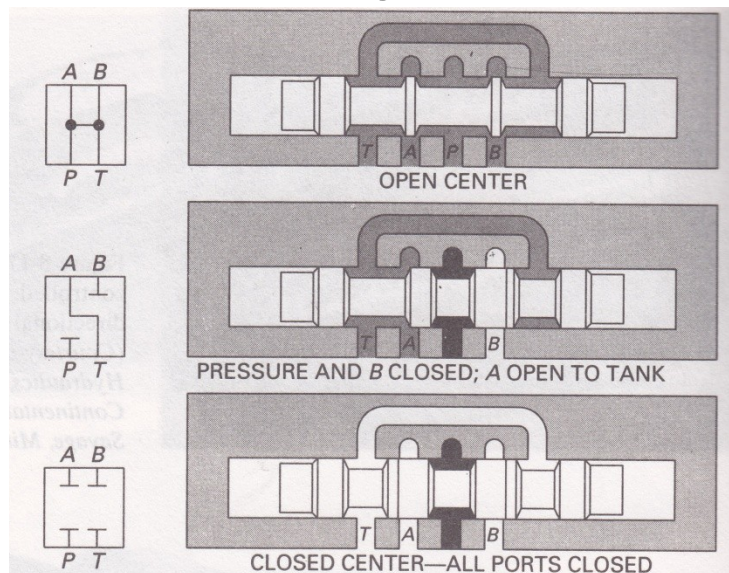


The solenoid valve of Figure 8-15 has a wet pin solenoid. Its armature moves in a tube that is open to the tank cavity of the valve. The fluid around the armature serves to cool it and cushion its stroke without appreciably affecting response time. This valve has a solenoid at each end and it is a solenoid-actuated four-way; three-position, spring-centered directional control valve. Note the graphic symbol of solenoid at both ends of the spool. 13

Figure 8-16 shows a single solenoid-actuated four-way, two-position' spring-offset directional control valve along with its graphic symbol.

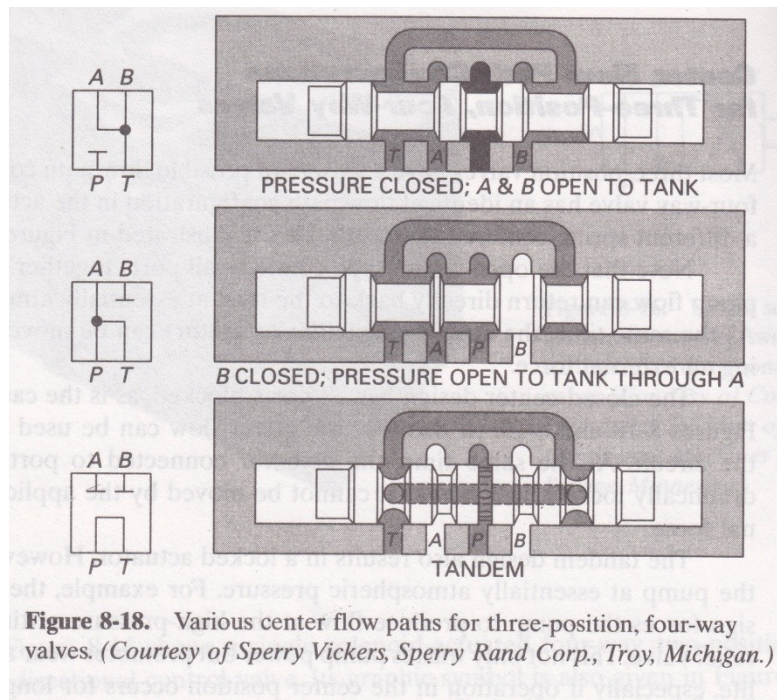
Center Flow Path Configurations for three-Position, Four-Way Valves

Most three-position valves have a variety of possible flow path configurations. Each four-way valve has an identical flow path configuration in the actuated position but a different spring-centered flow path. This is illustrated in Figure 8-18.



Open-center-type connects all ports together. In this design the pump flow can return directly back to the tank at essentially atmospheric pressure. At the same time, the actuator (cylinder or motor) can be moved freely by applying an external force.

The **closed-center design** has all ports blocked. In this way the pump flow can be used for other parts of the circuit. At the same time, the actuator connected to ports A and B is hydraulically locked. This means it cannot be moved by the application of an external force.



The **tandem design** also results in a locked actuator. However, it also unloads the pump at essentially atmospheric pressure. For example, the closed-center design forces the pump to produce flow at the high-pressure setting of the pressure relief valve.

This not only wastes pump power but promotes wear and shortens pump life, especially if operation in the center position occurs for long periods.

Another factor is that the wasted power raises the temperature of the oil. This promotes oil oxidation, which increases the acidity of the oil. Such oil tends to corrode the critical metallic parts not only of the pump but also of the actuators and valves. Higher temperature lowers the viscosity, which in turn increases leakage and reduces the lubricity of the oil. To keep the temperature at a safe level, an expensive oil cooler may be required.

So, to avoid these complexities when the actuator needs to be frequently locked, tandem design is sometimes preferred over closed center design.

Shuttle Valves

A shuttle valve is a type of directional control valve. It permits a system to operate from either of two fluid power sources. One application is for safety in the event that the main pump can no longer provide hydraulic power to operate emergency devices. The shuttle valve will shift to allow fluid to flow from a secondary backup pump.

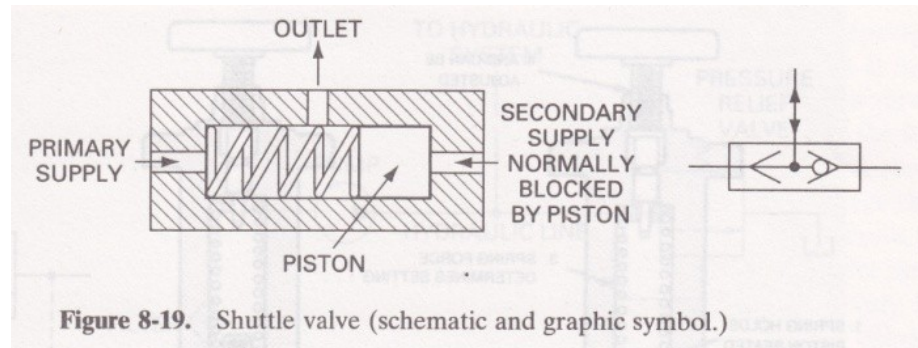


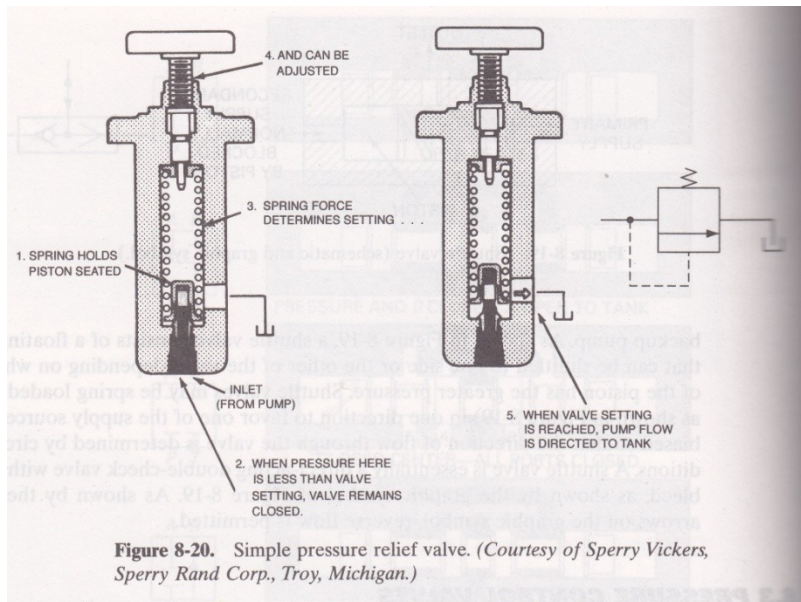
Figure 8-19. Shuttle valve (schematic and graphic symbol.)

As shown in Figure 8-19, a shuttle valve consists of a floating piston that can be shuttled to one side or the other of the valve depending on which side of the piston has the greater pressure. Shuttle valves may be spring loaded in one direction to favor one of the supply sources or unbiased so that the direction of flow through the valve is determined by circuit conditions. A shuttle valve is essentially a direct-acting double-check valve with a cross-bleed. As shown by the double arrows on the graphic symbol, reverse flow is permitted.

PRESSURE CONTROL VALVES

Simple Pressure Relief Valves

The most widely used type of pressure control valve is the **pressure relief valve**. It is found in practically every hydraulic system. Its function is to limit the pressure to a specified maximum value by diverting pump flow back to the tank. It is normally a closed valve.

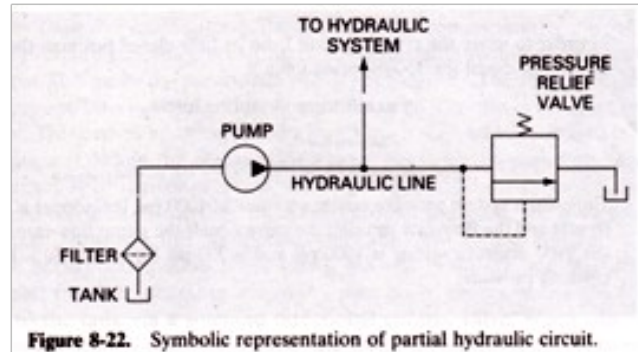
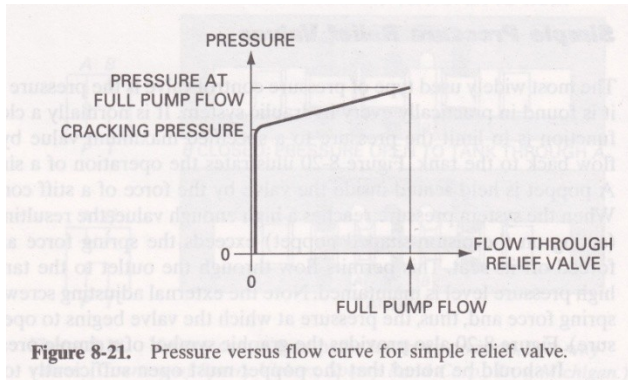


In a pressure relief valve, a poppet is held seated inside the valve by the force of a stiff compression spring.

When the system pressure reaches a high enough value, the resulting hydraulic force (acting on the piston-shaped poppet) exceeds the spring force and the poppet is forced off its seat. This permits flow through the outlet to the tank as long as this high

pressure level is maintained. An external adjusting screw varies the spring force and, thus, the **cracking pressure** (at which the valve begins to open).

The poppet must open sufficiently to allow full pump flow. The pressure that exists at full pump flow can be substantially greater than the cracking pressure. This is shown in Figure 8-21, where system pressure is plotted versus flow through the relief valve.



The stiffness of the spring (spring constant) and the amount the poppet must open to permit full pump flow determine the difference between the full pump flow pressure and the cracking pressure. The pressure at full pump flow is the pressure level that is specified when referring to the pressure setting of the relief valve. It is the maximum pressure level permitted by the relief valve.

Figure 8-22 shows a partial hydraulic circuit containing a pump and pressure relief valve. If the hydraulic system (not shown) does not accept any flow, then all the pump flow must return to the tank via the relief valve. The pressure relief valve provides protection against any overloads in the hydraulic system.

EXAMPLE

A pressure relief valve contains a poppet with a 0.75 in^2 area on which system pressure acts. During assembly a spring with a spring constant of 2500 lb/in is installed to the poppet against its seat. The adjustment mechanism is then set so that the spring is initially compressed 0.20 in from its free length condition. In order to pass full pump flow through the valve at the PRV pressure setting, the poppet must move 0.10 in from the fully closed position. Determine the (a). cracking pressure and (b). full pump flow pressure (PRV pressure setting)

Solution

- a. The spring force on the poppet when fully closed

$$F = kS = (2500 \text{ lb/in}) \times (0.20 \text{ in}) = 500 \text{ lb}$$

In order to put the poppet on the verge of opening (cracking), the hydraulic force must equal to spring force. Thus

$$P_{\text{cracking}} \times A = 500 \text{ lb} = P_{\text{cracking}} \times (0.75 \text{ in}^2)$$

$$\text{It gives, } P_{\text{cracking}} = 667 \text{ psi}$$

- b. At full flow, the poppet moves 0.10 inch from the fully closed position, the spring has compressed a total of 0.30 in from its free length condition.

$$F = kS = (2500 \text{ lb/in}) \times (0.30 \text{ in}) = 750 \text{ lb}$$

$$\text{Now, } P_{\text{full flow}} \times A = 750 \text{ lb} = P_{\text{full flow}} \times (0.75 \text{ in}^2)$$

$$\text{It gives, } P_{\text{full flow}} = 1000 \text{ psi} \Rightarrow \text{PRV pressure setting.}$$

Compound Pressure Relief Valves

A compound pressure relief valve operates in two stages. Pilot stage is located in the upper valve body and contains a pressure-limiting poppet that is held against a seat by an adjustable spring. The lower body contains the port connections. Diversion of the full pump flow is accomplished by the balanced piston in the lower body.

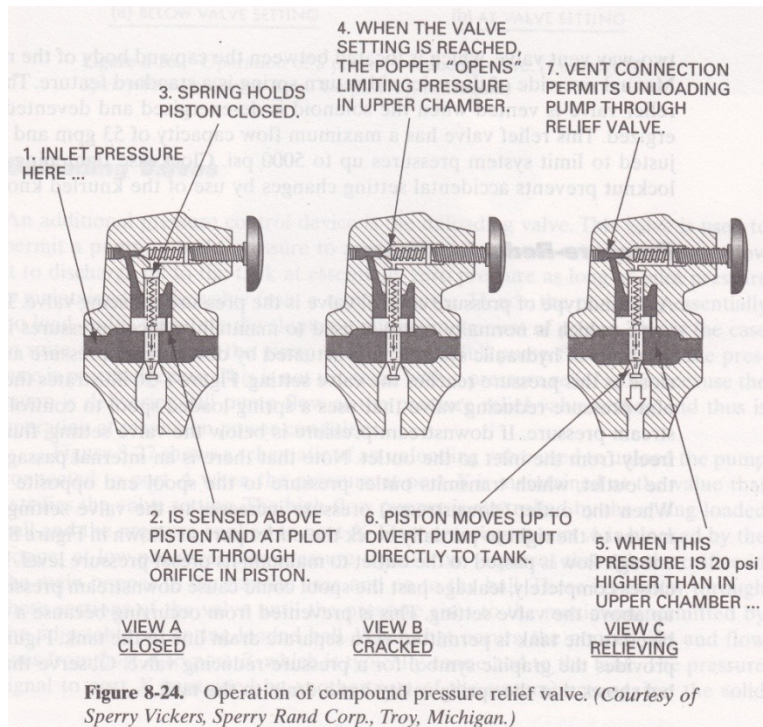


Figure 8-24. Operation of compound pressure relief valve. (Courtesy of Sperry Vickers, Sperry Rand Corp., Troy, Michigan.)

In normal operation the balanced piston is in hydraulic balance.

Pressure at the inlet port acts under the piston and also on its top, because an orifice is drilled through the large land.

For pressures less than the valve setting, the piston is held on its seat by a light spring.

As soon as pressure reaches the setting of the adjustable spring, the poppet is forced off its seat. This limits the pressure in the upper chamber.

The restricted flow through the orifice and into the upper chamber results in an increase in pressure in the lower chamber. This causes an unbalance in hydraulic forces, which tends to raise the piston off its seat.

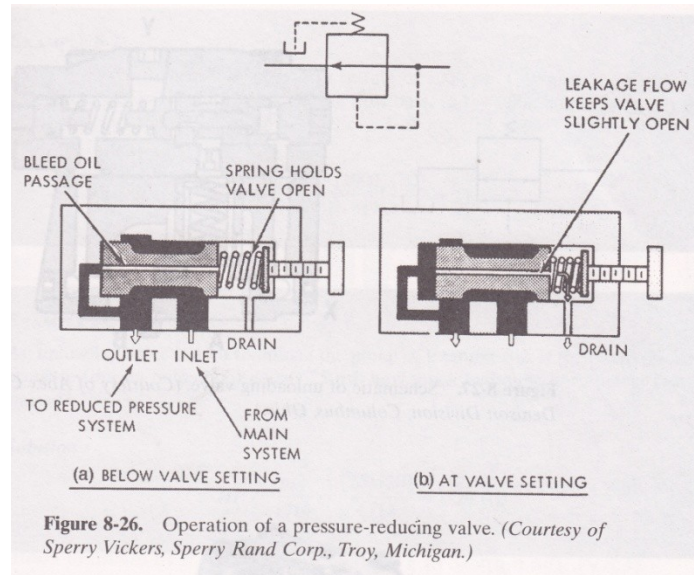
When the pressure difference between the upper and lower chambers reaches approximately 20 psi, the large piston lifts off its seat to permit flow directly to the tank. If the flow increases through the valve, the piston lifts farther off its seat. However, this compresses only the light spring and hence very little override occurs.

Compound relief valves may be remotely operated by using the outlet port from the chamber above the piston. For example, this chamber can be vented to the tank via a solenoid directional control valve. When this valve vents the pressure relief valve to the tank, the 20-psi pressure in the bottom chamber overcomes the light spring and unloads the pump to the tank. Some compound pressure relief valves have remote operation capability.

Pressure- Reducing Valves

Pressure-reducing valve (normally open) is used to maintain reduced pressures in specified locations of hydraulic systems. It is actuated by downstream

pressure and tends to close as this pressure reaches the valve setting. Figure 8-26 illustrates the operation of a pressure-reducing valve that uses a spring-loaded spool to control the downstream pressure.

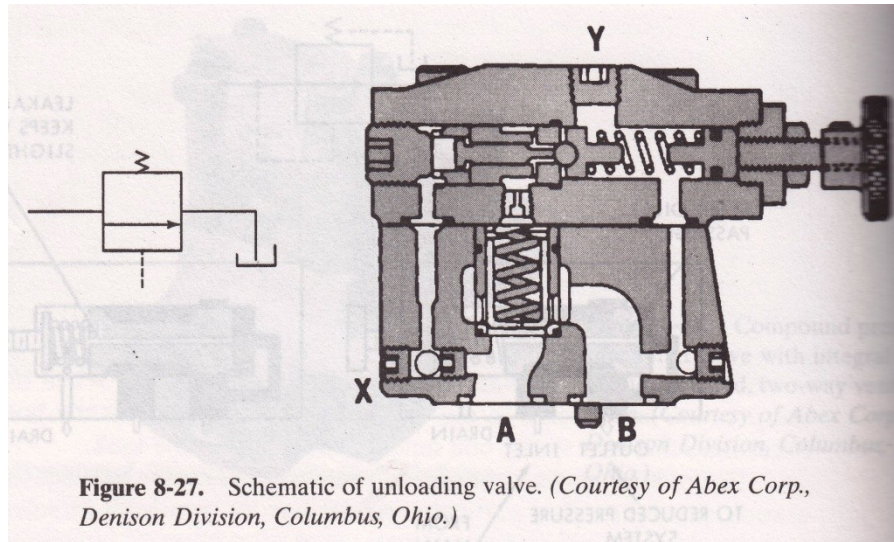


If downstream pressure is below the valve setting, fluid will flow freely from the inlet to the outlet. There is an internal channel from the outlet, which transmits outlet pressure to the spool end opposite the spring. When the outlet (downstream) pressure increases to the valve setting, the spool moves to the right to partially block the outlet port.

Just enough flow is passed to the outlet to maintain its preset pressure level. If the valve closes completely, leakage past the spool could cause downstream pressure to build up above the valve setting. This is prevented from occurring because a continuous bleed to the tank is permitted via a separate drain line to the tank. Figure 8-26 also provides the graphic symbol for a pressure-reducing valve. Observe that the symbol shows that the spring cavity has a drain to the tank.

Unloading Valves

Unloading valve is used to permit a pump to build pressure to an adjustable pressure setting and then allow it to discharge oil to the tank at essentially zero pressure as long as pilot pressure is maintained on the valve from a remote source.



Hence, the pump has essentially no load and is therefore developing a minimum amount of power. This is the case in spite of the fact that the pump is delivering a full pump flow because the pressure is practically zero. This is not the same with a pressure relief valve because the pump is delivering full pump flow at the pressure relief valve setting and thus is operating at maximum power conditions.

EXAMPLE

A **pressure relief valve** has a pressure setting of 1000 psi. Compute the horse power loss across this valve if it returns all the flow back to the tank from a 20 gpm pump.

Solution

$$\begin{aligned} \text{HP} &= pQ/1714 = (1000 \text{ psi}) \times (20 \text{ gpm})/1714 \\ &= 11.7 \text{ HP} \end{aligned}$$

EXAMPLE

An **unloading valve** is used to unload the 20 gpm pump of the previous example. If the pump discharge pressure during unloading is 25 psi, compute the horse power loss across this valve.

Solution

$$\text{HP} = pQ/1714 = (25 \text{ psi}) \times (20 \text{ gpm})/1714 = 0.29 \text{ HP}$$

Thus wasted power saving is $(11.7 - 0.29) \times 100 / 11.7 = 97.5\%$ if an unloading valve is used in place of the pressure relief valve in the above example.

Sequence Valves

Sequence valves cause a hydraulic system to operate in a pressure sequence. After the components connected to one port (A in Figure) have reached the adjusted pressure of the sequence valve, the valve passes fluid through the second port (B in figure) to do additional work in a different portion of the system.

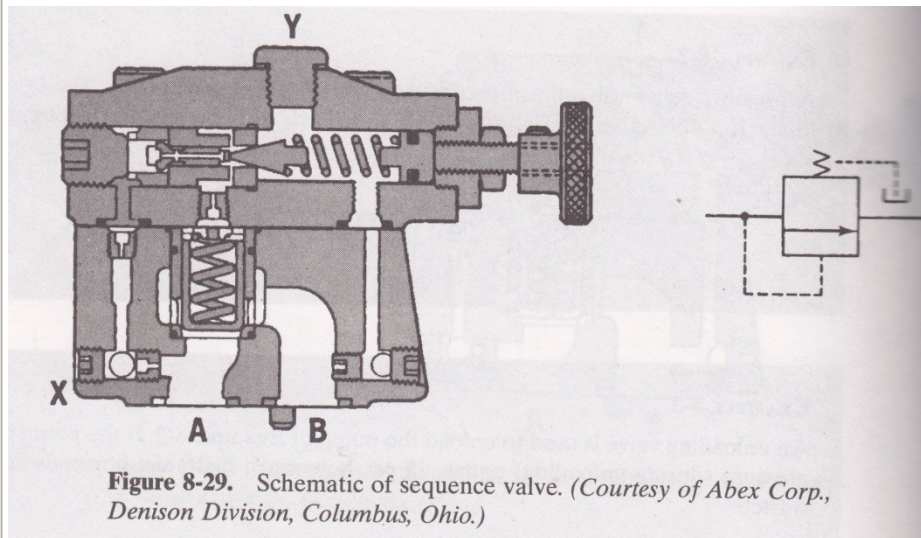


Figure 8-29. Schematic of sequence valve. (Courtesy of Abex Corp., Denison Division, Columbus, Ohio.)

The high-flow poppet of the sequence valve is controlled by the spring-loaded cone. Flow entering at port A is blocked by the poppet at low pressures. The pressure signal at A passes through orifices to the topside of the poppet and to the cone. There is no flow through these sections until the pressure rises at A to the maximum permitted

by the adjustably set spring-loaded cone. When the pressure at A reaches that value, the main poppet lifts, passing flow to port B. It maintains the adjusted pressure at port A until the pressure at B rises to the same value. A small pilot flow (about 1.14 gpm) goes through the control piston and past the pilot cone 25

to the external drain at this time.

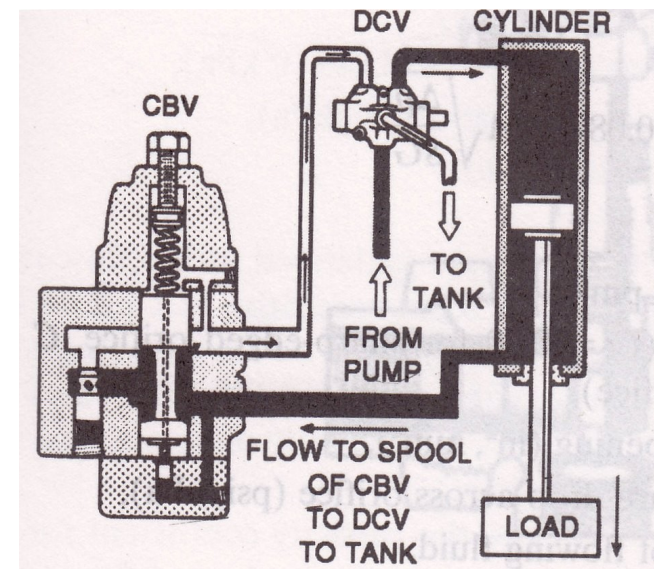
When the pressure at B rises to the pressure at A, the control piston seats and prevents further pilot flow loss. The main poppet opens fully and allows the pressure at A and B to rise to higher values together. Flow may go either way at this time.

The spring cavity of the control cone drains externally from port Y, generally to the tank. This sequence valve may be remotely controlled from vent port X. Figure 8-29 also includes the graphic symbol for a sequence valve. The pilot line can come from anywhere in the circuit and not just from directly upstream, as shown.

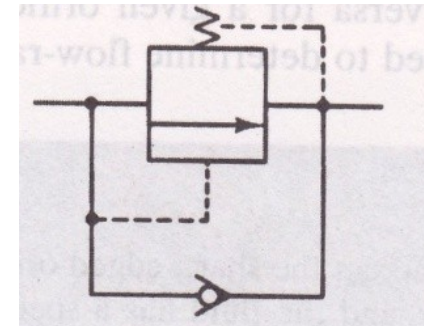
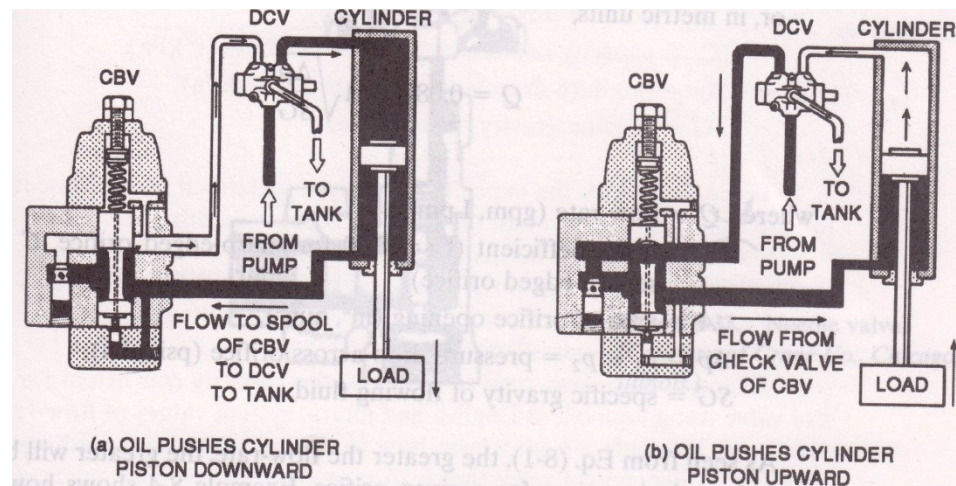
Counterbalance valve

The counterbalance valve is used to maintain control of a vertical hydraulic cylinder to prevent it from descending due to the weight of its external load.

The primary port of the valve is connected to the bottom of the cylinder and the secondary



port is connected to a directional control valve (DCV). The pressure setting of this valve is somewhat higher than is necessary to prevent the cylinder load from falling down due to its weight.



When pump flow is directed to the top of the cylinder, the piston is pushed downward. This causes the pressure at the primary port to increase to a value above the pressure setting of the counterbalance valve.

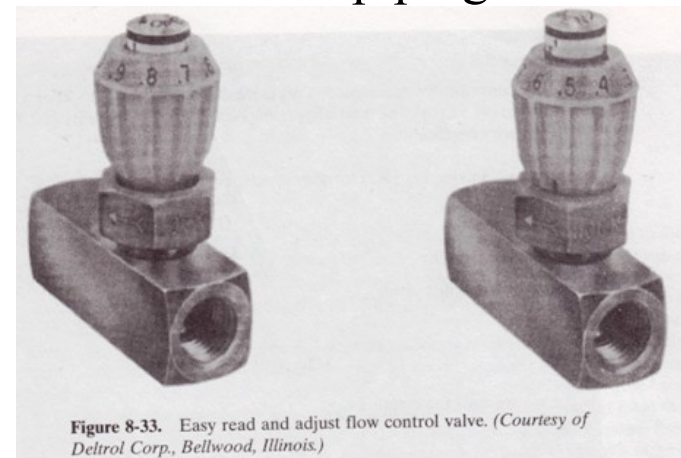
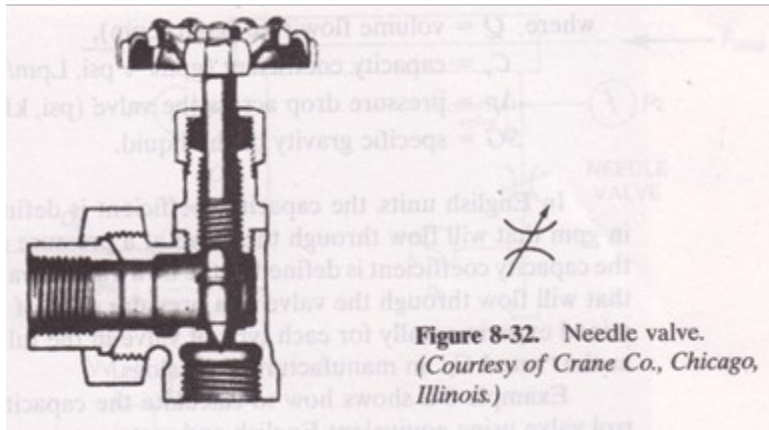
This opens a flow path through the valve for discharge through the secondary port to the DCV and back to the tank. When raising the cylinder, an integral check valve opens to allow free flow for retracting the cylinder.

FLOW CONTROL VALVES

Flow control valves are used to regulate the speed of hydraulic cylinders and motors by controlling the flow-rate to these actuators.

Needle Valves

They are of two types: **fixed orifice** or **adjustable** needle valve. Needle valves are designed to give fine control of flow in small-diameter piping.



Their name is derived from their sharp, pointed conical disk and matching seat. The graphic symbol for a needle valve (which is a variable orifice) is also given above. Figure 8-33 shows a flow control valve that is easy to read and adjust. The system has several color rings, which, in conjunction with a numbered knob, permits reading of a given valve opening as shown. A locknut prevents unwanted changes in flow.

For given valve settings and pressure drops, the flow-rate can be determined from charts and tables supplied by the manufacturer.

For a given opening position, a needle valve behaves as an orifice. However unlike an orifice, the flow area (A) in a needle valve can be varied. Thus the pressure drop and flow-rate for a needle valve may be related by,

$$Q = C_v \sqrt{\frac{\Delta p}{SG}}$$

The capacity coefficient, C_v , is determined experimentally for each type of valve in fully open position and is listed as the “rated C_v ” in manufacturers catalogs.

EXAMPLE 8.5

A flow control valve experiences a pressure drop of 100 psi (687 kPa) for a flow rate of 25 gpm (94.8 lpm). The fluid is hydraulic oil with a specific gravity of 0.90. Determine the capacity coefficient.

Solution:

Capacity coefficient,

$$C_v = \frac{Q}{\sqrt{\Delta p / SG}}$$

In English unit,

Capacity coefficient,

$$C_v = \frac{25}{\sqrt{100/0.9}} = 2.37 \text{ gpm}/\sqrt{\text{psi}}$$

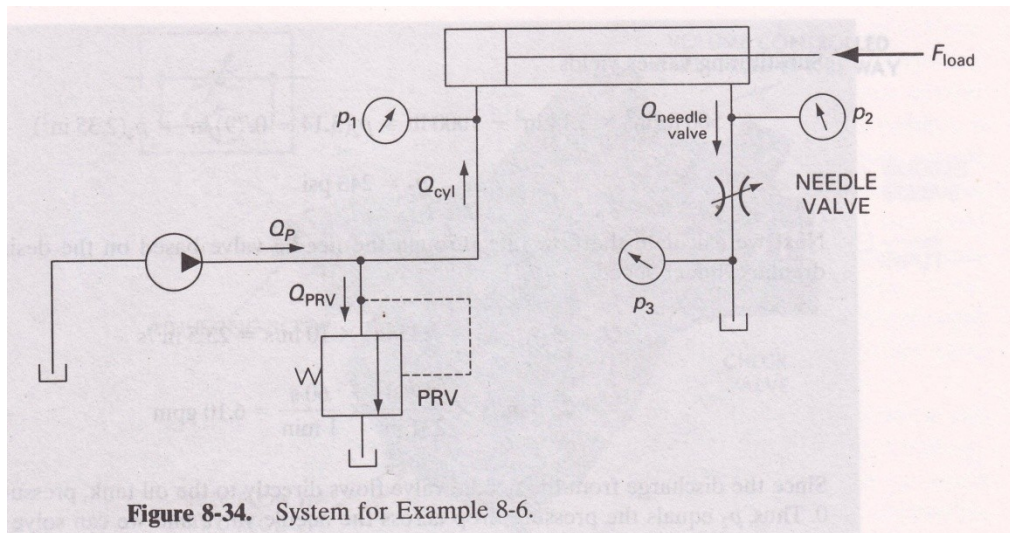
In metric unit,

Capacity coefficient,

$$C_v = \frac{94.8}{\sqrt{687/0.9}} = 3.43 \text{ lpm}/\sqrt{\text{kPa}}$$

EXAMPLE 8.6

A needle valve is used to control the extending speed of a hydraulic circuit. The needle valve is placed in the outlet line of the hydraulic cylinder as shown in figure 8.34.

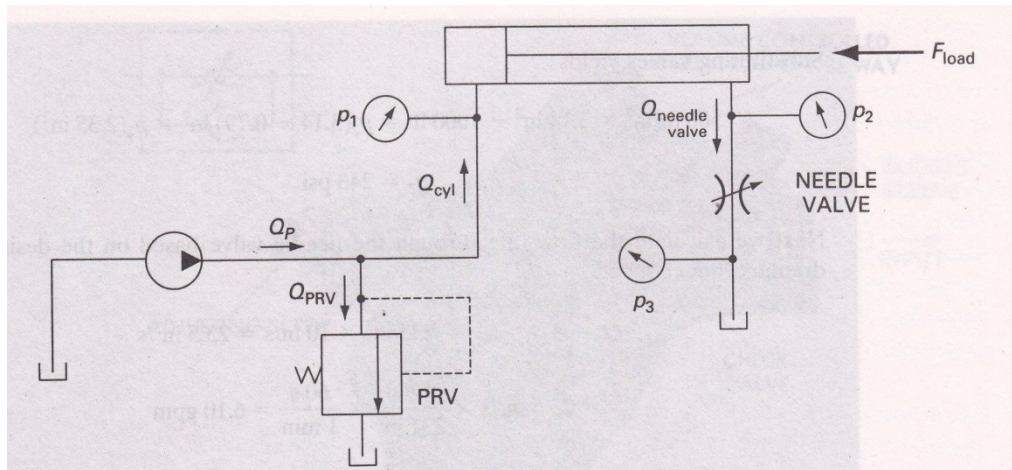


Determine the required capacity coefficient of the needle valve, if the following data are given.

Desired cylinder speed = 10 in/s
 Cylinder piston diameter = 2 in (area = 3.14 in²)
 Cylinder rod diameter = 1 in (area = 0.79 in²)
 Cylinder load = 1000 lb
 Specific gravity of oil = 0.90
 Pressure relief valve (PRV) setting = 500 psi

Solution:

When the cylinder speed reaches the desired value, the blank end pressure p_1 should reach the value of the PRV setting. Now the rod end pressure p_2 that causes p_1 to be equal to PRV setting is given by,



$$p_1 A_1 - F_{\text{load}} = p_2 A_2 \Rightarrow 500 \times 3.14 - 1000 = p_2 \times (3.14 - 0.79) \Rightarrow p_2 = 243 \text{ psi}$$

Now the flow rate through the needle valve based on the desired hydraulic cylinder speed is,

$$Q = A_2 V_{\text{cylinder}} = (3.14 - 0.79) \times 10 = 23.5 \text{ in}^3/\text{s} = 6.10 \text{ gpm}$$

Since the discharge from the needle valve flows directly to the oil tank, pressure $p_3 = 0$ and the pressure drop across the needle valve is equal to p_2 .

$$C_v = \frac{6.10}{\sqrt{243/0.9}} = 0.37 \text{ gpm}/\sqrt{\text{psi}}$$

Non - Pressure - Compensated Valves

There are two basic types of flow control valves:

non-pressure-compensated and **pressure-compensated**.

The non-pressure-compensated type is used where system pressures are relatively constant and motoring speeds are not too critical.

They work on the principle that the flow through an orifice will be constant if the pressure drop remains constant. It includes a check valve, which permits free flow in the direction opposite to the flow control direction.

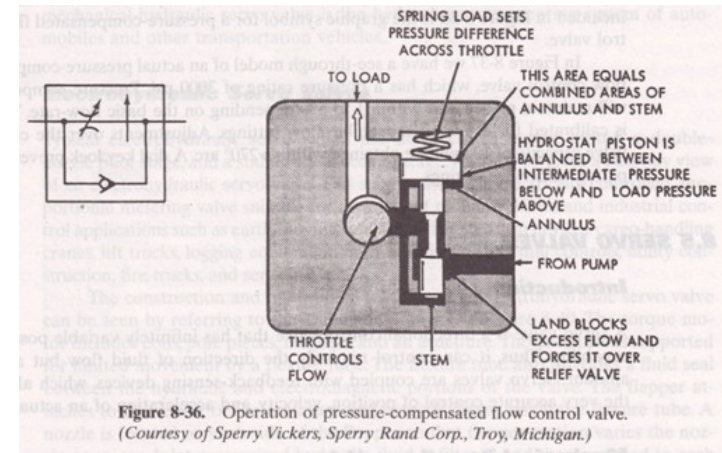
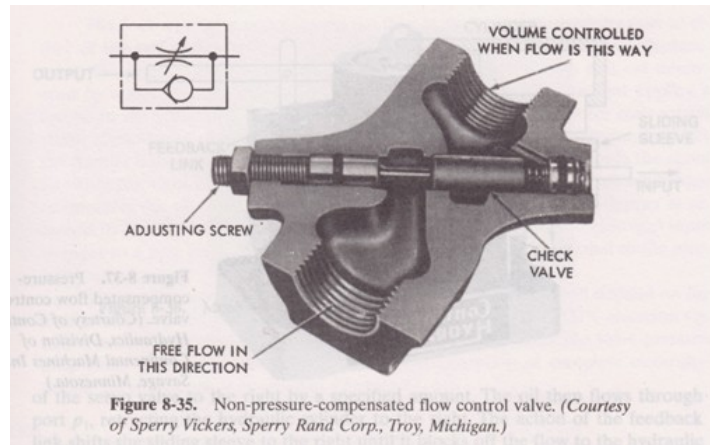


Figure 8.35 gives a cutaway view of a non-pressure-compensated flow control valve and its graphic symbol.

Pressure - Compensated Valves

If the load on an actuator changes significantly, system pressure will change appreciably. Thus, the flow-rate through a non-pressure-compensated valve will change for the same flow-rate setting.

Figure 8-36 illustrates the operation of a pressure-compensated valve. In this design a hydrostat is used to maintain a constant 20-psi differential across the throttle, which is an orifice whose area can be adjusted by an external knob setting. The orifice area setting determines the flow-rate to be controlled.

The hydrostat is held normally open by a light spring. However, it starts to close as inlet pressure increases and overcomes the light spring force. This closes the opening through the hydrostat and thereby blocks off all flow in excess of the throttle setting.

As a result, the only oil that will pass through the valve is the amount that 20 psi can force through the throttle. Flow exceeding this amount can be used by other parts of the circuit or return to the tank via the pressure relief valve.

SERVO VALVES

A servo valve is a directional control valve that has *infinitely variable positioning* capability. Thus, it can control not only the direction of fluid flow but also the amount.

Servo valves are coupled with feedback-sensing devices, which allow for the very accurate control of position, velocity, and acceleration of an actuator.

Mechanical-Type Servo Valves

Mechanical-type servo valve, is essentially a force amplifier used for positioning control.

In this design, if a small input force shifts the **spool** of the servo valve to the right by a specified amount, the oil flows through port p1, retracting the hydraulic cylinder to the right. The action of the feedback link shifts the sliding **sleeve** to the right until it blocks off the flow to the hydraulic cylinder. Thus, a given input motion produces a specific and controlled amount of output motion.

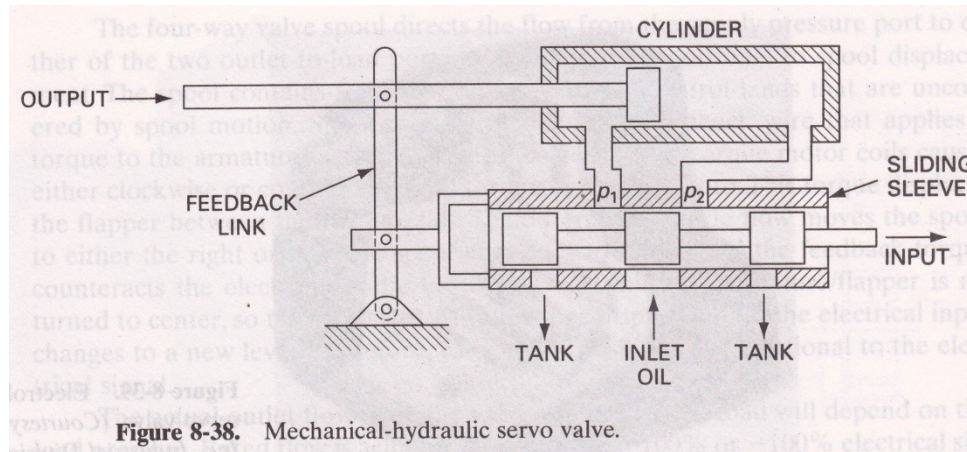


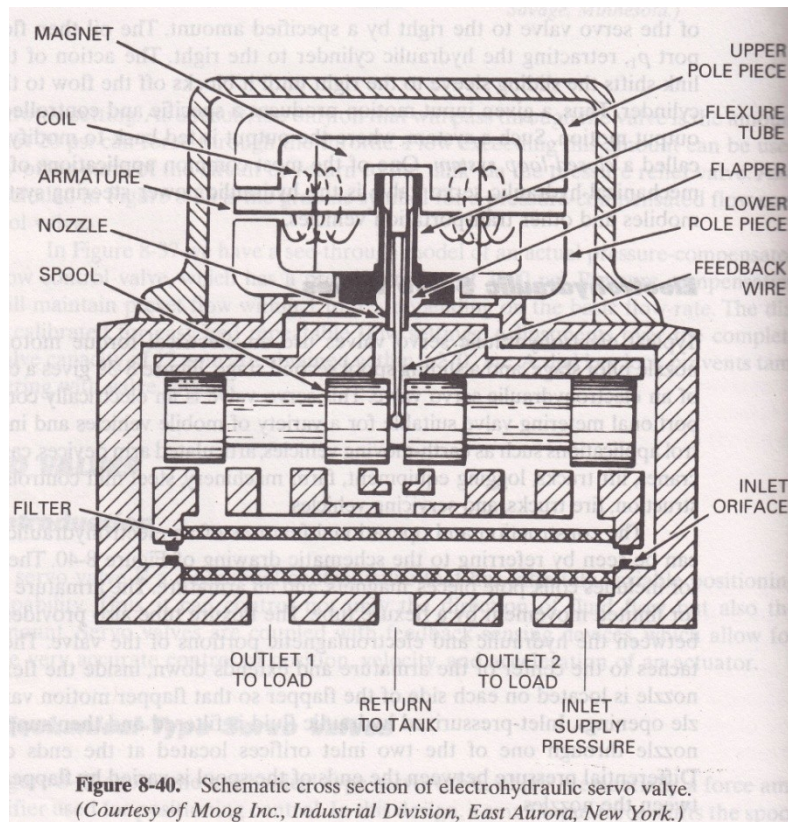
Figure 8-38. Mechanical-hydraulic servo valve.

Such a system, where the output is fed back to modify the input is called a **closed-loop system**. One of the most common applications of this type of mechanical-hydraulic servo valve is the *hydraulic power steering system* of automobiles and other transportation vehicles.

Electrohydraulic Servo Valves

Typical electrohydraulic servo valves use an electrical torque motor, a double-

nozzle pilot stage, and a sliding spool second stage. This servo valve is an electrically controlled, proportional metering valve suitable for a variety of mobile vehicles and industrial control applications such as articulated arm devices, cargo-handling cranes, lift trucks, logging equipment, farm machinery steel mill controls, utility construction, fire trucks, and servicing vehicles.



The torque motor of the valve includes coils, pole pieces, magnets, and an armature. The armature is supported for limited movement by a flexure tube. A flapper is attached to the center of the armature and extends down, inside the flexure tube. The flapper motion varies the openings of the nozzle. Inlet-pressurized hydraulic fluid is filtered and then supplied to each nozzle through one of the two inlet orifices located at the ends of the filter. Differential pressure between the ends of the spool is varied by flapper motion between the nozzles.

PROPORTIONAL CONTROL VALVES

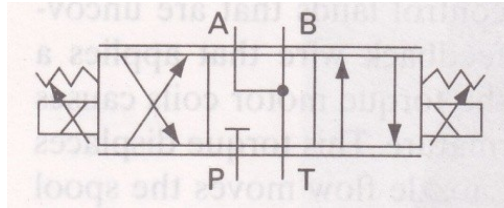
Proportional control valves, which are also called **electrohydraulic proportional valves**, are similar to electrohydraulic servo valves in that they both are electrically controlled.

However there are a number of differences between these two types of valves. For example servo valves are used in closed-loop systems whereas proportional valves are used in open-loop systems.

In Servo valves, electrical current in a torque motor coil causes either clockwise or counterclockwise torque on an armature to control the movement of the valve spool.

On the other hand, a proportional valve uses a solenoid that produces a force proportional to the current in its coils. Thus, by controlling the current in the solenoid coil, the position of the spring-loaded spool can also be controlled. This means that unlike a standard solenoid valve, a proportional valve can provide both directional and flow control capability in a single valve.

Although proportional valves designed to control pressure are available, the proportional direction control valve is the most widely used.



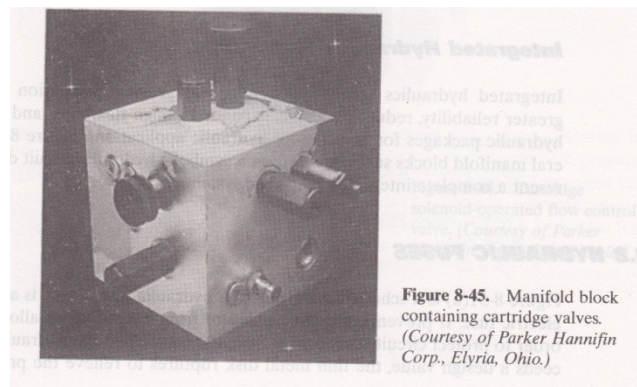
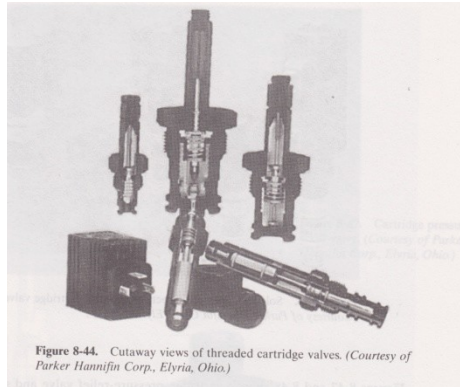
The graphic symbol contains two horizontal lines (one at the top of the symbol and one at the bottom) to indicate infinite positioning capability of the spool.

A proportional directional control valve looks very similar to a conventional solenoid-actuated directional control valve. However, the spool of a proportional valve is designed specifically to provide precise metering of the oil for good speed control of cylinders and motors. To accomplish this precise control, clearances between the spool lands and mating valve bore are very small (approximately 0.0005 in).

CARTDIGE VALVES

Different types of cartridge valves and other components are sometimes integrated to form **Integrated hydraulic circuits** (compact hydraulic systems) into a single, machined, ported manifold block.

A cartridge valve is designed to be assembled into a cavity of a ported manifold block (alone or along with other cartridge valves and hydraulic



components) in order to perform the valve's intended function. The cartridge valve is assembled into the manifold block either by screw threads (threaded design) or by a bolted cover (slip-in design).

HYDRAULIC FUSES

A hydraulic fuse is analogous to an electric fuse. It prevents hydraulic pressure from exceeding an allowable value in order to protect circuit components from damage.

When the hydraulic pressure exceeds a design value, the thin metal disk ruptures to relieve the pressure as oil is drained back to the oil tank. After rupture, a new metal disk must be inserted before operation can be restarted.

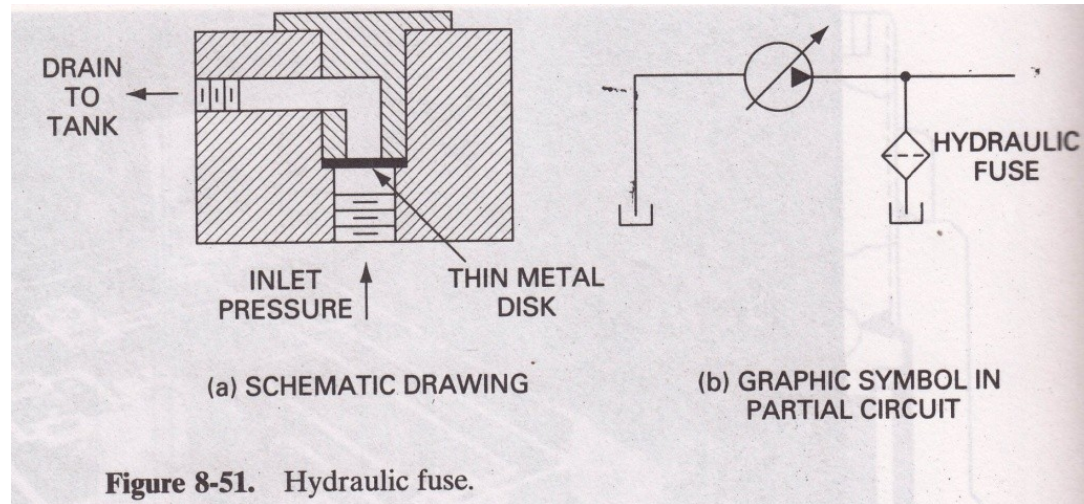


Figure 8-51. Hydraulic fuse.

Hydraulic fuses are used mainly with pressure compensated pumps for fail-safe overload protection in case the compensator control on the pump fails to operate.

Figure 8-51(b) is the symbolic representation of a partial circuit consisting of a pressure-compensated pump and a hydraulic fuse.

A hydraulic fuse is analogous to an electrical fuse because they both are one-shot devices.

On the other hand, a pressure relief valve is analogous to an electrical circuit breaker because they both are resettable devices.