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MEC-119 EXAM PREVIEW

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Exam Preview:

1. Which of the following valves is used when a straight-line flow of fluid and minimum flow restriction are needed?
    a. Butterfly
    b. Gate
    c. Globe
    d. Needle
2. In a globe valve, the disk is used to control flow.
    a. True
    b. False
3. In most valves the poppet is held in the seated position by the packing.
    a. True
    b. False
4. Which of the following is NOT a way that rotary spool valves can be operated?
    a. Electrically
    b. Fluid pressure
    c. Manually
    d. Pneumatically
5. In a dynamic seal application the inner or outer member of the gland move in an arc around the axis of the shaft?
    a. True
    b. False

6. O-rings are usually molded from Nylon.
    a. True
    b. False
7. Which of the following does the simplex Bourdon-tube gauge measure?
    a. Air temperature
    b. Steam pressure
    c. Oil level in the reservoir
    d. Water level in holding tanks
8. A bronze Bourdon-tube gauge is suitable to be used for pressures over 350psi?
    a. True
    b. False
9. What other term is used when referring to static seals?
    a. Dynamic rings
    b. Gaskets
    c. Liners
    d. Washers
10. The type of material is what distinguishes between U-cups and U-packings.
    a. True
    b. False

CHAPTER 6

VALVES

It is all but impossible to design a practical fluid power system without some means of controlling the volume and pressure of the fluid and directing the flow of fluid to the operating units. This is accomplished by the incorporation of different types of valves. A valve is defined as any device by which the flow of fluid may be started, stopped, or regulated by a movable part that opens or obstructs passage. As applied in fluid power systems, valves are used for controlling the flow, the pressure, and the direction of the fluid flow.

Valves must be accurate in the control of fluid flow and pressure and the sequence of operation. Leakage between the valve element and the valve seat is reduced to a negligible quantity by precision-machined surfaces, resulting in carefully controlled clearances. This is one of the very important reasons for minimizing contamination in fluid power systems. Contamination causes valves to stick, plugs small orifices, and causes abrasions of the valve seating surfaces, which results in leakage between the valve element and valve seat when the valve is in the closed position. Any of these can result in inefficient operation or complete stoppage of the equipment.

Valves may be controlled manually, electrically, pneumatically, mechanically, hydraulically, or by combinations of two or more of these methods. Factors that determine the method of control include the purpose of the valve, the design and purpose of the system, the location of the valve within the system, and the availability of the source of power.

LEARNING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Identify the functions of valves in a fluid power system.
2. Recognize the functions and operating characteristics of flow control valves.
3. Identify the construction features of the various types of flow control valves.
4. Recognize the operation and function requirements of pressure control devices for fluid power systems.
5. Identify the construction characteristics of pressure control devices for fluid power systems.
6. Recognize the construction features of the various types of directional control valves.
7. Identify the operating characteristics of directional control valves.
8. Identify the uses of various types of directional control valves.

CLASSIFICATIONS

Valves are classified according to their use: flow control, pressure control, and directional control. Some valves have multiple functions that fall into more than one classification.

FLOW CONTROL VALVES

Flow control valves are used to regulate the flow of fluids in fluid-power systems. Control of flow in fluid-power systems is important because the rate of movement of fluid-powered machines depends on the rate of flow of the pressurized fluid. These valves may be manually, hydraulically, electrically, or pneumatically operated. Some of the different types of flow control valves are discussed in the following paragraphs.

Stop Valves

Stop valves are used to shut off or, in some cases, control the flow of fluid. They are controlled by the movement of the valve stem. Stop valves can be divided into four general categories: globe, gate, butterfly, and ball. (Plug valves and needle valves are also considered to be stop valves). An example of a typical ball valve is shown in *Figure 6-1.*

Most ball valves are the quick-acting type. They require only a 90-degree turn to either completely open or close the valve. However, many are operated by planetary gears. This type of gearing allows the use of a relatively small handwheel and limited operating force to operate a fairly large valve. The gearing does, however, increase the operating time for the valve. Some ball valves also contain a swing check located within the ball to give the valve a check valve feature. A ball-stop, swing-check valve with a planetary gear operation is shown in *Figure 6-2*.

In addition to the ball valves shown in *Figures 6-1 and 6-2*, there are three-way ball valves that are used to supply fluid from a single source to one component or the other in a two-component system (*Figure 6-3*).

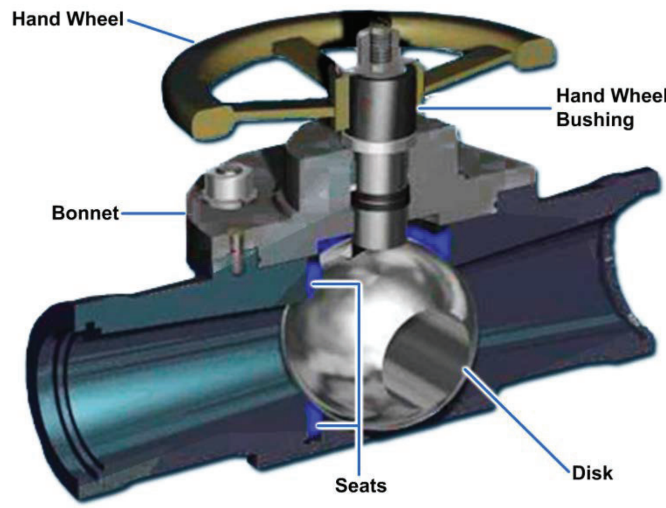


Figure 6-1 — Typical ball valve.

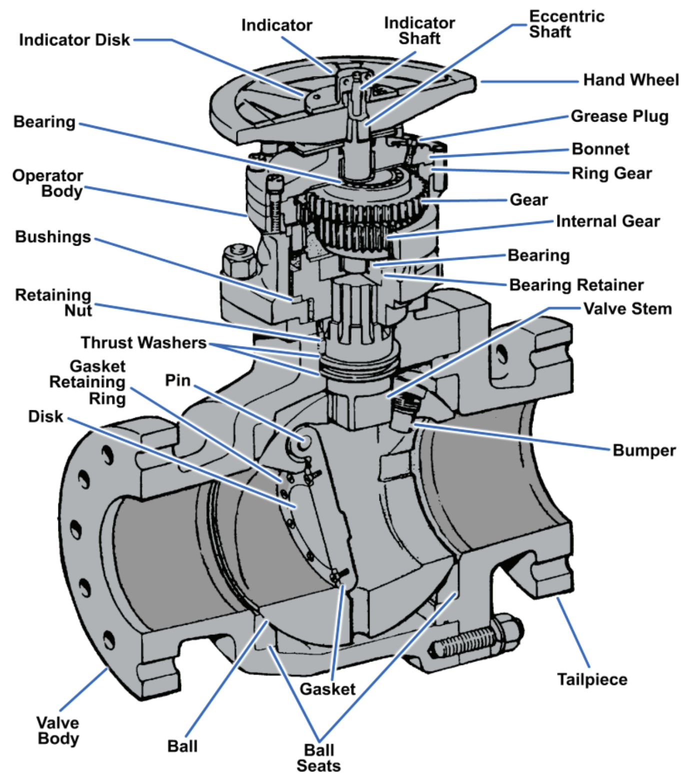


Figure 6-2 — Typical ball-stop, swing-check valve.

Gate Valves

Gate valves are used when a straight-line flow of fluid and minimum flow restriction are needed. Gate valves are so-named because the part that either stops or allows flow through the valve acts somewhat like a gate. The gate is usually wedge-shaped. When the valve is wide open the gate is fully drawn up into the valve bonnet. This leaves an opening for flow through the valve the same size as the pipe in which the valve is installed (*Figure 6-4*). Therefore, there is little pressure drop or flow restriction through the valve.

Gate valves are not suitable for throttling purposes. The control of flow is difficult because of the valve's design, and the flow of fluid slapping against a partially open gate can cause extensive damage to the valve. Except as specifically authorized, gate valves should not be used for throttling.

Gate valves are classified as either rising-stem or non-rising-stem valves (*Figure 6-4, frames 1 through 3*). In the design of the rising-stem valve, the stem is attached to the gate. The gate and stem rise and sink together as the valve is operated.

NOTE

Except as specifically authorized, gate valves should not be used for throttling.

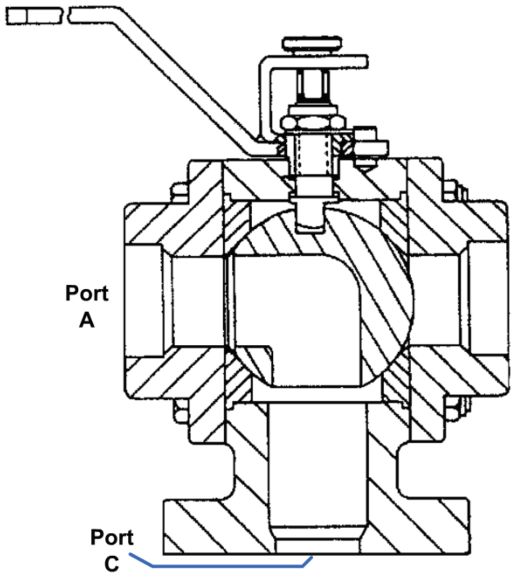


Figure 6-3 — Three-way ball valve.

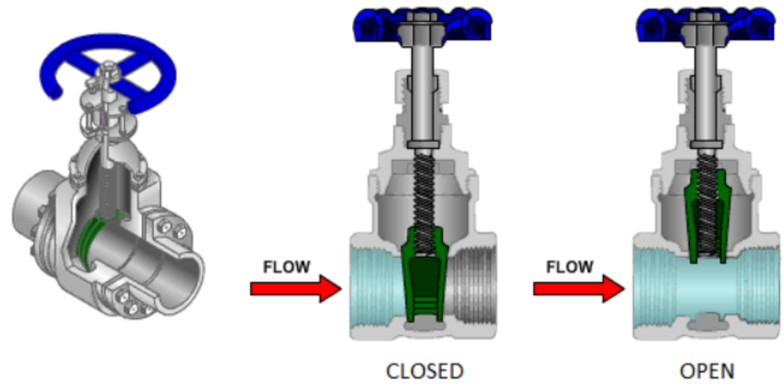


Figure 6-4 — Operation of a gate valve.

In the design of the non-rising-stem gate valve, the stem is threaded on the lower end into the gate. As the handwheel on the stem is rotated, the gate travels up or down the stem on the threads while the stem remains vertically stationary. This type of valve will almost always have a pointer type of indicator threaded onto the upper end of the stem to indicate the position of the gate inside the valve.

Globe Valves

Globe valves are probably the most common valves in existence. The globe valve gets its name from the globular shape of the valve body. Other types of valves may also have globular-shaped bodies. Thus, it is the internal structure of the valve that identifies this type of valve (*Figure 6-5*).

The inlet and outlet openings for globe valves are arranged in a way to satisfy the flow requirements. Straight-, angle-, and cross-flow valves are shown in *Figure 6-5*.

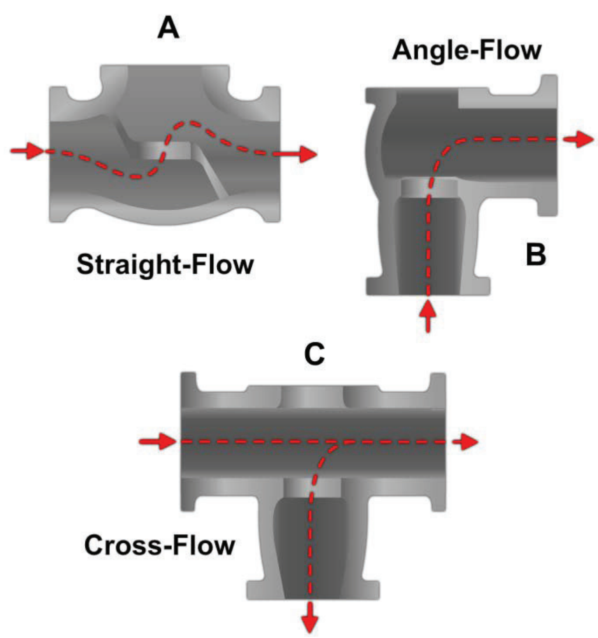


Figure 6-5 — Types of globe valve bodies.

The moving parts of a globe valve consist of the disk, the valve stem, and the handwheel. The stem connects the handwheel and the disk. It is threaded and fits into the threads in the valve bonnet.

The part of the globe valve that controls flow is the disk, which is attached to the valve stem (disks are available in various designs). The valve is closed by turning the valve stem in until the disk is seated into the valve seat. This prevents fluid from flowing through the valve (*Figure 6-6*). The edge of the disk and the seat are very accurately machined so that they form a tight seal when the valve is closed. When the valve is open, the fluid flows through the space between the edge of the disk and the seat. Since the fluid flows equally on all sides of the center of support when the valve is open, there is no unbalanced pressure on the disk to cause uneven wear. The rate at which fluid flows through the valve is regulated by the position of the disk in relation to the seat. The valve is commonly used as a fully open or fully closed valve, but it may be used as a throttle valve. However, since the seating surface is a relatively large area, it is not suitable as a throttle valve, where fine adjustments are required in controlling the rate of flow.

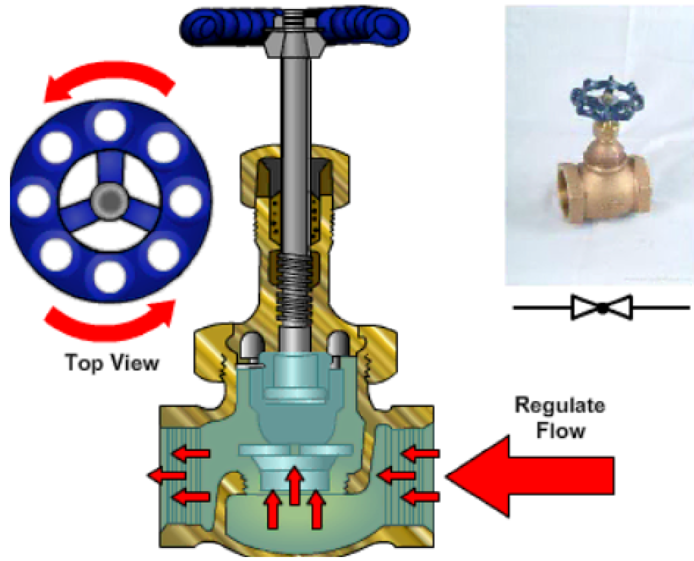


Figure 6-6 — Operation of a globe valve.

The globe valve should never be jammed in the open position. After a valve is fully opened, the handwheel should be turned toward the closed position approximately one-quarter turn. Unless this is done, the valve is likely to seize in the open position, making it difficult, if not impossible, to close the valve. Many valves are damaged in this manner. Another reason for not leaving globe valves in the fully open position is that it is sometimes difficult to determine if the valve is open or closed. If the valve is jammed in the open position, the stem may be damaged or broken by someone who thinks the valve is closed, and attempts to open it.

It is important that globe valves be installed with the pressure against the face of the disk to keep the system pressure away from the stem packing when the valve is shut.

Butterfly Valves

The butterfly valve is light in weight and is relatively small and quick acting. Butterfly valves are used in freshwater, fuel, lube oil, and chilled water systems where quick action and positive flow control are required (*Figure 6-7, frame 1*). Butterfly valves operate in the same manner as the throttle valves and the choke valves in carburetors. A disk attached to a shaft pivots between the open and closed positions as the shaft is turned.

This older design of the butterfly valve is still widely used. This valve provides for positive shutoff, but it should not be used for throttling as standard practice. It consists of a body, a resilient seat, a butterfly-type disk, a stem, packing, a notched positioning plate, and a handle. The seat is under compression when it is installed in the valve body. This design provides a seal for the disk and the upper and lower points where the stem passes through the seat. The packing provides a positive seal around the stem for added protection in case the seal formed by the seat becomes damaged. To gain access to the seat for replacement, you must first remove the stem and valve disk.

A newer, high-performance butterfly valve is shown in *Figure 6-7, frame 2*. This improved design has higher pressure capabilities and allows for a full range of throttling positions not offered in the older design of butterfly valves. The newer design of butterfly valve has been introduced into the fleet and is gradually replacing the older design. Unlike the older style of butterfly valve, the new style has a removable retaining ring that holds the seat in place. To change the seat, all you must do is remove the retaining ring, remove the old seat, place a new seat into its groove, and reinstall the retainer ring.

To open or close a butterfly valve, turn the handle only one quarter of a turn to rotate the disk 90 degrees. Some larger butterfly valves may have handwheels or actuators that are driven by pneumatic, electric, or hydraulic means through a gearing arrangement (*Figure 6-7, frame 3*).

Figure 6-7 — Butterfly valves.

Needle Valves

Needle valves are similar in design and operation to the globe valve. Instead of a disk, a needle valve has a long tapered point at the end of the valve stem. A cross-sectional view of a needle valve is illustrated in *Figure 6-8*.

The long taper of the valve element permits a much smaller seating surface area than that of the globe valve; therefore, the needle valve is more suitable as a throttle valve. Needle valves are used to control flow into delicate gauges, which might be damaged by sudden surges of fluid under pressure. Needle valves are also used to control the end of a work cycle, where it is desirable for motion to be brought slowly to a halt, and at other points where precise adjustments of flow are necessary and where a small rate of flow is desired.

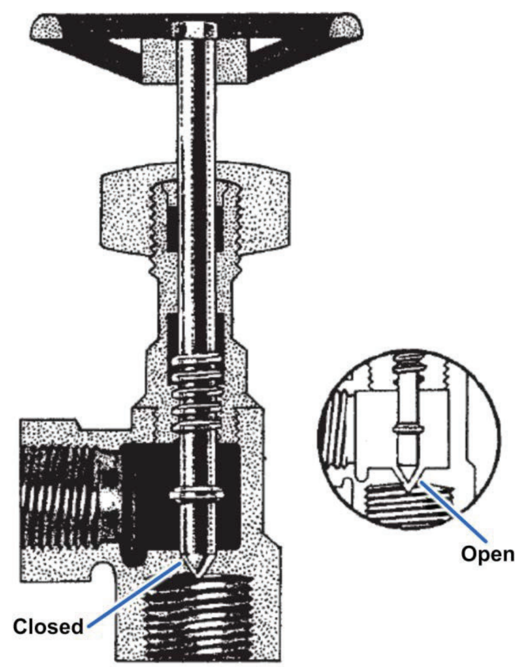


Figure 6-8 — Cross-sectional view of a needle valve.

Although many of the needle valves used in fluid power systems are the manually operated type (*Figure 6-8*), modifications of this type of valve are often used as variable restrictors. This valve is constructed without a handwheel and is adjusted to provide a specific rate of flow. This rate of flow will provide a desired time of operation for a particular subsystem. Since this type of valve can be adjusted to conform to the requirements of a particular system, it can be used in a variety of systems. A needle valve that was modified as a variable restrictor is illustrated in *Figure 6-9*.

Hydraulic and Pneumatic Globe Valves

The valve consists of a valve body and a stem cartridge assembly. The stem cartridge assembly includes the bonnet, gland nut, packing, packing retainer, handle, stem, and seat. On small valves (1/8 and 1/4 inch) the stem is made in one piece, but on larger sizes it is made of a stem, guide, and stem retainer. The valve disk is made of nylon and is swaged into either the stem, for 1/8- and 1/4-inch valves, or the guide, for larger valves. The bonnet screws into the valve body with left-hand threads and is sealed by an O-ring (including a back-up ring).

The valve is available with either a rising stem or a non-rising stem. The rising stem valve uses the same port body design as does the non-rising stem valve. The stem is threaded into the gland nut and screws outward as the valve is opened.

This valve does not incorporate provisions for tightening the stem packing nor replacing the packing while the valve is in service; therefore, complete valve disassembly is required for maintenance. A rising stem hydraulic and pneumatic globe valve is illustrated in *Figure 6-10*.

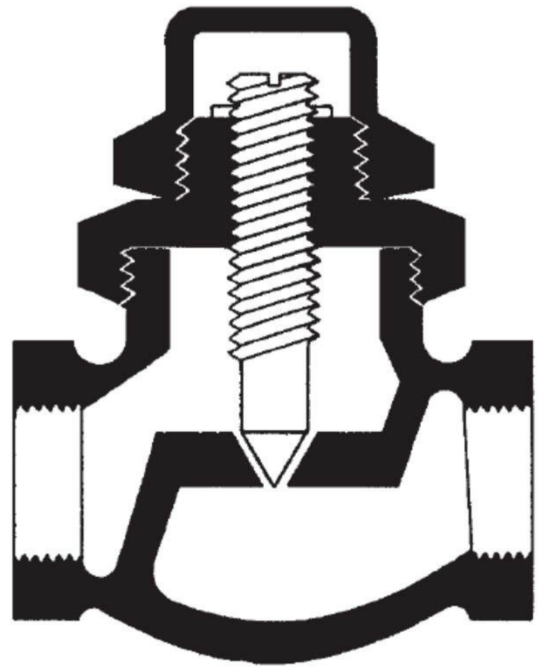


Figure 6-9 — Variable restrictor.

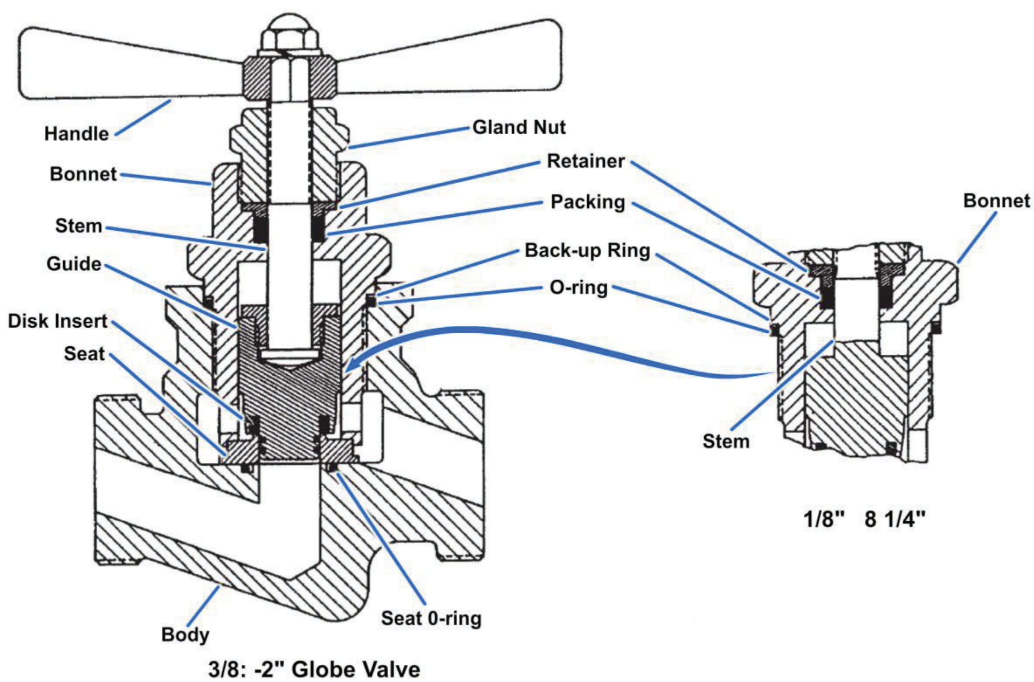


Figure 6-10 — Hydraulic and pneumatic globe valve (rising stem).

SPECIAL-PURPOSE VALVES

The safe and efficient operation of fluid power systems, system components, and related equipment requires a means of controlling pressure. There are many types of automatic pressure control valves. Some of them merely provide an escape for pressure that exceeds a set limit; some only reduce the pressure to a lower pressure system or subsystem; and some keep the pressure in a system within a required range.

Relief Valves

Some fluid power systems, even when operating normally, may temporarily develop excessive pressure; for example, when an unusually strong work resistance is encountered. Relief valves are used to control this excess pressure.

Relief valves are automatic valves used on system lines and equipment to prevent overpressurization. Most relief valves simply lift (open) at a preset pressure and reset (shut) when the pressure drops slightly below the lifting pressure. Relief valves do not maintain flow or pressure at a given amount, but prevent pressure from rising above a specific level when the system is temporarily overloaded.

Main system relief valves are generally installed between the pump or pressure source and the first system isolation valve. The valve must be large enough to allow the full output of the hydraulic pump to be delivered back to the reservoir. In a pneumatic system, the relief valve controls excess pressure by discharging the excess gas to the atmosphere.

Smaller relief valves, similar in design and operation to the main system relief valve, are often used in isolated parts of the system where a check valve or directional control valve prevents pressure from being relieved through the main system relief valve and where pressures must be relieved at a set point lower than that provided by the main system relief. These small relief valves are also used to relieve pressures caused by thermal expansion (see glossary) of the fluids.

A typical relief valve is shown in *Figure 6-11*. System pressure acts on the valve disk at the inlet to the valve. When the system pressure exceeds the force exerted by the valve spring, the valve disk lifts off of its seat, allowing some of the system fluid to escape through the valve outlet until the system pressure is reduced to just below the relief set point of the valve.

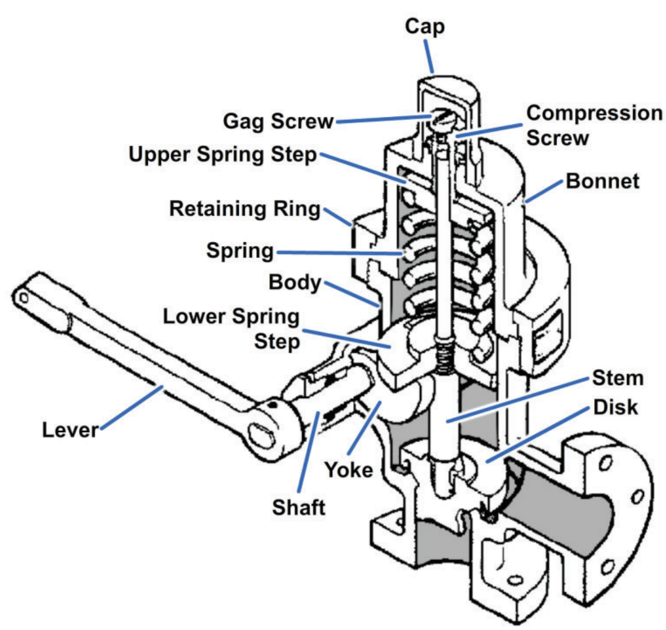


Figure 6-11 — Relief valve.

All relief valves have an adjustment for increasing or decreasing the set relief pressure. Some relief valves are equipped with an adjusting screw for this purpose. This adjusting screw is usually covered with a cap, which must be removed before an adjustment can be made. Some type of locking device, such as a lock nut, is usually provided to prevent the adjustment from changing through vibration. Other types of relief valves are equipped with a handwheel for making adjustments to the valve. Either the adjusting screw or the handwheel is turned clockwise to increase the pressure at which the valve will open. In addition, most relief valves are also provided with an operating lever or some type of device to allow manual cycling or gagging the valve open for certain tasks.

The relief valve shown in *Figure 6-11* is used to efficiently serve the requirements of some fluid power systems; however, this relief valve is unsatisfactory for some applications. To give you a better understanding of the operation of relief valves, we will discuss some of the undesirable characteristics of this valve.

A simple relief valve, such as the one illustrated in *Figure 6-11*, with a suitable spring adjustment can be set so that it will open when the system pressure reaches a certain level, 500 pounds per square inch (psi) for example. When the valve does open, the volume of flow to be handled may be greater than the capacity of the valve; therefore, pressure in the system may increase to several hundred psi above the set pressure before the valve brings the pressure under control. A simple relief valve will be effective under these conditions only if it is very large. In this case, it would operate stiffly and the valve element would chatter back and forth. In addition, the valve will not close until the system pressure decreases to a point somewhat below the opening pressure.

The surface area of the valve element must be larger than that of the pressure opening if the valve is to seat satisfactorily, as shown in *Figure 6-12*. The pressure in the system acts on the valve element to open to it. In each case, the force exerted directly upward by system pressure when the valve is closed depends on the area (*Figure 6-12, area A*) across the valve element where the element seats against the pressure tube. The moment the valve opens, however, the upward force exerted depends on the horizontal area (*Figure 6-12, area* B) of the entire valve element, which is greater than area in *Figure 6-12, area A*. This force causes an upward jump of the valve element immediately after it opens, because the same pressure acting over different areas produces forces proportional to the areas. It also requires a greater force to close the valve than was required to open it. As a result, the valve will not close until the system pressure has decreased to a certain point below the pressure required to open it.

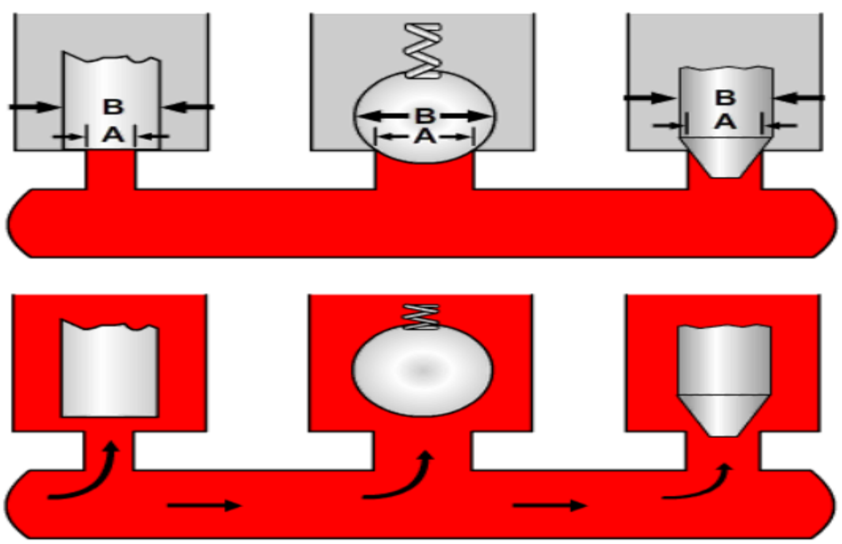


Figure 6-12 — Pressure acting on different areas of valve elements.

Let us assume that a valve of this type is set to open at 500 psi. When the valve is closed, the pressure acts on the area in *Figure 6-12, area A*. If this area is 0.5 square inch, an upward force of 250 pounds (500 x 0.5) will be exerted on the valve at the moment of opening. With the valve open, however, the pressure acts on the area in *Figure 6-12, area B*. If the area in *Figure 6-12, area B* is 1 square inch, the upward force is 500 pounds, or double the force at which the valve actually opened.

For the valve to close, pressure in the system would have to decrease well below the point at which the valve opened. The exact pressure would depend on the shape of the valve element.

In some hydraulic systems, there is pressure in the return line. This back pressure is caused by restrictions in the return line and will vary in relation to the amount of fluid flowing in the return line. This pressure creates a force on the back of the valve element and will increase the force necessary to open the valve and relieve system pressure.

Simple relief valves have a tendency to open and close rapidly as they “hunt” above and below the set pressure, causing pressure pulsations and undesirable vibrations and producing a noisy chatter. Because of the unsatisfactory performance of the simple relief valve in some applications, compound relief valves were developed.

Compound relief valves use the principles of operation of simple relief valves for one stage of their action—that of the pilot valve. Provision is made to limit the amount of fluid that the pilot valve must handle, and thereby avoid the weaknesses of simple relief valves. (A pilot valve is a small valve used for operating another valve.)

The operation of a compound relief valve is illustrated in *Figure 6-13*. In *Figure 6-13, view A*, the main valve, which consists of a piston, stem, and spring, is closed, blocking flow from the high pressure line to the reservoir. Fluid in the high pressure line flows around the stem of the main valve as it flows to the actuating unit. The stem of the main valve is hollow (the stem passage) and contains the main valve spring, which forces the main valve against its seat. When the pilot valve is open the stem passage allows fluid to flow from the pilot valve, around the main valve spring, and down to the return line.

There is also a narrow passage (piston passage) through the main valve piston. This passage connects the high pressure line to the valve chamber.

The pilot valve is a small, ball-type, springloaded check valve, which connects the top of the passage from the valve chamber with the passage through the main valve stem. The pilot valve is the control unit of the relief valve because the pressure at which the relief valve will open depends on the tension of the pilot valve spring. The pilot valve spring tension is adjusted by turning the adjusting screw so that the ball will unseat when system pressure reaches the preset limit.

Fluid at line pressure flows through the narrow piston passage to fill the chamber. Because the line and the chamber are connected, the pressure in both are equal. The top and bottom of the main piston have equal areas; therefore, the hydraulic forces acting upward and downward are equal, and

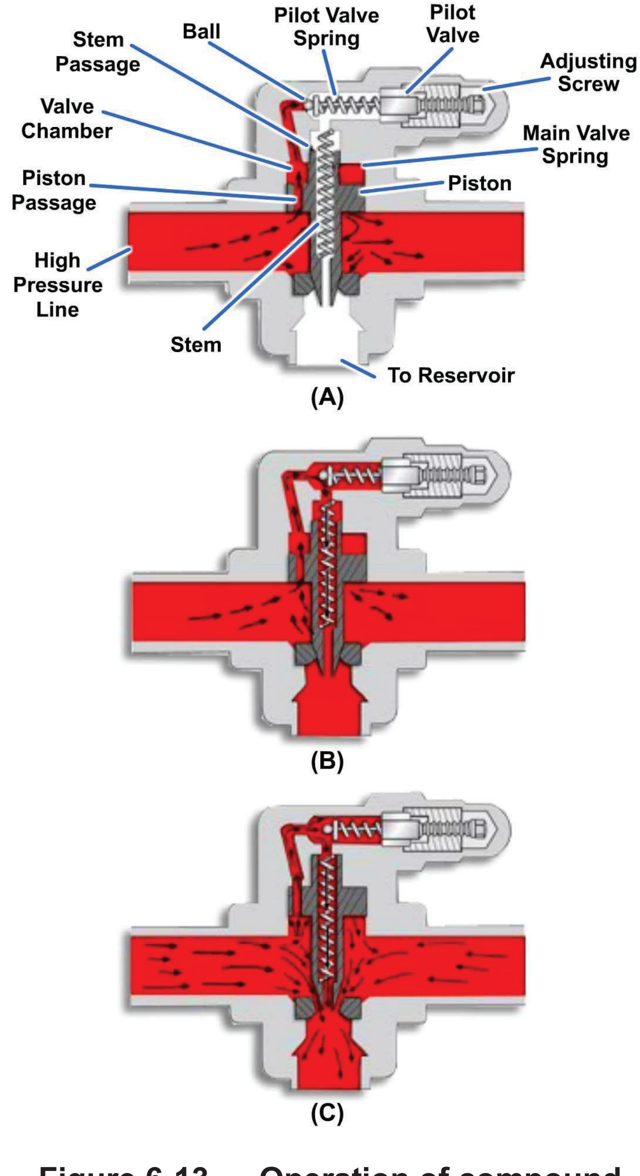


Figure 6-13 — Operation of compound relief valve.

there is no tendency for the piston to move in either direction. The only other force acting on the main valve is that of the main valve spring, which holds it closed.

When the pressure in the high pressure line increases to the point at which the pilot valve is set, the ball unseats (*Figure 6-13, view B*). This opens the valve chamber through the valve stem passage to the low pressure return line. Fluid immediately begins to flow out of the chamber, much faster than it can flow through the narrow piston passage. As a result the chamber pressure immediately drops, and the pilot valve begins to close again, restricting the outward flow of fluid. Chamber pressure therefore increases, the valve opens, and the cycle repeats.

So far, the only part of the valve that has moved appreciably is the pilot, which functions just like any other simple spring-loaded relief valve. Because of the small size of the piston passage, there is a severe limit on the amount of overpressure protection the pilot can provide the system. All the pilot valve can do is limit fluid pressure in the valve chamber above the main piston to a preset maximum pressure, by allowing excess fluid to flow through the piston passage, through the stem passage, and into the return line. When pressure in the system increases to a value that is above the flow capacity of the pilot valve, the main valve opens, permitting excess fluid to flow directly to the return line. This is accomplished in the following manner.

As system pressure increases, the upward force on the main piston overcomes the downward force, which consists of the tension of the main piston spring and the pressure of the fluid in the valve chamber (*Figure 6-13, view C*). The piston then rises, unseating the stem, and allows the fluid to flow from the system pressure line directly into the return line. This causes system pressure to decrease rapidly, since the main valve is designed to handle the complete output of the pump. When the pressure returns to normal, the pilot spring forces the ball onto the seat. Pressures are equal above and below the main piston, and the main spring forces the valve to seat.

As you can see, the compound valve overcomes the greatest limitation of a simple relief valve by limiting the flow through the pilot valve to a quantity it can satisfactorily handle. This limits the pressure above the main valve and enables the main line pressure to open the main valve. In this way, the system is relieved when an overload exists.

PRESSURE REGULATORS

Pressure regulators, often referred to as unloading valves, are used in fluid power systems to regulate pressure. In pneumatic systems, the valve, commonly referred to as a pressure regulator, simply reduces pressure. This type of valve is discussed later in this chapter under pressure-reducing valves. In hydraulic systems the pressure regulator is used to unload the pump and to maintain and regulate system pressure at the desired values. All hydraulic systems do not require pressure regulators. The open-center system does not require a pressure regulator. Many systems are equipped with variable-displacement pumps, which contain a pressure-regulating device.

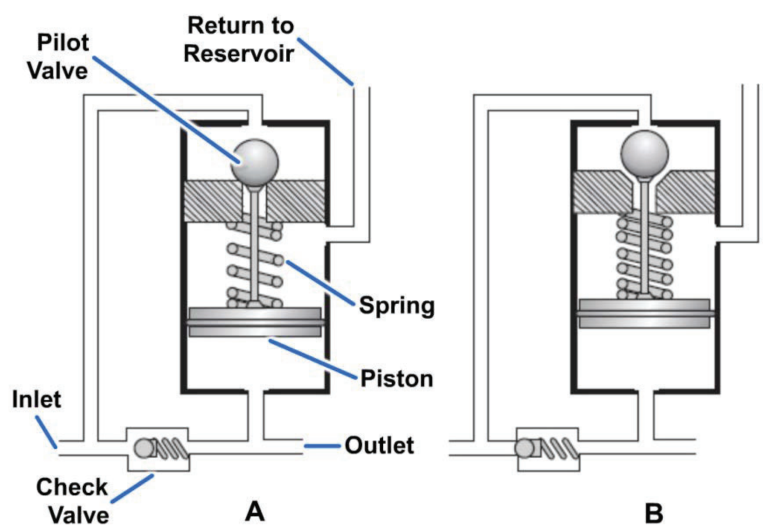


Figure 6-14 — Hydraulic pressure regulator.

Pressure regulators are made in a variety of types and by various manufacturers; however, the basic operating principles of all regulators are similar to the one illustrated in *Figure 6-14*.

A regulator is open when it is directing fluid under pressure into the system (*Figure 6-14, view A*). In the closed position (*Figure 6-14, view B*), the fluid in the part of the system beyond the regulator is trapped at the desired pressure, and the fluid from the pump is bypassed into the return line and back to the reservoir. To prevent constant opening and closing (chatter), the regulator is designed to open at a pressure somewhat lower than the closing pressure. This difference is known as differential or operating range. For example, assume that a pressure regulator is set to open when the system pressure drops below 600 psi, and close when the pressure rises above 800 psi. The differential or operating range is 200 psi.

Assume that the piston has an area of 1 square inch (*Figure 6-14*), the pilot valve has a cross-sectional area of 1/4 square inch, and the piston spring provides 600 pounds of force pushing the piston down. When the pressure in the system is less than 600 psi, fluid from the pump will enter the inlet port, flow to the top of the regulator, and then to the pilot valve. When the pressure of the fluid at the inlet increases to the point where the force it creates against the front of the check valve exceeds the force created against the back of the check valve by system pressure and the check valve spring, the check valve opens. This allows fluid to flow into the system and to the bottom of the regulator against the piston. When the force created by the system pressure exceeds the force exerted by the spring, the piston moves up, causing the pilot valve to unseat. Since the fluid will take the path of least resistance, it will pass through the regulator and back to the reservoir through the return line.

When the fluid from the pump is suddenly allowed a free path to return, the pressure on the input side of the check valve drops and the check valve closes. The fluid in the system is then trapped under pressure. This fluid will remain pressurized until a power unit is actuated, or until pressure is slowly lost through normal internal leakage within the system.

When the system pressure decreases to a point slightly below 600 psi, the spring forces the piston down and closes the pilot valve. When the pilot valve is closed, the fluid cannot flow directly to the return line. This causes the pressure to increase in the line between the pump and the regulator. This pressure opens the check valve, causing the fluid to enter the system.

In summary, when the system pressure decreases a certain amount, the pressure regulator will open, sending fluid to the system. When the system pressure increases sufficiently, the regulator will close, allowing the fluid from the pump to flow through the regulator and back to the reservoir. The pressure regulator takes the load off of the pump and regulates system pressure.

SEQUENCE VALVES

Sequence valves control the sequence of operation between two branches in a circuit; that is, they enable one unit to automatically set another unit into motion. An example of the use of a sequence valve is in an aircraft landing gear actuating system.

In a landing gear actuating system, the landing gear doors must open before the landing gear starts to extend. Conversely, the landing gear must be completely retracted before the doors close. A sequence valve installed in each landing gear actuating line performs this function.

A sequence valve is somewhat similar to a relief valve except that, after the set pressure has been reached, the sequence valve diverts the fluid to a second actuator or motor to do work in another part of the system. An installation of two sequence valves that control the sequence of operation of three actuating cylinders is shown in *Figure 6-15*. Fluid is free to flow into cylinder A. The first sequence valve (1) blocks the passage of fluid until the piston in cylinder A moves to the end of its stroke. At this time, sequence valve 1 opens, allowing fluid to enter cylinder B. This action continues until all three pistons complete their strokes.

There are various types of sequence valves. Some are controlled by pressure and some are controlled mechanically.

Pressure-Controlled Sequence Valves

The operation of a typical pressure-controlled sequence valve is illustrated in *Figure 6-16*. The opening pressure is obtained by adjusting the tension of the spring that normally holds the piston in the closed position.

> **NOTE**
>
> The top part of the piston has a larger diameter than the bottom part.

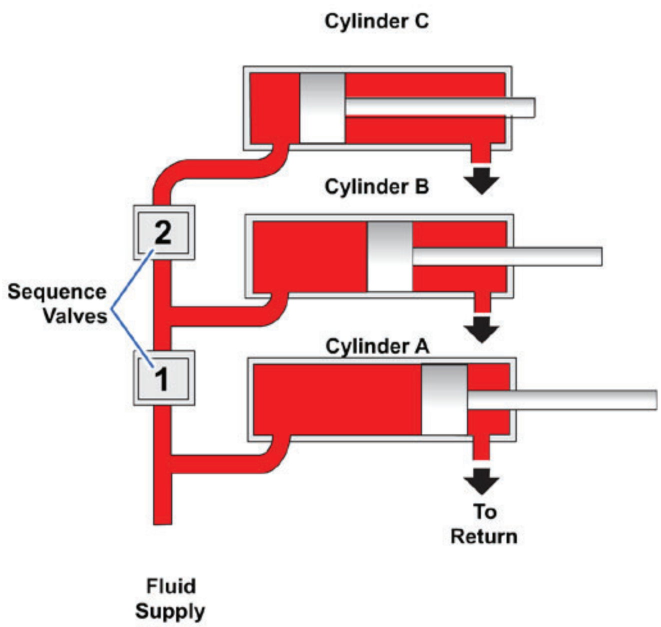


Figure 6-15 — Installation of sequence valves.

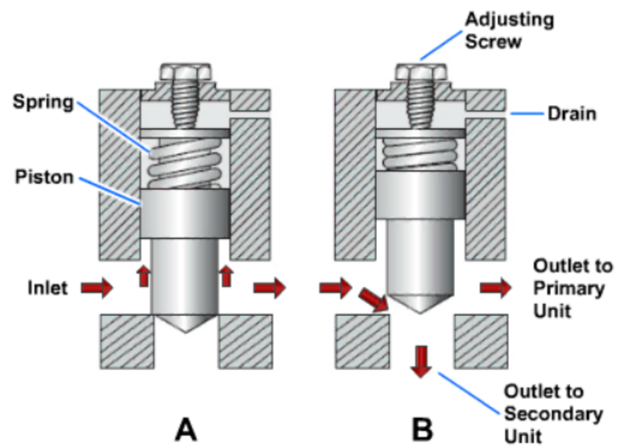


Figure 6-16 — Operation of a pressure-controlled sequence valve.

Fluid enters the valve through the inlet port, flows around the lower part of the piston and exits the outlet port, where it flows to the primary (first) unit to be operated (*Figure 6-16, view A*). This fluid pressure also acts against the lower surface of the piston.

When the primary actuating unit completes its operation, pressure in the line to the actuating unit increases sufficiently to overcome the force of the spring, and the piston rises. The valve is then in the open position (*Figure 6-16, view B*). The fluid entering the valve takes the path of least resistance and flows to the secondary unit.

A drain passage is provided to allow any fluid leaking past the piston to flow from the top of the valve. In hydraulic systems, this drain line is usually connected to the main return line.

Mechanically Operated Sequence Valves

The mechanically operated sequence valve (*Figure 6-17*) is operated by a plunger that extends through the body of the valve. The valve is mounted so that the plunger will be operated by the primary unit.

A check valve, either a ball or a poppet, is installed between the fluid ports in the body. It can be unseated by either the plunger or fluid pressure.

Port A (*Figure 6-17*) and the actuator of the primary unit are connected by a common line. Port B is connected by a line to the actuator of the secondary unit. When fluid under pressure flows to the primary unit, it also flows into the sequence valve through port A to the seated check valve in the sequence valve. In order to operate the secondary unit, the fluid must flow through the sequence valve. The valve is located so that the primary unit depresses the plunger as it completes its operation. The plunger unseats the check valve and allows the fluid to flow through the valve, out port B, and to the secondary unit.

This type of sequence valve permits flow in the opposite direction. Fluid enters port B and flows to the check valve. Although this is return flow from the actuating unit, the fluid overcomes spring tension, unseats the check valve, and flows out through port A.

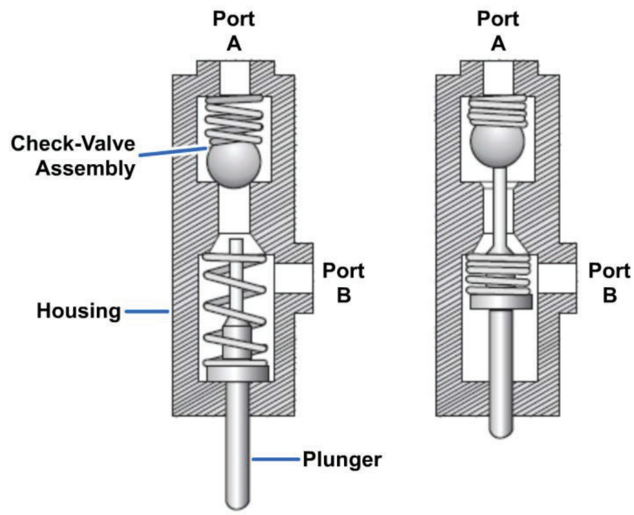


Figure 6-17 — Mechanically operated sequence valve.

PRESSURE-REDUCING VALVES

Pressure-reducing valves provide a steady pressure into a system that operates at a lower pressure than the supply system. A reducing valve can normally be set for any desired downstream pressure within the design limits of the valve. Once the valve is set, the reduced pressure will be maintained regardless of changes in supply pressure (as long as the supply pressure is at least as high as the reduced pressure desired) and regardless of the system load, providing the load does not exceed the design capacity of the reducer.

There are various designs and types of pressure-reducing valves. The spring-loaded reducer and the pilot-controlled valve are discussed in this text.

Spring-Loaded Reducing Valves

The spring-loaded pressure-reducing valve (*Figure 6-18*) is commonly used in pneumatic systems. It is often referred to as a pressure regulator.

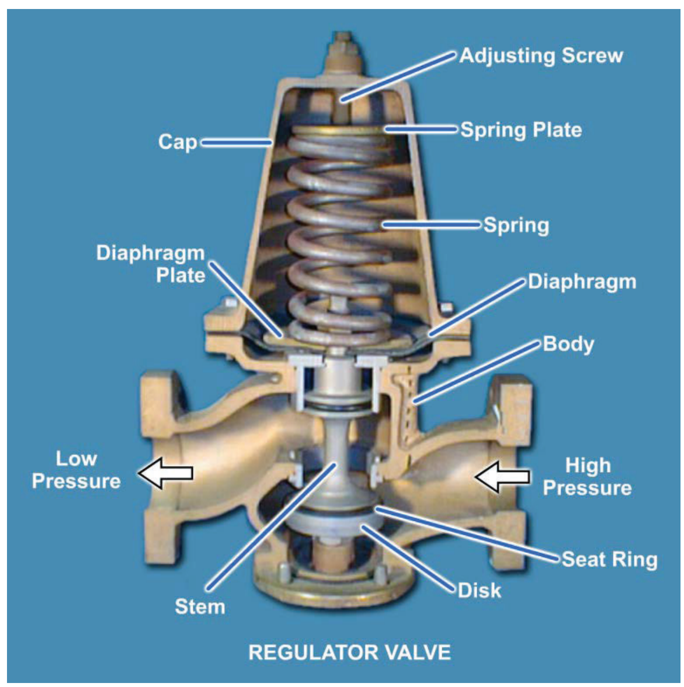


Figure 6-18 — Spring-loaded pressure-reducing valve.

One type of spring-loaded reducing valve is shown in *Figure 6-18*. These valves are used in a wide variety of applications. Low pressure air reducers, auxiliary machinery cooling-water reducing stations, and some reduced-steam system reducers are of this type. The valve simply uses spring pressure against a diaphragm to open the valve. On the bottom of the diaphragm, the outlet pressure (the pressure in the reduced-pressure system) of the valve forces the disk upward to shut the valve. When the outlet pressure drops below the set point of the valve, spring pressure overcomes the outlet pressure and forces the valve stem downward, opening the valve. As outlet pressure increases, approaching the desired value, the pressure under the diaphragm begins to overcome spring pressure. This forces the valve stem upward, shutting the valve. Downstream pressure can be adjusted by removing the valve cap and turning the adjusting screw, which varies the spring pressure against the diaphragm. This particular spring-loaded valve will fail in the open position in the case of a diaphragm rupture.

Internal Pilot-Actuated Pressure-Reducing Valves

The internal pilot-actuated pressure-reducing valve (*Figure 6-19*) uses a pilot valve to control the main valve. The pilot valve controls the flow of upstream fluid, which is ported from the pilot valve, to the operating piston, which operates the main valve. The main valve is opened by the operating piston and closed by the main valve spring. The pilot valve opens when the adjusting spring pushes downward on the pilot diaphragm. It closes when downstream pressure exerts a force that exceeds the force of the adjusting spring. When the pilot valve shuts off or throttles the flow of upstream fluid to the operating piston, the main valve then pushes the valve and stem upward to throttle or close the main valve. When downstream pressure falls below the set point, the adjusting spring force acts downward on the diaphragm. This action overcomes the force of the downstream system pressure, which is acting upward on the diaphragm. This opens the pilot valve, allowing upstream pressure to the top of the operating piston to open the main valve.

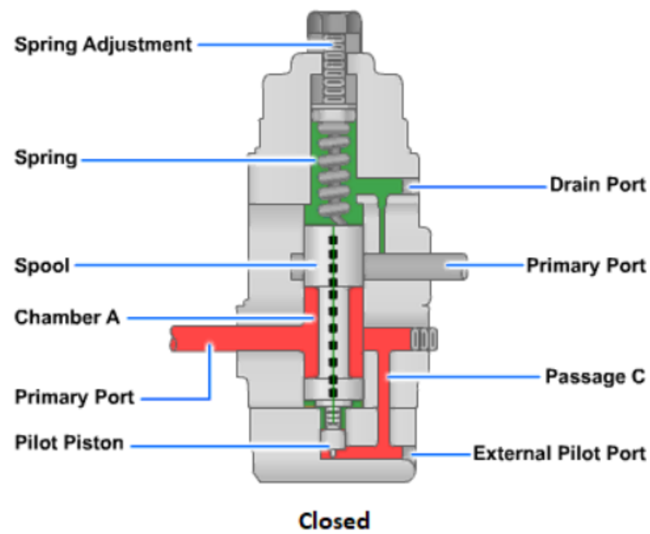


Figure 6-19 — Internal pilot-actuated pressure-reducing valve.

Pneumatic-Pressure-Controlled Reducing Valves

For engines that use compressed air as a power source, starting air comes directly from the ship's medium or high pressure air service line or from starting air flasks, which are included in some systems for the purpose of storing starting air. From either source, the air, on its way to the engine, must pass through a pressure reducing valve, which reduces the higher pressure to the operating pressure required to start a particular engine.

One type of pressure-reducing valve is the regulator (*Figure 6-20*), in which compressed air, sealed in a dome, furnishes the regulating pressure that actuates the valve. The compressed air in the dome performs the same function as a spring used in a more common type of regulating valve. The dome is tightly secured to the valve body, which is separated into an upper (low pressure outlet) and a lower (high pressure inlet) chamber by the main valve. At the top of the valve stem is another chamber, which contains a rubber diaphragm and a metal diaphragm plate. This chamber has an opening leading to the low pressure outlet chamber. When the outlet pressure drops below the pressure in the dome, air in the dome forces the diaphragm and the diaphragm plate down on the valve stem. This partially opens the valve and permits high pressure air to pass the valve seat into the low pressure outlet and into the space under the diaphragm. As soon as the pressure under the diaphragm is equal to that in the dome, the diaphragm returns to its normal position, and the valve is forced shut by the high pressure air acting on the valve head.

When the dome-type regulator is used in the air start system for a diesel engine during the starting event, the regulator valve continuously and rapidly adjusts for changes in air pressure by partially opening and partially closing to maintain a safe, constant starting pressure. When the engine starts and there is no longer a demand for air, pressure builds up in a low pressure chamber to equal the pressure in the dome, and the valve closes completely.

Pilot-Controlled Pressure-Reducing Valves

The operation of a pilot-controlled pressure-reducing valve is illustrated in *Figure 6-21*. This valve consists of an adjustable pilot valve, which controls the operating pressure of the valve, and a spool valve, which reacts to the action of the pilot valve.

The pilot valve consists of a poppet (1), a spring (2), and an adjusting screw (3). The valve spool assembly consists of a valve spool (10) and a spring (4).

Fluid under main pressure enters the inlet port (11) and under all conditions is free to flow through the valve and the outlet port (5). (Either port (5) or port (11) may be used as the high pressure port.)

The valve in the open position is shown in *Figure 6-21, view A*. In the open position, the pressure in the reduced-pressure outlet port (6) has not reached the preset operating pressure of the valve. The fluid also flows through passage (8), through smaller passage (9) in the center of the valve spool, and into chamber (12). The fluid pressure at outlet port (6) is therefore distributed to both ends of the spool. When these pressures are equal the spool is hydraulically balanced. Spring (4) is a low-tension spring and applies only a slight downward force on the spool. Its main purpose is to position the spool and to maintain opening (7) at its maximum size.

As the pressure increases in outlet port (6) (*Figure 6-21, view B*), this pressure is transmitted through passages (8) and (9) to chamber (12). This pressure also acts on

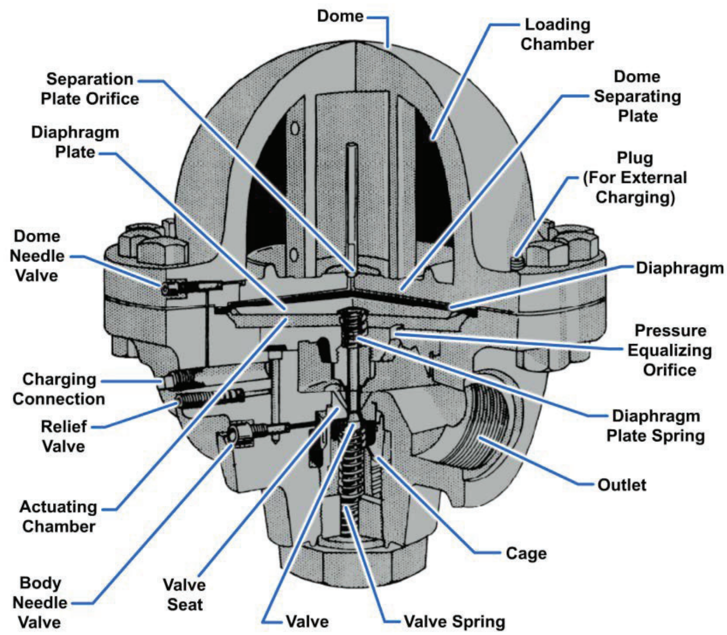


Figure 6-20 — Pressure-reducing (regulator) valve.

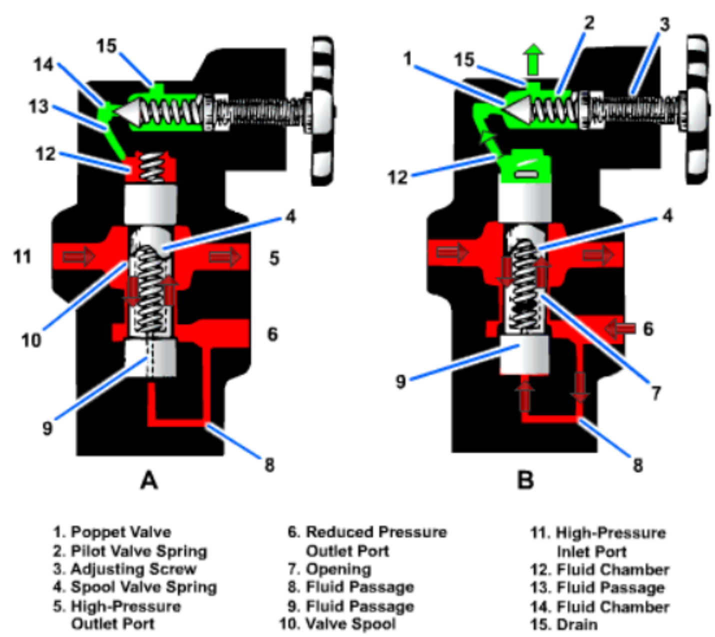


Figure 6-21 — Pilot-controlled pressure-reducing valve.

the pilot valve poppet (1). When this pressure increases above the preset operating pressure of the valve, it overcomes the force of pilot valve spring (2) and unseats the poppet. This allows fluid to flow through the drain port (15). Because the small passage (9) restricts flow into chamber (12), the fluid pressure in the chamber drops. This causes a momentary difference in pressure across the valve spool (10), which allows fluid pressure acting against the bottom area of the valve spool to overcome the downward force of spring (4). The spool is then forced upward until the pressures across its ends are equalized. As the spool moves upward, it restricts the flow through opening (7) and causes the pressure to decrease in the reduced pressure outlet port (6). If the pressure in the outlet port continues to increase to a value above the preset pressure, the pilot valve will open again and the cycle will repeat. This allows the spool valve to move up higher into chamber (12); thus further reducing the size of opening (7). These cycles repeat until the desired pressure is maintained in outlet (6).

When the pressure in outlet (6) decreases to a value below the preset pressure, spring (4) forces the spool downward, allowing more fluid to flow through opening 7.

Air-Pilot-Operated Diaphragm Control Valves

These valves are used extensively on naval ships. The valves and their control pilots are available in several designs to meet different requirements. They may be used as unloading valves to reduce pressure or to provide continuous regulation of pressure and temperature. They may also be used for the control of liquid levels.

The air-operated control pilot may be either direct acting or reverse acting. A direct-acting pilot is shown in *Figure 6-22*. In this type of pilot, the controlled pressure—that is, the pressure from the discharge side of the diaphragm control valve—acts on top of a diaphragm in the control pilot. This pressure is balanced by the pressure exerted by the pilot adjusting spring. When the controlled pressure increases and overcomes the pressure exerted by the pilot adjusting spring, the pilot valve stem is forced downward. This action opens the pilot valve to increase the amount of operating air pressure going from the pilot to the diaphragm control valve. A reverse acting pilot has a lever that reverses the pilot action. In a reverse-acting pilot, an increase in controlled pressure produces a decrease in operating air pressure.

In the diaphragm control valve, operating air from the pilot acts on a diaphragm contained in the superstructure of the valve operator or positioner (*Figure 6-23*). It is direct-acting in some valves and reverse-acting in others. If the valve operator is direct-acting, the operating air pressure from the control pilot is applied to the TOP of the valve diaphragm. When the valve operator is reverse-acting, the operating air pressure from the pilot is applied to the UNDERSIDE of the valve diaphragm.

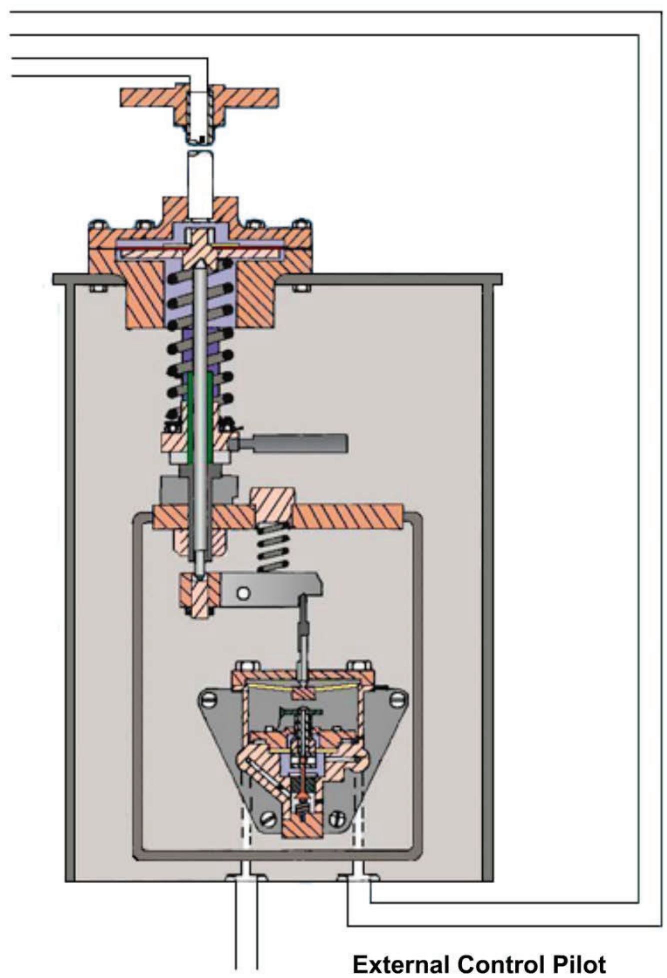


Figure 6-22 — Air-operated control pilot.

A very simple type of direct-acting diaphragm control valve is shown in *Figure 6-23*, *frames 1 and 2*. The operating air pressure from the control pilot is applied to the top of the valve diaphragm. The valve in *Figure 6-23*, *frame 1* is a downward-seating valve. Any increase in operating air pressure pushes the valve stem downward. This tends to close the valve.

Now look at *Figure 6-23, frame 2*; this is also a direct-acting valve. The operating air pressure from the control pilot is applied to the top of the valve diaphragm. The valve in *Figure 6-23, frame 2* is an upward-seating valve rather than a downward-seating valve. Therefore, any increase in operating air pressure from the control pilot tends to OPEN this valve rather than to close it.

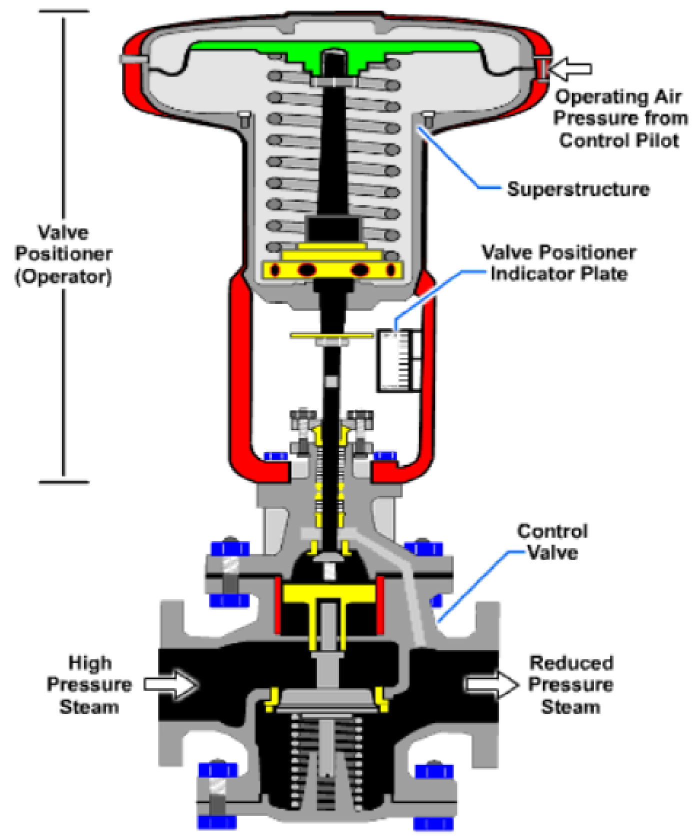


Figure 6-23 — Diaphragm control valves.

As we have seen, the air-operated control pilot and the positioner of the diaphragm control valve may be either direct-acting or reverse-acting. In addition, the diaphragm control valve may be either upward-seating or downward-seating. These factors, as well as the purpose of the installation, determine how the diaphragm control valve and its air-operated control pilot are installed in relation to each other.

To see how these factors are related, let's consider an installation; a diaphragm control valve and its air-operated control pilot are used to supply reduced steam pressure (*Figure 6-24*). We will assume that the service requirements indicate the need for a direct-acting, upward-seating, diaphragm control valve. Can you figure out which kind of a control pilot—direct-acting or reverse-acting— should be used in this installation?

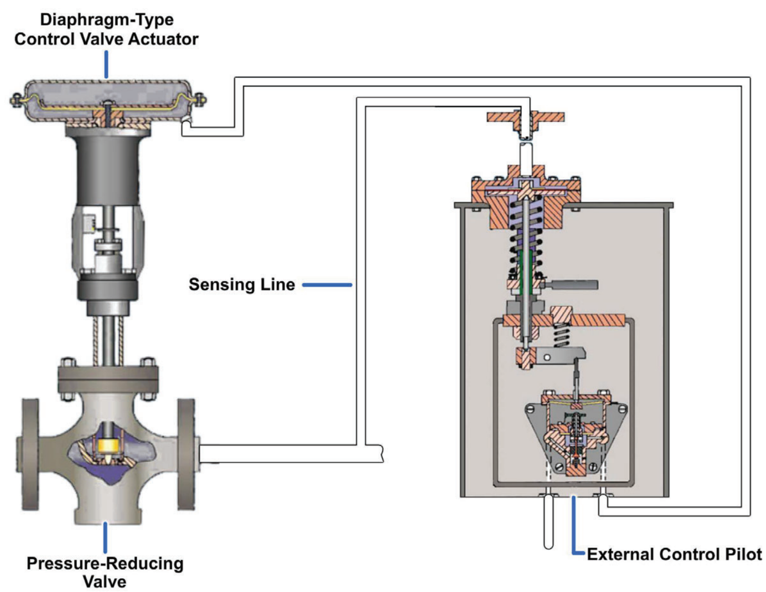


Figure 6-24 — Arrangement of control pilot and diagram control valve for supplying reduced steam pressure.

Let's try it first with a direct-acting control pilot. The controlled pressure (discharge pressure from the diaphragm control valve) increases. When that happens, increased pressure is applied to the diaphragm of the direct-acting control pilot. The valve stem is pushed downward and the valve in the control pilot is opened. This sends an increased amount of operating air pressure from the control pilot to the top of the diaphragm control valve. The increased operating air pressure acting on the diaphragm of the valve pushes the stem downward. Since this is an upward-seating valve, this action OPENS the diaphragm control valve still wider. Obviously, this won't work—for this application, an INCREASE in controlled pressure must result in a DECREASE in operating air pressure. Therefore, we made a mistake in choosing the direct-acting control pilot. For this particular pressure-reducing application, we should choose a REVERSE-ACTING control pilot.

You will probably not need to decide which type of control pilot and diaphragm control valve are needed in any particular installation. But you must know how and why they are selected so that you will not make mistakes in repairing or replacing these units.

REMOTE-OPERATED VALVES

Remote-operating gears provide a means of operating certain valves from distant stations. Remote-operating gears may be mechanical, hydraulic, pneumatic, or electric. A reach rod or series of reach rods and gears may be used to operate engine-room valves in instances where valves are difficult to reach. Two types of remote-operated valves are illustrated in *Figure 6-25*.

Mechanical Remote Operator

Electrical Remotely Controlled Valve

Figure 6-25 — Remote-operated valves.

Other remote-operating gear is installed as emergency equipment. Some split-plant valves, main drainage system valves, and overboard valves are equipped with remote-operating gears. These valves can be operated normally or, in an emergency, they may be operated from remote stations. Remote-operating gears also include a valve position indicator to show whether the valve is open or closed.

COUNTERBALANCE VALVES

The counterbalance valve is normally located in the line between a directional control valve and the outlet of a vertically mounted actuating cylinder which supports weight or must be held in position for a period of time. This valve serves as a hydraulic resistance to the actuating cylinder. For example, counterbalance valves are used in some hydraulically operated forklifts. The valve offers a resistance to the flow from the actuating cylinder when the fork is lowered. It also helps to support the fork in the UP position.

Counterbalance valves are also used in airlaunched weapons loaders. In this case the valve is located in the top of the lift cylinder. The valve requires a specific pressure to lower the load. If adequate pressure is not available, the load cannot be lowered. This prevents collapse of the load due to any malfunction of the hydraulic system.

One type of counterbalance valve is illustrated in *Figure 6-26*. The valve element is a balanced spool (4). The spool consists of two pistons permanently fixed on either end of a shaft. The inner surface areas of the pistons are equal; therefore, pressure acts equally on both areas regardless of the position of the valve and has no effect on the movement of the valve—hence, the term *balanced.* The shaft area between the two pistons provides the area for the fluid to flow when the valve is open. A small piston (9) is attached to the bottom of the spool valve.

When the valve is in the closed position, the top piston of the spool valve blocks the discharge port (8). With the valve in this position, fluid flowing from the actuating unit enters the inlet port (5). The fluid cannot flow through the valve because discharge port (8) is blocked. However, fluid will flow through the pilot passage (6) to the small pilot piston. As the pressure increases, it acts on the pilot piston until it overcomes the preset pressure of spring (3). This forces the valve spool (4) up and allows the fluid to flow around the shaft of the valve spool and out discharge port (8). *Figure 6-26* shows the valve in this position. During reverse flow, the fluid enters port (8). The spring (3) forces valve spool (4) to the closed position. The fluid pressure overcomes the spring tension of the check valve (7). The check valve opens and allows free flow around the shaft of the valve spool and out through port (5).

The operating pressure of the valve can be adjusted by turning the adjustment screw (1), which increases or decreases the tension of the spring. This adjustment depends on the weight that the valve must support.

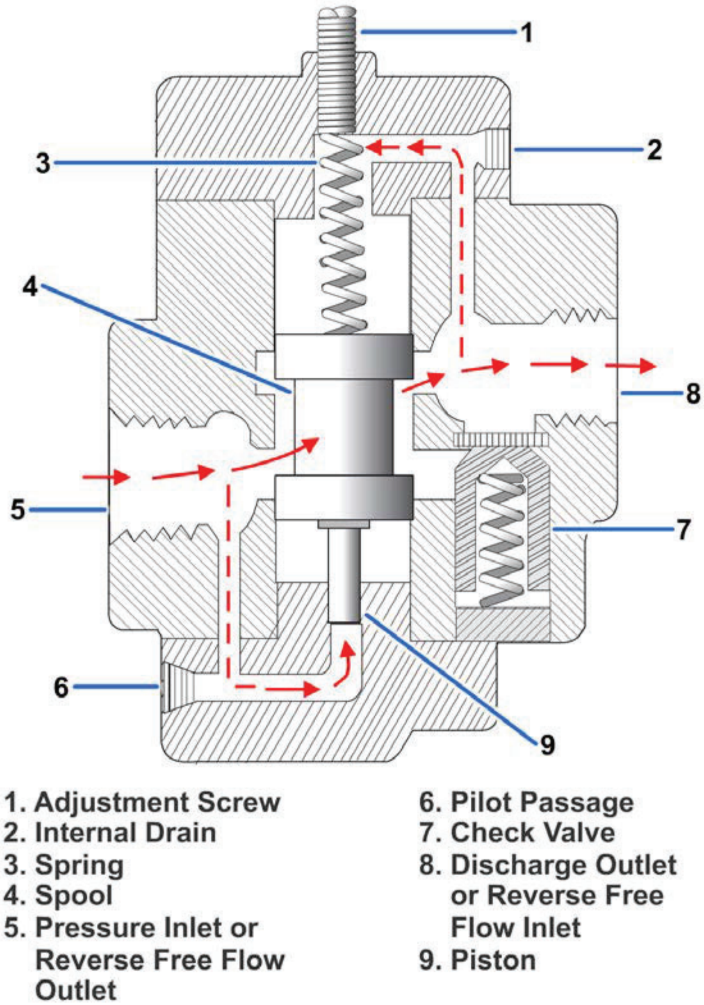


Figure 6-26 — Counterbalance valve.

It is normal for a small amount of fluid to leak around the top piston of the spool valve and into the area around the spring. An accumulation would cause additional pressure on top of the spool valve. This would require additional pressure to open the valve. The drain (2) provides a passage for this fluid to flow to port (8).

DIRECTIONAL CONTROL VALVES

Directional control valves are designed to direct the flow of fluid, at the desired time, to the point in a fluid power system where it will do work. The driving of a ram back and forth in its cylinder is an example of when a directional control valve is used. Various other terms are used to identify directional valves, such as selector valve, transfer valve, and control valve. This manual will use the term directional control valve to identify these valves.

Directional control valves for hydraulic and pneumatic systems are similar in design and operation. However, there is one major difference. The return port of a hydraulic valve is ported through a return line to the reservoir, while the similar port of a pneumatic valve, commonly referred to as the exhaust port, is usually vented to the atmosphere. Any other differences are pointed out in the discussion of the valves.

Directional control valves may be operated by differences in pressure acting on opposite sides of the valving element, or they may be positioned manually, mechanically, or electrically. Often two or more methods of operating the same valve will be used in different phases of its action.

Directional control valves may be classified in several ways. Some of the different ways are by the type of control, the number of ports in the valve housing, and the specific function of the valve. The most common method is by the type of valving element used in the construction of the valve. The most common types of valving elements are the ball, cone or sleeve, poppet, rotary spool, and sliding spool. The basic operating principles of the poppet, rotary spool, and sliding spool valving elements are discussed in this text.

Poppet

The poppet fits into the center bore of the seat (*Figure 6-27*). The seating surfaces of the poppet and the seat are lapped or closely machined so that the center bore will be sealed when the poppet is seated (shut). The action of the poppet is similar to that of the valves in an automobile engine. In most valves the poppet is held in the seated position by a spring.

The valve consists primarily of a movable poppet that closes against the valve seat. In the closed position, fluid pressure on the inlet side tends to hold the valve tightly closed. A small amount of movement from a force applied to the top of the poppet stem opens the poppet and allows fluid to flow through the valve.

The use of the poppet as a valving element is not limited to directional control valves.

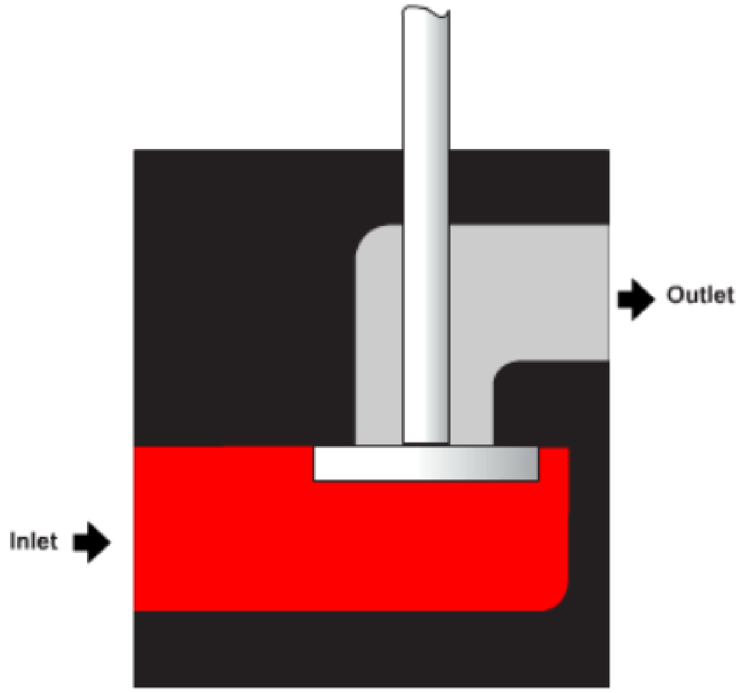


Figure 6-27 — Operation of a simple poppet valve.

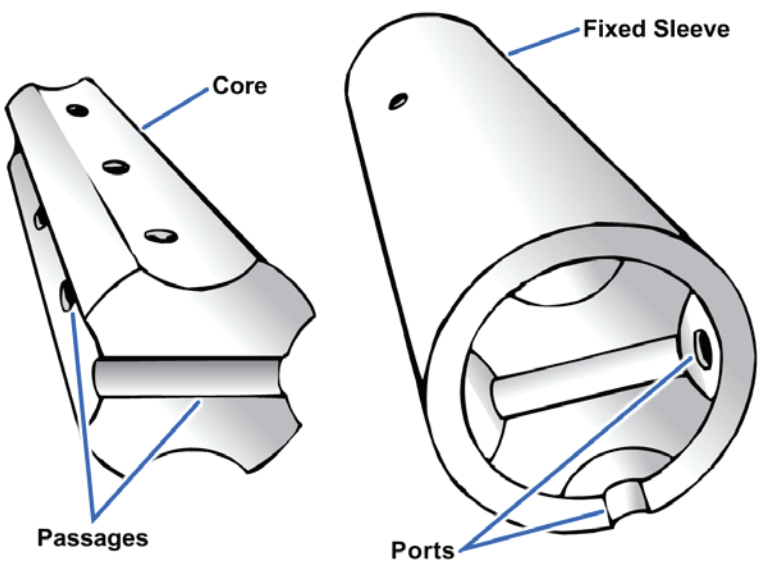


Figure 6-28 — Parts of a rotary spool directional control valve.

Rotary Spool Valve

The rotary spool directional control valve (*Figure 6-28*) has a round core with one or more passages or recesses in it. The core is mounted within a stationary sleeve. As the core is rotated within the stationary sleeve, the passages or recesses connect or block the ports in the sleeve. The ports in the sleeve are connected to the appropriate lines of the fluid system.

Sliding Spool Valve

The operation of a simple sliding spool directional control valve is shown in *Figure 6-29*. The valve is so-named because of the shape of the valving element that slides back and forth to block and uncover ports in the housing. (The sliding element is also referred to as a piston.) The inner piston areas (lands) are equal. Thus fluid under pressure that enters the valve from the inlet ports acts equally on both inner piston areas regardless of the position of the spool. Sealing is usually accomplished by a very closely machined fit between the spool and the valve body or sleeve. For valves with more ports, the spool is designed with more pistons or lands on a common shaft. The sliding spool is the most commonly used type of valving element in directional control valves.

Check Valve

Check valves are used in fluid systems to permit flow in one direction and to prevent flow in the other direction. They are classified as one-way directional control valves. The check valve may be installed independently in a line to allow flow in one direction only, or it may be used as an integral part of globe, sequence, counterbalance, and pressure-reducing valves.

Check valves are available in various designs. They are opened by the force of fluid in motion flowing in one direction, and are closed by fluid attempting to flow in the opposite direction. The force of gravity or the action of a spring aids in closing the valve.

A ball-stop swing-check valve with planetary gear operation is shown in *Figure 6-30*. Ball valves are normally found in the following systems aboard ship: seawater, sanitary, trim and drain, air, hydraulic, and oil transfer.

The most common type of check valve installed in fluid-power systems uses either a ball or cone for the sealing element. As fluid pressure is applied in the direction of the arrow the ball is forced off its seat, allowing fluid to flow freely through the valve. This valve is known as a spring-loaded check valve (*Figure 6-31*).

The spring is installed in the valve to hold the cone or ball on its seat whenever fluid is not flowing. The spring also helps to force the cone or ball on its seat when the fluid attempts to flow in the opposite direction. Since the opening and closing of this type of valve is not dependent on gravity, its location in a system is not limited to the vertical position.

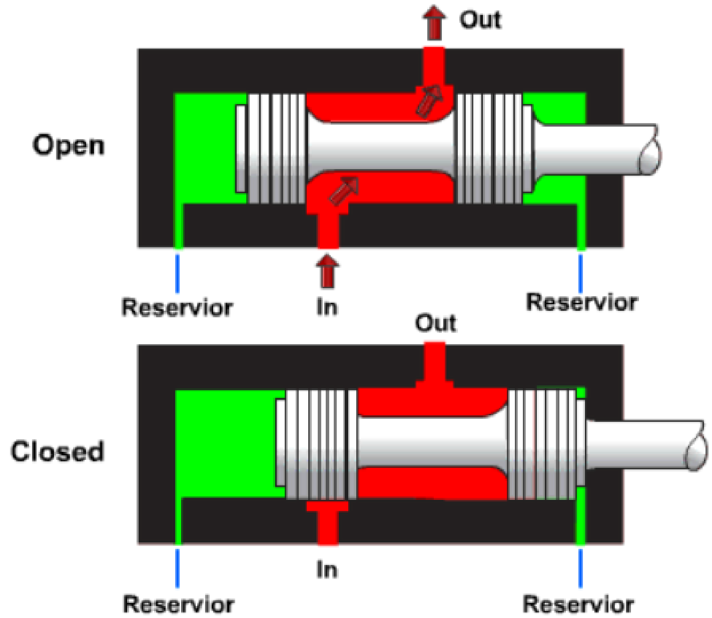


Figure 6-29 — Two-way, sliding spool directional control valve.

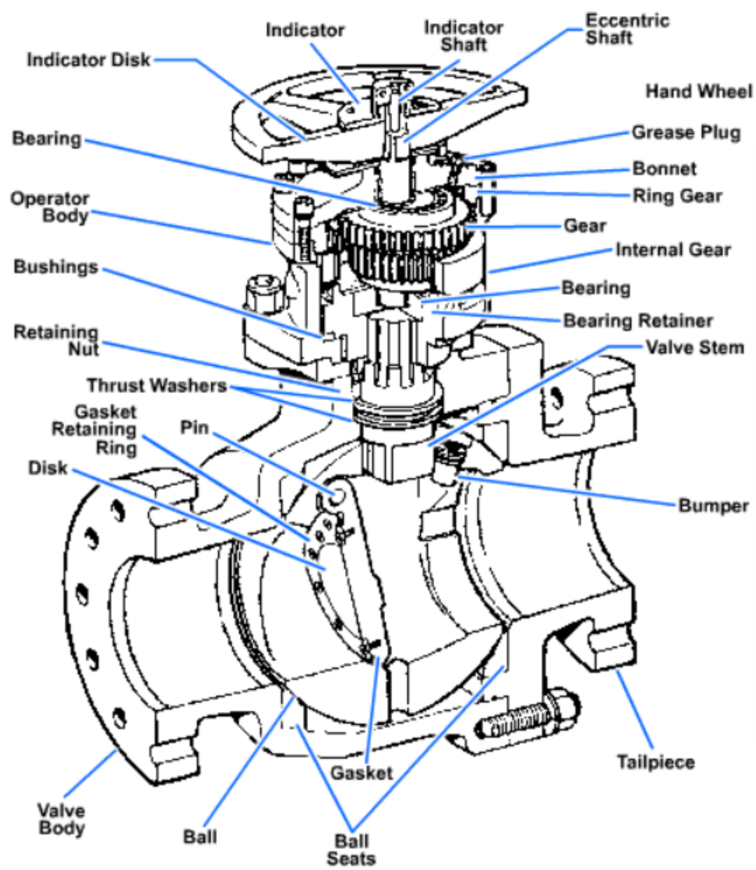


Figure 6-30 — Typical ball-stop swing-check valve for seawater service.

A modification of the spring-loaded check valve is the orifice check valve (*Figure 6-32*). This valve allows normal flow in one direction and restricted flow in the other. It is often referred to as a one-way restrictor.

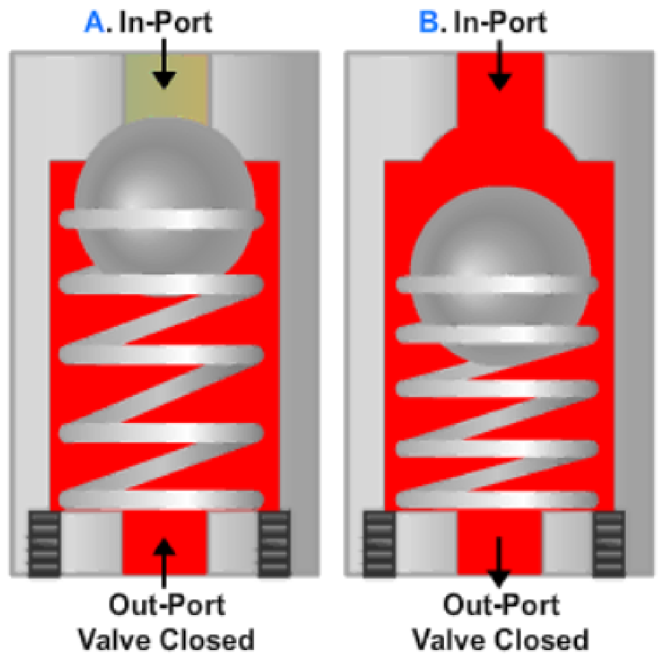


Figure 6-31 — Spring-loaded check valves.

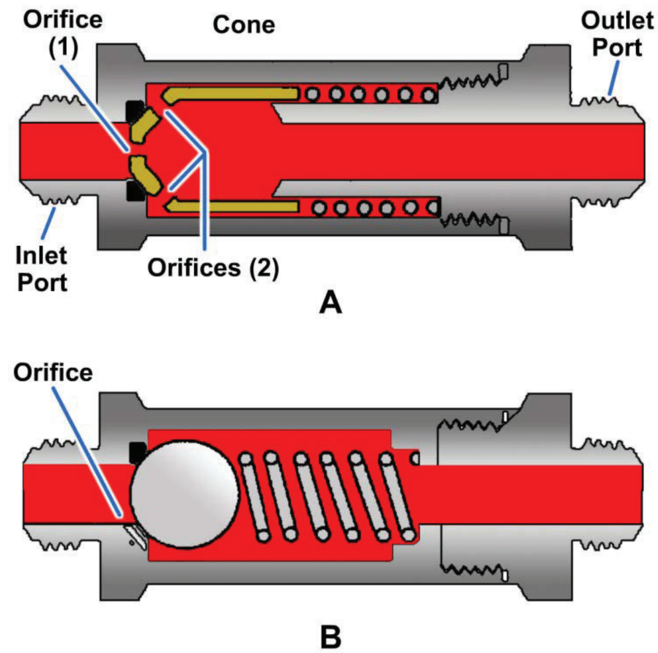


Figure 6-32 — Typical orifice check valves.

A cone-type orifice check valve is shown in *Figure 6-32, view A*. When sufficient fluid pressure is applied at the inlet port, it overcomes spring tension and moves the cone off of its seat. The two orifices in the illustration represent several openings located around the slanted circumference of the cone. These orifices allow free flow of fluid through the valve while the cone is off of its seat. When fluid pressure is applied through the outlet port, the force of the fluid and spring tension move the cone to the left and onto its seat. This action blocks the flow of fluid through the valve, except through the orifice in the center of the cone. The size of the orifice (in the center of the cone) determines the rate of flow through the valve as the fluid flows from right to left.

A ball-type orifice check valve is shown in *Figure 6-32, view B*. Fluid flow through the valve from left to right forces the ball off of its seat and allows normal flow. Fluid flow through the valve in the opposite direction forces the ball onto its seat. Thus, the flow is restricted by the size of the orifice located in the housing of the valve.

NOTE

The direction of free flow through the orifice check valve is indicated by an arrow stamped on the housing.

Shuttle Valve

In certain fluid power systems, the supply of fluid to a subsystem must be from more than one source to meet system requirements. In some systems an emergency system is provided as a source of pressure in the event of normal system failure. The emergency system will usually actuate only essential components.

The main purpose of the shuttle valve is to isolate the normal system from an alternate or emergency system. It is small and simple; yet, it is a very important component.

A cutaway view of a typical shuttle valve is shown in *Figure 6-33*. The housing contains three ports—normal system inlet, alternate or emergency system inlet port, and outlet port fitting. A shuttle valve used to operate more than one actuating unit may contain additional unit outlet ports. Enclosed in the housing is a sliding part called the shuttle. Its purpose is to seal off either one or the other inlet ports. There is a shuttle seat at each inlet port.

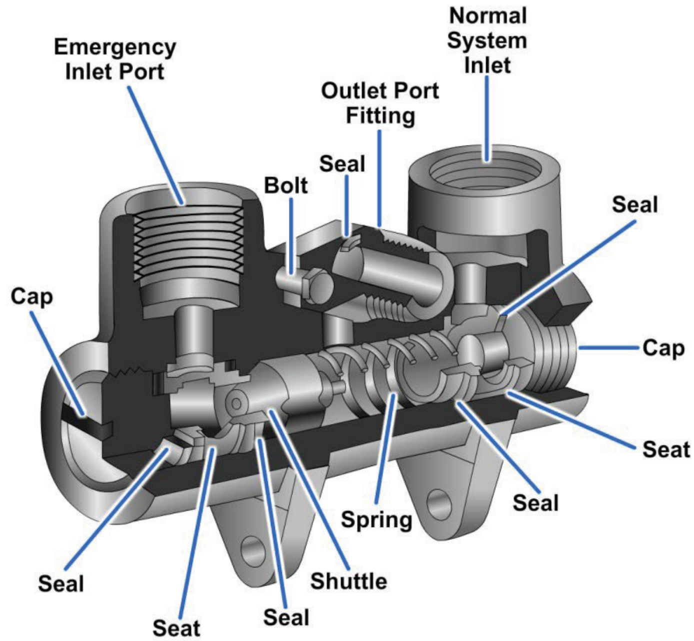


Figure 6-33 — Shuttle valve.

When a shuttle valve is in the normal operation position, fluid has a free flow from the normal system inlet port, through the valve, and out through the outlet port to the actuating unit. The shuttle is seated against the alternate system inlet port and held there by normal system pressure and by the shuttle valve spring. The shuttle remains in this position until the alternate system is activated. This action directs fluid under pressure from the alternate system to the shuttle valve and forces the shuttle from the alternate system inlet port to the normal system inlet port. Fluid from the alternate system then has a free flow to the outlet port, but is prevented from entering the normal system by the shuttle, which seals off the normal system port.

The shuttle may be one of four types: (1) sliding plunger, (2) spring-loaded piston, (3) spring-loaded ball, or (4) spring-loaded poppet. In shuttle valves that are designed with a spring, the shuttle is normally held against the alternate system inlet port by the spring.

Two-Way Valves

The term two-way indicates that the valve contains and controls two functional flow control ports—an inlet and an outlet. A two-way, sliding spool directional control valve is shown in *Figure 6-29*. As the spool is moved back and forth, it either allows fluid to flow through the valve or prevents flow. In the open position, the fluid enters the inlet port, flows around the shaft of the spool, and through the outlet port. The spool cannot move back and forth by difference of forces set up within the cylinder, since the forces there are equal. As indicated by the arrows against the pistons of the spool, the same pressure acts on equal areas on their inside surfaces. In the closed position, one of the pistons of the spool simply blocks the inlet port, thus preventing flow through the valve.

A number of features common to most sliding spool valves are shown in *Figure 6-29*. The small ports at either end of the valve housing provide a path for any fluid that leaks past the spool to flow to the reservoir. This prevents pressure from building up against the ends of the pistons, which would hinder the movement of the spool. When spool valves become worn, they may lose balance because of greater leakage on one side of the spool than on the other. In that event, the spool would tend to stick when it is moved back and forth. Small grooves are therefore machined around the sliding surface of the piston; and in hydraulic valves, leaking liquid will encircle the pistons and keep the contacting surfaces lubricated and centered.

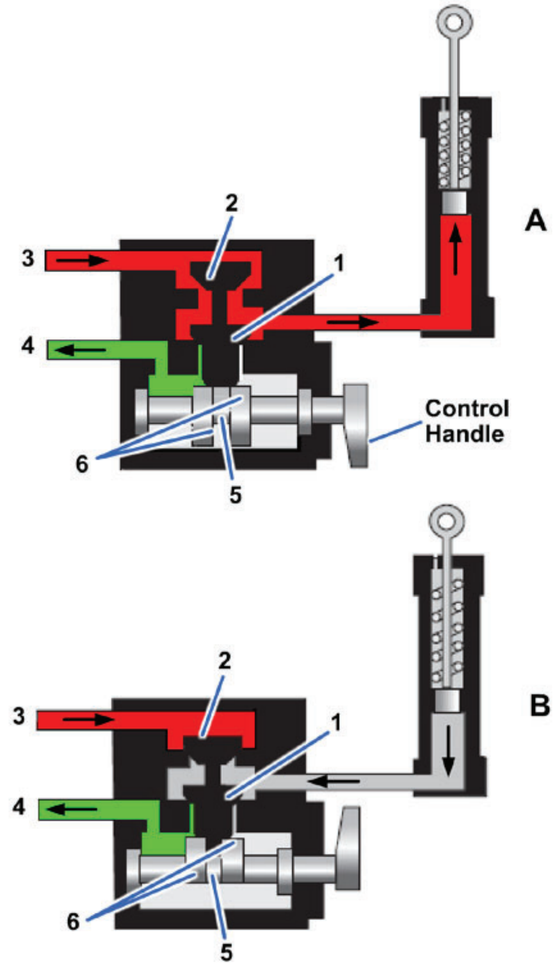
Three-Way Valves

Three-way valves contain a pressure port, a cylinder port, and a return or exhaust port. The three-way directional control valve is designed to operate an actuating unit in one direction; it permits either the load on the actuating unit or a spring to return the unit to its original position.

Cam-Operated Three-Way Valves

The operation of a cam-operated, three-way, poppet-type directional control valve is shown in *Figure 6-34*. *View A* shows fluid under pressure forcing the piston outward against a load. The upper poppet (2) is unseated by the inside cam (5), permitting fluid to flow from the line (3) into the cylinder to actuate the piston. The lower poppet (1) is seated, sealing off the flow into the return line (4). As the force of the pressurized fluid extends the piston rod, it also compresses the spring in the cylinder.

View B shows the valve with the control handle turned to the opposite position. In this position, the upper poppet (2) is seated, blocking the flow of fluid from the pressure line (3). The lower poppet (1) is unseated by the outside cam (6). This releases the pressure in the cylinder and allows the spring to expand, which forces the piston rod to retract. The fluid from the cylinder flows through the control valve and out the return port (4). In hydraulic systems, the return port is connected by a line to the reservoir. In pneumatic systems, the return port is usually open to the atmosphere.



1. Lower (Return or Exhaust) Poppet
2. Upper (Pressure) Poppet
3. Pressure Line
4. Return or Exhaust Port
5. Inside Cam
6. Outside Cam

Figure 6-34 — Three-way, poppet-type directional control.

Pilot-Operated Three-Way Valves

A pilot-operated, poppet-type, three-way directional control valve is shown in *Figure 6-35*. Valves of this design are often used in pneumatic systems. This valve is normally closed and is forced open by fluid pressure entering the pilot chamber. The valve contains two poppets connected to each other by a common stem. The poppets are connected to diaphragms which hold them in a centered position.

The movement of the poppet is controlled by the pressure in the pilot port and the chamber above the upper diaphragm. When the pilot chamber is not pressurized, the lower poppet is seated against the lower valve seat. Fluid can flow from the supply line through the inlet port and through the holes in the lower diaphragm to fill the bottom chamber. This pressure holds the lower poppet tightly against its seat and blocks flow from the inlet port through the valve. At the same time, due to the common stem, the upper poppet is forced off of its seat. Fluid from the actuating unit flows through the open passage, around the stem, and through the exhaust port to the atmosphere.

When the pilot chamber is pressurized, the force acting against the diaphragm forces the poppet down. The upper poppet closes against its seat, blocking the flow of fluid from the cylinder to the exhaust port. The lower poppet opens, and the passage from the supply inlet port to the cylinder port is open so that the fluid can flow to the actuating unit.

The valve in *Figure 6-35* is a normally closed valve. Normally open valves are similar in design. When no pressure is applied to the pilot chamber, the upper poppet is forced off of its seat and the lower poppet is closed. Fluid is free to flow from the inlet port through the cylinder to the actuating unit. When pilot pressure is applied, the poppets are forced downward, closing the upper poppet and opening the lower poppet. Fluid can now flow from the cylinder through the valve and out the exhaust port to the atmosphere.

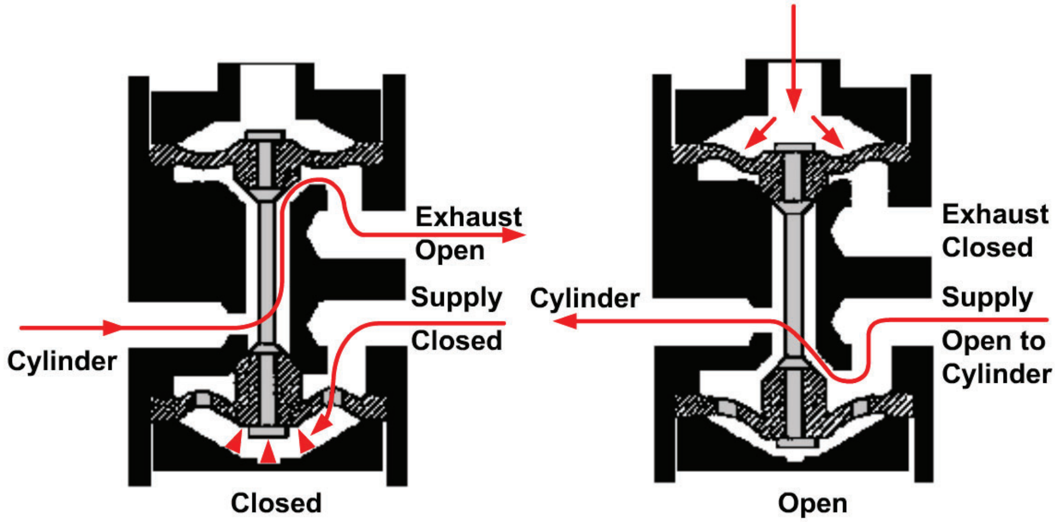


Figure 6-35 — Three-way, poppet-type, normally closed directional control valve.

Four-Way Valves

Most actuating devices require system pressure for operation in either direction. The four-way directional control valve, which contains four ports, is used to control the operation of such devices. The four-way valve is also used in some systems to control the operation of other valves. It is one of the most widely used directional control valves in fluid power systems.

The typical four-way directional control valve has four ports: a pressure port, a return or exhaust port, and two cylinder or working ports. The pressure port is connected to the main system pressure line and the return line is connected to the reservoir in hydraulic systems. In pneumatic systems the return port is usually vented to the atmosphere. The two cylinder ports are connected by lines to the actuating units.

Poppet-Type Four-Way Valves

Figure 6-36 shows a typical four-way, poppet-type directional control valve. This is a manually operated valve and consists of a group of conventional spring-loaded poppets. The poppets are enclosed in a common housing and are interconnected by ducts to direct the flow of fluid in the desired direction.

The poppets are actuated by cams on a camshaft (*Figure 6-36*). The camshaft is controlled by the movement of the handle. The valve may be operated by manually moving the handle, or, in some cases, the handle may be connected by mechanical linkage to a control handle, which is located in a convenient place for the operator some distance from the valve.

The camshaft may be rotated to any one of three positions (neutral and two working positions). In the neutral position the camshaft lobes are not contacting any of the poppets. This assures that the poppet springs will hold all four poppets firmly seated. With all poppets seated, there is no fluid flow through the valve. This also blocks the two cylinder ports, so when the valve is in neutral, the fluid in the actuating unit is trapped. Relief valves are installed in both working lines to prevent overpressurization caused by thermal expansion.

> **NOTE**
>
> In some versions of this type of valve, the cam lobes are designed so that the two return/exhaust poppets are open when the valve is in the neutral position. This compensates for thermal expansion, because both working lines are open to the return/exhaust when the valve is in the neutral position.

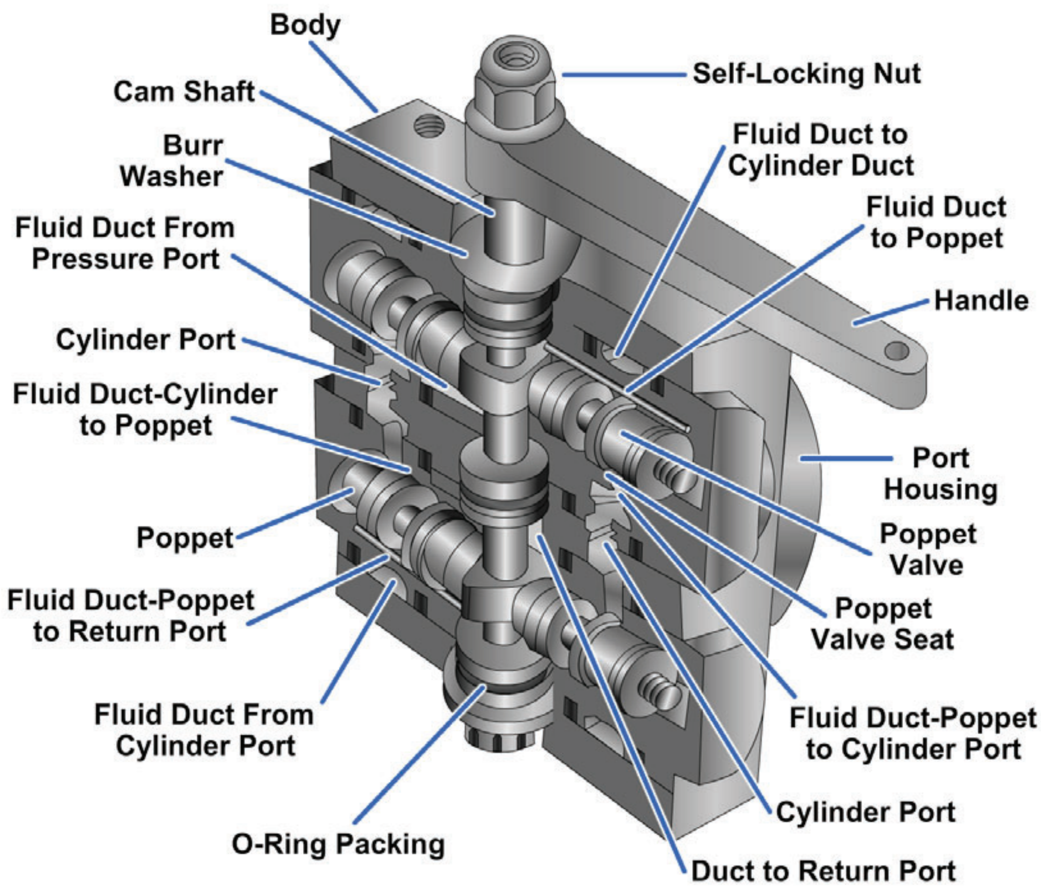


Figure 6-36 — Cutaway view of poppet-type, four-way directional control valve.

The poppets are arranged so that rotation of the camshaft will open the proper combination of poppets to direct the flow of fluid through the desired working line to an actuating unit. At the same time, fluid will be directed from the actuating unit through the opposite working line, through the valve, and back to the reservoir (hydraulic systems) or exhausted to the atmosphere (pneumatic systems).

To stop rotation of the camshaft at an exact position, a stop pin is secured to the body and extends through a cutout section of the camshaft flange. This stop pin prevents overtravel by ensuring that the camshaft stops rotating at the point where the cam lobes have moved the poppets the greatest distance from their seats and where any further rotation would allow the poppets to start returning to their seats.

O-rings are spaced at intervals along the length of the shaft to prevent external leakage around the ends of the shaft and internal leakage from one of the valve chambers to another. The camshaft has two lobes, or raised portions. The shape of these lobes is such that when the shaft is placed in the neutral position the lobes will not contact any of the poppets.

When the handle is moved in either direction from neutral, the camshaft is rotated. This rotates the lobes, which unseat one pressure poppet and one return/exhaust poppet (*Figure 6-37*). The valve is now in the working position. Fluid under pressure, entering the pressure port, flows through the vertical fluid passages in both pressure poppets seats. Since only one pressure poppet, IN (2), is unseated by the cam lobe, the fluid flows past the open poppet to the inside of the poppet seat. From there it flows through the diagonal passages, out one cylinder port, C2, and to the actuating unit.

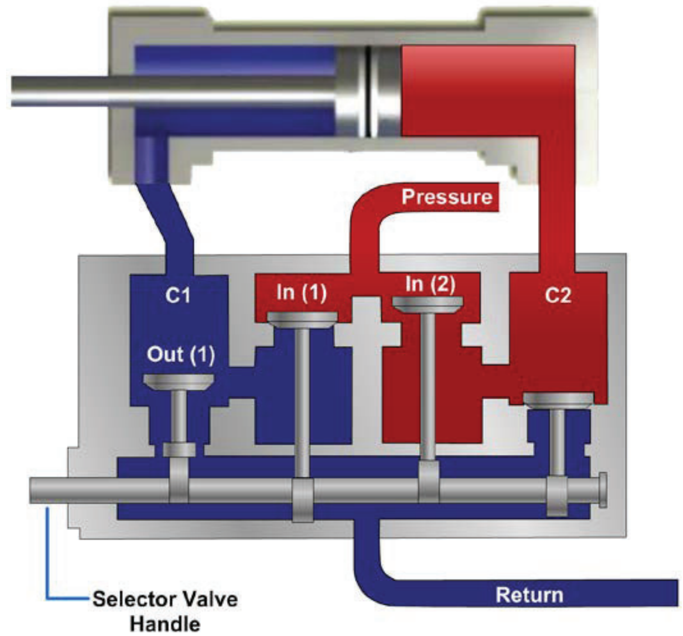


Figure 6-37 — Working view of a poppet-type, four-way directional control valve.

Return fluid from the actuating unit enters the other cylinder port, C1. It then flows through the corresponding fluid passage, past the unseated return poppet, OUT (1), through the vertical fluid passages, and out the return/exhaust port. When the camshaft is rotated in the opposite direction to the neutral position, the two poppets seat and the flow stops. When the camshaft is further rotated in this direction until the stop pins hits, the opposite pressure and return poppets are unseated. This reverses the flow in the working lines, causing the actuating unit to move in the opposite direction.

Rotary Spool Valve

Four-way directional control valves of this type are frequently used as pilot valves to direct flow to and from other valves (*Figure 6-38*). Fluid is directed from one source of supply through the rotary valve to another directional control valve, where it positions the valve to direct flow from another source to one side of an actuating unit. Fluid from the other end of the main valve flows through a return line, through the rotary valve, to the return or exhaust port.

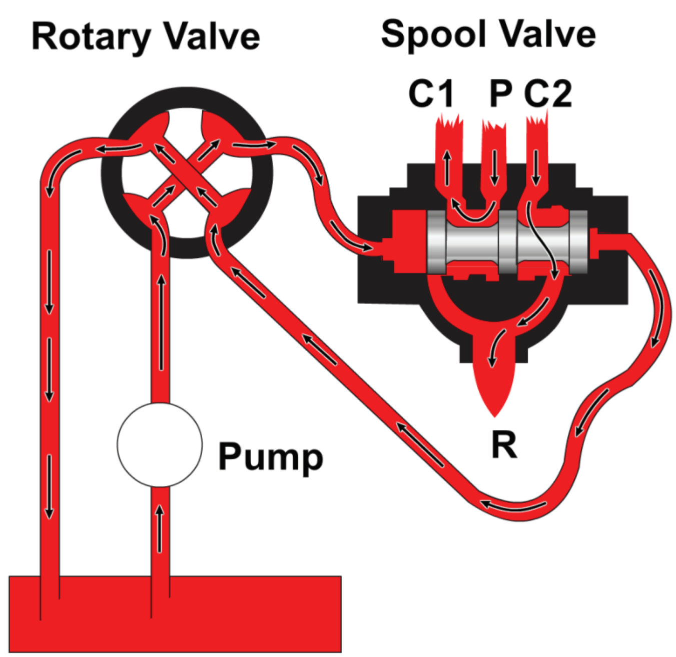


Figure 6-38 — Sliding spool valve controlled by a rotary spool valve.

The principal parts of a rotary spool directional control valve are shown in *Figure 6-39*. *Figure 6-39* shows the operation of a rotary spool valve. *Views A and C* show the valve in a position to deliver fluid to another valve, while *view B* shows the valve in the neutral position, with all passages through the valve blocked. Rotary spool valves can be operated manually, electrically, or by fluid pressure.

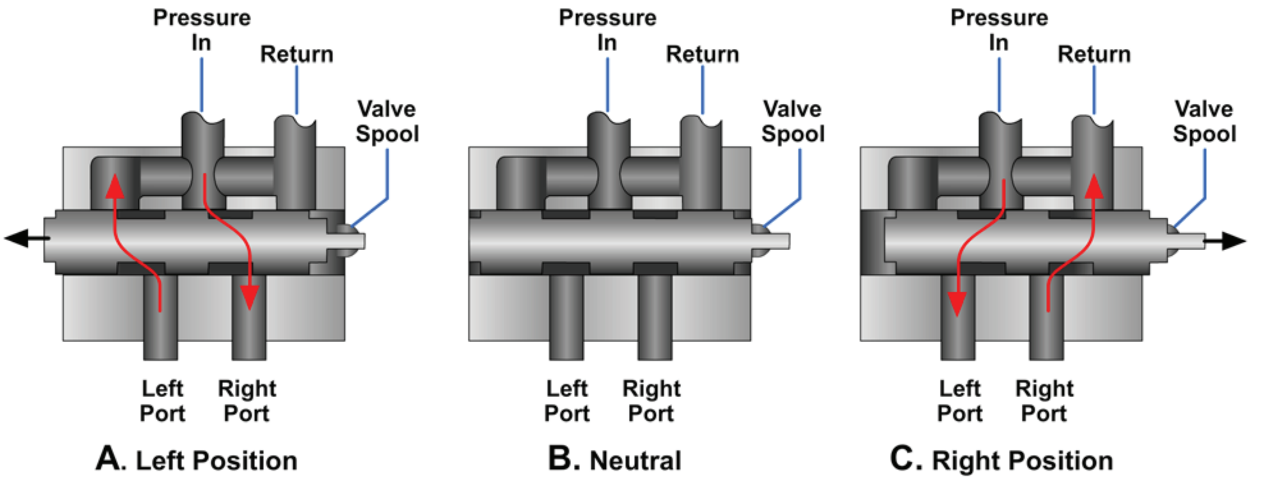


Figure 6-39 — Operation of a rotary spool, four-way directional control valve.

Sliding Spool Valve

The sliding spool four-way directional control valve is similar in operation to the two-way valve previously described in this chapter. It is simple in its principle of operation and is the most durable and trouble-free of all four-way directional control valves.

The valve described in the following paragraphs is a manually operated type. The same principle is used in many remotely controlled directional control valves.

The valve (*Figure 6-40*) consists of a valve body containing four fluid ports—pressure (P), return/exhaust (R), and two cylinder ports (C1 and C2). A hollow sleeve fits into the main bore of the body. There are O-rings placed at intervals around the outside diameter of the sleeve. These O-rings form a seal between the sleeve and the body, creating chambers around the sleeve. Each of the chambers is lined up with one of the fluid ports in the body. The drilled passage in the body accounts for a fifth chamber, which results in having the two outboard chambers connected to the return/exhaust port. The sleeve has a pattern of holes drilled through it to allow fluid to flow from one port to another. A series of holes are drilled into the hollow center sleeve in each chamber.

The sleeve is prevented from turning by a sleeve retainer bolt or pin that secures it to the valve body.

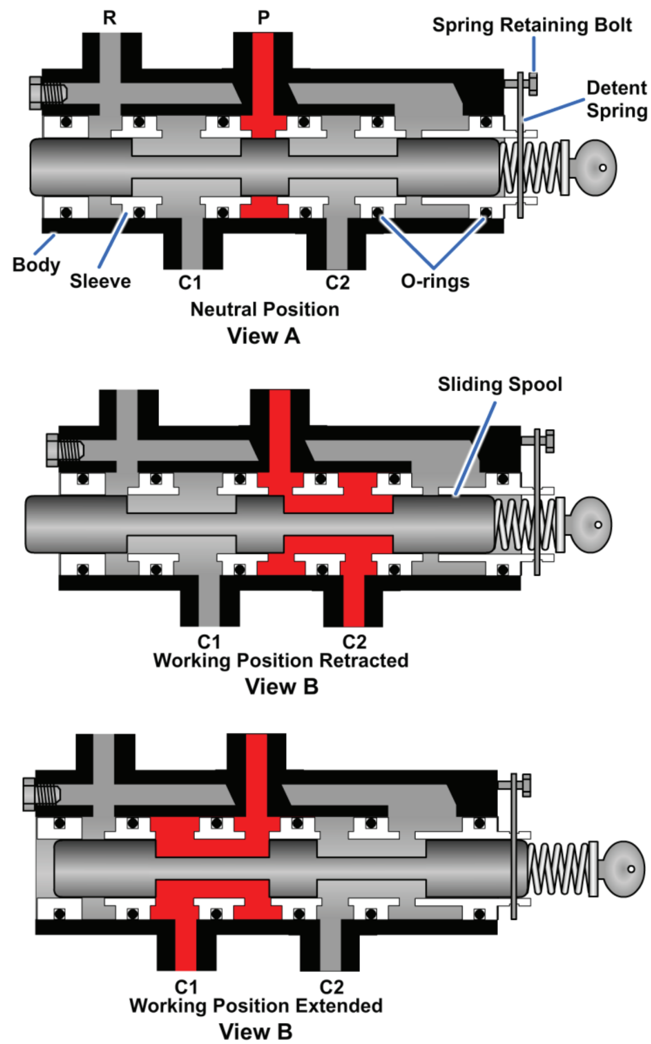


Figure 6-40 — Operation of a sliding spool, four-way directional control valve.

The sliding spool fits into the hollow center sleeve. This spool is similar to the spool in the two-way valve, except that this spool has three pistons or lands. These lands are lapped or machine fitted to the inside of the sleeve.

One end of the sliding spool is connected to a handle either directly or by mechanical linkage to a more desirable location. When the control handle is moved, it will position the spool within the sleeve. The lands of the spool then line up different combinations of fluid ports, thus directing a flow of fluid through the valve.

The detent spring is a clothespin-type spring, secured to the end of the body by a spring retaining bolt. The two legs of the spring extend down through slots in the sleeve and fit into the detents. The spool is gripped between the two legs of the spring. To move the spool, enough force must be applied to spread the two spring legs and allow them to snap back into the next detent, which would be for another position.

Figure 6-40, view A, shows a manually operated sliding spool valve in the neutral position. The detent spring is in the center detent of the sliding spool. The center land is lined up with the pressure port (P) preventing fluid from flowing into the valve through this port. The return/exhaust port is also blocked, preventing flow through that port. With both the pressure and return ports blocked, fluid in the actuating lines is trapped. For this reason, a relief valve is usually installed in each actuating line when this type of valve is used.

Figure 6-40, view B, shows the valve in the working position with the end of the sliding spool retracted. The detent spring is in the outboard detent, locking the sliding spool in this position. The lands have shifted inside the sleeve, and the ports are opened. Fluid under pressure enters the sleeve, passes through it by way of the drilled holes, and leaves through cylinder port C2. Return fluid, flowing from the actuator enters port C1, flows through the sleeve, and is directed out the return port back to the reservoir or exhausted to the atmosphere. Fluid cannot flow past the spool lands because of the lapped surfaces.

Figure 6-40, view C, shows the valve in the opposite working position with the sliding spool extended. The detent spring is in the inboard detent. The center land of the sliding spool is now on the other side of the pressure port, and the fluid under pressure is directed through the sleeve and out port C1. Return fluid flowing in the other cylinder port is directed to the drilled passage in the body. It flows along this passage to the other end of the sleeve where it is directed out of the return/exhaust port.

The directional control valves previously discussed are for use in closed-center fluid power systems. *Figure 6-41* shows the operation of a representative open-center, sliding spool directional control valve.

When this type of valve is in the neutral position, (*Figure 6-41, frame 1*) fluid flows into the valve through the pressure port (P) through the hollow spool, and return to the reservoir.

When the spool is moved to the right of the neutral positio (*Figure 6-41, frame 2*) one working line (C1) is aligned to system pressure and the othe working line (C2) is open through the hollow spool to th return port. *Figure 6-41, frame 3* shows the flow of fluid through the valve with the spool moved to the left of neutral.

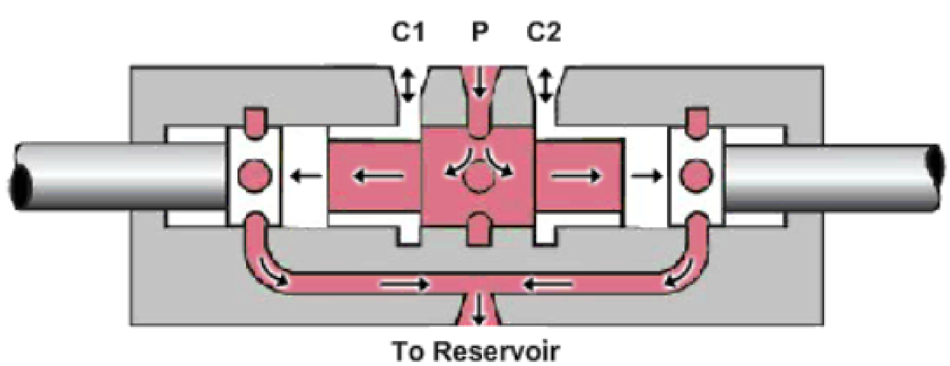


Figure 6-41 — Open-center, sliding spool directional control valve.

CHAPTER 7

SEALING DEVICES AND MATERIALS

Sealing devices and materials prevent leakage, and contain pressure or exclude contamination between components. The two most common classifications of seals are gaskets and packings. There are many commercial types and forms of packing and gasket materials. The Navy has simplified the selection of packing and gasket materials commonly used in service.

This chapter deals primarily with the different types of materials used in the construction of seals. You will also learn about the different shapes and designs of seals and their application as gaskets and/or packings in fluid power systems. Lastly in this chapter are sections concerning the functions of wipers and scrapers in fluid power systems and the selection, storage, and handling of sealing devices.

LEARINING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Recognize the required characteristics of sealing devices used in fluid power systems.
2. Identify the functions of sealing devices used in fluid power systems.
3. Recognize the types and materials of sealing devices used in fluid power systems.
4. Recognize the identification procedures of various types of seals.
5. Describe the characteristics of various types of seals.
6. Describe the inspection of various types of seals.
7. Explain the installation techniques of various types of seals.

DEFINITIONS

Gaskets and Packings

Gaskets (*Figure 7-1*) depend upon mechanical compression to provide a positive seal between two stationary joints, whereas packings generally are used where some form of relative motion occurs between members of the joint. Packing (*Figure 7-2*) consists of deformable material, which is shaped by adjustable compression to provide a controlled seal. Certain types of seals (for example, the O-ring, which is discussed later) may be used either as a gasket or a packing.

The sealing devices and materials used in fluid power systems and components are divided into two general classes—static seals and dynamic seals (*Figure 7-3*).

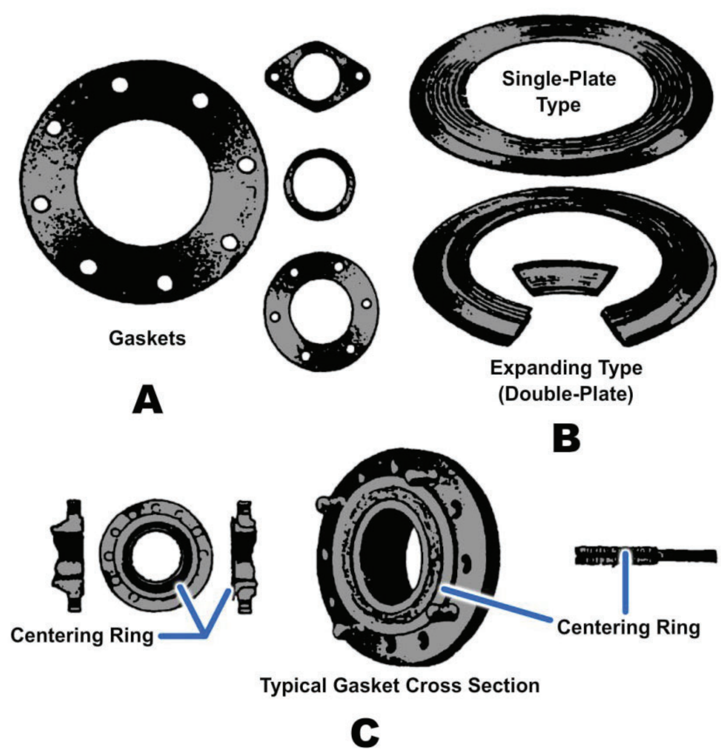


Figure 7-1 — Gaskets.

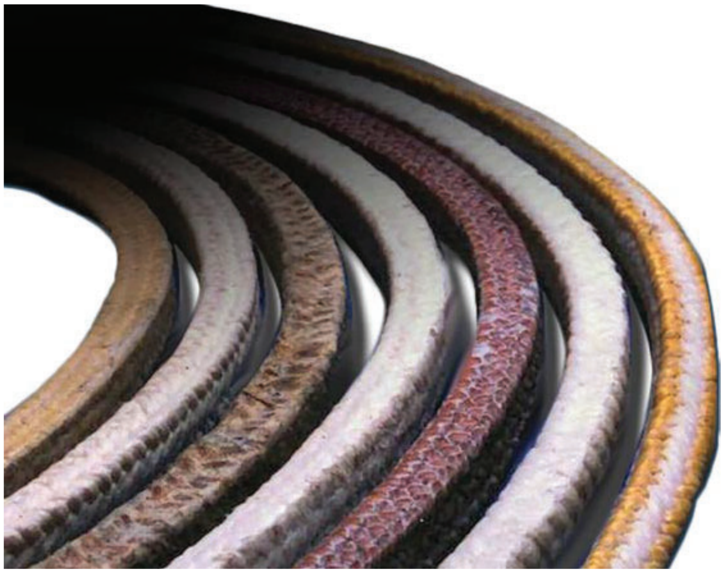


Figure 7-2 — Graphite filament yarn gasket.

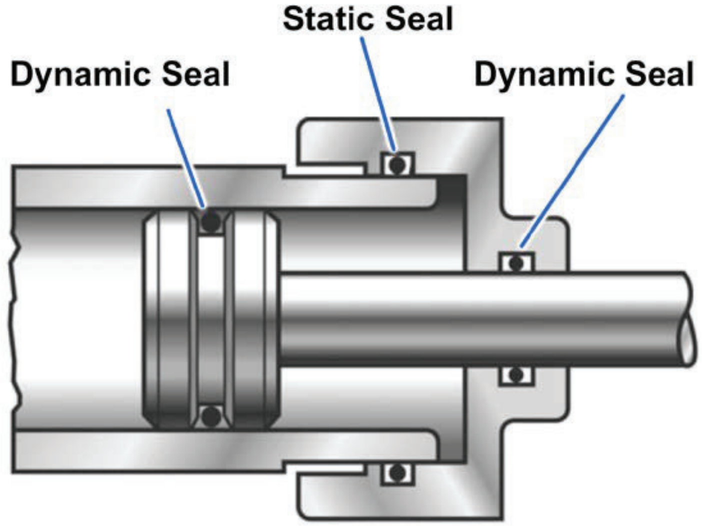


Figure 7-3 — Dynamic seal.

Static and Dynamic Seals

The static seal is used to prevent leakage in a mechanical joint where there is no relative motion between mating surfaces. Material used to create a seal between two stationary faces of a mechanical joint are called gaskets. The gasket must function to confine liquids or gasses within an assembly and maintain this seal under various operating conditions. To create an effective barrier, gasket material will deform to fill the space between imperfect mating surfaces of mechanical joints to prevent fluids from leaking. This compression requires that the joint be tightly bolted or otherwise held together. The compression of a gasket forming a seal between mating parts is shown in *Figure 7-4*.

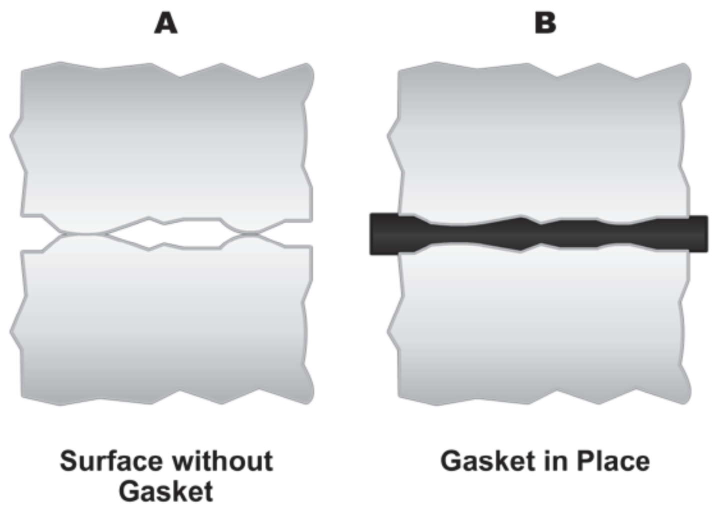


Figure 7-4 — Compression of a gasket.

The dynamic seal (*Figure 7-3*) is a seal provided in a mechanical coupling where movement between the sealed surfaces is intended, such as packing material sealing to a rotating or reciprocating shaft. Material used to provide a seal in a mechanical coupling where some form of movement between the surfaces to be sealed is intended or anticipated is called Packing. Packing material usually consists of bulk deformable materials which are shaped by manually adjusted compression.

Rotating, Reciprocating, and Oscillating Seals

Rotary seals are used in a variety of different application conditions. These conditions can vary from high-speed shaft rotation with light oil mist, to a low speed reciprocating shaft in muddy environments. Reciprocating seals involve relative reciprocating motion along the shaft axis between the inner and outer elements. In reciprocating seal applications, the O-ring slides or rocks back and forth within its gland with the reciprocating motion. Oscillating seals are commonly used in faucet valves. In oscillating applications, the shaft or housing rotates back and forth through a limited number of turns around the axis of the shaft.

Mechanical seals are sealing devices that are installed on rotating equipment such as pumps to prevent the leakage of liquids and gases from escaping the operating system. A mechanical seal consists of two principle components. One component is stationary and the other rotates against it to achieve a seal (*Figure 7-5*). There are many types of mechanical seal, ranging from simple single spring designs to considerably more complex cartridge seal types. The design, arrangement, and materials of construction are essentially determined by the pressure, temperature, speed of rotation, and product being sealed.

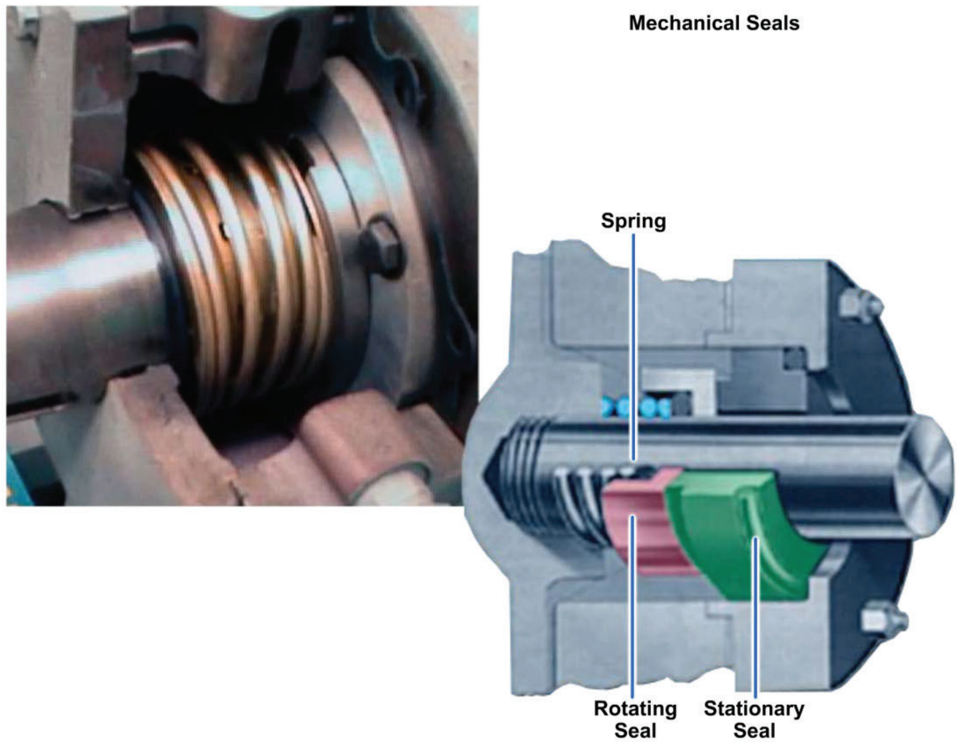


Figure 7-5 — Mechanical seal.

SEAL MATERIALS

Many different materials have been used in the development of sealing devices. The material used for a particular application depends on several factors: fluid compatibility, resistance to heat, pressure, wear resistance, hardness, and type of motion.

The selection of the correct packings and gaskets and their proper installation are important factors in maintaining an efficient fluid power system. The types of seals to be used in a particular piece of equipment are specified by the equipment manufacturer.

Often the selection of seals is limited to seals covered by military specifications. However, there are occasions when nonstandard or proprietary seals reflecting the advancing state of the art may be approved. Thus, it is important to follow the manufacturer's instructions when you replace seals. If the proper seal is not available, you should give careful consideration in the selection of a suitable substitute. To find the right packing material, check the maintenance requirement card (MRC) or the Commander Naval Sea Systems Command (NAVSEA) packing and gasket chart. The MRC lists the symbol numbers and the size and number or rings required. The NAVSEA packing and gasket chart lists symbol numbers and materials. For additional information concerning packing and gasket material, refer to Naval Ships' Technical Manual (NSTM), Chapter 078.

Seals are made of materials that have been carefully chosen or developed for specific applications. These materials include tetrafluoroethylene (TFE), commonly called Teflon; synthetic rubber (elastomers); cork; leather; metal; and asbestos (its use is not permitted in the construction, overhaul, repair or maintenance of Navy ships where suitable substitute materials have been identified). Non-asbestos materials have been identified for use in some gasket applications and must be used in place of asbestos gaskets in such applications when available. Some of the most common materials used to make seals for fluid power systems are discussed in the following paragraphs.

Cork

Cork has several of the required properties, which makes it ideally suited as a sealing material in certain applications. The compressibility of cork seals makes them well suited for confined applications in which little or no spread of the material is allowed. The compressibility of cork also makes a good seal that can be cut to any desired thickness and shape to fit any surface and still provide an excellent seal.

One of the undesirable characteristics of cork is its tendency to crumble. If cork is used as packing or in areas where there is a high fluid pressure and/or high flow velocity, small particles will be cast off into the system. Cork use in fluid power systems is therefore limited. It is sometimes used as gasket materials for inspection plates of hydraulic reservoirs.

> **NOTE**
>
> Cork should not be used where temperatures exceed 160 degrees Fahrenheit (°F) (71 Celsius (°C)) or at sub-zero temperatures.

Cork and Rubber

Cork and rubber seals are made by combining synthetic rubber and cork. This combination has the properties of both materials. This means that seals can be made with the compressibility of cork, but with a resistance to fluid comparable to the synthetic rubber on which they are based. Cork and rubber composition is sometimes used to make gaskets for applications similar to those described for cork gaskets.

Leather

Leather is a closely knit material that is generally tough, pliable, and relatively resistant to abrasion, wear, stress, and the effects of temperature changes. Because it is porous, it is able to absorb lubricating fluids. This porosity makes it necessary to impregnate leather for most uses. In general, leather must be tanned and treated to make it useful as a gasket material. The tanning processes are those normally used in the leather industry.

Leather is generally resistant to abrasion regardless of whether the grain side or the flesh side is exposed to abrasive action. Leather remains flexible at low temperatures and can be forced with comparative ease into contact with metal flanges. When properly impregnated, it is impermeable to most liquids and some gases, and is capable of withstanding the effects of temperatures ranging from –70 °F to +220 °F.

Leather has four basic limitations. First, the size of the typical hide limits the size of the seals that can be made from leather. A second limitation is the number of seals that are acceptable. Another limitation is that under heavy mechanical pressures leather tends to extrude. Finally, many of the properties (such as impermeability, tensile strength, high- and low-temperature resistance, pliability, and compatibility with environment) depend upon the type of leather and impregnation. Leathers not tanned and impregnated for specific conditions and properties will become brittle, dry, and completely degreased by exposure to particular chemicals. Leather is never used with steam pressure of any type, or with acid or alkali solutions.

Leather may be used as packing. When molded into V's and U's, cups, and other shapes, it can be applied as dynamic packing, while in its flat form it can be used as straight compression packing.

Metal

Various types of metals are used in gasket products. Sheet lead and copper are effective, since they are soft metals and easily compressed. Woven-metal and spun-metal products are being used in high temperature service applications. A combination of metal and other gasket materials are commonly used where high strength, service pressure and working temperature demands are great. Spiral-wound gaskets (*Figure 7-6*) are preformed for a particular assembly and are available in many sizes. The gasket is normally steel formed with another softer material (fibrous glass, graphite, etc). The gasket consists of multiple layers of material spirally wound and cut to a required thickness.

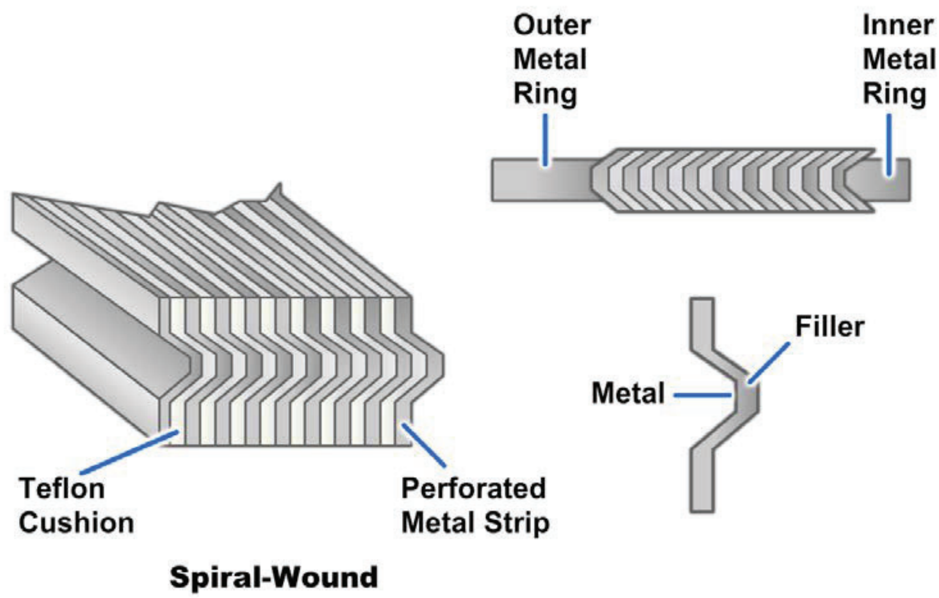


Figure 7-6 — Spiral-wound gasket.

Rubber

The term rubber covers many natural and synthetic rubbers, each of which can be compounded into numerous varieties. The characteristics of these varieties have a wide range, as shown in *Table 7-1*. The table shows, with the exception of a few basic similarities, that rubbers have diverse properties and limitations; therefore, specific applications require careful study before the sealing material is selected.

Natural rubbers have many of the characteristics required in an effective seal. However, their very poor resistance to petroleum fluids and rapid aging when exposed to oxygen or ozone limit their use. Rubber gaskets are usually restricted to low pressure uses.

There are two general classes of synthetic rubber seals. One class is made entirely of a certain synthetic rubber. The term frequently used to describe this class of seal is homogeneous (having uniform structure or composition throughout). The other class of seal is made by impregnating woven cotton duck or fine-weave asbestos with synthetic rubber (see NSTM, Chapter 078 for asbestos substitutes), this class is sometimes referred to as fabricated seals.

For additional information concerning sealing materials, refer to NSTM, Chapter 078.

Table 7-1 — General Properties of Natural and Synthetic Rubbers

	Natural Rubber[a]	Styrene Butadiene Rubber (SBR)	Acrylonitrile Butadiene Rubber (Nitrile[b])		Polychloroprene (Neoprene[c])	Butyl[e]	Polysulfide (Thiokol[f])	Silicone[g]	Polyacrylates (Acrylic)
			Low Swell	High Swell					
Specific Gravity: Pure Gum	0.92	0.94	0.98	0.98	1.23	0.92	1.34	0.98	1.1
Tensile Strength, psi Pure Gum Black Reinforced	3000 4500	400 3000	600 3000	600 3500	3500 3500	3000 3000	300 1500	200- 450	--- 2500
Elongation, percent	700	500	600	600	600	700	400	300	500
Tear Resistance	G	P-F	F	F	G	G	P-F	P	F
Aging Resistance to: Ozone Oxidation Heat Shelf Life	F P-G F-G G	P P-G F-G G	P P-G G G	P P-G G G	E G-E VG VG	E G-E G E	E G-E P G	E E E E	VG VG E VG
Compression Set Resistance	G	G	VG	VG	d	P-G	P	E	P-G
Oil-Resistance: Low-Aniline Oils High-Aniline Oils	P P	P P	E G	G E	F G	P P	E E	P G	E E
Gasoline Resistance: Aromatic Non-aromatic	P P	P P	P F	G E	P G	P P	E E	P P	E E
Acid Resistance: Dilute (Under 10%) Concentrated (Except Nitric and Sulfuric Acids)	G F-G	G F-G	G G	G G	G F	E E	F F	F P	F F

	Natural Rubber[a]	Styrene Butadiene Rubber (SBR)	Acrylonitrile Butadiene Rubber (Nitrile[b])		Polychloroprene (Neoprene[c])	Butyl[e]	Polysulfide (Thiokol[f])	Silicone[g]	Polyacrylates (Acrylic)
Alkali Resistance: Dilute (Under 10%) Concentrated	G F	G F	G F	G F	G G	G G	P P	F P	P P
High-Temperature Resistance [200°F (93°C) or more]	F	G	G	G	G	G	F-G	E	E
Low-Temperature Resistance [-67°F (-55°C) or more]	G	G	F	F	F	G	F	E	P
Impermeability to Gases	F	F	F	F	G	E	G	G	G
Water Resistance	G	VG	VG	VG	F	G	F	F	F

Note

E = Excellent, VG = Very Good, G = Good, F = Fair, P = Poor

[a] Swells in contact with turpentine, carbon bisulfide, chloroform, carbon tetrachloride, and vegetable oils. White glycerine, ethylene glycol, and water produce negligible swell. Functions best at temperature under 160 degrees F, but can tolerate intermittent exposures to 250 degrees F.

[b] Resist swelling action of petroleum oils, fuels, and solvents. Usually will not adhere to metal flanges.

[c] Includes types GN and W.

[e] Excellent resistance to vegetable oils, dilute organic acids, and alkalis. Poor solvent resistance. Pool compression set properties.

[f] Includes types PR-1 and ST. Excellent solvent resistance.

[g] Excellent dielectric properties, high- and low-temperature resistance, and resistance to tendencies to adhere at high temperatures. Good resistance to oxidation, weathering, high-aniline-point oils. Poor resistance to low-aniline-point oils, aromatic and non-aromatic gasolines. Low abrasion resistance. Deteriorates in contact with steam under pressure.

TYPES OF SEALS

Fluid power seals are usually typed according to their shape or design. These types include T-seals, V-rings, O-rings, U-cups, and so on. Some of the most commonly used seals are discussed in the remainder of this chapter.

T-Seals

The T-seal has an elastomeric bidirectional sealing element resembling an inverted letter *T*. This sealing element is always paired with two special extrusion-resisting backup rings, one on each side of the *T*. The basic T-seal configuration is shown in *Figure 7-7, view A*. The backup rings are single turn, bias cut, and usually made of TFE (Tetrafluoroethylene), molybdenum-disulfide-impregnated nylon, or a combination of TFE and nylon. Nylon is widely used for T-seal backup rings because it provides excellent resistance to extrusion and has low friction characteristics.

The special T-ring configuration adds stability to the seal, eliminating spiraling and rolling. T-seals are used in applications where large clearances could occur as a result of the expansion of the thin-walled hydraulic cylinder. The T-ring is installed under radial compression and provides a positive seal at zero or low pressure. Backup rings, one on each side, ride free of T-ring flanges and the rod or cylinder wall (*Figure 7-7, view B*). These clearances keep seal friction to a minimum at low pressure. When pressure is applied (*Figure 7-7, view C*), the T-ring acts to provide positive sealing action as fluid pressure increases. One frequently used T-ring, manufactured by Greene, Tweed and Company (called a G-T® Ring) incorporates a unique, patented backup ring feature. One corner on the inside diameter (ID) of each radius-styled backup ring on the G-T® Ring set has been rounded to mate with the inside corner of the rubber *T. Figure 7-7, views B and C*, shows the G-T® Ring.

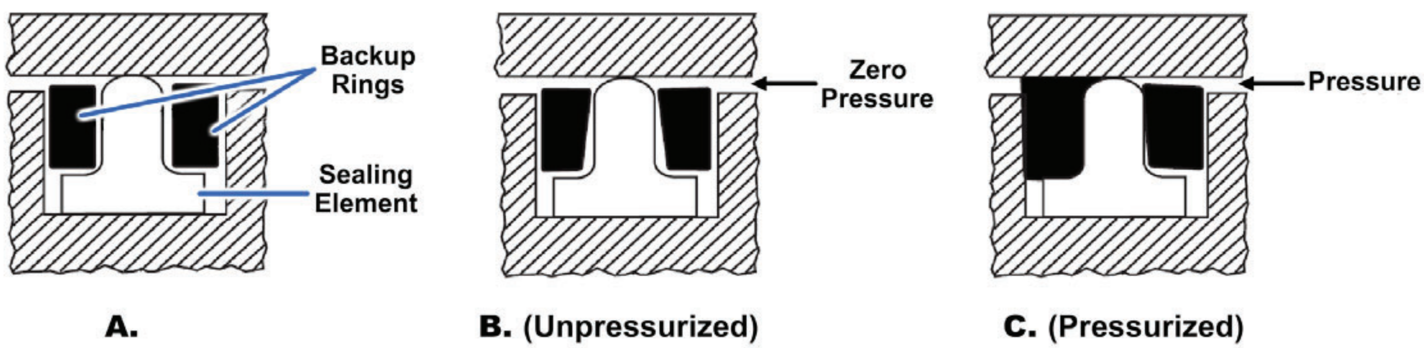


Figure 7-7 — T-seals.

There is no military standard part numbering system by which T-seals can be identified. In general, each manufacturer issues proprietary part numbers to identify seals. However, it is common practice to identify T-seal sizes by the same dash numbers used for equivalent O-ring sizes (discussed later in this chapter) as defined by AS568 and MS28775 dimension standards. Typically, an O-ring groove that accepts a certain O-ring dash number will accept the same dash number T-seal.

In the absence of an existing military standard for identifying T-seals, a new and simple numbering system was created to identify T-seals required for hydraulic actuators (piston seals only) without reference to a particular manufacturer's part number. The Navy number is composed of the letters *G-T* followed by a dash number of three digits and one letter, *R, S,* or *T* (for example, G-T-217T). The three digits are the appropriate O-ring size dash number according to AS568 or MS28775. The letters *R, S,* and *T* designate the number of backup rings that the groove of the T-seal is designed to accommodate: none, one, or two, respectively.

V-Rings

The V-ring is one of the most frequently used dynamic seals in ship service although its identification, installation, and performance are probably most misunderstood. Properly selected and installed, V-rings can provide excellent service life; otherwise, problems associated with friction, rod and seal wear, noise, and leakage can be expected.

The V-ring is the part of the packing set that does the sealing. It has a cross section resembling the letter *V* (*Figure 7-8*), from which its name is derived. To achieve a seal, the V-ring must be installed as part of a packing set or stack, which includes one male adapter, one female adapter, and several V-rings (*Figure 7-8*). The male adapter is the first ring on the pressure end of the packing stack and is flat on one side and wedge-shaped on the other to contain the *V* of the adjacent V-ring. The female adapter, the last ring of the packing stack, is flat on one side and V-shaped on the other to properly support the adjacent V-ring. Proper design and installation of the female adapter has significant impact on the service life and performance of the V-rings because the female adapter bridges the clearance gap between the moving surfaces and resists extrusion.

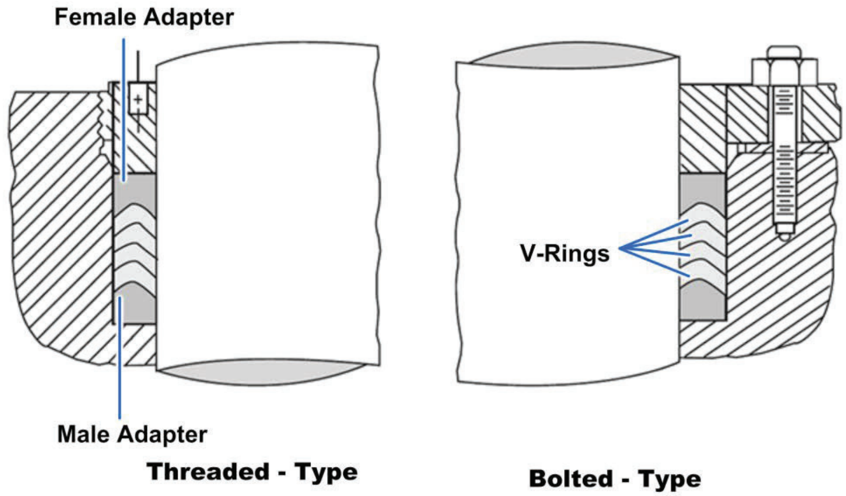


Figure 7-8 — Outside packed V-ring installations.

The packing set is installed in a cavity that is slightly deeper than the free stack height (the nominal overall height of a V-ring packing set, including the male and female adapters as measured before installation) and as wide as the nominal cross section of the V-rings. This cavity, called a packing gland or stuffing box, contains and supports the packing around the shaft, rod, or piston. Adjustment of the packing gland depth through the use of shims or spacers is usually necessary to obtain the correct squeeze or clearance on the packing stack for good service life.

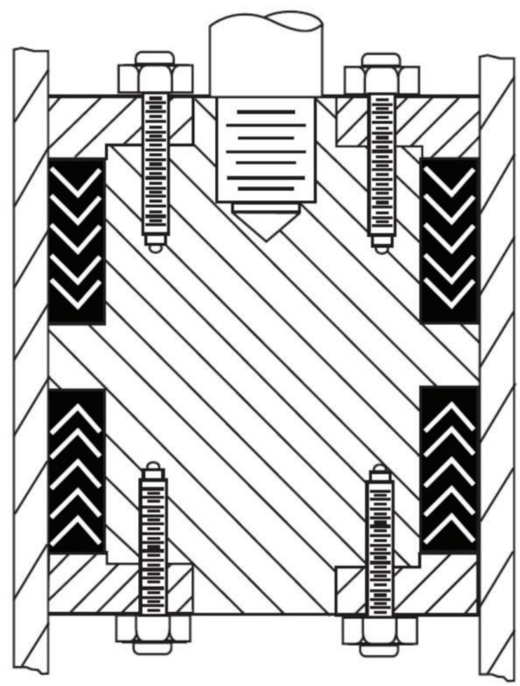


Figure 7-9 — Inside packed V-ring installation.

Two basic installations apply to V-ring packings. The more common is referred to as an outside packed installation, in which the packing seals against a shaft or rod, as shown in *Figure 7-8*. The inside packed installation is shown as a piston seal in *Figure 7-9*. When V-ring packing is to be used in an inside packed installation, only endless ring packing should be used. Pressures exist in both directions, as on a double-acting piston, opposing sets of packing should always be installed so the sealing lips face away from each other (*Figure 7-9)*. This prevents trapping pressure between the sets of packings. The female adapters in inside packed installations should always be located adjacent to a fixed or rigid part of the piston.

O-Rings

An O-ring is circular in shape, and its cross section is small in relation to its diameter. O-rings are usually molded from rubber compounds; however, they can be molded or machined from plastic materials. The O-ring is usually fitted into a rectangular groove (usually called a gland) machined into the mechanism to be sealed. An O-ring seal consists of an O-ring mounted in the gland so that the O-ring's cross section is compressed (squeezed) when the gland is assembled (*Figure 7-10*).

An O-ring sealing system is often one of the first sealing systems considered when a fluid closure is designed because of the following advantages of such a system:

- Simplicity
- Ruggedness
- Low cost
- Ease of installation
- Ease of maintenance
- No adjustment required
- No critical torque in clamping
- Low distortion of structure
- Small space requirement
- Reliability
- Effectiveness over wide pressure and temperature ranges

As stated previously, O-rings are used in both static (as gaskets) and dynamic (as packing) applications. An O-ring will almost always be the most satisfactory choice of seal in static applications if the fluids, temperatures, pressure, and geometry permit.

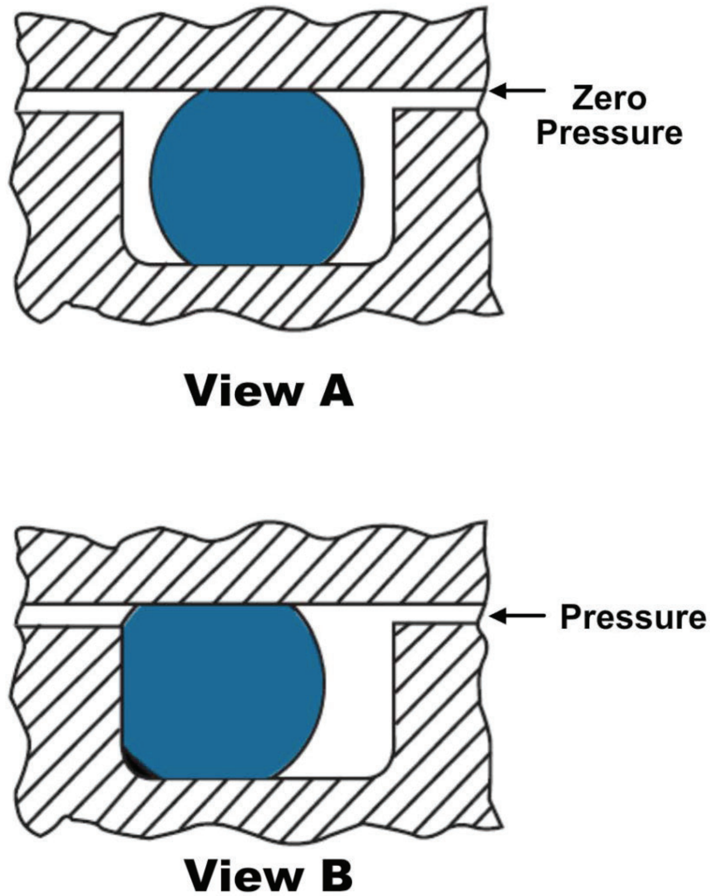


Figure 7-10 — O-ring installed in a gland.

Standard O-ring packings are not specifically designed to be used as rotary seals. When infrequent rotary motion or low peripheral velocity is involved, standard O-ring packings may be used, provided consistent surface finishes over the entire gland are used and eccentricities are accurately controlled. O-rings cannot compensate for out-of-round or eccentrically rotating shafts.

As rotary seals, O-rings perform satisfactorily in two application areas:

- In low-speed applications where the surface speed of the shaft does not exceed 200 feet per minute (ft/min)
- In high-speed moderate-pressure applications, between 50 and 800 pounds per square inch (psi)

The use of low-friction extrusion-resistant devices helps prolong the life and improve the performance of O-rings used as rotary seals.

O-rings are often used as reciprocating seals in hydraulic and pneumatic systems. While best suited for short-stroke, relatively small diameter applications, O-rings have been used successfully in long-stroke, large diameter applications. Glands for O-rings used as reciprocating seals are usually designed according to MIL-G-5514 to provide a squeeze that varies from 8 to 10 percent minimum and 13.5 to 16 percent maximum. A squeeze of 20 percent is allowed on O-rings with a cross section of 0.070 inch or less. In some reciprocating pneumatic applications, a floating O-ring design may simultaneously reduce friction and wear by maintaining no squeeze by the gland on the O-ring. When air pressure enters the cylinder, the air pressure flattens the O-ring, causing sufficient squeeze to seal during the stroke. If the return stroke does not use pneumatic power, the O-ring returns to its round cross section, minimizing drag and wear on the return stroke.

Identification

As a maintenance person or supervisor working with fluid power systems, you must be able to positively identify, inspect, and install the correct size and type of O-ring to ensure the best possible service. These tasks can be difficult since part numbers cannot be put directly on the seals and because new types of seals are continually introduced and others made obsolete. (NSTM, chapter 078, contains a table that cross-references obsolete and current O-ring specifications for ship applications.)

O-rings are packaged in individually sealed envelopes. O-ring seals manufactured to government specifications are marked according to the requirements of the specification and standard. The required marking for each package is as follows:

- National stock number (NSN)
- Nomenclature
- Military part number
- Material specification
- Manufacturer's name
- Manufacturer's compound number
- Manufacturer's batch number
- Contract number
- Cure date

> **NOTE**
>
> Keep preformed packings in their original envelopes, which provide preservation, protection, identification, and cure date.

When you select an O-ring for installation, carefully observe the information on the package. If you cannot positively identify an O-ring, discard it. The part number on the sealed package provides the most reliable and complete identification.

Sizes

A standardized dash number system for O-ring sizes is contained in Aerospace Standard AS568 published by the Society of Automotive Engineers. The dash numbers are divided into groups of one hundred. Each hundred group identifies the cross section size of the O-rings within the group (*Table 7-2*).

Table 7-2 — O-Ring Dash Numbers Versus Cross Section Sizes

DASH NUMBER	CROSS SECTION (INCHES)
-001 thru -099	0.070 and smaller
-100 thru -199	0.103
-200 thru -299	0.139
-300 thru -399	0.210
-400 thru -499	0.275

The 900 series dash numbers contained in AS568 identify all the presently standardized straight thread tube fitting boss gaskets. With the exception of -901, the last two digits of the dash designate the tube size in 16ths of an inch. For example, the -904 size is for a 1/4-inch tube.

Dimensions

The critical dimensions of an O-ring are its ID, its cross-sectional diameter (W), and the height and width of the residual molding flash (*Figure 7-11*).

Nominal dimensions have been used to describe O-ring sizes, although this practice is rapidly being replaced by the use of dash numbers. The actual ID of a seal will be slightly less than the nominal ID, but the actual outside diameter (OD) will be slightly larger than the nominal OD. For example, an AS568-429 O-ring is described in nominal dimensions as 5 inches ID by 5 1/2 inches OD by 1/4 inch W. Actual dimensions are 4.975 inches ID by 5.525 inches OD by 0.275 inches W.

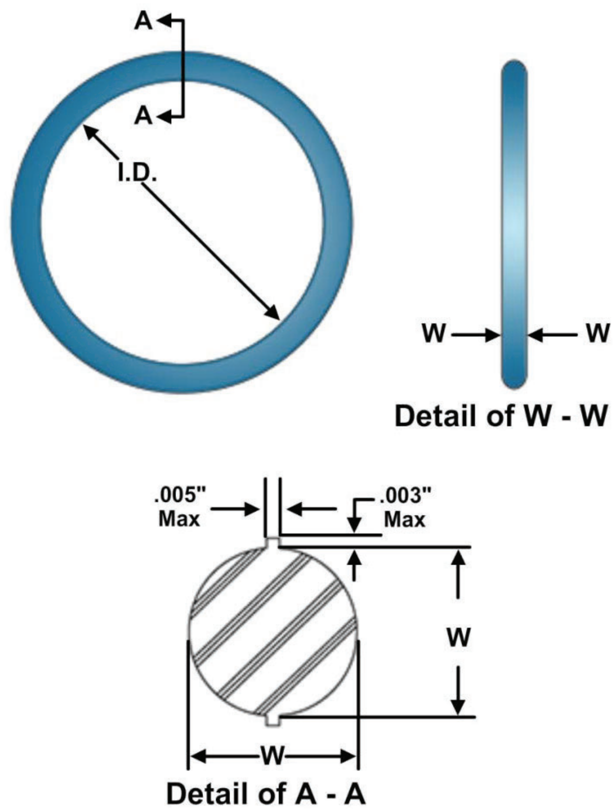


Figure 7-11 — Critical dimensions of an O-ring.

Specifications

Material and performance requirements for O-rings are often identified in military specifications. The dimensions of these O-rings will usually be found in accompanying slash sheets (which bear the specification number and are a part of the specification) or will be identified by various drawings and standards that relate to the specification. Included among the specifications are Air Force-Navy Standards (AN), Military Standards (MS), and National Aerospace Standards (NAS). If the specification does not identify sizes, the sizes should be identified by the AS568 dash number. Usually, you can use drawings, technical manuals, and allowance parts lists (APLs) to identify replacement O-rings.

Cure Date

The cure date is the date the rubber is fully cured or the manufacture date. Two methods of expressing the cure date are as follows:

- Shelf life to a maximum of 3 years. Cure date stated in terms of month of calendar year and the year, e.g., 6-13

- Shelf life in excess of 3 years. Cure date stated in terms of the quarter of calendar year and the year, e.g., 2Q-13

For additional information concerning sealing materials, refer to NSTM, Chapter 078.

Shelf Life and Expiration Date

The shelf life for rubber products is the period of time during which an unopened, properly stored item should be suitable for unrestricted use.

Check the age of natural or synthetic rubber preformed packings before installation to determine whether they are acceptable for use. Make a positive identification, indicating the source, cure date, and expiration date. Ensure that this information is available for all packing used. Shelf life requirements do not apply once the packing is installed in a component. If the source of an item cannot be determined, or it is not in the original package, discard it.

The expiration date is the date after which packing should not be installed. The expiration date of all packings can be determined by adding the shelf life to the cure date.

Replacement

A typical O-ring installation is shown in *Figure 7-12*. When such an installation shows signs of internal or external leakage, the component must be disassembled and the seals replaced. Sometimes components must be resealed because of the age limitations of the seals. The O-ring should also be replaced whenever a gland that has been in service is disassembled and reassembled.

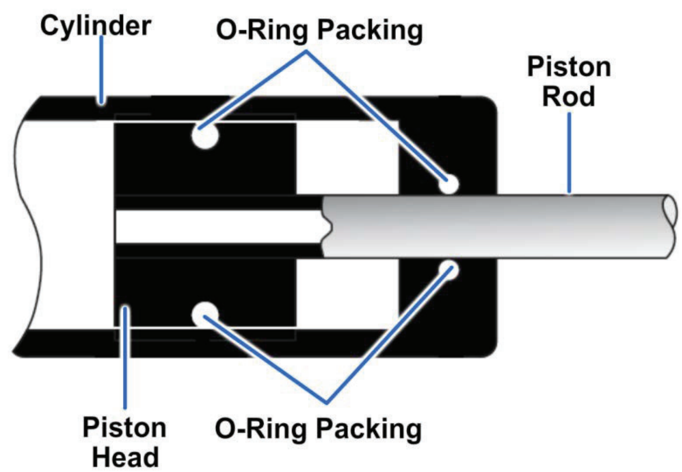


Figure 7-12 — Typical O-ring installation.

Often a poor O-ring installation begins when an old seal is removed. O-ring removal involves working with parts that have critical surface finishes. If hardened-steel, pointed, or sharp-edged tools are used for removal of O-rings or backup rings, scratches, abrasions, dents, and other deformities on critical sealing surfaces can result in seal failure, which, in turn, can result in functional failure of the equipment.

When removing or installing O-rings, do NOT use pointed or sharp-edged tools, which might scratch or mar component surfaces or damage the O-ring. An O-ring tool kit is available in the supply system for O-ring installation or removal. If these tools are not on hand, special tools can be made for this purpose. A few examples of tools used in the removal and installation of O-rings are illustrated in *Figure 7-13*. These tools should be fabricated from soft metal such as brass or aluminum; however, tools made from phenolic rod, wood, or plastic may also be used.

Tool surfaces must be well rounded, polished, and free of burrs. Check the tools often, especially the surfaces that come in contact with O-ring grooves and critical polished surfaces.

Notice in *Figure 7-13, view A*, how the hook-type removal tool is positioned under the O-ring and then lifted to allow the extractor tool, as well as the removal tool, to pull the O-ring from its cavity. *Figure 7-13, view B* shows the use of another type of extractor tool in the removal of internally installed O-rings.

In *Figure 7-13, view C*, the extractor tool is positioned under both O-rings at the same time. This method of manipulating the tool positions both O-rings, which allows the hook-type removal tool to extract both O-rings with minimum effort. *Figure 7-13, view D*, shows practically the same removal as *Figure 7-13, view C*, except for the use of a different type of extractor tool.

The removal of external O-rings is less difficult than the removal of internally installed O-rings. *Figure 7-13, views E and F,* show the use of a spoon-type extractor, which is positioned under the seal. After the O-ring is dislodged from its cavity, the spoon is held stationary while the piston is simultaneously rotated and withdrawn. *View F* is similar to *view E*, except that only one O-ring is installed, and a different type of extractor tool is used. The wedge-type extractor tool is inserted beneath the O-ring; the hook-type removal tool hooks the O-ring. A slight pull on the latter tool removes the O-ring from its cavity.

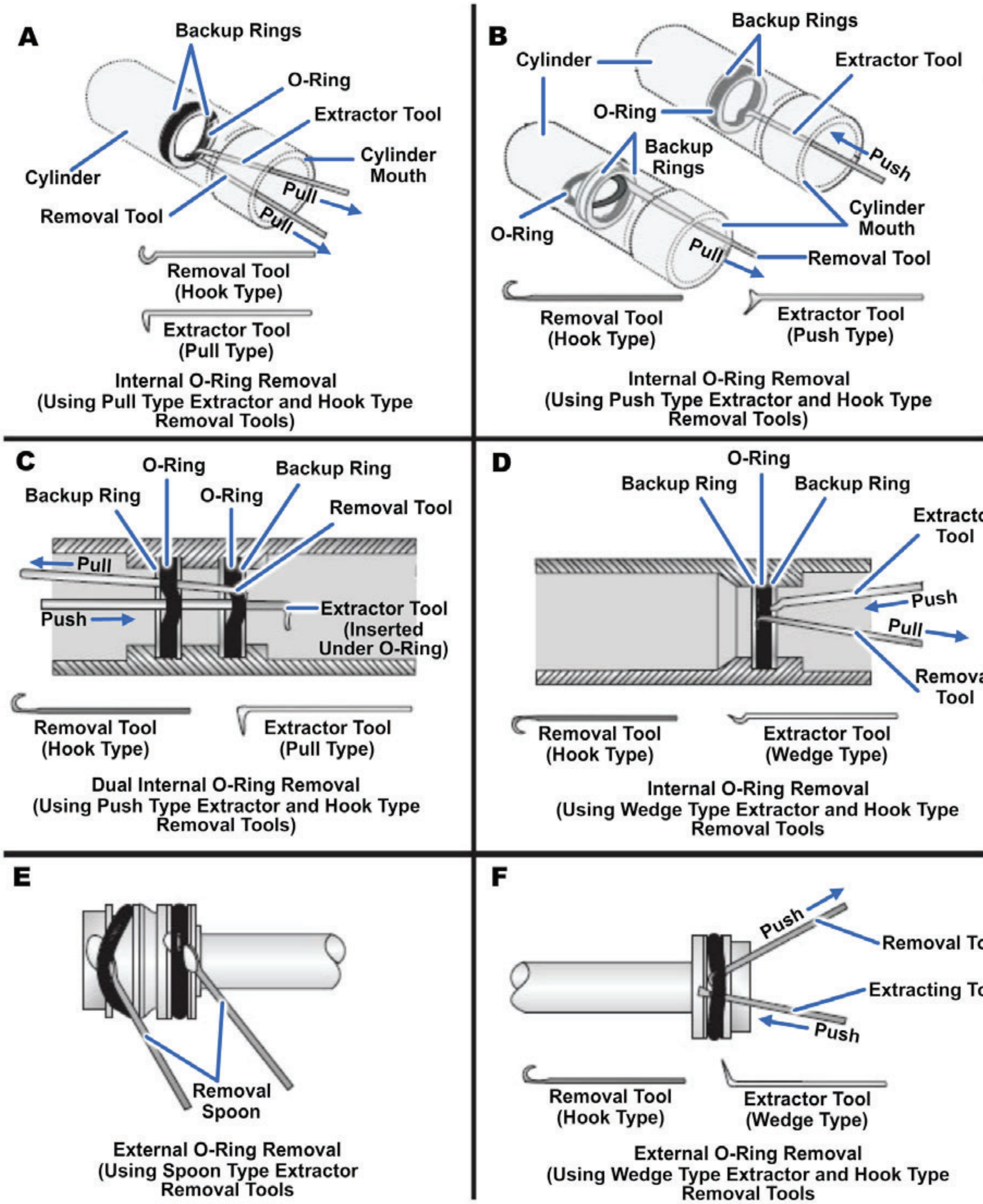


Figure 7-13 — O-ring tools and O-ring removal.

After removing all O-rings, you must clean the affected parts that will receive new O-rings. Ensure that the area used for such installations is clean and free from all contamination.

Remove each O-ring that is to be installed from its sealed package and inspect it for defects such as blemishes, abrasions, cuts, or punctures. Although an O-ring may appear perfect at first glance, slight surface flaws may exist. These are often capable of preventing satisfactory O-ring performance. O-rings should be rejected for flaws that will affect their performance.

By rolling the ring on an inspection cone or dowel, you can check the inner diameter surface for small cracks, particles of foreign material, and other irregularities that will cause leakage or shorten its life. The slight stretching of the ring when it is rolled inside out will help to reveal some defects not otherwise visible. You should further check each O-ring by stretching it between the fingers, but take care not to exceed the elastic limits of the rubber. Following these inspection practices will prove to be a maintenance economy. It is far more desirable to take care identifying and inspecting O-rings than to repeatedly overhaul components with faulty seals.

After inspection and prior to installation, lubricate the O-ring and all the surfaces that it must slide over with a light coat of the system fluid or a lubricant approved for use in the system. Consult the applicable technical instruction or NSTM for the correct lubricant for pneumatic systems.

Assembly must be made with care so that the O-ring is properly placed in the groove and not damaged as the gland is closed. During some installations, such as on a piston, it will be necessary to stretch the O-ring. Stretch the O-ring as little and as uniformly as possible. Avoid rolling or twisting the O-ring when maneuvering it into place. Keep the position of the O-ring mold line constant. O-rings should not be left in a twisted condition after installation.

If the O-ring installation requires spanning or inserting through sharp-threaded areas, ridges, slots, and edges, use protective measures, such as the O-ring entering sleeve (*Figure 7-14, view A*). If the recommended O-ring entering sleeve (a soft, thin-wall, metallic sleeve) is not available, paper sleeves and covers may be fabricated by using the seal package (glossy side out) or lint-free bond paper (*Figure 7-14, views B and C*).

After you place the O-ring in the cavity provided, gently roll the O-ring with your fingers to remove any twist that might have occurred during the installation. After installation, an O-ring should seat snugly but freely in its groove. If backup rings are installed in the groove, be certain the backup rings are installed on the correct side of the ring.

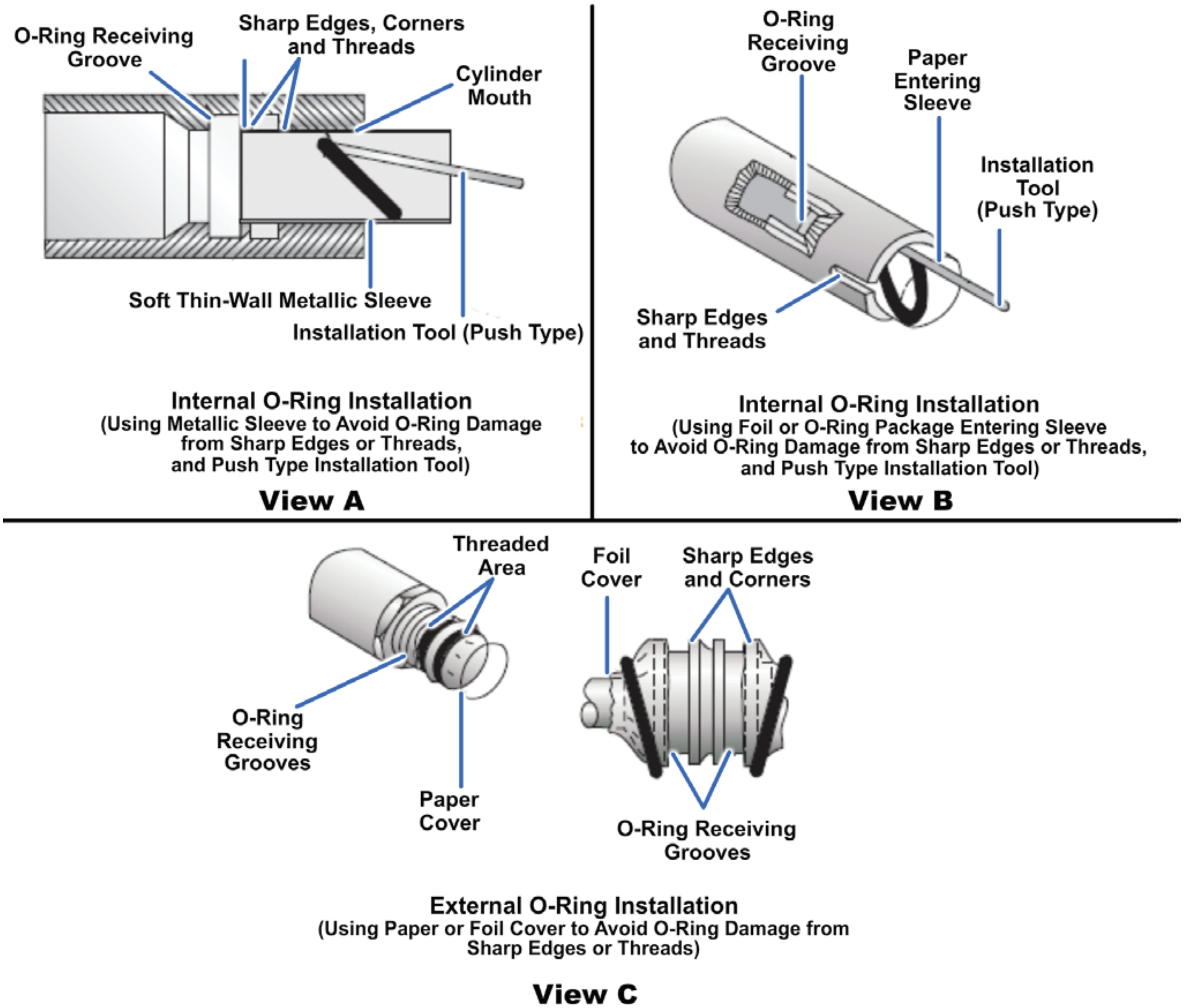


Figure 7-14 — O-ring installation.

Backup Rings

Backup rings, also referred to as retainer rings, anti-extrusion devices, and non-extrusion rings, are washer-like devices that are installed on the low-pressure side of packing to prevent extrusion of the packing material. Backup rings in dynamic seals minimize erosion of the packing materials and subsequent failure of the seal. At lower pressures, backup rings will prolong the normal wear life of the packing. At higher pressures, backup rings permit greater clearances between the moving parts.

Backup rings can be made of polytetrafluoroethylene, hard rubber, leather, and other materials. The most common material currently used is TFE. Backup rings are available as single-turn continuous (uncut or solid), single-turn (bias) cut, and spiral cut (*Figure 7-15*). Leather rings are always furnished in solid ring form (unsplit). Rings of TFE are available in all three types.

Packaging and Storing

Backup rings are not color-coded or otherwise marked and must be identified from the packaging labels. The dash number following the military standard number found on the package indicates the size and usually relates directly to the dash number of the O-rings for which the backup ring is dimensionally suited. Backup rings made of TFE do not deteriorate with age and do not have shelf life limitations. TFE backup rings are provided by the manufacturer either in individually sealed packages or on mandrels. If unpackaged rings are stored for a long time without the use of mandrels, a condition of overlap may develop. Overlap occurs when the ID of the backup ring becomes smaller and its ends overlap each other. To correct this overlap condition, stack TFE rings on a mandrel of the correct diameter, and clamp the rings with their coils flat and parallel. Place the rings in an oven at a maximum temperature of 177 °C (350 °F) for approximately 10 minutes. Do not overheat them because fumes from decomposing TFE are toxic. Remove and water-quench the rings. The rings should then be stored at room temperature for 48 hours prior to use.

Figure 7-15 — Types of backup rings.

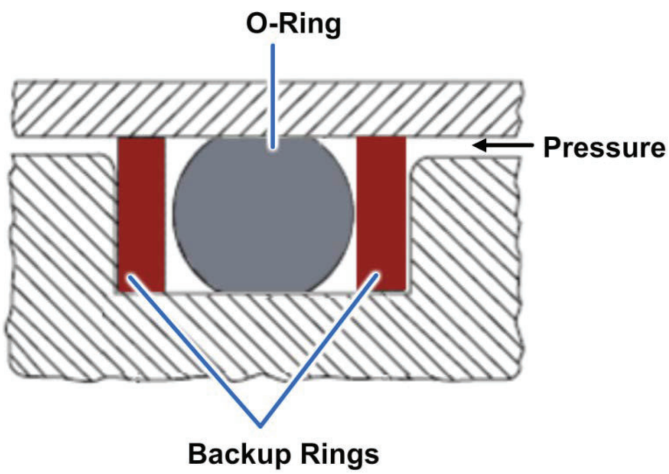


Figure 7-16 — Two backup ring configuration.

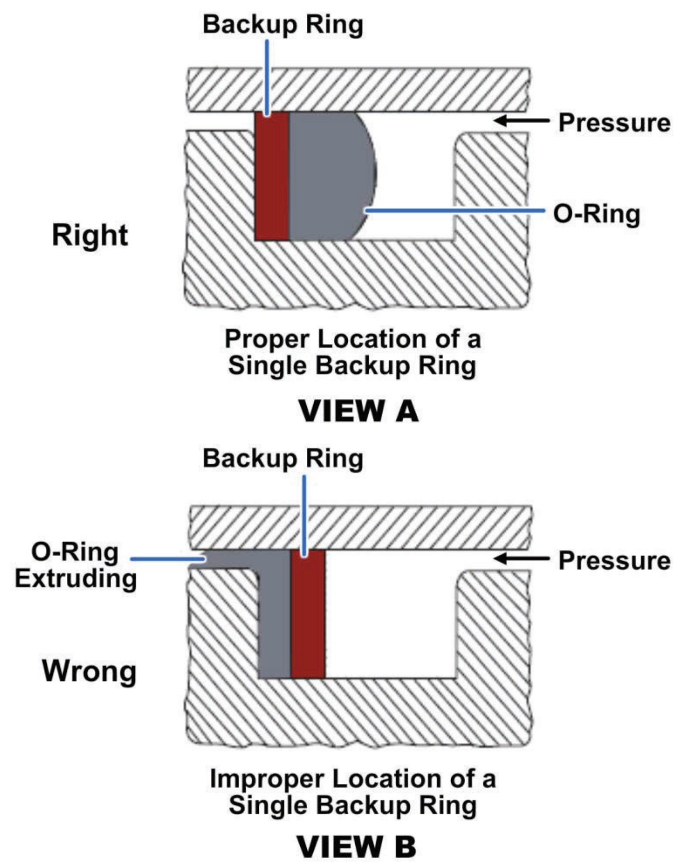


Figure 7-17 — Location of a single backup ring.

Installation

Care must be taken in handling and installing backup rings. Do not insert them with sharp tools. Prior to use, backup rings must be inspected for evidence of compression damage, scratches, cuts, nicks, or frayed conditions. Where backup rings and O-rings are installed in the same groove, never replace the O-ring without replacing the backup rings, or vice versa. Many seals use two backup rings, one on either side of the O-ring (*Figure 7-16*). Two backup rings are used primarily in situations (such as a reciprocating piston seal) where alternating pressure direction can cause packing to be extruded on both sides of the gland.

If only one backup ring is used, place the backup ring on the low-pressure side of the packing (*Figure 7-17, view A*). When a backup ring is placed on the high-pressure side of the packing, the pressure against the relatively hard surface of the backup ring forces the softer packing against the low-pressure side of the gland, resulting in a rapid failure due to extrusion (*Figure 7-17, view B*).

When dual backup rings are installed, stagger the split scarfed ends as shown in *Figure 7-18*. When installing a spiral cut backup ring (MS28782 or MS28783), be sure to wind the ring correctly to ease installation and ensure optimum performance.

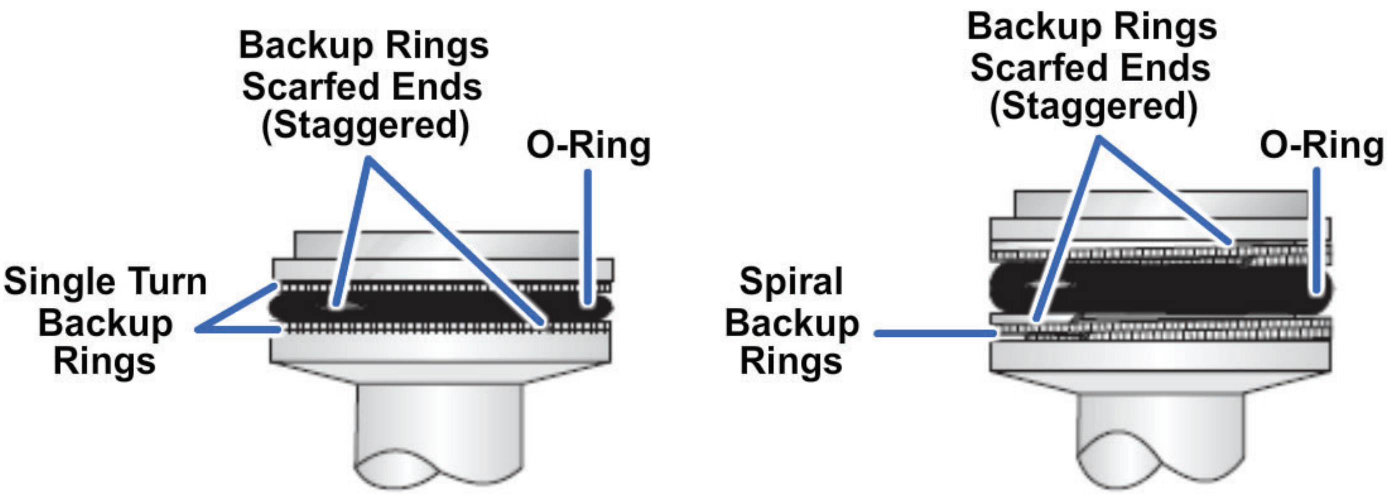


Figure 7-18 — Installation of cut dual.

When TFE spiral rings are being installed in internal grooves, the ring must have a right-hand spiral. *Figure 7-19, view A*, shows how to change the direction of the spiral. The ring is then stretched slightly, as shown in *view B*, prior to installation into the groove. While the TFE ring is being inserted into the groove, rotate the component in a clockwise direction. This action will tend to expand the ring diameter and reduce the possibility of damaging the ring.

When TFE spiral rings are being installed in external grooves, the ring should have a left-hand spiral. As the ring is being inserted into the groove, rotate the component in a clockwise direction. This action will tend to contract the ring diameter and reduce the possibility of damaging the ring.

In applications where a leather backup ring is called for, place the smooth-grained side of the leather next to the ring. Do not cut leather backup rings. Use a leather backup ring as one continuous ring and lubricate the ring prior to installing it, particularly the smaller sizes. If stretching is necessary for proper installation, soak the backup ring in the system fluid or in an acceptable lubricant at room temperature for at least 30 minutes.

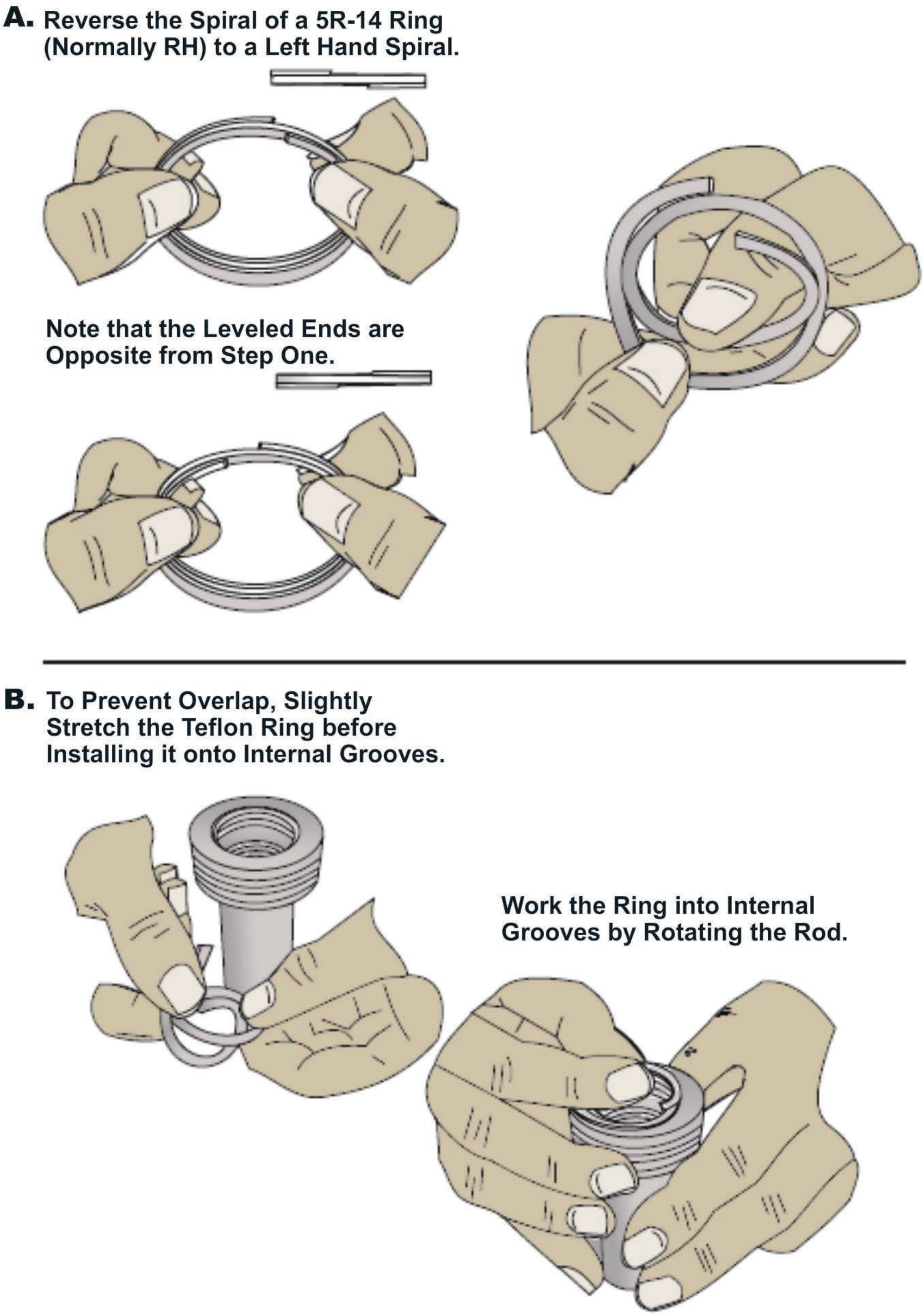


Figure 7-19 — Installation of TFE backup rings (internal).

Quad-Rings®

The Quad-Ring® seal is a special configuration ring packing, manufactured by the Minnesota Rubber and Plastics. As opposed to an O-ring, a Quad-Ring® seal has a more square cross-sectional shape with rounded corners (*Figure 7-20*). The Quad-Ring® seal design offers more stability than the O-ring design and practically eliminates the spiraling or twisting that is sometimes encountered with the O-ring.

Quad-Ring® seals are completely interchangeable with O-rings in the sizes offered by the manufacturer. They may be installed with one or two backup rings, depending upon the specific seal groove application and width. The Quad-Ring® seal works well in both hydraulic and pneumatic systems.

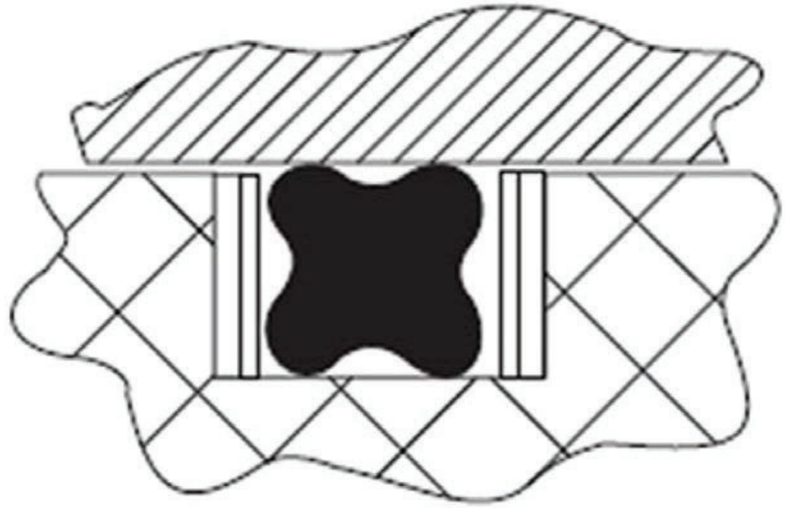


Figure 7-20 — Quad-Ring®.

Many Quad-Ring® seal sizes have been assigned NSNs and are stocked in the Federal Supply System. Quad-Ring® seals in manufacturer's sizes designated as Q1 through Q88 are interchangeable with O-rings conforming to AN6227 in the respective dash sizes from -1 through -88. Likewise, Quad-Ring® seals in commercial sizes Q101 through Q152 are interchangeable with O-rings conforming to AN6230 in the respective dash sizes from -1 through -52. Therefore, the Quad-Ring® seal stock part number uses the AN standard O-ring designations AN6227 and AN6230 and the commercial Q dash number designation. For example, NSNs are found under such reference part numbers as AN6227Q10 and AN6230Q103. If the letter Q does not follow AN6227 or AN6230, the part number is an O-ring not a Quad-Ring® seal.

If Quad-Ring® seals are not available for maintenance actions, appropriate sized O-rings can be installed and they work satisfactorily.

Quad-O-Dyn® Seals

The Quad-O-Dyn®, also manufactured by Minnesota Rubber and Plastics, is a special form of the Quad-Ring®. The Quad-O-Dyn® differs from the Quad-Ring® in configuration (*Figure 7-21*), is harder, is subject to greater squeeze, and is made of a different material. The Quad-O-Dyn® seal also works well in O-ring glands.

The Quad-O-Dyn® is used in relatively few applications. However, for difficult dynamic sealing applications, the Quad-O-Dyn® can perform better than the Quad-Ring®. Quad-O-Dyn ® rings are installed in submarine hydraulic systems plant accumulators.

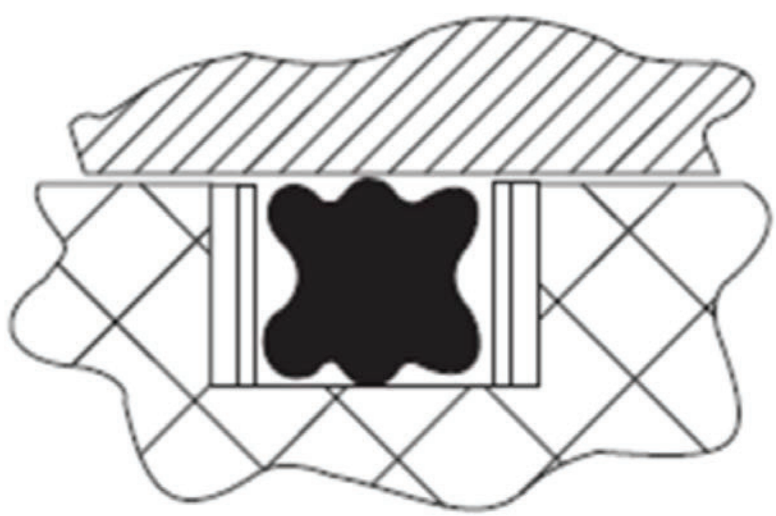


Figure 7-21 — Quad-O-Dyn® seal.

U-Cups and U-Packings

The distinction between U-cups and U-packings results from the difference in materials used in their fabrication. The U-cup is usually made of homogeneous synthetic rubber; U-packings are usually made of leather or fabric-reinforced rubber. Special aspects of each type will be discussed separately. However, all U-cups and U-packings have cross sections resembling the letter U. Both types are balanced packings, both seal on the ID and the OD, and both are applied individually, not in stacks like V-rings. Size differences between U-cups and U-packings are usually substantial enough to prevent interchangeability. There are a few sizes with smaller diameters and cross sections that may appear to be dimensionally equivalent but are not. Therefore, U-packings should not be substituted for U-cups (or vice versa) in any installation.

U-Cups

The U-cup (*Figure 7-22*) has been a popular packing in the past because of installation ease and low friction. U-cups are used primarily for pressures below 1,500 psi, but higher pressures are possible with the use of anti-extrusion rings. For double-acting pistons, two U-cups are installed in separate grooves, back-to-back or heel-to-heel. Two U-cups are never used in the same groove. This heel-to-heel type of installation is common for single-acting (mono-directional) seals, such as U-cups and V-rings, and is necessary to prevent a pressure trap (hydraulic lock) between two packings. Installation of two U-cups with sealing lips facing each other can result in hydraulic lock and must be avoided.

Figure 7-22 — Typical U-cup seal.

Leather U-Packings

As a rule, leather U-packings are made with straight side walls (no flared sealing lips) as seen in *Figure 7-23*. The leather may be chemically treated or otherwise impregnated to improve its performance. Leather U-packings are available in standard sizes conforming to industrial specifications. For support, the cavity of the U-packing should contain a metal pedestal ring or should be filled with a suitable material. Leather U-packings with an integral pedestal support have been installed in some submarine steering and diving ram piston seals.

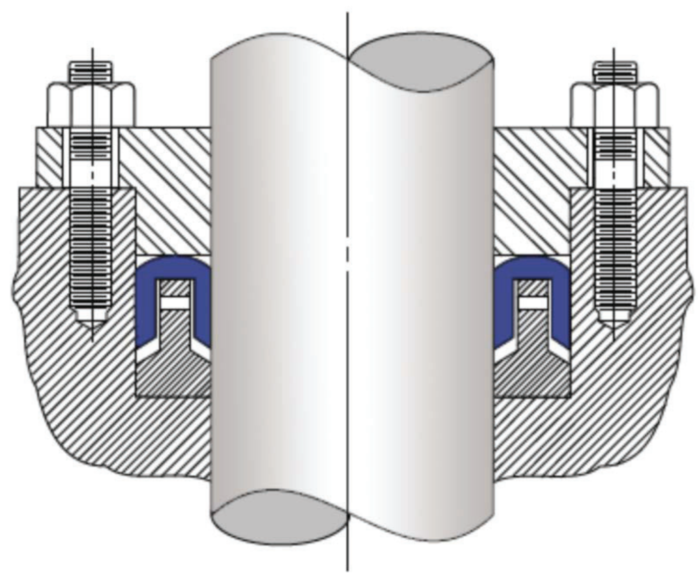


Figure 7-23 — U-packing.

Cup Packings

Cup packings resemble a cup or deep dish with a hole in the center for mounting (*Figure 7-24*). Cup seals are used exclusively to seal pistons in both low- and high-pressure hydraulic and pneumatic service. They are produced in leather, homogeneous synthetic rubber, and fabric-reinforced synthetic rubber. Although the cup packing lip flares outward, the rubbing contact is made at the lip only when the fluid pressure is low. As the fluid pressure increases, the cup heel expands outward until it contacts the cylinder wall, at which point high-pressure sealing is in effect. As the pressure loading shifts the sealing line to the cup heel, the lip is actually pulled into the cup and away from the cylinder wall. On the return stroke when the pressure is relaxed, the heel will shrink slightly, leaving only the lip in contact with the wall, avoiding unnecessary wear at the heel.

For reciprocating pistons, two cups installed back-to-back in separate glands are required.

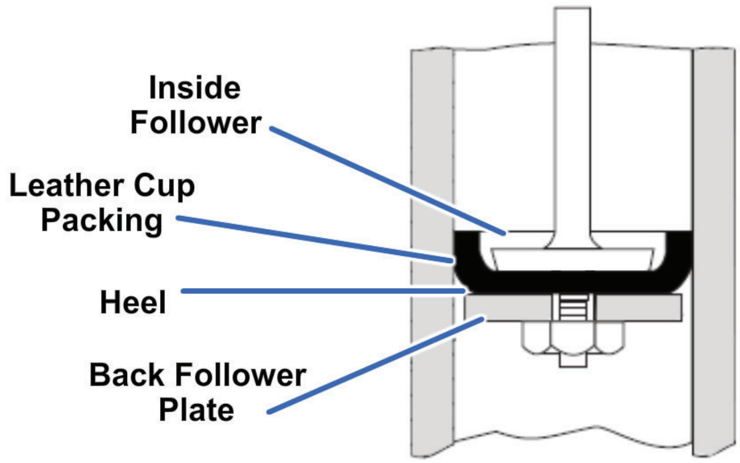


Figure 7-24 — Cup packing.

Flange Packings

Flange packings are used exclusively in low-pressure, outside-packed installations, such as rod seals. The flange (sometimes called the hat) is made of leather, fabric-reinforced rubber, or homogeneous rubber. Lip sealing occurs only on the packing ID (*Figure 7-25*). Flange packings are generally used only for rod seals when other packings such as V-rings or U-seals cannot be used.

Dirt Exclusion Seals (Wipers and Scrapers)

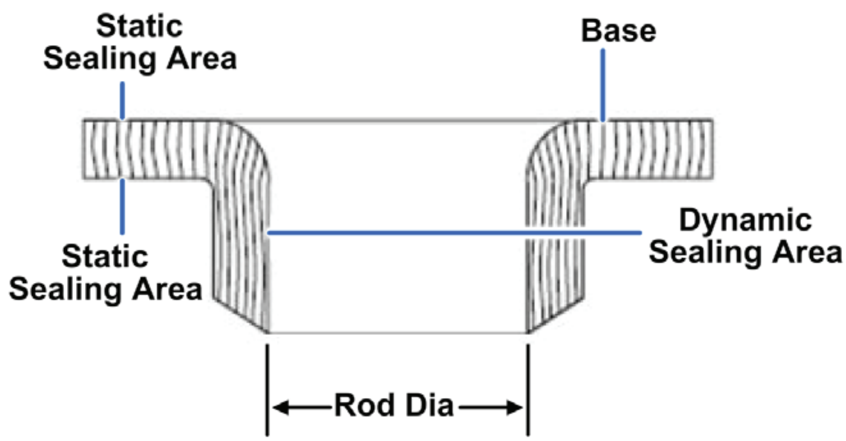


Figure 7-25 — Typical flange packing cross section.

Dirt exclusion devices are essential if a satisfactory life is to be obtained from most rod seals. The smooth finished moving rod surface, if not enclosed or protected by some sort of covering, will accumulate a coating of dust or abrasive material that will be dragged or carried into the packing assembly area on the return rod stroke. Exclusion devices called wipers or scrapers are designed to remove this coating. While the terms wiper and scraper are often used interchangeably, it is useful to reserve scraper for metal lip-type devices that remove heavily encrusted deposits of dirt or other abrasive material that would merely deflect a softer lip and be carried into the cylinder. Sometimes a rod will have both a scraper and a wiper, the former to remove heavy deposits and the latter to exclude any dust particles that remain. Whenever metallic scrapers are used with felt wipers in the same groove, the felt wiper must not be compressed nor restricted in any way that affects its function as a lubricator. A wiper installed in a seal assembly in a pneumatic application may remove too much oil from the rod, requiring some method of replacing the oil. A common remedy is to provide a periodically oiled felt ring between the wiper and the seal. Felt wipers provide lubrication to extended operating rods, thus increasing component wear life. These wipers are only used to provide lubrication to parts.

Much longer life could be obtained from most seals if proper attention were given to wipers and scrapers. Often, wiper or scraper failure is not noticed when a seal packing fails. As a result, only the packing is replaced, and the same worn wiper or scraper is reinstalled to destroy another packing. Check the wiper or scraper condition upon its removal. If the wiper is worn, dirty, or embedded with metallic particles, replace it with a new one. It is usually good practice to replace the wiper every time you replace the seal and even more frequently if the wiper is readily accessible without component disassembly. If replacements are not available, wash dirty wipers that are still in good condition with suitable solvent and reinstall them. Remember that a wiper or scraper is deliberately installed as a sacrificial part to protect and preserve the sealing packing. Therefore, from a user's standpoint, wipers and scrapers should be inspected and replaced as necessary.

STORAGE OF SEALS

Proper storage practices must be observed to prevent deformation and deterioration of seals. Most synthetic rubbers are not damaged by storage under ideal conditions. However, most synthetic rubbers will deteriorate when exposed to heat, light, oil, grease, fuels, solvents, thinners, moisture, strong drafts, or ozone (form of oxygen formed from an electrical discharge). Damage by exposure is magnified when rubber is under tension, compression, or stress. There are several conditions to be avoided, which include the following:

- Deformation as a result of improper stacking of parts and storage containers
- Creasing caused by force applied to corners and edges, and by squeezing between boxes and storage containers
- Compression and flattening as a result of storage under heavy parts
- Punctures caused by staples used to attach identification
- Deformation and contamination due to hanging the seals from nails or pegs. Seals should be kept in their original envelopes, which provide preservation, protection, identification, and cure date
- Contamination by piercing the sealed envelope to store O-rings on rods, nails, or wire hanging devices
- Contamination by fluids leaking from parts stored above and adjacent to the seal surfaces
- Contamination caused by adhesive tapes applied to seal surfaces. A torn seal package should be secured with a pressure-sensitive moisture proof tape, but the tape must not contact the seal surfaces
- Retention of overage parts as a result of improper storage arrangement or illegible identification. Seals should be arranged so the older seals are used first

CHAPTER 8

MEASUREMENT AND PRESSURE CONTROL DEVICES

For safe and efficient operation, fluid power systems are designed to operate at a specific pressure and/or temperature, or within a pressure and/or temperature range.

You have learned that the lubricating power of hydraulic fluids varies with temperature and that excessively high temperatures reduce the life of hydraulic fluids. Additionally, you have learned that the materials, dimensions, and method of fabrication of fluid power components limit the pressure and temperature at which a system operates.

Most fluid power systems are provided with pressure gauges and thermometers for measuring and indicating the pressure and/or the temperature in the system. Additionally, various temperature and pressure switches are used to warn of an adverse pressure or temperature condition. Some switches will even shut the system off when an adverse condition occurs. These devices will be discussed in this chapter.

LEARNING OBJECTIVES

When you have completed this chapter, you will be able the do the following:

1. Recognize the construction of the different types of fluid pressure indicators and thermometers.
2. Recognize the uses of different types of fluid pressure indicators and thermometers.
3. Recognize the construction of the different types of fluid pressure control switches.
4. Identify the operational characteristics of fluid pressure control switches.

PRESSURE GAUGES

The types of pressure gauges used in an engineering plant include Bourdon-tube gauges, bellows and diaphragm gauges, and manometers. Bourdon-tube gauges are generally used for measuring pressures above and below atmospheric pressure. Bellows and diaphragm gauges and manometers are generally used to measure pressures below 15 pounds per square inch gauge (psig). They are also used for low vacuum pressure. Low vacuum pressure is slightly less than 14.7 pounds per square inch absolute (psia). Often, pressure measuring instruments have scales calibrated in inches of water (inH_2O) to allow greater accuracy.

> **NOTE**
>
> On dial pressure gauges, set the adjustable red hand (if installed) at or slightly above the maximum normal operating pressure, or at or slightly below the minimum normal operating pressure. (Refer to Naval Ships' Technical Manual, Chapter 504, for specific instructions).

Bourdon-Tube Gauges

The device usually used to indicate temperature changes by its response to volume changes or to pressure changes is called a Bourdon tube. A Bourdon tube is a C-shaped, curved or twisted tube that is open at one end and sealed at the other (*Figure 8-1*). The open end of the tube is fixed in position, and the sealed end is free to move. The tube is more or less elliptical in cross section; it does not form a true circle. The tube becomes more circular when there is an increase in the volume or the internal pressure of the contained fluid. The spring action of the tube metal opposes this action and tends to coil the tube. Since the open end of the Bourdon tube is rigidly fastened, the sealed end moves as the pressure of the contained fluid changes.

There are many types of Bourdon-tube gauges used in the Navy. The most common ones are the simplex, duplex, vacuum, compound, and differential pressure gauges. They operate on the principle that pressure in a curved tube has a tendency to straighten out the tube. This curved tube is made of bronze for pressures less than 200 pounds per square inch (psi) and of steel for pressures 200 psi and over.

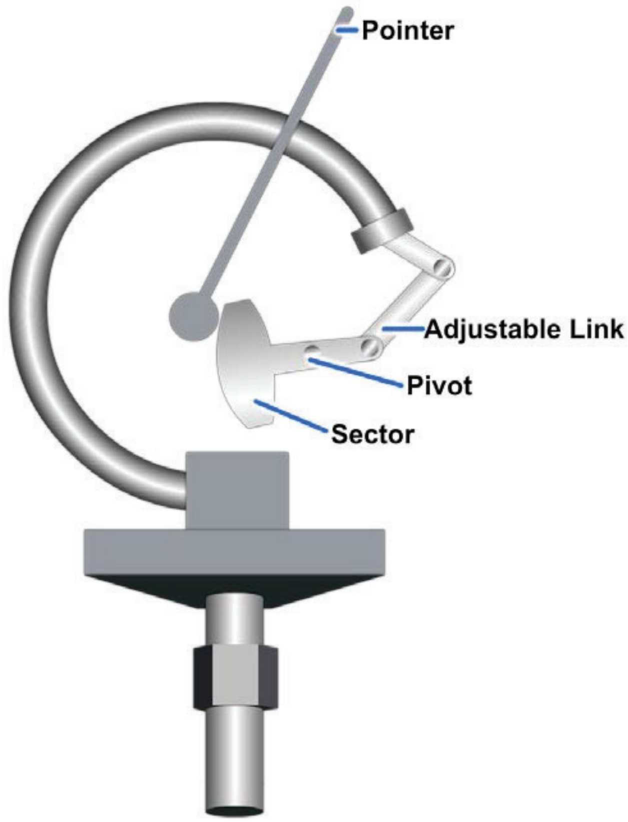


Figure 8-1 — C-shaped Bourdon tube.

Simplex Bourdon-Tube Gauge

A simplex Bourdon tube installed in a gauge case is shown in *Figure 8-2*. Notice that the Bourdon tube is in the shape of the letter C and is welded or silver-brazed to the stationary base. The free end of the tube is connected to the indicating mechanism by a linkage assembly. The threaded socket, welded to the stationary base, is the pressure connection. When pressure enters the Bourdon tube, the tube tends to straighten out. The tube movement through linkage causes the pointer to move proportionally to the pressure applied to the tube. The simplex gauge is used for measuring the pressure of steam, air, water, oil, and similar fluids or gases.

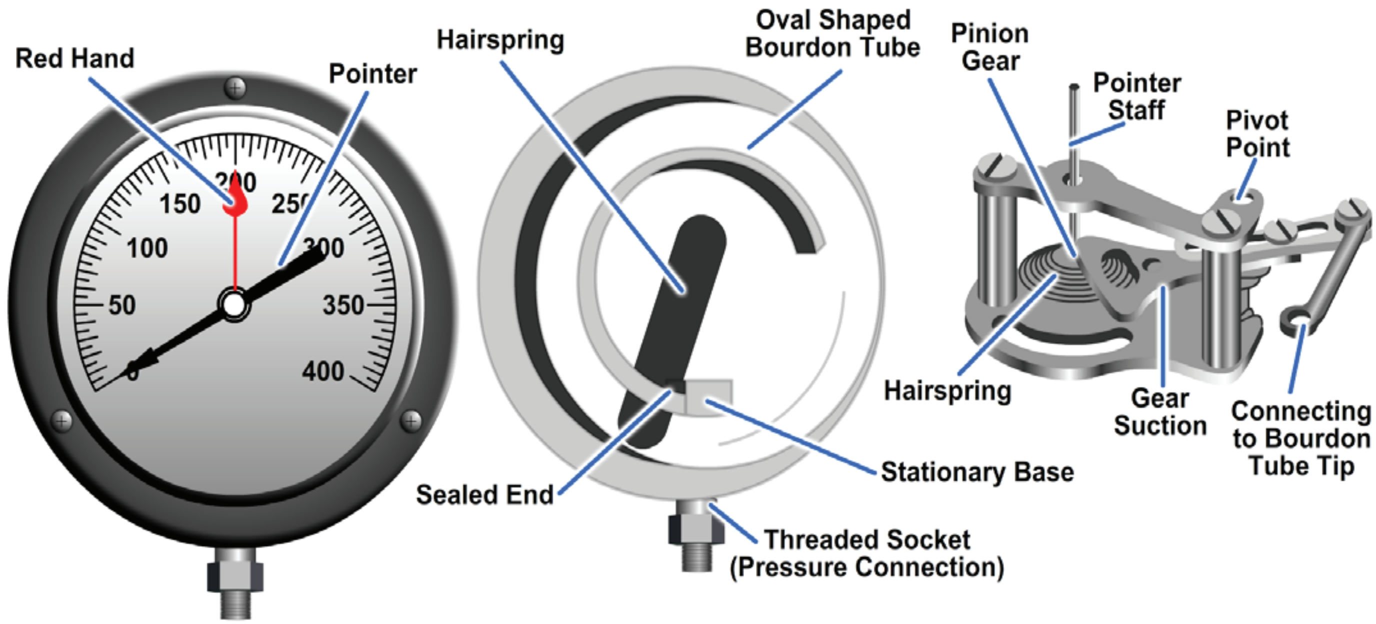


Figure 8-2 — Simplex Bourdon-tube pressure gauge.

Duplex Bourdon-Tube Gauge

The duplex Bourdon-tube gauge (*Figure 8-3*) has two tubes and two separate gear mechanisms within the same case. A pointer is connected to the gear mechanism of each tube. Each pointer operates independently. Duplex gauges are normally used to show pressure drops between the inlet and outlet sides of lube oil and fuel oil strainers. If the pressure reading for the inlet side of a strainer is much greater than the pressure reading for the outlet side, it may be assumed that the strainer is likely to be dirty and is restricting the flow of lube oil and fuel oil through the strainer.

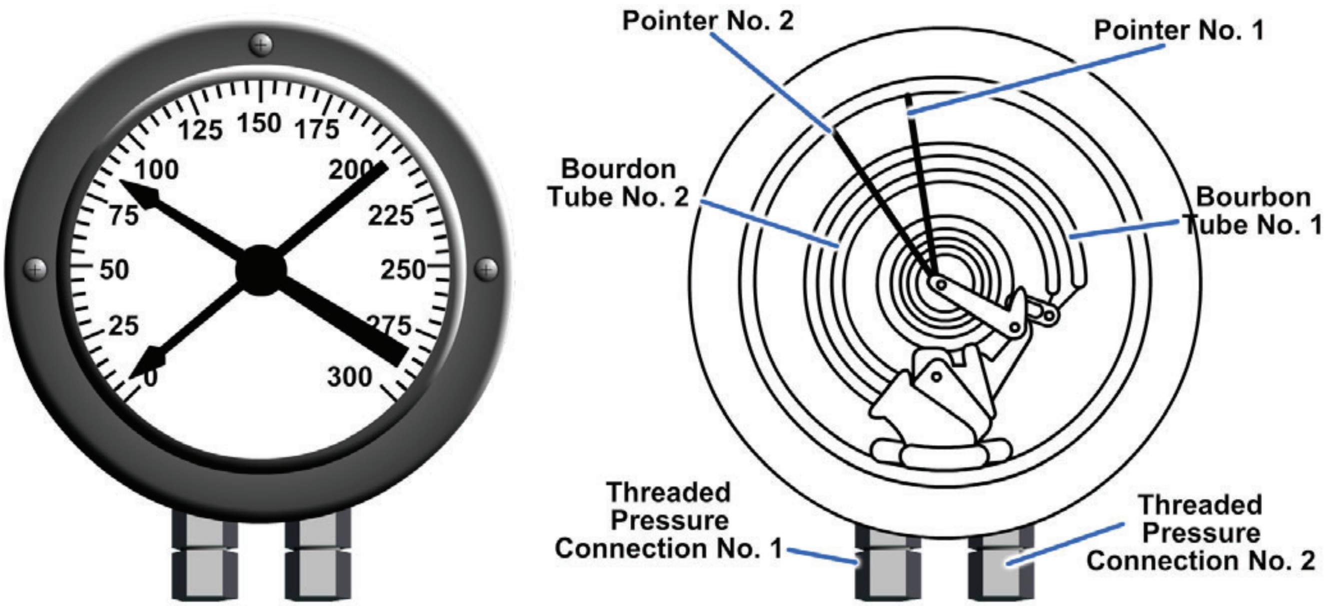


Figure 8-3 — Duplex Bourdon-tube pressure gauge.

Bourdon-Tube Vacuum Gauge, Compound Gauge, and Differential Pressure Gauge

Bourdon-tube vacuum gauges are marked off in inches of mercury (inHg) (*Figure 8-4*). When a gauge is designed to measure both vacuum and pressure, it is called a compound gauge. Compound gauges are marked off in both in Hg and psig (*Figure 8-5*).

Figure 8-4 — Bourdon-tube vacuum gauge.

Figure 8-5 — Compound Bourdon-tube gauge.

Differential pressure may also be measured with Bourdon-tube gauges. One of the types of Bourdon-tube differential pressure gauges is shown in *Figure 8-6*. This gauge has two Bourdon tubes, but only one pointer. The Bourdon tubes are connected in such a way that they show the pressure difference, rather than either of the two actual pressures indicated by the pointer.

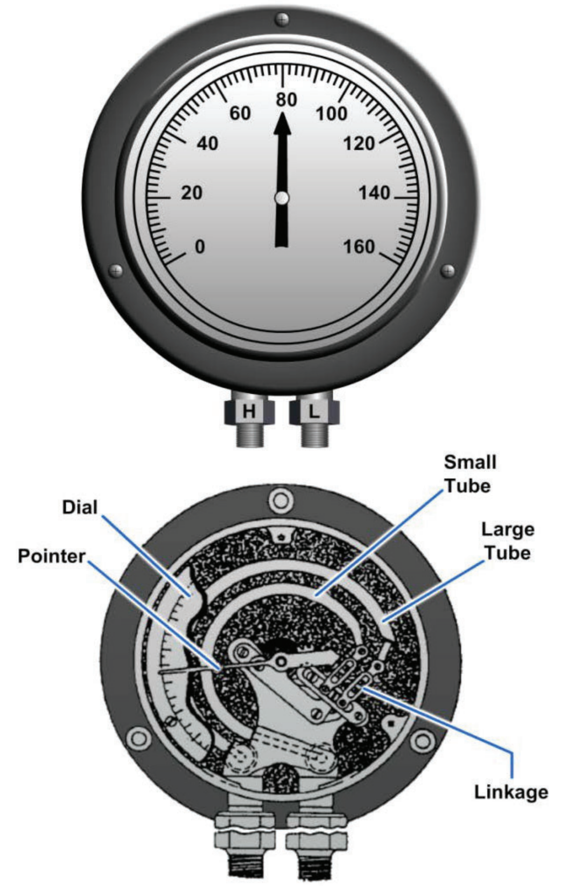


Figure 8-6 — Bourdon-tube differential pressure gauge.

Bellows Gauge

A bellows gauge contains an elastic element that is a convoluted unit that expands and contracts axially with changes in pressure. The pressure to be measured can be applied to the outside or inside of the bellows. However, in practice, most bellows measuring devices have the pressure applied to the outside of the bellows (*Figure 8-7*). Like Bourdon-tube elements, the elastic elements in bellows gauges are made of brass, phosphor bronze, stainless steel, beryllium-copper, or other metal that is suitable for the intended purpose of the gauge.

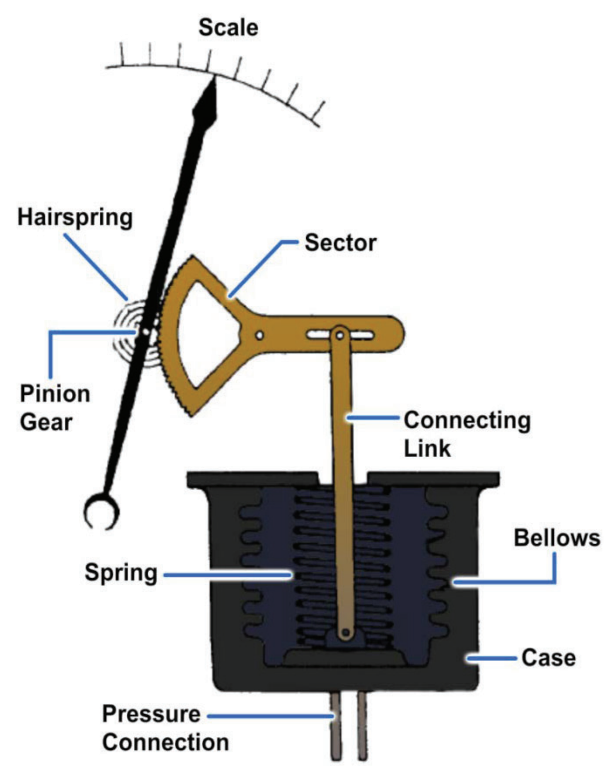


Figure 8-7 — Bellows gauge.

Most bellows gauges are spring-loaded; that is, a spring opposes the bellows, thus preventing full expansion of the bellows. Limiting the expansion of the bellows in this way protects the bellows and prolongs its life. In a spring-loaded bellows element, the deflection is the result of the force acting on the bellows and the opposing force of the spring.

Although some bellows instruments can be designed for measuring pressures up to 800 psig, their primary application aboard ship is in the measurement of low pressures or small pressure differentials.

PRESSURE SWITCHES

It is often desirable to have an alarm sound a warning, a light give a signal, or an auxiliary control system energize or de-energize when a measured pressure reaches a certain minimum or maximum value. A pressure switch is the device commonly used for this purpose.

One of the simplest pressure switches is the single-pole, single-throw, quick-acting type shown in *Figure 8-8*. This switch is contained in a metal case that has a removable cover, an electrical connection, and a pressure-sensing connection. The switch contains a seamless metallic bellows located in its housing. Changes in the measured pressure cause the bellows to work against an adjustable spring. This spring determines the pressure required to actuate the switch. Through suitable linkage, the spring causes the contacts to open or close the electrical circuit automatically when the operating pressure falls below or rises above a specified value. A permanent magnet in the switch mechanism provides a positive snap on both the opening and closing of the contacts. The switch is constantly energized. However, it is the closing of the contacts that energizes the entire electrical circuit.

Another pressure switch is an electrohydraulic assembly that is used for shutting off the pump's motor whenever the system pressure exceeds a pre-determined maximum value (*Figure 8-9*). The switch is mounted on the pump housing so that the former's low pressure ports drain directly into the pump housing.

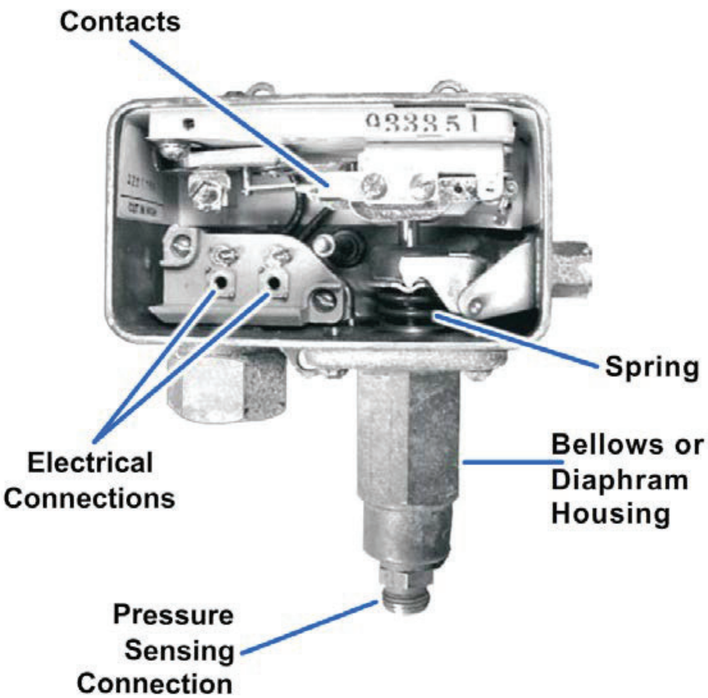


Figure 8-8 — Typical pressure switch.

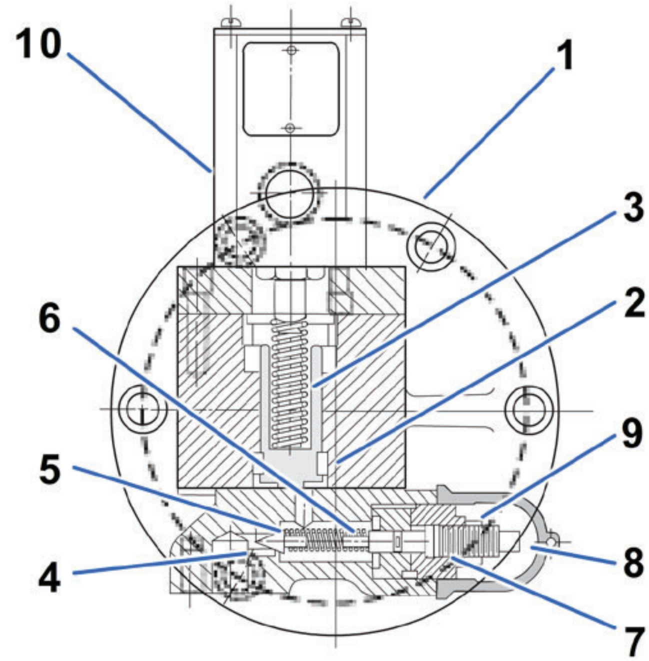


Figure 8-9 — Electrohydraulic pressure switch.

This pressure switch principally consists of a flange-mounted hydraulic valve to which is fixed a normally closed electrical limit switch. The valve consists of two hydraulically interconnected components. The pilot valve subassembly, which bolts on the bottom of the body (1), functions to sense system pressure continuously, and initiates pressure switch action whenever this pressure exceeds the adjusted setting of the pilot adjustment. System pressure is directed into the bottom port and is applied against the exposed tip of the pilot piston (5). This piston is held on its seat by compression from the piston spring (6) which is dependent on the position of the adjusting screw (8). Whenever the pressure causes a force large enough to raise the pilot piston from its seat, fluid flows through an interconnecting passage to the actuating piston (2) chamber. The accompanying fluid force raises the actuating piston against the force of spring (3) and causes depression of the extended switch plunger. This action disconnects the contained electrical switch, which may be connected into the pump motor's electric supply system.

Pressure switches come in many sizes and configurations depending on how they will be used.

TEMPERATURE MEASURING DEVICES

Temperature is one of the basic engineering variables. Therefore, temperature measurement is essential to the proper operation of a shipboard engineering plant. As a watchstander, you will use both mechanical and electrical instruments to monitor temperature levels. You will frequently be called on to measure the temperature of steam, water, fuel, lubricating oil, and other vital fluids. In many cases, you will enter the results of measurements in engineering logs and records.

Thermometers (Mechanical)

Mechanical devices used to measure temperature are classified in various ways. In this section, we will discuss only the expansion thermometer types. Expansion thermometers operate on the principle that the expansion of solids, liquids, and gases has a known relationship to temperature change. The following types of expansion thermometers are discussed in this section:

- Liquid-in-glass thermometers
- Bimetallic expansion thermometers
- Filled-system thermometers

Liquid-in-Glass Thermometers

Liquid-in-glass thermometers are the oldest, simplest, and most widely used devices for measuring temperature. A liquid-in-glass thermometer (*Figure 8-10*) has a bulb and a very fine-bore capillary tube. The tube contains alcohol or some other liquid that uniformly expands or contracts as the temperature rises or falls. The selection of liquid is based on the temperature range for which the thermometer is to be used.

Almost all liquid-in-glass thermometers are sealed so atmospheric pressure does not affect the reading. The space above the liquid in this type of thermometer may be a vacuum, or this space maybe filled with an inert gas, such as nitrogen, argon, or carbon dioxide.

The capillary bore may be round or elliptical. In either case, it is very small; therefore, a relatively small expansion or contraction of the liquid causes a relatively large change in the position of the liquid in the capillary tube. Although the capillary bore has a very small diameter, the walls of the capillary tube are quite thick. Most liquid-in-glass thermometers have an expansion chamber at the top of the bore to provide a margin of safety for the instrument if it should accidentally overheat.

Liquid-in-glass thermometers may have graduations etched directly on the glass stem or placed on a separate strip of material located behind the stem. Many thermometers used in shipboard engineering plants have the graduations marked on a separate strip because this type is generally easier to read.

You will find liquid-in-glass thermometers in use in the oil and water test lab for analytical tests on fuel, oil, and water.

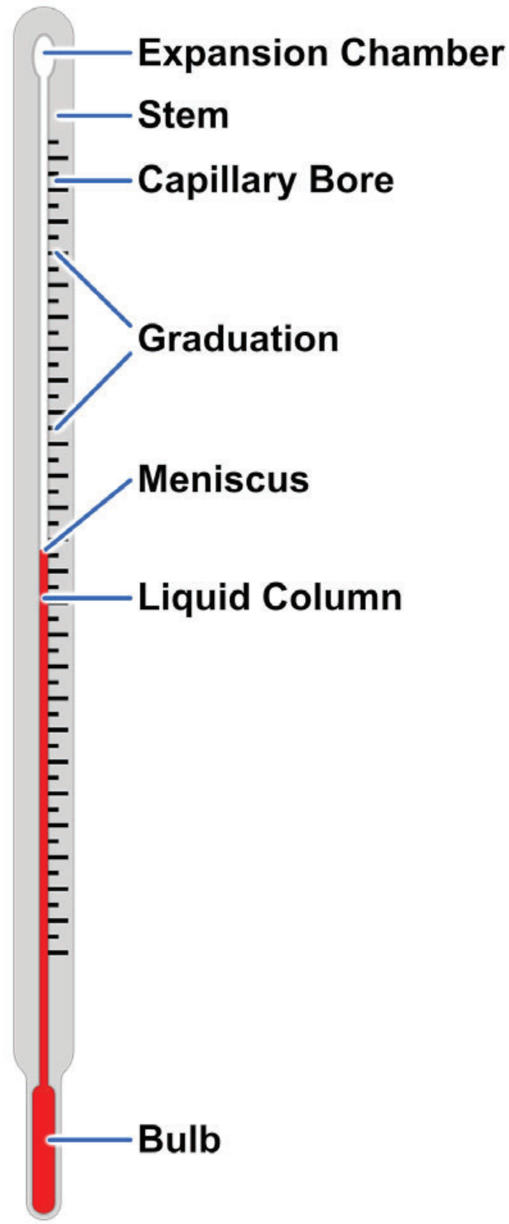


Figure 8-10 — Liquid-in-glass thermometer.

Bimetallic Expansion Thermometers

Bimetallic expansion thermometers make use of different metals that have different coefficients of linear expansion. The essential element in a bimetallic expansion thermometer is a bimetallic strip consisting of two layers of different metals fused together. When such a strip is subjected to temperature changes, one layer expands or contracts more than the other, thus tending to change the curvature of the strip.

The basic principle of a bimetallic expansion thermometer is shown in *Figure 8-11*. One end of a straight bimetallic strip is fixed in place. As the strip is heated, the other end tends to curve away from the side that has the greater coefficient of linear expansion.

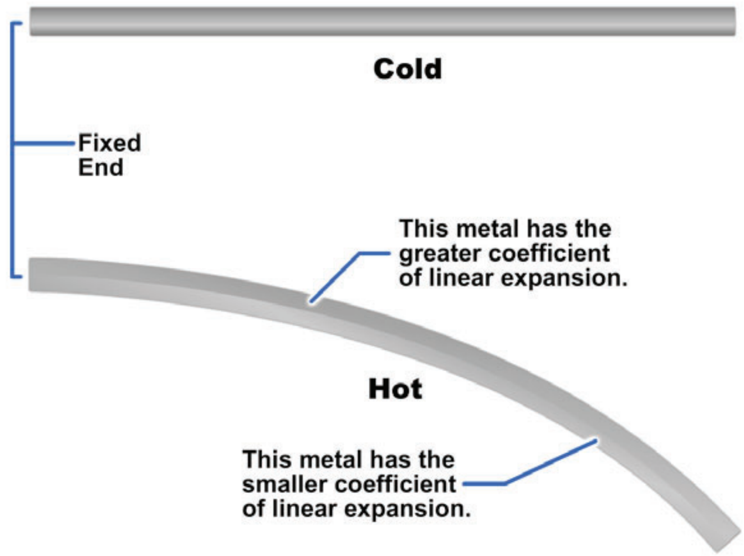


Figure 8-11 — Effect of unequal expansion of a bimetallic strip.

When used in thermometers, the bimetallic strip is normally wound into a flat spiral, a single helix, or a multiple helix (*Figure 8-12*). The end of the strip that is not fixed in position is fastened to the end of a pointer that moves over a circular scale. Bimetallic thermometers are easily adapted for use as recording thermometers. This function is accomplished by attaching a pen to the pointer and positioning the bimetallic thermometer so that it marks on a revolving chart.

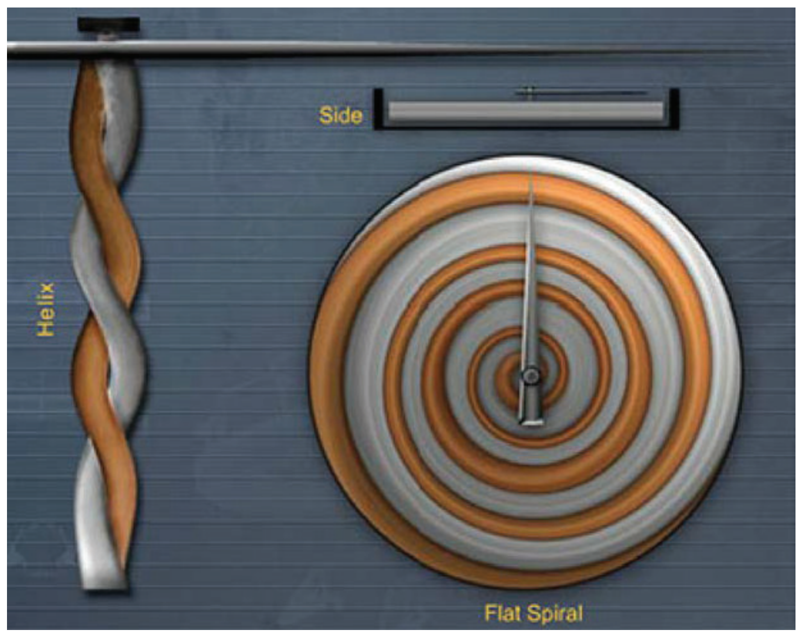


Figure 8-12 — Bimetallic thermometer (flat, spiral strip).

Filled-System Thermometers

Generally, filled-system thermometers are used in locations where the indicating part of the instrument must be placed some distance away from the point where the temperature is to be measured. In a filled-system thermometer, temperature is converted into a mechanical motion caused by pressure or expansion. The components of a filled-system thermometer are comprised of the thermometer bulb, an expansion element, such as a Bourdon tube, diaphragm, capsule or bellows, and a capillary tube connecting the bulb and the expansion element. Some distant-reading thermometers have capillaries as long as 125 feet.

There are two basic types of filled-system thermometers used in Navy applications. One type has a Bourdon tube that responds primarily to changes in the volume of the filling fluid. The other type has a Bourdon tube that responds primarily to changes in the pressure of the filling fluid.

A distant-reading thermometer (*Figure 8-13*) consists of a hollow metal sensing bulb at one end of a small-bore capillary tube. The tube is connected to a Bourdon tube or other device that responds to volume changes or pressure changes. The system is partially or completely filled with a fluid that expands when heated and contracts when cooled. The fluid may be a gas, an organic liquid, or a combination of liquid and vapor.

Pyrometers

Pyrometers are used to measure temperature through a wide range, generally between 300 and 3,000 degrees Fahrenheit (°F). Aboard ship, pyrometers are used to measure temperatures in heat treatment furnaces, measure the exhaust temperatures of diesel engines, and for other similar purposes.

The pyrometer consists of a thermocouple and a meter (*Figure 8-14*). The thermocouple is made of two dissimilar metals joined together at one end. It produces an electric current when heat is applied at its joined end. The meter, calibrated in degrees, indicates the temperature at the thermocouple.

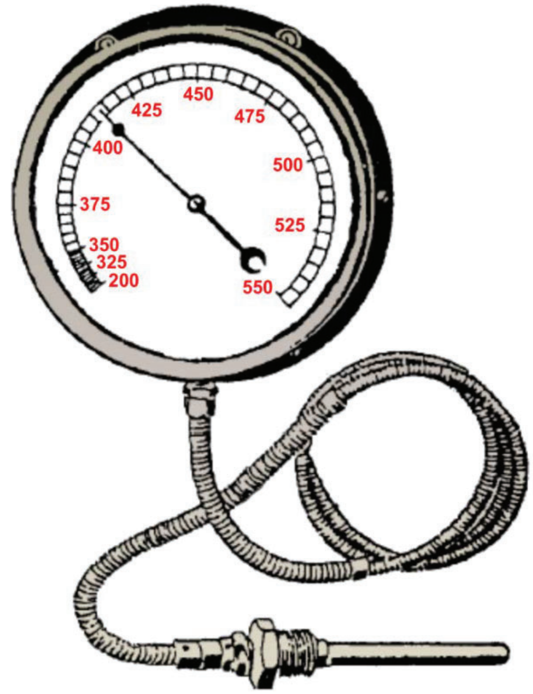


Figure 8-13 — Distant-reading, Bourdon-tube thermometer.

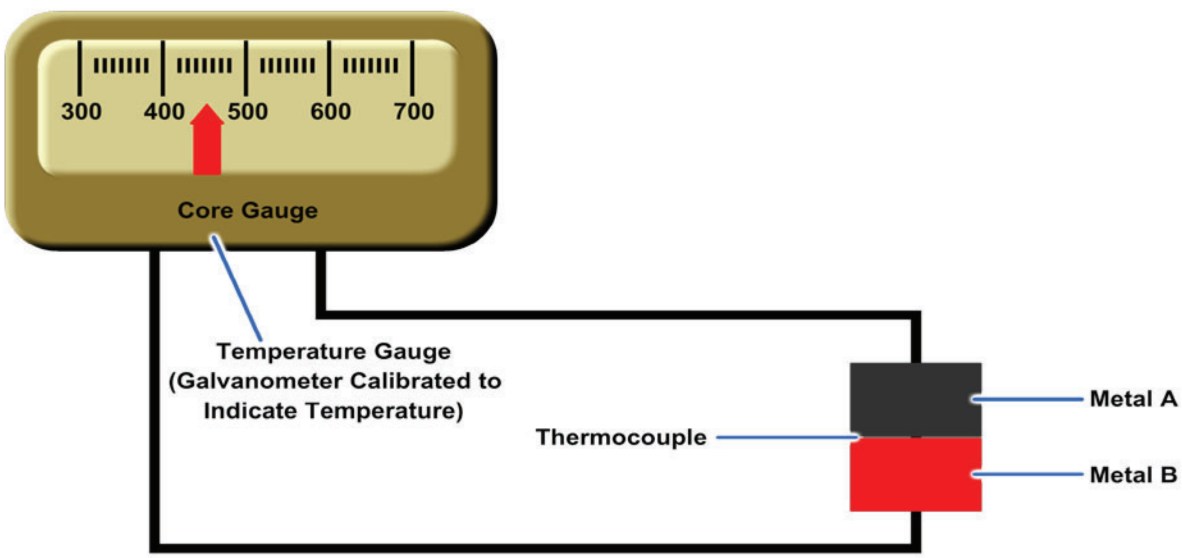


Figure 8-14 — Diagram arrangement of a thermocouple.

ELECTRICAL TEMPERATURE MEASURING DEVICES

On newer propulsion plants, temperature readings are monitored at remote locations. Expansion thermometers provide indications at the machinery locations or on gauge panels in the immediate thermometer area. To provide remote indications at a central location, electrical measuring devices along with signal conditioners are used. The devices discussed in this section include the resistance temperature detectors (RTDs), resistance temperature elements (RTEs), and thermocouples. These devices sense variable temperatures at a given point in the system and transmit the signals to a remotely located indicator.

Resistance Temperature Detectors (RTDs)

The RTDs operate on the principle that electrical resistance changes in a predictable manner with changes in temperature. The elements of RTDs are made of nickel, copper, or platinum. Nickel and copper are used to measure temperatures below 600 °F. Platinum elements are used to measure temperatures above 600 °F. Two typical types of RTDs are shown in *Figure 8-15*.

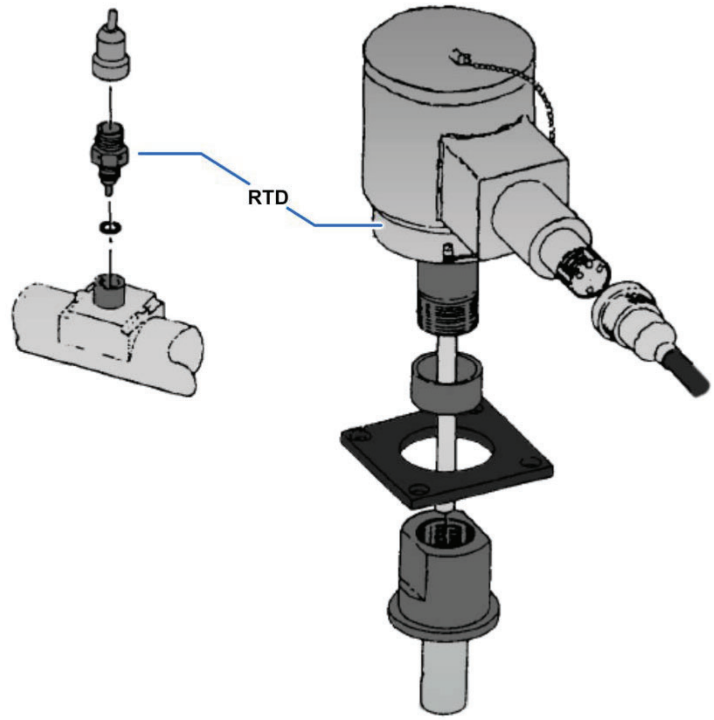


Figure 8-15 — Two typical types of RTDs.

Like bimetallic thermometers, RTDs are usually mounted in thermowells. Thermowells protect the sensors from physical damage by keeping them isolated from the medium being measured. This arrangement also allows the RTD to be changed without securing the system in which it is mounted, making the maintenance job easier.

As temperature increases around an RTD, the corresponding resistance also increases proportionally. The temperature applied to an RTD, if known, gives a known resistance value. These resistance values can be found listed in tables in the manufacturers' technical manuals. Normally, only a few resistance values are given.

To test an RTD, it must be heated to a specific temperature. At this temperature, the resistance of the RTD should be at the resistance shown in the manufacturer's table. The most common method of heating an RTD is to use a pan of hot water and a calibrated thermometer. Some newer ships and repair activities test RTDs using a thermobulb tester. This method is more accurate and easier to use. For specific instructions, refer to the manufacturers' technical manuals supplied with the equipment.

The most common fault found with an RTD is either a short circuit or an open circuit. These faults can be quickly diagnosed by using digital display readings or data log printouts. By observing the reading or the printout, the indication will be either zero or a very low value. A malfunction of this type means a short circuit exists in either the RTD or its associated wiring. A very high reading, such as 300 °F on a 0 to 300 °F RTD, could indicate an open circuit. These readings should be compared to local thermometers. This precaution ensures that no abnormal conditions exist within the equipment that the RTD serves.

If an RTD is faulty, it should be replaced. Internal repairs cannot be made at the shipboard level. Until the faulty RTD is replaced, the watchstanders should be informed that the RTD is unreliable. The engine-room watchstanders should take local readings periodically to make sure the equipment is operating normally.

Resistance Temperature Elements (RTEs)

The RTEs are the most common type of temperature sensor found in gas turbine propulsion plants. The RTEs operate on the same principle as the RTDs. As the temperature of the sensor increases, the resistance of the RTE increases proportionally. All RTEs watchstanders encounter have a platinum element. They have an electrical resistance of 100 ohms at a temperature of 32 °F. Four different temperature ranges of RTEs are commonly used, and the probe sizes vary. The four temperature ranges and their corresponding probe sizes are as follows:

TEMPERATURE RANGE (Degree Fahrenheit)	RTE PROBE LENGTH (Inches)
-20 to +150	6
0 to +400	2, 4, and 10
0 to +1,000	2
-60 to +500	6

Some RTEs are connected to remote mounted signal conditioning modules. These modules convert the ohmic value of the RTE to an output range of 4 to 20 milliamperes (mA) direct current (dc). However, most RTEs read their value directly into the propulsion electronics as an ohmic value.

The RTEs with temperature ranges from 0 to +400 °F and from -60 to +500 °F are commonly mounted in thermowells. Since an RTE can be changed without securing the equipment it serves, maintenance is simplified.

GAUGE SNUBBERS

The irregularity of impulses applied to the fluid power system by some pumps or air compressors causes the gauge pointer to oscillate violently. This oscillation makes reading of the gauge not only difficult but often impossible. Pressure oscillations and other sudden pressure changes existing in fluid power systems will also affect the delicate internal mechanism of gauges and cause either damage to or complete destruction of the gauge. A pressure gauge snubber (*Figure 8-16*) is therefore installed in the line that leads to the pressure gauge.

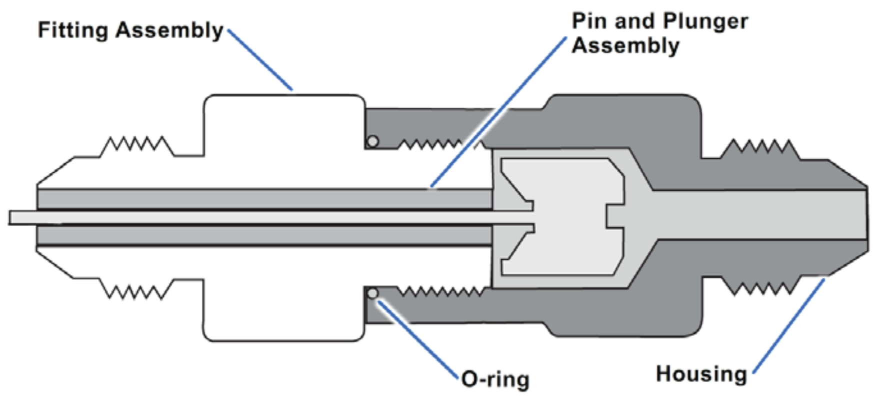


Figure 8-16 — Basic components of a snubber.

The purpose of the snubber is to dampen the oscillations and thus provide a steady reading and protection for the gauge. The basic components of a snubber are the housing, fitting assembly with a fixed orifice diameter, and a pin and plunger assembly. The snubbing action is obtained by metering fluid through the snubber. The fitting assembly orifice restricts the amount of fluid that flows to the gauge, thereby snubbing the force of a pressure surge. The pin is pushed and pulled through the orifice of the fitting assembly by the plunger, keeping it clean and at a uniform size.

APPENDIX I

GLOSSARY

ABSOLUTE TEMPERATURE—The temperature measured using absolute zero (-273.16 degrees Celsius or -459.69 degrees Fahrenheit) as a reference.

ACCELERATION—The increase in the rate or speed of an object.

ACCUMULATOR—A device for storing liquid under pressure. It usually consists of a chamber separated into a gas compartment and a liquid compartment by a piston or diaphragm. An accumulator also serves to smooth out pressure surges in a hydraulic system.

ACTUATOR—A device that converts fluid power into mechanical force and motion.

ADDITIVE—A chemical compound or compounds added to a fluid to change its properties.

AIR, COMPRESSED—Air at any pressure greater than atmospheric pressure.

AMBIENT—Surrounding, such as ambient air, meaning surrounding air.

BAROMETER—An instrument that measures atmospheric pressure.

BAROMETER, ANEROID—Uses the change in shape of an evacuated metal cell (aneroid) to measure variations in atmospheric pressure.

BERNOULLI'S PRINCIPLE—If a fluid flowing through a tube reaches a constriction, or narrowing of the tube, the velocity of the fluid flowing through the constriction increases and the pressure decreases.

BOYLE'S LAW—The absolute pressure of a fixed mass of gas varies inversely with the volume, provided the temperature remains constant.

CAVITATION—A localized gaseous condition within a liquid stream that occurs where the pressure is reduced to the vapor pressure.

CELSIUS—The temperature scale using the freezing point of water as zero and the boiling point as 100, with 100 equal divisions between, called degrees. This scale was formerly known as the centigrade scale.

CENTIGRADE—(See Celsius.)

CENTRIFUGAL FORCE—A force exerted on a rotating object in a direction outward from the center of rotation.

CHARLES' LAW—If the pressure is constant, the volume of dry gas varies directly with the absolute temperature.

CHEMICAL CHANGE—A change that alters the composition of the molecules of a substance.

CIRCUIT—An arrangement of interconnected component parts.

CLOSED-CENTER SYSTEM—A type of fluid power system in which fluid is pressurized any time a power pump is operated.

COMPRESSIBILITY—The change in volume of a unit volume of a fluid when it is subjected to a unit change of pressure.

COMPRESSOR—A device that converts mechanical force and motion into pneumatic fluid power.

COMPUTER—A device capable of accepting information, applying prescribed processes to the information, and supplying the results of these processes.

CONDENSATION—The change from a gaseous (or vapor) state to a liquid state.

CONTAMINATION—Any foreign material or substance whose presence in a fluid is capable of adversely affecting system performance or reliability.

CONTINUITY EQUATION—The mass rate of fluid flow into any fixed space is equal to the mass flow rate out. Therefore, the mass flow rate of fluid past all cross sections of a conduit is equal.

CONTROL—A device used to regulate the function of a component or system.

CONTROL, CYLINDER—A control in which a fluid cylinder is the actuating device.

CONTROL, ELECTRIC—A control actuated electrically.

CONTROL, HYDRAULIC—A control actuated by a liquid.

CONTROL, MANUAL—A control actuated by the operator.

CONTROL, MECHANICAL—A control actuated by linkages, gears, screws, cams, or other mechanical elements.

CONTROL, PNEUMATIC—A control actuated by air or other gas pressure.

CONTROL, SERVO—A control actuated by a feedback system that compares the output with the reference signal and makes corrections to reduce the difference.

CONTROLS, PUMP—Controls applied to positive-displacement variable delivery pumps to adjust their volumetric output or direction of flow.

CONVERGENT—That which inclines and approaches nearer together, as the inner walls of a tube that is constricted.

COOLER—A heat exchanger, which removes heat from a fluid.

COOLER, AFTERCOOLER—A device that cools a gas after it has been compressed.

COOLER, INTERCOOLER—A device that cools a gas between the compressive steps of a multiple stage compressor.

COOLER, PRECOOLER—A device that cools a gas before it is compressed.

CORROSION—The slow destruction of materials by chemical agents and electromechanical reactions.

CYCLE—A single complete operation consisting of progressive phases starting and ending at the neutral position.

CYLINDER—A device that converts fluid power into linear mechanical force and motion. It usually consists of a movable element, such as a piston and piston rod, plunger, or ram, operating within a cylindrical bore.

CYLINDER, CUSHIONED—A cylinder with a piston-assembly deceleration device at one or both ends of the stroke.

CYLINDER, DOUBLE-ACTING—A cylinder in which fluid force can be applied to the movable element in either direction.

CYLINDER, DOUBLE-ROD—A cylinder with a single piston and a piston rod extending from each end.

CYLINDER, DUAL-STROKE—A cylinder combination that provides two working strokes.

CYLINDER, PISTON—A cylinder in which the movable element has a greater cross-sectional area than the piston rod.

CYLINDER, PLUNGER—A cylinder in which the movable element has the same cross-sectional area as the piston rod.

CYLINDER, SINGLE-ACTING—A cylinder in which the fluid force can be applied to the movable element in only one direction.

CYLINDER, SINGLE-ROD—A cylinder with a piston rod extending from one end.

CYLINDER, SPRING-RETURN—A cylinder in which a spring returns the piston assembly.

CYLINDER, TANDEM—Two or more cylinders with interconnected piston assemblies.

CYLINDER, TELESCOPING—A cylinder with nested multiple tubular rod segments, which provide a long working stroke in a short retracted envelope.

DENSITY—The weight per unit volume of a substance.

DIAGRAM, COMBINATION—A drawing using a combination of graphical, cutaway, and pictorial symbols.

DIAGRAM, CUTAWAY—A drawing showing principal internal parts of all components, controls, and actuating mechanisms, all interconnecting lines, and functions of individual components.

DIAGRAM, GRAPHICAL—A drawing or drawings showing each piece of apparatus, including all interconnecting lines, by approved standard symbols.

DIAGRAM, PICTORIAL—A drawing showing each component in its actual shape according to the manufacturer's installation.

DIAGRAM, SCHEMATIC—See **DIAGRAM, GRAPHICAL.**

DIAPHRAGM—A dividing membrane or thin partition.

DIFFUSER—A duct of varying cross section designed to convert a high-speed gas flow into low-speed flow at an increased pressure.

DISPLACEMENT—The volume of fluid that can pass through a pump, motor, or cylinder in a single revolution or stroke.

DIVERGENT—Moving away from each other, as the inner wall of a tube that flares outward.

EDUCTOR—A jet-type pump with no moving parts that is designed to pump large volumes of water.

EFFICIENCY—The ratio of the output power to the input power, generally expressed as a percentage.

ENERGY—The ability or capacity to do work.

EQUILIBRIUM—A state of balance between opposing forces or actions.

FAHRENHEIT—The temperature scale using the freezing point of water as 32 and the boiling point as 212, with 180 equal divisions between, called degrees.

FEEDBACK—A transfer of energy from the output of a device to its input.

FILTER—A device whose primary function is the retention by a porous media of insoluble contaminants from a fluid.

FILTER ELEMENT—The porous device that performs the actual process of filtration.

FILTER MEDIA—The porous materials that perform the actual process of filtration.

FILTER MEDIA, SURFACE—Porous materials that primarily retain contaminants on the influent face.

FIRE POINT—The temperature at which a substance gives off vapor in a sufficient quantity to ignite and continue to burn when exposed to a spark or flame.

FLASHPOINT—The temperature to which a liquid must be heated under specified test conditions to give off sufficient vapor to form a mixture with air that can be ignited momentarily by a specified flame.

FLOW, LAMINAR—A flow situation in which fluid moves in parallel layers (also referred to as streamline flow).

FLOW, METERED—Flow at a controlled rate.

FLOW, TURBULENT—A flow situation in which the fluid particles move in a random manner.

FLOW RATE—The volume, mass, or weight of a fluid passing through any conductor per unit of time.

FLOWMETER—An instrument used to measure quantity or the flow rate of a fluid motion.

FLUID—A liquid or a gas.

FLUID FLOW—The stream or movement of a fluid, or the rate of its movement.

FLUID FRICTION—Friction due to the viscosity of fluids.

FLUID, FIRE-RESISTANT—A fluid, difficult to ignite, which shows little tendency to propagate flame.

FLUID, HYDRAULIC—A fluid suitable for use in a hydraulic system.

FLUID, PETROLEUM—A fluid composed of petroleum oil. It may contain additives.

FLUID, PHOSPHATE ESTER BASE—A fluid that contains a phosphate ester as one of the major components.

FLUID, SILICONE—A fluid composed of silicones. It may contain additives.

FLUID, WATER-GLYCOL—A fluid whose major constituents are water and one or more glycols or polyglycols.

FLUID STABILITY—Resistance of a fluid to permanent change in properties.

FLUID POWER—Energy transmitted and controlled through the use of fluids under pressure.

FLUID POWER SYSTEM—A system that transmits and controls power through use of a pressurized fluid within an enclosed circuit.

FOAMING—An emulsion of gas bubbles in a fluid. Foaming in a hydraulic system results from compressed gases in the hydraulic fluid.

FOOT-POUND—The amount of work accomplished when a force of 1 pound produces a displacement of 1 foot.

FORCE—The action of one body on another tending to change the state of motion of the body acted upon.

FREE FLOW—Flow that encounters negligible resistance.

FRICTION—The action of one body or substance rubbing against another, such as fluid flowing against the walls of pipe; the resistance to motion caused by this rubbing.

FRICTION PRESSURE DROP—The decrease in the pressure of a fluid flowing through a passage attributable to the friction between the fluid and the passage walls.

GAS—The form of matter that has neither a definite shape nor a definite volume.

GASKET—A class of seals that provides a seal between two stationary parts.

GAUGE—An instrument or device for measuring, indicating, or comparing a physical characteristic.

GAUGE PRESSURE—Pressure above atmospheric pressure.

GAUGE SNUBBER—A device installed in the line to the pressure gauge used to dampen pressure surges and thus provide a steady reading and protection for the gauge.

GAUGE, BELLOWS—A gauge in which the sensing element is a convoluted closed cylinder. A pressure differential between the outside and the inside causes the cylinder to expand or contract axially.

GAUGE, BOURDON TUBE—A pressure gauge in which the sensing element is a curved tube that tends to straighten out when subjected to internal fluid pressure.

GAUGE, DIAPHRAGM—A gauge in which the sensing element is relatively thin and its inner portion is free to deflect with respect to its periphery.

GAUGE, PRESSURE—A gauge that indicates the pressure in the system to which it is connected.

GAUGE, VACUUM—A pressure gauge for pressures less than atmospheric.

GRAVITY—The force that tends to draw all bodies toward the center of the earth. The weight of a body is the resultant of gravitational force acting on the body.

HEAD—The height of a column or body of fluid above a given point expressed in linear units. Head is often used to indicate gauge pressure. Pressure is equal to the height times the density of the fluid.

HEAD, FRICTION—The head required to overcome the friction at the interior surface of a conductor and between fluid particles in motion. It varies with flow, size, type, and condition of conductors and fittings, and fluid characteristics.

HEAD, STATIC—The height of a column or body of fluid above a given point.

HEAD, VELOCITY—The equivalent head through which the liquid would have to fall to attain a given velocity. Mathematically it is equal to the square of the velocity (in feet) divided by 64.4 feet per second squared.

HEAT EXCHANGER—A device that transfers heat through a conducting wall from one fluid to another.

HYDRAULICS—Engineering science pertaining to liquid pressure and flow.

HYDRAULIC POWER DRIVE SYSTEM—Typically consists of an outside power source, hydraulic pump, hydraulic motor, control signal, and mechanical shafting and gearing.

HYDROMETER—An instrument for determining the specific gravities of liquids.

HYDROPNEUMATICS—Pertaining to the combination of hydraulic and pneumatic fluid power.

HYDROSTATICS—Engineering science pertaining to the energy of liquids at rest.

IMPACT PRESSURE—The pressure of a moving fluid brought to rest that is in excess of the pressure the fluid has when it does not flow; that is, total pressure less static pressure. Impact pressure is equal to dynamic pressure in incompressible flow; but in compressible flow, impact pressure includes the pressure change owing to the compressibility effect.

IMPINGEMENT—The striking or dashing upon with a clash or sharp collision, as air impinging upon the rotor of a turbine or motor.

IMPULSE TURBINE—A turbine driven by a fluid at high velocity under relatively low pressure.

INERTIA—The tendency of a body at rest to remain at rest, and a body in motion to continue to move at a constant speed along a straight line, unless the body is acted upon in either case by an unbalanced force.

INHIBITOR—Any substance that slows or prevents chemical reactions such as corrosion or oxidation.

INVERSE PROPORTION—The relation that exists between two quantities when an increase in one of them produces a corresponding decrease in the other.

KELVIN SCALE—The temperature scale using absolute zero as the zero point and divisions that are the same size as centigrade degrees.

KINETIC ENERGY—The energy that a substance has while it is in motion.

KINETIC THEORY—A theory of matter that assumes that the molecules of matter are in constant motion.

LINE—A tube, pipe, or hose that is used as a conductor of fluid.

LIQUID—A form of matter that has a definite volume but takes the shape of its container.

LOAD—The power that is being delivered by any power-producing device. Also, the equipment that uses the power from the power-producing device.

LUBRICATOR—A device that adds controlled or metered amounts of lubricant into a fluid power system.

MANIFOLD—A type of fluid conductor that provides multiple connections ports.

MANOMETER—A differential pressure gauge in which pressure is indicated by the height of a liquid column of known density. Pressure is equal to the difference in vertical height between two connected columns multiplied by the density of the manometer liquid. Some forms of manometers are U-tube, inclined tube, well, and bell types.

MATTER—Any substance that occupies space and has weight.

MECHANICAL ADVANTAGE—The ratio of the resisting weight to the acting force. The ratio of the distance through which the force is exerted divided by the distance the weight is raised.

METER-IN—To regulate the amount of fluid into a system or an actuator.

METER-OUT—To regulate the flow of fluid from a system or actuator.

MICRON—A millionth of a meter or about 0.00004 inch.

MOLECULE—A small natural particle of matter composed of two or more atoms.

MOTOR—A device that converts fluid power into mechanical force and motion. It usually provides rotary mechanical motion.

MOTOR, FIXED-DISPLACEMENT—A motor in which the displacement per unit of output motion cannot be varied.

MOTOR, LINEAR—(See Cylinder.)

MOTOR, ROTARY—A motor capable of continuous rotary motion.

MOTOR, ROTARY LIMITED—A rotary motor having limited motion.

MOTOR, VARIABLE-DISPLACEMENT— A motor in which the displacement per unit of output motion can be varied.

NEOPRENE—A synthetic rubber highly resistant to oil, light, heat, and oxidation.

NEUTRALIZATION NUMBER—A measure of the total acidity or basicity of an oil; this includes organic or inorganic acids or bases or a combination of them.

OPEN-CENTER SYSTEM—A type of fluid power system that circulates fluid from a reservoir, through selector valves, and then back to a reservoir.

OXIDATION—The process by which oxygen unites with some other substance, causing rust or corrosion.

PACKING—A class of seal that is used to provide a seal between two parts of a unit that move in relation to each other.

PASCAL'S LAW—A pressure applied to a confined fluid at rest is transmitted with equal intensity throughout the fluid.

PERIPHERY—The outside surface, especially that of a rounded object or body.

PIPE—A type of fluid line whose dimensions are designated by nominal (approximate) inside diameter and wall thickness.

PNEUMATICS—Engineering science pertaining to gaseous pressure and flow.

PORT—An internal or external terminus of a passage in a component.

POTENTIAL ENERGY—The energy a substance has because of its position, its condition, or its chemical composition.

POUR POINT—The lowest temperature at which a liquid will flow under specified conditions.

POWER UNIT—A combination of pump, pump drive, reservoir, controls, and conditioning components that may be required for the unit's application.

POWER—The rate of doing work or the rate of expanding energy.

PRESSURE—The amount of force distributed over each unit of area, usually expressed in pounds per square inch.

PRESSURE, ABSOLUTE—The sum of atmospheric and gauge pressures.

PRESSURE, ATMOSPHERIC—Pressure exerted by the atmosphere at any specific location.

PRESSURE, BACK—The pressure encountered on the return side of a system.

PRESSURE, DIFFERENTIAL—The difference in pressure between any two points of a system or a component.

PRESSURE, HEAD—The pressure due to the height of a column or body of fluid. It is usually expressed in feet.

PRESSURE, OPERATING—The pressure at which a system operates.

PRESSURE, PRECHARGE—The pressure of compressed gas in an accumulator prior to the admission of a liquid.

PRESSURE, PROOF—The nondestructive test pressure in excess of the maximum rated operating pressure.

PRESSURE, STATIC—The pressure in a fluid at rest.

PRESSURE SWITCH—An electrical switch operated by the increase or decrease of fluid pressure.

PRIME MOVER—The source of mechanical power used to drive the pump or compressor.

PUMP—A device that converts mechanical force and motion into hydraulic fluid power.

RANKINE SCALE—A thermometer scale based on absolute zero of the Fahrenheit scale, in which the freezing point of water is approximately 492 degrees Rankine (°R).

RATIO—The value obtained by dividing one number by another, indicating their relative proportions.

RECEIVER—A container in which gas is stored under pressure as a supply source for pneumatic power.

RECIPROCATING—Moving back and forth, as in a piston reciprocating in a cylinder.

RESERVOIR—A container for storage of liquid in a fluid power system.

RESPONSE TIME—The time lag between a signal input and the resulting change of output.

RESTRICTOR—A device that reduces the cross-sectional flow area.

RESTRICTOR, ORIFICE—A restrictor, the length of which is relatively small with respect to its cross-sectional area. The orifice may be fixed or variable. Variable types are non-compensated, pressure compensated, or pressure and temperature compensated.

RETURN LINE—A line used for returning fluid back into the reservoir or atmosphere.

SEPARATOR—A device whose primary function is to isolate undesirable fluids and or contaminants by physical properties other than size.

SERVO—A device used to convert a small movement into a greater movement of force.

SOLID—The form of matter that has a definite shape and a definite volume.

SPECIFIC GRAVITY—The ratio of the weight of a given volume of a substance to the weight of an equal volume of some standard substance.

STEADY FLOW—A flow in which the velocity, pressure, and temperature at any point in the fluid do not vary with time.

STRAINER—A coarse filter.

STUFFING BOX—A cavity and closure with manual adjustment for a sealing device.

SUPPLY LINE—A line that conveys fluid from the reservoir to the pump.

SURGE—A momentary rise of pressure in a circuit.

SYNCHRONIZE—To make two or more events or operations occur at the proper time with respect to each other.

SYNTHETIC MATERIAL—A complex chemical compound that is artificially formed by the combining of two or more simpler compounds or elements.

TANK—A container for the storage of fluid in a fluid power system.

THEORY—A scientific explanation, tested by observations and experiments.

THERMAL EXPANSION—The increase in volume of a substance due to temperature change.

TORQUE—A force or combination of forces that produces or tends to produce a twisting or rotary motion.

TOXICITY—The quality, state, or degree of being toxic or poisonous. Some liquids contain chemicals that are a serious hazard.

TUBING—A type of fluid line whose dimensions are designated by actual measured outside diameter and by actual measured wall thickness.

TURBINE—A rotary motor actuated by the reaction, impulse, or both, of a flow of pressurized fluid.

VALVE—A device that controls fluid flow direction, pressure, or flow rate.

VELOCITY—The rate of motion in a particular direction. The velocity of fluids is usually expressed in feet per second.

VENTURI—A tube having a narrowing throat or constriction to increase the velocity of fluid flowing through it. The flow through the venturi causes a pressure drop in the smallest section, the amount being a function of the velocity of flow.

VISCOSITY—A measure of the internal friction or resistance of a fluid to flow.

VISCOSITY INDEX—A measure of the viscosity-temperature characteristics of a fluid as referred to that of two arbitrary reference fluids.

VISCOSITY, SAYBOLT UNIVERSAL SECONDS (SUS)—The time in seconds for 60 milliliters of oil to flow through a standard orifice at a given temperature.

VISCOSITY, KINEMATIC—The absolute viscosity divided by the density of the fluid. It is usually expressed in centistokes.

VOLUME OF FLOW—The quantity of fluid that passes a certain point in a unit of time. The volume of flow is usually expressed in gallons per minute for liquids and cubic feet per minute for gases.

WORK—The transference of energy from one body or system to another. That which is accomplished by a force acting through a distance.

APPENDIX II

REFERENCES

> **NOTE**
>
> Although the following references were current when this NRTC was published, their continued currency cannot be assured. When consulting these references, keep in mind that they may have been revised to reflect new technology or revised methods, practices, or procedures; therefore, you need to ensure that you are studying the latest references.
>
> If you find an incorrect or obsolete reference, please use the Rate Training Manual User Update Form provided at the end of each chapter to contact the SWOS Rate Training Manager.

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APPENDIX III

GRAPHIC SYMBOLS FOR FLUID POWER DIAGRAMS

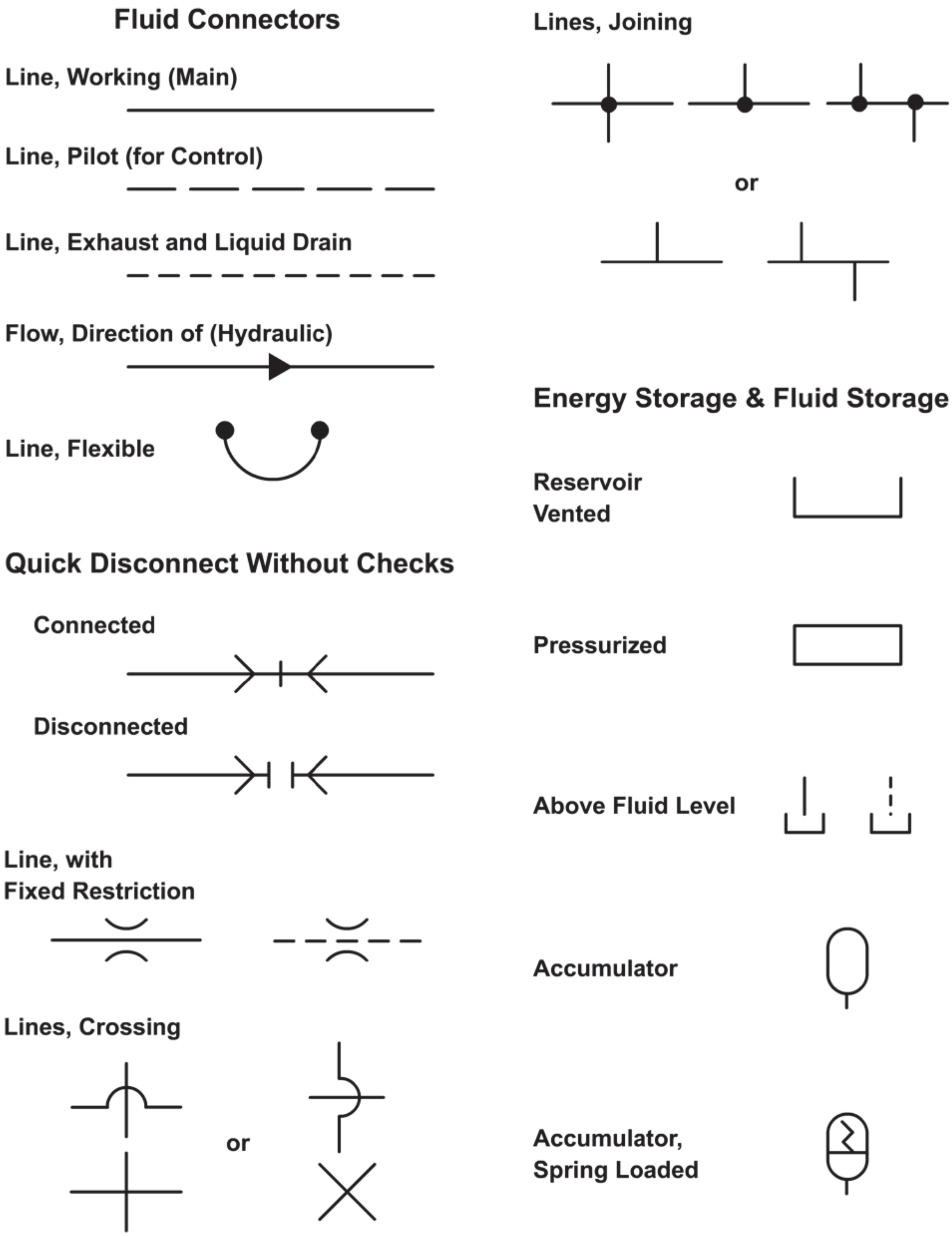

Figure AIII-1 — Fluid power graphic symbols.

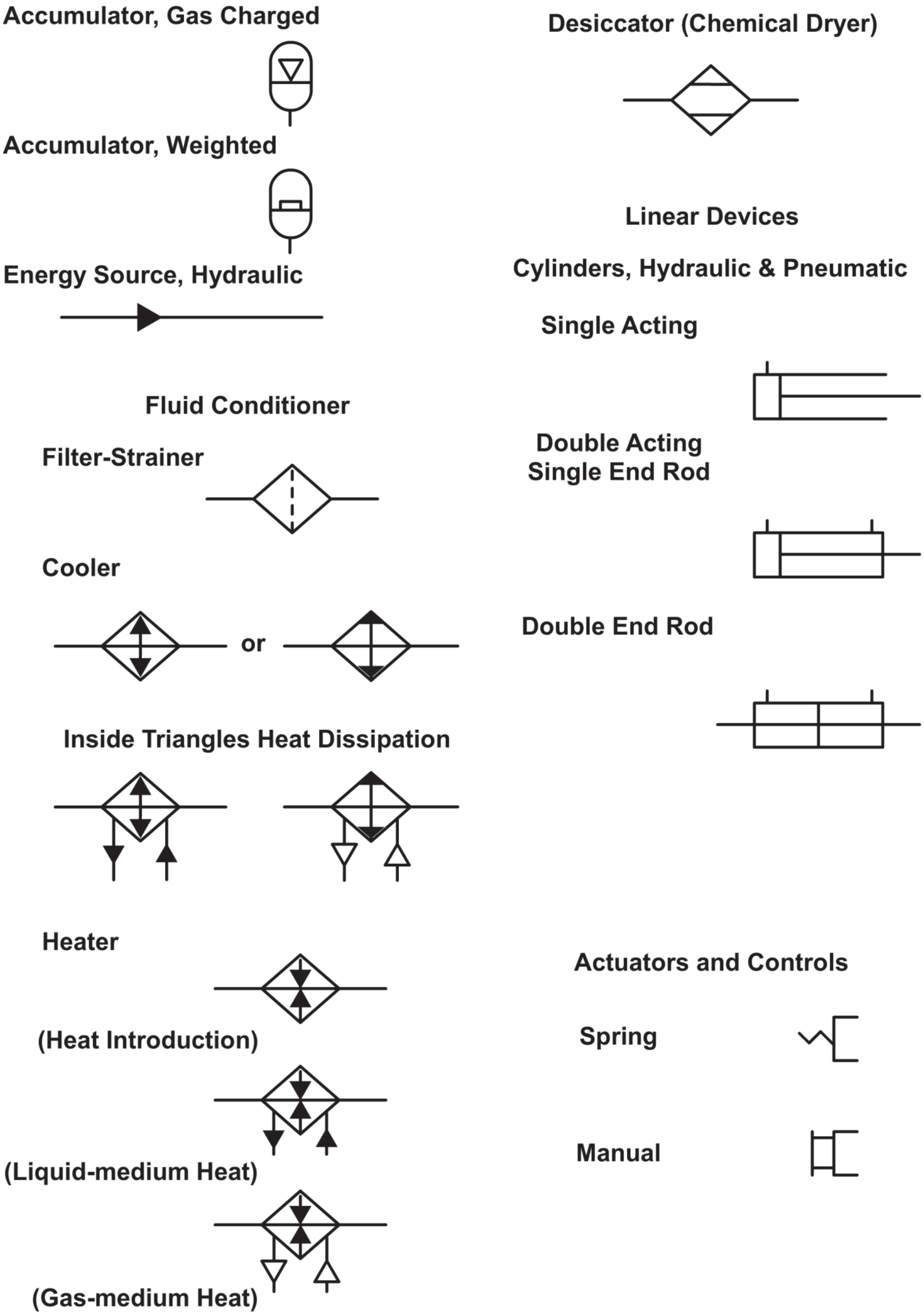

Figure AIII-1 — Fluid power graphic symbols (continued).

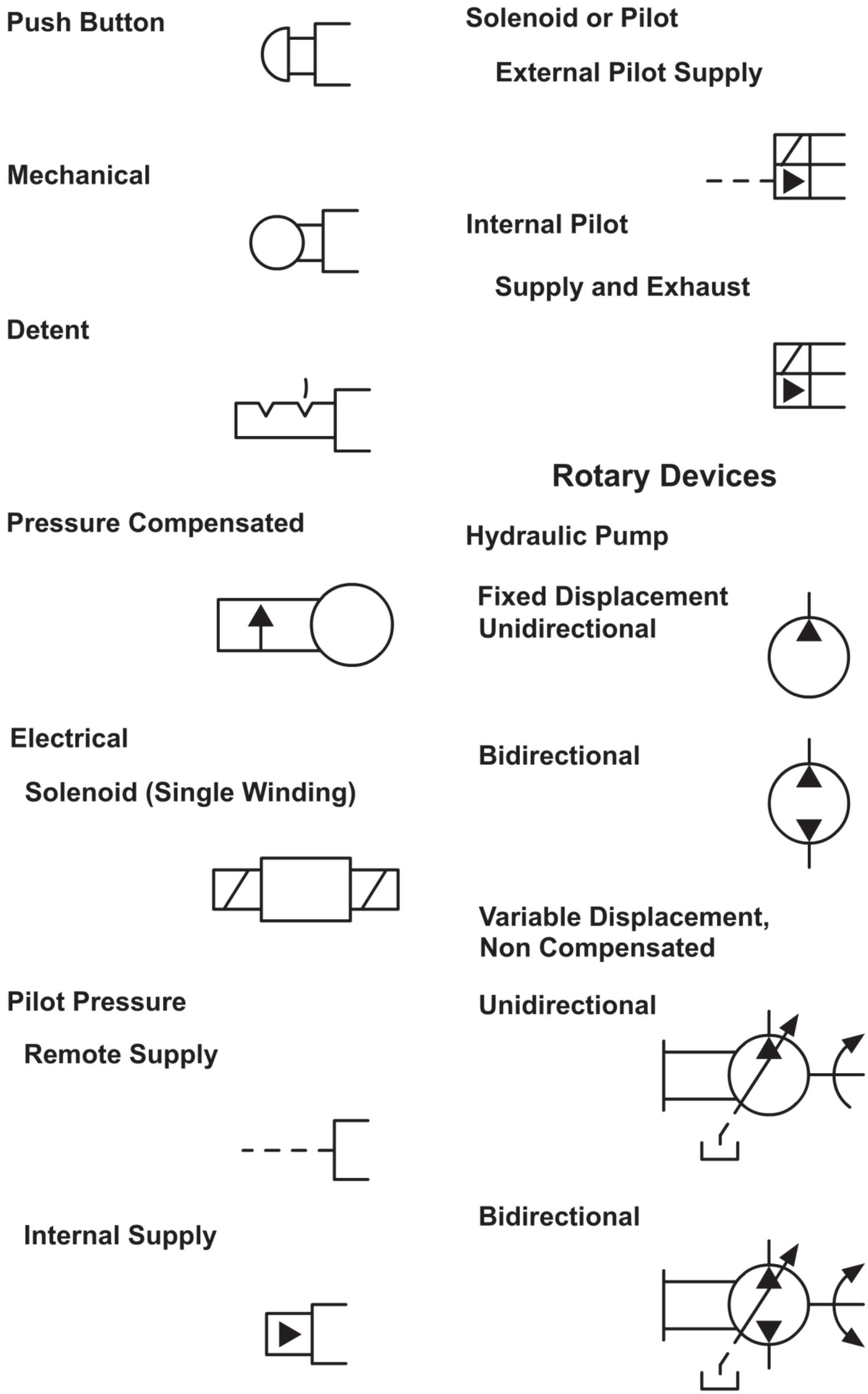

Figure AIII-1 — Fluid power graphic symbols (continued).

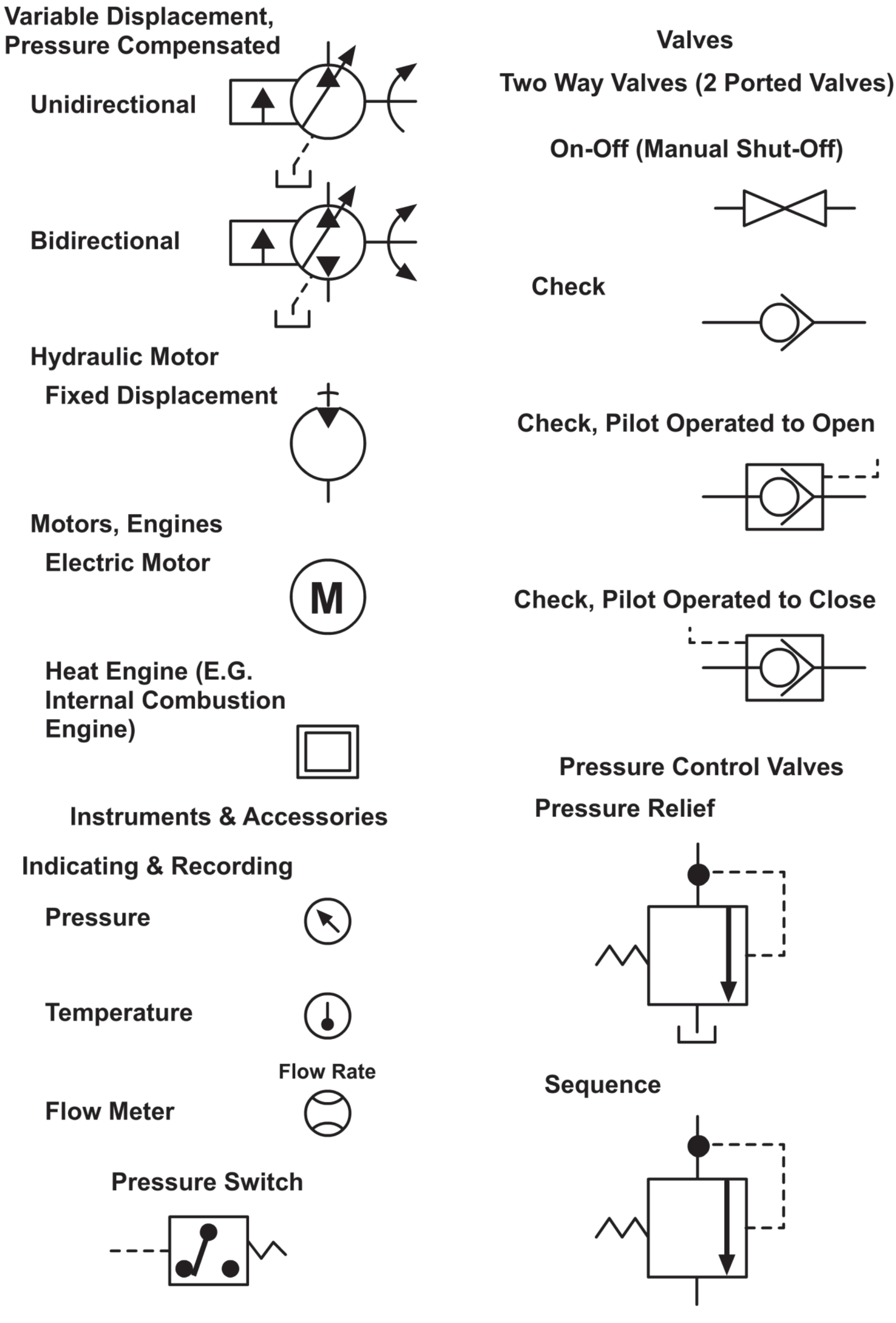

Figure AIII-1 — Fluid power graphic symbols (continued).

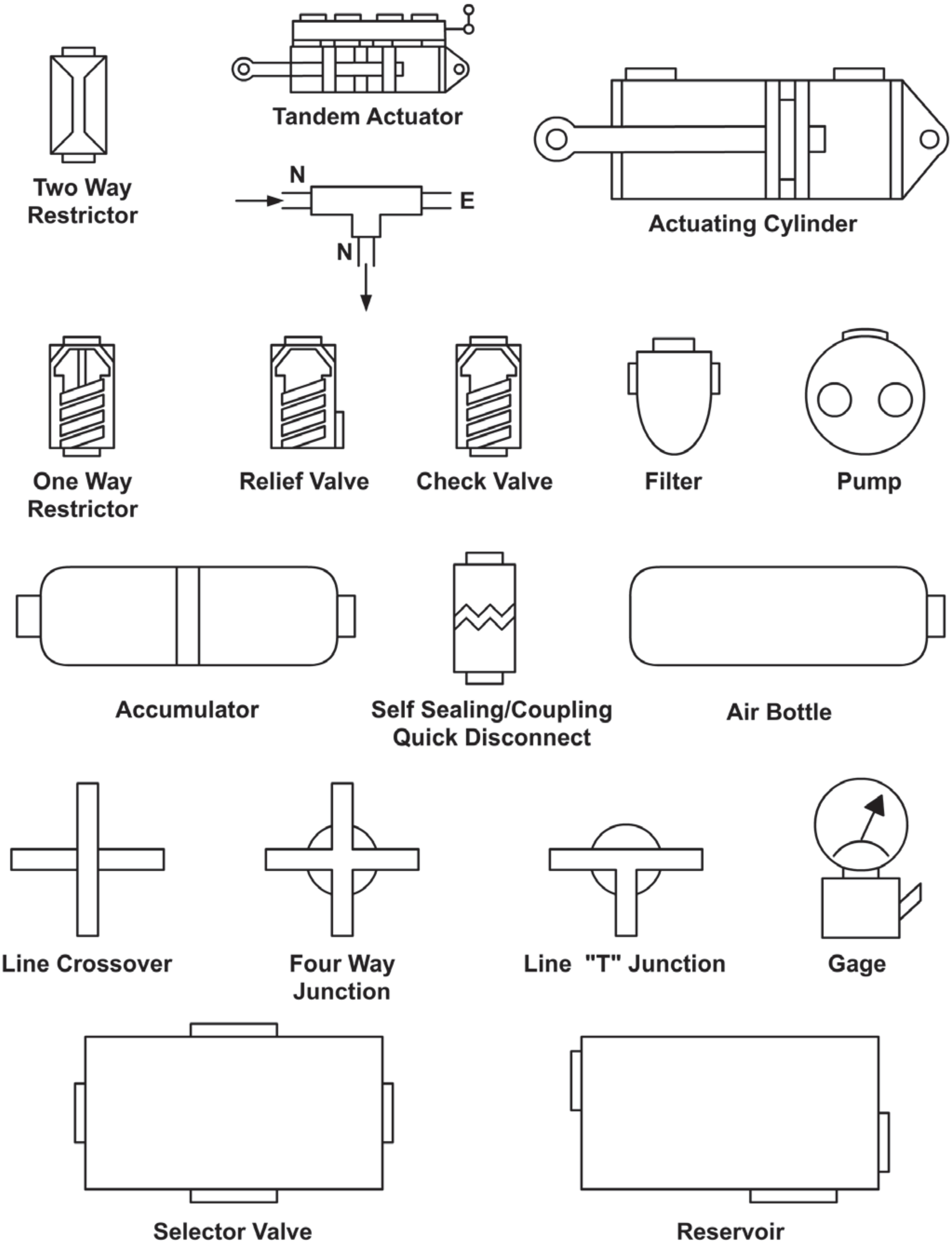

Figure AIII-1 — Fluid power graphic symbols (continued).

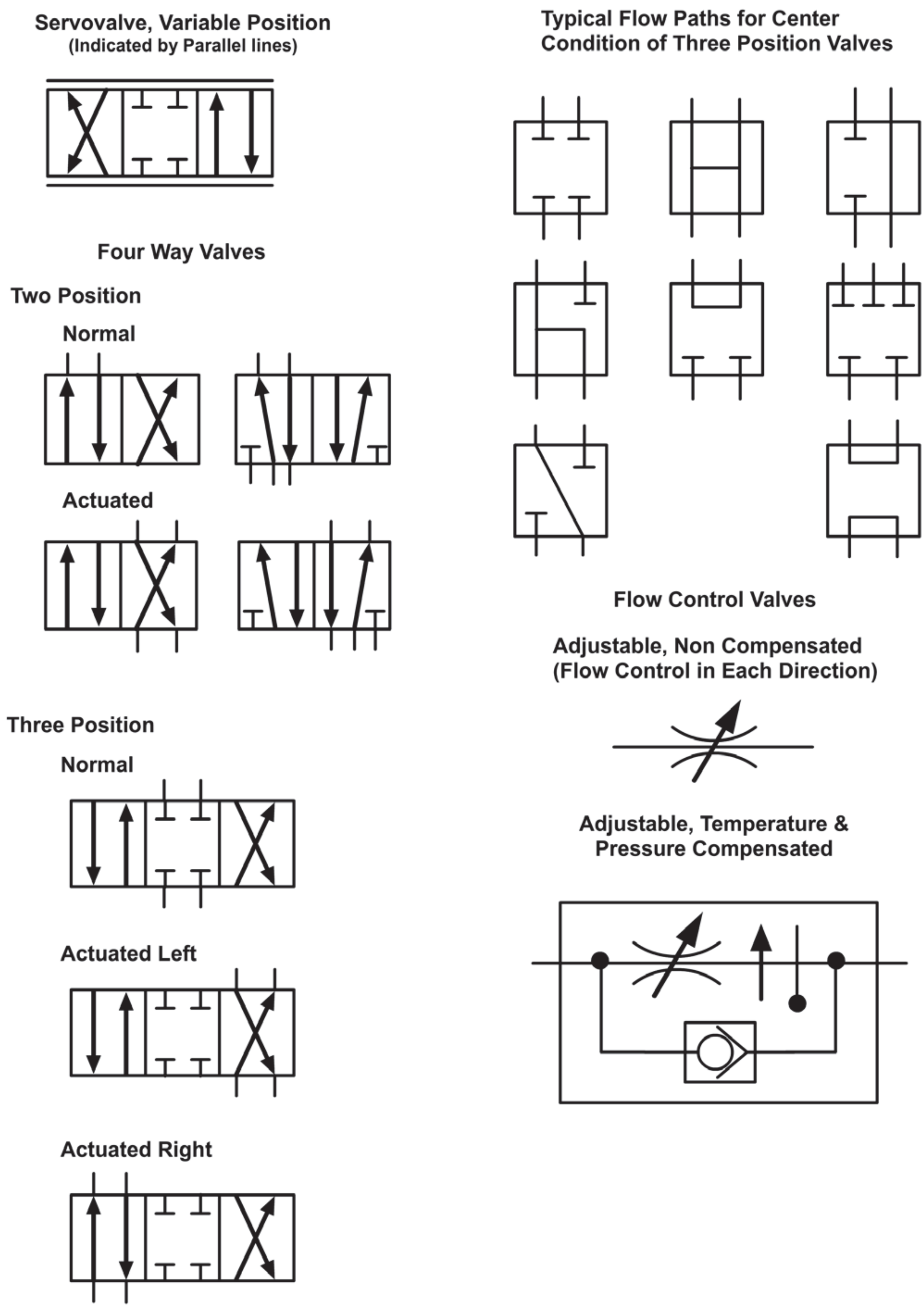

Figure AIII-1 — Fluid power graphic symbols (continued).