ENGINEERING-PDH.com
ONLINE CONTINUING EDUCATION

AUTOMOTIVE HYDRAULIC SYSTEM BASICS

Main Category:	Mechanical Engineering
Sub Category:	-
Course #:	MEC-160
Course Content:	34 pgs
PDH/CE Hours:	3

COURSE/EXAM PREVIEW

(HIT BACK TO RETURN TO ENGINEERING-PDH.COM)

WWW.ENGINEERING-PDH.COM
TOLL FREE (US & CA): 1-833-ENGR-PDH (1-833-364-7734)
SUPPORT@ENGINEERING-PDH.COM

MEC-160 EXAM PREVIEW

Instructions:

- Review the course & exam preview below.
- Click "Add to Cart" from the course page on the website. You can "Continue Shopping" to add additional courses, or checkout. Don't forget to apply your coupon code if you have one before checkout.
- After checkout you will be provided with links to download the official courses/exams.
- At your convenience and own pace, you can review the course material. When ready, select "Take Exam" to complete the live graded exam. Don't worry, you can take an exam as many times as needed to pass.
- Upon a satisfactory completion of the course exam, which is a score of 70% or better, you will be provided with your course completion certificate. Be sure to download and print your certificates to keep for your records.

Exam Preview:

1. According to the reference material, for all practical purposes, fluids are incompressible.
    a. True
    b. False
2. According to ______ law, any force applied to a confined fluid is transmitted in all directions throughout the fluid regardless of the shape of the container.
    a. Bernoulli's
    b. Newton's
    c. Pascal's
    d. Plank's
3. Gear pumps are classified by their method of meshing together. This style pump is simple in design and finds wide use in high-pressure hydraulic systems.
    a. True
    b. False
4. When it is used in CESE hydraulic systems, the micronic element normally prevents the passage of solids of __ microns or greater in size. The micronic filter element is disposable.
    a. 2
    b. 5
    c. 10
    d. 15

5. The purpose of a selector valve is to control the direction of fluid flow; this, in turn, controls the operation or direction of the mechanism. The valving element of these units may be one of three types: the poppet type, the rotary sped type, or the sliding spool type. Which of the following valve types matches the description: probably the most common type of valving element used in directional control valves?
    a. N/A
    b. Poppet
    c. Rotary sped
    d. Sliding spool
6. Regardless of their classification, check valves are probably the most widely used valves in fluid power systems.
    a. True
    b. False
7. In the separator type of air-operated accumulator, a means is provided to separate the gas from the liquid. The three styles of separators are bladder (bag), diaphragm, and piston (cylinder). Which of the following types matches the description: usually spherical in shape, the shell is constructed of two metal hemispheres, that are either screwed or bolted together?
    a. Bladder
    b. Diaphragm
    c. Cylinder
    d. N/A
8. According to the reference material, when hydraulic filters are being classified, the following factors are considered: flow characteristics, filtering medium, bypass characteristics, and contamination indicators.
    a. True
    b. False
9. A liquid, flowing at a high velocity in a pipe, will create a backward surge when stopped suddenly. Even the closing of a valve will develop instantaneous pressures _____ times the operating pressure of the system.
    a. 2 to 3
    b. 3 to 4
    c. 4 to 5
    d. 5 to 6
10. Hydraulic systems maintenance includes servicing, preoperational inspections, periodical (scheduled) inspections, repair, and test/check following repair. Which of the following components matches the description: the most common trouble is leakage?
    a. Filters
    b. Accumulator
    c. Hydraulic pumps
    d. Actuator

HYDRAULIC SYSTEMS

As a CM1, you will be responsible for the maintenance, repair, and troubleshooting of hydraulic systems. You must be able to analyze the malfunctions of these systems and supervise your personnel in the required corrective action. To be able to do this, you must thoroughly understand the basic system, the operational principles, and the components of the system.

NOTE: Before you continue with this chapter, you should review the appropriate chapters of the *CM 3&2,* NAVEDTRA 10645-G1.

The first part of this chapter briefly covers some of the basic principles associated with hydraulics, followed by coverage of various system components. The purpose of this information is to give you an analytical understanding of the interrelationships of principles and components in an operating system. When you understand the operation of a system, it is much easier to analyze a malfunction.

BASIC PRINCIPLES OF HYDRAULICS AND PNEUMATICS

In automotive and construction equipment, the terms *hydraulic* or *pneumatic* describe a method of transmitting power from one place to another through the use of a liquid or a gas. Several kinds of gases are used in the various hydraulic systems; however, certain physical laws or principles apply to all liquids and gases. As a CM, you should be aware of this. You should also be familiar with the following terms as they are associated with hydraulic and pneumatic systems.

- HYDRAULICS is that branch of science that deals with the study and use of liquids, as related to the mechanical aspects of physics.

- PNEUMATICS is that branch of science that deals with the study and use of air and other gases, as related to the mechanical aspects of physics.

- FORCE is the push or pull on an object. In hydraulics and pneumatics, force is usually expressed in pounds.

- PRESSURE is the amount of force distributed over each unit on the area of an object. In hydraulics/pneumatics, pressure is expressed in pounds per square inch (psi).

A FLUID is defined as any substance made up of small particles or molecules that have the ability to flow or move easily (conforms to the outline of its container); this includes both liquid and gas. The terms *liquids* and *fluids* are often used interchangeably; however, fluids have a much broader meaning. All liquids are fluids, but not all fluids are liquid; fluids can be liquid, but they can also be air and other gases that are not liquid. In support equipment, hydraulics mean liquid and pneumatics mean air or other gases.

INCOMPRESSIBILITY AND EXPANSION OF LIQUIDS

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

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

COMPRESSIBILITY AND EXPANSION OF GASES

A gas is a substance in which the molecules are separated by relatively large spaces. The two major differences between liquids and gases are their compressibility and expansion. While liquids are incompressible, gases are highly compressible because of these large spaces between the molecules.

Gases, like liquids, expand and contract because of temperature change; but unlike liquids, a gas expands to till completely any closed container in which it is contained; a liquid tills the container only to the extent of its normal volume.

PASCAL'S LAW

Pascal was a noted French physicist who discovered that a closed container of fluid could be used to transfer force from one place to another or to multiply forces by its transmission through a fluid. Pascal's law may be stated as follows: PRESSURE APPLIED ANYWHERE ON A CONFINED FLUID IS TRANSMITTED UNDIMINISHED IN EVERY DIRECTION. THE FORCE THUS EXERTED BY THE CONFINED FLUID ACTS AT RIGHT ANGLES TO EVERY PORTION OF THE SURFACE OF THE CONTAINER AND IS EQUAL UPON EQUAL AREAS. It should be noted that Pascal's law applies to fluids-both gas and liquid. It is the use of Pascal's law that makes possible today's hydraulic and pneumatic systems.

According to Pascal's law, any force applied to a confined fluid is transmitted in all directions throughout the fluid regardless of the shape of the container. Consider the effect of this in the systems shown in views A and B of figure 10-1. If there is a resistance on the output piston (view A, piston 2) and the input piston is pushed downward, a pressure is created through the fluid, which acts equally at right angles to surfaces in all parts of the container.

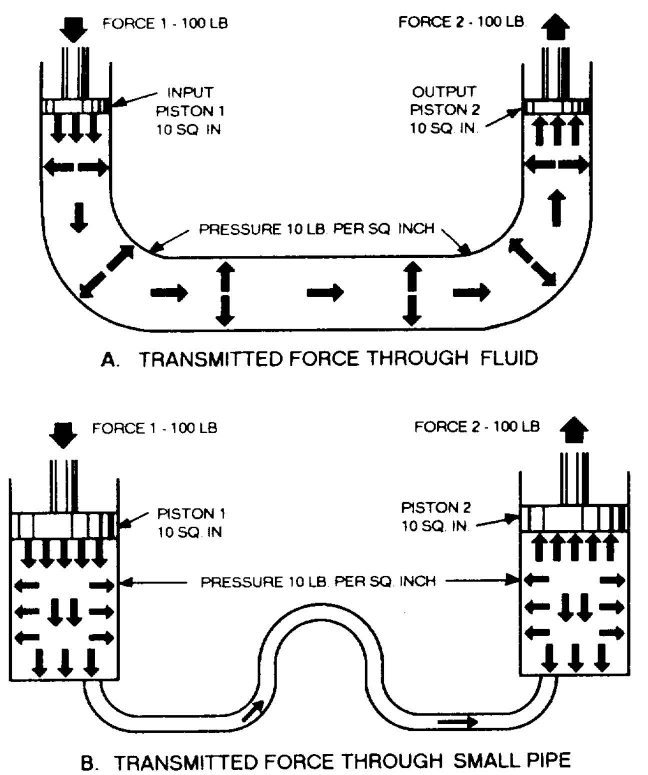


Figure 10-1.-Force transmitted from piston to piston.

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

At this point, it should be noted that since Pascal's law is independent of the shape of the container, it is not necessary that the tube connecting the two pistons should be the full area of the pistons. A connection of any size, shape, or length will do so long as an unobstructed passage is provided. Therefore, the system shown in view B of figure 10-1 (a relatively small, bent pipe connects two cylinders) will act exactly the same as that shown in view A.

Multiplication of Forces

In figure 10-1, views A and B, the systems contain pistons of equal area wherein the output force is equal to the input force. Consider the situation in figure 10-2 where the input piston is much smaller than the output piston. Assume that the area of the input piston 1 is 2

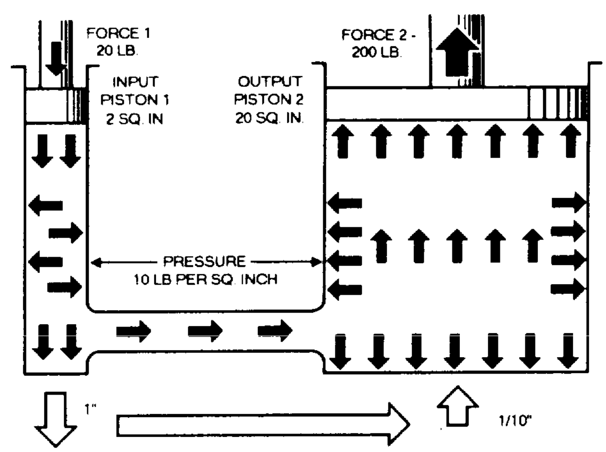


Figure 10-2.-Multiplication of force.

square inches. With a resistant force on piston 2, a downward force of 20 pounds acting on piston 1 creates 10 psi (20÷2) in the fluid. Although this force is much smaller than the applied forces in figure 10-1, the pressure is the same because the force is concentrated on a relatively small area.

This pressure of 10 psi acts on all parts of the fluid container, including the bottom of the output piston 2; therefore, the upward force on the output piston 2 is 10 pounds for each of its 20 square inches of area, or 200 pounds (10 x 20). In this case, the original force has been multiplied tenfold while using the same pressure in the fluid as before. In any system with these dimensions, the ratio of output force to input force is always 10 to 1 regardless of the applied force; for example, if the applied force of the input piston 1 is 50 pounds, the pressure in the system is increased to 25 psi. This will support a resistant force of 500 pounds on the output piston 2.

The system works the same in reverse. Consider piston 2 as the input and piston 1 as the output; then the output force will always be one-tenth the input force. Sometimes such results are desired.

Therefore, the first basic rule for two pistons used in a fluid power system is *the force acting on each is directly proportional to its area and the magnitude of each force is the product of the pressure and its area,* is totally applicable.

Volume and Distance Factors

In the systems shown in views A and B of figure 10-1, the pistons have areas of 10 square inches. Since the areas of the input and output pistons are equal, a force of 100 pounds on the input piston will support a resistant force of 100 pounds on the output piston. At this point, the pressure of the fluid is 10 psi. A slight force, in excess of 100 pounds, on the input piston will increase the pressure of the fluid, which will, in turn, overcome the resistance force. Assume that the input piston is forced downward 1 inch. This displaces 10 cubic inches of fluid. Since liquid is practically incompressible, this volume must go some place. In the case of a gas, it will compress momentarily but will eventually expand to its original volume at 10 psi. This is provided, of course, that the 100 pounds of force is still acting on the input piston. Thus this volume of fluid moves the output piston. Since the area of the output piston is likewise 10 square inches, it moves 1 inch upward to accommodate the 10 cubic inches of fluid. The pistons are of equal areas; therefore, they will move equal distances, though in opposite directions.

Applying this reasoning to the system in figure 10-2, it is obvious that if the input piston 1 is pushed down 1 inch, only 2 cubic inches of fluid is displaced. The output piston 2 will have to move only one-tenth of an inch to accommodate these 2 cubic inches of fluid, because its area is 10 times that of the input piston 1. This leads to the second basic rule for two pistons in the same fluid power system, which is *the distances moved are inversely proportional to their areas.*

While the terms and principles mentioned above are not all that apply to the physics of fluids, they are sufficient to allow further discussion in this training manual. It is recommended that *Fluid Power*, NAVEDTRA 12964 (latest edition), be studied for a more detailed and knowledgeable coverage of the physics of fluids and basic hydraulic/pneumatic systems.

COMPONENTS

Since fluids are capable of transmitting force and at the same time flow easily, the force applied to the fluid atone point is transmitted to any point the fluid reaches. Hydraulic and pneumatic systems are assemblies of units capable of doing this. They contain a unit for generating force (pumps), suitable tubing and hoses for containing and transmitting the fluid under pressure, and units in which the energy in the fluid is converted to mechanical work (cylinders and fluid motors). In addition, all operative systems contain valves and restrictors to control and direct the flow of fluid and limit the maximum pressure in the system.

Because of the similarities of hydraulic and pneumatic systems (that is, from a training point of view), only the components of hydraulic systems are covered in this section. Remember that most of the information is also applicable to pneumatic systems and their components.

PUMPS

The heart of any hydraulic system is its pumps; it is the pump that generates the force required by the actuating mechanisms. The pump causes a flow of fluid; thus, the amount of pressure created in a system is not controlled by the pump but by the workload imposed on the system and the pressure-regulating valves.

Basically, pumps may be classified into two groups based on performance: (1) fixed delivery when running at a given speed and (2) variable delivery when running at a given speed.

Pumps may further be divided into types, based upon the design used to create force (fluid flow). Practically all hydraulic pumps fall within three classifications of design–rotary, reciprocating, and centrifugal. The centrifugal style pumps find little use in CESE hydraulic systems used in the Naval Construction Force and will not be covered here. Pumps may be driven by air pressure, electric motors, gas turbine engines, or the conventional internal combustion engines (gasoline and diesel).

Rotary Pumps

All rotary pumps operate by means of rotating parts, that trap the fluid at the inlet (suction) port and force it through the discharge port into the hydraulic system. Gears, lobes, and vanes are commonly used as elements in rotary pumps. Rotary pumps operate on the positive displacement principle and are of the fixed displacement type.

There are numerous types of rotary pumps and various methods of classification. They may be classified as to shaft position—either vertically or horizontally mounted; the type of drive-electric motor, internal combustion engine, and so forth; manufacturer's name; or service application; however, classification of rotary pumps is generally made according to the type of rotating element. A few of the most common types of rotary pumps are covered in the paragraphs below.

GEAR PUMP.— Gear pumps are classified by their method of meshing together. This style pump is simple in design and finds wide use in low-pressure hydraulic systems. A gear pump delivers a constant volume of fluid at any given rpm (fig. 10-3).

The pump shown is known as a spur tooth and consists of two meshed gears that revolve alongside each other in one housing. The drive gear in the illustration is turned by a drive shaft that engages the power source. The clearances between the gear teeth, as they mesh, and the pump housing are very small.

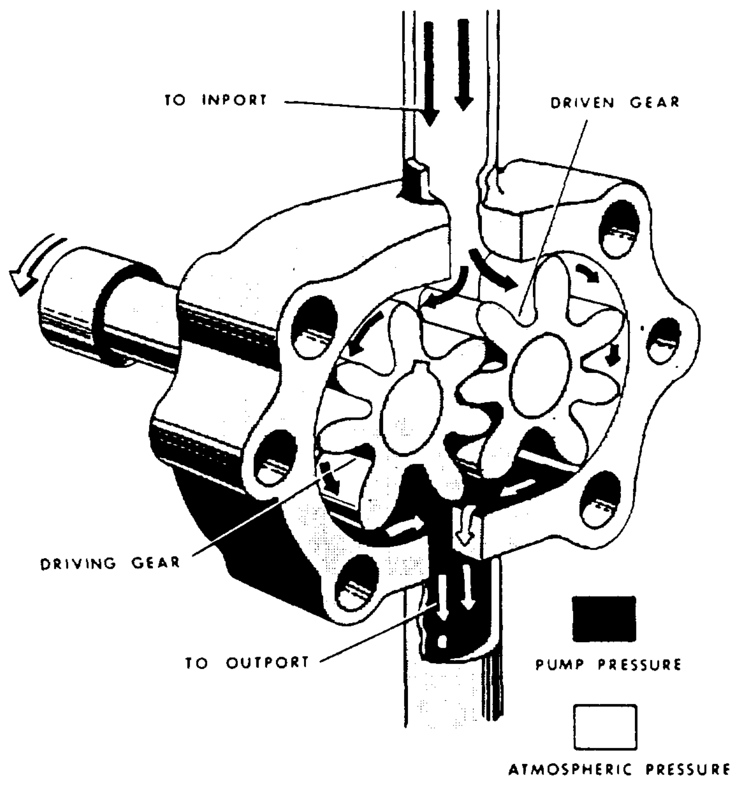


Figure 10-3.-Typical gear type of hydraulic pump.

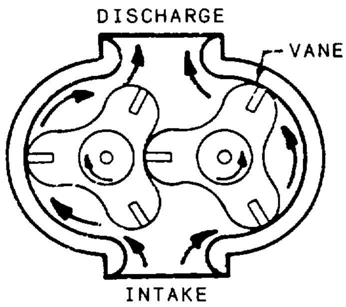


Figure 10-4.-Lobe type of pump.

The inlet port is connected to the fluid supply line, and the outlet port is connected to the pressure line. Referring to the figure, the drive gear is rotating in a counterclockwise direction, and the driven gear (idler gear) is rotating in a clockwise direction. As the teeth pass the inlet port, fluid is trapped between the teeth and the housing; this liquid is carried around the housing to the outlet port. As the teeth mesh again, the liquid between the teeth is displaced into the outlet port. This action produces a positive flow of liquid into the system. A shear pin or shear section is incorporated in the drive shaft to protect the power source or reduction gears if the pump fails because of excessive load or binding of parts.

A variation of the spur tooth pump is the lobe pump (fig. 10-4), which is also used on many diesel-powered equipments for an intake blower as well as in a variety of hydraulic systems. The principle of operation of this pump is exactly the same as the spur tooth. The lobes are so constructed that there is a continuous seal (vane) at the point of juncture at the center of the pump and also on the housing.

Another popular style of gear pump is the internal gear (fig. 10-5). This pump consists of a pair of gear-shaped elements (one within the other) located in

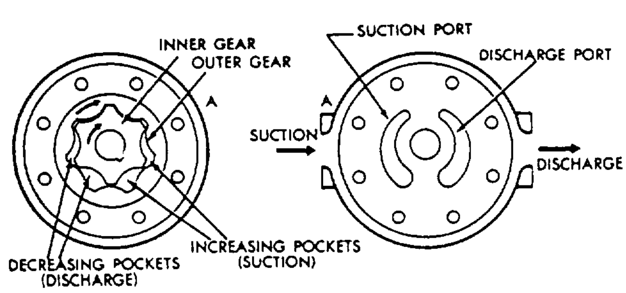


Figure 10-5.-Internal gear type of pump.

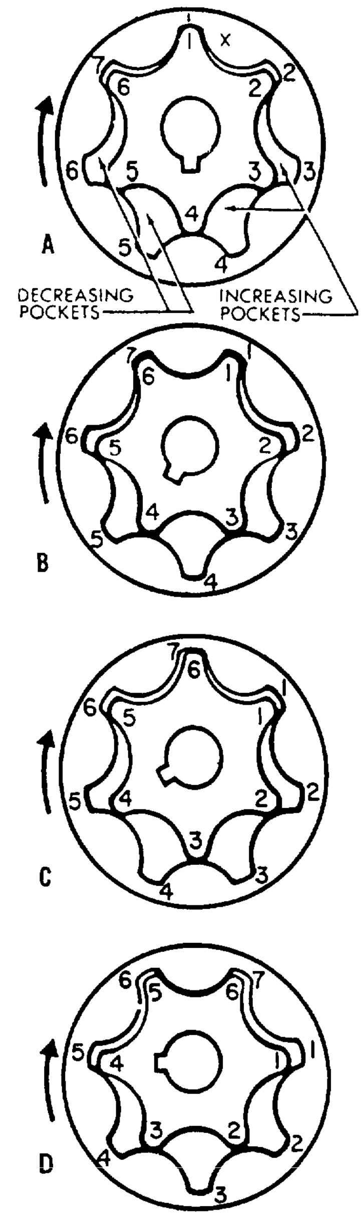


Figure 10-6.-Principles of operation of the internal gear type of pump.

the pump chamber. The inner gear is connected to the drive shaft of the source of power.

For an explanation of the operation of this type of pump, refer to figure 10-6. The teeth of the inner gear and the spaces between the teeth of the outer gear are numbered. Note that the inner gear has one less tooth than the outer gear has spaces. The tooth force of each gear is related to that of the other in such away that each tooth of the inner gear is always in sliding contact with the surface of the outer gear. Each tooth of the inner gear meshes with the outer gear at just one point during each revolution. In the illustration, this point is at the top (X). In view A, tooth 1 of the inner gear is in mesh with space 1 of the outer gear. As the gears continue to rotate in clockwise direction and the teeth approach point (X), tooth 6 of the inner gear will mesh with space 7 of the outer gear, tooth 5 with space 6, and so forth. During this revolution, tooth I will mesh with space 3. As a result, the outer gear rotates at 1,400 rpm, and the outer gear will rotate at 1,200 rpm.

At one side of the point of mesh, pockets of increasing size are formed as the gears rotate, while on the other side the pockets decrease in size. The pockets on the right-hand side of the drawings are increasing in size as one moves down the illustration, while those on the left-hand side are decreasing in size. The intake side of the pump would therefore be to the right and the discharge to the left. Since the right-hand side of the drawing in figure 10-5 was turned over to show the ports, the intake and discharge appear reversed. Actually, A in one drawing covers A in the other.

VANE PUMP.— Figure 10-7 illustrates a vane pump of the unbalanced design. The rotor is attached to the drive shaft and is rotated by an outside power source, such as an electric motor or gasoline engine. The rotor is slotted, and each slot is fitted with a rectangular vane. These vanes, to some extent, are free to move outward in their respective slots. The rotor and vanes are enclosed in a housing, the inner surface of which is offset with the drive axis.

As the rotor turns, centrifugal force keeps the vanes snug against the wall of the housing. The vanes divide the area between the rotor and housing into a series of chambers. The chambers vary in size according to their respective positions around the shaft. The inlet port is located in that part of the pump where the chambers are expanding in size so that the partial vacuum (low-pressure area) formed by this expansion allows liquid to flow into the pump. The liquid is trapped between the vanes and carried to the outlet side of the pump. The chambers contract in size on the outlet side, and this action forces the liquid through the outlet port and into the system.

The pump is referred to as unbalanced because all of the pumping action takes place on one side of the shaft and rotor. This causes a side load on the shaft and rotor. Some vane pumps are constructed with an elliptical-shaped housing that forms two separate pumping areas on opposite sides of the rotor. This cancels out the side loads; therefore, such pumps are used quite extensively in power steering units in CESE to provide the flow.

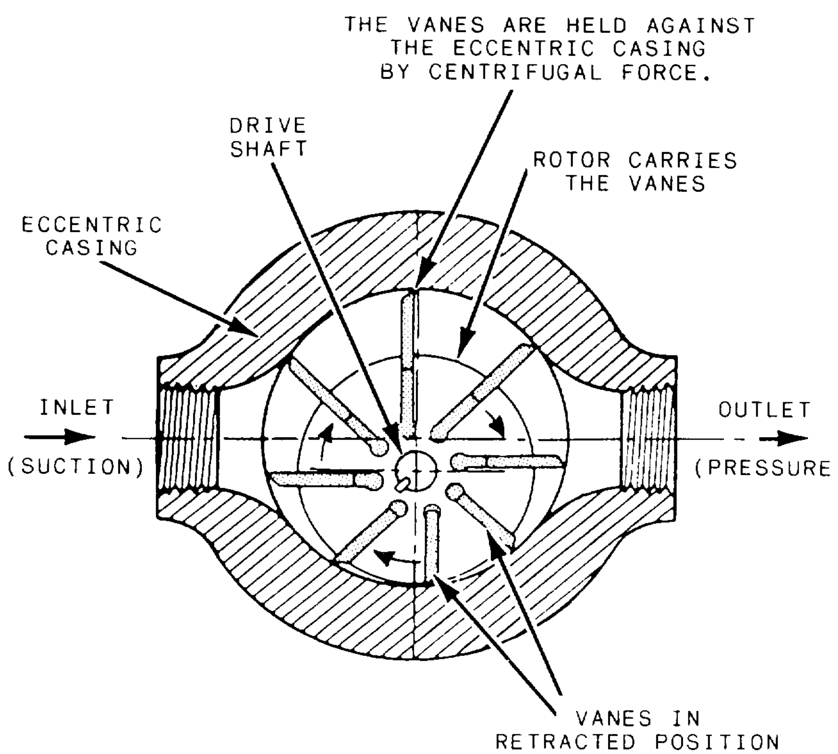


Figure 10-7.-Typical vane type of hydraulic pump.

Reciprocating Pumps

Reciprocating pumps are most commonly used for applications requiring high pressures and accurate control of the discharge volume. There are many variations of this pump, which is normally refereed to as a piston pump in support equipment; however, they are generally based on the axial piston or hand pump principle. There are also radial piston pumps, but they are hardly ever used in design of support equipment systems.

It is not within the scope of this TRAMAN to cover all the variations of the piston pump since there are more than 20 manufacturers of these pumps; each has its own patented improvements to achieve efficiency and reduce wear. You should consult the appropriate technical manual for specific pump maintenance and repair information.

AXIAL-PISTON PUMPS.— Axial-piston pumps are classified as either constant volume or variable volume. The paragraphs below explain the overall operation of the pump and the means designed into the variable volume pump to provide stroke reduction.

Constant Volume Piston Pump.— The constant volume piston pump (fig. 10-8) produces a constant flow of fluid for any given rpm. The pistons, usually about nine (always an odd number), are fastened by a universal linkage to a drive shaft. The universal link in the center drives the cylinder block; it is held at an angle to the drive shaft by the pump housing. Everything within the pump housing rotates with the drive shaft. As the piston is rotated to the upper position, its movement forces fluid out of the pressure port. As the same piston moves from the upper position to the lower position, it draws in fluid through the intake port. Since each piston is always somewhere between the upper and lower position, constant intake and output of fluid results. The volume output of the pump is determined by the angle between the drive shaft and the cylinder block, as the degree of angle decreases or increases the piston stroke. The larger the angle, the greater the output per revolution.

If you follow one piston through one complete revolution, you can see how the pump operates. Start with the piston at the top of its cylinder (fig. 10-8). It has just completed its pressure stroke and is ready to begin its intake stroke. As the cylinder starts its rotation from this point, the piston immediately aligns with the intake port as it moves toward the bottom of the cylinder. The partial vacuum created by the movement of the piston in the cylinder and the gravity pressure (in some cases, boost pressure) on the fluid cause the space above the piston to fill with fluid. When the cylinder has gone through 180 degrees or one-half revolution, the piston reaches the bottom of the cylinder; the cylinder is now full of fluid.

As rotation continues beyond this point, the piston now aligns with the outlet port slot. Thus, when the last 180 degrees have been completed, the piston will have moved forward in the cylinder; the fluid will have been forced into the outlet line. At this point, the piston and cylinder are again ready to start another cycle. There are several pistons performing the same function just described. Since the pump rotates rapidly, there is a constant flow of fluid through the outlet port.

This pump normally uses case pressure and fluid flow for cooling and lubricating. Fluid seeps by the pistons in the cylinder block and fills all the space inside the pump. The fluid is prevented from escaping through the drive end of the pump by a drive shaft seal. Excessive case pressure is prevented by routing the fluid back to the inlet port of the pump through one or more relief

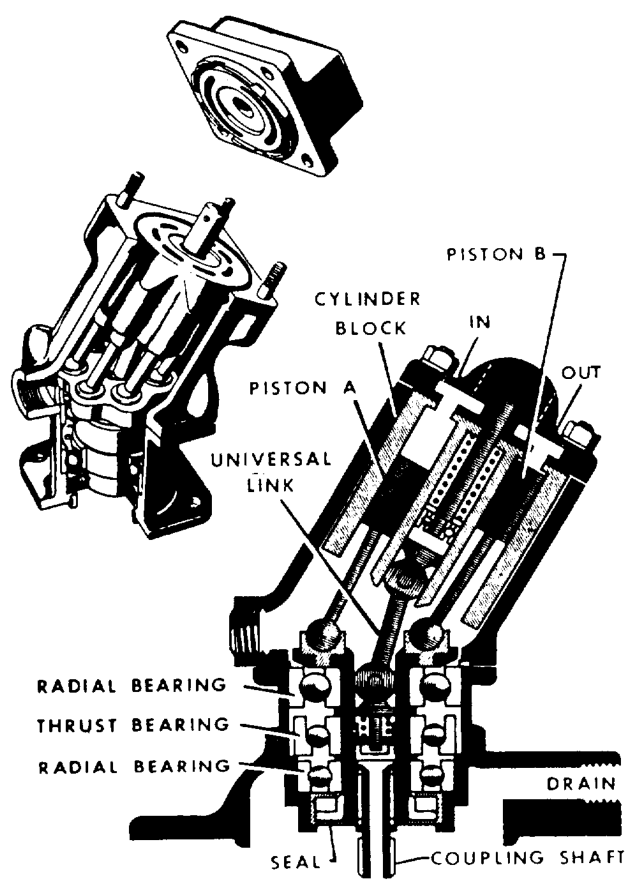
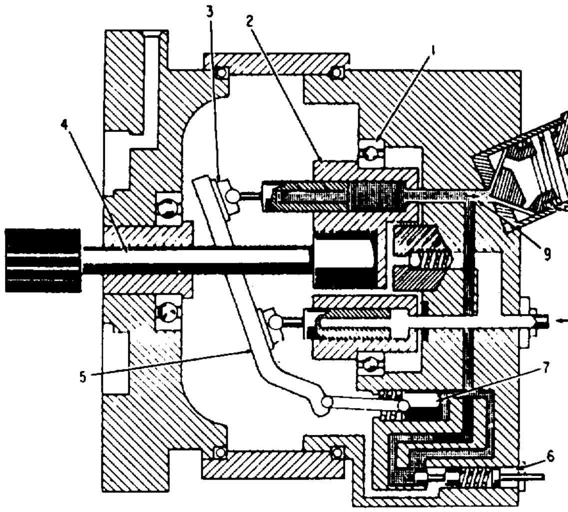


Figure 10-8.-Example of a constant volume piston pump.



1. **Bearing**
2. **Cylinder**
3. **Piston plate**
4. **Drive shaft**
5. **Cam plate**
6. **Compensator valve**
7. **Stroking piston**
8. **Inlet**
9. **Outlet**
10. **Check valve**

Figure 10-9.-Example of a variable volume, stroke reduction pump with variable cam plate.

valves. These valves are usually set at about 15 psi; this ensures circulation of fluid in the pump.

The piston pump discussed is a constant displacement type; that is, for any given rpm, the volume output is constant. However, there is another version of the piston pump used more extensively than the constant volume pump; that is, the variable volume pump.

Variable Volume Piston Pump.— There are many versions of the variable volume pump; several different control methods are used to vary the fluid flow through the pump. Some of the pumps vary the volume by controlling the inlet fluid; some vary it by changing the angle between the pump drive shaft and the piston cylinder block; others by using a system bypass within the pump to vary volume output.

One advantage of the variable volume pump is that it eliminates the need for a system pressure regulator. A second advantage is that it provides a more stable pressure, thus reducing pressure surges and the need for a system accumulator; however, they are retained for use during peak load occurrences.

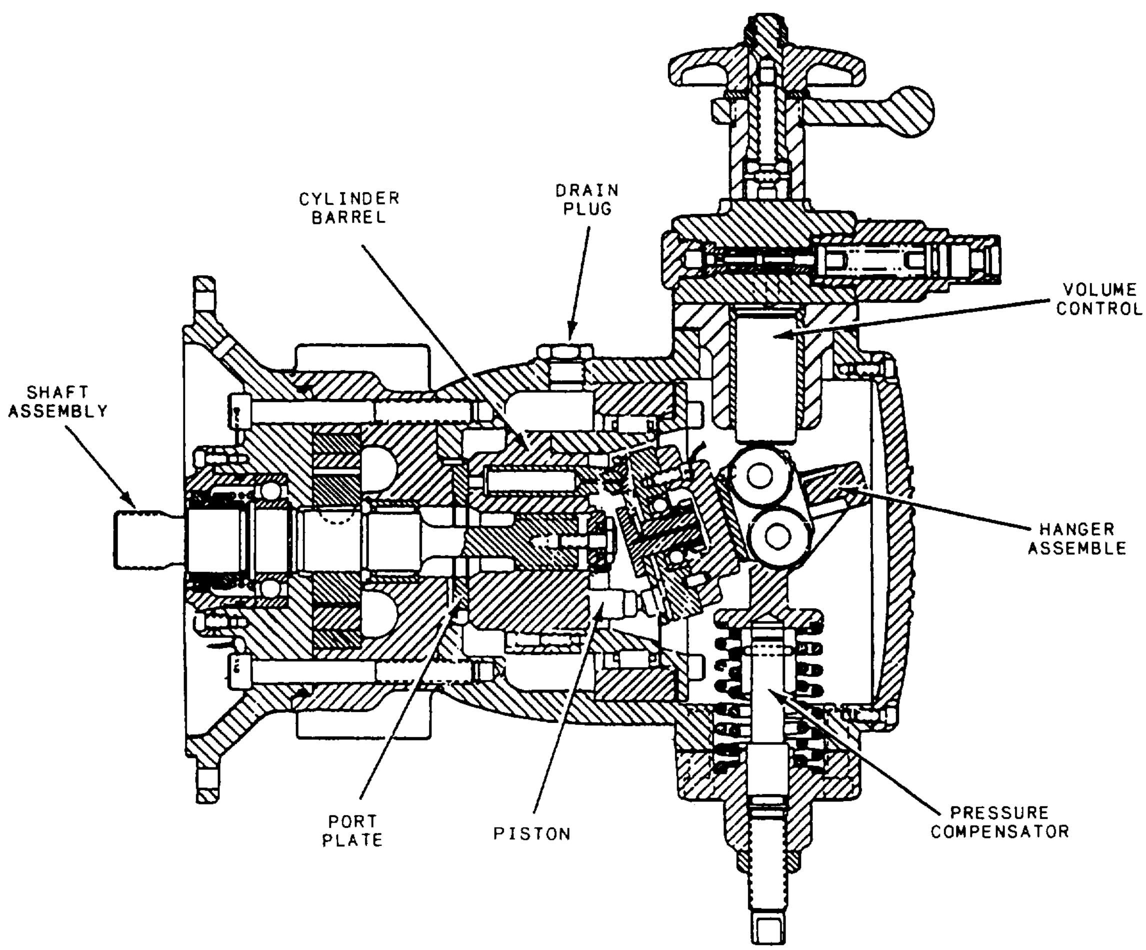


Figure 10-10.-Variable displacement axial-piston pump.

As stated previously, the output of the constant volume pump is determined by pump rpm and the fixed angle between the drive shaft and the rotating cylinder block. If the angle was not fixed and could be varied, the piston stroke would be changed, thus varying the pump output. Changing the pump piston stroke is the method used on most variable volume pumps found in support equipment.

The stroke reduction pumps (figs. 10-9 and 10- 10) are fully automatic variable volume pumps. The pressure compensating valves shown in both figures use system pressure to control and vary the piston stroke of the pump, thus changing the output.

NOTE: The piston stroke of the pump (fig. 10-10) is determined by the angle of the cam plate. The drive shaft passes through, but does not touch, the inclined cam plate to rotate the cylinder block and pistons. The hanger assembly in figure 10-10 provides this same function as the cam plate in figure 10-9.

The pumps may also be configured to allow manual volume control of the pump. Manual volume is controlled by a handwheel to vary the piston stroke or may use manual pressure compensating valves such as those used on many hydraulic test stands.

HAND PUMPS.— The hand pump normally serves as a substitute for the main power pump on most hydraulic systems; however, the hand pump is widely used as the only power source in some equipment. Examples are hydraulic jacks, hydraulically actuated workstands, and similar equipment.

The two designs of hand pumps you will be using are *single action* and *double action* (fig. 10- 11). The double-action hand pump creates the flow of fluid with each stroke of the pump handle; two strokes are required for the single-action pump. There are several versions of single- and double-action hand pumps but all operate on the reciprocating piston principle. The unit shown in figure 10-11, view A, consists of a cylinder, a piston, an operating handle, and two check valves-check valve A and check valve B. The inlet port is connected to the reservoir, and the outlet port is connected to the pressure system. As the piston is moved to the right by the pump handle, fluid from the reservoir flows through check valve A into the pump cylinder. As the piston is moved to the left, check valve A closes and check valve B opens. The fluid in the pump cylinder is forced out of the outlet port into the pressure line. Thus, with each two strokes of the hand, a single pressure stroke is produced.

The double-action hand pump (fig. 10-11, view B) consists of a cylinder, a piston containing a built-in check valve A, a large piston rod, an operating handle, and check valve B at the inlet port.

When you move the piston to the right, check valve A closes and check valve B opens. Fluid from the reservoir then flows into the cylinder through the inlet port. When you move the piston to the left, check valve B closes. The pressure created in the fluid then opens check valve A, admitting fluid behind the piston. (Note that the large piston rod takes up much of the space behind by the piston rod.) Because of the space occupied by the piston rod, there is room for only part of the fluid; thus, the remainder of fluid is forced through the outlet port into the pressure line. This is one pressure stroke. Again if you move the piston to the right, check valve A closes. The fluid behind the piston is forced through the outlet port. At the same time fluid from the reservoir flows into the cylinder through check valve B. his pump has a pressure stroke for each stroke of the handle.

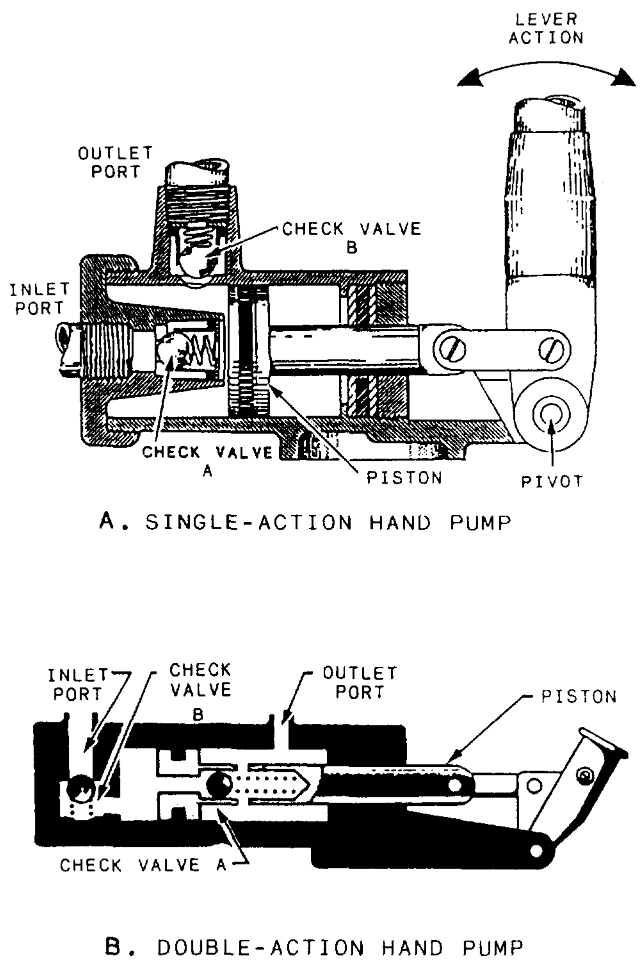


Figure 10-11-Typical hand pumps.

ACTUATORS

The purpose of hydraulic actuators is to transform fluid pressure into mechanical energy. They are used where linear motion or rotary motion is required. Actuators are generally of the cylinder or motor design.

Cylinders

An actuating cylinder is a device that converts fluid power to linear or straight-line force and motion. Since linear motion is a back-and-forth motion along a straight line, this type of actuator is sometimes referred to as a reciprocating or linear motor. The cylinder consists of a ram or piston operating within a cylindrical bore.

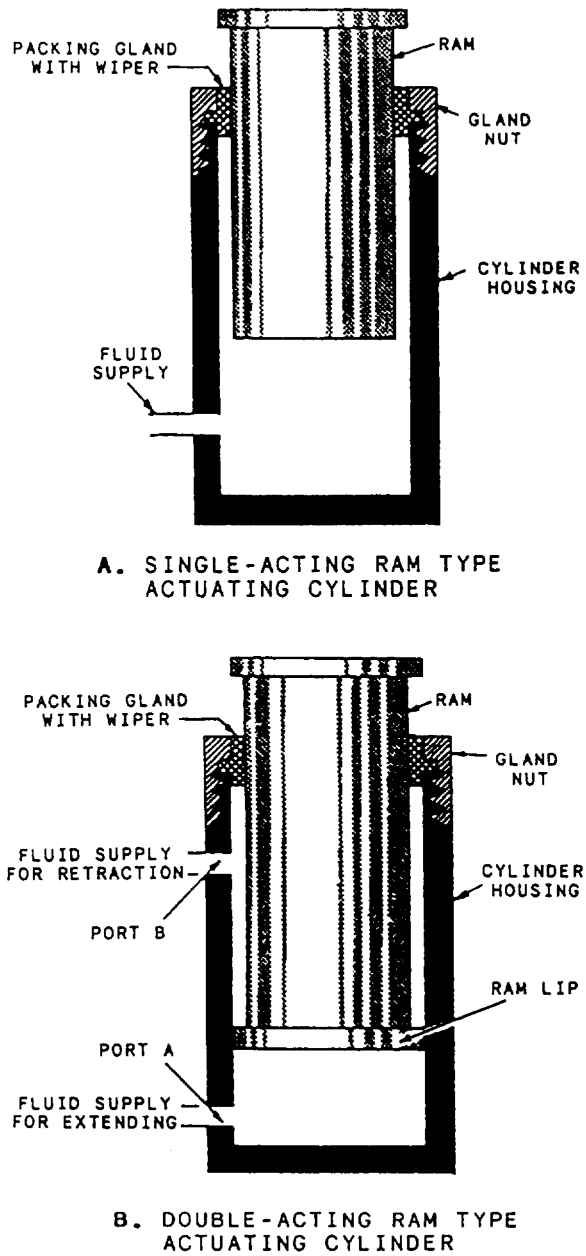


Figure 10-12.-Example of ram type of cylinders.

Actuating cylinders for pneumatic and hydraulic systems are similar in design and operation. Some of the variations of ram- and piston-type actuating cylinders are described in the paragraphs below.

RAM TYPE OF CYLINDER.— The ram type of cylinder (fig. 10-12) is used primarily for push functions rather than pull. Some applications simply require a flat surface on the external part of the ram for pushing or lifting the unit to be operated. Other applications require some mechanical means of attachment, such as a clevis or eyebolt. The design of ram-type cylinders varies in many other respects to satisfy the requirements of different applications. Some of these various designs are discussed in the paragraphs below.

Single-Acting Ram.— The single-acting ram (fig. 10-12, view A) applies force in only one direction. Fluid directed into the cylinder displaces the ram and forces it outward. Since there is no provision for retracting the ram by the use of fluid power, the retracting force can be gravity or some mechanical means, such as a spring. This type of actuating cylinder is often used in the hydraulic jack.

Double-Acting Ram.— A double-acting ram type of cylinder is illustrated in figure 10-12, view B. In this cylinder, both strokes of the ram are produced by pressurized fluid. There are two fluid ports–one at or near each end of the cylinder. To extend the ram and apply force, fluid under pressure is directed to the closed end of the cylinder through port A. To retract the ram and reduce force, fluid is directed to the opposite end of the cylinder through port B.

PISTON TYPE OF CYLINDER.— This type of cylinder is normally used for applications that require both push and pull functions. Thus, the piston type serves many more requirements than the ram type; therefore, it is the most common type used in fluid power systems.

The housing consists of a cylindrical barrel that usually contains either external or internal threads on both ends. End caps with mating threads are attached to the ends of the barrel. These end caps usually contain the fluid ports. The end cap on the rod end contains a hole for the piston rod to pass through. Suitable packing must be used between the hole and the piston rod to prevent external leakage of fluid and the entrance of dirt and other contaminants. The opposite end cap of most cylinders is provided with a fitting for securing the actuating cylinder to some structure. For obvious reasons, this end cap is referred to as the anchor end cap.

The piston rod may extend through either or both ends of the cylinder. The extended end of the rod is normally threaded for the attachment of some type of mechanical connector, such as an eyebolt or a clevis, and a locknut. This threaded connection of the rod and mechanical connector provides for adjustment between the rod and the unit to be actuated. After correct adjustment is obtained, the locknut is tightened against the connector to prevent the connector from turning. The other end of the eyebolt or clevis is connected, either directly or through additional mechanical linkage, to the unit to be actuated.

To satisfy the many requirements of fluid power systems, you may get piston type cylinders in various designs. Two of the more common designs (fig. 10-13) are described in the paragraphs below.

Single-Acting Piston.— The single-acting piston-type cylinder (fig. 10-13, view A) is similar in design and operation to the single-acting ram-type cylinder previously covered. The single-acting piston-type cylinder uses fluid pressure to apply force in only one direction. In some designs of this type, the force of gravity moves the piston in the opposite direction; however, most cylinders of this type apply force in both directions. Fluid pressure provides the force in one direction, and spring tension provides the force in the opposite direction. In some single-acting cylinders, compressed air or nitrogen is used instead of a spring for movement in the direction opposite that achieved with fluid pressure.

The end of the cylinder opposite the fluid port is vented to the atmosphere. This prevents air from being trapped in this area. Any trapped air would compress during the extension stroke, creating excess pressure on the rod side of the piston. This would cause sluggish movement of the piston and could eventually cause a complete lock, preventing the fluid pressure from moving the piston.

You should note that the air vent ports are normally equipped with an air filtering attachment to prevent ingestion of contaminates when the piston retracts into the cylinder.

A three-way directional control valve is normally used to control the operation of this type of cylinder. To extend the piston rod, fluid under pressure is directed through the port and into the cylinder. This pressure acts on the surface area of the blank side of the piston and forces the piston to the right. This action, of course, extends the rod to the right through the end of the cylinder. This moves the actuated unit in one direction. During this action, the spring is compressed between the rod side of the piston and the end of the cylinder. Within limits of the cylinder, the length of the stroke depends upon the desired movement of the actuated unit.

Double-Acting Piston.— Most piston type actuating cylinders are double-acting, which means that fluid under pressure can be applied to either side of the piston to provide movement and apply force in the corresponding direction.

One design of the double-acting piston type actuating cylinder is illustrated in figure 10-13, view B. This cylinder contains one piston and piston rod assembly. The stroke of the piston and piston rod assembly in either direction is produced by fluid pressure. The two fluid ports, one near each end of the cylinder, alternate as inlet and outlet, depending upon the direction of flow from the directional control valve.

This is referred to as an unbalanced actuating cylinder; that is, there is a difference in the effective working areas on the two sides of the piston. Assume that the cross-sectional area of the piston is 3 square inches and the cross-sectional area of the rod is 1 square

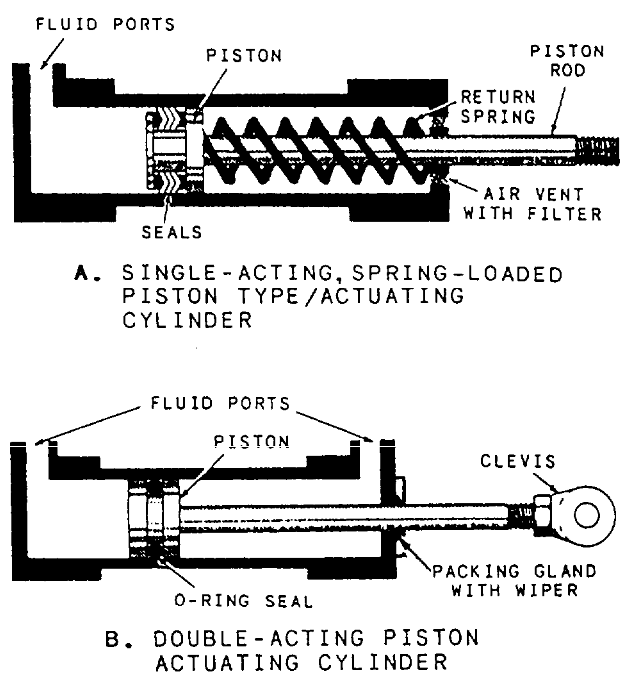


Figure 10-13.-Example of piston type of cylinder.

inch. In a 2,000-psi system, pressure acting against the blank side of the piston creates a force of 6,000 pounds (2,000 x 3). When the pressure is applied to the rod side of the piston, the 2,000 psi acts on 2 square inches (the cross-sectional area of the piston less the cross-sectional area of the rod) and creates a force of 4,000 pounds (2,000 x 2). For this reason, this type of cylinder is normally installed in such a manner that the blank side of the piston carries the greater load; that is, the cylinder carries the greater load during the piston rod extension stroke.

A four-way directional control valve is normally used to control the operation of this type of cylinder. The valve can be positioned to direct fluid under pressure to either end of the cylinder and allow the displaced fluid to flow from the opposite end of the cylinder through the control valve to return/exhaust.

Motors

A fluid power motor is a device that converts fluid power to rotary motion and force. Basically, the function of a motor is just the opposite as that of a pump; however, the design and operation of fluid power motors are very similar to pumps. In fact, some hydraulic pumps can be used as motors with little or no modifications; therefore, your having a thorough knowledge of the pumps will be extremely helpful to you in understanding the operation of fluid power motors.

Motors serve many applications in fluid power systems. In hydraulic power drives, pumps and motors are combined with suitable lines and valves to form hydraulic systems. The pump, commonly referred to as the A-end, is driven by some outside source, such as a diesel or gasoline engine. The pump delivers fluid to the motor. The motor, referred to as the B-end, is actuated by this flow, and, through mechanical linkage, conveys rotary motion and force to the work.

Fluid motors are usually classified according to the type of internal element, which is directly actuated by the flow. The most common types of elements are the gear, vane, and piston. All three of these types are adaptable for hydraulic systems, while only the vane type is used in pneumatic systems.

GEAR TYPE.— The gears of the gear-type motor are of the external type and may be of the spur, helical, or herringbone design. These designs are the same as those used in gear pumps.

The operation of a gear-type motor is illustrated in figure 10-14. Both gears are driven gears; however, only one is connected to the output shaft. As fluid under pressure enters chamber A, it takes the path of least resistance and flows around the inside surface of the housing, forcing the gears to rotate as indicated. The flow continues through the outlet port to return. This rotary motion of the gears is conveyed through the attached shaft to the work unit.

Although the motor illustrated in figure 10-14 shows operation in only one direction, the gear-type motor is capable of providing rotary motion in either direction. The ports alternate as inlet and outlet, To reverse the direction of rotation, the fluid is directed through the port-labeled outlet, into chamber B. The flow through the motor rotates the gears in the opposite direction, thus actuating the work unit accordingly.

VANE TYPE.— A typical vane-type air motor is illustrated in figure 10-15, view A. This particular motor provides rotation in only one direction. The rotating element is a slotted rotor mounted on a drive shaft. Each slot of the rotor is fitted with a freely sliding rectangular vane. The rotor and vane are enclosed in the housing–the inner surface of which is offset with the drive shaft axis. When the rotor is in motion, the vanes tend to slide outward because of centrifugal force. The distance the vanes slide is limited by the shape of the rotor housing.

This motor operates on the principle of differential areas. When compressed air is directed into the inlet port, its pressure is exerted equally in all directions. Since area A is greater than area B, the rotor will turn counterclockwise. Each vane, in turn, assumes the No. 1 and No. 2 position and the rotor turns continuous y. The potential energy of the compressed air is thus

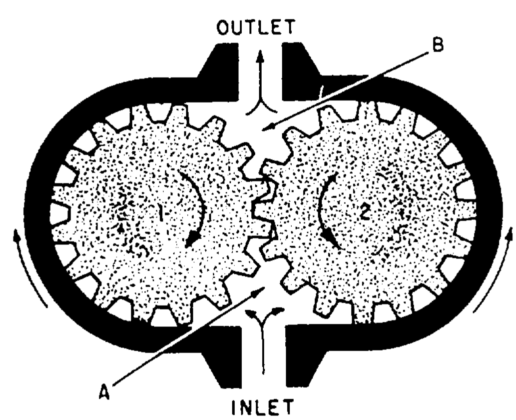
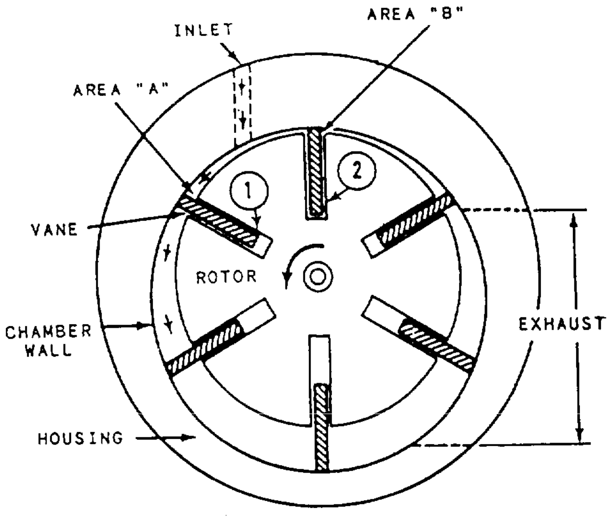
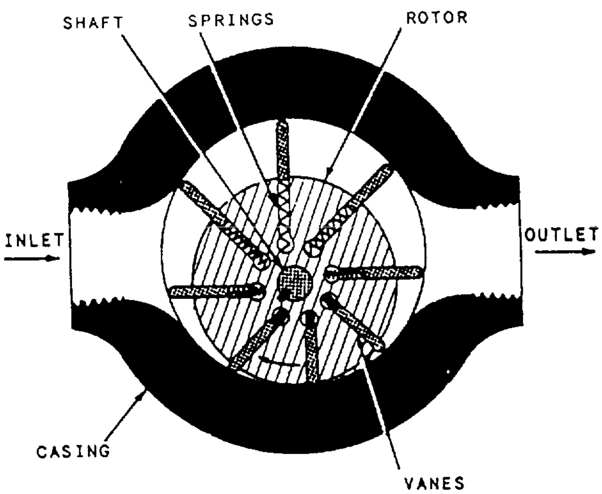


Figure 10-14.-Example of a gear-type of hydraulic motor.



A. VANE TYPE OF AIR MOTOR



B. VANE TYPE OF HYDRAULIC MOTOR

Figure 10-15.-Typical vane type of hydraulic motor.

converted into kinetic energy in the form of rotary motion and force. The air at reduced pressure is exhausted to the atmosphere. The shaft of the motor is connected to the unit to be actuated.

Many vane-type motors are capable of providing rotation in either direction. A motor of this design is illustrated in figure 10-15, view B. The principle of operation is the same as that of the vane type of motor previously described. The two ports may be alternately used as inlet and outlet, thus providing rotation in either direction. Note the springs in the slots of the rotors. Their purpose is to hold the vanes against the housing during the initial starting of the motor, since no centrifugal force exists until the rotor begins to rotate. Springs are not required in vane-type pumps because the drive shaft provides the initial centrifugal force.

PISTON TYPE.— Like piston (reciprocating) type pumps, the most common design of the piston type of motor is the axial. This type of motor is the most commonly used in hydraulic systems.

Although some piston-type motors are controlled by directional control valves, they are often used in combination with variable displacement pumps. This pump-motor combination (hydraulic transmission) is used to provide a transfer of power between a driving element (for example, an electric motor or gasoline engine) and a driven element. Some of the applications for which hydraulic transmissions may be used are speed reducer, variable speed drive, constant speed or constant torque drive, and torque converter. Some advantages of hydraulic transmission over mechanical transmission of power are as follows:

1. Quick easy speed adjustment over a wide range while the power source is operating at constant (most efficient) speed. Rapid, smooth acceleration or deceleration.
2. Control over maximum torque and power.
3. Cushioning effect to reduce shock loads.
4. Smoother reversal of motion.

While you are studying the description of the piston type of motor in the paragraphs below, it may be necessary to refer back to the piston type of pump for a review of the operation and particularly the parts nomenclature.

The operation of the axial-piston motor (fig. 10-16) is similar to that of a radial piston motor. Fluid from the system flows through one of the ports in the valve plate and enters the bores of the cylinder block that are open

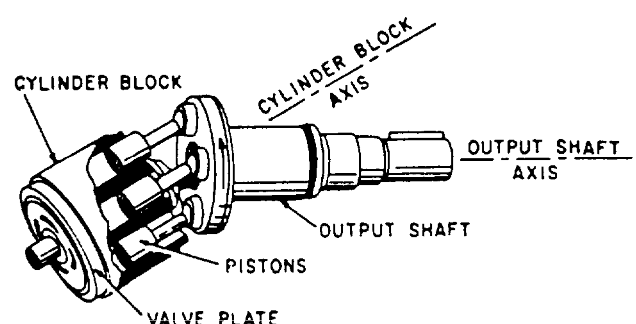


Figure 10-16.-Example of a piston type of hydraulic motor.

to the inlet port. (For example, in a nine piston motor, four cylinder bores are receiving fluid while four are discharging.) The fluid acting on the pistons in those bores forces the pistons to move away from the valve plate. Since the pistons are held by connecting rods at a fixed distance from the output shaft flange, they can move away from the valve plate only by moving in a rotary direction. The pistons move in this direction to a point around the shaft axis, which is the greatest distance from the valve plate. Therefore, driving the pistons axially causes them to rotate the drive shaft and cylinder block. While some of the pistons are being driven by liquid flow from the system, others are discharging flow from the outlet port.

This type of motor may be operated in either direction of rotation. The direction of rotation is controlled by the direction of flow to the valve plate. The direction of flow may be instantly reversed without damage to the motor. This design is found mainly on construction equipment as an auxiliary drive motor.

The speed of the rotation of the motor is controlled by the length of the piston stroke in the pump. When the pump is set to allow a full stroke of each piston, each piston of the motor must move an equal distance. In this condition, the speed of the motor will equal that of the pump. If the tilting plate of the pump (normally called a swash plate or hanger assembly) is changed so that the piston stroke of the pump is only one half as long as the stroke of the motor, it will require the discharge piston one full stroke; therefore, in this position of the plate, the motor will revolve just one half as fast as the pump. If there is no angle on the tilting plate of the pump, the pumping pistons will not move axially, and liquid will not be delivered to the motor; therefore, the motor will deliver no power.

If the angle of the tilting plate is reversed, the direction of flow is reversed. Liquid enters the motor through the port by which it was formally discharged. This reverses the direction of rotation of the motor.

An additional benefit to this axial-piston pump/axial-piston motor configuration is the dynamic braking effect created when the motor, in a coasting situation, in effect, becomes a pump itself and attempts to reverse-rotate the hydraulic pump. In this situation the pump now becomes a motor and attempts to reverse-rotate the prime mover. The degree of reverse angle on the tilting plate in the pump determines the effectiveness of the dynamic braking.

VALVES

Once the pump has begun to move the fluid in a hydraulic system, valves are usually required to control, monitor, and regulate the operation of the system. While the pump is recognized as the heart of the system, the valves are the most important devices for providing flexibility in today's complex hydraulic systems.

Valves are included in a hydraulic system to control primarily (1) the direction of fluid flow, (2) the volume of fluid going to various parts of the system, and (3) the pressure of the fluid at different points in the system.

It is beyond the scope of this training manual to cover all of the many different valves in use today; however, since most of these valves are almost always combinations and elaborations of basic types, an understanding of their operation can be obtained by a review of the basic types.

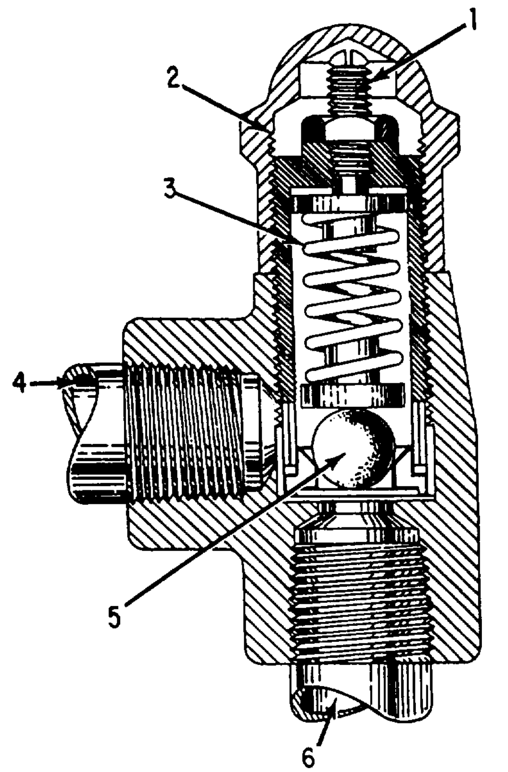
The basic valves are those designed to do one of the primary functions mentioned above; that is, control direction of flow, control volume, and regulate fluid pressure.

Valves, like pumps, are precision made. Usually, no packing is used between the valve element and the valve seat since leakage is reduced to a minimum by machined clearances. (Packing is required around valve stems, between lands of spool valves, etc.) Here again is an important reason for preventing system contamination. Even the most minute particle of dirt, dust, and lint can do considerable damage to hydraulic valves.

Relief Valves

A relief valve is a simple pressure-limiting device. It is incorporated in most hydraulic systems and acts as a safety valve, used to prevent damage to the system in case of overpressurization.

A simple two-port relief valve is shown in figure 10-17. An adjustment is provided so that the valve may be regulated to any given pressure; therefore, it can be used on a variety of systems. Before the system pressure can become high enough to rupture the tubing or damage the system units, it exceeds the pressure required to overcome the relief valve spring setting. This pushes the ball off its seat and bypasses excess fluid to the reservoir. If the system pressure decreases, the spring setting reseats the ball; the ball then remains seated until the pressure again reaches the predetermined maximum.



1. Adjusting screw
2. Adjusting screwcap
3. Spring
4. Return port
5. Ball
6. Pressure port

Figure 10-17.-Typical relief valve.

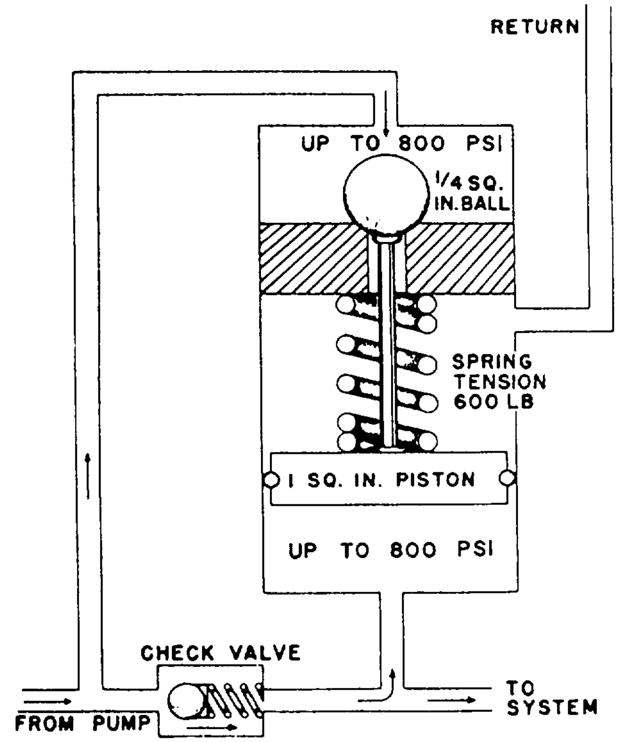


Figure 10-18.-Pressure regulator at the cut-in position.

Pressure Regulator Valves

As the name implies, the pressure regulator valve is designed to regulate system pressure between a maximum operating pressure and a minimum operating pressure. This valve is often referred to as an unloading valve. It is designed to remove the system load from the pump once system pressure has been reached.

The functions performed by the regulator valve are accomplished by its two operational phases-cut-in and cutout. The regulator is said to be cut-in when it is directing fluid under pressure into the system. The regulator is cutout when fluid is bypassed into the return line and back to the reservoir. Figure 10-18 shows atypical pressure regulator in the cut-in position. Figure 10-19 shows the regulator in the cut out position. Notice the check valve in these figures. The check valve can bean integral part of the regulator or a separate unit, but it is necessary that a check valve be used, as shown in the figures.

Referring back to figure 10-18, you can see the pump supplies a pressure to the top and bottom of the regulator valve. By finding the pressure areas of the ball and piston, plus the 600-pound spring tension, you can find the balanced state of the valve-in this case, 800 psi. This means that any pressure in excess of 800 psi unseats

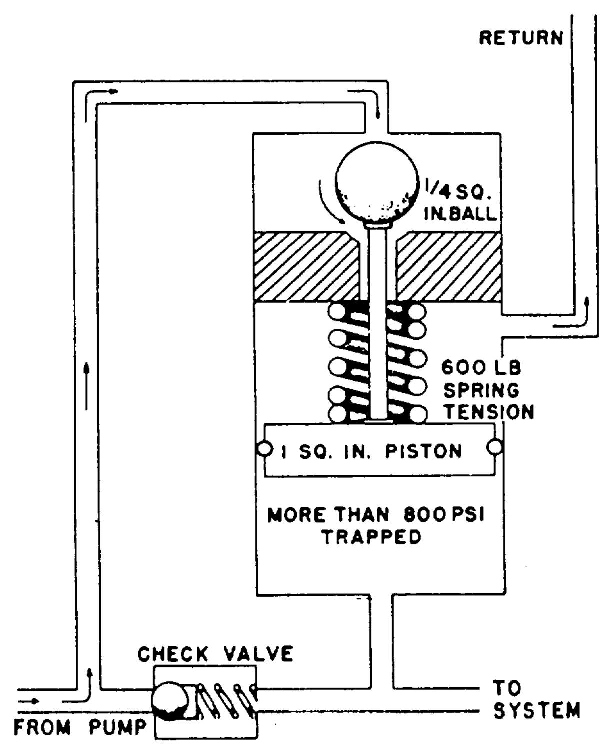


Figure 10-19.-Pressure regulator at the cut out position.

the regulator ball and provides the pump with an unrestricted fluid flow back to the reservoir.

In figure 10-19 the regulator ball is unseated. When this happens, pressure drops immediately. Now the importance of the check valve can be seen. With the sudden reduction in pressure, the check valve snaps shut; and the fluid trapped in the system line continues to hold the regulator piston in the raised position. This trapped fluid also maintains pressure on the system until the mechanism actuates or is relieved by leakage, either of which can cause the regulator to cut-in.

Hydraulic systems using a constant volume pump require a pressure regulator valve; those using a variable volume pump do not.

Selector Valves

The purpose of a selector valve is to control the direction of fluid flow; this, in turn, controls the operation or direction of the mechanism. Although all selector valves share the common purpose of controlling the direction of fluid flow, they vary considerably in physical characteristics and operation.

The valving element of these units may be one of three types: the poppet type, in which a piston or ball moves on and off a seat; the rotary sped type, in which the spool rotates about its axis; or the sliding spool type, in which the spool slides axially in a bore. Selector valves may be actuated mechanically, manually, electrically, hydraulically, or pneumatically.

POPPET VALVE.— Figure 10-20 illustrates the operation of a simple poppet valve. The valve consists primarily of a movable poppet that closes against a 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 poppet, usually made of steel, fits into the center bore of the seat. The seating surfaces of the poppet and the seat are lapped or closely machined, so the center bore will be sealed when the poppet is seated. The action of the poppet is similar to the valves of an automobile engine. An O-ring seal is usually installed on the stem of the poppet to prevent leakage past this portion of the housing. In most valves the poppet is held in the seated position by a spring. The number of poppets in a particular valve depends upon the design and purpose of the valve.

ROTARY SPOOL VALVE.— The rotary spool type of directional control valve has a round core with one or more passages or recesses in it. The core is mounted within a stationary sleeve (fig. 10-21). As the core is rotated (generally by a hand lever or a knob) 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 pressure, working and return lines of the fluid power system.

SLIDING SPOOL VALVE.— The sliding spool valve is probably the most common type of valving element used in directional control valves. The operation of a simple sliding spool directional control valve is illustrated in figure 10-22. The valve is so named because the shape of the valving element resembles that of a spool and because the valving element slides back and forth to block and uncover ports in the housing.

The valve is shown in neutral position (no fluid flow); but by moving the spool valve to the left position,

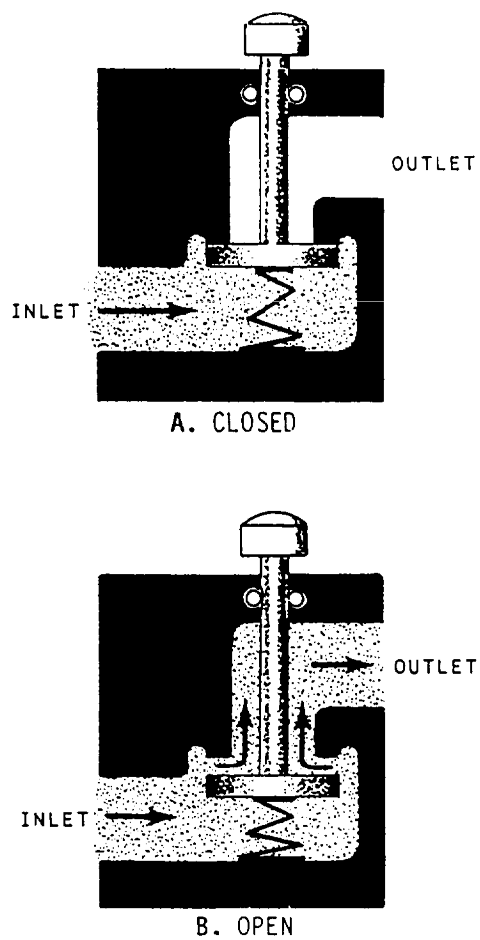


Figure 10-20.-The basic operation of a simple poppet valve.

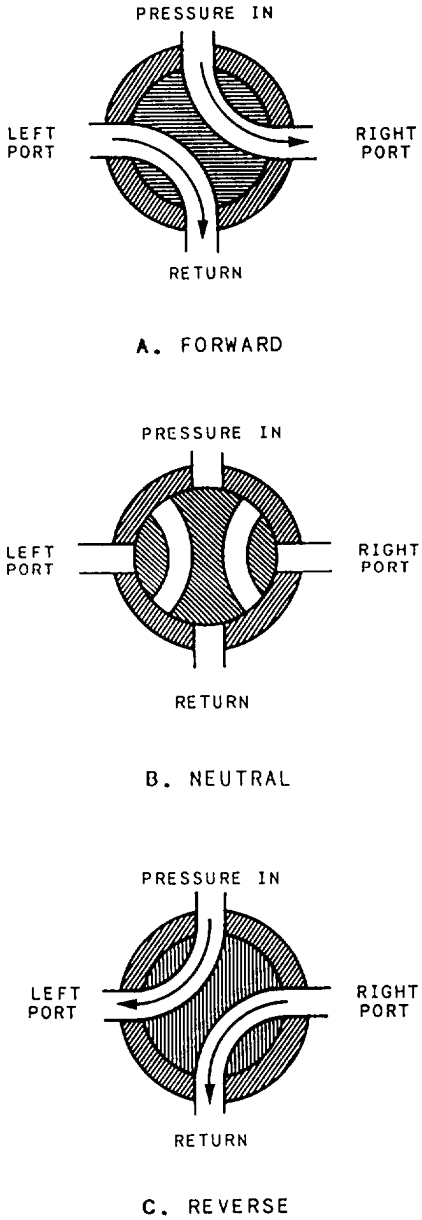


Figure 10-21.-Operation of a rotary spool valve.

fluid flows from the pressure line out through the right port; fluid returns back through the left port to the return line. Movement of the spool to the right position gives similar results; the left port becomes a pressure port and the right port becomes the return port.

Like all classes of directional control valves, various methods are used for positioning the sliding spool valve. Some of the most common methods are by hand levers, cam angle plates, directional control arms, and self-regulating poppet valve linkage.

Check Valves

Some authorities classify check valves as flow control valves. However, since the check valve permits flow in one direction and prevents flow in the other direction, most authorities classify it as a one-way directional control valve-the "diode" of the hydropneumatic world.

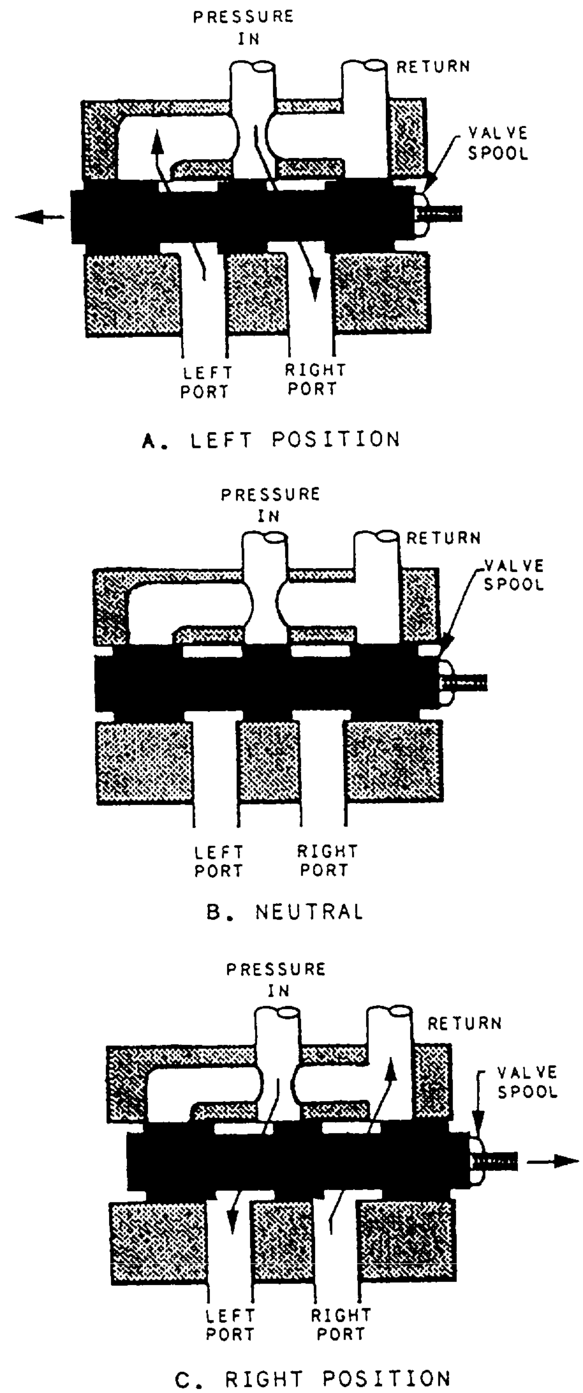


Figure 10-22.-Operation of a spool selector valve.

Regardless of their classification, check valves are probably the most widely used valves in fluid power systems. The check valve may be installed independently in a line to allow flow in one direction only. This is indicated in the simple system described earlier with the hand pumps. Check valves are also incorporated as an integral part of some other valve, such as the sequence valve, the counterbalance valve, and the pressure regulator valve, also described earlier. A modification of the check valve-the orifice check valve-allows free flow in one direction and a limited or restricted flow in the opposite direction.

Check valves are available in various designs. As stated previously, the ball and the cone, or sleeve, are commonly used as the valving elements. The poppet, piston, spool, or disk are also used as valving elements in some types of check valves. The force of the fluid in motion opens a check valve, while it is closed by fluid attempting to flow in the opposite direction aided by the action of a spring or by gravity.

RESERVOIRS

As stated previously, an adequate supply of the recommended fluid is an important requirement for the efficient operation of a fluid power system. The reservoir, which provides a storage space for fluid in hydraulic systems, differs to a great extent from the receivers used for this purpose in pneumatic systems. For this reason, the two components are covered separately in the paragraphs below.

The reservoir is the fluid storehouse for the hydraulic system. It contains enough fluid to supply the normal operating needs of the system and an additional supply to replace fluid lost through minor leakage. Although the function of a reservoir is to supply an adequate amount of fluid to the entire hydraulic system, it is more than just a vessel containing fluid. It is here that the fluid has the greatest potential danger of becoming contaminated. It is in the reservoir where any air entering the fluid system has the opportunity of escaping; dirt, water, and other matter settle to the bottom. Reservoirs are designed in a way that permit just clean hydraulic fluid to come to the top.

The construction features of a typical reservoir are shown in figure 10-23. These reservoirs have a space above the fluid, even when they are full. This space allows the fluid to foam, and thus purge itself of air bubbles that normally occur as the fluid makes its way

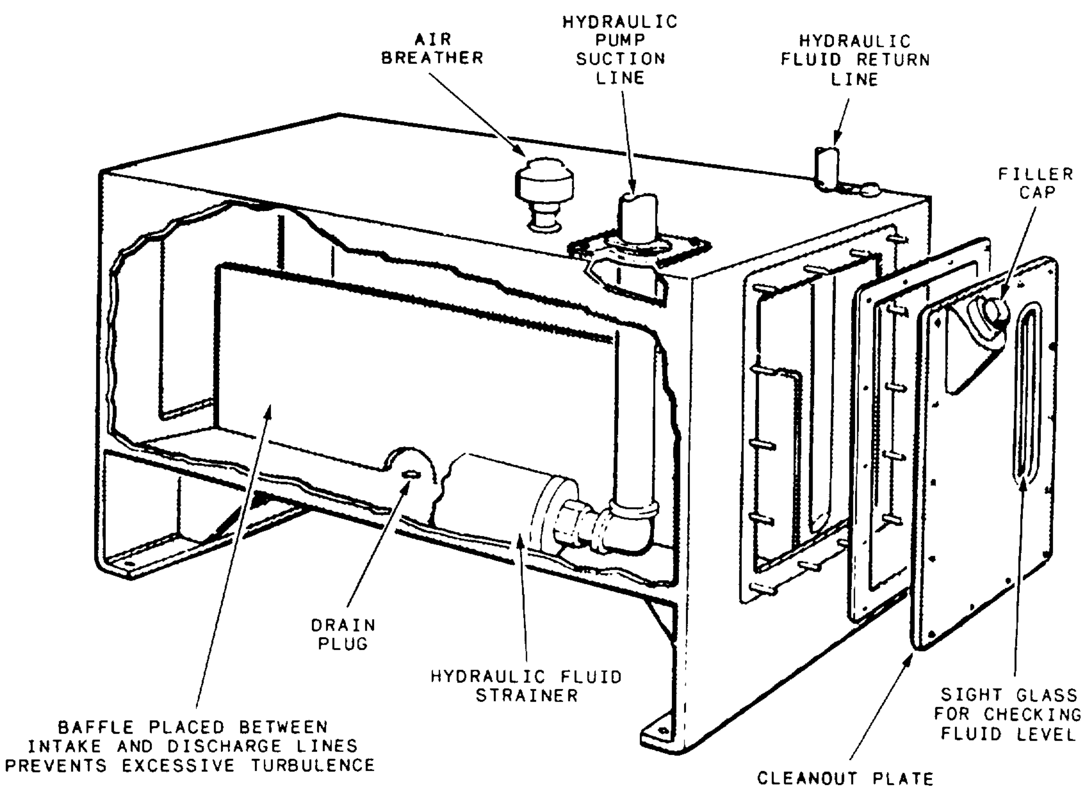


Figure 10-23.-Typical hydraulic reservoir.

from the reservoir, through the system, and back to the reservoir.

An air vent allows the air to be drawn in and pushed out of the reservoir by the ever-changing fluid level. An air filter is attached to the air vent to prevent drawing atmospheric dust into the system by the ever-changing fluid level. A securely fastened filling strainer of fine mesh wire is always placed below the system filler cap.

The sight gauge is provided so the normal fluid level can always be seen, as it is essential that the fluid in the reservoir be at the correct level. The baffle plate segregates the outlet fluid from the inlet fluid. Although not a total segregation, it does allow time to dissipate the air bubbles, lessen the fluid turbulence (contaminants settle out of nonturbulent fluid), and cool the return fluid somewhat before it is picked up by the pump.

Reservoirs used on CESE may vary considerably from that shown in figure 10-23; however, manufacturers retain as many of the noted features as possible, depending on design limits and use.

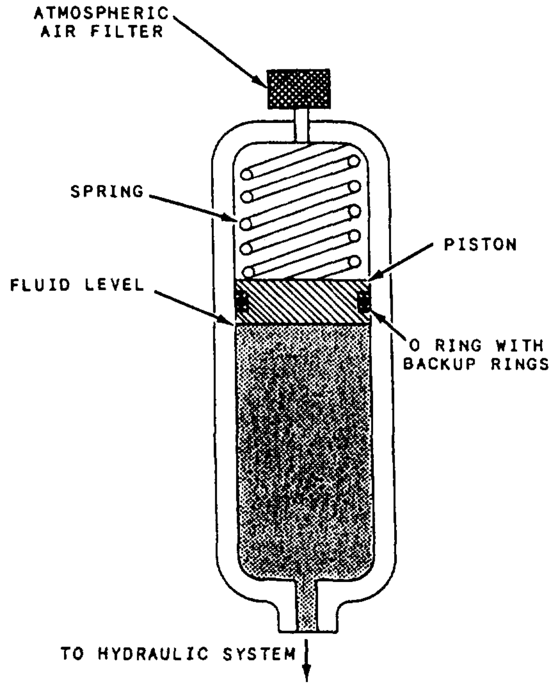


Figure 10-24.-Spring-operated accumulator.

ACCUMULATORS

Hydraulic accumulators are incorporated in some hydraulic systems to store a volume of liquid under pressure for subsequent conversion into useful work or to absorb rapid fluid pulsations when valves are operated repeatedly. Two types of accumulators are the spring operated and the air operated.

Spring-Operated Accumulator

In this type of accumulator, the compression resulting from the maximum installed length of the spring or springs should provide the minimum pressure required of the liquid in the cylinder assembly. As liquid is forced into the cylinder (fig. 10-24), the piston is forced upward and the spring or springs are further compressed, thus providing a reservoir of potential energy for later use.

Air-Operated Accumulators

The air-operated accumulator is often referred to as a pneumatic or hydropneumatic accumulator. This type of accumulator uses compressed gas (usually air or nitrogen) to apply force to the stored liquid. Air-operated accumulators are classified as either nonseparator or separator types.

NONSEPARATOR TYPE OF ACCUMULATOR.— In the nonseparator type of accumulator (fig. 10-25), no means are provided for separating the gas from the liquid. It consists of a fully closed cylinder, mounted in a vertical position, containing a liquid port on the bottom and a pneumatic charging port (Schrader valve) at the top.

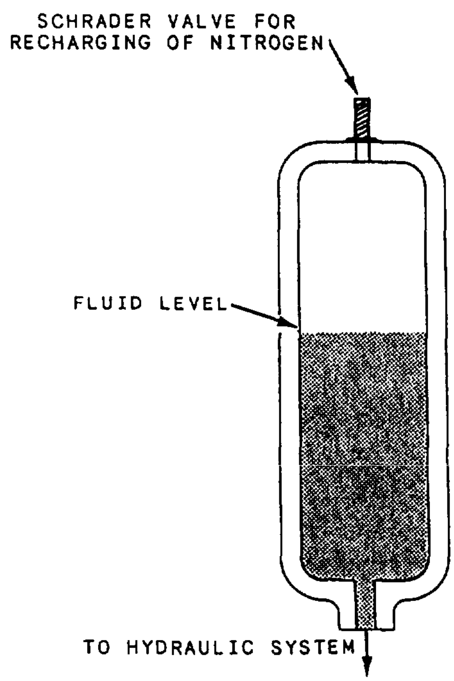


Figure 10-25.-Air-operated accumulator (nonseparator type).

SEPARATOR TYPE OF ACCUMULATOR.— In the separator type of air-operated accumulator, a means is provided to separate the gas from the liquid. The three styles of separators are bladder (bag), diaphragm, and piston (cylinder).

Figure 10-26 illustrates one version of an air-operated accumulator of the *bladder style.* This accumulator derives its name from the shape of the synthetic rubber bladder or bag that separates the liquid and gas within the accumulator.

Although there are several different modifications of the *diaphragm style* accumulator, it is usually spherical in shape. Figure 10-27 illustrates an example of this type. The shell is constructed of two metal hemispheres, that are either screwed or bolted together. The fluid and gas chambers are separated by a synthetic rubber diaphragm.

A *cylinder style* accumulator is illustrated in figure 10-28. This accumulator contains a free-floating piston that separates the gas and liquid chambers. The cylindrical accumulator consists of a barrel assembly, a piston assembly, and two end cap assemblies, The barrel assembly houses the piston and incorporates provisions for securing the end caps.

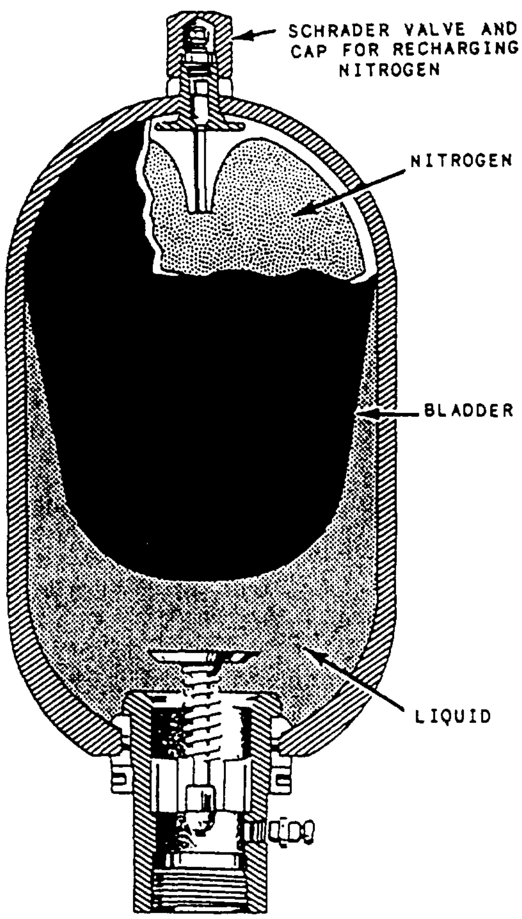


Figure 10-26.-Air-operated bladder type of accumulator (separator type).

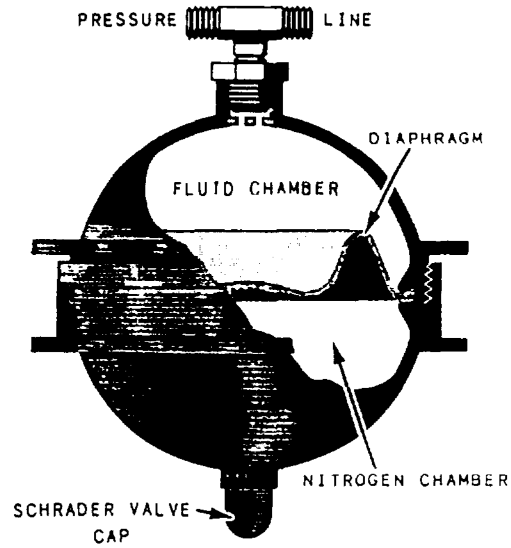


Figure 10-27.-Diaphragm type of accumulator.

APPLICATION

Much of today's CESE is equipped with one or more hydraulic accumulators that serve several purposes in the hydraulic system, as described in the paragraphs below. Some of the hydraulic systems illustrated and described later in this chapter show the applications of accumulators and their relationship to other components in the system.

Shock Absorber

A liquid, flowing at a high velocity in a pipe, will create a backward surge when stopped suddenly. Even the closing of a valve will develop instantaneous pressures two to three times the operating pressure of the system. This shock will result in objectional noise and vibration, which can cause considerable damage to tubing, fittings, and components. The incorporation of an accumulator will enable such shocks and surges to be absorbed or cushioned by the entrapped gas, thereby reducing their effects. The accumulator will also dampen pressure surges caused by the pulsating delivery from the pump.

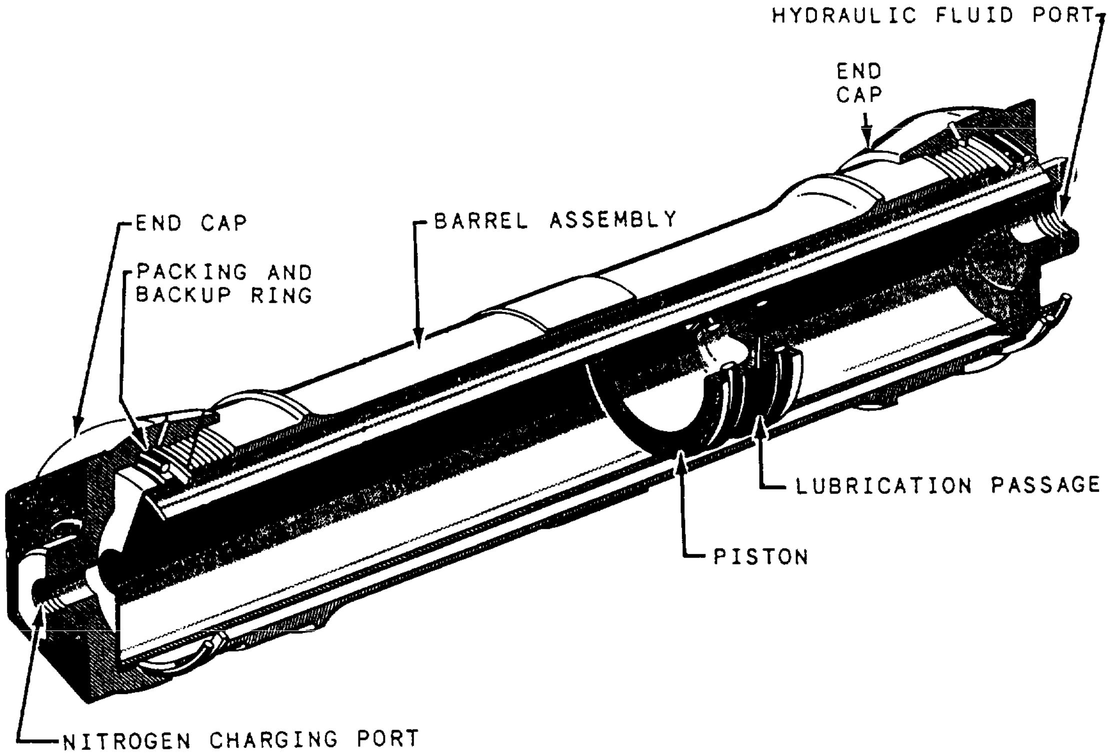


Figure 10-28.-Cylinder type of accumulator.

Emergency Power Supply

The energy stored in an accumulator may be used to actuate a unit in the event of normal hydraulic system failure; for example, the hydroboost power braking system used in the 1 1/4-ton tactical cargo truck or cucv has sufficient energy stored in the accumulator for limited emergency braking operation.

FILTERS

When small bits of metal, rubber, paper, dust, and dirt enter into a system, they contaminate the fluid. The fluid may be contaminated in many different ways. The contaminants may enter the system during the manufacturing of the components or during servicing and maintenance of the system; they can be created in the system by internal wear of the components, or because of deterioration of seals, hoses, and gaskets. These impurities can become suspended in the fluid and circulate throughout the system. Because of the close tolerance of the system components, the contamination in a system must be kept at an acceptable level; otherwise, the components are damaged, destroyed, or become clogged and inoperative. It is for these reasons that filters are essential in hydraulic and pneumatic systems.

A filter in a hydraulic system is a screening or straining device used to remove impurities from the hydraulic fluid. Filters may be located within the reservoir, in the pressure line, in the return line, or in other locations where they are needed to safeguard the hydraulic system against impurities. There are several different types and arrangements of filters. Their position in equipment and design requirements determine their shape and size.

Filter Elements

The filter element is the part or parts (single or dual element) of the filter that removes the impurities from the hydraulic fluid as the fluid passes through the filter. Filter elements are usually classified by either their material and/or their design and construction. The most common filter elements used in CESE equipment are wire mesh, micronic, and porous metal.

WIRE MESH FILTER.— A wire mesh filter element is made of a fine wire mesh (screen) and is usually used where the fluid enters and/or leaves a container or component (view (A) of fig. 10-29). The size of wire mesh openings varies with the particular filter element, but normally a wire mesh filter element removes only the larger particles of contamination from the fluid.

A wire mesh filter element can be reused. It should be removed, cleaned, and reinstalled at scheduled intervals or when it becomes dirty. Replace it when it cannot be properly cleaned or is damaged.

MICRONIC FILTER.— *Micronic,* a term derived from the word *micron,* can be used to describe any filter element. Through usage, micronic has become associated with a specific filter with a filtering element made of a specially treated cellulose paper. The paper is formed in vertical convolutions (wrinkles) and is made in a cylindrical pattern. A spring in the hollow core of the element holds the element in shape (view (B) of fig. 10-29).

Micron is a unit of measurement used to express the degree of filtration. A micron equals one millionth of a meter or 0.0000394 inch. For comparison value, consider that the normal lower level of visibility to the naked eye is about 40 microns. (A grain of table salt measures about 100 microns; the thickness of a human hair is about 70 microns; and a grain of talcum powder is about 10 microns.)

When it is used in CESE hydraulic systems, the micronic element normally prevents the passage of solids of 10 microns or greater in size. The micronic filter element is disposable.

POROUS METAL FTLTER.— Use porous metal filter elements in hydraulic systems in which high pressures exist and/or a high degree of filtration is required. The two porous metal elements discussed–sintered bronze and stainless steel–are capable of filtering out solid particles and 5 and 15 microns, respectively.

Porous metal filter elements are reusable. When the filter element becomes contaminated, it is removed from the system, cleaned, tested, and reinstalled for further use. The number of times a filter element can be cleaned and reused depends on the particular type of element and the system in which it is used. Likewise, if the filter element is damaged in any way or does not meet test requirements, it must be discarded.

Sintered Bronze Filter.— The sintered bronze element consists of minute bronze balls joined together as one solid piece while still remaining porous (view(C) of fig. 10-29).

Stainless Steel Filter.— Stainless steel filter elements are used in many of the Navy's most modern hydraulic systems. This element is similar in

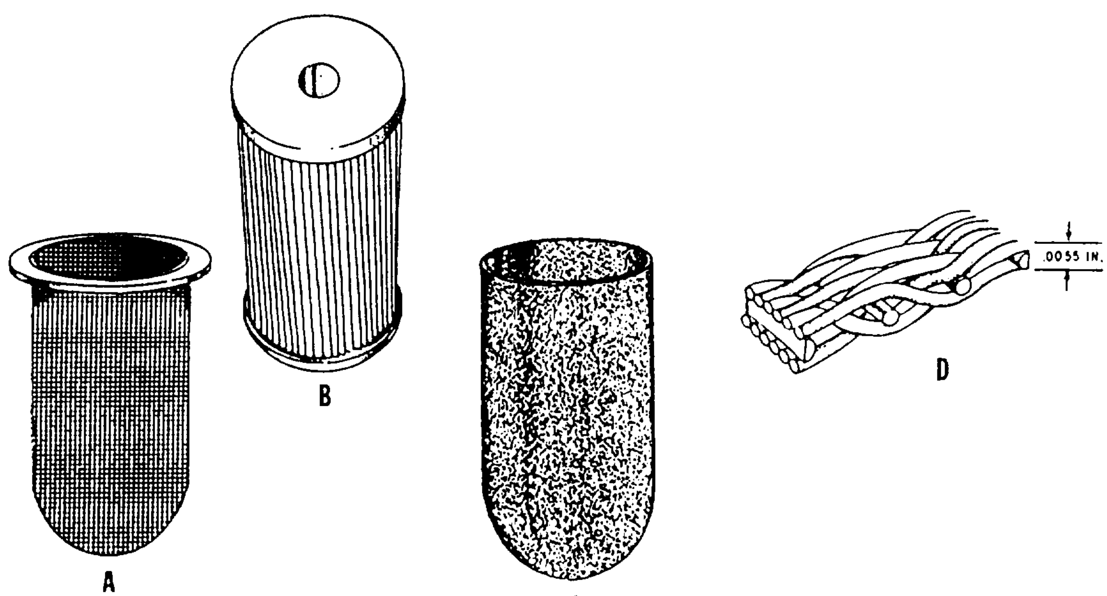


Figure 10-29.-Some typical types of hydraulic screens and filters.

construction to the sintered bronze element described previously. The design is usually a corrugated, sintered, stainless steel mesh, such as the magnified cross section shown in view (D) of figure 10-29. One manufacturer calls the design a "Dutch Twill" pattern. The curved passages of the filter element (through which the fluid passes) limit the length of the particles that pass through the element. Most filters that use the stainless steel are equipped with a contamination indicator, described later in this chapter.

Filter Classifications

The hydraulic systems of CESE use several different types of filters. There are a number of factors to be considered in determining the full classification of a particular type of filter. When hydraulic filters are being classified, the following factors are considered:

1. Flow characteristics
2. Filtering medium
3. Bypass characteristics
4. Contamination indicators

FLOW CHARACTERISTICS.— In the full-flow filter, all the fluid that enters the unit passes through the filter element, while in a proportional flow, only a portion of the fluid passes through the element. Practically all filters used in the hydraulic systems of CESE are full flow.

FILTERING MEDIUM.— The different filter elements–wire mesh, micronic, and porous–were discussed earlier. Normally, only one element is used in each filter; however, some equipment uses two or more elements in order to obtain the desired degree of filtration.

A full-flow, micronic, bypass filter is shown in figure 10-30. This filter provides a positive filtering action; however, it offers resistance to flow, particularly when the element becomes dirty. For this reason, a full-flow filter usually contains a bypass valve; the valve automatically opens to allow the fluid to bypass the element when the flow of fluid is restricted because of contamination buildup on the element.

Hydraulic fluid enters the filter assembly through the inlet port in the body and flows around the filter element inside the filter bowl. Filtering takes place as the fluid passes through the filter element and into the hollow core, leaving dirt and impurities deposited on the outside of the filter medium. The filtered fluid then flows from the hollow core, through the outlet port, and continues on through the system.

BYPASS CHARACTERISTICS.— TMS bypass relief valve in the body allows the fluid to bypass the filter element and pass directly into the outlet port if the filter element becomes clogged. In many micronic filters, the relief valve is set to open when the differential in pressure exceeds 50 psi; for example, if the pressure at the filter inlet port is 90 psi and the pressure at the outlet drops below 40 psi, the bypass valve opens and allows the liquid to bypass the element.

ATTENTION: Oil that bypasses the hydraulic oil filter is unfiltered oil. his is a clear indication of a hydraulic system in need of serious maintenance, repair or both.

CONTAMINATION INDICATORS.— Contamination indicators are often used on bypass filters. The full-flow, porous metal, bypass electrical-indicating

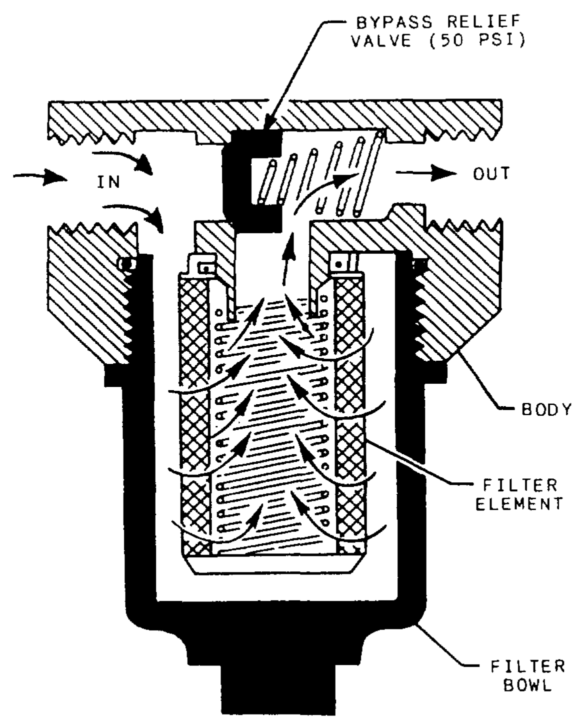


Figure 10-30.-Full-flow, bypass type of hydraulic filter.

hydraulic filter (fig. 10-31) is used in some hydraulic systems. This filter uses one or a combination of the contamination indicators previously described.

Under normal conditions the fluid enters the inlet of the filter (view (A) of fig. 10-31), passes through the filter element, and leaves the filter through the outlet. As the fluid passes through the filter element, impurities are deposited on the outside of the element. As the deposits accumulate, they cause a differential pressure to build up between the inlet and outlet of the filter. The pressure is sensed across the contamination indicator switch; on this particular filter, the switch closes at 70 ÷ 10 psi, actuating a warning device (light, horns, etc.). The equipment should be stopped and the filter serviced, cleaned, or replaced. An important fact for you to remember is that cold hydraulic fluid can produce a false pressure indication. To prevent needless changing of filters, fluid should beat operating temperature for a true

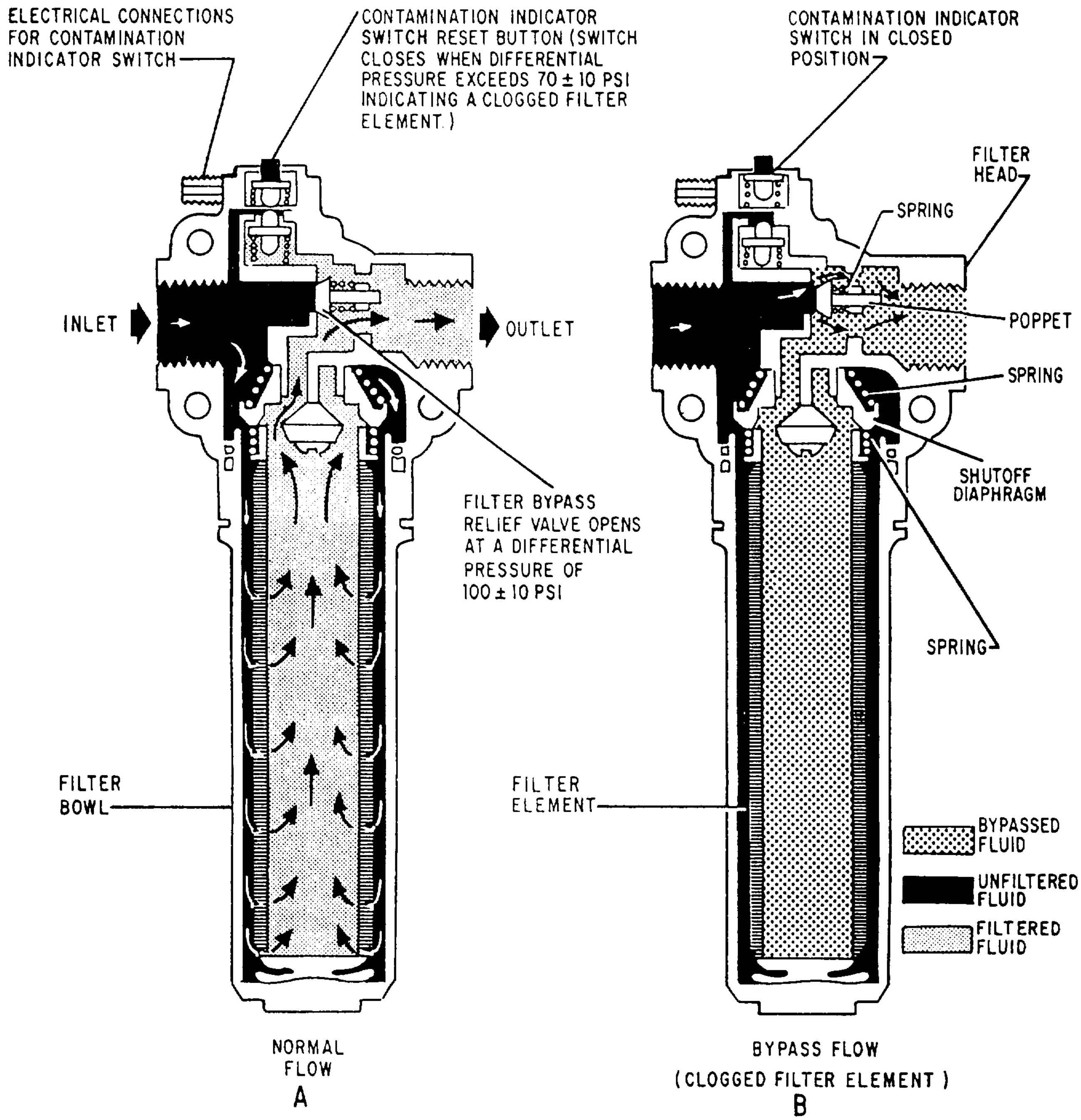


Figure 10-31.-Full-flow, porous metal, bypass electrical-indicating hydraulic filter.

indication of a contaminated filter. Some filters have a button to reset the switch after the filter has been serviced; however, on other filters, the switch resets automatically when the differential pressure is relieved.

If the filter is not properly serviced following the contamination indication and the equipment is kept in operation, the differential pressure continues to build. At 100 ÷ 10 psi, the bypass valve will open and allow the fluid to flow straight through, bypassing the filter element (view (B) of fig. 10-31). But on this filter the contamination indicator is to warn the operator that the filter element is clogged. The equipment can then be stopped before the bypass valve opens, thus preventing contaminated fluid from being passed through the hydraulic system.

HYDRAULIC SYSTEMS

In spite of the great variety of support equipment, all hydraulic systems–from the simplest to the most complex-operate according to the basic principles and make use of the components discussed thus far in this chapter.

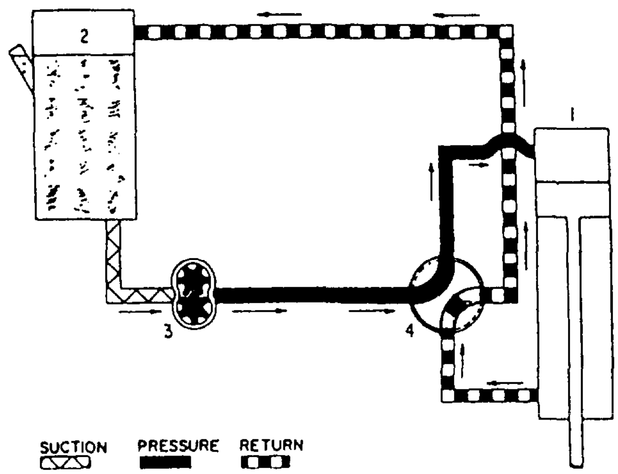
As a CM1 you are responsible for analyzing the malfunctions of hydraulic equipment, ranging from the simple jack to large earth-moving equipment. Thus, the development, piece by piece, of a representative system should assist you in analyzing any hydraulic system.

REPRESENTATIVE HYDRAULIC SYSTEM

Basically, any system must contain the following units: PUMP, ACTUATOR, RESERVOIR, CONTROL VALVE, and TUBING. Figure 10-32 shows a simple system that uses only these essentials.

The flow of hydraulic fluid can be easily traced from the reservoir through the pump to the selector valve. With the selector valve in the position indicated by the solid lines, the flow of fluid created by the pump flows through the valve to the upper end of an actuating cylinder. Fluid pressure then forces the piston down, and at the same time, forces out the fluid on the lower side of the piston, up through the selector valve, and back to the reservoir.

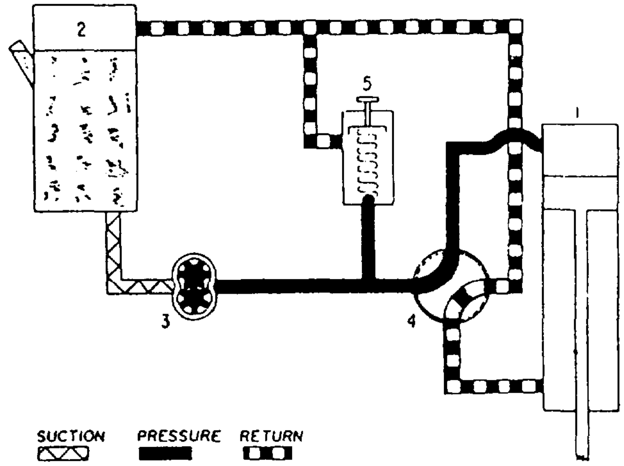
When the selector valve is rotated 90 degrees, the fluid from the pump then flows to the lower side of the actuating cylinder, thus reversing the process. The movement of the piston can be stopped at any time simply by moving the selector valve to the neutral position (45-degree movement either way). In this position, all four ports are closed and pressure is trapped in both working lines.



1. Actuating cylinder
2. Reservoir
3. Power pump
4. Selector valve

Figure 10-32.-A simple hydraulic system.

The hydraulic system just described would be practical if it were operated by a hand pump, such as a system common to the engine installation/removal stands and bomb trucks. However, since the illustrated pump is a power-driven, constant delivery gear pump, pressure builds up immediately to such proportions that either the pump fails or a line bursts. Therefore, a pressure relief valve is incorporated in the system to protect it, as shown in figure 10-33. This valve is set to



1. Actuating cylinder
2. Reservoir
3. Power pump
4. Selector valve
5. Relief valve

Figure 10-33.-Hydraulic system with a relief valve incorporated.

relieve system pressure before it becomes sufficient enough to rupture the system or damage the pump. The relief valve ball is unseated at a predetermined pressure, and excess fluid is bypassed to the reservoir.

At this point, figure 10-33 illustrates a workable system, but it is still impractical. After a few hours, an ordinary pump would probably fail because it has to maintain a constant load. (The pump is keeping the relief valve unseated except when the cylinder is being moved.) With the addition of a check valve and pressure regulator (fig. 10-34), the work load on the pump is relieved and the system is more efficient, safer, and more durable. (A variable volume pump with its own built-in pressure control serves the same purpose in a system as the pressure regulator valve in this system.) The pressure regulator maintains system pressure between two predetermined pressure limits and relieves the pump when no mechanisms are moving, bypassing the pump flow unrestricted back to the reservoir. When you are adding the regulator valve to the system, the relief valve becomes a safety valve, used to prevent system damage in case of regulator or variable volume pump control failure.

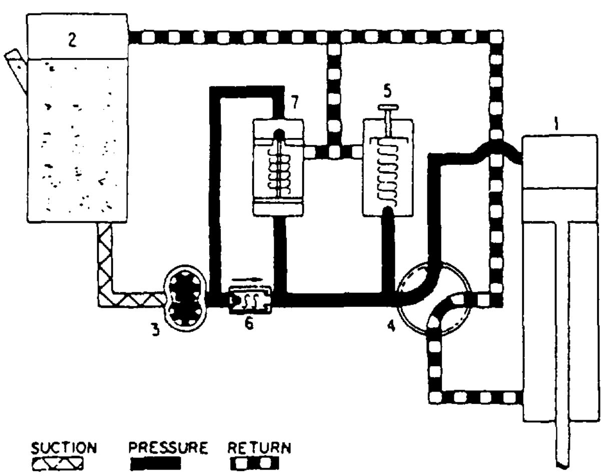
The hydraulic system (fig. 10-34) is a practical, workable system; however, today's more complex equipment normally incorporates more components for the purpose of increasing efficiency, safety, and emergency or standby operation.

A complete hydraulic system is shown in figure 10-35. In addition to the components already mentioned, this system includes more check valves, pressure gauge, filters, and a hand pump. The hand pump is added as art auxiliary system, normally used as an emergency power source in case of main power pump failure.

The complete hydraulic system discussed above may be further expanded by including a pressure manifold, more selector control valves, actuating mechanisms, and more power-driven pumps connected in parallel. You should remember that all systems can be broken down into a simplified system (as illustrated in figures 10-32 through 10-35). Thus, even the most complex system can be analyzed, not from the standpoint of a complex system but from that of a simple system.

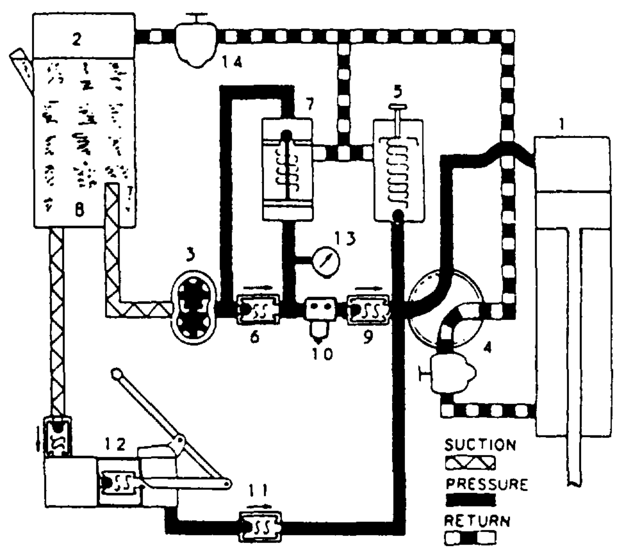
TYPES OF HYDRAULIC SYSTEMS

There are two types of hydraulic systems used in support equipment. A system may be either an open center or a closed center, or in some cases, both.



1. Actuating cylinder
2. Reservoir
3. Power pump
4. Selector valve
5. Relief valve
6. Check valve
7. Pressure regulator

Figure 10-34.-Hydraulic system with a relief valve and regulator incorporated.



1. Actuating cylinder
2. Reservoir
3. Power pump
4. Selector valve
5. Relief valve
6. Check valve
7. Pressure regulator
8. Reservoir standpipe
9. Check valve
10. Pressure line filter
11. Check valve
12. Hand pump
13. Pressure gauge
14. Return line filter

Figure 10-35.-Complete hydraulic system.

Open-Center System

An open-center system is one having fluid flow, but no pressure in the system whenever the actuating mechanisms are idle. Fluid circulates from the reservoir, through the pump, through the selector valves, and back to the reservoir. Pressure developed in the system of an open-center system is controlled by open-center selector valves and is limited by a system relief valve. Figure 10-36 shows an open-center system. Note the position of the selector valves and the fact that the valves are connected in series. In this type of system, there is no pressure in the system until one of the subsystems is actuated by the positioning of the selector valve. When in the neutral position (fig. 10-36, view A), the open-center selector valve directs the fluid to the return line. When the selector valve is positioned out of neutral, pressure builds up in the actuating section and operates the selected mechanism (fig. 10-36, view B). When an open-center system is not being used (no actuating mechanisms), the pump is said to be idling because there is no pressure buildup in the system; therefore, there is no load on the pump. Constant volume pumps are used in open-center systems and normally do not require a pressure regulator.

Closed-Center System

The closed-center system always has fluid stored under pressure whenever the pump is operating; however, when pressure is built up to predetermined value, the load is automatically removed from the pump by a pressure regulator or the integral control valve of the variable volume pump.

The representative hydraulic system discussed earlier is a closed-center system, but all closed-center systems are basically the same. Any number of subsystems may be incorporated into the closed-center system. This system differs from the open-center system in that the selector valves are arranged in parallel rather than in series.

HYDRAULIC SYSTEM TROUBLESHOOTING AND MAINTENANCE

Every hydraulic system has two major parts or sections: the power section and the actuating section. A power section develops, limits, and directs the fluid pressures that actuate various mechanisms on the equipment. The actuating section is the section

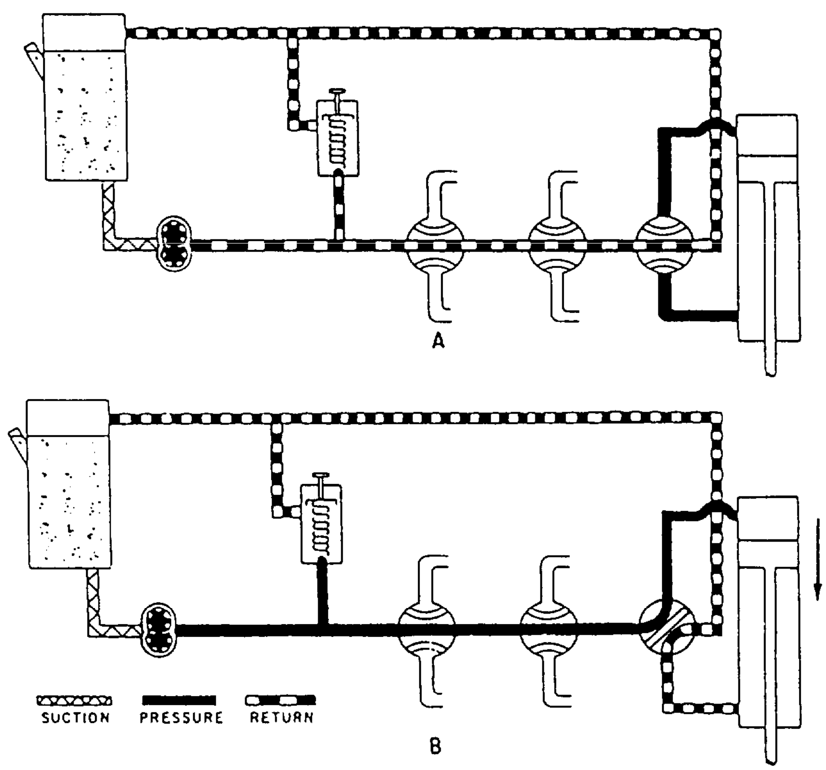


Figure 10-36.-Basic open-center hydraulic system.

containing the various operating mechanisms and their units, such as brakes, steering, lift cylinders, extend cylinders, and hydraulic motors.

Since an actuating mechanism is dependent on the power system, some of the troubles exhibited by the actuating system may be caused by difficulties in the power system. By the same token, a trouble symptom indicated by a unit of the power system may be caused by leakage from one of the units of an actuating system. When any part of the hydraulic system becomes inoperative, refer to the schematic diagrams located in the applicable technical manual (in conjunction with tests performed on the equipment) to assist in tracing the malfunction to its source. As previously stressed, NO UNIT SHOULD BE REMOVED AND REPLACED (OR ADJUSTED) UNLESS THERE IS SOUND REASON TO BELIEVE IT IS FAULTY.

Troubleshooting

Most hydraulic troubles can be included in one or more of the following categories: lack of fluid supply, external leaks, internal leaks, physically defective units, or related troubles caused by mechanical control linkages and electrical control circuits.

Insufficient fluid in the system results in no pump delivery or at best a sluggish or erratic operation. The reservoir must always contain sufficient fluid to till the system completely without letting the pump run dry. The proper fluid must always be used to replenish a low system. Do not mix hydraulic fluids or reuse old fluid. Make sure all replenishment fluid is properly filtered before it is dispensed into the reservoir. Remove and repair or replace defective units when there is an indication of external leakage of the unit.

If foreign particles are found when you remove and disassemble a unit, identify and trace them to the source; for example, a common source of foreign particles is found in flexible hose. Generally, the cause is improper installation or internal deterioration; either can release slivers of the lining into the system, causing units to leak or become inoperative.

To analyze malfunctions in hydraulic systems, like all other systems, you need to have a complete understanding of the system and its operating components. Also, you need to know the interrelationship of one component to another; for instance, a complete understanding of a pressure regulator lends itself to troubleshooting the entire system as well as the regulator itself.

Pressure regulators, like all hydraulic components, are normally reliable pieces of equipment; nevertheless, the y can malfunction. Keep in mind, though, that instead of being a source of trouble, the regulator can be a fairly reliable watchdog on the other units in the system. The particular behavior of the regulator may be the only indication of leakage in places where no other indication is available. It should be kept in mind that troubleshooting the regulator is done only after the obvious steps have been taken, such as checking the system fluid level to check for external fluid loss and opening shutoff valves.

Troubleshooting the pressure regulator is done by timing the cycle of operation-from the cut-in position to the cutout and back to the cut-in position. A standard regulator operating in a normal system completes this cycle in a certain period of time. This time can be obtained from the equipment manual or closely estimated by maintenance personnel.

Since you normally use the pressure regulator only with a constant volume pump, it should take a certain definite time to buildup system pressure; for example, suppose a pump has a volume output of 6 gallons per minute, and the system requires 1 gallon of fluid to become completely tilled (pressurized). As the system takes only one sixth of the pump output to build up pressure, it should require only one sixth of a minute (10 seconds) to pressurize the system. This is true if the system is in good operating condition. But what if the system contains an internal leak? In the 10 seconds usually required to build up pressure, the pump is still delivering 1 gallon, but some of the fluid is being lost. Thus, at the end of 10 seconds, the system cannot be pressurized; therefore, the regulator cannot be cutout. The cut-in and cutout pressure of the regulator can be seen on the system pressure gauge. Once the regulator is cut out, the system should hold fluid under pressure for a reasonable length of time; however, if the system leaks, pressure drops fast and the regulator cuts in faster than normal. These indications may mean that the regulator is faulty or the other components in the system are faulty; however, by isolation techniques, such as subsystem operation, and checking shutoff valves, the problem can be located.

If the fault is the regulator, it is probably leaking at the regulator check valve or at the regulator bypass valve.

A leaking regulator check valve is one of the most common and easily recognized troubles. Again the regulator cycle is affected. With the regulator cut-in, the check valve is open, and fluid is flowing into the system.

When the system pressurizes, the check valve closes, and the regulator is cut out; therefore, a leaking check valve does not effect the cutout time of the regulator, but it does affect the cut-in time.

The purpose of the check valve is to trap fluid under pressure in the system during the regulator cutout operation; however, it cannot do this if there is leakage around the seat. Even a slight leak around the valve seat causes the regulator to cut in faster than it should, but a bad leak causes the regulator to cycle rapidly (chatter). This rapid cycling, as indicated on the system pressure gauge, is usually caused only by a leaking valve. Thus, a leaking check valve gives normal regulator cutout and faster than normal cut-in operation.

The regulator bypass valve may also leak, causing an indication that affects the cycle of the regulator. If the bypass leaks, part of the fluid from the pump, which should be going into the system, bypasses and returns to the reservoir. This bypass causes the regulator to take longer than usual to cut out. Once the regulator has cut out, the bypass opens; therefore, it does not affect the regulator cut-in cycle.

Maintenance

Hydraulic systems maintenance includes servicing, preoperational inspections, periodical (scheduled) inspections, repair, and test/check following repair. The key to hydraulic system dependability is the attention given to the cleanliness of the repair facilities. Externally introduced contaminants are credited for more component failure than any of the self-induced contaminations during normal operating conditions. Hydraulic contamination is discussed in great length later in this chapter. The various repair procedures for the more common hydraulic system components are addressed in the paragraphs below.

HYDRAULIC PUMPS.— All hydraulic pumps have one thing in common–precision construction. In general, damaged or worn pump parts should be replaced, as they do not lend themselves readily to repair; however, some manufacturers do allow restoration of sealing surfaces to their original flat plane if it can be done by lapping. Also, very minor scratches, scoring, and corrosion can be removed with a crocus cloth.

Generally, the maintenance of hydraulic pumps consists of disassembly, inspection repair (including replacement of parts and reassembly), and testing. After disassembly, thoroughly clean and critically inspect all parts for nicks, cracks, scratches, corrosion, or other damage that might cause pump malfunction. Inspect all threaded parts and surfaces for damage; inspect pistons, piston shafts and springs for distortion, and all check valves for proper seating. Replace all defective parts, and before reassembly, lubricate all internal parts with the specified type of clean hydraulic fluid.

Because of the many different versions of pumps and the complexity of most piston pumps, refer to the applicable technical manual for repair limits, procedures, and testing information.

The test after repair of hydraulic pumps is a must. This should be done by activities that have proper test machines. Hydraulic shops usually have the correct testing machines and trained personnel to test these pumps along with other accessories, such as relief valves, selector valves, and actuating cylinders.

ACTUATORS.— Maintenance of cylinders in general is relatively simple-the most common trouble is leakage. As with all other hydraulic units discussed in this chapter, consult the technical manual for the specific cylinder for all maintenance information.

Maintenance of hydraulic motors is generally the same as that discussed earlier for hydraulic pumps.

HYDRAULIC VALVES.— Hydraulic valves, like most other hydraulic units, normally require little maintenance if the fluid is kept clean; however, they do occasionally fail. Internal leakage and control adjustments are the most common valve problems.

Generally, the maintenance of hydraulic valves consists of disassembly, inspection, repair, and testing. The amount of maintenance that can be performed is primarily determined by the type of valve and the available facilities. Some valves are not repairable; in this case, return them to supply or scrap the valve and install a new one.

Replace all defective parts that are not repairable, including all kitted parts and cure-dated parts at each disassembly. Before reassembly, lubricate all internal parts with the specified type of clean hydraulic fluid After you reassemble a valve, test it on a test machine. The tests normally include flow control, pressure settings (for relief valves and regulators), and internal leakage. Consult the applicable technical manual for maintenance, testing, and repair information.

RESERVOIRS.— Reservoirs are fairly simple tanks that require periodic flushing and cleaning. Since the reservoir collects much foreign material contaminants in the bottom, the drain valve in the bottom of the tank should be opened to allow any sediment to be purged.

Additionally, most reservoirs are designed with cleanout covers, illustrated earlier in figure 10-23, to assist in inspection and maintenance.

ACCUMULATORS.— Accumulators, being designed like cylinder actuators, are similarly repaired using the same techniques. Caution must be exercised to ensure that the pneumatic pressure has been relieved before disassembly of an air-operated accumulator.

FILTERS.— Maintenance of filters is relatively simple since it mainly involves cleaning the filter housing and replacing or cleaning the filter elements. Replace the element on filters, using the micronic (paper) element, and clean the elements on filters using the porous metal elements according to the applicable technical manuals.

Completely test the filters that have been cleaned and repaired before reinstalling them in the system. This test includes pressure setting of the relief valve, operation of the contamination indicators, leakage tests, and proof pressure test. Consult the technical manual for the equipment or the filter design for the test information.

HYDRAULIC SYSTEM CONTAMINATION

Contamination is the director indirect cause of more hydraulic system failures than any other single source; therefore, contamination prevention is a major concern for all who operate, service, and maintain hydraulic systems.

A small mistake involving injection of contaminants can result in damage to equipment that cannot have a money value placed upon it; for example, a hydraulic in a line tester that contains contaminated fluid is used to service construction equipment. This can result in damage to expensive equipment, loss of CESE costing thousands of dollars, or injury and loss of life to personnel on the jobsite.

For further reading, NAVEDTRA 12964 (latest edition) is an excellent publication on the subject of hydraulic contamination (see your ESO for this correspondence course).

Classes of Contamination

The two general contamination classes are as follows:

1. Abrasives. This includes such particles as dust, dirt, core sand weld spatter, machining chips, and rust.

2. Nonabrasives. This includes things that result from oil oxidation and soft particles worn or shredded from seals and other organic components.

The mechanics of the destructive action by abrasive contaminants are clear. When the size of the particles circulating in the hydraulic system is greater than the clearance between moving parts, the clearance openings act as filters and retain such particles. Hydraulic pressure then embeds these particles into the softer materials; the reciprocating or rotating motion of component parts develops scratches on finely finished surfaces. Such scratches result in increased tolerances and decreased efficiency.

Oil-oxidation products, usually called sludge, have no abrasive properties; nevertheless, sludge may prevent proper functioning of a hydraulic system by clogging valves, orifices, and filters. Frequent changing of hydraulic system liquid is not a satisfactory solution to the contamination problem. Abrasive particles contained in the system are not usually flushed out, and new particles are continually created as friction products; furthermore, every minute remnant of sludge acts as an effective catalyst to speed up oxidation of the fresh fluid. (A catalyst is a substance that, when added to another substance, speeds up or slows down chemical reaction, but is itself unchanged at the end of the reaction.)

Origin of Contaminants

The origin of contaminants in hydraulic systems can be traced to the following areas:

PARTICLES ORIGINALLY CONTAINED IN THE SYSTEM. These particles originate during fabrication of welded system components, especially in reservoirs and pipe assemblies. The presence is minimized by proper design; for example, seam-welded overlapping joints are preferred; arc welding of open sections is usually avoided. Hidden passages in valve bodies, inaccessible to sandblasting, are the main source of core sand entering the system. Even the most carefully designed and cleaned casting occasionally frees some sand particles under the action of hydraulic pressure. Rubber hose assemblies always contain some loose particles, most of which can be removed by flushing; others withstand cleaning and are freed later by the action of hydraulic pressure and heat.

Rust or corrosion initially present in a hydraulic system can usually be traced to improper storage of replacement materials and component parts. Particles can range in size from large flakes to abrasives of microscopic dimensions (remember the discussion earlier on the size of a single micron). Proper preservation of stored parts is helpful in eliminating corrosion.

PARTICLES OF LINT FROM CLEANING MATERIAL. These can cause abrasive damage in hydraulic systems, especially to closely fitted moving parts. In addition, lint in a hydraulic system packs easily into clearances between packings and contacting surfaces, leading to component leakage and decreased efficiency. Also, lint helps clog falters prematurely.

PARTICLES INTRODUCED FROM OUTSIDE FORCES. Particles can be introduced into hydraulic systems at points where either the liquid or certain working parts of the system (e.g., piston rods) are at least in temporary contact with the atmosphere. The most common danger areas are at the refill and breather openings and at cylinder rod packings. Contamination arising from carelessness during servicing operations is minimized by the use of an approved dispensing cart using proper filters and filler strainers in the filling adapters of hydraulic reservoirs. Hydraulic cylinder piston rods incorporate wiper rings and dust seals to prevent the dust that settles on the piston rod during its outward stroke from being drawn into the system when the piston rod retracts. Similarly, single-acting actuating cylinders incorporate an air filter in the vent to prevent ingestion of airborne contamination during the return stroke (refer back to view A of figure 10-13).

PARTICLES CREATED WITHIN THE SYSTEM DURING OPERATION. Contaminants created during system operation are of two general types: mechanical and chemical. Particles of a mechanical nature are formed by wearing of parts in frictional contact, such as pumps, cylinders, and packing gland components. Additionally, overaged hydraulic hose assemblies tend to breakdown inside and contaminate the system. These particles can vary from large chunks of packings and hose material down to steel shavings of microscopic dimensions that are beyond the retention potential of system filters.

The chief source of chemical contaminants in hydraulic liquid is oxidation. These contaminants are formed under high pressure and temperatures and are promoted by the catalytic action of water and air and of metals, like copper or iron oxides. Oil-oxidation products appear initially as organic acids, sludge, gums, and varnishes-sometimes combined with dust particles as sludge. Liquid soluble oxidation products tend to increase liquid viscosity, while insoluble types form sediments and precipitates, especially on colder elements, such as heat exchanger coils.

Liquids containing antioxidant have little tendency to form gums under normal operating conditions; however, as the temperature increases, resistance to oxidation diminishes. Hydraulic liquids that have been subjected to excessively high temperatures (above 250°F) break down in substance, leaving minute particles of asphalting suspended in the liquids. The liquid changes to brown in color and is referred to a decomposed liquid. This explains the importance of keeping the hydraulic liquid temperature below specified levels.

The second contaminant producing chemical action in hydraulic liquids is one that permits these liquids to establish a tendency to react with certain types of rubber. This causes structural changes in the rubber, turning it brittle, and finally causing its complete disintegration. For this reason, the compatibility of system liquid with seals and hose material is an important factor.

PARTICLES INTRODUCED BY FOREIGN LIQUIDS. One of the most common foreign-fluid contaminants is water, especially in hydraulic systems that require petroleum base oils. Water, which enters even the most carefully designed systems by condensation of atmospheric moisture, normally settles to the reservoir bottom. Oil movement in the reservoir disperses the water into fine droplets; agitation of the liquid in the pump and in high-speed passages forms an oil-water-air emulsion. Such an emulsion normally separates out during the rest period in the system reservoir; but when fine dust and corrosion particles are present, the emulsion is catalyzed by high pressures into sludge. The damaging action of sludge explains the need for water-separating qualities in hydraulic liquids.

Control of Contamination

Filters (discussed earlier) provide adequate control of the contamination problem during all normal hydraulic system operations. Control of the size and amount of contamination entering the system from any other source must be the responsibility of the personnel who service and maintain the equipment; therefore, precaution must be taken to ensure that contamination is held to a minimum during service and maintenance. Should the system become excessively contaminated, the filter element should be removed and cleaned or replaced.

As an aid to exercising contamination control, the following maintenance and servicing procedures should be adhered to at all times:

1. Maintain all tools and the work area (workbenches and test equipment) in a clean, dirt-free condition.

2. A suitable container should always be provided to receive the hydraulic fluid which is spilled during component removal or disassembly procedures.

NOTE: The reuse of hydraulic fluid is not recommended; however, in some large-capacity systems, the reuse of fluid is permitted. When liquid is drained from the latter systems, it must be stored in a clean and suitable container. This liquid must be strained and/or filtered as it is returned to the system reservoir.

3. Before disconnecting hydraulic lines or fittings, clean the affected area with an approved dry-cleaning solvent.

4. All hydraulic lines and fittings should be capped or plugged immediately after disconnecting.

5. Before assembly of any hydraulic components, wash all parts with an approved dry-cleaning solvent.

6. After cleaning parts in dry-cleaning solvent, dry the parts thoroughly and lubricate them with the recommended preservative or hydraulic liquid before assembly.

NOTE: Use only clean, lint-free cloths to wipe or dry component parts.

7. All packings and gaskets should be replaced during the assembly procedures.

8. All parts should be connected with care to avoid stripping metal slivers from threaded areas. All fittings and lines should be installed and torqued according to applicable technical instructions.

9. All hydraulic servicing equipment should be kept clean and in good operating condition.

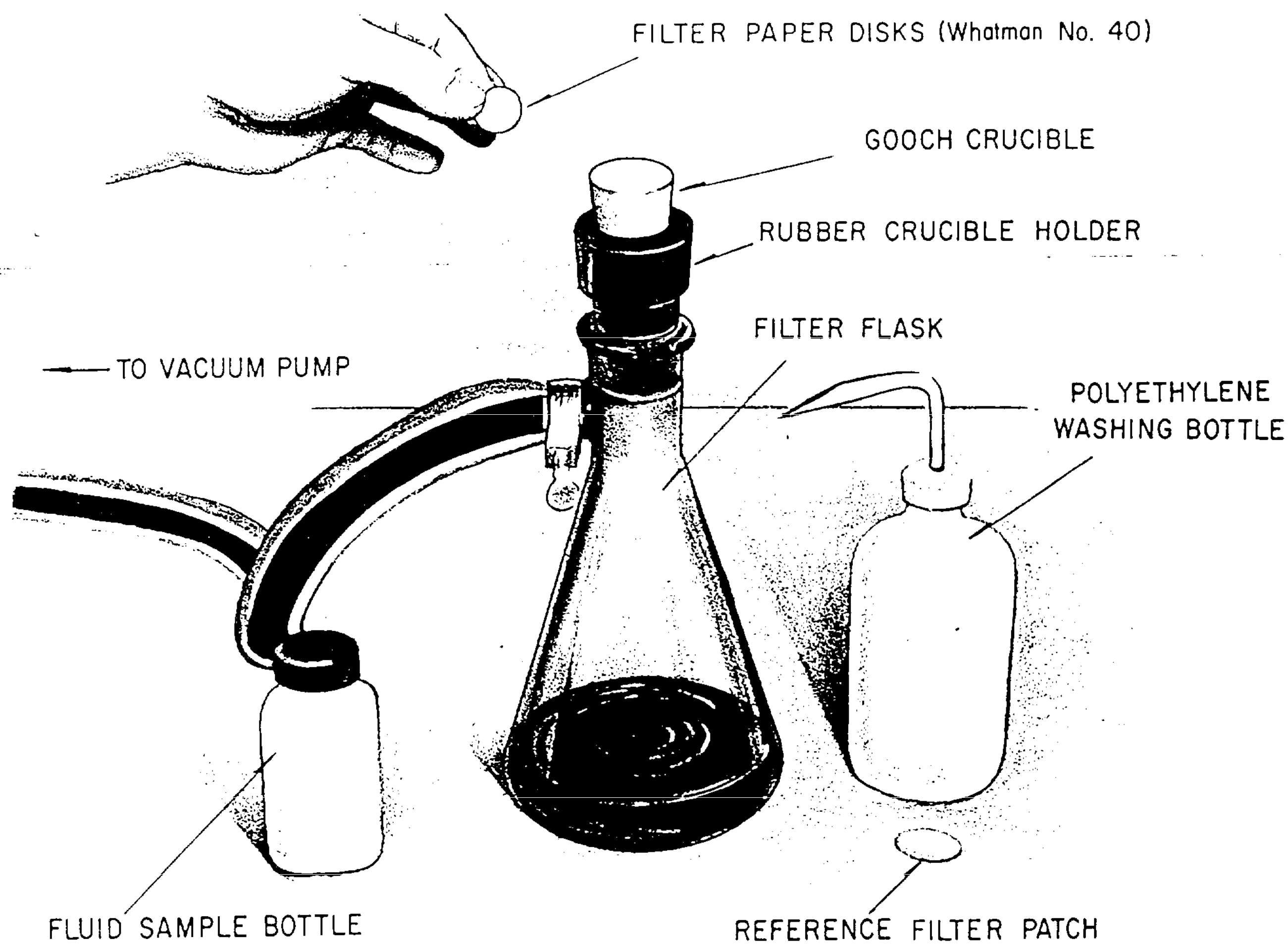


Figure 10-37.—One example of a hydraulic liquid contamination test kit.

Checks for Contamination

Whenever it is suspected that a hydraulic system has become excessively contaminated or the system has been operated at temperatures in excess of the specified maximum, a check of the system should be made. The filters inmost hydraulic systems are designed to remove most foreign particles that are visible to the naked eye; however, hydraulic liquid which appears clean to the naked eye may be contaminated to the point that it is unfit for use.

Thus, visual inspection of the hydraulic liquid does not determine the total amount of contamination in the system. Large particles of impurities in the hydraulic system are indications that one or more components in the system are being subjected to excessive wear. Isolating the defective component requires a systematic process of elimination. Liquid returned to the reservoir may contain impurities from any part of the system. In order to determine which component is defective, liquid samples should be taken from the reservoir and various other locations in the system.

FLUID SAMPLING.– Liquid samples should be taken according to the instructions provided in applicable technical publications for the particular system and the contamination test kit. Some hydraulic systems are provided with permanently installed bleed valves for taking liquid samples; while on other systems, lines must be disconnected to provide a place to take a sample. In either case, while the liquid is being taken, a small amount of pressure should be applied to the system. This ensures that the liquid will flow out of the sampling point and thus prevent dirt and other foreign matter from entering the hydraulic system. Hypodermic syringes are provided with some contamination test kits for the purpose of taking samples.

CONTAMINATION TESTING.– Various procedures are recommended to determine the contaminant level in hydraulic liquids. The filter patch test provides a reasonable idea of the condition of the fluid. This test consist basically of filtration of a sample of hydraulic system liquid through a special filter paper. This filter paper darkens in degree in relation to the amount of contamination present in the sample and is compared to a series of standardized filter disks which, by degree of darkening, indicates the various contamination levels. The equipment provided with one type of contamination test kit is illustrated in figure 10-37.

When you are using the liquid contamination test kit, the liquid samples should be poured through the filter disk (fig. 10-37), and the test filter patches should be compared with the test patches supplied with the test kit. A microscope is provided with the more expensive test kits for the purpose of making this comparison. Figure 10-38 shows test patches similar to those supplied with the testing kit.

To check liquid for decomposition, pour new hydraulic liquid into a sample bottle of the same size and color as the bottle containing the liquid to be checked. Visually, compare the color of the two liquids. Liquid which is decomposed will be darker in color.

At the same time the contamination check is made, it may be necessary to make a chemical analysis of the liquid. This analysis consists of a viscosity check, a moisture check, and a flash point check; however, since special equipment is required for these checks, the liquid samples must be sent to a laboratory where a technician will perform the test.

Flushing the System

Whenever a contamination check indicates impurities in the system or indicates decomposition of

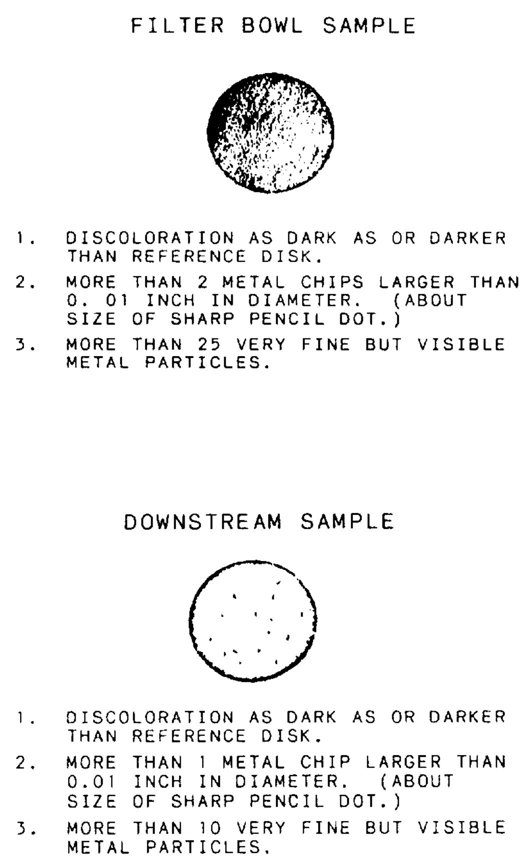


Figure 10-38.—Hydraulic fluid contamination test patches.

the hydraulic liquid, the hydraulic system must be flushed.

NOTE: The presence of foreign particles in the hydraulic system indicates a possible component malfunction that you should correct before flushing the system.

A hydraulic system in which the liquid is contaminated should be flushed according to current applicable technical instructions. Flushing procedures are normally recommended by the manufacturer. The procedure varies with different hydraulic systems. One method is as follows:

Drain out as much of the contaminated liquid as possible. Drain valves are provided in some systems for this purpose; while on other systems, lines and fittings must be disconnected at the low points of the system to remove any trapped fluid in the lines and components. Close all the connections and till the system with the applicable flushing medium. Any of the hydraulic liquids approved for use in power-transmission systems may be used for flushing purposes.

CAUTION

Diesel fuel oil must not be used for flushing hydraulic systems in active service, because of its poor lubricating qualities and its contaminating effect on the subsequent till of hydraulic liquid.

While being flushed with an approved hydraulic liquid, power-transmission systems can be operated at full load to raise the temperature of the liquid. Immediately following the warming operation, the system should be drained by opening all drain outlets and disconnecting the hydraulic lines to remove as much of the flushing medium as possible. All filter elements, screens, and chambers should be cleaned with new fluid before filling the system with the required service liquid.

CAUTION

The system should not be operated while or after draining the liquid.

Power-transmission systems and their interconnected hydraulic controls whose inner surfaces have been inactivated and treated with a corrosion prevention or preservation compound must be flushed to remove the compound. The latest current instructions for flushing and other operations required to reactivate a particular system must be strictly followed to prevent damage.

Some hydraulic systems are flushed by forcing new liquid into the system under pressure, forcing out the contaminated or decomposed liquid.

Hydraulic liquid which has been contaminated by continuous use in hydraulic equipment or has been expanded as a flushing medium must not be used again but should be discarded according to the prevailing instructions.

CAUTION

Never permit high-pressure air to be in direct contact with petroleum base liquids in a closed system, because of the danger of ignition. If gas pressure is needed in a closed system, nitrogen or some other inert gas should be used.

REFERENCES

Aviation Hydraulics Manual, NAVAIR 01-1A-17, Commander, Naval Air Systems Command, Washington, D.C., 1989.

Aviation Support Equipment Technician, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1990.

Base Vehicle Equipment Mechanic, Extension Course Institute, Air University, Gunter Air Force Station, Montgomery, Ala., 1986.

Fluid Power, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1990.