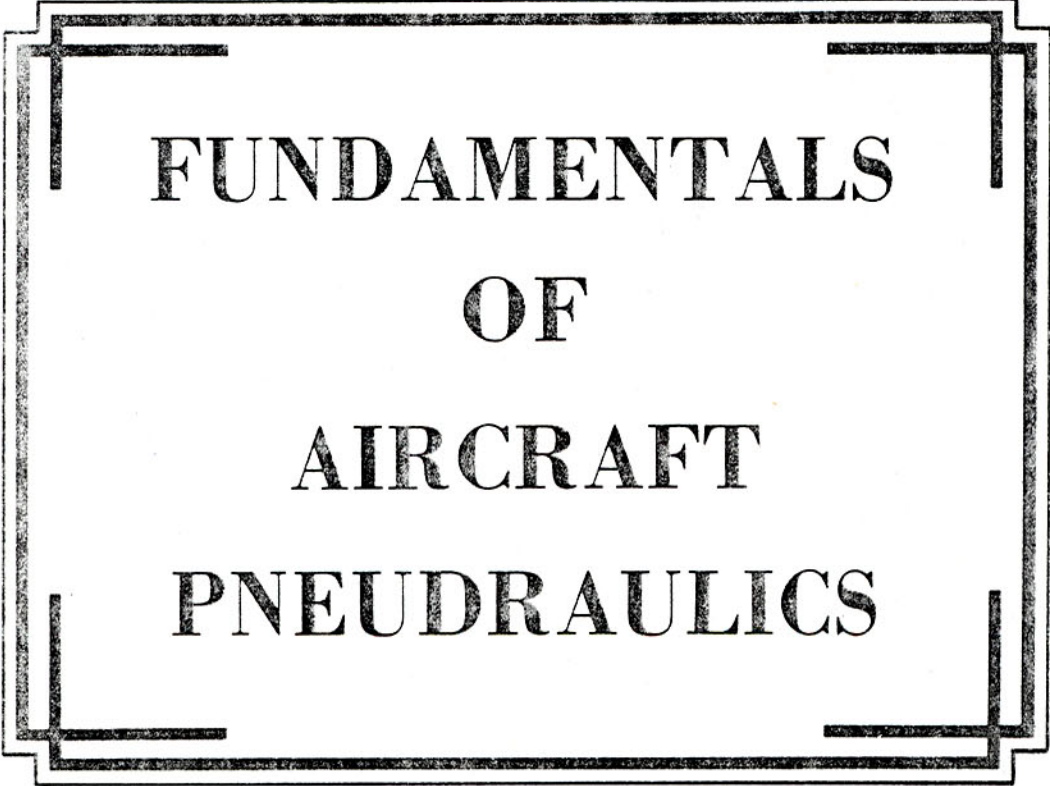


FM 1-509



**FUNDAMENTALS  
OF  
AIRCRAFT  
PNEUDRAULICS**

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OCTOBER 1987**

FIELD MANUAL  
NO 1-509

HEADQUARTERS  
DEPARTMENT OF THE ARMY  
Washington, DC, 8 OCTOBER 1987

# FUNDAMENTALS OF AIRCRAFT PNEUDRAULICS

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\*This publication supersedes FM 55-409, 29 December 1980.

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## PREFACE

This manual--

- Provides guidance for repairing pneumatic and hydraulic systems.
- Covers basic hydraulic principles.
- Describes hydraulic systems used in United States Army aircraft.
- Discusses aircraft in general, not specific types of aircraft.

Military personnel holding MOS 68H (aircraft pneudraulics repairer) will use this manual as a guide in repairing pneumatic/hydraulic systems. For instructions in repairing hydraulic systems on a particular aircraft, refer to the technical manual written for that aircraft. More information about hydraulics can be found in TM 9-243, TM 55-1500-204-25/1, TB 55-1500-334-25, TB 750-103, and NAVPERS 10310-B.

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Unless otherwise stated, whenever the masculine gender is used, both men and women are included.

# CHAPTER 1

## HYDRAULIC SYSTEMS

### FUNCTIONS

Hydraulic systems perform a variety of functions in Army aircraft. They are used in fixed-wing aircraft to change the propeller pitch and operate the landing gear, wing flaps, wheel brakes, and shock struts. Also, they are used in helicopters to start engines and operate brakes, shock struts, dampers, flight control systems, loading ramps, folding pylons, winch hoists, and hydraulic clutches.

### ADVANTAGES

A hydraulic system has many advantages:

- It is almost 100 percent efficient. The slight loss of efficiency (a fraction of 1 percent) is due to internal friction in the system machinery.
- Moving parts of a hydraulic system are lightweight and can quickly be put into motion or brought to rest. The valves in a hydraulic system quickly start or stop the flow of fluid under pressure; very little effort is needed to operate them. For these reasons, the system is easy for the operator to control.
- Hydraulic lines can be routed almost anywhere. Unlike mechanical systems which must follow straight pathways, the lines of a hydraulic system can easily be bent around obstructions. Also, major parts of hydraulic systems can be located in a wide variety of places.
- Since components of a hydraulic system are smaller than those of other systems, the space requirement is small.
- Most of the parts of a hydraulic system operate in a bath of oil, making the system practically self-lubricating.

### USE OF LIQUIDS AND AIR

#### Liquids.

Characteristics. The aircraft hydraulic system transmits engine power to distant points in the aircraft. The force is carried by a liquid (oil) confined in a system of tubes. To understand this system, certain characteristics of liquid must be understood; the primary one is fluidity. Fluids--substances that flow--can be liquids or gases, but the two differ

in degree of fluidity. Liquids cannot expand indefinitely to fill containers as gases do. Liquids have three physical qualities:

- Incompressibility. For practical purposes, liquids are incompressible. Even under extremely high pressure, a liquid cannot be made smaller. The brake system in a car takes advantage of this physical law. When you push the pedal, the brakes are applied instantly because no time is lost in compressing the liquid. Consider how much longer the brake stroke would be if the master cylinder contained air.
- Expansion and contraction. Liquids expand (become larger) and contract (become smaller) with changes in temperature. When a liquid in a closed container is heated, it expands and puts pressure on the walls of the container. As the liquid cools, the pressure decreases.
- Pressure transmission. Pressure applied to a confined liquid is transmitted equally. Again, a car's brake system shows how this principle works. When a force (a foot on the brake pedal) is applied to a liquid in a closed container (the car's master cylinder), the resulting pressure is sent out equally in all directions; that is, the same amount of pressure is exerted on each wheel of the car.

Types. Hydraulic fluids are classified generally as petroleum base, synthetic base, and vegetable base. Vegetable-base fluid is no longer authorized in Army aircraft. For most operations, the Army is converting from petroleum-base fluid MIL-H-5606 to MIL-H-83282, which has a synthetic hydrocarbon base. There are several reasons for this change. MIL-H-83282 contains additives that provide better antiwear characteristics and help stop oxidation and corrosion. It also has an operational high-temperature limit of 400°F as compared to 275°F for MIL-H-5606. Flash point, fire point, and spontaneous ignition temperatures of MIL-H-83282 exceed those of MIL-H-5606 by more than 200°F. Also, tests show that MIL-H-83282 stops burning when the outside source of flame or heat is removed. MIL-H-83282 is compatible with all materials used in systems presently employing hydraulic fluid MIL-H-5606. It may be combined with the latter fluid with no bad effects except that it may reduce the fire-resistant properties of MIL-H-5606. However, amounts of MIL-H-5606 exceeding 3 percent by volume will compromise the fire-resistant performance of MIL-H-83282. Although MIL-H-83282 exceeds the performance of MIL-H-5606 at normal temperatures, the viscosity of MIL-H-83282 increases at low temperatures. For this reason, MIL-H-5606 is still used for cold weather operations.

Petroleum-base fluid MIL-H-6083 is also authorized in Army aircraft. This fluid is supplied in only one grade. It should be used as a preservative oil in shock struts, hydraulic equipment, and spare parts, and as a testing and flushing oil for some hydraulic components. MIL-H-6083 should not be used in composite aircraft hydraulic systems.

NOTE: Use only the fluid authorized for a particular component or system. To determine the correct fluid, consult the applicable

technical manual. Also, read the instruction plate affixed to the individual unit or reservoir, and check the color of the fluid contained in the system.

CAUTION

EVEN THOUGH VEGETABLE-BASE FLUID IS NOT AUTHORIZED IN ARMY AIRCRAFT, IT MIGHT BY CHANCE GET INTO THE MAINTENANCE SHOP. NEVER USE THIS FLUID WHEN WORKING WITH HYDRAULIC SYSTEMS. IT DETERIORATES THE SYNTHETIC RUBBER SEALS USED IN SYSTEMS DESIGNED FOR PETROLEUM- OR SYNTHETIC-BASE FLUIDS. VEGETABLE-BASE FLUID IS READILY DISTINGUISHED BY ITS BLUISH COLOR.

Resistance. Resistance to liquid flow is a factor that must be dealt with in hydraulic systems. Resistance results partly from the viscosity (or thickness) of the liquid itself. The greater the viscosity, the greater the resistance. Resistance also occurs as liquids flow through tubing. This movement creates a shearing action between the wall of the tube and the liquid. This action results in a turbulent flow (a nonsmooth whirling flow) along the walls. Turbulence working against the smooth flow of a liquid causes resistance, which causes the temperature to rise; this, in turn, causes a loss of energy.

When engineers design an aircraft hydraulic system, they have to consider energy loss. Accordingly, they design the tubing and other units to reduce the resistance as much as possible. Power pumps (like the power-steering pump in a car) are made large enough to take care of the aircraft's operational needs, plus the energy loss. No resistance occurs when the liquid is not moving in the system. When it starts to move, resistance begins and increases as the speed of flow increases. For this reason, an orifice plate or restriction is sometimes installed in a line to limit the rate of flow. For example, when a landing gear is being extended, it tends to drop with great force. A restrictor installed in the hydraulic return line (the up line, in this case) decreases the speed of fluid flow. This decrease reduces the speed when the landing gear comes down and prevents possible structural damage.

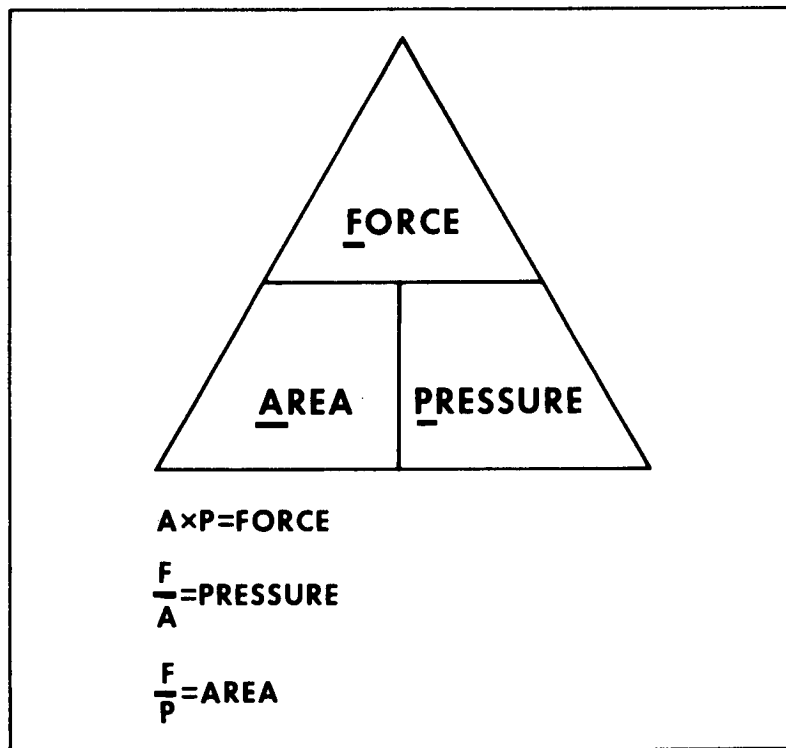
Computing Force, Area, and Pressure. Hydraulic systems are designed to take advantage of liquid characteristics as they relate to force, area, and pressure. These terms, as used in hydraulics, are defined as follows:

- Force is the amount of push or pull applied to an object. For example, the force applied to a piston head is the energy applied to the total area of the piston head. In this manual, force is measured in pounds.
- Area is the measurement of a surface. In the aircraft hydraulic system, the areas of piston heads are a main concern. If these areas are known, the amount of force needed can be computed to start a mechanism moving. In this manual, area is measured in square inches.



- Pressure is the force applied to one unit of area--usually 1 square inch. For example, the pressure on a piston head develops the force that operates a mechanism. In this manual, pressure is measured in pounds per square inch (psi).

If any two of the above factors are known, the third can be computed by using the equation in Figure 1-1. To apply this equation, multiply the two lower factors together to get the top factor; then divide the top factor by the known lower factor to get the unknown lower factor. If the area in square inches and the pressure in psi are known, simply multiply the area (A) times the pressure (P) to obtain the force (F) in pounds. Similarly, if the force in pounds and the area in square inches are known, divide F by A to obtain P in psi. Finally, to obtain the area in square inches, divide F in pounds by P in psi. For example, a pressure of 50 pounds psi acts on a piston whose surface area is 5 square inches. What force is acting on the piston? Using the equation in Figure 1-1, multiply P (50 psi) times A (5 square inches) to obtain F. The answer is that a 250-pound force acts on the surface of the piston.



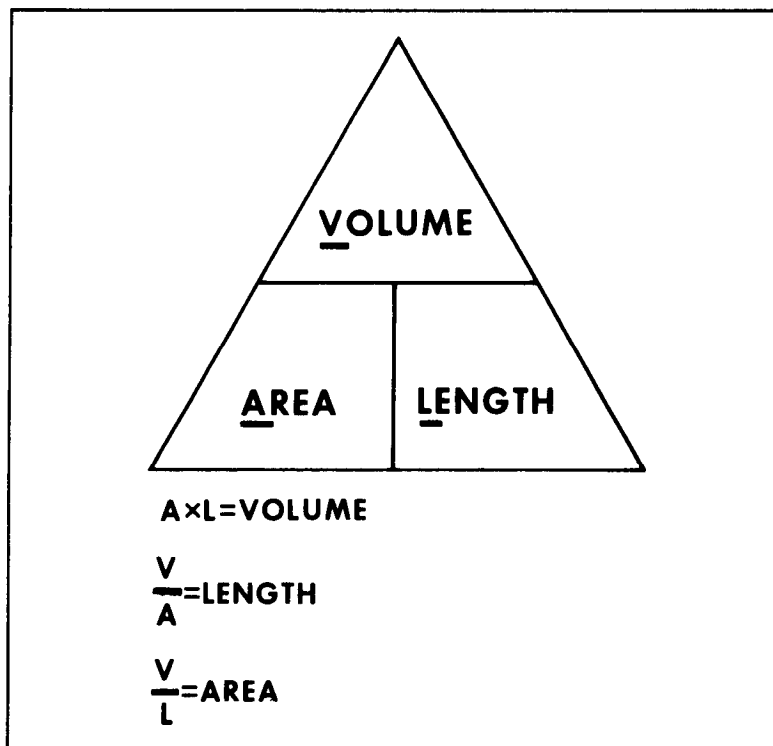
**Figure 1-1. Force, area, and pressure formula.**

Computing Volume, Area, and Length of Stroke. The same type of triangular equation can be used to compute volume, area, and length of stroke. These terms, as used in hydraulics, are defined as follows:

- Volume is a measurement of quantity expressed in cubic inches. For example, the volume is the amount of liquid in a cylinder or the amount of liquid displaced by a pump or actuating cylinder.

- Area is a surface measurement expressed in square inches.
- Length of stroke is a measurement of distance expressed in inches. The stroke length discussed in this manual refers to the distance a piston moves in a cylinder.

If any two of the above factors are known, the third can be computed by using the equation in Figure 1-2. To apply this equation, multiply the two lower factors together to obtain the top factor, and divide the top factor by the known lower factor to obtain the unknown lower factor. For example, a piston having an area of 8 square inches moves a distance of 10 inches within a cylinder. To find the volume of liquid moved, multiply A (8 square inches) times L (10 inches) to obtain V (80 cubic inches).



**Figure 1-2. Volume, area, and length-of-stroke formula.**

Pascal's Law. Practical applications of hydraulic principles are based on Pascal's law: When external pressure (force) is applied to any confined fluid, the pressure is increased at every point in the fluid by the amount of external pressure (force). (Check the definitions of force and pressure.) An understanding of Pascal's law depends on the interpretation of these terms. Pascal's law applies to confined fluids only; it does not apply to fluids in motion, since moving fluid is not confined. Figure 1-3 illustrates how Pascal's law applies in an aircraft hydraulic system. When a force is applied to the piston in cylinder 1, it is transmitted to all portions of the confined fluid. For example, if the applied force is 5 psi, the pressure in cylinders 1, 2, and 3, and in the tubing will be 5 psi. But suppose a change takes place where a lack of resistance causes

either piston 2, 3, or both to move upward. This momentarily lowers the pressure in cylinders 2 and 3; in cylinder 1, it is still 5 psi. An unbalanced condition such as this cannot last. Fluid will flow from cylinder 1 to cylinders 2 and 3. This happens because pistons 2 and 3 are not confining the fluid as long as they move upward. Pascal's law does not apply to this condition. When pistons 2 and 3 reach the end of their strokes, the fluid stops flowing. At this point, the fluid is again confined and the pressure equalizes--Pascal's law applies once more.

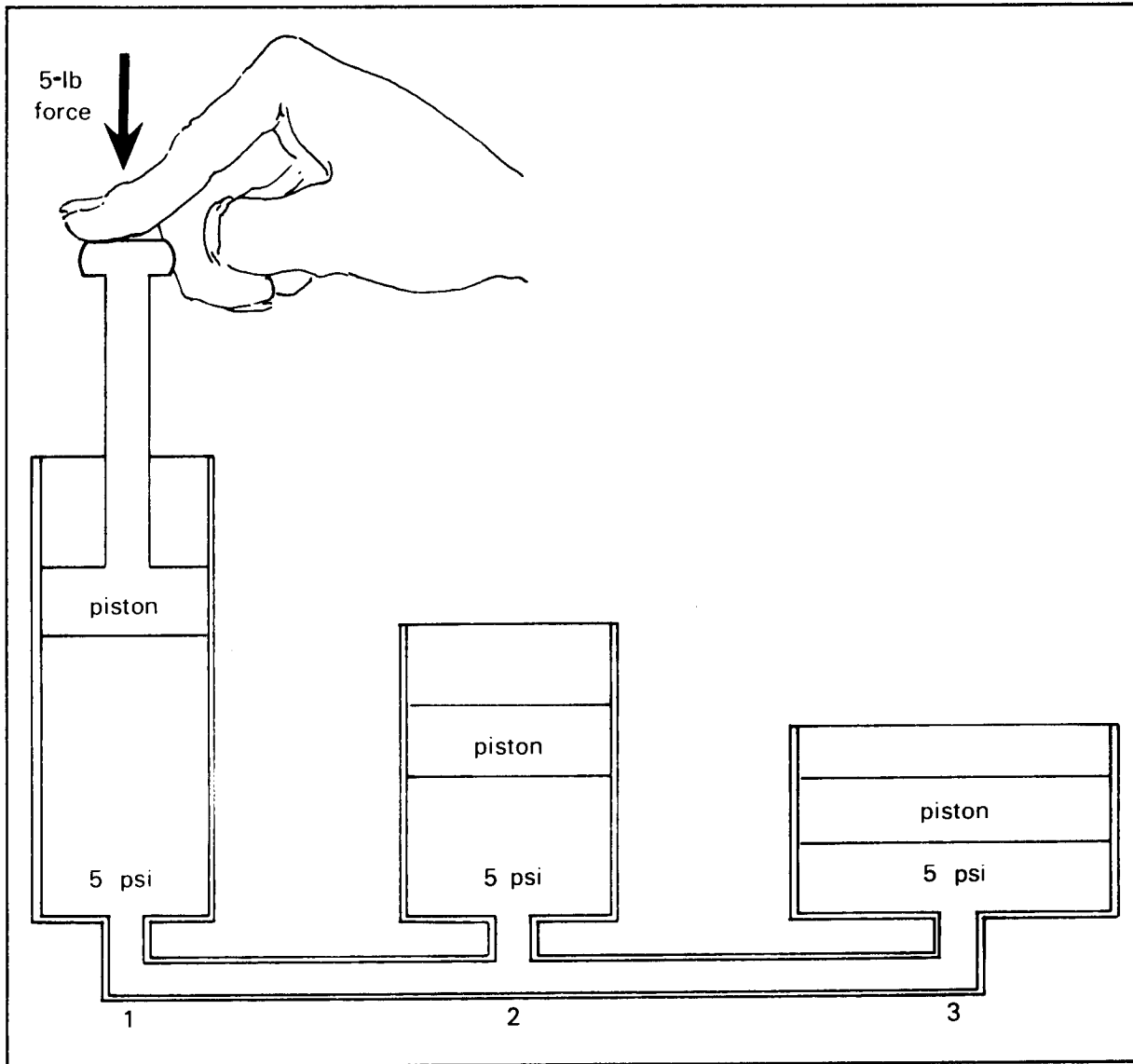


Figure 1-3. Principle of Pascal's law.

**Mechanical Advantage.** A mechanical advantage is a small force that is used over a great distance to get a great force over a short distance; in other words, it is the amount by which the input effort is multiplied in the output of a device. Using a claw hammer to remove a nail from a two-by-four board or using a jack to raise a vehicle is an example of the

mechanical advantage. The aircraft hydraulic system uses this principle because it is a system that transmits engine power to distant points in the aircraft where power is needed. This is done by multiplying the input effort (or force) enough to do the required job--in other words, gaining a mechanical advantage.

In hydraulics, the mechanical advantage is the ratio between two pistons with regard to the factors of area and force. Figure 1-4 illustrates this principle; note the difference in the areas of the small and large pistons. This difference in size is how the mechanical advantage is obtained. When a 50-pound force is applied to the small piston, the fluid pressure shows 25 psi on the gage; however, 25 psi acting on the large piston gives an upward force of 250 pounds. This gain in force (from 50 pounds to 250 pounds) is attained by increasing the surface area of the output piston. This 5-to-1 ratio does not change if the pounds per square inch change. For example, if the input force is limited to 20 psi or raised to 30 psi, the forces involved would obviously change, but the ratio between the forces would still be 5 to 1.

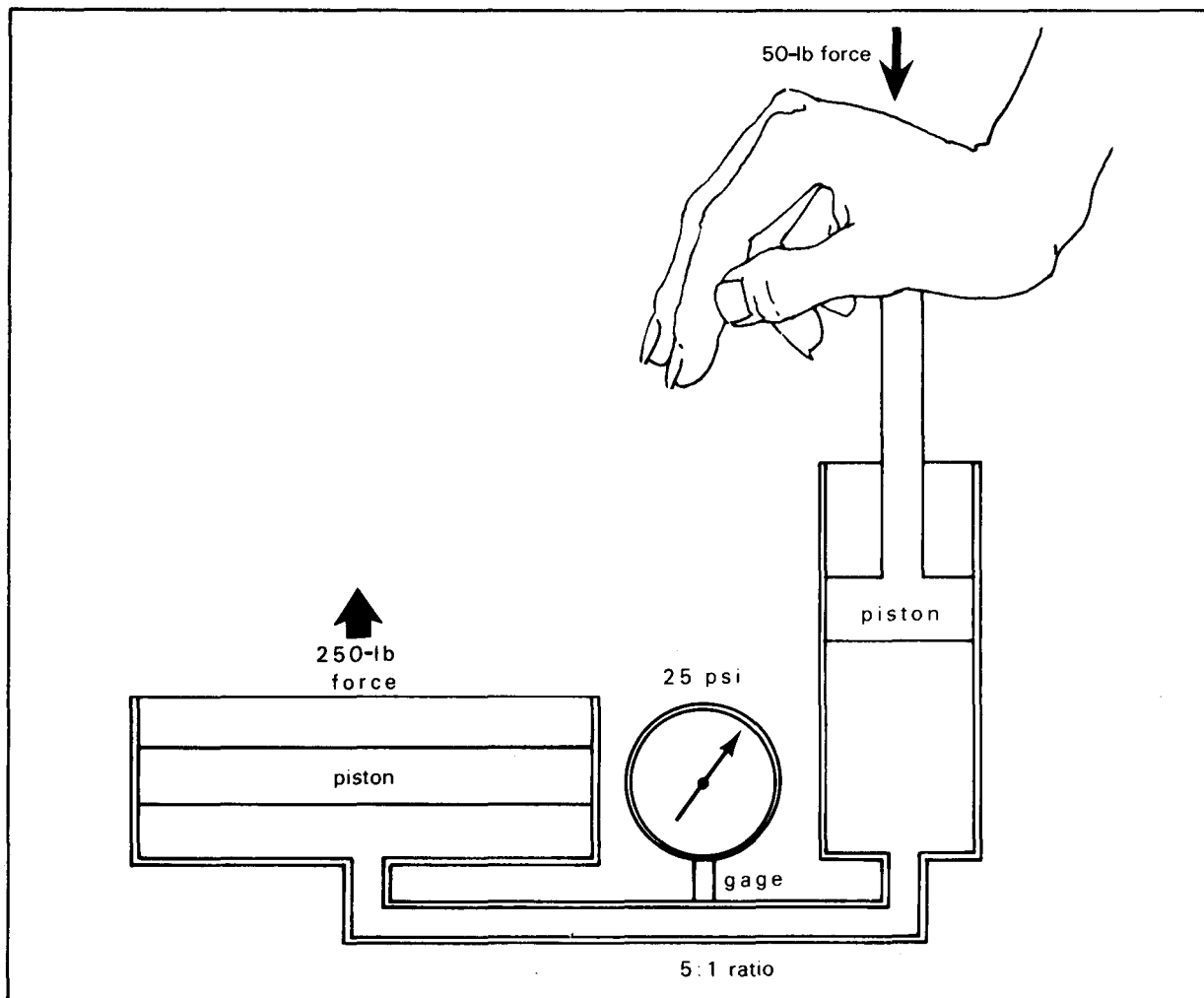
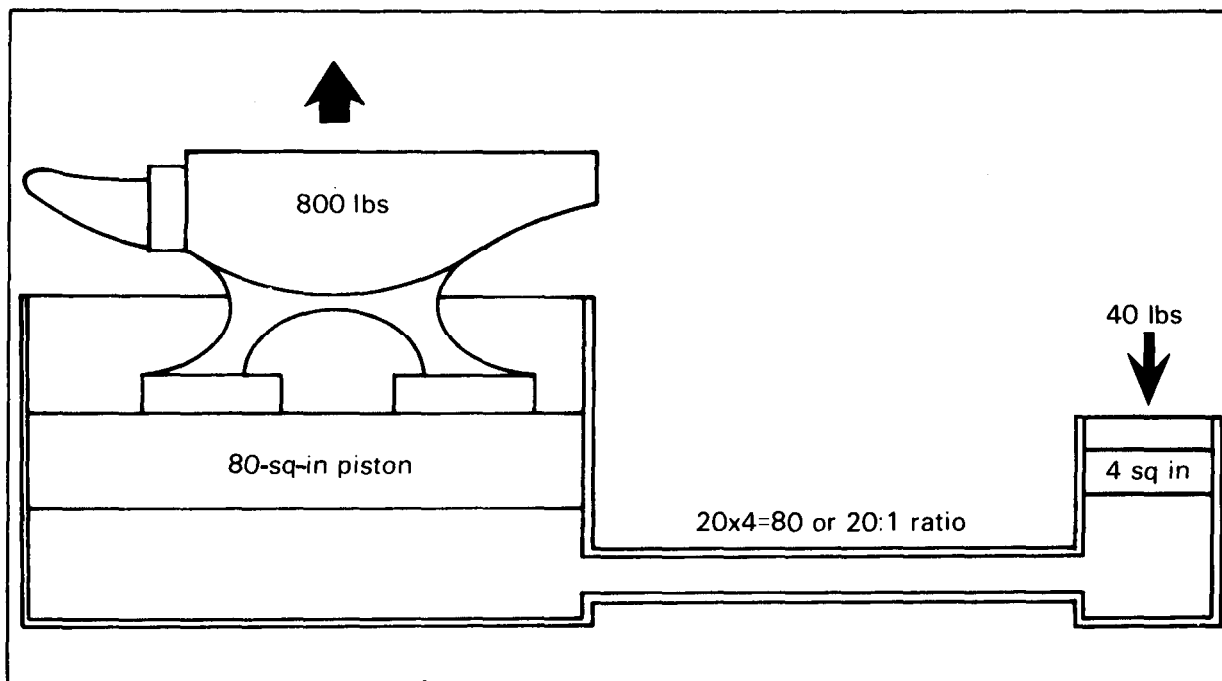


Figure 1-4. Principle of mechanical advantage.

An example of how to apply the mechanical advantage is illustrated in Figure 1-5. It shows how big the large piston must be to raise an 800-pound weight. The 800-pound weight must be raised by applying a 40-pound force to the 4-square-inch piston. The mechanical advantage in this case is 20 (800 pounds divided by 40 pounds) and is expressed as a 20-to-1 ratio. By multiplying 20 times 4 square inches (area of the small piston), the area of the large piston should be 80 square inches.



**Figure 1-5. Application of mechanical advantage.**

The mechanical advantage also applies to the distance the piston moves--length of stroke. Assuming that the large piston must move 10 inches, multiplying this factor by 20 gives 200 inches as the length of stroke for the small piston. Of course, the small piston moving that far on a single stroke would not be feasible; therefore, the small piston must move through a series of short repeated strokes.

**Contamination.** Contamination of fluids in a hydraulic system occurs when any material is present other than the hydraulic fluid being used. This includes water, metal, dust, and other solids. Contamination sources may be internal or external. Internal contamination can cause normal wear of the pump or other components. When filters are used too long (especially the paper-element type), particles may begin breaking off from the filter element. Moving seals and backup rings also add contamination to the system. External contamination is generally caused by poor maintenance practices. Examples include leaving hydraulic lines open after removing a part; wiping fittings with dirty rags; leaving valves, tubing, and so forth uncovered on workbenches; changing fluid with dirty test equipment; and installing new or rebuilt parts that have not been properly cleaned.

A kit has been developed to sample fluid for contamination. Fluid samples are taken periodically and forwarded to area laboratories for analysis. The laboratory checks for viscosity, corrosion, oxidation, emulsion, fire resistance, vapor pressure, flash point, water, hydrolytic stability, viscosity-temperature coefficient, neutralization number, and pour point. Contamination checks should become routine; check for dirt, metal, and visible solids every time a unit is removed or disassembled. Normal contamination checks for most aircraft are made by examining the condition of the filter elements. For example, a clogged filter or an extended filter indicator pin is a symptom of contaminated fluid. These findings, as well as pump failures, require flushing of the system. To prevent contamination--

- Cap or plug all open connections when removing a part.
- Never use dirty rags to wipe off connections.
- Clean and deburr new tubing and fittings before installing them.
- Store new or overhauled parts in sealed containers.
- Fill the pump with hydraulic fluid before installing it.
- Take good care of test stands and ground equipment.
- Handle flexible hydraulic hoses carefully. Particles from the hose walls may enter the system when hoses are kinked, run over, or when quick-disconnect couplings are not cleaned before being joined.

CAUTION

NEVER REUSE FLUID THAT HAS BEEN DRAINED FROM AN AIRCRAFT HYDRAULIC SYSTEM OR COMPONENT.

**Maintenance.** A hydraulic unit, when disassembled and overhauled, must be cleaned with a suitable solvent to remove dirt, grit, sludge, or other foreign matter. Always check the applicable technical manual to find the correct procedure for disassembling, cleaning, assembling, and testing a unit. If a particular type of solvent is not specified, use PD-680 to clean units operating with petroleum-base fluid; denatured alcohol for units using vegetable-base fluid; and trichloroethylene for units using synthetic-base fluid. Whatever type of solvent is used, thoroughly soak and wash the unit and its internal parts in the solvent. Use a small brush on the inside passageways and chambers; be sure that its bristles are not so stiff that it scratches the metal. All parts must be dried completely with compressed air or a lint-free cloth before being assembled. some solvents are very flammable, proper precautions should be taken to store them in tightly sealed containers. The work area must be well ventilated when using solvents indoors.

Air.

Characteristics. Assuming a constant temperature, the volume of a confined gas changes in opposite order to changes in pressure. For example, if a given-volume of gas is reduced to half its initial size, its pressure doubles; if the volume doubles, the pressure is halved. This characteristic of gases is known as Boyle's law and is expressed by the equation--

$$V \times P = V' \times P'$$

where

V = initial volume

P = initial pressure

V' = changed volume

P' = changed pressure

If the measurements of any three factors above are known, the fourth factor can be determined. For example, assume that 30 cubic inches of gas (V) at a constant temperature and under 90 psi of pressure (P) is forced into a 15 cubic-inch space (V'). To find the changed pressure (P'), substitute in the equation as follows:

$$90 \times 30 = 15 \times P'$$

$$2700 = 15P'$$

$$\frac{2700}{15} = P'$$

$$180 = P'$$

Uses. When subjected to an applied force, a gas (such as air or nitrogen) acts in a manner similar to a spring: it yields but pushes back with as much force as is being applied to it. This characteristic of gases makes them useful in aircraft systems. In fact, some components are designed to use gas even though a spring would work. This is because gases weigh less than metal springs and are not subject to metal fatigue.

Air is the gas commonly used in hydraulic systems. It is used in accumulators, shock struts, emergency systems, and system reservoirs. In terms of compressibility, almost any gas could be used, but many are dangerous because they are flammable or explosive. Pure nitrogen is the only safe substitute authorized for atmospheric air in hydraulic systems.

**SAFETY DEVICES**

Aircraft vibration tends to loosen or change the adjustment of various parts such as nuts, turnbuckles, and screws. Therefore, parts that are used for disassembly or adjustment are safetied by some device. The safeying devices commonly used on aircraft are cotter pins, check nuts, lock washers, safety pins, lock rings, and safety wire. An incorrectly installed safeying device or failure to install one where it is needed can cause a component to fail. See TM 55-1500-204-25/1 for detailed information on safeying devices.

## CHAPTER 2

### PNEUDRAULIC LINES

#### RIGID TUBING

Characteristics. Rigid tubing assemblies are made of aluminum alloy, stainless steel, or copper. Some air systems aboard aircraft have copper tubing. Two aluminum alloys are commonly used: 5052 and 6061. Alloy 5052 may be used for lines carrying pressures up to 1,500 psi; alloy 6061 may be used for pressures up to 3,000 psi. As a general rule, exposed lines and lines subject to abrasion, intense heat, or extremely high pressure are made of stainless steel.

The tubing used to produce rigid tubing assemblies is sized by its outside diameter (OD) and wall thickness. Outside diameter sizes are in sixteenth-of-an-inch increments, the number of the tube indicating its size in sixteenths of an inch. For example, number 6 tubing is 6/16 or 3/8 inch, number 8 tubing is 8/16 or 1/2 inch, and so forth. Wall thickness is specified in thousandths of an inch. Most aircraft maintenance manuals contain a table which lists the original material and acceptable substitutes and gives the wall thickness for each.

Damage. Nicks and scratches on tubing can be reduced by using care. Most damage of this kind occurs because of careless handling of tools during aircraft maintenance. Any dent less than 20 percent of the tubing diameter is not objectionable unless it is on the heel of a short-bend radius. A nick no deeper than 15 percent of wall thickness of aluminum, aluminum alloy, copper, or steel tubing may be reworked by burnishing with hand tools; any nicks in excess of 15 percent of wall thickness should be rejected. Nicked tubing is not only weaker due to internal pressure, but it must be burnished out to reduce a notch effect. If nicks are not burnished out, stress concentration under vibration will cause the tubing to become weak and break at nicked points.

Burnishing removes notches by removing the surrounding material. Burnishing is not allowed in the heel of bends where material has already been stretched thin during forming. Tubing which is nicked in a bend should be replaced if it is carrying over 100 psi pressure. For tubing carrying pressures of 100 psi or less, a nick no deeper than 20 percent of wall thickness of aluminum, aluminum alloy, copper, or steel tubing may be reworked by burnishing with hand tools. When tubing is used for fluids at atmospheric pressure or less, the bursting strength of the tubing is unimportant; however, it must be leak-tight at all times. Dents can be removed from tubing by drawing a bullet through the tubing. The diameter of the bullet must be equal to or slightly less than the inside diameter of the tubing.

All tubing is pressure-tested before installation and is designed to withstand several times the operating pressure which it will be subjected



to. Generally, bursting or cracking of a tube is due to improper installation, damage caused by collision with an object, or excessive vibrations. When tubing fails, the cause should be determined. Replacements should be of the same size and material as the original, or an acceptable substitute listed in the applicable maintenance manual may be used.

**Repairs.** A damaged line should be carefully removed so that it may be used as a template or pattern for the replacement item. If the old piece of tubing cannot be used as a pattern, make a pattern key by placing one end of a piece of soft wire into one of the fittings where the tube is to be connected; then form the bends that are necessary to place the opposite end of the wire into the other connection. When the template satisfactorily spans the area between the fittings, it can be used as a pattern to bend the new tube.

Select a path with the least amount of bend. This reduces flow loss and simplifies bending. If possible, use a path with all bends in the same plane. Never select a path that requires no bends; tube cannot be cut or flared accurately or installed satisfactorily without bends. Bends absorb vibration and permit the tubing to expand or contract under temperature changes. If the tube is small (under 1/4 inch) and can be hand-formed, casual bends may be made. If the tube must be machine-formed, definite bends must be made to avoid a straight assembly. All bends must start a reasonable distance from the end fittings. This is because the sleeves and nuts must be slipped back along the tube during the fabrication of flares and during inspections. In all cases, the new tube assembly should be so formed before installation that pulling or deflecting the assembly into alignment by the coupling nuts is not necessary.

The objective in bending the tube is to obtain a smooth bend without flattening the tube. Usually a tube is bent with a tube bender; only in extreme emergencies would a tube be bent without using a hand-held or mechanical bending tool. A hand-held tube bender has a hand-clip handle, radius block, and slide-bar handle. The two handles act as levers to provide the mechanical advantage necessary to bend the tubing. A mechanical tube bender is issued as a kit. The kit contains the necessary equipment and instructions to bend tubing from 1/4 to 3/4 inch in diameter. This tube bender is used with metal tubing such as aircraft high-strength stainless steel.

Rigid tubing is repaired by replacing fittings and splicing sections of tubing using the permaswage repair procedure. Repairs may be done on or off the helicopter. The basic repair method is to mechanically swage the permaswage fitting onto the tube with a hydraulically operated tool. Fittings are permanent unions, elbows, tees, and crosses; flared, flareless, and separable sleeves; and combinations of permanent and threaded fittings.

The portable hydraulic power supply provides pressure required to operate the swaging tool. MIL-H-5606 fluid is fed to the tool through a 1/4-inch quick-disconnect, high-pressure hose. A swaging pressure of 5,500 psi may be applied to all tubing sizes and materials by manually operating the hand pump or using air-to-hydraulic fluid pressure from a 60- to

100-psi shop air source. A remote control air switch is provided to activate the air-to-hydraulic fluid valve. To prevent tool damage, keep the swaging pressure level from reaching more than 5,500 psi by using a pressure-relief valve. After swaging is finished, reduce the pressure to zero by turning the manual four-way selector valve to EXHAUST.

To repair damaged tubing, use the following procedures:

NOTE: Repair procedures are typical for all separable and permanent fittings.

1. Determine the type of repair to be performed by using the chart in Figure 2-1.

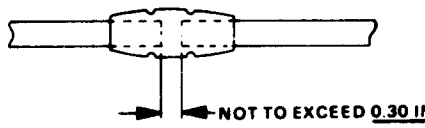

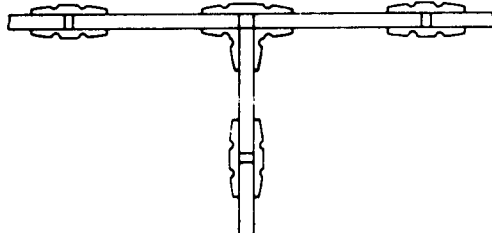
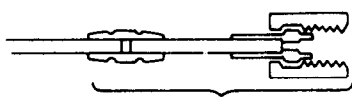
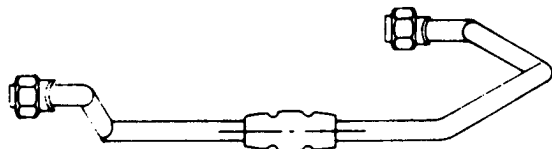
TYPE OF FAILURE	REPAIR METHOD
<p>1. PINHOLE LEAK OR CIRCUMFERENTIAL CRACK IN TUBING.</p> 	<p>1.a. MAKE 1 OR 2 CUTS AS NECESSARY TO REMOVE DAMAGED SECTION. IF 2 CUTS ARE REQUIRED, THE DISTANCE BETWEEN THEM SHALL NOT EXCEED 0.30 INCH. IF THIS MEASUREMENT IS EXCEEDED, GO TO REPAIR METHOD 2.</p> <p>b. SWAGE ONE PERMANENT UNION IN TUBE SECTION UNDER REPAIR.</p>
<p>2. LONGITUDINAL CRACK IN TUBING (CRACK LENGTH IN EXCESS OF 0.30 INCH).</p> 	<p>2.a. MAKE 2 CUTS TO REMOVE DAMAGED SECTION.</p> <p>b. REMOVE DAMAGED SECTION AND DUPLICATE.</p> <p>c. SWAGE REPLACEMENT SECTION INTO TUBING UNDER REPAIR USING TWO PERMANENT UNIONS.</p>
<p>3. LEAKING TEE OR ELBOW (PERMANENT TUBE-CONNECTION TYPE).</p> 	<p>3.a. CUT OUT DEFECTIVE TEE OR ELBOW.</p> <p>b. DUPLICATE TUBING SECTIONS FOR EACH BRANCH.</p> <p>c. SWAGE SPLICE SECTIONS TO TEE OR ELBOW.</p> <p>d. CONNECT EACH SPLICED SECTION TO TUBING UNDER REPAIR USING A TUBE-TO-TUBE UNION.</p>
<p>4. LEAKING SEPARABLE END FITTING.</p> 	<p>4.a. CUT TUBING TO REMOVE DEFECTIVE FITTING.</p> <p>b. MAKE UP SPLICE SECTION.</p> <p>c. SWAGE APPROPRIATE END FITTING TO END OF SPLICE SECTION.</p> <p>d. CONNECT NEW END FITTING TO MATING EQUIPMENT CONNECTION, TORQUING NUT AS REQUIRED.</p> <p>e. SWAGE 1 PERMANENT UNION CONNECTING NEW TUBE-END ASSEMBLY TO TUBE SECTION BEING REPAIRED.</p>

Figure 2-1. Troubleshooting procedures to repair tubing.

WHEN USING ANY OF THE FOUR REPAIR METHODS, (1 THROUGH 4) REFER TO THE FOLLOWING PROCEDURES:



1. BEFORE CUTTING THE TUBE, USE THE MARKING PEN AND A RULER TO DRAW A LINE PARALLEL TO THE TUBE RUN ACROSS THE SECTION TO BE CUT.
2. CUT THE TUBING.
3. IF A TUBE END IS TO BE REPLACED, PLACE THE LINE IN THE SAME LOCATION ON THE NEW TUBE AS THE TUBE SECTION THAT HAS BEEN REMOVED.

**CAUTION**

DO NOT FORGET TO PLACE TUBE INSERTION MARK ON ALL TUBE ENDS.

4. DRAW A LINE ACROSS THE FITTING.
5. INSTALL THE TUBE RUN AND LOCATE THE FITTING. FINGER TIGHTEN ANY END FITTINGS. (ONE END OF THE FITTING MAY BE SWAGED ON THE BENCH, IF POSSIBLE.)
6. PLACE THE SWAGE TOOL ON THE FIRST END BEING SWAGED, LINING UP THE LINE ON THE TUBE END BEING SWAGED WITH THE LINE ON THE FITTING.
7. REPEAT THIS STEP WITH THE OTHER ENDS TO BE SWAGED.
8. TIGHTEN ANY END FITTINGS TO THEIR PROPER TORQUE VALUE.

42x34

D145-10963-SPA

Figure 2-1. Troubleshooting procedures to repair tubing (continued).

2. Select applicable repair kit from the list in Figure 2-2.

MAJOR EQUIPMENT COMPONENTS:	FOR USE WITH TUBE SIZES:
Tube Repair Kit D12102C-01-01	3/16, 1/4, 5/16, and 3/8 inch
Tube Repair Kit D12102C-06-06	1/2, 5/8, and 3/4 inch
Tube Repair Kit D12102C-09-04	1, 1-1/4, and 1-1/2 inches

Figure 2-2. Repair kits.

3. Determine correct tube and fitting clearances (see Figure 2-3).

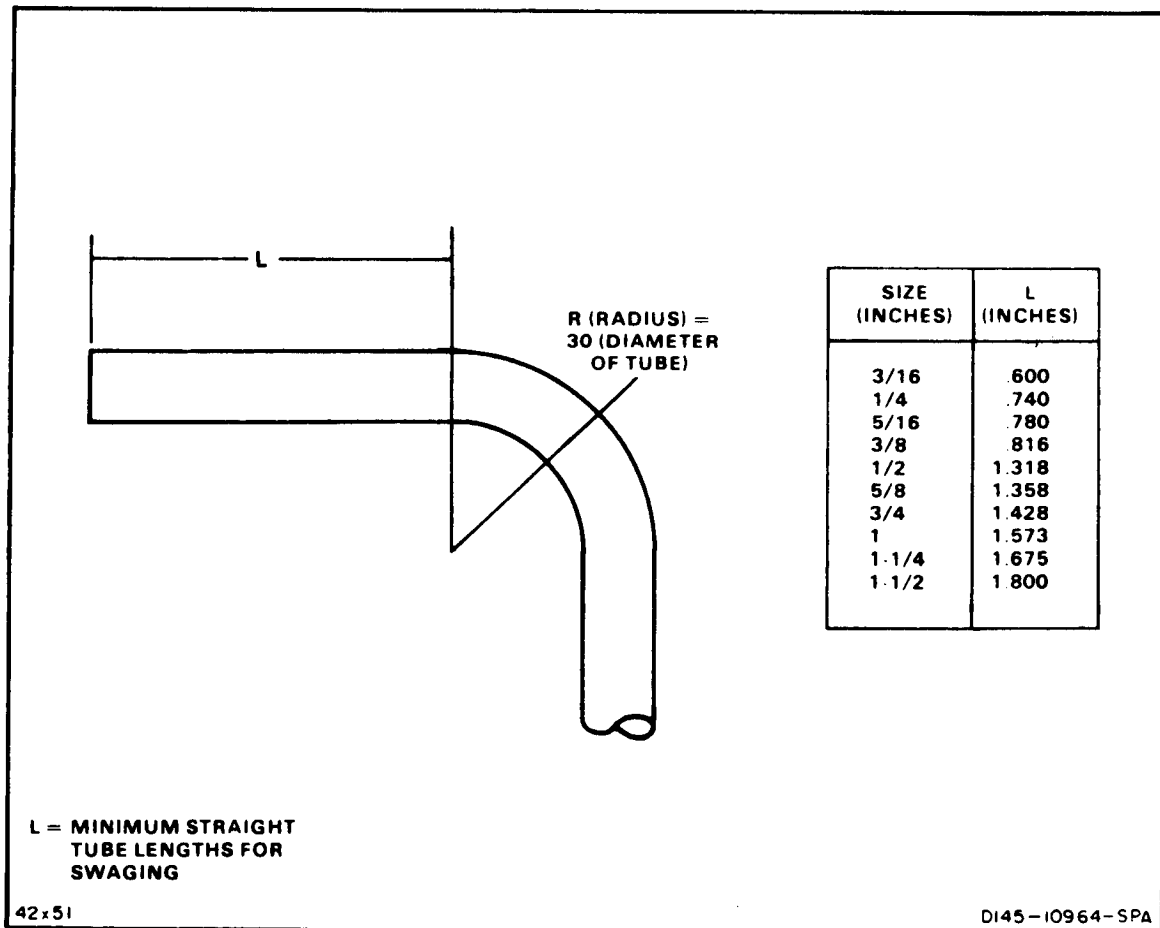
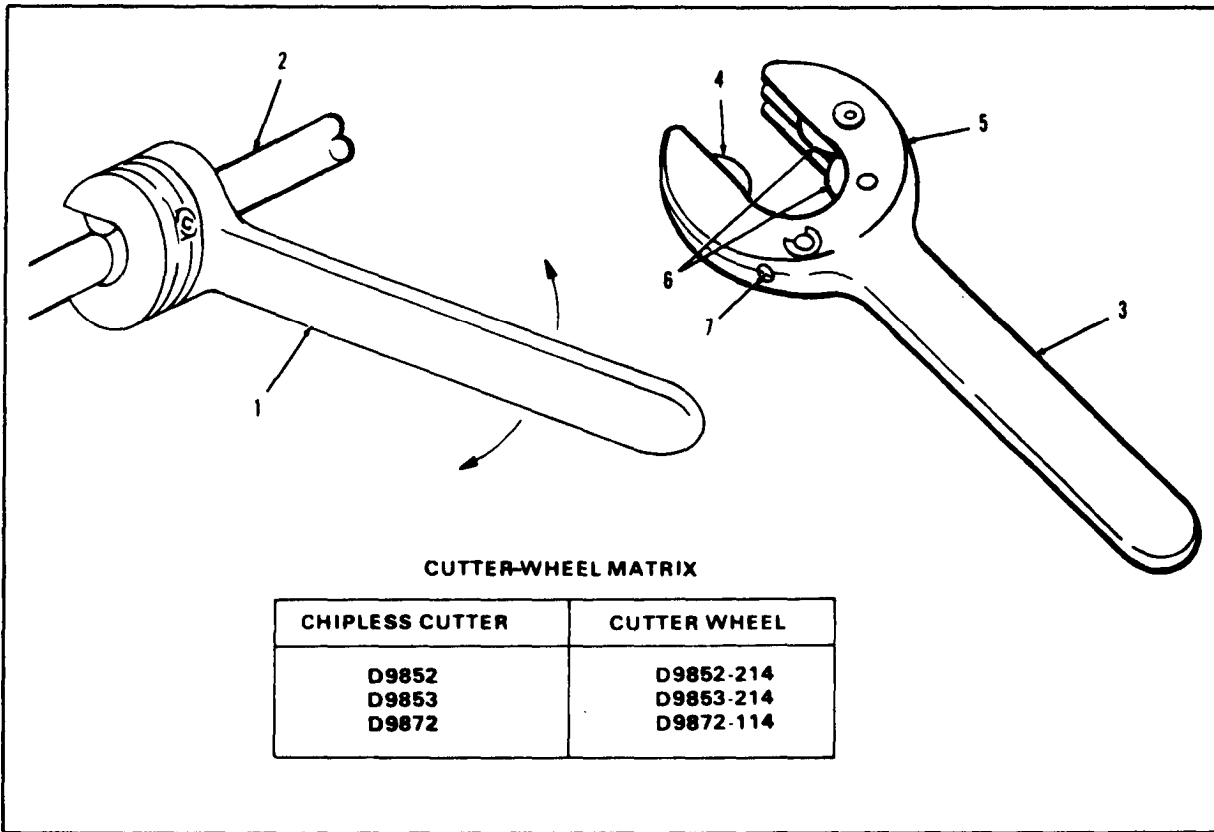


Figure 2-3. Tube and fitting clearances.

Then cut the tubing. When cutting the tubing, the objective is to produce a square end that is free from burrs. Tubing may be cut with a tube cutter (Figure 2-4) or with a fine-tooth hacksaw (not shown). To use the tube cutter correctly, place the tube in the cutter with the cutting wheel at the point where the cut is to be made. Tighten the adjusting knob so light cutter pressure can be applied on the tube; then rotate the cutter towards its open side. As the cutter is rotated around the tube, continue to apply light pressure to the cutting wheel by intermittently tightening the knob. Too much pressure applied to the cutting wheel at one time may damage the tubing or cause too many burrs. After the cut is completed, remove all burrs inside and outside of the tube. Then clean the tube to make sure that no foreign particles remain.

If a tube cutter is not available, a fine-tooth (32 teeth per inch) hacksaw may be used. After cutting the tubing with a hacksaw, remove all saw marks by filing. After filing, remove all burrs and sharp edges from inside and outside of the tube. Then clean out the tube and make sure that

no foreign particles remain. Refer to Figure 2-4 to complete steps 4 through 9 below.



**Figure 2-4. Tube cutter and cutter-wheel matrix.**

**CAUTION**

OVERTORQUING SOFT TUBING WILL CAUSE A LARGE BURR.  
OVERTORQUING HARD TUBING CAN DAMAGE THE CUTTER WHEEL.

4. Select the appropriate chipless cutter (1) for the size of the tube (2). Check that the handle (3) is operating freely and that the cutter wheel (4) is clear of the cutter-head opening. Make sure the cutter is clean and properly lubricated. (See step 3 for correct tube and fitting clearance.)
5. Rotate the cutter head (5) to accept the tube (2). Locate the cutter (1) in cutting position on the tube. Center the tube on the two rollers (6) and the cutter wheel (4).
6. Tighten the drive screw (7) until the cutter wheel (4) makes light contact on the tube (2). Tighten the screw an additional 1/8 to 1/4 turn. Do not overtorque.

7. Rotate the handle (3) through the arc of clearance until rotation eases noticeably.
8. Tighten the screw (7) an additional 1/8 to 1/4 turn. Repeat step 7 until the cut is complete.
9. Check the remaining section of tube (2). The cut should be square to the tube centerline within one-half of a degree.

After the tubing has been properly cut, deburr it using steps 10 through 15 below.

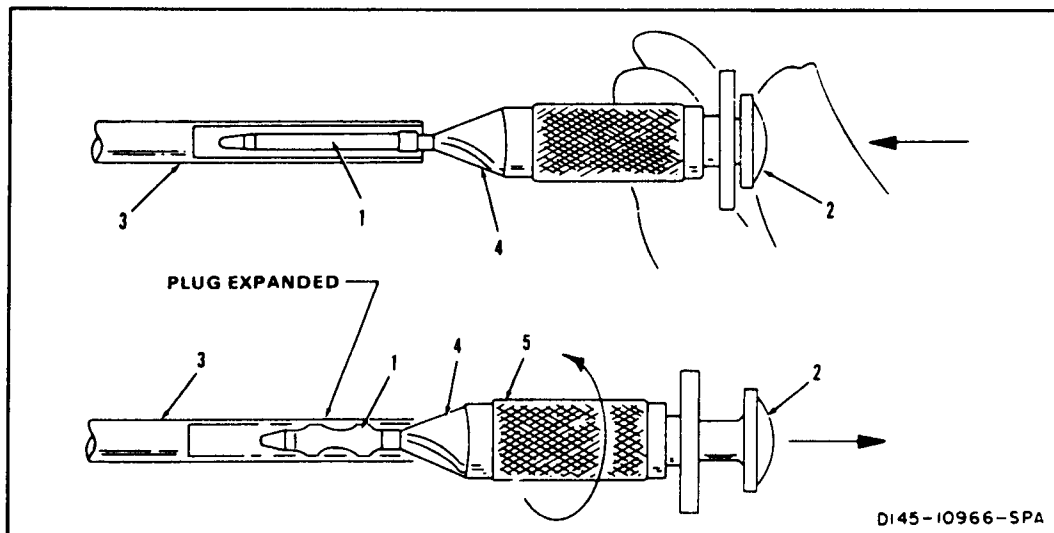
**CAUTION**

DO NOT PLACE THE FITTING OVER THE TUBE END UNTIL THE TUBE END IS PROPERLY DEBURRED. DAMAGE TO THE FITTING MAY RESULT.

10. Inspect and assemble the correct deburring tool and stem subassembly using Table 2-1. Also refer to Figure 2-5 to complete steps 11 through 15 below.

**Table 2-1. Deburring Tools and Stems**

DEBURRING TOOL	TUBE OD (INCH)	TUBE WALL THICKNESS (INCH)	STEM SUBASSEMBLY REQUIRED
<b>D9851</b>	1/4	0.016 - 0.028 0.028 - 0.050	D9851-13-04 D9851-13-03
	1/16	0.016 - 0.035	D9851-13-05
	3/8	0.016 - 0.035 0.035 - 0.058	D9851-13-06 D9851-13-07
	1/2	0.016 - 0.042 0.042 - 0.065	D9850-13-08 D9850-13-09
<b>D9850</b>	5/8	0.016 - 0.058	D9850-13-10
	3/4	0.016 - 0.065	D9850-13-12
<b>D9849</b>	1	0.020 - 0.083	D9849-13-06
	1-1/4	0.024 - 0.065 0.065 - 0.109	D9849-13-20 D9849-13-21
	1-1/2	0.028 - 0.083	D9849-13-24



**Figure 2-5. Deburring tool.**

11. Lightly lubricate the plug (1) with hydraulic fluid (E199).
12. Press in the plunger (2). Carefully insert the tool into the tube (3) until the cutter (4) is approximately 1/8 inch away from the burr. Release the plunger (2) to allow the plug to expand and seal the tube.
13. Rotate the knurled body (5) of the deburring tool clockwise while applying slight pressure to the cutter (1). Continue to rotate until the cutter rotates smoothly, indicating the tube end is deburred. Do not cut too deeply into the wall of the tube. The width of the deburring chamfer should not exceed one-half of the wall thickness of the tube.
14. Without depressing the plunger, pull the tool from the tube (3) until the first bulge of the plug (1) is exposed. Wipe off the tube and plug. Inspect the tube end for proper deburring. Repeat step 13, if necessary.
15. Remove the deburring tool from the tube (3). Clean all chips from the tube and tool.

After the tube has been properly deburred, prepare the replacement tube. First select a piece of tubing; it must be the same size and length as the one being replaced. Then bend the replacement tube to the shape of the original tubing. Leave some excess tubing for the trim at both ends. Remove all burrs from the replacement tube (refer to steps 10 through 15).

**CAUTION**

DO NOT PLACE THE FITTING OVER THE TUBE END UNTIL THE TUBE END IS PROPERLY DEBURRED. DAMAGE TO THE FITTING MAY RESULT.

16. Trim the fitting end of the tube. Place the fitting over the tube to compare the length to the original fitting and tube.
17. Install the fitting onto the applicable component. Position the tube within the fitting, aligning the other end of the tube with the mating tube. Remove the tube, and trim the other end as required. The maximum gap allowed between mating tubes is 0.30 inch; see Figure 2-6 for types of mismatches and ways to handle them.

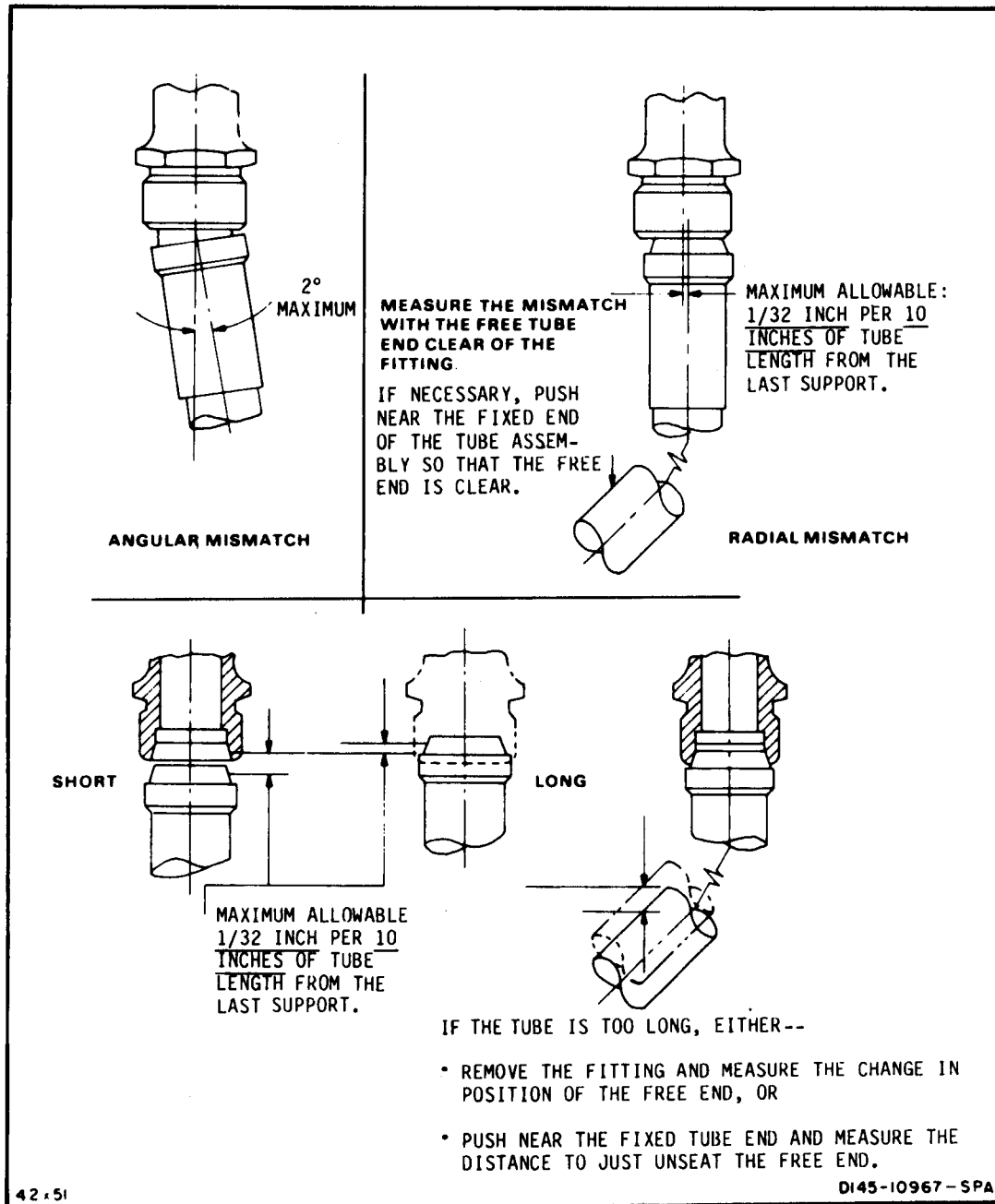
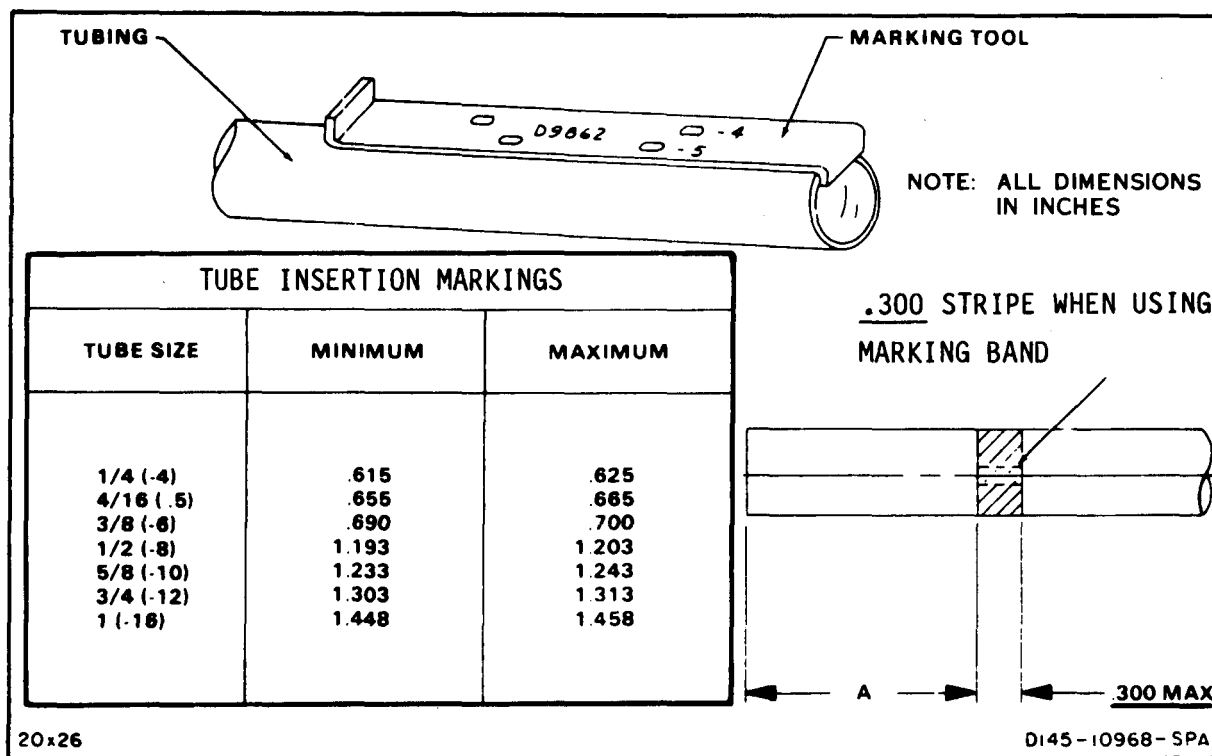


Figure 2-6. Types of mismatches.



After the replacement tube has been made, swage the tube using the permaswage repair procedure in steps 18 through 32 below.

18. Mark tube ends. Use the correct marking tool for the size of the tube to be swaged. When marking with tool 09862, place the lip stop against the end of the tube. (See Figure 2-7.) Using the slot as a guide, mark the tube in two places (180° apart) with the marking pen. If marking tool 09862 and marking pen D10058 are not available, see the chart in Figure 2-7 for the tube insertion band.



**Figure 2-7. Marking tool and tube insertion markings/band.**

19. Position the prepared tube within the fitting. Align the mating ends and position the union fitting. Check to see if the separable fitting can be swaged with the fitting installed on the component. If not, mark the fitting and tube so that proper clocking is obtained. Then swage the fitting off the aircraft using steps 20 through 32 below.
20. Connect the hydraulic pressure line from the portable hydraulic power supply to the fitting on the base of the swaging tool.
21. Set the selector valve on the power supply to EXHAUST to relieve all line pressure.
22. Install the set of die blocks in the swaging tool. Position the tool below the level of the power supply. These steps will

prevent air from getting in the hose and power supply. Cycle the power supply to 2,000 psi followed by EXHAUST; complete two or three cycles so all trapped air is bled from the cylinder.

NOTE: Some separable fittings are swaged without locators.

23. See Figure 2-8 for components of a hydraulic system and a chart of swage tool envelopes. Select the correct upper and lower die block assemblies for the size of the fitting to be swaged. Insert the lower die block with the correct fitting locator into the tool. When properly inserted, the fitting locator is on the opposite end of the tool from the latch.

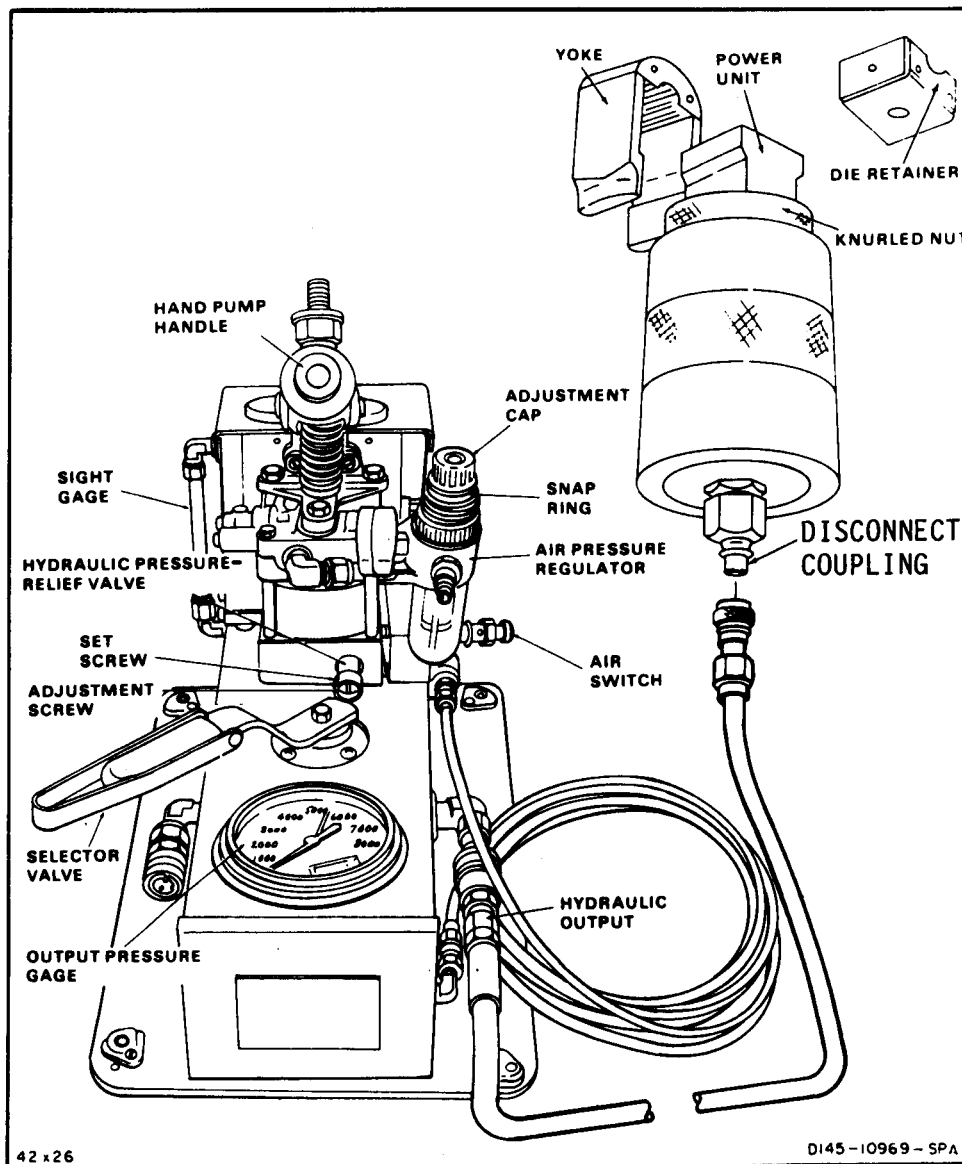


Figure 2-8. External and internal components of a hydraulic system and a chart of swage tool envelopes.

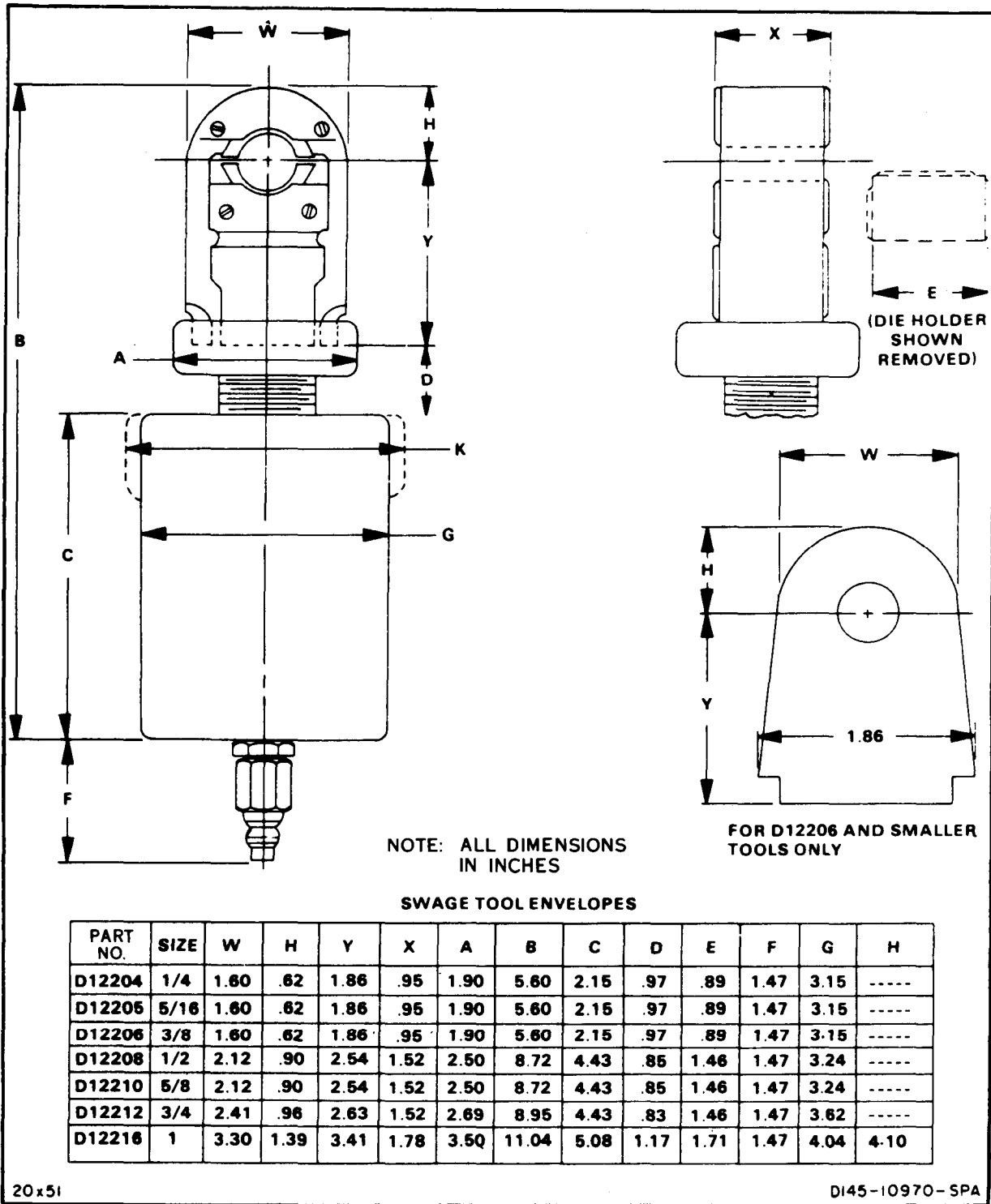


Figure 2-8. External and internal components of a hydraulic system and a chart of swage tool envelopes (continued).

24. Place the swaging tool and dies over the separable fitting. Make sure the fitting is positioned properly. Acceptable limits of tube insertion into the union are shown in Figure 2-9. Push up the latch to lock dies in place.

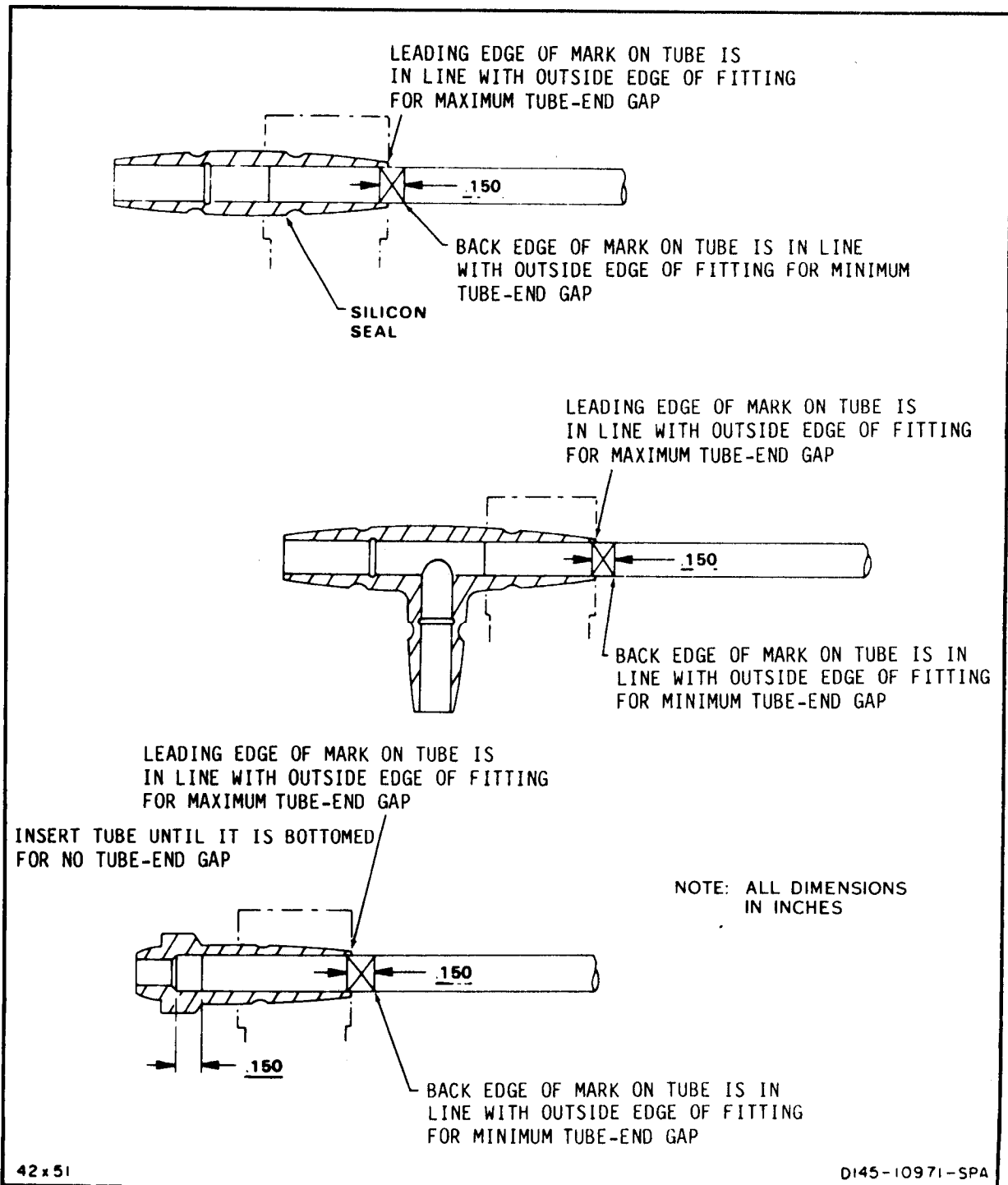
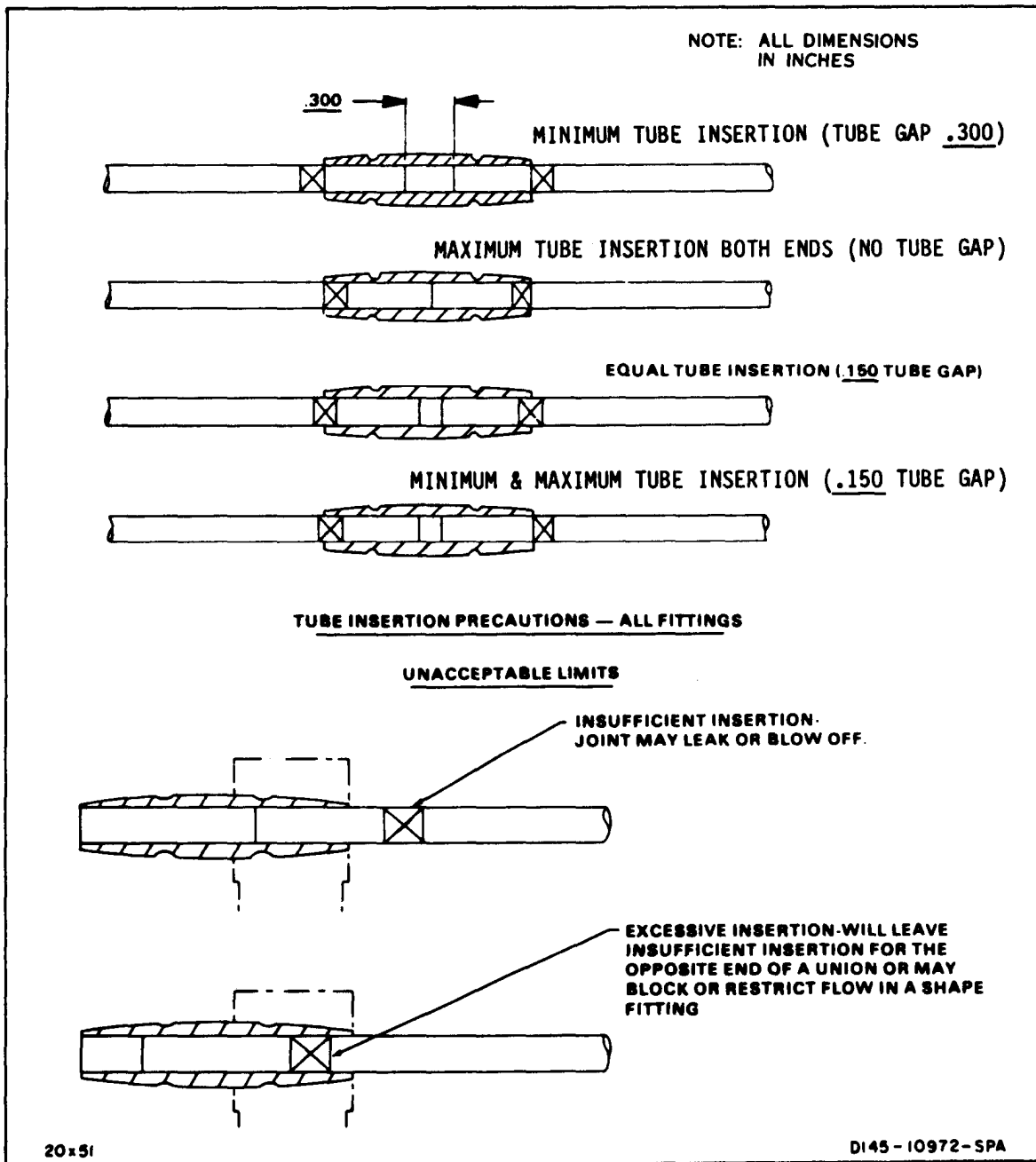


Figure 2-9. Acceptable limits of tube insertion into a union.



**Figure 2-9. Acceptable limits of tube insertion into a union (continued).**

25. Position the face of the swaging tool against the location mark on the tube. The outer edge of the latch must fall within the location mark. Tube insertion must be as shown in Figure 2-9.
26. Set the selector valve to the appropriate hydraulic output.
27. Actuate the swaging tool with 5,250- to 5,750-psi hydraulic pressure. If the shop air input is not available, use the hand pump.

- 28. Set the selector valve to EXHAUST to relieve the pressure completely.
- 29. Slide open the latch and remove the swaging tool from the swaged joint.

NOTE: Swaging dies make ridges on swaged fitting. Check after-swage dimensions between ridges.

- 30. Inspect the swaged end with the appropriate size go/no-go inspection gage according to the illustration in Figure 2-10. The fitting may be reswaged only once if the gage does not fit (repeat steps 24 through 30).
- 31. If the swaging operation was done off the aircraft, position and attach the separable fitting to the component. Align the mating ends and position the union fitting. Torque the fitting to its final torque; ensure the fixed portion of the fitting is held stationary.
- 32. With the union fitting positioned correctly, repeat steps 21 through 28 for both ends of the fitting.

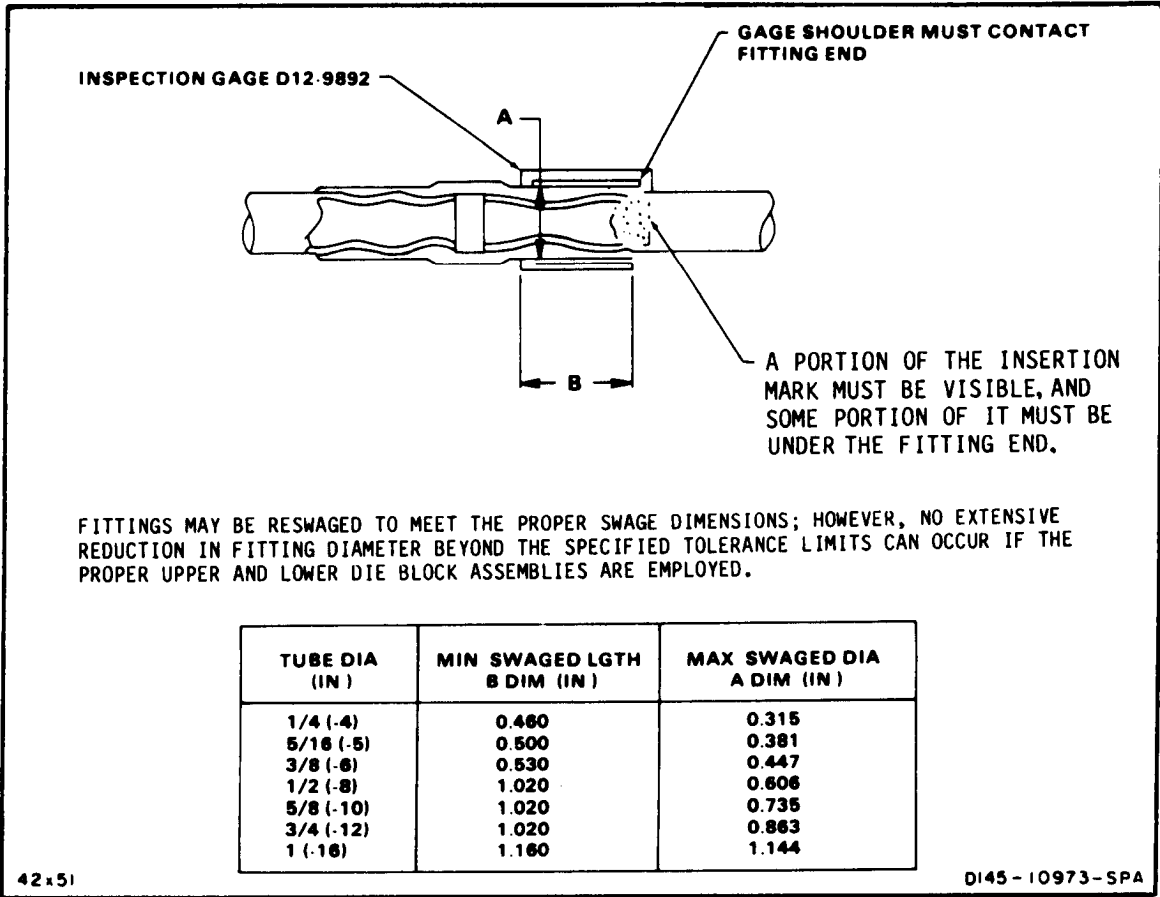


Figure 2-10. Measuring after-swage dimensions.

Flaring. The flaring tool used by the Army produces tubing flares with 74° angles. It produces a double-lap flare on 3/16- through 3/4-inch mild aluminum tubing and a single-lap flare on all grades of aircraft tubing, including 1/8-through 3/4-inch corrosion-resistant steel. When making flares, use the operating instructions furnished with the tool.

Single-flared tubing is used for tubing joints on all sizes of steel tubing, 6061 aluminum alloy tubing, and 5052 aluminum alloy tubing with more than a 1/2-inch outside diameter. Double-flared tubing is used for tubing joints on all sizes of 5052 aluminum alloy tubing with an outside diameter of 1/2 inch or less. Double flares are less apt to be cut by overtightening, and the tube assembly is less likely to fail under operating pressure. Refer to TM 55-1500-204-25/1 for more detailed information on bending and flaring tubing.

### Installation.

Rigid Tube Assemblies. Before installing a rigid tube assembly in an aircraft, inspect it carefully and remove dents and scratches, if possible, without weakening the tube. Install the proper nuts and sleeves, and obtain a proper fit where the tubing is flared. Pressure-test the tube assembly to twice its operating pressure before installation. Ensure that the rigid tube assembly is clean and free of all foreign matter. Hand-screw the nuts to the mating connector, and then tighten therewith the proper wrench. Never use pliers. Avoid pulling the rigid tube assembly into place with the nut; line it up before tightening. Install rigid tubing that runs through cutouts with care so that it will not be scarred when it is worked through the hole. When the tubing assembly is long, tape the edges of any cutouts before installing the tubing.

Flared Tube Assemblies. After installing an aluminum alloy tube assembly and tightening to the required torque, check for leaks. If it leaks, do not tighten it any further. Overtightening can badly damage or completely cut off the tubing flare or damage the sleeve or nut. If the assembly is overtightened, disassemble the leaking connection and correct the fault. Undertightening connections can also be serious; it can cause the tubing to leak at the connector because of the insufficient grip on the flare by the sleeve. In this case, use a torque wrench to prevent undertightening. A nut should never be tightened when pressure is in the line; this could damage the connection without adding any appreciable torque. Common faults that cause leaking are--

- The flare is distorted into the nut threads.
- The sleeve is cracked.
- The flare is out of round.
- The flare is cracked or split.
- The inside of the flare is rough or scratched.

- The connector mating surface is rough or scratched.
- The connector threads or nuts are dirty, damaged, or broken.

If a steel tube assembly leaks, it may be tightened one-sixth of a turn beyond the normal torque to stop the leakage. If the assembly still leaks, it must be disassembled and repaired.

**Flareless Tube Assemblies.** When installing flareless tube assemblies, inspect them to ensure that they have no scratches or nicks and that the sleeve is properly preset. Lubricate the threads of the nuts and connectors with hydraulic fluid. Place the assembly in the proper position in the aircraft and finger-tighten clamps, brackets, supports, and nuts. The tubing ends should fit snugly in the connectors; little pressure should be required to hold them in place.

Tighten the nut by hand until you feel an increase in resistance to turning. If running the nut down with the fingers is impossible, use a wrench, but be alert for the first signs of bottoming. It is important that the final tightening start at the point where the nut just begins to bottom. With a wrench, turn the nut one-sixth of a turn (one flat on a hex nut). Use a wrench on the connector to stop it from turning while tightening the nut. Flareless tube fittings have no specific torque setting; therefore, use care when finding the exact point where the nut begins to bottom and when applying the required amount of turn on the nut.

After the tube assembly is installed, pressure-test the system. If a connection leaks, tighten the nut an additional one-sixth of a turn (making a total of one-third turn). If the connection still leaks after tightening the nut a total of one-third turn, remove the assembly. After removal, inspect the components of the assembly for scores, cracks, foreign material, or damage from overtightening. Overtightening a flareless tube nut drives the cutting edge of the sleeve deeply into the tube. This causes the tube to be weakened to the point where normal in-flight vibration could cause the tube to shear. After inspection (if no faults are found), reassemble the connections and repeat the pressure-test procedures. Do not in any case tighten the nut beyond one-third of a turn (two flats on the hex nut); this is the maximum the fitting may be tightened without the possibility of permanently damaging the sleeve and tube.

## **FLEXIBLE HOSE**

Hose is used when flexibility is required in the connections between moving parts and where a line is subject to vibration. The hose is made of a flexible, leakproof inner tube and one or more layers of metal or fabric reinforcement braid. Rubber or teflon is used for making the flexible inner tubes. The type of material used for the reinforcement braid and the number of layers needed depend mostly on the pressure range of the hose. Medium and high pressure are the two range classifications in aircraft hydraulics. The medium range includes operating pressures of 1,500 psi and below; the high range includes pressures up to 3,000 psi.



Types. The two types of hoses are the rubber type and the teflon type.

**Rubber Hose.** The inner tube of rubber hoses used in aircraft hydraulic systems is made of synthetic rubber. Various compounds of rubber are used. Each compound provides a hose with some special capability, such as how it is used with certain fluids or how it operates within certain ranges of temperature. The kind of braid and the number of layers depend on the intended operating pressure range. The outer covering of most rubber hoses consists of wire, fabric, or rubber.

Bulk rubber hose has markings on its outer cover--in ink or paint or a metal tag--for identification. The information provided by the marking generally includes the identity of the manufacturer, date made, size, and military specification number. By referring to this number in a specification table in Chapter 7 of TM 55-1500-204-25/1, you can find additional information about the hose such as its pressure capability, its temperature limitations, and the fluids with which it may be used. On some hoses, a lay strip provides an easy method to determine whether an installed hose is twisted.

Rubber hose is used in aircraft hydraulic systems only as assemblies. An assembly is formed by attaching metal end connection fittings to each end of a section of bulk hose. A metal band around the assembly shows its national stock number, operating pressure, and pressure-test data. to Chapter 7 of TM 55-1500-204-25/1 for information on how to fabricate high- and medium-pressure assemblies.

**Teflon Hose.** Teflon is the registered trade name for tetrafluoroethylene, which is a synthetic resin. Teflon hose is widely used in Army aircraft. It offers the advantage of an unlimited shelf life in contrast to that of rubber hose.

Teflon hose has a flexible, leakproof inner tube reinforced with one or more layers of stainless steel braid. The size of the hose and the intended operating pressure determine the number of layers of braid that should be used. The outer covering is always of steel braid. Removable metal bands are placed along lengths of bulk hose for identification. These bands, usually made of brass, provide the military specification number, manufacturer's code number, and allowable operating pressure.

Teflon hose is used in aircraft hydraulic systems only as assemblies. A teflon hose assembly is identified by a permanently affixed stainless steel band. This band provides the national stock number, part number, and pressure-test date. Both medium-and high-pressure teflon hose assemblies are used in Army aircraft. Refer to TB 750-125 for information on how to fabricate teflon hose assemblies.

Installation. Before installation, visually inspect and pressure-test all field-fabricated hose assemblies. This applies regardless of whether they were just made or were previously made, tested, and placed in storage. Also pressure-test all factory- or depot-made assemblies before use. When connecting hose, remember--

- To lubricate fittings with hydraulic fluid before connecting the hose assemblies. Never connect dry fitting parts.
- To avoid making a straight hose connection between two rigid connection points. Allow slack of at least 5 percent of the hose length for operation and shrinkage.
- To add 5 percent to the hose length when installing a hose with only a slight bend. Where a hose is attached to an engine-mounted hydraulic component, provide hose slack of at least 1 1/2 inches between the component and the hose support nearest the engine.
- To tighten fittings to exact torque specifications given in the applicable technical manuals. Avoid guesswork.
- To visually check for backed-out retaining wires on swivel nuts.

Teflon hose requires a different kind of support than that of rubber hose; however, the following principles apply to both rubber and teflon hose:

- Supports should be spaced in 24-inch intervals or closer, depending on the size of the hose.
- A hose assembly connecting two rigidly mounted fittings must be supported firmly but not rigidly.

To protect the hose against damage from chafing, provide adequate clearance between the hose and other objects. For example, use grommets to protect the hose passing through bulkheads. The hose must also be protected from extreme temperatures. For example, shrouding or relocating the hose provides protection from engine exhaust and hot engine parts.

Vibration is harmful to hose. When a hose is connected to a unit that moves in a direction opposite to the movement of the airframe, install the hose with slack between the last point of support and the movable unit. The slack must be great enough to prevent the hose from being pulled off its end fittings. However, the hose must be firmly supported to eliminate vibration-caused strain on the hose connection.

Hydraulic lines in Army aircraft are identified by color-coded tape applied in one of two ways. In some aircraft, the word HYDRAULIC is printed on blue tape running along the line; circles applied to the tape further identify the lines as hydraulic ones. In other aircraft, three 1/4-inch-wide bands of tape colored blue, yellow, and green are spaced one-sixth of an inch apart to identify the hydraulic lines. With either system, additional white tape with arrows printed on it to indicate direction of flow may run adjacent to the colored tape to identify a pressure line or a return line.

## HYDRAULIC FITTINGS

Hydraulic fittings are used throughout the hydraulic system to provide simple connections between hydraulic components and tubing. Standard MS

(flareless) and AN (flared) fittings are used in Army aircraft. Both types are made in many different shapes and designs. They may be ordered in either male or female designs or in combination designs (male on one end and female on the other). The hydraulic repairer is concerned with installing both the AN and MS fittings in aircraft hydraulic systems. Normally the fittings are selected according to the design of the system. The hydraulic repairer repairs fitting failures by duplicating the original installation.

Flareless Fittings (MS). These fittings are used to connect unflared tubing. They have a counterbore in which the tube end is installed. Figure 2-11 shows a half-sectional view of an MS fitting. Notice the 24° beveled portion of the counterbore and its seat. The seat forms a slope for the tube during the connection of one tube to another or of a tube to a component. The beveled area causes the tube connector sleeve to seal the connection as the tube B-nut is tightened. See Figure 2-12 for an MS fitting properly installed.

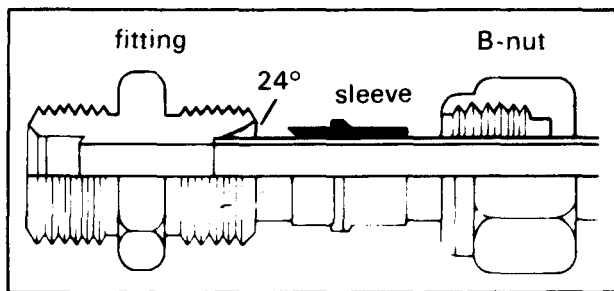


Figure 2-11. Half-sectional view of an MS fitting.

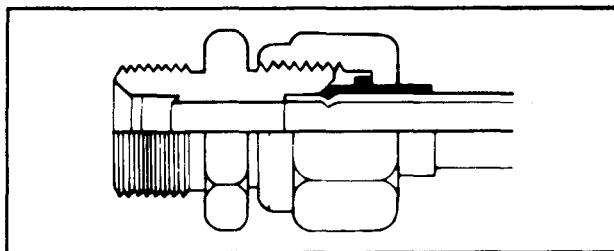


Figure 2-12. MS flareless fitting installed.

**Identification.** MS fittings are made of aluminum alloy or steel. Aluminum alloy fittings can be identified visually by their yellow color, which is caused from the anodizing treatment. The cadmium plating on steel fittings gives them a silvery white color. MS fittings are identified by letter-number codes; for example, MS21900-4 is interpreted as follows:

- MS.....prefix (military specification)
- 21900..design part number (adapter, flareless tube to AN flared tube)
- 4.....size of fitting in sixteenths of an inch (4/16 inch)

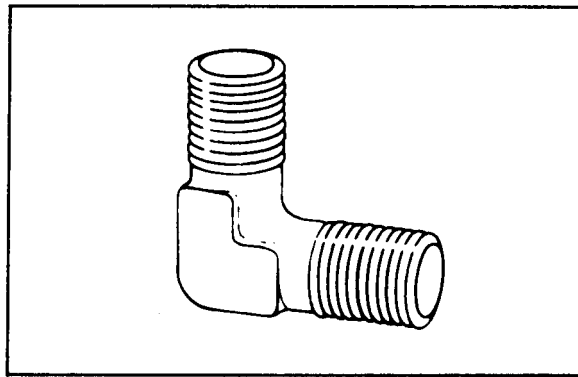
The material from which the fittings are made is indicated by the absence of a letter at the end of the MS number or by the addition of a letter at the end of the number; for example--

MS21900-4 is made from carbon steel.

MS21900-8-D is made from aluminum alloy.

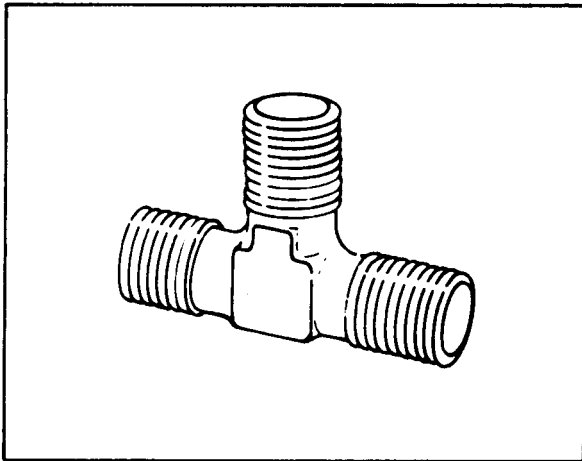
MS21900-8-S is made from corrosion-resistant steel, Class 347.

Types. MS fittings may be procured in many styles. See Figure 2-13 for an MS21904 elbow with a 90° angle. The fitting is used where the routing of tubing requires a 90° change in direction in a limited area. The flat surface between the threaded ends allows an open-end wrench to be used to hold the fitting in position while tube connections are being made.

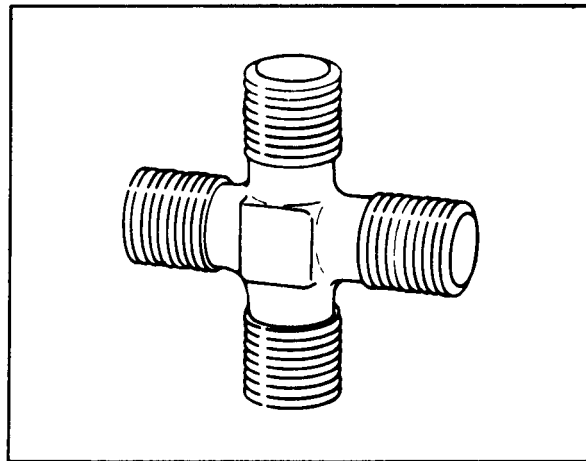


**Figure 2-13. MS21904 elbow with a 90° angle.**

The MS21905 tee (Figure 2-14) and the MS21906 cross fitting (Figure 2-15) connect common-purpose lines that come together within the hydraulic system. They, like the 90° fittings, have flat surfaces where an open-end wrench may be placed to assist in maintaining the fitting in the correct position.



**Figure 2-14. MS21905 tee.**



**Figure 2-15. MS21906 cross fitting.**

At times, it may be necessary to reduce or expand a hydraulic connection. An MS21916 reducer (Figure 2-16) is normally used in the first case, and an MS21915 bushing (Figure 2-17) in the latter. Both bushings and reducers are usually necessary when connecting components to hydraulic test equipment.

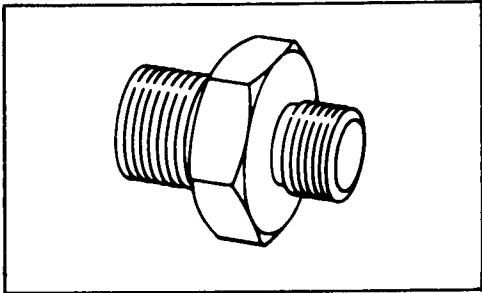


Figure 2-16. MS21916 reducer.

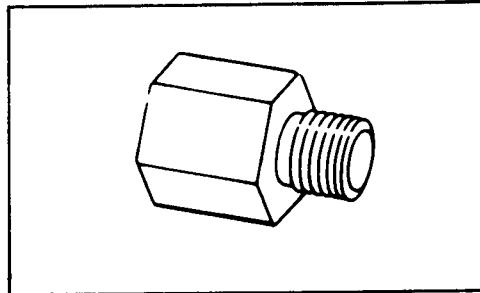


Figure 2-17. MS21915 bushing.

The MS21902 flareless tube union (Figure 2-18) is used for straight connections of tube to tube or tube to component.

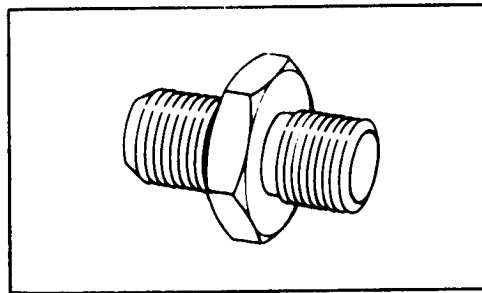


Figure 2-18. MS21902 flareless tube union.

Plugs MS21913 (Figure 2-19) and caps MS21914 (Figure 2-20) should be used whenever any aircraft undergoing maintenance has a line or component disconnected that is not to be reconnected immediately. These fittings prevent loss of hydraulic fluid or entrance of foreign matter whether the system is in a static or a pressurized condition. MS plugs are used on any MS female connector of corresponding size. MS caps are used on all MS male fittings of the same size.

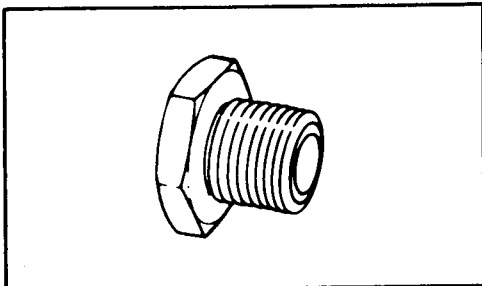


Figure 2-19. MS21913 plug.

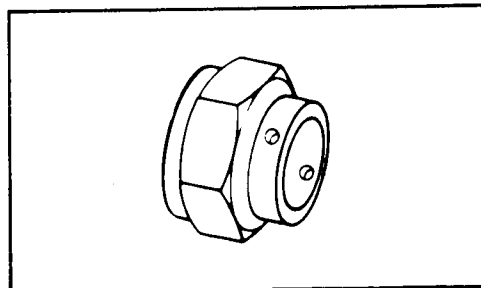
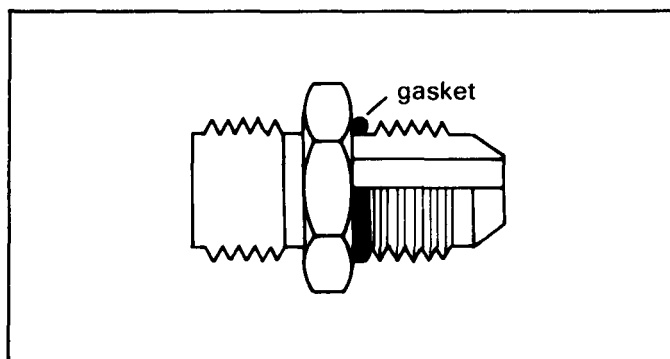


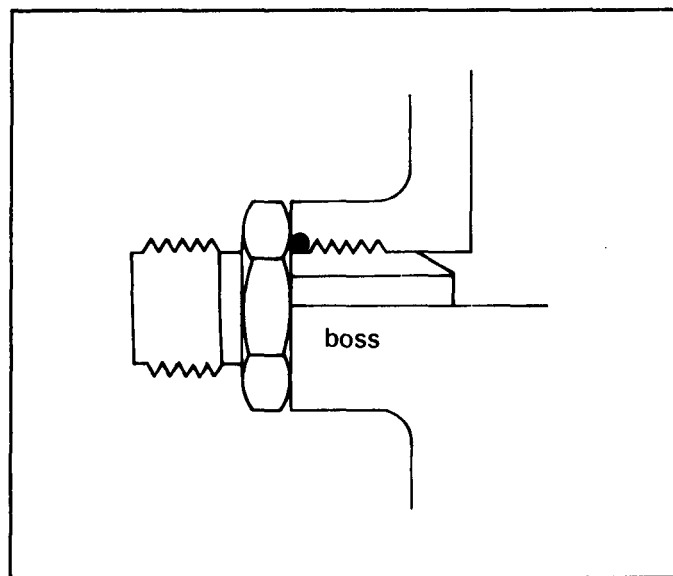
Figure 2-20. MS21914 cap.

Installation. MS fittings must be inspected before installation. Sometimes it is impossible to see through a fitting or tube; in this case, blow clean, dry, compressed air through it to be certain that no obstructions exist. Any lines that have caps removed in storage or before installation should be flushed with clean hydraulic fluid. Male threads and sleeves of the fittings being assembled should be lubricated with the same hydraulic fluid used in the system. On fittings with tapered threads, use antiseize compound on the threads except for the first three, which are left dry.

To make a connection between the tubing and a component, select, lubricate, and install the proper gasket in the position shown in Figure 2-21. Screw the fitting into the boss of the component until it bottoms on the boss. (See Figure 2-22.)



**Figure 2-21. MS fitting with gasket.**



**Figure 2-22. MS fitting screwed into the boss.**

When tubing is connected to an MS fitting, align the tube with the fitting, and start the nut by hand without excessive strain on the line. Do not use force to align tubing. Align the tube by loosening clamps on

connecting lines or by rotating fittings. (See Figure 2-23.) Connect both ends of the tubing, and tighten them until an increase in resistance to turning is encountered in the B-nut. At this point, tighten the clamps and ensure that they do not pull the tubing out of alignment; place clamps in a binding position. Complete the installation by turning the B-nut one-sixth of a turn. Pressurize the hydraulic system and inspect for leaks. If leakage is noted, release system pressure and back off (loosen completely) the B-nut. If possible, rotate the sleeve to a new position, and then retorque the B-nut to its previous position plus one-sixth of a turn. Normally this action will stop the leak; if it does not, replace the assembly.

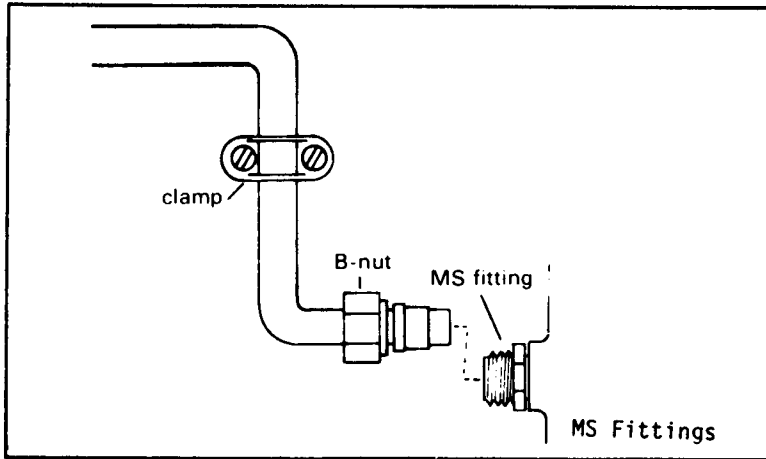
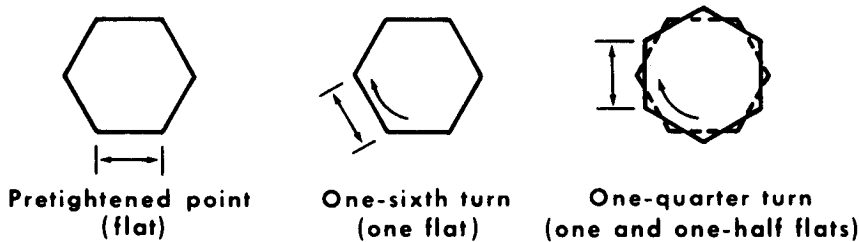


Figure 2-23. Alignment of tubing.

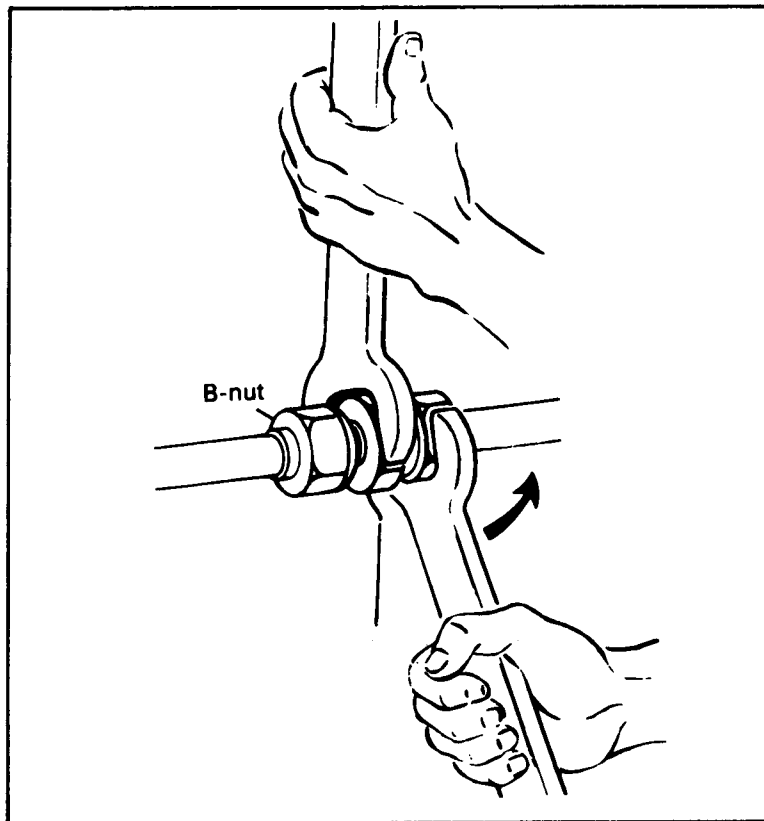
When connecting tubing to an MS fitting, refer to Table 2-2 for the torque and flat-turn values for nuts on flareless tubing.

Table 2-2. Torque and Flat-Turn Values for MS Fittings

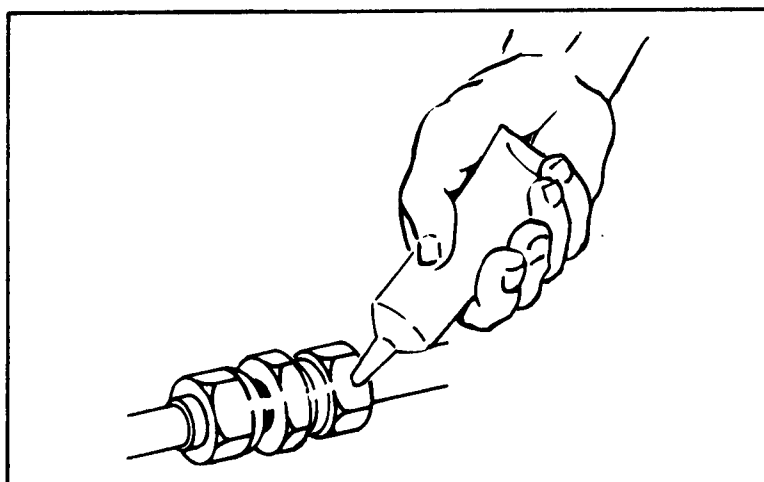


Tubing	Size	Torque (inch-pounds)	Tightening - Rule of Thumb (Flat Turns after Pretightening)	
			Normal tight	Extra tight
Aluminum or steel	- 3	65 to 95		
	- 4	100 to 150	1 to 1 1/2	2 Maximum
	- 6	175 to 300	1 to 1 1/2	2 Maximum
	- 8	325 to 500	1 to 1 1/2	2 Maximum
	-10	400 to 700	1 to 1 1/2	2 Maximum
	-12	500 to 800	1 to 1 1/2	2 Maximum
	-16	500 to 800	1 to 1 1/2	2 Maximum
Aluminum	-20	600 to 900	1 to 1 1/2	2 Maximum
	-24	600 to 900	5/6 to 1	1 1/2 Maximum

To make a tube-to-tube connection, tighten the tube B-nut until a definite resistance is felt; then turn it one-sixth of a turn farther. The upper wrench is held stationary while the lower wrench is moved upward until the B-nut is tightened a sufficient amount. (See Figure 2-24.) On this tube connection, like most others, paint a 1/8-inch colored stripe across the completed assembly so that loosening can readily be detected. (See Figure 2-25.)



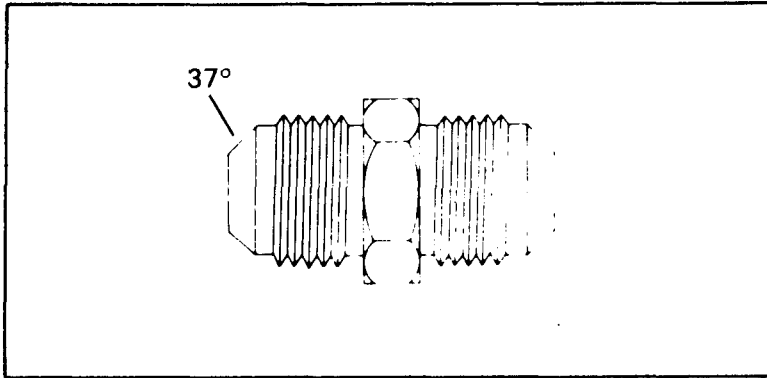
**Figure 2-24. Tightening an MS fitting.**



**Figure 2-25. Marking an MS fitting.**



**Flared Fittings (AN).** Flared fittings, like flareless (MS) fittings, come in many different shapes. They are easily identified by their distinguishing colors; aluminum alloys are blue, and steel alloys are black. Aluminum-bronze fittings are cadmium-plated and are not otherwise colored. Only steel fittings are used with steel tubing (3/8-inch outside diameter and smaller); other fittings and tubing can be intermixed. The main difference between AN and MS fittings is the manner in which the hydraulic tube fits to the fitting. The MS fitting has a counterbore in which the tubing is inserted; the AN fitting has a 37° flared (beveled) face to which the tubing is fitted. (See Figure 2-26.) This flared area of the fitting is the sealing surface and must be maintained. Any bad flare on this sealing surface will show up as a hydraulic leak.



**Figure 2-26. Standard AN fitting (union).**

**Identification.** Standard AN fittings used in Army aircraft are manufactured from aluminum alloy and steel. For identification only, aluminum alloy fittings are blue; carbon steel fittings are black; and cadmium-plated fittings are silvery white. Like MS fittings, AN fittings are identified by letter-number codes; for example, AN6289-4 is interpreted as follows:

- AN .....prefix (Army-Navy)
- 6289 .....design part number (nut)
- 4 .....size of fitting in sixteenths of an inch  
(4/16 inch)

The material from which flared fittings are made is indicated by the absence of a letter between the design part number and size number or by the addition of a letter at this location; for example--

- AN6289-4 is made from carbon steel.
- AN6289-D-4 is made from aluminum alloy.
- AN6289-S-4 is made from corrosion-resistant steel, Classes 304L and 347.

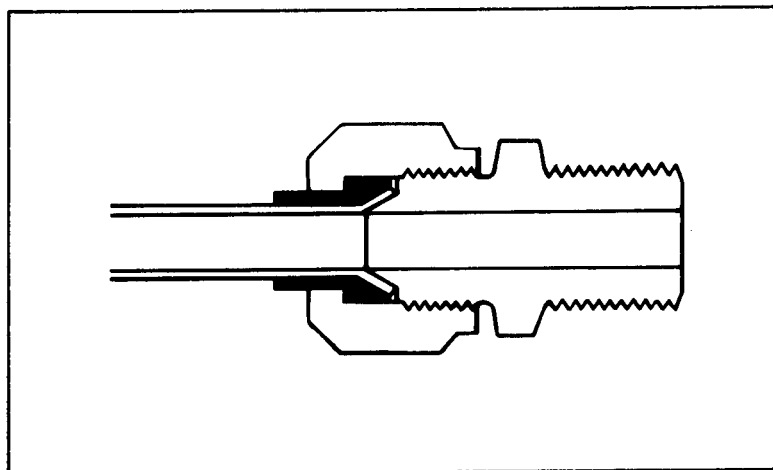
Installation. Standard AN fittings are installed the same as MS fittings with the exception of the B-nuts and sleeve installation. Like the MS fittings and tube assemblies, the AN fittings and tube assemblies must be inspected before installation. Ensure that the sealing surface of the fitting to which the tube will be attached is free of scratches, cuts, burrs, nicks, and other imperfections that might prevent a leakproof connection.

Before installation, lubricate all male fittings and the outside of the tube flare and sleeve with the same type hydraulic fluid used in the system. During installation, ensure that the tube assembly is aligned and that the B-nut starts by hand. The nut should be fitted and started with at least three full turns to prevent cross-threading. All B-nuts should be tightened until a slight resistance is felt. From this point, where possible, B-nuts should be tightened with a torque wrench to the values specified in Table 2-3.

**Table 2-3. B-Nut Torque Values**

TORQUE ON TUBE NUT		
TUBE OUTSIDE DIAMETER	ALUMINUM ALLOY TUBING	STEEL TUBING
1/4 INCH	40-65 INCH POUNDS	135-150 INCH POUNDS
5/16 INCH	60-80 INCH POUNDS	180-200 INCH POUNDS
3/8 INCH	75-125 INCH POUNDS	270-300 INCH POUNDS
1/2 INCH	150-250 INCH POUNDS	450-500 INCH POUNDS
5/8 INCH	200-350 INCH POUNDS	650-700 INCH POUNDS
3/4 INCH	300-500 INCH POUNDS	900-1,000 INCH POUNDS
1 INCH	500-700 INCH POUNDS	1,200-1,400 INCH POUNDS

If flared connections leak, disconnect the fitting and inspect the sealing surfaces. If no faults exist, check the tube assembly for misalignment. A correctly torqued fitting is shown in Figure 2-27.



**Figure 2-27. Properly torqued flared fitting.**

## CHAPTER 3

# HYDRAULIC SEALS

### TYPES

Seals reduce or prevent internal and external leakage between two objects. Hydraulic seals are used throughout aircraft hydraulic systems to cut down on internal and external leakage of hydraulic fluid, thereby preventing loss of system pressure. Two general types of seals used in hydraulic and pneumatic systems are the dynamic type and the static type. A dynamic seal is used between two moving parts of a unit. A static seal is used between two stationary parts.

### IDENTIFICATION

Seals are classified according to their shapes. (See Figure 3-1.) Notice that the O-ring is circular in shape, the T-ring looks like an upside down T, the D-ring looks like a D, and the V-ring looks like a V.

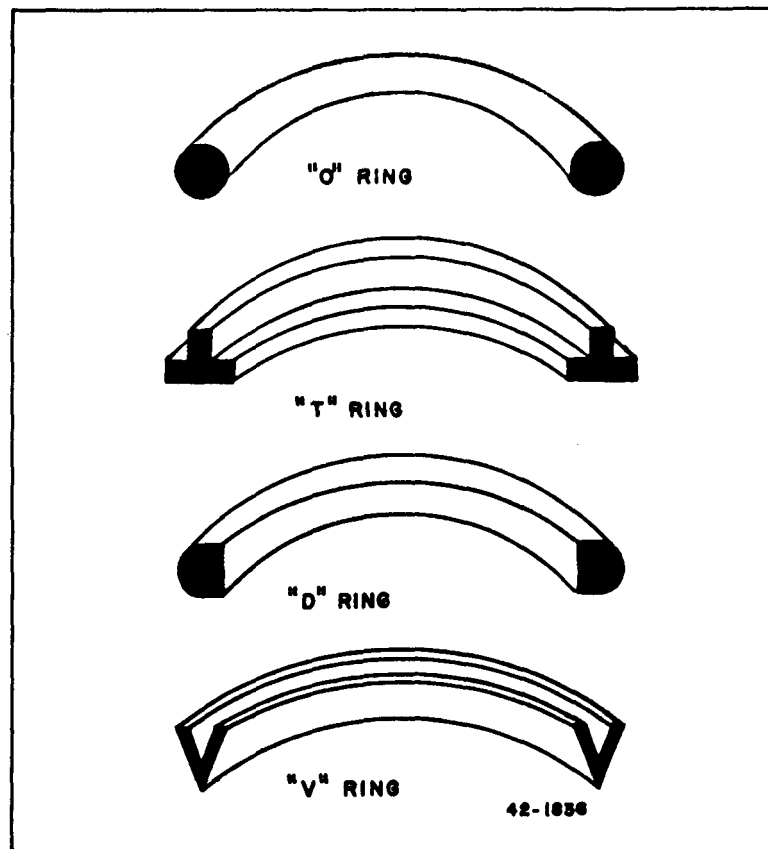
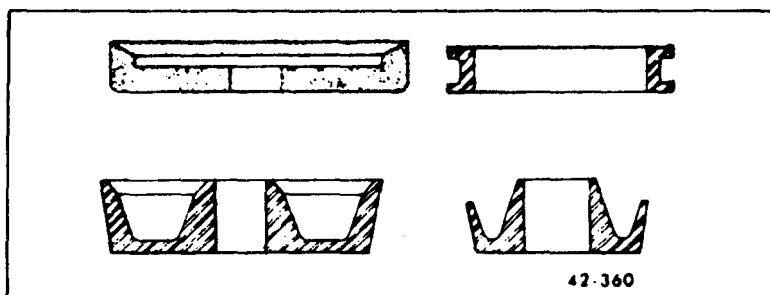


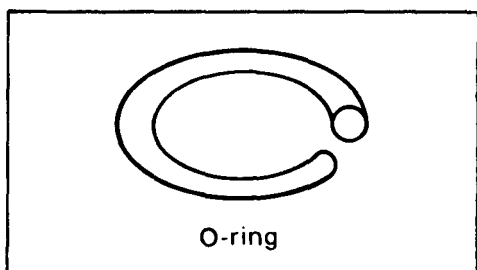
Figure 3-1. Hydraulic seals.

Most of the dynamic and static seals used on today's aircraft are manufactured in the form of O-rings and are called packings. However, conditions will arise when special nonstandard seals will have to be made for specific uses on the aircraft. (See Figure 3-2.)

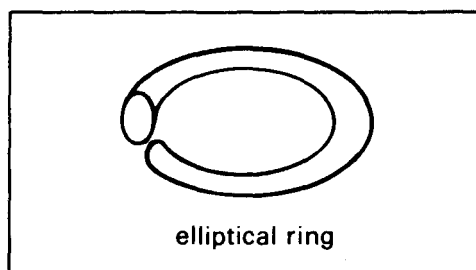


**Figure 3-2. Nonstandard seals.**

A hydraulic seal may consist of more than one component, such as an O-ring and a backup ring or possibly an O-ring and two backup rings. Hydraulic seals between nonmoving fittings are called gaskets; hydraulic seals inside a sliding or moving part are called packings. Most gaskets and packings used in Army aircraft are manufactured in the form of O-rings (Figure 3-3), but elliptical seals are used in some landing gear struts. (See Figure 3-4.)



**Figure 3-3. O-ring seals.**



**Figure 3-4. Elliptical seals.**

## COMPOSITION

Seals are composed of several different types of materials. The material depends on the use of the seal and the type of fluid it will come in contact with. The seals used in petroleum-base hydraulic fluid (MIL-H-5606) are made from synthetic rubber (nitrile). Seals in Skydrol 500 fluid systems are made from ethylene-propylene. Since our current aircraft use synthetic-base fluid MIL-H-83282 with limited amounts of petroleum-base fluid MIL-H-5606, only the seals associated with these fluids will be discussed.

Advances in aircraft design make it necessary to develop O-ring seals out of compounds that could meet the changing conditions. Hydraulic O-rings were originally established under AN (Air Force-Navy) specification numbers (6227, 6230, and 6290) for use in MIL-H-5606 fluid at operating temperatures ranging from  $-65^{\circ}$  to  $160^{\circ}$ F. When aircraft designs raised the operating temperatures, newer compounds were developed under MS

specifications with an operating range of -65° to 275°F. These newer compounds are used to manufacture the MS28775 and MS28778 O-ring seals (packings). The MS28775 O-ring replaces AN6227 and AN6230, and MS28778 replaces AN6290; however, O-ring replacement should only be accomplished by part number as specified in the technical manual. (See Figure 3-5.)

NUMBER	NAME	APPLICATION	SYSTEM	REMARKS
<b>O-RING</b>				
AN6227	Packing, O-ring	Static and dynamic	Hydraulic Pneudraulic	General use -65°F to +160°F
AN6230	Gasket, O-ring	Static only	Hydraulic Pneudraulic	General use -65°F to +160°F
MS28775	Packing, O-ring	Static and dynamic	Hydraulic (MIL-H- 5606) Pneudraulic	General use -65°F to +275°F
<b>O-RINGS FOR FLARED TUBE FITTINGS</b>				
MS28778	Packing, flared tube	Flared tube bosses	Hydraulic Pneudraulic	Replaces AN6290
<b>NONEXTRUSION RINGS</b>				
MS9058	Ring	Teflon backup for use with MS28778 O- ring gaskets in flared tube bosses	All	Replaces AN6291
MS28774	Retainer, single turn	Teflon backup for use with AN6227, AN 6230, MS28775	All	—
MS28782	Retainer, double turn	Teflon backup for use with AN6227 and MS28775	All	In process of re- placing AN6246
MS28783	Ring, double turn	Teflon backup for use with AN6230 and MS28775	All	Replaces AN6244

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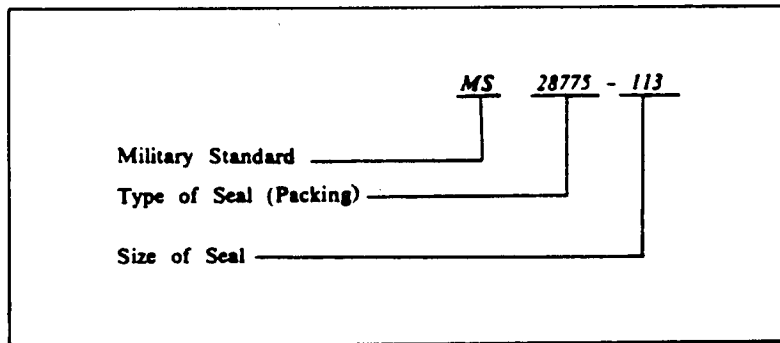
Figure 3-5. Application of O-ring seals and backup rings.

**STORAGE**

Packings and gaskets should be stored in a dark, cool, dry place; they should be kept away from excessive heat, strong air currents, dampness, and dirt. Do not expose them to electric motors or other equipment that gives off heat and ozone.

**O-RINGS**

Identification. O-rings are manufactured according to military specifications. They are identified from the technical information printed on the O-ring package. Because the size of O-rings cannot be positively identified visually without the use of special equipment, O-rings are packaged in individual sealed envelopes labeled with all the necessary data. Colored dots, dashes, and stripes, or combinations of dots and dashes on the surface of the O-ring are no longer used to identify O-rings. The part number of a standard O-ring seal is illustrated at Figure 3-6.



**Figure 3-6. Part number of standard O-ring seal.**

KZ5330-833-7491  
 PACKING PREFORMED SYNTHETIC RUBBER  
 1 EACH (MS28778-5)  
 DISC-38329  
 A-5/80  
 SR 810-B-90  
 MFD DATE 4-80; CURE DATE 2Q80  
 STILLMAN RUBBER CO.(MFGR/CONTR)  
 MIL-G-5510A

**Figure 3-7. Manufacturer's cure date.**

If the seal's part number cannot be found in the technical order, its size may help determine the part number. The size of an O-ring seal may be determined by measuring the seal's width (W), the inside diameter (ID), or the outside diameter (OD). Figure 3-7 illustrates the various dimensions that can be measured. If two are known, the third can easily be determined. For example, the outside diameter can be found if the width and inside diameter are known. Twice the width plus the inside diameter will equal the outside diameter. Once the measurements of the seal are known, cross-reference it in the supply catalogs.

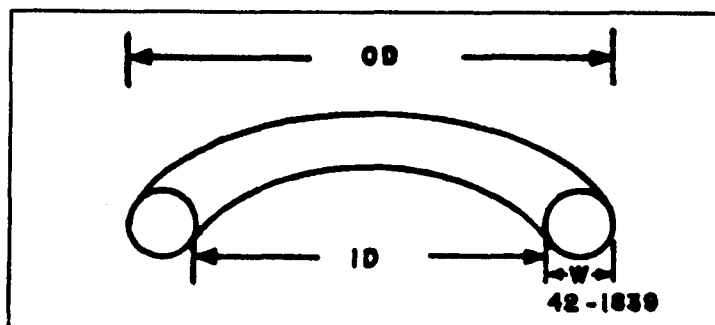


Figure 3-8. Seal dimensions.

**Replacement Schedules.** Packings, gaskets, and O-rings used in Army aircraft have indefinite shelf life. (See TM 55-1500-204-25/1 for further guidance.)

**Removal.** Some seals may be removed by squeezing the seal between the thumb and forefinger; this will force the O-ring out of the groove. Then the entire seal is removed. Seals may also be removed with a tool; however, you must carefully choose the correct tool. A variety of tools may be used on any given job, but they should be made from soft metal such as brass and aluminum. Also, tools made from phenolic rod, plastics, and wood may be used. Avoid using pointed or sharp-edged tools that might scratch or mar surfaces or damage the O-rings.

**Internal O-Rings.** Two acceptable removal methods are as follows:

1. As shown in Figure 3-9, position the hook-type removal tool under the O-ring. Then lift it to allow the extractor tool and the removal tool to pull the O-ring from its place.

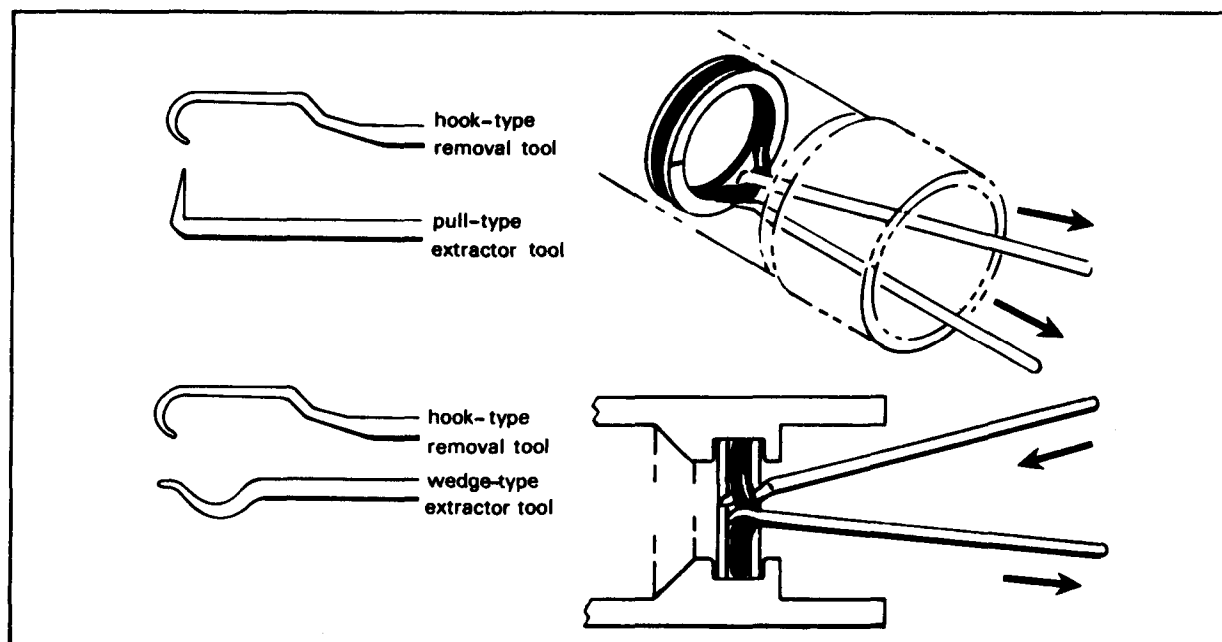


Figure 3-9. Pull method (single internal O-ring).

The pull method may be used to remove dual O-rings. (See Figure 3-10.) Position the extractor tool under both O-rings, and use the hook-type removal tool to extract both O-rings with little effort.

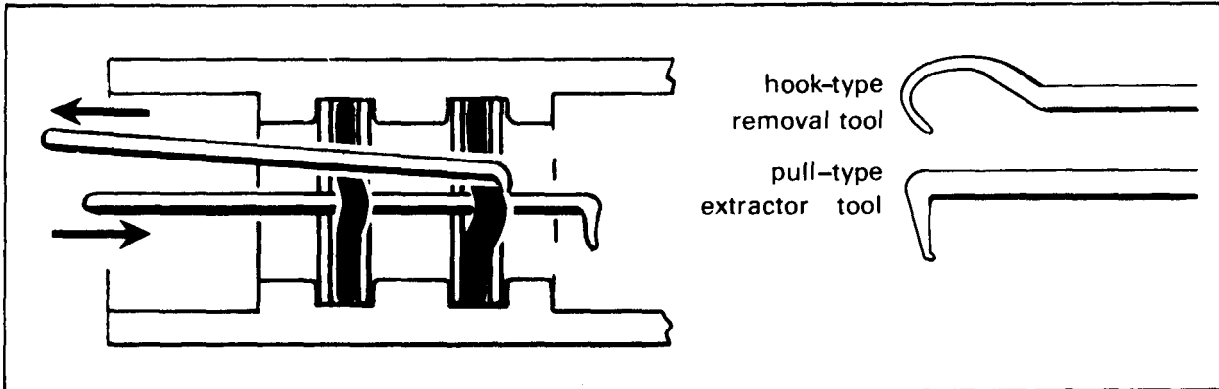


Figure 3-10. Pull method (dual internal O-rings).

2. There is a similar method to remove internal O-rings. Use the extractor tool to push, rather than pull, the O-ring from its place. (See Figure 3-11.)

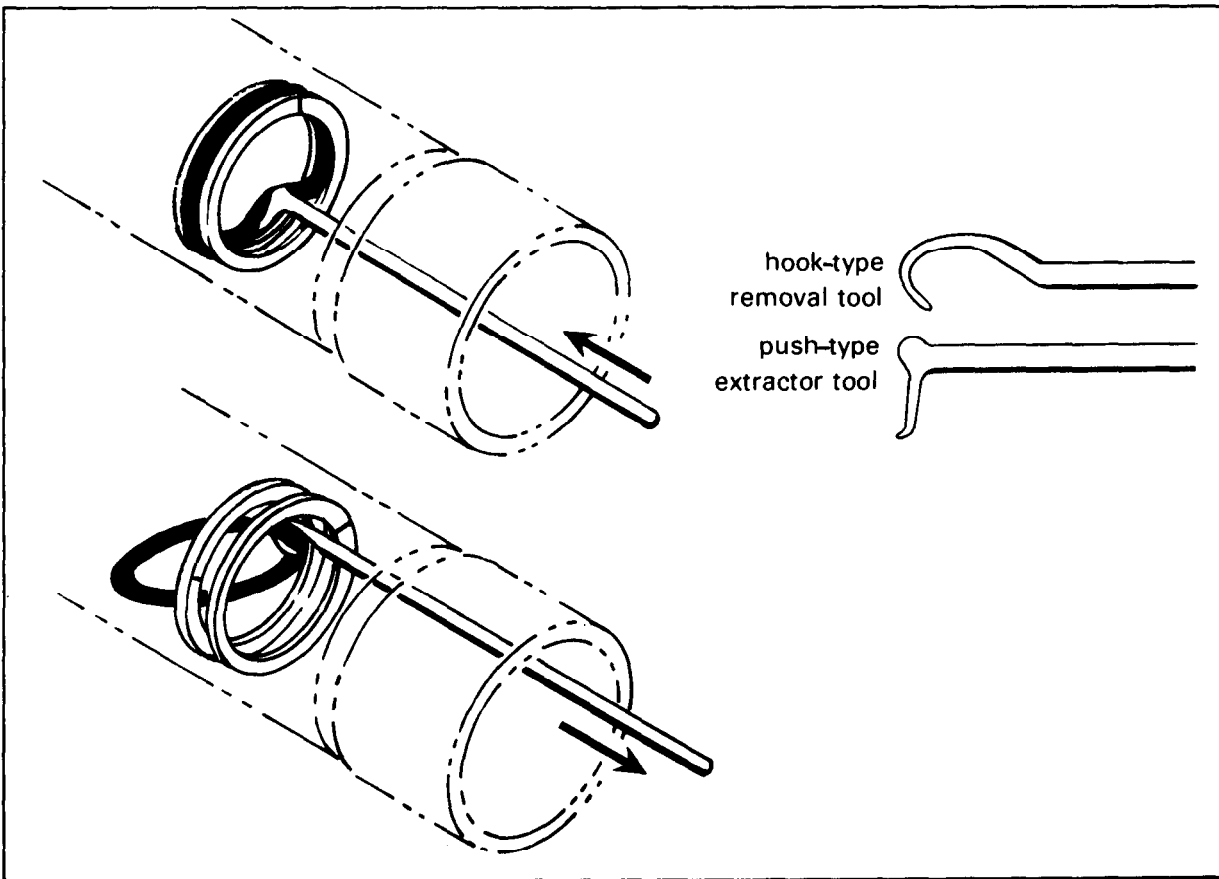
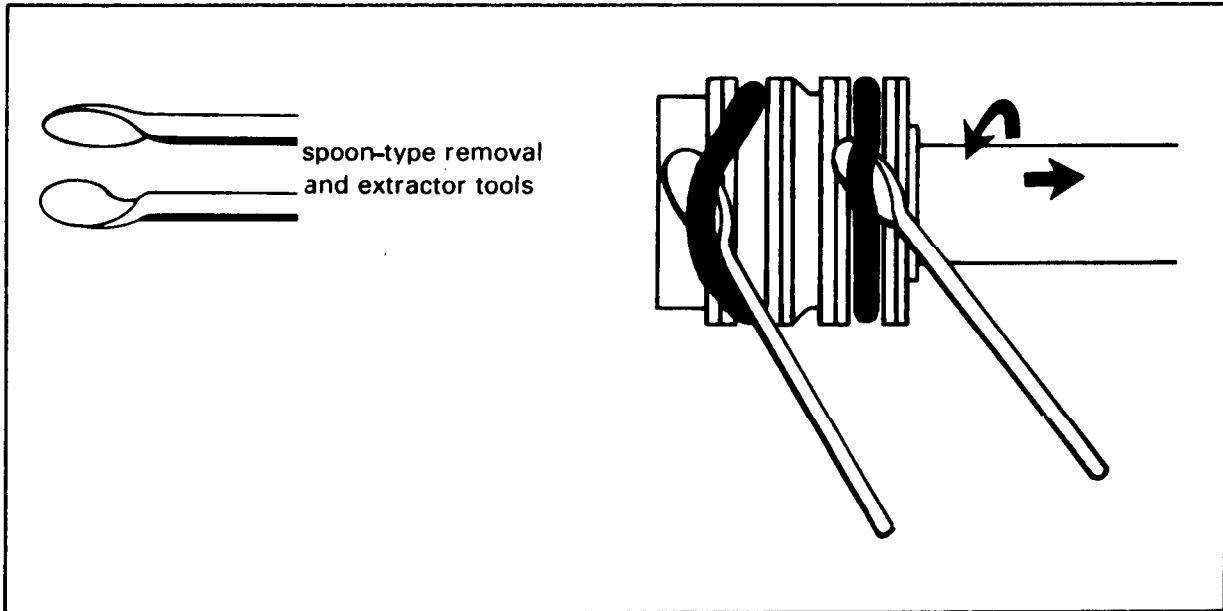


Figure 3-11. Push method (internal O-rings).

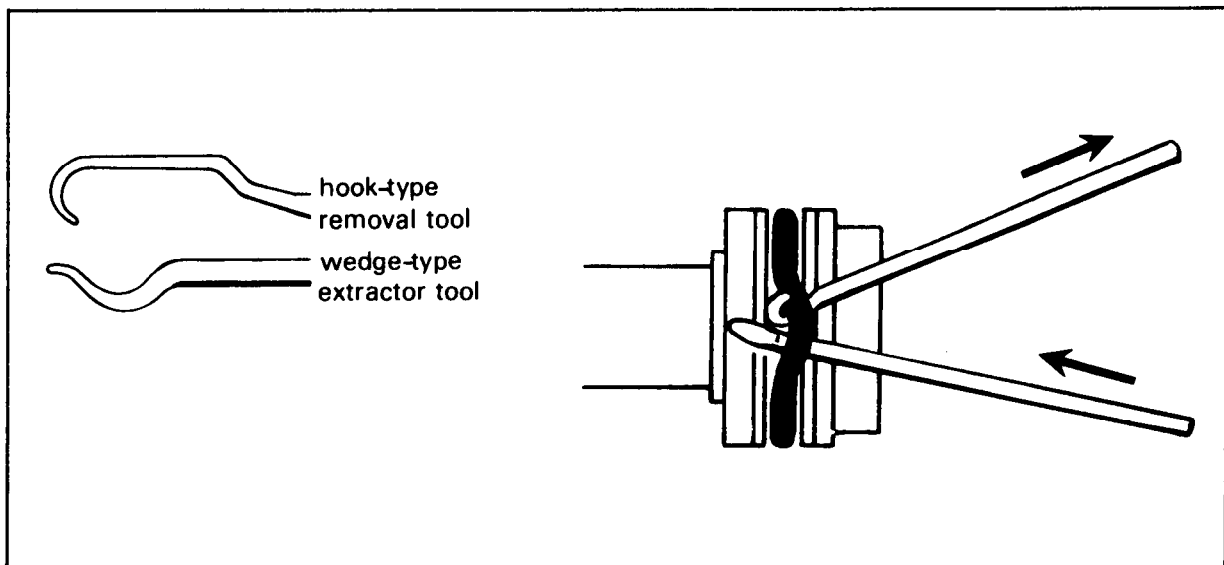


**External O-Rings.** It is easier to remove external O-rings than internal ones. Two acceptable removal methods are as follows:

1. Position a spoon-type extractor under the seal. After taking the O-ring from its cavity, hold the spoon still, and rotate and withdraw the piston. (See Figure 3-12.)



2. Insert a wedge-type extractor tool under an O-ring, and use the hook-type removal tool to hook the O-ring. Pull slightly on the hook to remove the O-ring from its cavity. (See Figure 3-13.)



**Figure 3-13. Pull method (external O-rings).**

**Inspection.** After removing all O-rings, thoroughly clean the parts that will receive new O-rings. Remove each replacement O-ring from its sealed package and inspect it for defects, such as blemishes, abrasions, cuts, or punctures. Although the outer surface of an O-ring may appear perfect at first glance, surface flaws may exist. These flaws can prevent satisfactory O-ring performance under the variable operating pressures of aircraft systems. Reject O-rings with flaws.

Also check the inner surface for small cracks, particles of foreign material, and other defects that might cause leakage or shorten the life of the ring by rolling the ring on an inspection cone or dowel. The slight stretching of the ring when it is rolled inside out will help to reveal some defects not otherwise visible. Check each O-ring further by stretching it between the fingers, but take care not to exceed the elastic limits of the rubber.

**Installation.** Before installing the O-ring, ensure that the area where it is to be installed is clean and free from all contamination. Then immerse the O-ring in clean hydraulic fluid. A hydraulic system cannot operate successfully if hydraulic seals are not handled and installed properly. These seals are comparatively soft and should not be nicked, scratched, or dented. They should be kept free of dirt and foreign matter and should not be exposed to extreme weather conditions. Hydraulic seals should not be picked up with sharp instruments, and the preservative should not be removed until they are ready for installation.

Generally the O-ring seal requires no adjustment when it is installed; however, you must observe a few precautions during installation, or early failure will result. First, check to see that the seal is the right size. The applicable technical manual will specify what special lubricant should be applied. When installing the seal, use extreme care to prevent scratching or cutting it on threads or sharp corners.

During installation, avoid rolling and twisting the O-ring to put it into place. If possible, keep the position of the O-ring's mold line constant. Use protective measures such as the O-ring entering sleeves (soft, thin-walled, metallic sleeves illustrated in Figure 3-14) when installation requires spanning or inserting the O-ring through sharp, threaded areas, ridges, slots, and edges which may damage the O-ring. If the recommended O-ring entering sleeve is not available, make paper sleeves and covers by using the seal package (gloss side out) or lint-free bond paper. (See Figure 3-15.)

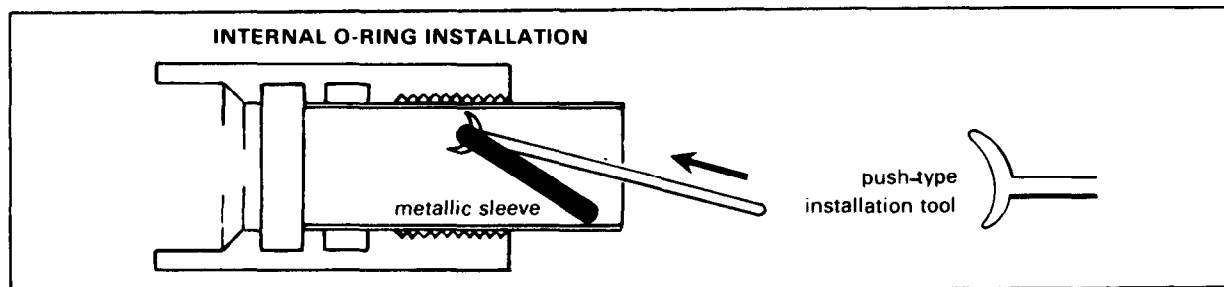
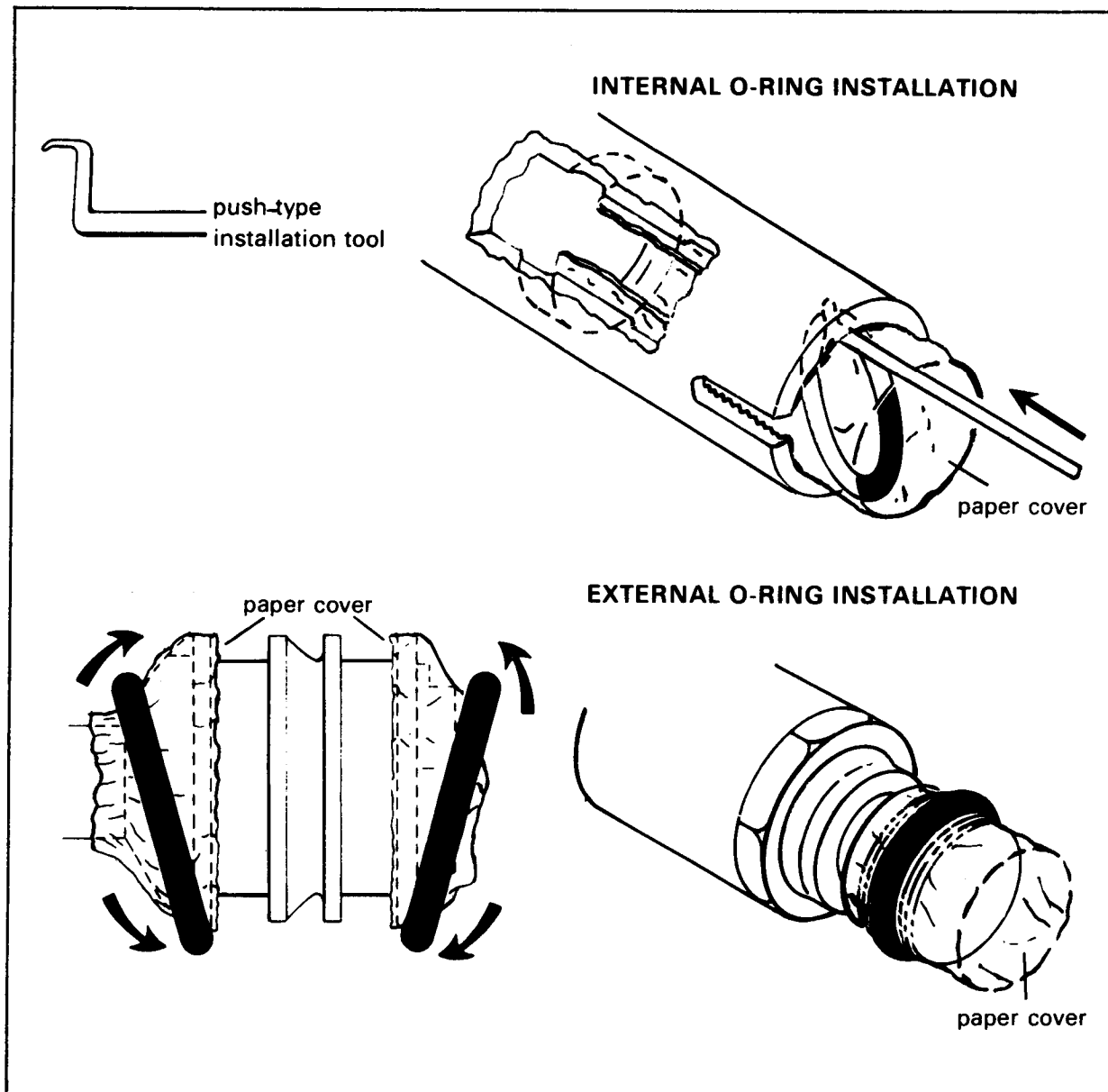


Figure 3-14. O-ring entering sleeves.



Never use adhesive tapes to cover danger areas on components. Gummy substances left by the adhesives are extremely detrimental to hydraulic systems. After the O-ring is placed in the provided cavity, gently roll the O-ring with the fingers to remove any twist that might have occurred during installation. Twists in the O-ring will prevent it from functioning properly.

**Storage.** Proper storage practices must be observed to protect O-rings. Most synthetic rubbers are not damaged by several years of storage under ideal conditions; however, their enemies are heat, light, moisture, oil, grease, fuels, solvents, thinners, strong drafts, or ozone (form of oxygen formed from an electrical charge). Damage by exposure is magnified when

rubber is under tension, compression, or stress. When storing O-rings, avoid the following conditions:

- Stacking parts improperly and storing them in improper containers, which can cause defects in shape.
- Applying force to the O-ring corners and edges and squeezing rings between boxes and storage containers, which can cause creases.
- Storing rings under heavy parts, which can cause compression and flattening.
- Using staples to attach identification, which can cause punctures.
- Hanging U-rings from nails or pegs which can cause the rings to become dirty and develop defective shapes (O-rings should be kept in their original envelopes).
- Allowing rings to become oily or dirty because of fluids leaking from parts stored above and adjacent to O-ring surfaces.
- Applying adhesive tape directly to O-ring surfaces (a torn O-ring package should be secured with pressure-sensitive, moisture-proof tape, but the tape must not contact the O-ring surface).
- Keeping overage parts because of improper storage arrangements or unreadable identification (O-rings should be arranged so that older seals are used first).

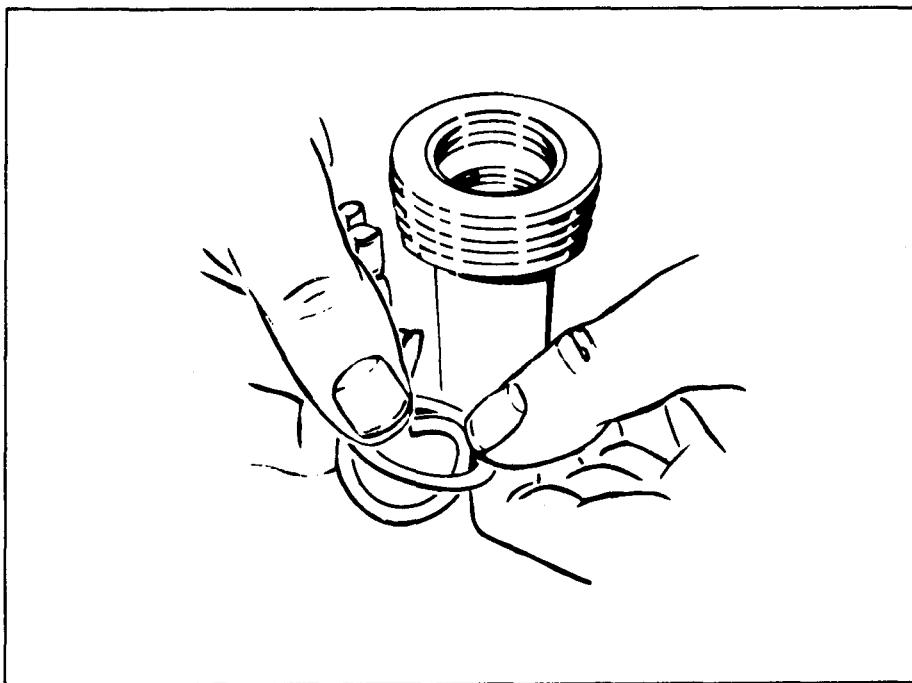
## BACKUP RINGS

Types. Backup rings support O-rings and prevent them from wearing and causing leakage. The two types of backup rings are the teflon type and the leather type. Teflon backup rings are generally used with packings and gaskets; however, leather backup rings may be used with gasket-type seals in systems operating up to 1,500 psi. Teflon rings are made from a fluorocarbon-resin material which is tough, friction-resistant, and more durable than leather. Teflon backup rings do not deteriorate with age, can tolerate temperatures greater than those encountered in high-pressure hydraulic systems, and are unaffected by any other system fluid or vapor.

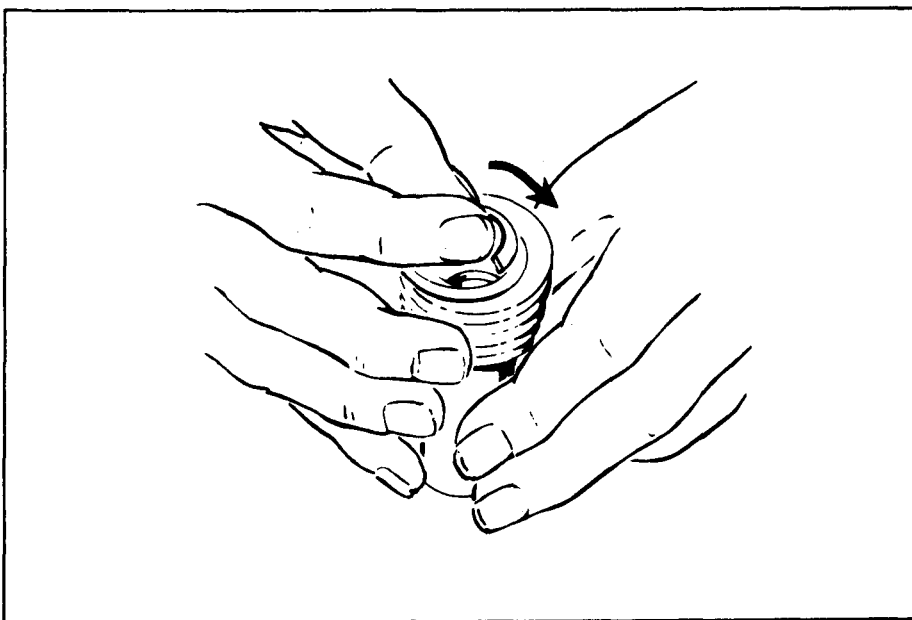
Identification. Backup rings are not color-coded or marked and must be identified from package labels. The dash number which follows the specification number on the package shows the size and, in some cases, relates directly to the dash number of the O-ring for which the backup ring is dimensionally suited. For example, the single spiral teflon ring MS28774-6 is used with the MS28775-006 O-ring, and the double spiral teflon ring MS28782-1 is used with the AN6227B-1 O-ring.

Installation. Care must be taken when handling and installing backup rings. They should be put on by hand without using sharp tools.

**Teflon Backup Rings.** Teflon backup rings must be inspected before reuse and must be discarded if they have compression damage, scratches, cuts, nicks, or fraying conditions. Before installing a teflon spiral ring in an internal groove, stretch it slightly. (See Figure 3-16.) While the teflon ring is being put in the groove, turn the component in a clockwise direction. (See Figure 3-17.) This will expand the ring diameter and reduce the possibility of damaging the ring.

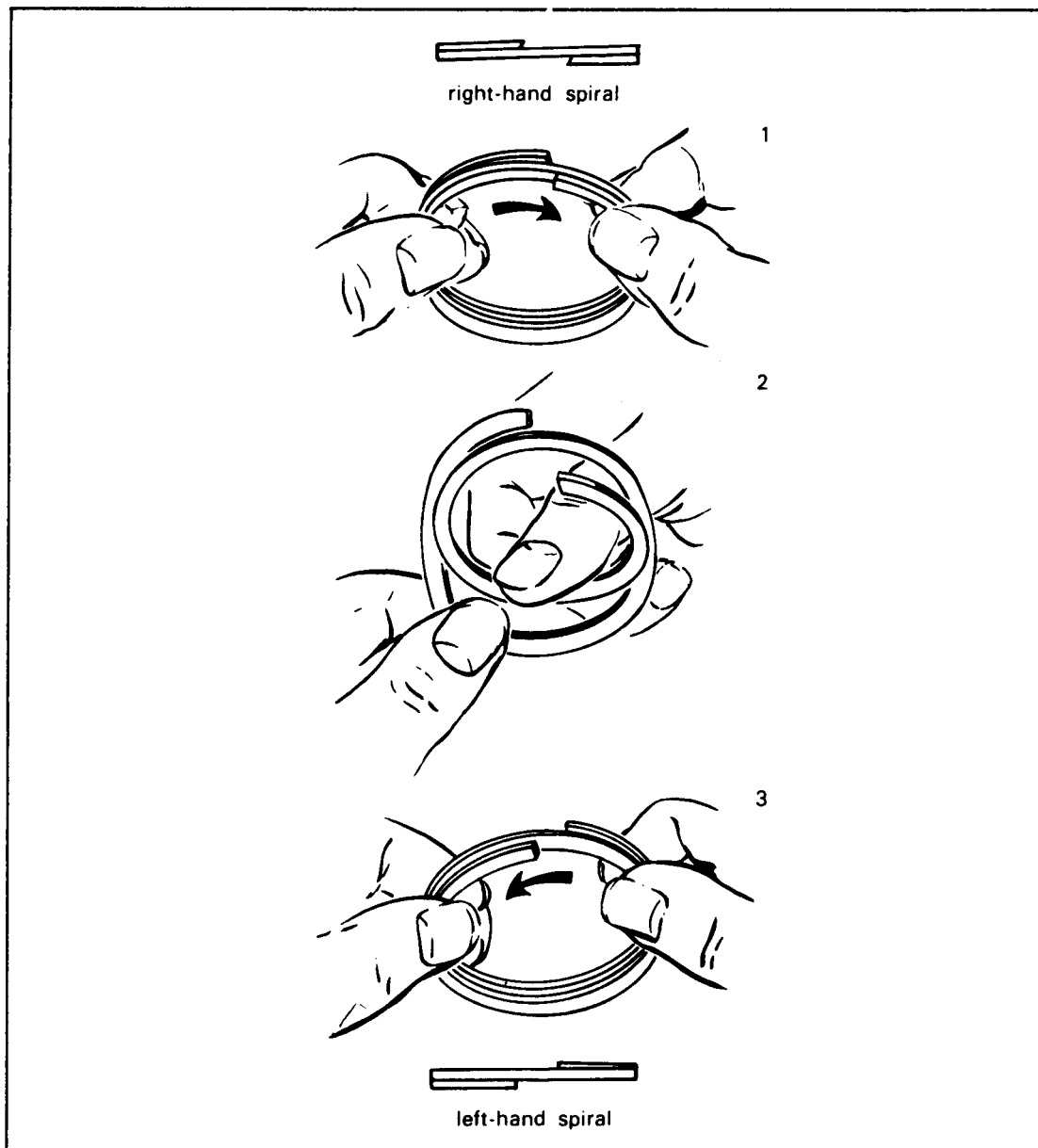


**Figure 3-16. Teflon spiral ring being stretched.**



**Figure 3-17. Component being turned in a clockwise direction.**

Before installing a teflon spiral ring in an external groove, change the ring's right-hand spiral to a left-hand one. (See Figure 3-18.) As the ring is put into the groove, turn the component in a clockwise direction. This will contract the ring diameter and reduce the possibility of damaging the ring.



**Figure 3-18. Ring's right-hand spiral changed to a left-hand spiral.**

Backup rings may be installed individually if pressure acts on only one side of the seal. (See Figure 3-19.) In this case, install the backup ring next to the O-ring and opposite the pressure force. Figure 3-20 illustrates the correct way to install single and dual backup rings. When dual backup rings are installed, the split scarfed ends must be staggered, as shown in Figure 3-21.

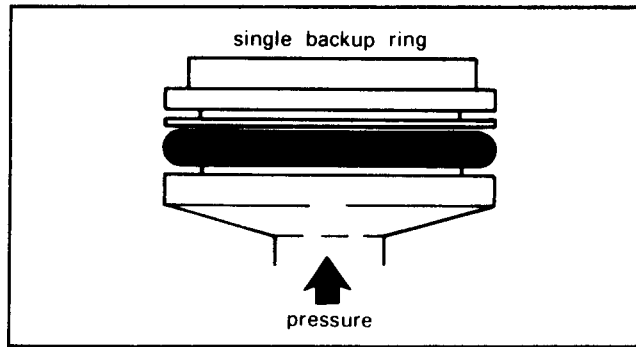


Figure 3-19. Single backup ring.

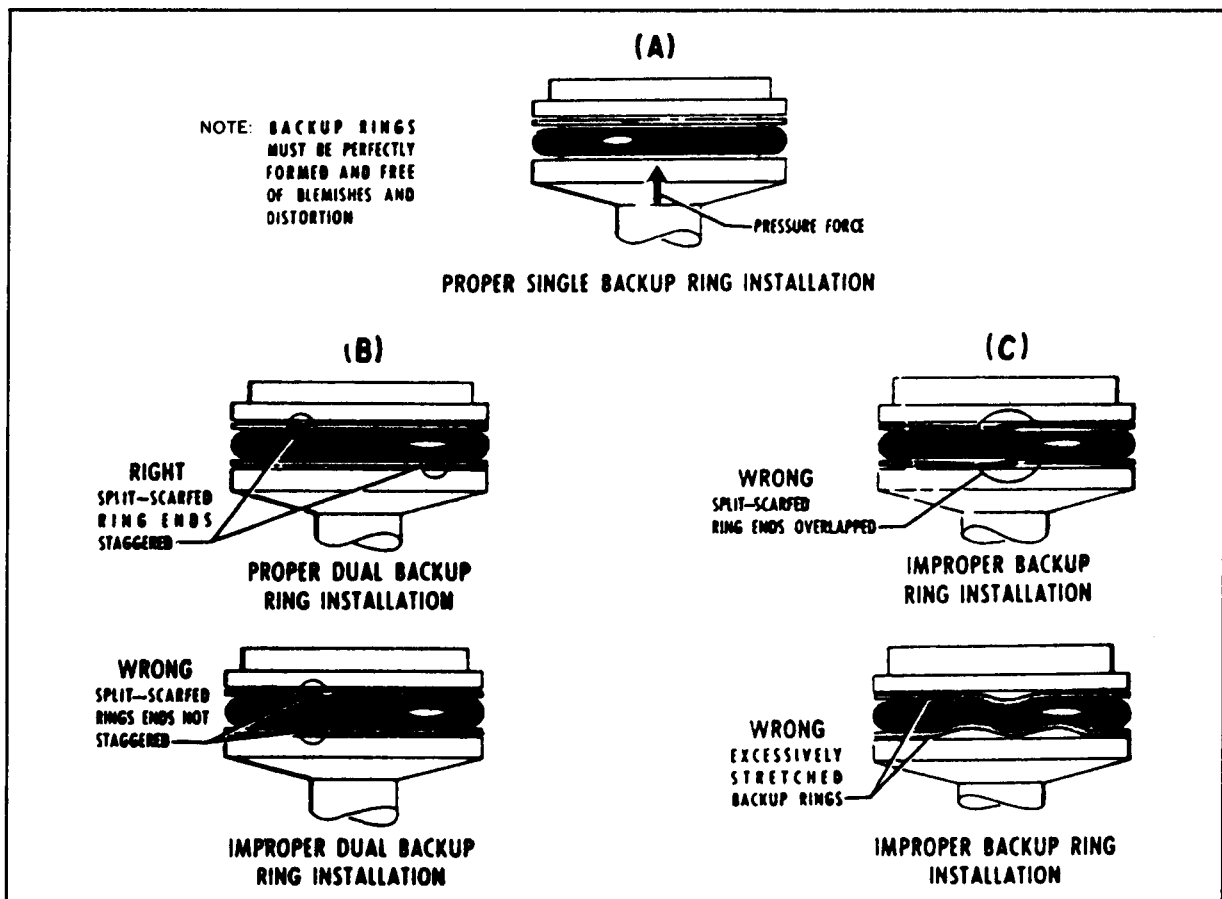


Figure 3-20. Single and dual backup ring installation.

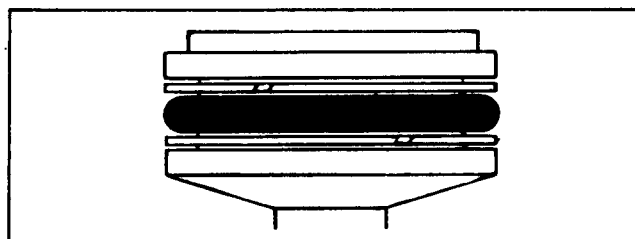
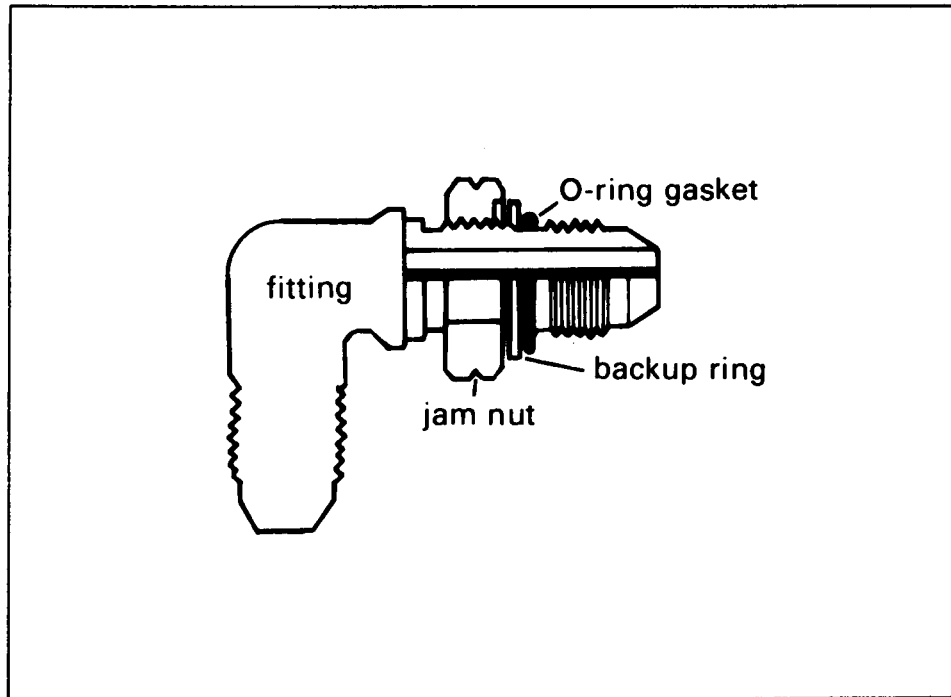


Figure 3-21. Dual (double) backup ring.

**Leather Backup Rings.** Leather backup rings must be inspected for defects before reuse. Defective rings must be discarded. Figure 3-22 shows a leather backup ring properly-installed.

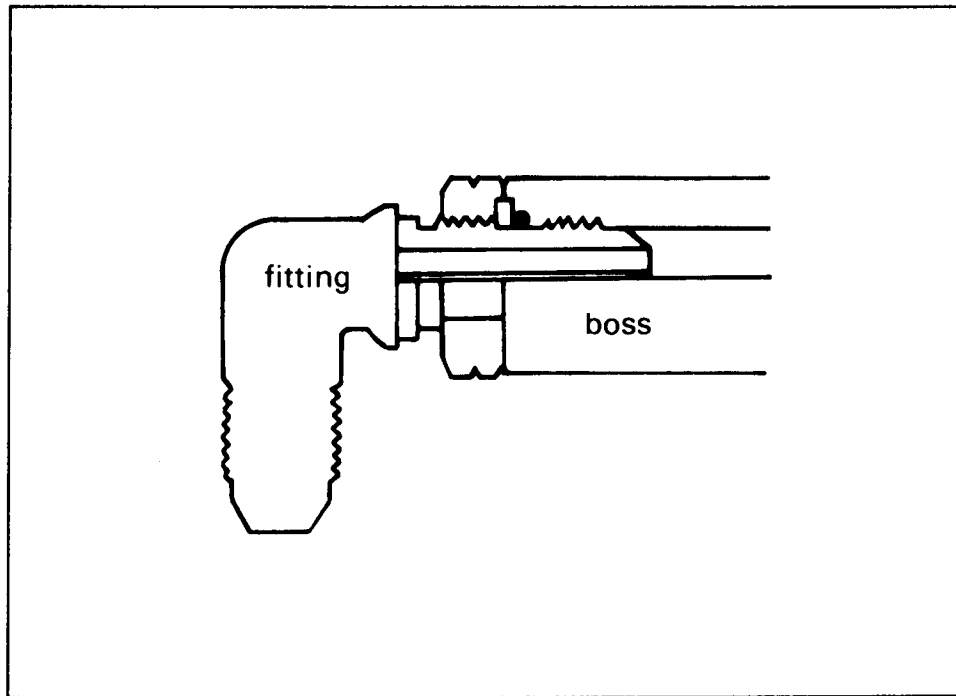


**Figure 3-22. Leather backup ring installed.**

To install a leather backup ring--

- Soak the new backup ring in clean hydraulic fluid until it is flexible enough for good installation.
- Soak the new gasket in the same type of hydraulic fluid used in the hydraulic system.
- Examine the fitting groove for roughness that might damage the seal.
- Position the jam nut above the fitting groove, and coat the male threads of the fitting sparingly with hydraulic fluid.
- Place the backup ring in the fitting groove with the smooth side away from the jam nut; then work it into the counterbore of the jam nut.
- Install the gasket in the fitting groove against the backup ring.
- Turn the jam nut down until the packing is pushed firmly against the threaded portion of the fitting.
- Install the fitting into the boss; turn it until the packing has contacted the boss (the jam nut must turn with the fitting). (See Figure 3-23.)





**Figure 3-23. Fitting installed.**

- While holding the jam nut to prevent it from turning, turn the fitting one and one-half additional turns.
- Position the fitting by turning it not more than one turn.
- Hold the fitting in the desired position, and turn the nut down tight against the boss.

**Storage.** Precautions similar to those for O-rings must be taken to prevent contamination of backup rings and damage to hydraulic components.

Teflon backup rings may be stocked in individual sealed packages like the O-rings, or several may be stored on a cardboard mandrel. If unpackaged rings are stored for a long time without using mandrels, an overlap may develop. To prevent this condition, stack teflon rings on a mandrel of a diameter comparable to the desired diameter of the spiral ring. Stack and clamp the rings with their coils flat and parallel.

Do not store leather backup rings on mandrels as this can possibly stretch and distort the original shape of the leather ring. Leather rings should be stored in sealed individual packets.

## SHAFT SEALS

Most shaft seals on pumps have two flat surfaces that rotate against each other. One flat surface is made from a soft material such as bronze or carbon and is called the sealing ring. The other flat surface is made

from stainless steel and is called the mating ring. (See Figure 3-24.) The mating ring rotates with the drive shaft. Although all makes of shaft seals differ in design, they perform the same function; they seal a moving part--the shaft. The shaft seal must limit the leakage of fluid trying to escape, but not stop it altogether. This is because the shaft seal acts like a bearing and must be lubricated like one. The lubricant comes from the slight leakage of fluid past the two mating surfaces. In Figure 3-24, notice that the sealing ring can move back and forth on the drive shaft. The O-ring seal will prevent leakage around the seal, while the spring forces the mating ring against the sealing ring. The spring compensates for the wear of the sealing ring by forcing the mating ring against the sealing ring. It also ensures a positive seal when the shaft is not rotating. Never scratch or damage the two mating surfaces because this will cause them to leak.

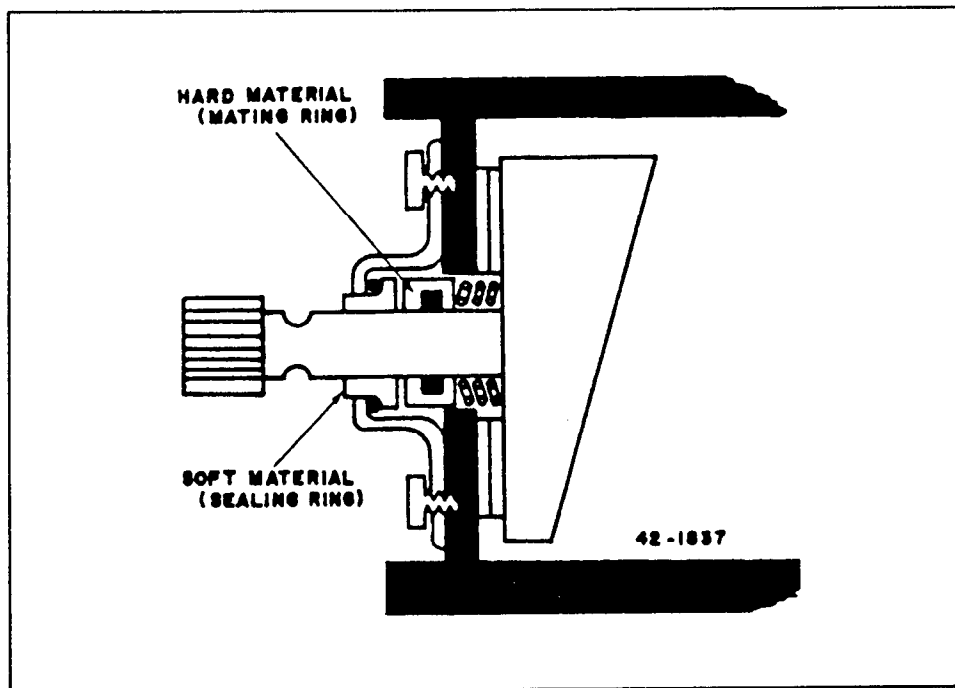


Figure 3-24. Pump shaft seal.

## QUICK-DISCONNECT COUPLINGS

Quick-disconnect couplings of the self-sealing type are used at various points in all hydraulic systems. These couplings are installed at locations where frequent uncoupling of lines is required for inspection and maintenance. Each coupling assembly consists of two halves held together by a union nut. Each half contains a valve which is held open when the coupling is connected; this allows fluid to flow in either direction through the coupling. When the coupling is disconnected, a spring in each half closes the valve. This prevents loss of fluid and entrance of air. The union nut has a quick-lead thread which allows the coupling to be connected or disconnected by turning the nut. Various types of union nuts are used in hydraulic systems. For one type, a quarter turn of the union

nut locks or unlocks the coupling. For another type, a full turn is required. Some couplings require wrench tightening; others are connected and disconnected by hand. Some installations require that the coupling be secured with safety wire; others do not require any form of safetying. Because of these differences, all quick-disconnect couplings must be installed according to the instructions in the applicable maintenance manual.

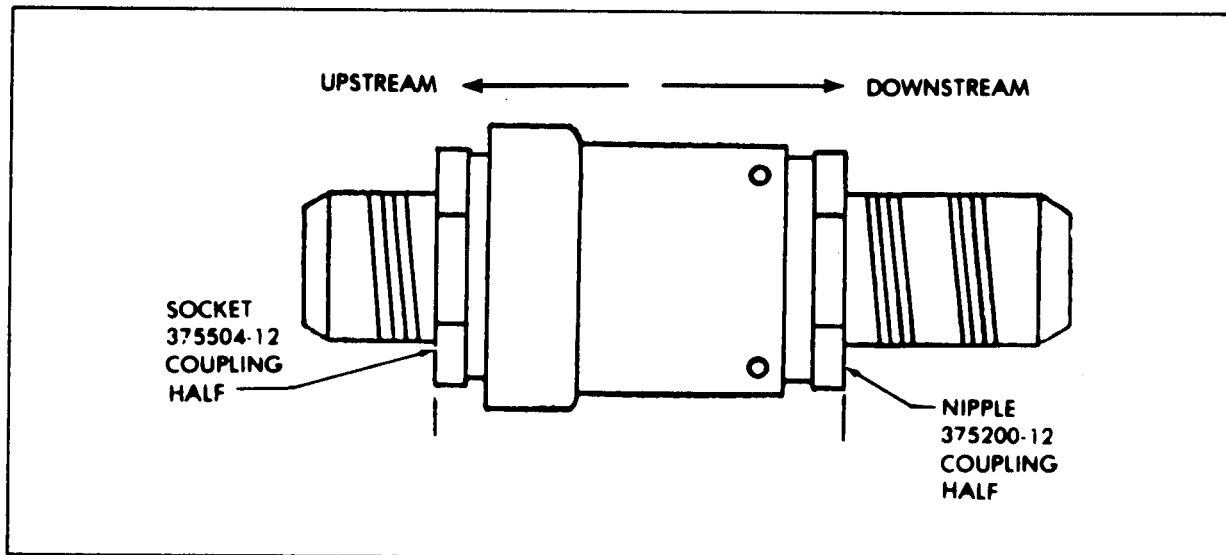


Figure 3-25. Typical quick-disconnect coupling.

## CHAPTER 4

# SYSTEM RESERVOIRS

### PURPOSE

The system reservoir holds enough fluid to keep the hydraulic system operating properly. It also replaces fluid lost through minor leakage or evaporation. Reservoirs--

- Provide space for fluid volume that increases over the initial amount; for example, an increase might occur through thermal expansion or foaming.
- Provide an escape for air trapped in the system.
- Help cool the system fluid.

### TYPES

The two types of reservoirs used in aircraft hydraulic systems are the in-line type and the integral type. The in-line reservoir has its own housing, is complete within itself, and is connected with other components in the system by tubing or hose. The integral type consists of a space that is set aside within some major component to hold a supply of operational fluid; it has no housing of its own. The in-line reservoir is the type commonly used in Army aircraft.

A space is provided in the in-line reservoir above the normal fluid level for fluid expansion. This space also enables trapped air to escape. Reservoirs are never intentionally filled to the top with fluid. In fact, most reservoirs are designed so that they cannot be overfilled during servicing. This is done by locating the rim of the filler neck below the top of the reservoir. Most reservoirs have a dipstick or glass-sight gage that enables the fluid level to be easily and accurately checked. All reservoirs are either vented (open to the atmosphere) or pressurized (closed to the atmosphere).

Vented Reservoirs. In vented reservoirs, atmospheric pressure and gravity are the forces which cause fluid to flow out of the reservoir and into the pump. To supply a pump with fluid, a vented reservoir must be positioned at a higher location than the pump. If the reservoir and the pump were at the same level, gravity would have no effect on fluid flow. If the reservoir was at a level below the pump, fluid would tend to run out of the pump and into the reservoir. Most hydraulic system reservoirs of current Army aircraft are vented.

**Pressurized Reservoirs.** In hydraulic systems of some aircraft, it is necessary to mount the reservoir at a level below the pump. This location deters the weight of the fluid rather than aids the flow of fluid into the pump. A pressurized reservoir must have its fluid under greater than atmospheric pressure to force it upward into the pump. A pressurized reservoir also enables aircraft to fly at very high altitudes. Since atmospheric pressure decreases as altitude increases and at very high altitudes becomes too low to force enough fluid into a pump, the reservoir has to be pressurized. The two general methods used to pressurize reservoirs are the fluid method and the air method.

**Fluid Method.** This method uses the fluid pressure bled from the pressure lines of the system in which the reservoir is incorporated. The reservoir is designed to develop a relatively low pressure on the supply fluid contained in the reservoir by using a stream of fluid fed into the reservoir at a much higher pressure. This reservoir is commonly called an airless reservoir. Figure 4-1 illustrates the construction and operation of a typical reservoir pressurized in this manner. The major parts of the assembly are a cylindrical housing that has three fluid ports and a polished bore, a housing tube which terminates in a head, a piston, and a piston-tube assembly. The piston and piston-tube assembly are free to slide in and out of the housing. The housing tube and head are stationary. In operation, fluid pressure admitted to the housing tube at system operating pressure--for example, at 3,000 psi--enters the space formed between the piston and the housing-tube head. This pressure tends to force the piston and housing-tube head in opposite directions. However, since the housing-tube head cannot move and the piston can, the piston moves toward the right, pushing against the supply fluid on its right, which develops pressure in the fluid. The surface of the housing tube is exposed to 3,000-psi pressure within a space that is one-sixtieth as large in area as the piston surface that contacts the supply fluid. This means that a pressure of 50 psi (3,000 psi divided by 60) is built up in the supply fluid. (See Figure 4-2.)

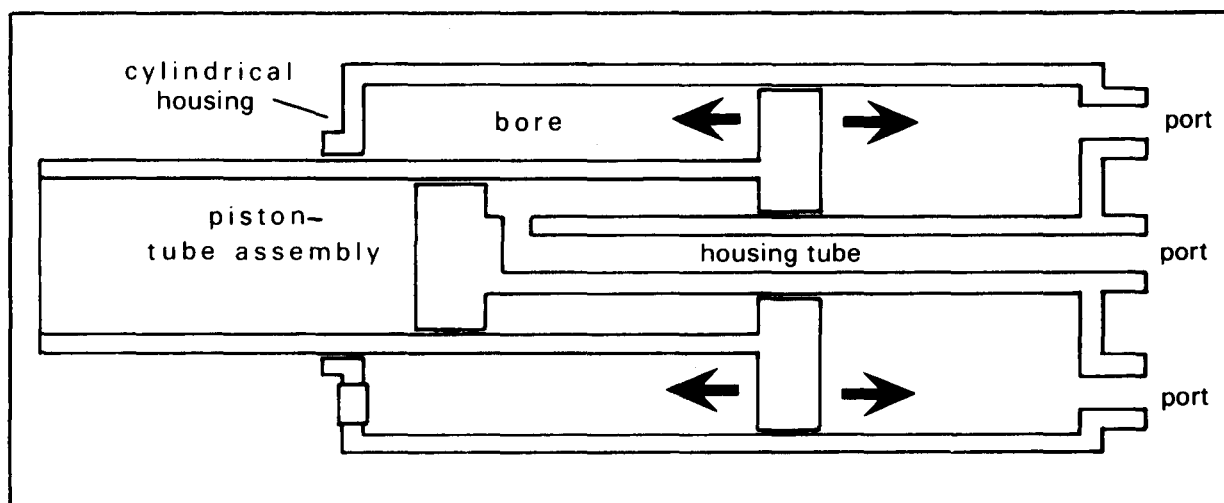
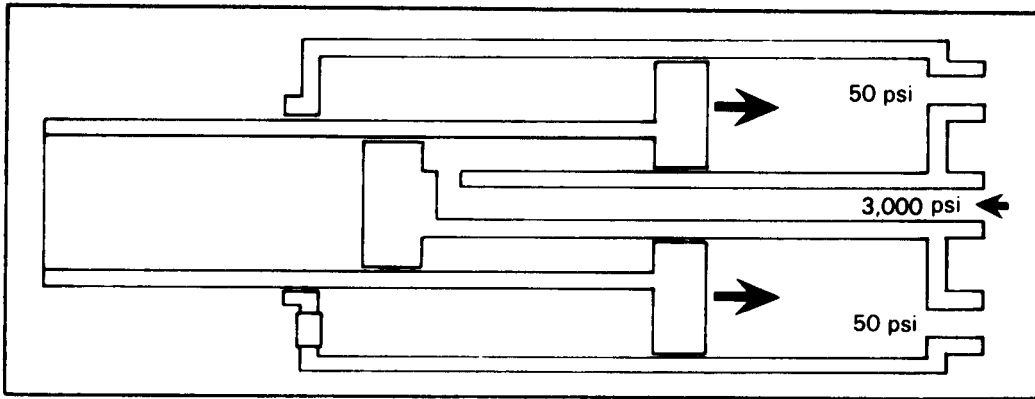


Figure 4-1. Schematic of a fluid-pressurized reservoir.

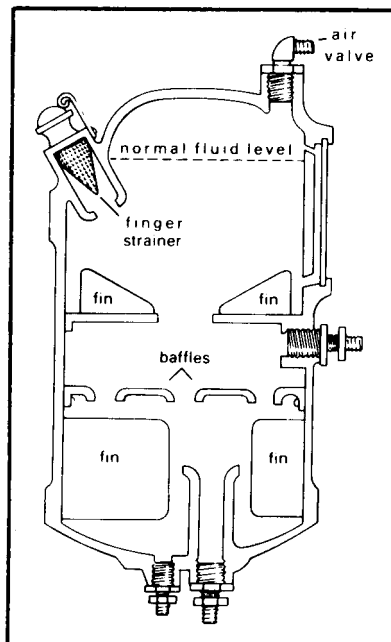


**Figure 4-2. Hydraulic reservoir pressurized with fluid.**

**Air Method.** This method forces air into the reservoir above the level of the fluid. The amount of pressure kept in an air-pressurized reservoir is usually around 15 psi. No attempt is made to keep the air and fluid separated. In most cases, the initial source of air-pressure is the compressor section of the aircraft engine. Since pressure within the engine compressor is normally about 100 psi, it has to be reduced before being delivered to the reservoir. This is done by passing air through an air-pressure regulator.

## COMPONENTS

**Baffles and Fins.** Baffles and fins (Figure 4-3) are used in most reservoirs to prevent the fluid within the reservoir from swirling and surging. These conditions could cause fluid to foam and air to enter the pump along with the fluid.



**Figure 4-3. Reservoir with baffles and fins.**

**Finger Strainers.** Many reservoirs have strainers in the filler neck to keep foreign matter from entering the reservoir when the filler cap is off. These strainers are made of fine gauze and are called finger strainers because of their shape. Finger strainers should never be removed or punctured to speed the pouring of fluid into the reservoir.

**Filter Elements.** Filter elements filter the air before it enters the reservoir or the fluid before it leaves the reservoir. An air-vent filter element is located in the upper part of the reservoir above the fluid level. A fluid filter element is located at or near the bottom of the reservoir. Fluid returning to the reservoir surrounds the filter element and flows through the wall of the element. This leaves any fluid contaminant on the outside of the element. The fluid filter elements commonly used in aircraft reservoirs are made of treated cellulose formed into accordion-like pleats. This construction exposes the fluid to the maximum amount of filter surface within a given space. Reservoirs having filter elements have a bypass valve to ensure that the pump will not be without fluid even if the filter element becomes clogged. This valve is normally held closed by a spring; it would be opened by the stronger partial vacuum if the element became badly clogged. Figure 4-4 shows a reservoir with all the filter elements.

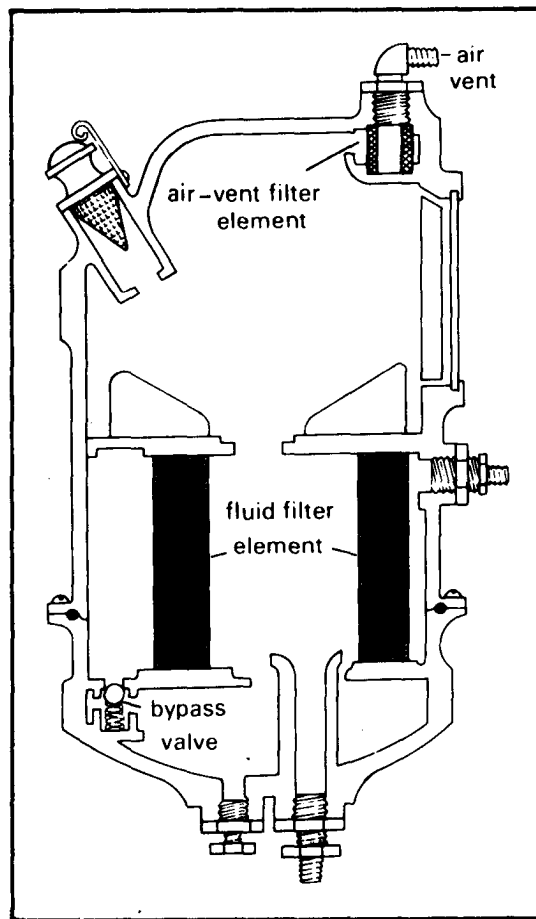


Figure 4-4. Reservoir with filter elements.

## EMERGENCY SOURCES

**Standpipes.** Some aircraft have emergency hydraulic systems that take over if the main system fails. In many cases, the pumps of both systems obtain fluid from a single reservoir. Under such circumstances, fluid for the emergency pump is drawn from the bottom of the reservoir; the main system draws its fluid through a standpipe located at a higher level. This arrangement ensures the operation of the emergency system if the main system fails.

**Air Cylinders.** Air cylinders are the pneumatic reservoirs in an aircraft's pneumatic system which serve as an emergency source of pressure for the hydraulic system. These cylinders are made of steel and may have a cylindrical or spherical shape. A spherical air cylinder is illustrated in Figure 4-5. Cooling of the high-pressure air in the storage cylinders will cause some condensation to collect in them. Storage cylinders must be cleared of moisture periodically to ensure a positive operation of systems. This is done by slightly cracking the moisture-drain fitting located on the cylinder manifold.

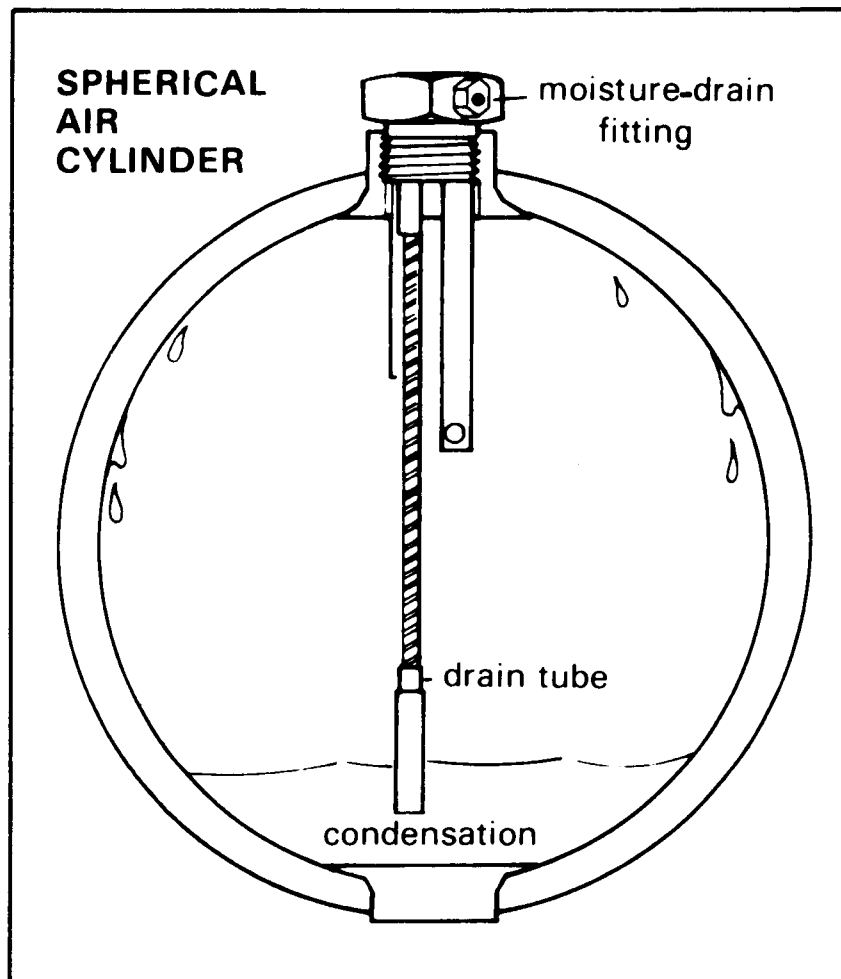


Figure 4-5. Spherical air cylinder.



## CHAPTER 5

# SYSTEM FILTERS

### FLUID FILTERS

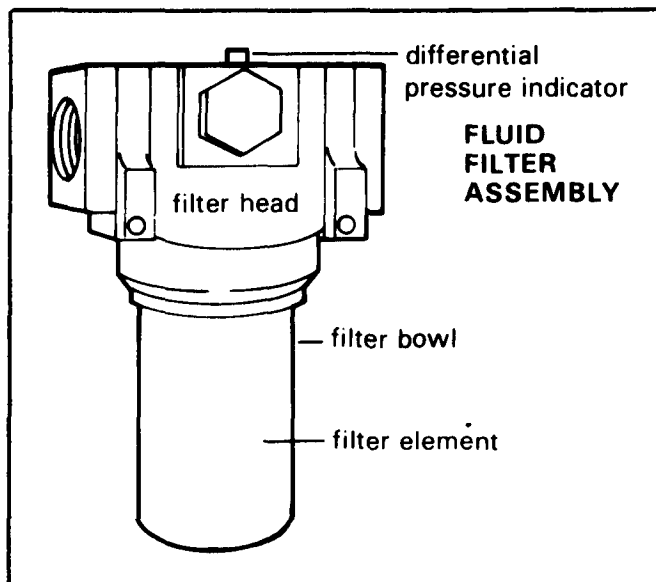
Purpose. Filters can remove practically all foreign particles found in hydraulic fluid. The degree of filtration needed depends on the acceptance level desired. Most high-pressure hydraulic systems use filters that have a 10- to 15-micron capability, but many later-model aircraft have 5-micron filters. Two-stage filters, one element of which has a 3-micron capability, are found in some recent models. When you consider that 1 micron equals one-millionth of a meter, you can appreciate the tremendous capability of these filters. They are, however, intended primarily to safeguard the operation of certain important units by filtering out foreign particles generated by the wear and tear of parts in the system. They cannot handle large quantities of foreign matter from outside the system.

Location. Fluid filters may be located in the pressure line, in the return line, or in any other location where they are needed to safeguard the system against foreign particles in the fluid. However, filters are not normally used in system supply lines. There are many models of filters, the variation being necessitated by the location of the filter within the particular aircraft.

Construction. The filtering elements in fluid filters are normally made of paper or stainless steel. Paper elements are used mostly in low-pressure systems and are thrown away when removed. Stainless steel elements are used in both high-pressure and low-pressure systems and may be reused. The size and shape of each element depend on its use and installation; however, all fluid filter assemblies are made up of three basic units: filter head, filter bowl, and filter element.

Figure 5-1 illustrates a typical fluid filter assembly where the differential pressure indicator is located in the top of the filter head assembly. (In some designs, the indicator is located on the side of the filter head assembly.) Also located within the head is a bypass valve assembly which routes hydraulic fluid directly from the inlet to the outlet

port if the filter element becomes clogged with foreign matter. The filter bowl is the housing that holds the element to the head assembly and is the part that is removed when the filter element is replaced.



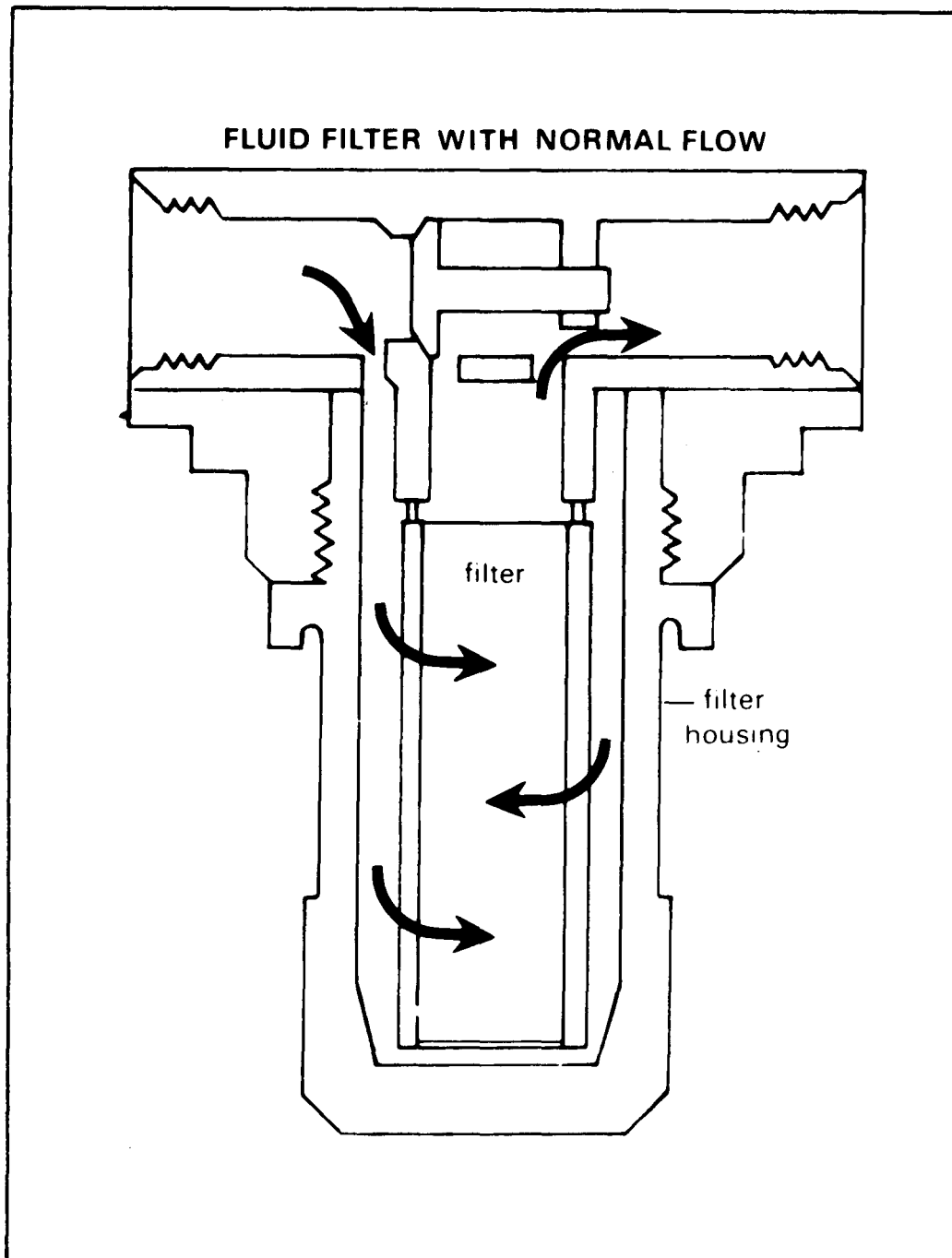
**Figure 5-1. Fluid filter assembly.**

**Types.** The three types of fluid filters used in hydraulic systems are filters with paper elements, filters with stainless steel elements, and two-stage filters.

**Fluid Filters With Paper Elements.** A typical fluid filter with a paper element removes 99 percent of all particles that are 10 microns (0.000394 inch) in diameter and larger. For example, if 100 particles measuring 0.000394 inch in cross section were dropped into pure hydraulic fluid, a 10-micron filter would intercept 99 percent of these particles in one pass. A 40-micron particle is considered the smallest that can be seen without magnification.

The filter has an external thread machined on the outside and top of the filter bowl which fits in the underside of the body assembly. A groove machined around the base of the threads provides for the packing between the filter bowl and the body assembly.

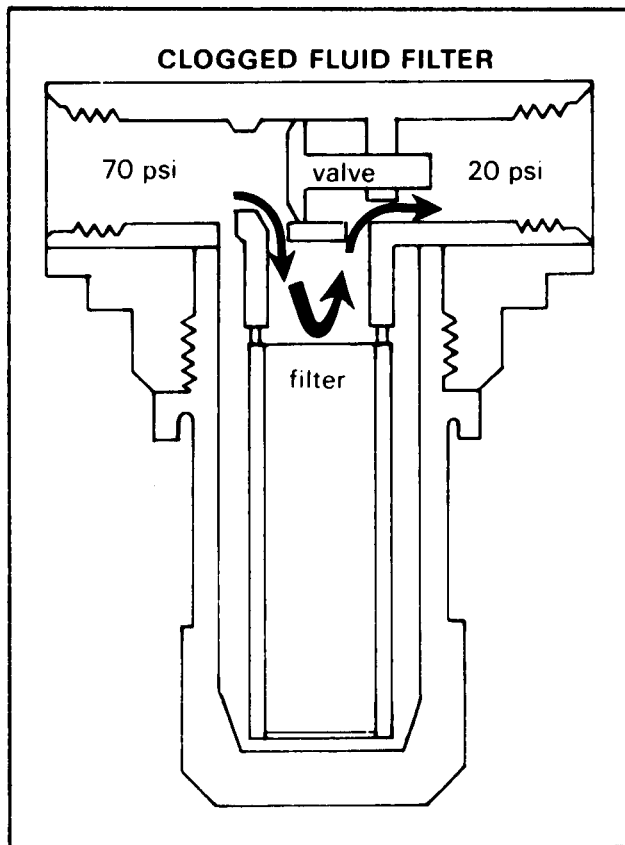
Hydraulic fluid enters the filter through the inlet port in the body assembly and flows around the element inside the filter bowl. The filter element, like those used in the reservoir, is made of specially treated cellulose paper formed in accordion-like pleats to present the maximum filtering surface to the fluid. Filtering takes place as the fluid passes through the filtering element at the hollow core, leaving the dirt and impurities on the outside of the filter element. Filtered fluid then flows from the hollow core to the outlet port in the body and into the system. Figure 5-2 illustrates a fluid filter with a normal flow of fluid.



**Figure 5-2. Fluid filter with normal flow.**

The bypass pressure-relief valve in the body allows the fluid to bypass the filter element and pass directly through the outlet port in case the filter element becomes clogged. In most filters of this type, the relief

valve is set to open if the pressure drop exceeds 50 psi; for example, if the pressure at the filter inlet port was 70 psi, and the pressure at the outlet port dropped below 20 psi, the relief valve would open. (See Figure 5-3.)



**Figure 5-3. Clogged fluid filter.**

Paper filter elements are replaced on a scheduled basis, depending on the needs of the specific aircraft system. Replacing unscheduled filter elements is also required when certain components are removed. Never try to gage the condition of a filter by visual inspection alone. Since the naked eye cannot detect particles smaller than 40 microns, an element could be heavily contaminated with 10- to 20-micron particles. The only way this condition could be determined would be by performing a back-pressure flow check on a test stand. Another danger of relying on visual inspection alone is that while filter elements may seem identical in outward appearance and in physical dimensions, they differ internally. For this reason, filters must always be identified by part numbers. Filters installed in the wrong fluid will go to pieces and cause major problems in the hydraulic system. To remove and replace paper filter elements--

- Relieve system pressure by operating the main system bypass valve or by actuating a hydraulically operated unit.
- Depressurize reservoir (if necessary).

- Cut lockwire.
- Unscrew the filter case and remove it from the filter head using a slight rocking and downward pull on the case after the case threads are free from the filter.
- Extract the retaining ring and remove the filter element from the case.
- Cut the filter element after ensuring that a replacement filter element is available, and inspect it internally for evidence of system contamination.
- Before installing the new filter, clean the filter head and case, and inspect them for damage; replace all damaged parts.
- Replace all O-ring packings.
- Fill the filter bowl with new fluid before attaching it to the filter housing head. Filling the bowl helps to stop the injection of air into the system.
- Install the filter in its case, and screw the case into the filter head. The correct torque is usually hand-tight plus one-eighth of a turn, but always check the appropriate maintenance manual for the specific torque value.
- Pressurize the hydraulic system, and inspect the filter assembly for leaks. If the assembly is satisfactory, replace the lockwire between the filter case and head assembly.

Fluid Filters With Stainless Steel Elements. Stainless steel filter elements are used in most modern aircraft. Filter element surfaces of this type usually have a corrugated stainless steel mesh construction. Such filters are usually rated from 5- to 10-micron nominal flow and 25-micron absolute flow. This means about 95 percent of 5- to 10-micron particles and 100 percent of 25-micron particles will be filtered from the fluid. The curved passages of the filter element limit the length of the particles that pass through the filter.

Filters with a differential pressure indicator (Figure 5-4) operate on the difference between the pressure entering the element and the pressure after it leaves the element. When contaminating particles collect on the outside of the filter element, the differential pressure across the element increases. When this increased pressure reaches a specific value, inlet pressure forces the spring-loaded magnetic piston downward, breaking the magnetic attachment between the indicator button and the magnetic piston. This allows the red indicator on the differential pressure indicator to pop out, which indicates that the element must be cleaned. (See Figure 5-5.) Because increased fluid viscosity at low temperatures might cause a false indication of contamination, a low-temperature lockout of the differential pressure indicator prevents actuation at low temperatures. If the filter

element is not replaced when the indicator shows contamination, the filter element will continue to collect foreign particles, and the pressure differential between the inlet and outlet ports will increase until the bypass valve opens and directs fluid through the filter element bypass. A nonbypassing-type filter prevents contaminated fluid from passing through the filter element and contaminating the entire system. This type of filter reduces the need for flushing the entire system and lessens the chance of pumps and other components failing in the power system.

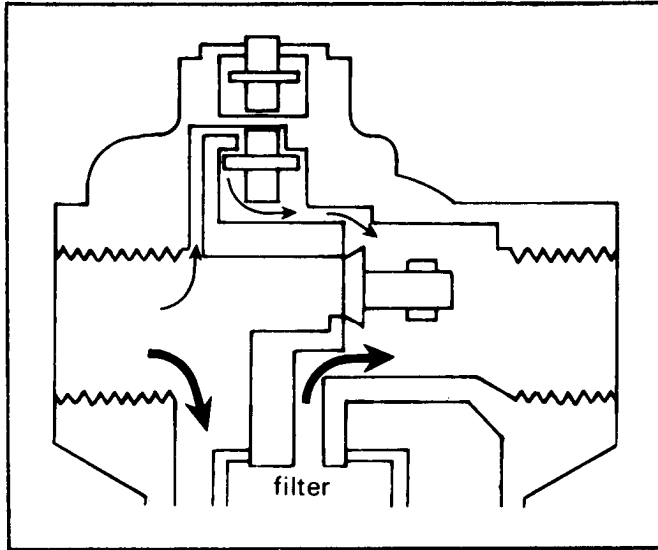


Figure 5-4. Differential pressure indicator.

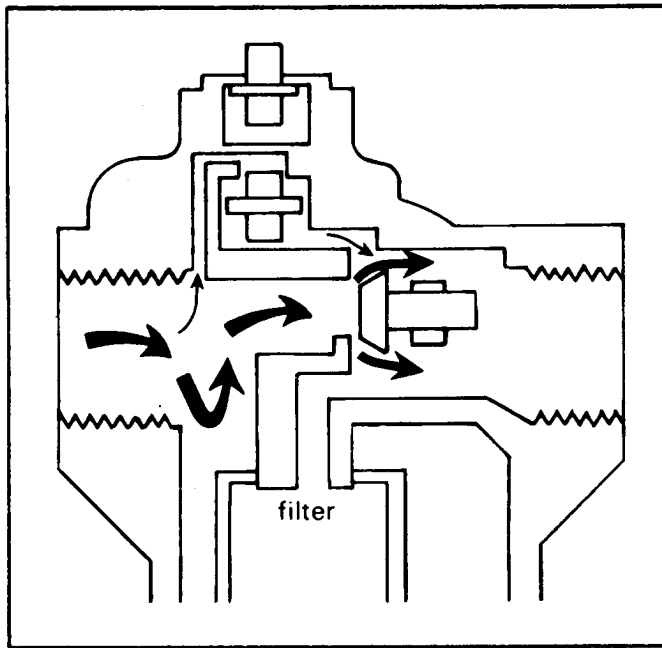


Figure 5-5. Differential pressure indicator "popped out."

**Two-Stage Fluid Filters.** Two-stage line-type hydraulic system filters are being used in some recent aircraft models. The typical two-stage filter has two filter elements, two bypass valves, and two differential pressure indicators. The first-stage element can filter out smaller particles than the second-stage element can. Normally the fluid passes through both elements, flowing first through the first-stage element and then through the second-stage element. No foreign matter will be left for the second-stage element to remove as long as the first-stage element is unclogged and functioning. If the first-stage element becomes clogged, its bypass valve opens and fluid goes directly from the filter inlet port to the second-stage element, which takes over the job of filtering out foreign particles. Although the second-stage element is not capable of filtering out the very small particles, it can be used until the first-stage element is unclogged.

## **AIR FILTERS**

An air filter is usually located in the line leading into the system supply source. Additional filters may be located at various points in the system lines to remove any foreign matter that may enter the system. Like hydraulic filters, air filters have a removable element and a built-in relief valve. The relief valve opens and bypasses the air supply around the filter element in case the element becomes clogged. Some air filters are equipped with a paper-type element which must be replaced periodically. Others have a mesh-type screen which requires periodic cleaning. The mesh-type screen may be returned to the system after being cleaned and dried.

## **MAINTENANCE**

Filters should be serviced according to the schedules and procedures in technical manuals on the specific aircraft involved. However, the following guidelines apply to the maintenance of all aircraft hydraulic system filters:

- Handle filters carefully. A hole no larger than a pinprick will permit large foreign particles to pass through the element.
- Service filters in a clean area. This will prevent dirt and other foreign particles from entering the system while the filter is being serviced.
- Do not leave a disassembled filter housing unprotected; this may cause contamination.
- Remove wrappings from a replacement element only when the element is to be inspected or installed.
- Hand-tighten the filter bowl to the head. Always safety the bowl and head together.

A popped-out indicator button indicates the need to service the filter. Push the button back in with the system at normal operating pressure. If the button pops out again, the filter needs servicing; if it stays in, the filter is not clogged.

Clean metal filter elements with ultrasonic cleaning equipment only. If ultrasonic equipment is not available, replace the contaminated element with one obtained from supply by repairable exchange. The replaced element is not an expendable item; it must be turned in for cleaning and reissue.



## CHAPTER 6

# HYDRAULIC PUMPS AND MOTORS

### POWER PUMPS

Purpose. A hydraulic pump is a mechanism that transfers and pressurizes the aircraft's hydraulic fluid. The primary energizing unit of the hydraulic system is the power pump. It is the unit that normally delivers hydraulic fluid under pressure to the actuators. Power pumps may be driven by an electric motor, a turbine unit, or the aircraft engine, transmission, or accessory gearbox. The piston-type power pumps used in modern hydraulic systems run at a rated speed of about one and one-half times the engine crankshaft speed. A thinned portion of the drive shaft in all power pumps provides a shearing action. If the pump seizes, the shaft will break and prevent damage to the engine or the transmission.

#### Operation.

Piston-type power pumps have common constructional features but vary in volume output and in methods of operation. Two types of piston-type power pumps are constant-volume pumps and variable-volume pumps.

Constant-Volume Pumps. Constant-volume piston-type pumps put out a constant flow of fluid for any given RPM. The pistons (usually seven or nine in number) are fastened by universal linkage to the drive shaft. (See Figure 6-1.) The universal link (B) in the center drives the cylinder block (D), which is held at an angle to the drive shaft (A) by the housing. Pumps are available with different angles between the drive shaft and the cylinder block. A large angle provides more output volume per revolution because the larger angle increases the piston stroke.

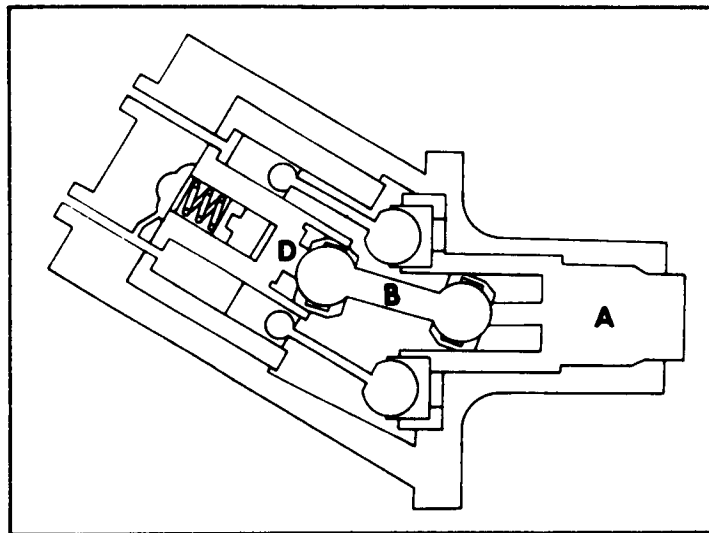
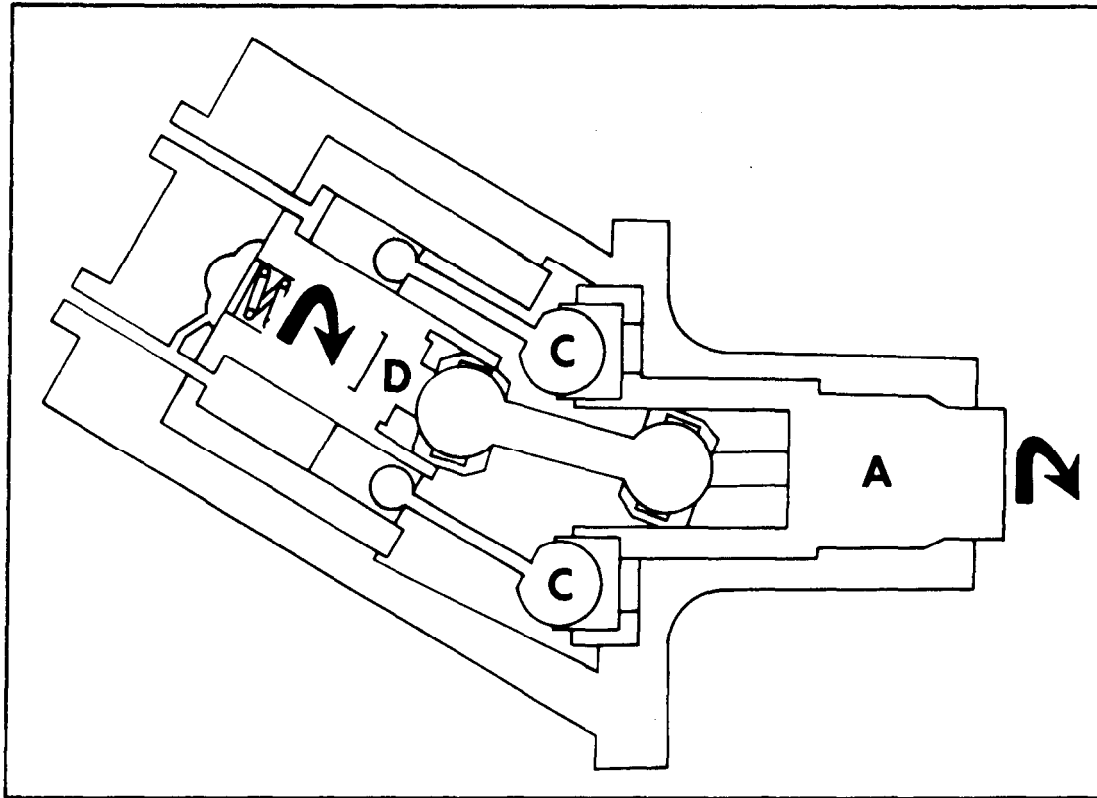


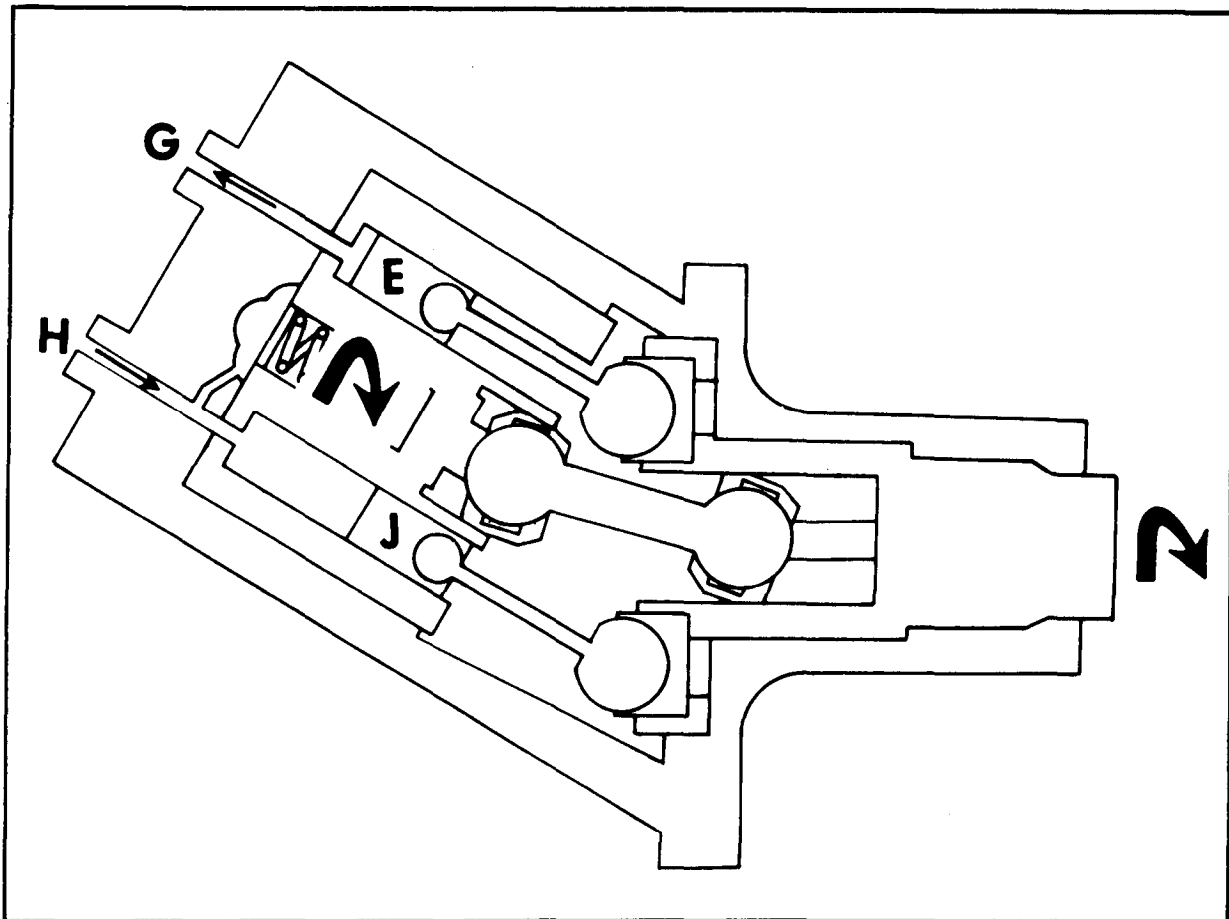
Figure 6-1. Constant-volume pump with pistons fastened.

As the drive shaft (A) rotates the cylinder block (D) and the piston assemblies, the pistons are always the same distance from their points of attachment (C) on the drive shaft. (See Figure 6-2.)



**Figure 6-2. Drive shaft rotating the cylinder block and piston assemblies.**

Although the pistons appear to move within the cylinders, actually the cylinders move back and forth around the pistons as the block and piston assembly rotate. However, since a piston normally moves within its cylinder, and since this appears to be happening in Figure 6-2, it is helpful to describe the action of this pump as though the pistons were actually moving within their cylinders. To follow a piston through one complete revolution, begin with the piston at the top of its cylinder (position E), having just completed its pressure stroke and beginning its intake stroke. (See Figure 6-3.) As the block starts to rotate from this point, the piston becomes aligned with the intake port (H). When the block has turned one-half of a revolution, the piston reaches the bottom of the cylinder (position J). The cylinder space formerly occupied by the piston is now full of fluid. As the block continues to rotate, the piston becomes aligned with the outlet port (G). Now that the piston has moved through the last 180° of rotation, it has exhausted all fluid from the cylinder and is ready to make another cycle. Since several pistons are operating, and since the cylinder block and piston assembly rotate rapidly, pistons are always somewhere between the upper and lower positions. This ensures a constant intake and output of fluid.

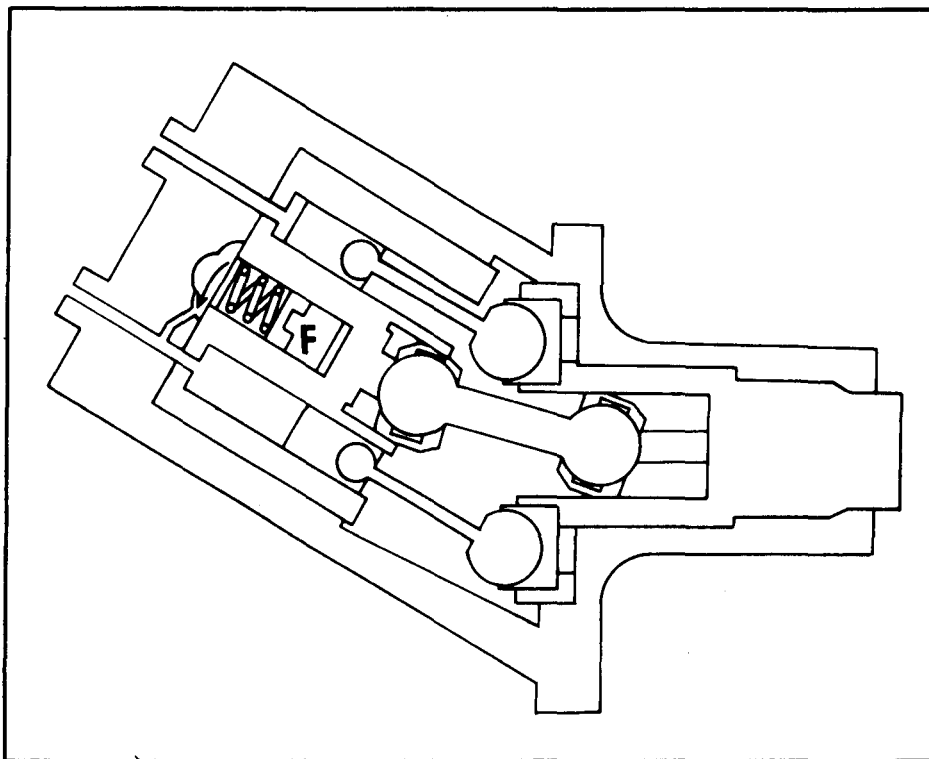


**Figure 6-3. Piston following through one complete revolution.**

The piston-type pump uses case pressure for cooling and lubrication. Fluid seeps by the pistons in the cylinder block and fills all the space inside the pump. This fluid cannot escape through the drive end of the pump because of a seal around the drive shaft. Excess case pressure within the housing is routed back to the intake side of the pump through a relief valve called a foot valve. This valve prevents the case pressure from rising above approximately 15 psi. Drilled passageways through the universal link rods help to keep the rod ball ends lubricated.

In Figure 6-4, the foot valve (F) is located inside the bearing around which the cylinder block rotates. Other models have the valve in the head, along with the intake and outlet ports. Some of the newer models have two foot valves located in the head. The direction in which the accessory drive rotates determines the direction of pump action. An arrow on the pump head indicates the direction of rotation for which the pump is set up. The direction of rotation of a piston-type pump with one foot valve can be reversed. To reverse the direction, remove the cylinder block head, rotate

it 180°, and reinstall it. Leave suction and pressure attachments as they were. This, in effect, reverses the intake and outlet port slots. It is not necessary to rotate the head on models with two foot valves; simply interchange the suction and pressure-line connections.

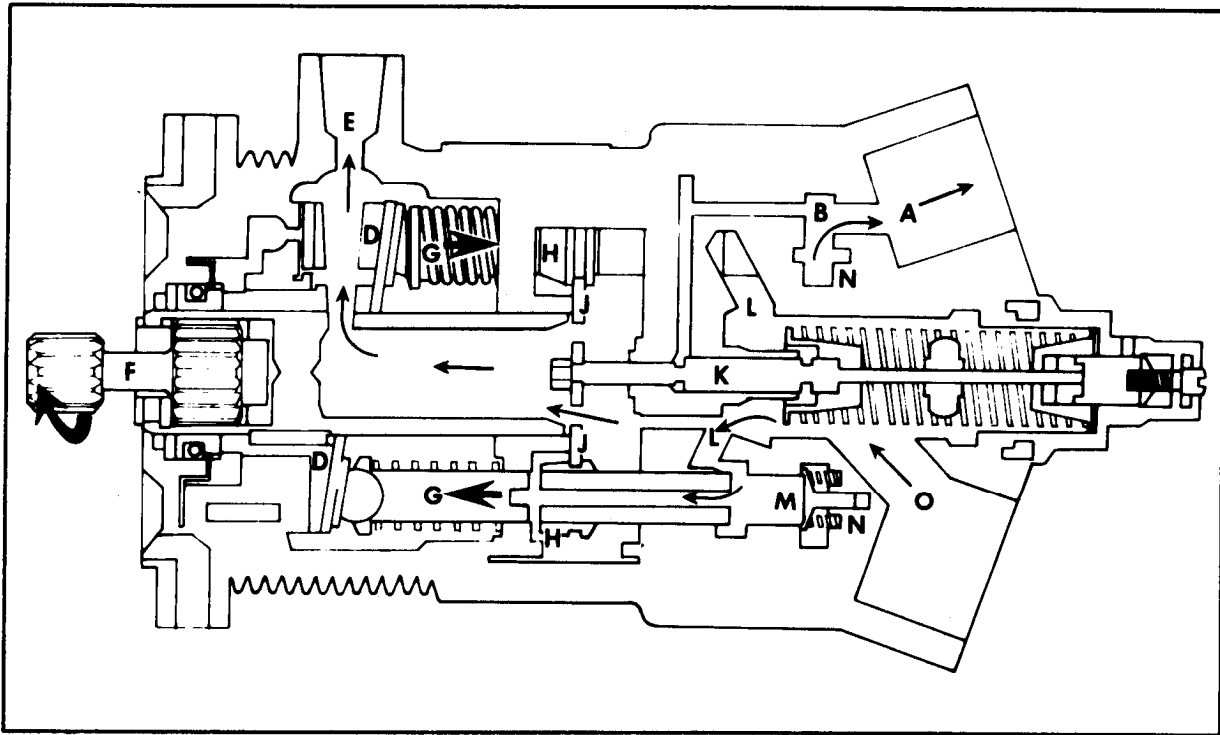


**Figure 6-4. Foot valve (located inside the bearing around which the cylinder block rotates).**

**Variable-Volume Pumps.** Variable-volume pumps have some advantages. One advantage is that they do away with a pressure regulator or an unloading valve; integral flow control valves regulate the pressure according to the demands made on the system. A second advantage is that pressure surges are reduced. Accumulators are not needed to smooth out surges with systems using variable-volume pumps; they are retained to aid the pump when peak loads occur. There are three types of variable-volume pumps.

**Stratopower effective stroke pump (variable-volume).** Figure 6-5 illustrates a full-flow stratopower pump. The drive shaft (F) rotates the cam (D). This cam causes the nine spring-loaded pistons (G) to move back and forth in their cylinders, which are in a stationary cylinder block. In operation, each piston is forced into and removed from the cylinder once for each revolution of the cam. The pistons are held in contact with the cam by piston springs which also return the pistons after each forward or power stroke. Each piston has a half-ball-bearing surface which acts like a universal linkage. The flat side contacts the cam during all angle changes. The pistons have fairly large hollow centers, connected with

cross-drilled holes. Around each piston, a sleeve (H) is attached to a spider (J), which is attached to the compensator (K). An increase in pressure moves the compensator to the right; decreased pressure allows it to move to the left because of the valve spring tension. As the pistons travel to the left, fluid drawn from the inlet port (O) passes through the open center of the cylinder block and then into the cylinders (M). At this point, hydraulic fluid fills the center of the pistons. Some fluid will continue to flow out through the cross-drilled holes to the pump's return port (E) on the drive end of the pump.

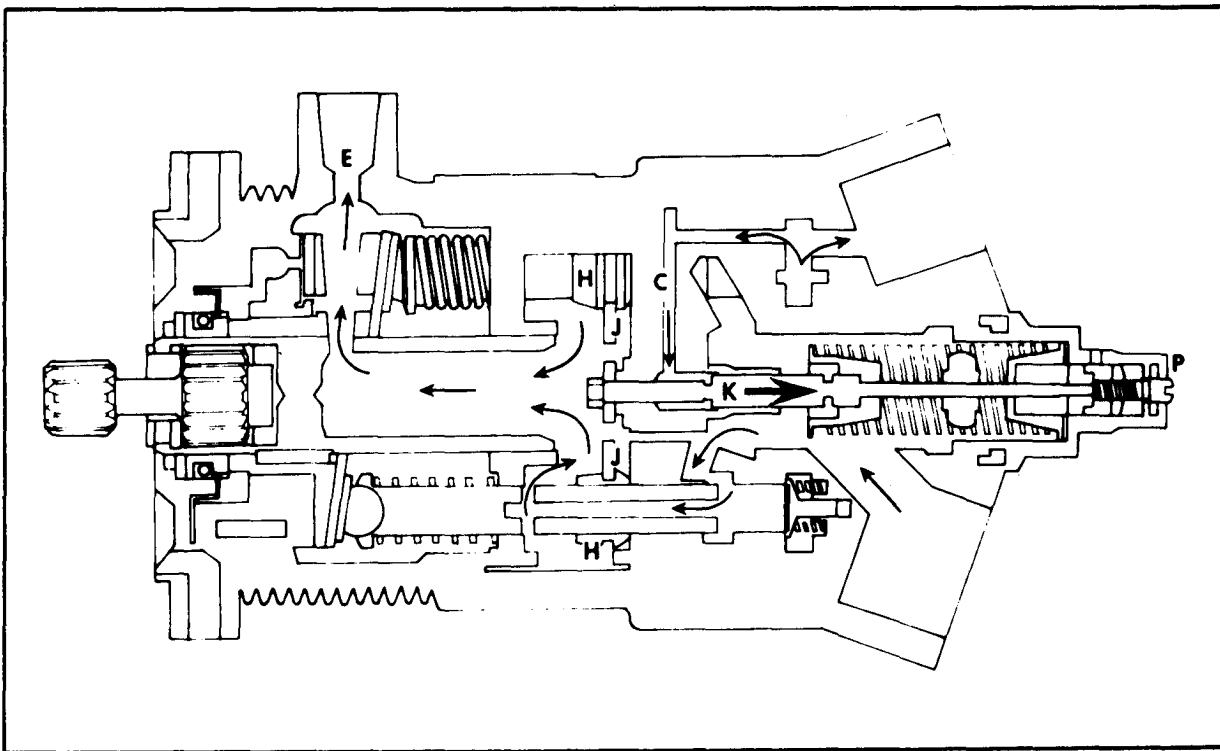


**Figure 6-5. Stratopower effective stroke pump (full-flow).**

As the pistons are forced to the right by the cam (D), the cross-drilled holes of each piston are blocked off by its sleeve. About the time that the cross-drilled passage is blocked off, the supply annulus (L) that surrounds the cylinder is also blocked off. This action traps the fluid in the piston and cylinder. As the piston continues to the right, pressure builds up against the check valve (N). Fluid under pressure goes out the check valve into the pressure chamber (B) and through the outlet port (A). When the piston moves as far right as possible, the cycle starts all over again. This cycle is the same for all nine pistons.

As pressure rises in the pressure outlet line, it is also felt in the passageway (C). This pressure acts on the compensator (K), forcing it to the right. This compresses the spring and carries the spider and sleeves (J and H) with the compensator. The more the sleeves move to the right, the farther each piston travels before the cross-drilled passage is covered. This means that less fluid is trapped by the right end of the

piston for output to the pressure manifold. The maximum setting of the compensator is all the way to the right. Then the output to the pressure manifold drops to zero as shown in the zero-flow illustration. (See Figure 6-6.)

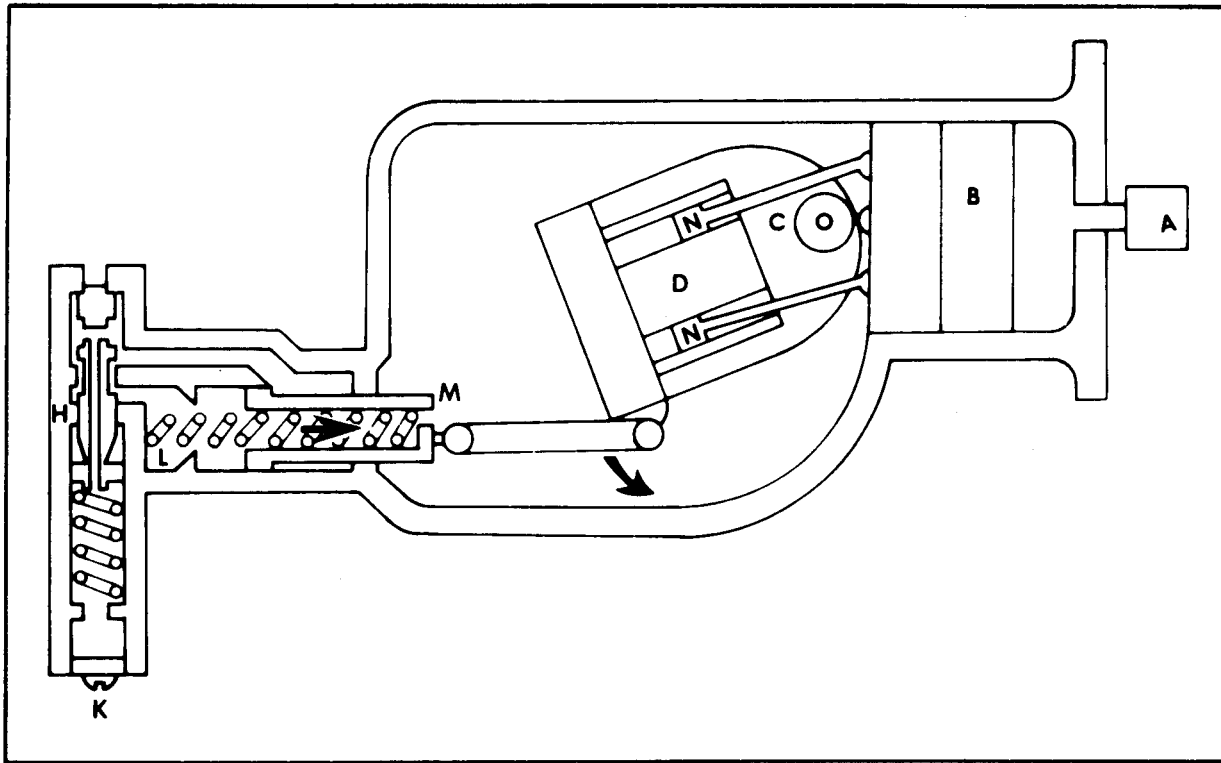


**Figure 6-6. Stratopower effective stroke pump (zero-flow).**

In this condition, all intake of the pump goes out the return port (E). Rotation of the cam draws fluid through the pump for cooling and lubrication. Fluid is always being pumped through the inlet port; fluid will not be pumped through the outlet port until the system pressure drops low enough to demand it. Always connect the proper lines to the ports marked IN, OUT, and RETURN. The stratopower pump does not require a pressure regulator. Instead, the compensator can increase pressure by turning the adjusting screw (P) clockwise or decrease it by turning it counterclockwise. This pump, like the constant-volume one, can be rotated in either direction.

Vickers stroke-reduction pump (variable-volume). The Vickers stroke-reduction pump operates somewhat like the constant-volume, piston-type pump. The main difference between the two is the angle between the drive shaft and the cylinder block. In the constant-volume pump, this angle is fixed; in the Vickers pump, the angle automatically varies to satisfy the pressure-volume demands of the system. In the stroke-reduction pump, the drive shaft (A), pistons (N), and cylinder block (D) are all supported by the bearing (B); they all rotate. A yoke (C) contains the cylinder block which swivels around the pivot pin (O). Before the pump

builds up any pressure, the yoke is held by the spring in the pressure-control piston (L) in the position shown in the full-flow illustration. (See Figure 6-7.)



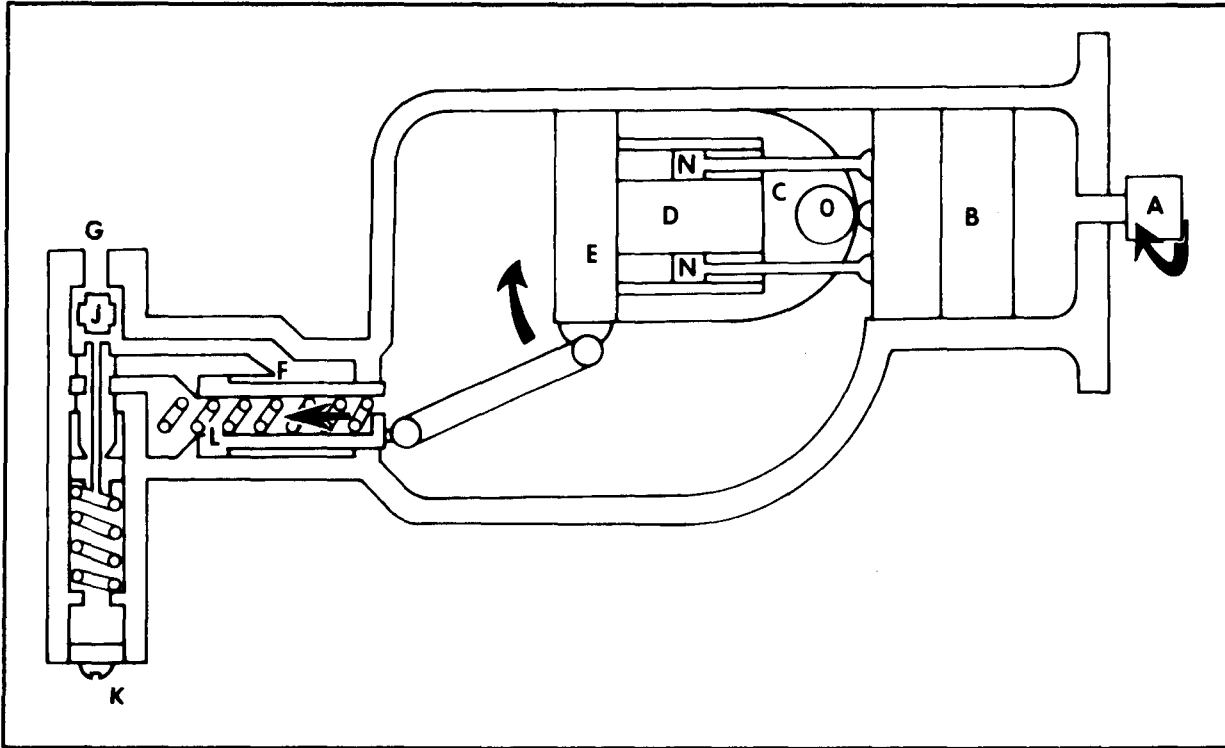
**Figure 6-7. Vickers stroke-reduction pump (full-flow).**

As the pressure in the system starts to drop, its force on the pilot valve is reduced. When this happens, the spring under the pilot valve moves the pressure upward. This reduces the opening to the passageway and cuts down the pressure on the pressure-control piston so that its spring pushes it to the right. Now the yoke swivels downward, causing the stroke of the pistons to increase. The pressure and volume output again start to increase until the system's demands are met. This action of the pressure-control valve (H) stabilizes the position of the cylinder block (D); its angle adjusts to meet the system's demands. Notice that the hollow center of the pressure-control piston is vented to the inside of the case (M) so that fluid trapped inside the piston can escape to the case. A foot valve (not shown) prevents case pressure from becoming too high.

The direction of the pump's rotation cannot be changed. Therefore, you must be sure to check the direction arrow on the mounting flange before installing the pump. Pressure is increased or decreased by turning the adjusting screw (K). An internal relief valve prevents damage in case the pressure-control valve fails to function properly.

As long as there is no pressure in the system, the cylinder block and yoke are in the extreme angle position. (See Figure 6-8.) System pressure

entering the connecting line (G) acts on the pilot valve (J), pushing it down against the spring toward the zero-flow position. This opens the passageway (F), sending pressure against the rod side of the pressure-control piston (L). As the piston moves to the left, its spring is compressed. This force, which is transmitted through the valve plate (E), causes the yoke to swivel upward so that the cylinder block moves toward a zero angle. If the cylinder block reaches the extreme zero-flow point, there is no fluid output to the system. This is because the pistons have no stroke in the cylinder block; they simply rotate with the cylinder block without moving back and forth.



**Figure 6-8. Vickers stroke-reduction pump (zero-flow).**

Kellogg stroke-reduction pump (variable volume). (See Figure 6-9.) The Kellogg pump consists of two major component groups: the rotating group and the pressure-compensating group. The rotating group consists of the drive shaft (E), cylinder barrel (B), and nine pistons (C) with their piston shoes and locking plates (D). The pressure-compensating group consists of a cam plate (F), a compensator valve (G), and a control piston (H). The cylinder barrel is supported in the housing by a roller bearing (A). The drive shaft passes through—but does not touch—the inclined cam plate to rotate the cylinder barrel unit. Pistons of the rotating group are actuated by tilting the nonrotating cam plate. The contact is a universal-action type consisting of hydraulically balanced shoes and locking plates. The length of the piston stroke is determined by the angle of the cam plate. Maximum pump output requires a high angle; zero pump output requires a flat angle setting.





need for pump output is reduced to zero. The pump senses the end of the actuator travel because the unused output causes a sudden increase in discharge pressure. As this pressure reaches the setting of the compensator valve, it pushes the valve to the right. The pressure then pushes on to the control piston, causing it to move to the left and decreasing the angle of the cam plate. This action decreases the effective length of the piston stroke and the volume of fluid delivered to the system. In actual operation, the cam plate assumes various angles to maintain the proper system pressure. It will meet all fluid demand conditions within the rating of the pump. A pump check valve (A) installed in the pump outlet line prevents a return flow into the pump during the system's operation using a portable hydraulic test stand. The reverse flow of hydraulic fluid motorizes the pump.

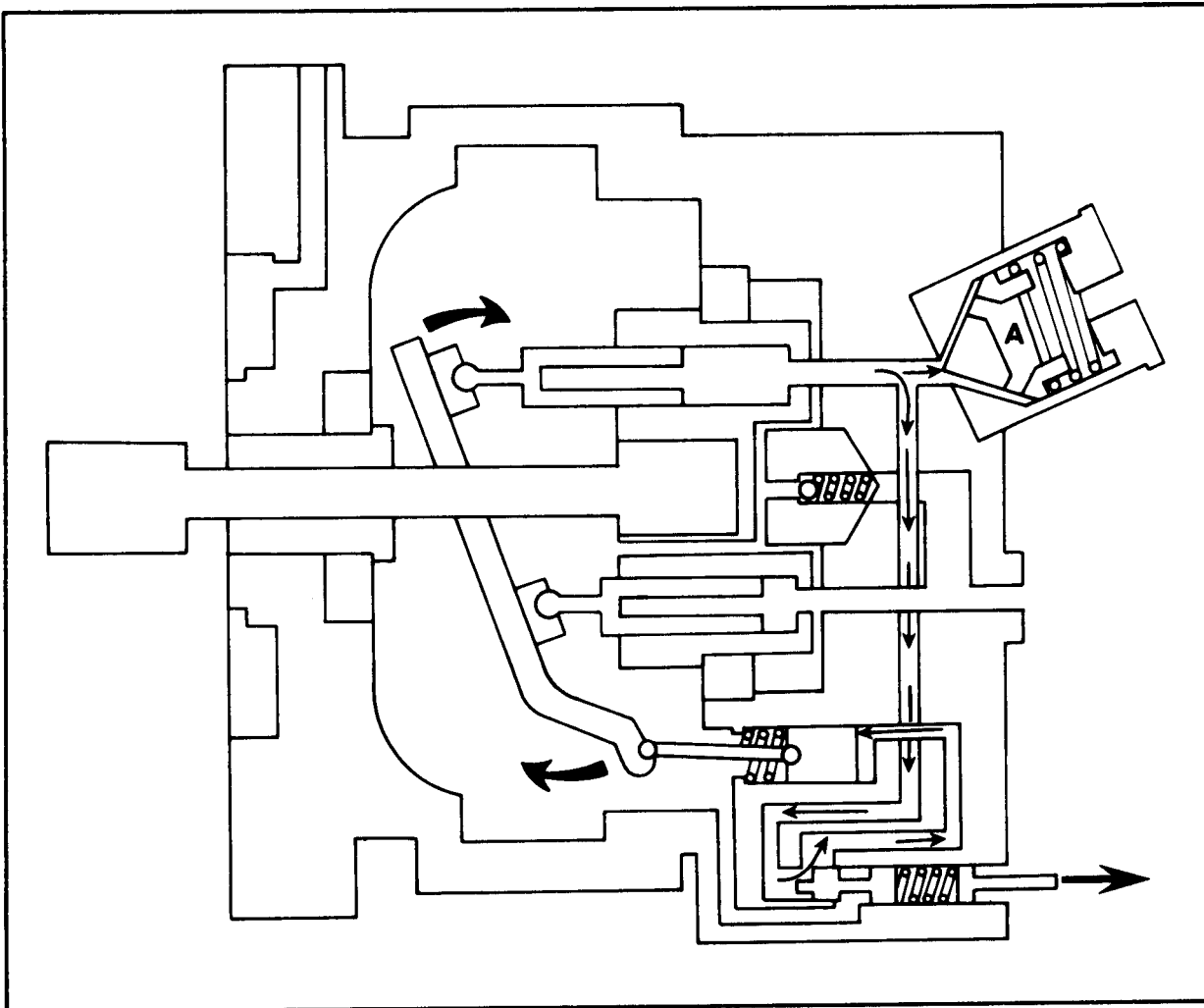


Figure 6-10. Kellogg stroke-reduction pump.

Maintenance. Hydraulic power pumps are repaired and overhauled at depots. This work requires special tools and equipment.

## HAND PUMPS

**Purpose.** Hand pumps serve as replacements for power pumps during emergencies in flight and as sources of power for checking the hydraulic system when the aircraft is on the ground. They are piston-type pumps and may be either single or double action; most are the double-action type. The double-action pumps deliver fluid under pressure on both the fore and aft strokes of the piston.

**Operation.** Figure 6-11 illustrates the construction of the double-action hand pump. It consists of a cylinder assembly containing a piston (A) and two spring-loaded check valves (B and C). When the piston moves to the right, the piston check valve (C) is held closed by the spring. The piston forces the fluid in the right chamber (D) out into the pressure line. At the same time, the suction in the left chamber (E) created by the moving piston draws fluid through the inlet-line check valve (B), filling that chamber. When the piston moves to the left, the inlet-line check valve is held closed by the pressure of the fluid in the left chamber. The space available for the fluid in the right chamber is now less than the space in the left chamber. This is caused by the piston rod displacement in the right chamber; with check valve (C) opened, the excess fluid under pressure is driven out through the discharge port of the system.

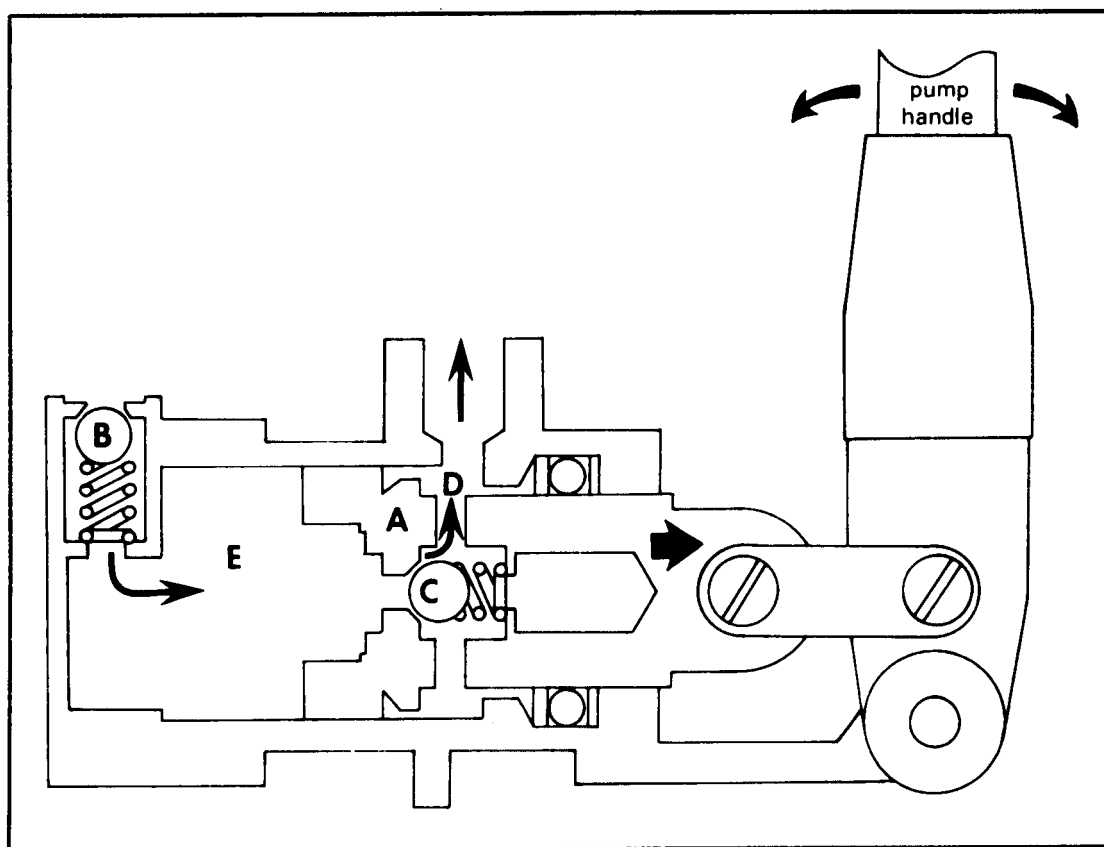


Figure 6-11. Double-action hand pump.

**Malfunctions.** Since hand pumps are only operated for short periods of time, malfunctions do not occur often. However, the most common cause of malfunctioning is failure of the check valves. Failure of either check valve will cause the hand pump to become completely inoperative. Some designs have a third check valve in the pressure (out) line which reduces this problem. With this design, even if one of the check valves or the piston-head seal should fail, the pump could still produce pressure on at least one stroke of the cycle. The third check valve prevents system pressure from reaching the hand pump during the system's normal operation. It also aids the mechanic in determining hand pump failure. If the check valve in the inlet port leaks, the pump will develop pressure on the piston extension stroke only. If the check valve in the piston rod leaks or if the piston-head seal leaks, the pump will develop pressure on the piston retraction stroke only. If the pressure (out) line check valve leaks, no immediate indication that this is happening will occur. In this case, the pump will still develop pressure on both strokes.

**Maintenance.** Basically, the care of hand pumps consists of disassembly, inspection, reassembly, and testing. After disassembly, thoroughly clean all parts and carefully inspect them for nicks, cracks, scratches, and corrosion. Inspect threaded surfaces for damaged threads and piston shaft and springs for distortion. Check the valve balls (poppets) for proper seating, and look for anything that can cause pump failure.

At each overhaul, replace all bad parts that are not repairable. Also replace cure-dated parts (natural or synthetic rubber items) anytime the pump is disassembled. Remove minor scratches and corrosion, or polish them out by using a specified type of crocus cloth. If necessary, clean internal threads with the correct size tap. Next, clean all external threads by filing or by using the proper size die. Before reassembly, coat all internal parts with clean hydraulic fluid of the type used in the system.

After the pump has been reassembled, test it for proof pressure and leakage. Figure 6-12 illustrates a setup for testing the hand pump. Basically it consists of a gage, shutoff valve, reservoir, and tubing.

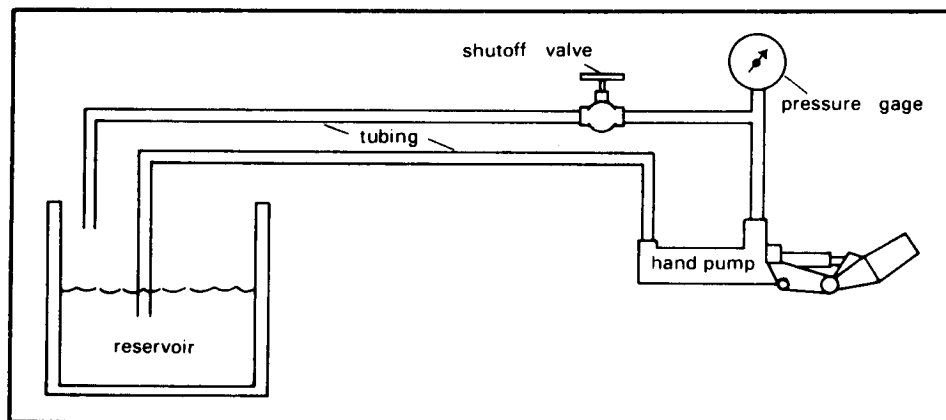


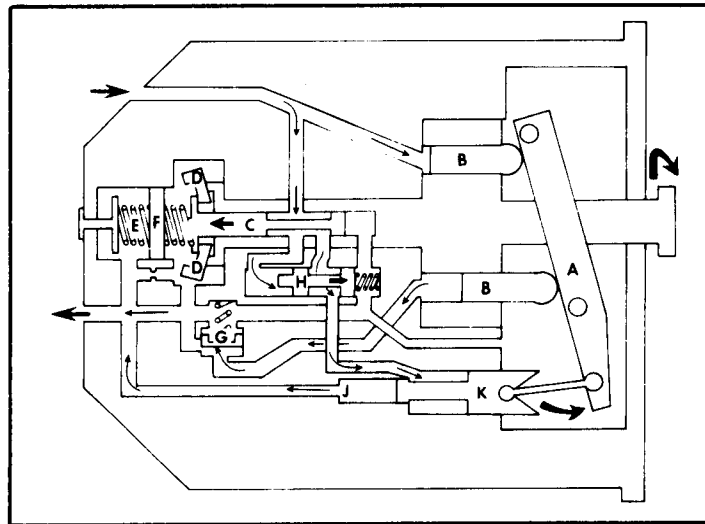
Figure 6-12. Test circuit for hand pumps.

To test for proof pressure, pump fluid through the circuit with the pump connected and the shutoff valve open. This bleeds all air from the system. Next, close the shutoff valve and operate the pump to obtain the required proof pressure; proof pressure is approximately one and one-half times normal operating pressure. The strokes should be controlled so that the final stroke will leave the piston in the retracted position; pressure should be maintained for a specified time (usually two to five minutes). Repeat the preceding step, but control the strokes so that the final stroke will leave the piston in the extended position.

For the leakage test, use the pump to pressurize the circuit to the normal operating pressure (the shutoff valve is closed during this check). The pressure must hold for a specified time (approximately two minutes). There should be no piston creep, and the pressure drop should not exceed the specified amount (usually 50 to 100 psi). After the test is completed, relieve the pressure and remove the pump from the test circuit. Drain the pump to the drop point; then refill it with the specified preservative fluid to about 90 percent of its capacity. Plug all ports and closures, and mark the rubber parts' cure date on the pump.

## HYDRAULIC MOTORS

**Purpose.** Hydraulic motors in Army aircraft start the landing gear wheels, power plant turbines, cargo ramp doors, and winch hoists. Figure 6-13 illustrates a variable-displacement, axial-piston, and rotating cylinder-block unit. It delivers a minimum of 16.6 horsepower at 8,000 RPM. This particular motor is used to drive an AC/DC generator at a constant RPM. Since an AC generator or alternator must put out the same number of cycles per second under all load conditions, a very sensitive flyweight governor is required on the motor. For components where the RPM is not critical, a constant displacement-type hydraulic motor would probably be used.



**Figure 6-13. Hydraulic motor with a variable-displacement, axial-piston, and rotating cylinder-block unit.**

Operation. Motors operate on the same principles as pumps, but in reverse. If the operation of the motor as illustrated in Figure 6-13 is understood, understanding other motors should not be difficult. When the hydraulic system is pressurized, fluid pressure is put on the pistons of the cylinder block. Pressure must also go to the closed starting valve of the motor. Normal system pressure will sustain cylinder and generator rotation, but higher pressure is needed to start the rotation.

The starting valve (H) starts the hydraulic motor. When system pressure builds up to 1,800 to 2,200 psi, the starting valve is moved to the right. This action permits fluid under pressure to move the control piston (K), which moves the bottom of the wobbler plate (A) to the right with sudden force. Movement of the wobbler plate kicks the upper and lower pistons (B) to give the cylinder block an initial spin. Then system pressure maintains the rotation of the cylinder block. As hydraulic pressure continues to increase, motor speed increases. As the rotational speed increases, the governor flyweights (D) begin to pivot outward, moving the governor control valve (C) proportionately to the left. This movement gradually blocks the pressure to the control piston (K). When the passage is completely blocked, pressure is no longer put on the control piston, and the motor speed ceases to increase. This is referred to as an on-speed condition.

The load imposed on the motor varies with the electrical load on the generator. To meet the changing demands, the motor must vary its torque to maintain its normal operating speed. For example, when the motor overspeeds, it causes the governor flyweights (D) to move outward, pulling the governor control valve (C) a little to the left. Movement to the left from the block position vents the control piston (K) passage to return system pressure. This reduces the force acting on the control piston. Now system pressure acting on the upper piston (B) is greater than the return system pressure on the control piston. The result is that the upper piston in the rotating cylinder block moves the wobbler plate (A) toward the right, reducing the angle of the plate. The reduced angle reduces the torque output and speed of the motor.

Movement of the wobbler plate also momentarily activates the preact piston (F) of the flyweight governor. This prevents over-travel of the governor control valve and hastens the motor's response to changes in load. The preact piston acts when the wobbler plate moves to the right and the control piston moves to the left. This action forces fluid in the feedback line (J) into the chamber on the left side of the preact piston. When fluid moves into this chamber, the preact piston moves to the right, increasing tension on the governor spring (E) and opposing movement of the governor control valve to the left. Motor speed decreases, and the fluid in the preact piston chamber bleeds off through the restrictor bleed. The governor control valve moves back to the right, blocking the control piston's passage and holding the wobbler plate in its new position. These events occur almost instantly to match the torque requirement with the load.

A back pressure valve (G) is installed in the discharge line of the lower piston to prevent the piston from floating and chattering. If this valve were not in the return line, return pressure would exist on both sides of the lower pistons. Under this condition, the pistons would tend to float. The back pressure valve puts 100 psi over return pressure load on the back side of the lower pistons. This load holds them against the wobbler plate and prevents chattering.

Maintenance. The maintenance performed on hydraulic motors will depend on the equipment on hand. As with hydraulic power pumps, repair and overhaul of hydraulic motors is depot-level work involving the use of special and complex test equipment.

## CHAPTER 7

## PRESSURE-REGULATING DEVICES

## HYDRAULIC PRESSURE GAGES

Purpose. Hydraulic pressure gages (sometimes called pressure indicators) (Figure 7-1) indicate the amount of pressure in hydraulic systems. Gage dials are calibrated to show this pressure in psi.

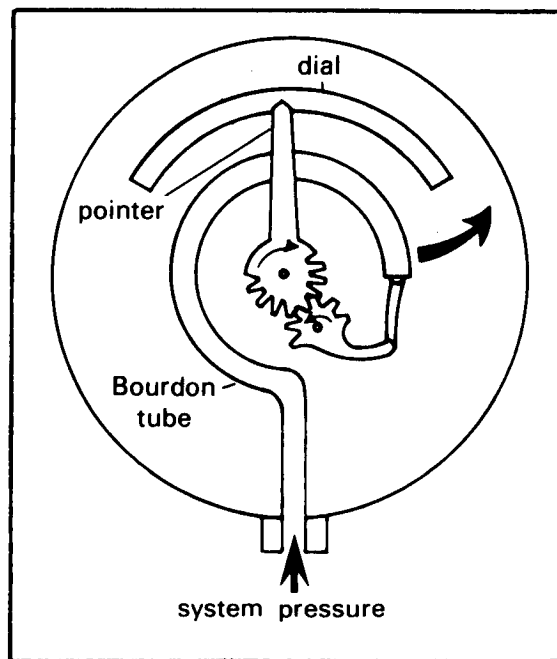


Figure 7-1. Hydraulic pressure gage.

Types. Two types of gages used are the direct-reading gage and the remote-indicating gage.

**Direct-Reading Gage.** This gage consists of a Bourdon tube, pointer, dial, and rain-tight case. The Bourdon tube and pointer are interconnected by gearing so that they will move together. Pressure within the hydraulic system is admitted into the Bourdon tube through a connecting line. As hydraulic system pressure increases, it causes the Bourdon tube to straighten to a corresponding degree. The change in the tube's curvature reacts on the gearing, causing the pointer to move to a higher reading on the dial. As hydraulic system pressure decreases, the Bourdon tube curls back toward its original shape. This causes the pointer to fall back to a lower dial reading. Pressure-gage snubbers are usually used with hydraulic pressure gages to dampen pointer oscillations.

**Remote-Indicating Gage.** In the remote-indicating gage, the gage transmitter contains a Bourdon-tube diaphragm, or bellows, where hydraulic



system pressure is admitted through a connecting line. The Burdon-tube diaphragm reacts to pressure changes in a manner similar to that of the direct-reading gage. The diaphragm's movement produces electrical signals that are transmitted through connecting wiring to the indicator unit, where they cause the indicator pointer to move.

## PRESSURE SWITCHES

**Purpose.** A pressure switch opens or closes an electrical circuit in response to a predetermined hydraulic pressure entering the switch from a connected source. Pressure switches on Army aircraft serve two main purposes. One is to close the circuit of a warning light that shows low pressure in a system. The other is to affect the circuits of solenoid valves in aircraft having dual hydraulic boost control systems; this ensures that operating pressure to one boost system cannot be shut off unless the other boost system is provided with enough operating pressure to fly the aircraft. Some pressure switches are designed with two sets of contacts to provide control for the warning light and solenoid valve.

**Types.** Two types of pressure switches commonly used in Army aircraft are the piston-type pressure switch and the diaphragm-type pressure switch.

**Piston-Type Pressure Switch.** (See Figure 7-2.) This switch consists of a rectangular-shaped housing, a cylinder bore and piston, an adjustable spring for loading the piston, a microswitch, and linkage for transmitting the piston's movement to the microswitch. The housing has a port for connecting the switch to a system pressure line and an electrical receptacle for connecting the switch with an electrical circuit.

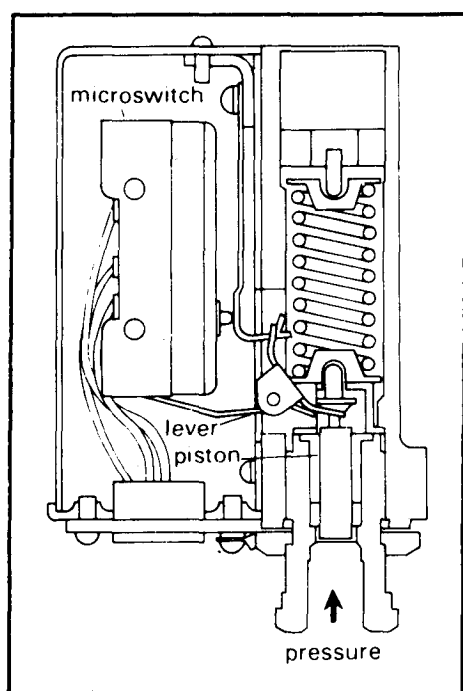


Figure 7-2. Piston-type pressure switch.

**Diaphragm-Type Pressure Switch.** This switch consists of a cylindrical-shaped housing, a diaphragm, an adjustable spring to load the diaphragm, a microswitch, and linkage for transmitting the diaphragm's movement to the microswitch. The housing has a port at one end for connecting the switch to a system pressure line and an electrical receptacle for connecting the switch with an electrical circuit at the other end.

**Operation.** The operation of the piston-type pressure switch will be discussed here; however, the diaphragm switch operates essentially on the same principles. Fluid pressure entering the port of the pressure switch acts on the face of the piston to move it against the resistance of the piston-return spring. When the fluid pressure acting on the piston becomes great enough to overcome the force of the piston-return spring, the piston's movement causes the pivoted lever of the connecting linkage between the piston and the microswitch to rotate. The pivoted lever's movement is transmitted through the idler spring to the microswitch actuating button. When the microswitch actuating button has moved a sufficient amount, the microswitch contacts move into the pressure-induced position. Normally open (NO) switches are designed so that their contacts remain open until they are closed by the action of fluid pressure against the switch position. Normally closed (NC) switches are designed so that their contacts remain closed until they are opened by the reaction of fluid pressure against the switch piston.

## **PRESSURE RELIEF VALVES**

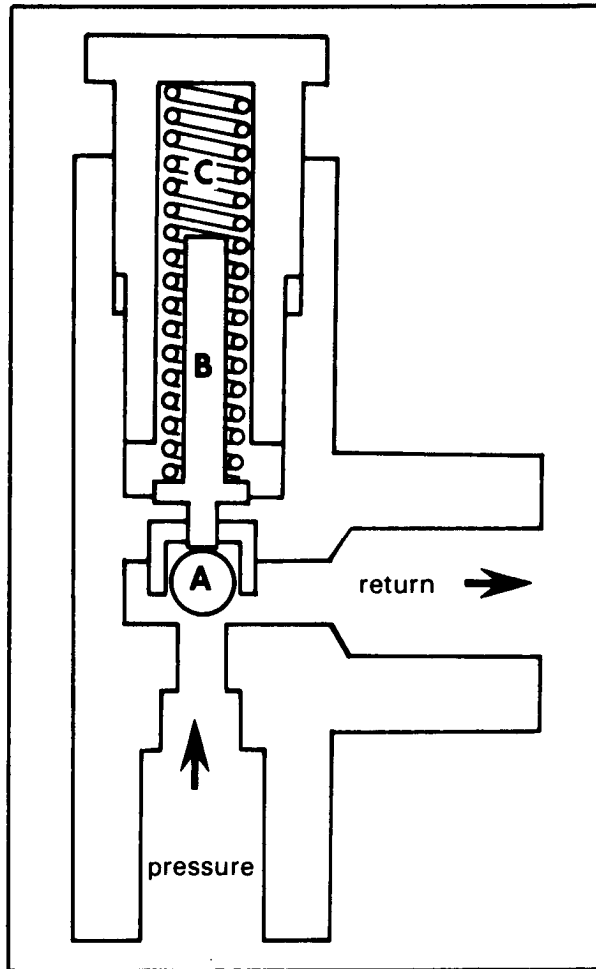
**Purpose.** Relief valves are safety devices that prevent pressure from building up to a point where it might blow seals and burst, or otherwise damage, the container in which the valves are installed. Relief valves are installed in aircraft hydraulic systems to relieve excessive fluid pressure caused by thermal expansion, pressure surges, and failure of a hydraulic pump's compensator or other-regulating devices.

**Types.** The two types of relief valves are the main system relief valve and the thermal relief valve.

**Main System Relief Valve.** This relief valve is set to open and close at pressures determined by the system in which it is installed. In systems made to operate at 3,000-psi normal pressure, the relief valve might be set to be completely open at 3,650 psi and to reseal at 3,190 psi. These pressure ranges may differ from one aircraft to another. In the open position, the relief valve sends excess pressurized fluid to the reservoir return line.

Figure 7-3 shows a typical main system relief valve with a breakdown of its component parts. The relief valve consists of a cylindrical housing containing a poppet valve and a piston assembly. Each end of the housing is made to include a wrench-holding surface and a threaded port for installing a hydraulic fitting. The housing is stamped to identify the ports as PRESS (pressure) and RET (return). The poppet valve (A), which is located just inside the pressure port, is seated over a passage through the valve. When fluid pressure at the pressure port reaches 3,650 psi, the

pressure forces the piston (B) to depress the load spring (C) and to move clear of the poppet valve. This action opens the piston's passage, and fluid flows through the valve into the return line. When pressure at the pressure port is reduced to 3,190 psi, the coil spring reseats the piston against the poppet valve. This action stops the fluid from flowing through the relief valve. If the pressure at the outlet port exceeds the pressure at the inlet port, the poppet valve will unseat, and fluid from the return line will flow through the valve into the pressure line.



**Figure 7-3. Main system relief valve with component parts.**

**Thermal Relief Valve.** This relief valve is usually smaller than a main system relief valve. The thermal relief valve is used in systems where a check valve or a selector valve prevents pressure from being relieved through the main system relief valve. As pressurized fluid in the line builds up to an excessive amount, the valve poppet is forced off its seat, and the excess pressurized fluid flows through the relief valve to the reservoir. When system pressure decreases to a preset pressure, spring tension overcomes system pressure and forces the valve poppet to the closed position.

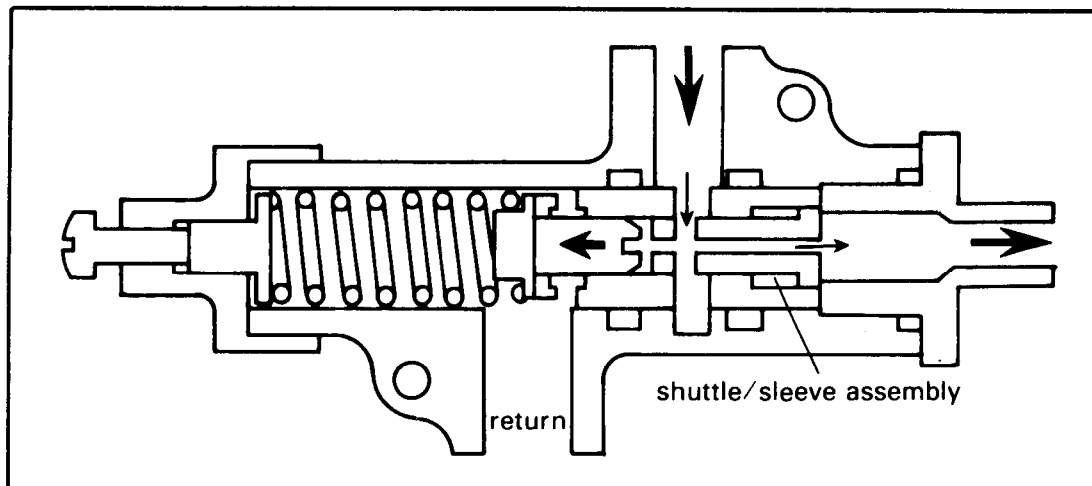
**Maintenance.** Relief valve maintenance is limited to adjusting the valve to the correct pressure setting and checking it for leaks. If a relief valve is suspected of leaking-internally, connect a flexible hose to the return port of the valve; any drippings can be caught in a container. The opening and closing pressure of the valve may also be checked in this manner if an external power source is used.

CAUTION

DO NOT ATTEMPT TO ADJUST A RELIEF VALVE WHILE IT IS INSTALLED ON AN AIRCRAFT. REMOVE AND ADJUST THE VALVE ON A TEST STAND. THE SAME RULE APPLIES TO ALL RELIEF VALVES: TURN THE ADJUSTING SCREW CLOCKWISE TO INCREASE OPENING PRESSURE AND COUNTERCLOCKWISE TO DECREASE OPENING PRESSURE.

### PRESSURE-REDUCING VALVES

**Purpose.** A pressure-reducing valve (Figure 7-4) is used in hydraulic systems to lower the normal system operating pressure to a specified amount. It also acts as a relief valve.



**Figure 7-4. Pressure-reducing valve.**

**Operation.** In Figure 7-4, system pressure is being ported to a subsystem through the shuttle and sleeve assembly. Subsystem pressurized fluid works on the large flange area of the shuttle, causing it to move to the left after reaching a set pressure and closing off the normal system. The valve will stay in this position until subsystem pressure is lowered. The shuttle will then move to its prior position, allowing the required amount of pressurized fluid to enter the subsystem. During the normal operation of the subsystem, the pressure-reducing valve continuously meters fluid to the system. When pressurized fluid builds up to an excess amount within the subsystem, the shuttle assembly overcomes spring tension and

moves farther to the left. This movement opens a passage to the return line, and all excess fluid is relieved. When pressure is lowered to an acceptable amount, the shuttle assembly returns to a balanced position.

## ACCUMULATORS

**Purpose.** An accumulator in a hydraulic system stores a volume of fluid under pressure. It also acts as a cushion against pressure surges caused by pulsating fluid delivery from the pump or the system's operation. The accumulator supplements the pump's output at peak loads and may also be used to actuate a unit if the pump fails. For example, enough energy is stored in the accumulator on the AH-1G helicopter to operate the collective flight controls several times.

Many aircraft have several accumulators in the hydraulic system. There may be a main system accumulator and an emergency system accumulator. Auxiliary accumulators may also be located in various unit systems. Regardless of their number and location within the system, all accumulators store an extra volume of hydraulic fluid under pressure.

**Types.** Two general types of accumulators used in Army aircraft are the spherical type and the cylindrical type. Until recently, the spherical type was the one more commonly used; however, the cylindrical type has been proved to be better for high-pressure hydraulic systems.

**Spherical Accumulator.** The spherical accumulator is made up of two halves screwed together. (See Figure 7-5.) A synthetic rubber diaphragm divides the accumulator into two chambers. The opening at the top of the accumulator contains a screen disk. This prevents the diaphragm from coming up through the threaded opening when system pressure is depleted; this action could rupture the diaphragm. On some designs, a button-type protector fastened to the center of the diaphragm replaces the screen. The assembled component has two threaded openings. The top threaded opening connects the fluid chamber of the accumulator to the hydraulic system. The bottom threaded opening is used to install an air filler valve. When open, this valve allows air (or nitrogen) to enter the accumulator. When the valve is closed, the air (or nitrogen) is trapped within the accumulator.

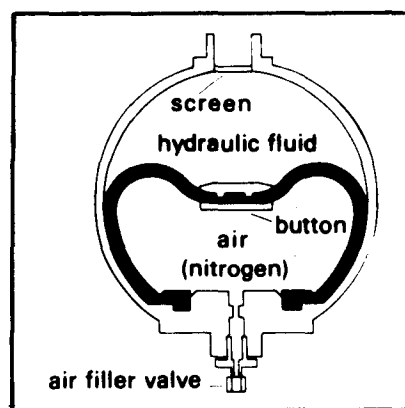
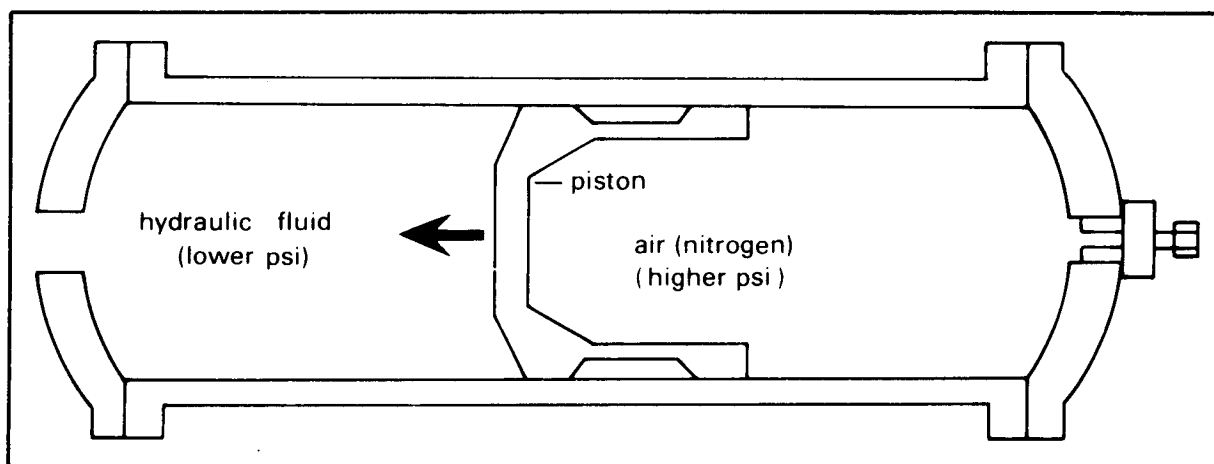


Figure 7-5. Spherical accumulator.

**Cylindrical Accumulator.** The cylindrical accumulator consists of a cylinder and piston assembly. (See Figure 7-6.) Caps are attached to both ends of the cylinder. The internal piston separates the fluid chamber from the air (or nitrogen) chamber. The end caps and the piston are sealed by gaskets and packings. These sealants prevent external leakage around the caps and internal leakage between the chambers. A hydraulic fitting in the end cap on the fluid side attaches the fluid chamber to the hydraulic system. An air filler valve in the other end performs the same function as the air filler valve in the spherical accumulator.

**Operation.** Spherical and cylindrical accumulators operate essentially the same. In operation, the compressed-air chamber is charged to a set pressure somewhat lower than the system operating pressure. This initial charge is known as the accumulator preload. To illustrate the operation of the accumulator, let us assume that the cylindrical accumulator shown in Figure 7-6 is designed for a preload of 1,300 psi in a 3,000-psi system. When the initial charge of 1,300 psi is introduced into the unit, hydraulic system pressure is zero. As air pressure is applied through the air pressure port, it moves the piston toward the opposite end until it bottoms. If the air behind the piston has a pressure of 1,300 psi, the hydraulic system pump will have to create a pressure within the system greater than 1,300 psi before the hydraulic fluid can actuate the piston. At 1,301 psi, the piston will start to move within the cylinder, compressing the air as it moves. At 2,000 psi, it will have backed up several inches. At 3,000 psi, the piston will have backed up to its normal operating position, compressing the air until it occupies a space less than one-half of the cylinder's length. When hydraulic units lower system pressure, the compressed air causes the piston to move, forcing fluid from the accumulator and supplying fluid to the hydraulic system.



**Figure 7-6. Cylindrical accumulator.**

**Maintenance.** Examine accumulators visually for external hydraulic fluid leaks. To find an external air leak, brush the exterior with soapy water; bubbles will form wherever air is leaking. To find an internal leak, loosen the air valve assembly. If hydraulic fluid comes out of the air valve, remove and replace the accumulator.

After relieving the hydraulic system pressure, check the preload pressure by operating a hydraulically actuated unit. Most accumulators installed in Army aircraft are equipped with air-pressure gages. If they are not so equipped, a high-pressure air gage may be installed at the air preload fitting. The required pressure is stated in the maintenance manual for each aircraft.

The air preload must be completely exhausted before disassembling any accumulator. To do this, loosen the swivel nut on the air filler valve until all air is out; then remove the valve. Overhaul or repair of accumulators is not an aviation unit maintenance function. Some aviation intermediate maintenance units may have this responsibility, but it is primarily a depot maintenance function.

## CHAPTER 8

# FLOW CONTROL UNITS

### SELECTOR VALVES

Purpose. A hydraulic selector valve controls the direction of movement of an actuating unit. It does this by--

- Providing pathways for the flow of a stream of fluid under pressure and for a stream of return fluid into and out of a connected actuating unit.
- Providing the means for immediately and conveniently switching the directions in which the two streams of fluid flow through the connected actuating unit. (This is necessary to reverse the direction of movement of the actuating unit.)

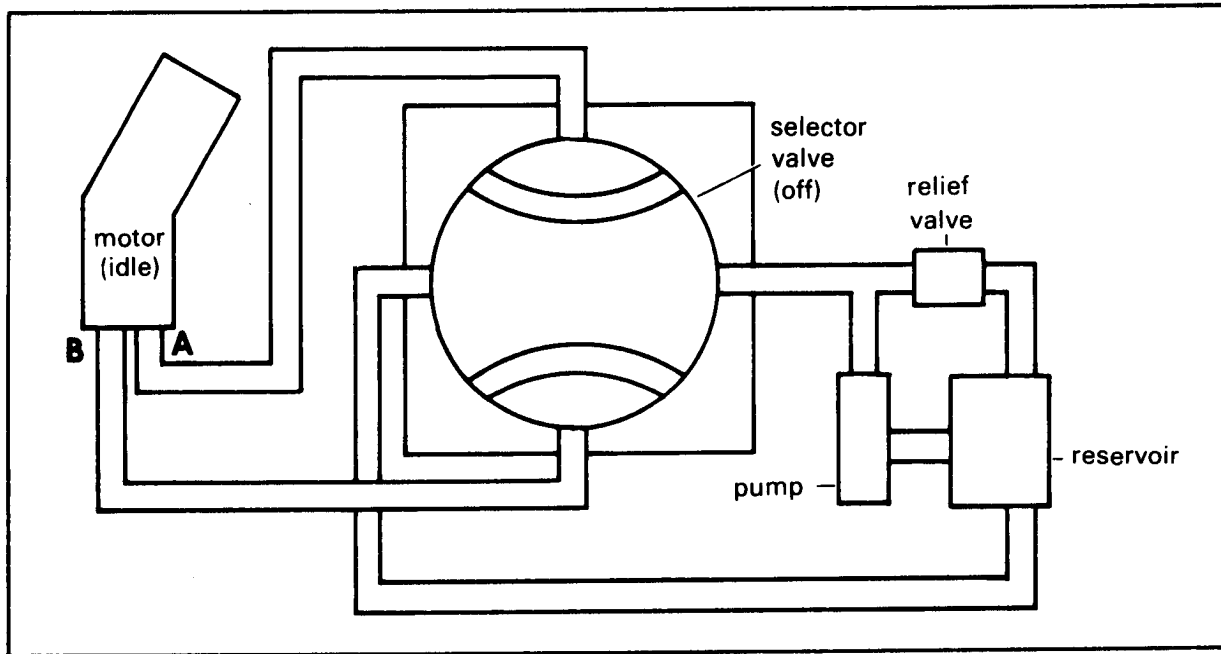
Operation. Selector valves are classified as closed-center and open-center types. These classifications are based on what happens to the flow of fluid when the selector valve is placed in the OFF position. When a closed-center selector valve is placed in the OFF position, its pressure passage is blocked to the flow of fluid; no fluid can pass through its pressure port. When an open-center selector valve is placed in the OFF position, its pressure passage and return passage become interconnected; fluid can flow into the pressure port and out of the return port. Selector valves may be further classified according to their design as cam-operated, in-line, radial, and compound. Valving devices common to all types of selector valves include rotors, spools, poppets, and balls. Selector valve spools are sometimes called pilot valves.

**Closed-Center Selector Valve.** Four-way, closed-center selector valves are most commonly used in aircraft hydraulic systems. Rotor and spool-type valving devices are used in these valves. The valves operate in one OFF position and two ON positions.

Closed-center, rotor-type selector valve. This valve has a thick circular disk-shaped rotor as its valving device. Figure 8-1 shows a typical four-way, closed-center, rotor-type selector valve in the OFF

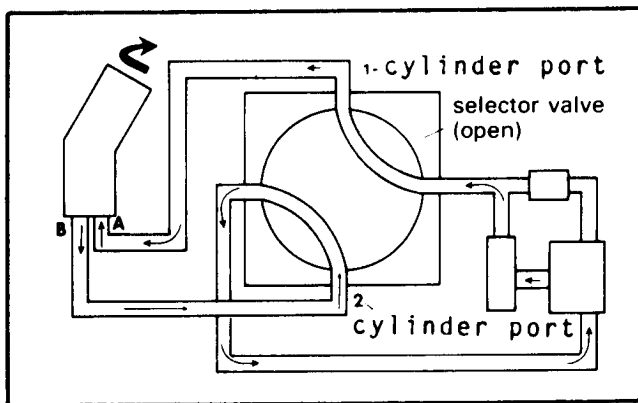


position. In this position, all the valve ports are blocked; no fluid can flow into or out of the valve.



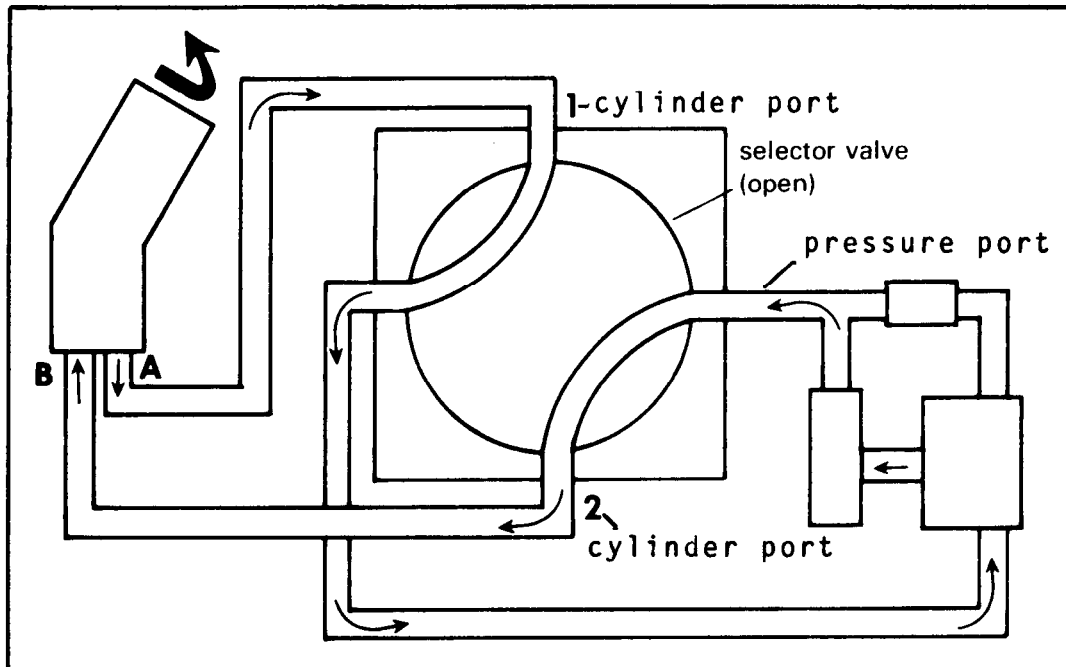
**Figure 8-1. Closed-center, rotor-type selector valve in the OFF position.**

Figure 8-2 shows the closed-center, rotor-type selector valve in the ON position. In this position, the pressure port and cylinder 1 port become interconnected within the valve. As a result, fluid flows from the pump through the selector valve pressure port, out of the selector valve cylinder 1 port, and through port A of the motor. This flow of fluid causes the motor to turn in a clockwise direction. At the same time, return fluid is forced out of port B and enters the selector valve cylinder 2 port. Fluid then proceeds through the passage in the valve rotor and leaves the valve through the return port.



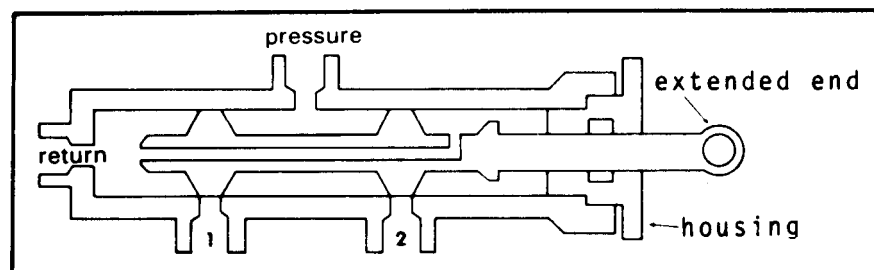
**Figure 8-2. Closed-center, rotor-type selector valve in the ON position.**

In Figure 8-3, the pressure port and cylinder 2 port become interconnected. This causes fluid pressure to be delivered to port B and the motor to turn in a counterclockwise direction. Return fluid then leaves port A, enters the selector valve cylinder 1 port, and leaves through the selector valve return port.



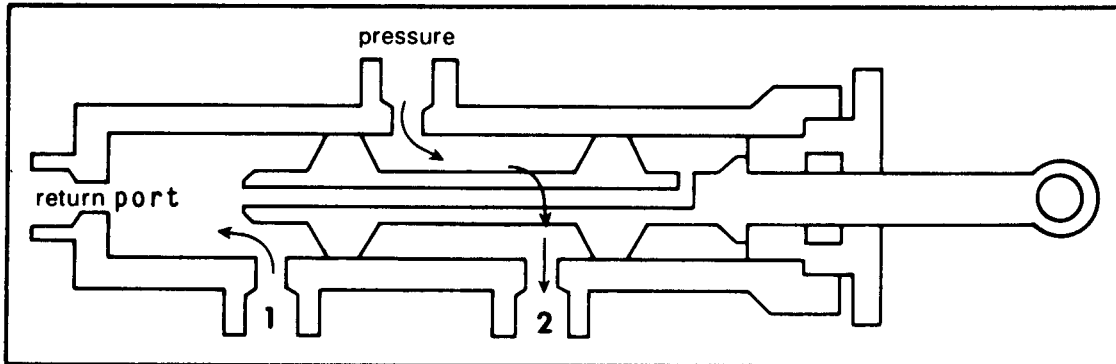
**Figure 8-3. Closed-center, rotor-type selector valve with pressure port and cylinder 2 port interconnected.**

Closed-center, spool-type selector valve. In this type selector valve, the spool is one piece, leaktight, and slides freely in the valve housing. It can be moved lengthwise in the housing by the extended end which sticks out through the housing. A drilled hole in the spool connects the two end chambers of the selector valve. In the OFF position, the two cylinder ports are directly blocked by the seats of the spool. (See Figure 8-4.) This indirectly blocks the pressure and return ports; no fluid can flow into or out of the valve. Moving the spool toward the right moves the spool seats away from the cylinder 1 and 2 ports.



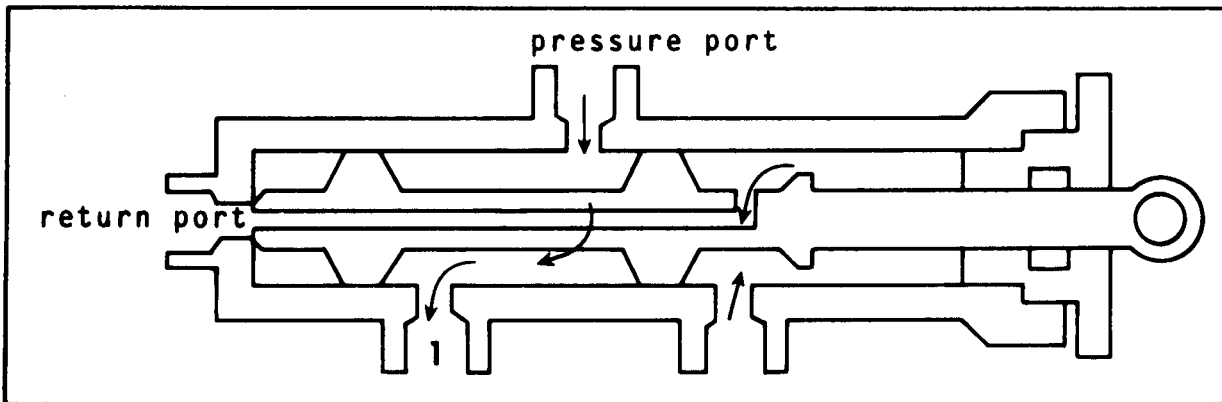
**Figure 8-4. Closed-center, spool-type selector valve in the OFF position.**

The pressure port and the cylinder 2 port then become interconnected. (See Figure 8-5.) This permits fluid pressure to pass on to the actuating unit. The return port and the cylinder 1 port also become interconnected. This provides an open route for the return of fluid from the actuating unit to the system reservoir.



**Figure 8-5. Closed-center, spool-type selector valve with pressure port and cylinder 2 port interconnected.**

Moving the spool toward the left moves the spool seats away from the cylinder 1 and 2 ports. The pressure port and the cylinder 1 port then become interconnected. (See Figure 8-6.) This permits fluid pressure to flow to the actuating unit. The return port and the cylinder 2 port also become interconnected, providing a route for the return of fluid from the actuating unit to the reservoir.



**Figure 8-6. Closed-center, spool-type selector valve with pressure port and cylinder 1 port interconnected.**

**Open-Center Selector Valve.** The outside appearance of the open-center selector valve is the same as that of the closed-center type. Like the closed-center type, four-way, open-center selector valves have four ports and operate in one OFF and two ON positions. The differences between the two are in the OFF-position operation of the valves. In the closed-center type, none of the ports are open to each other when the valve is in the OFF position; in the open-center type, the pressure and return ports are open

to each other when the valve is in the OFF position. Important points to remember about hydraulic systems incorporating an open-center selector valve are--

- The system is designated as an open-center system.
- When the selector valve is in the OFF position, the output of the system pump is returned through the selector valve to the reservoir with practically no resistance. Therefore, in an open-center system, operating pressure is present only when an actuating unit is being used. Because of this, a slight delay occurs in the response of an actuating unit in some open-center systems after the selector valve has been placed in the ON position.
- Only open-center-type selector valves are used in open-center systems.
- No more than one actuating unit can be efficiently used at one time in an open-center system.

Open-center, rotor-type selector valve. In open-center selector valves having rotor-type valving devices, two passages in the rotor interconnect the pressure and return ports with the cylinder ports. A third passage interconnects the pressure and return ports when the valve is in the OFF position. When the selector valve is turned to the OFF position, fluid from the pump enters the selector valve pressure port and passes through the open-center passage in the rotor, through the selector valve return port, and back to the reservoir. (See Figure 8-7.) When the selector valve is moved to the ON position, its operation is identical to that of the closed-center, rotor-type selector valve.

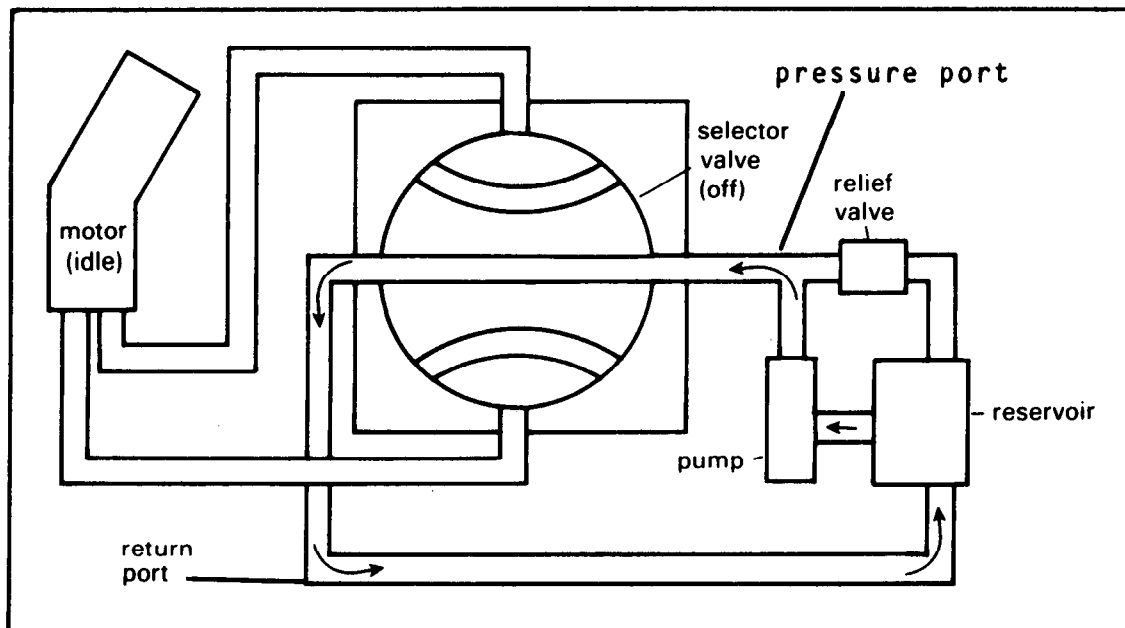
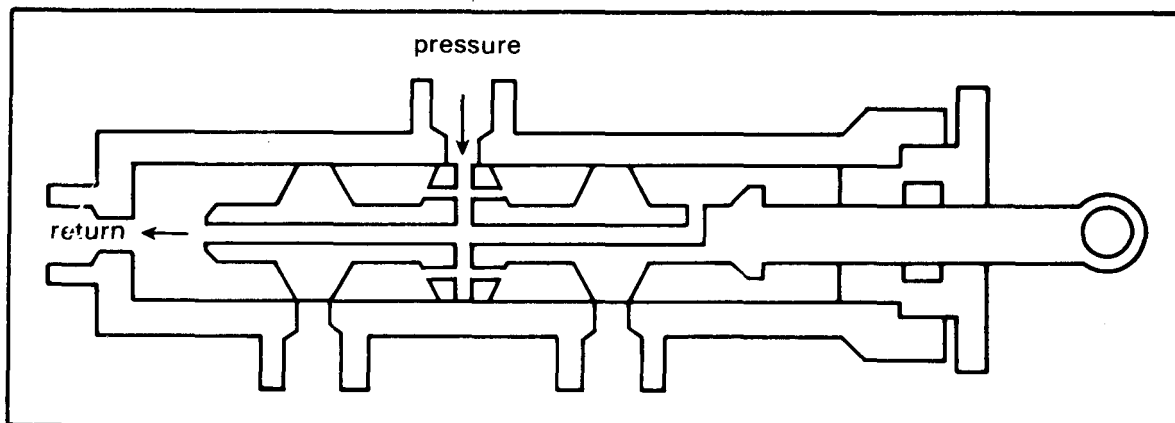


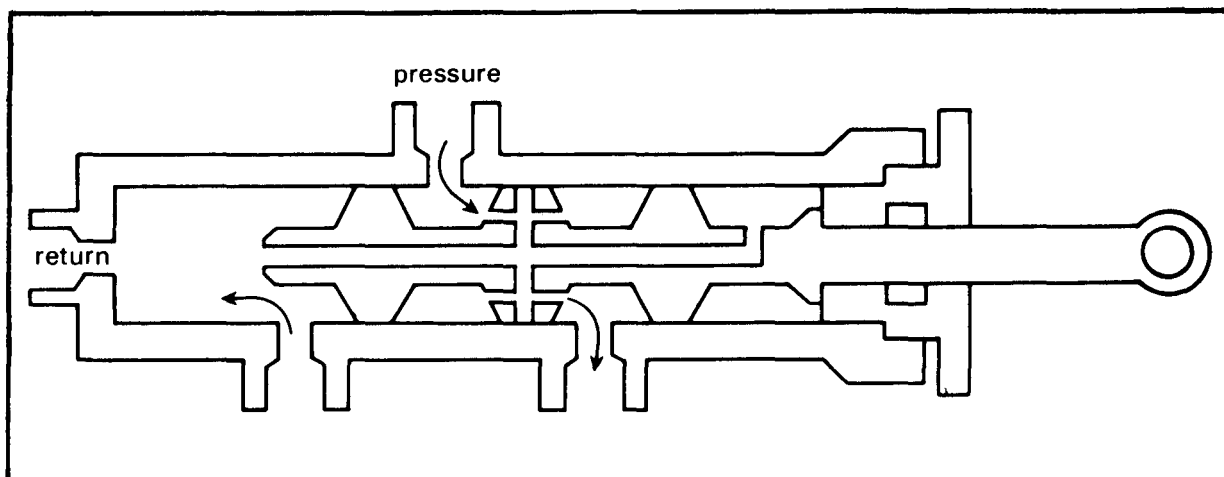
Figure 8-7. Open-center, rotor-type selector valve in the OFF position.

Open-center, spool-type selector valve. The operation of the open-center, spool-type selector valve is generally similar to the open-center, rotor-type selector valve. Figure 8-8 shows a typical open-center, spool-type selector valve in the OFF position. When the valve is in the OFF position, the center seat provides an interconnection between the pressure port and the drilled passage in the spool. This permits fluid entering the pressure port to pass freely through the valve and out of the return port.



**Figure 8-8. Open-center, spool-type selector valve in the OFF position.**

When the valve is placed in either of the ON positions (Figure 8-9), the groove in the center seat is blocked by the bore well of the valve housing; fluid cannot pass through it as it does in the OFF position. Under these conditions, fluid flows in the same direction as in the corresponding ON positions of the closed-center, spool-type selector valve described above.

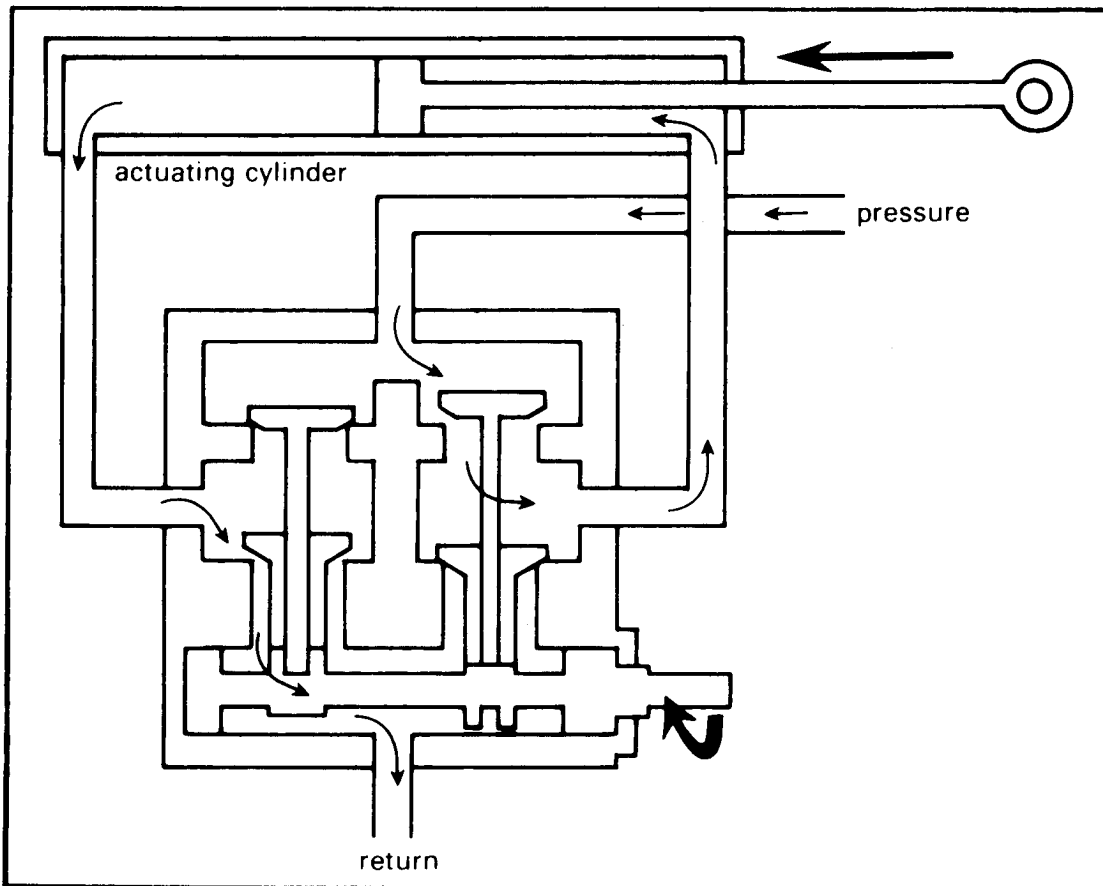


**Figure 8-9. Open-center, spool-type selector valve in the ON position.**

### Cam-Operated Selector Valve (Open-Center or Closed-Center).

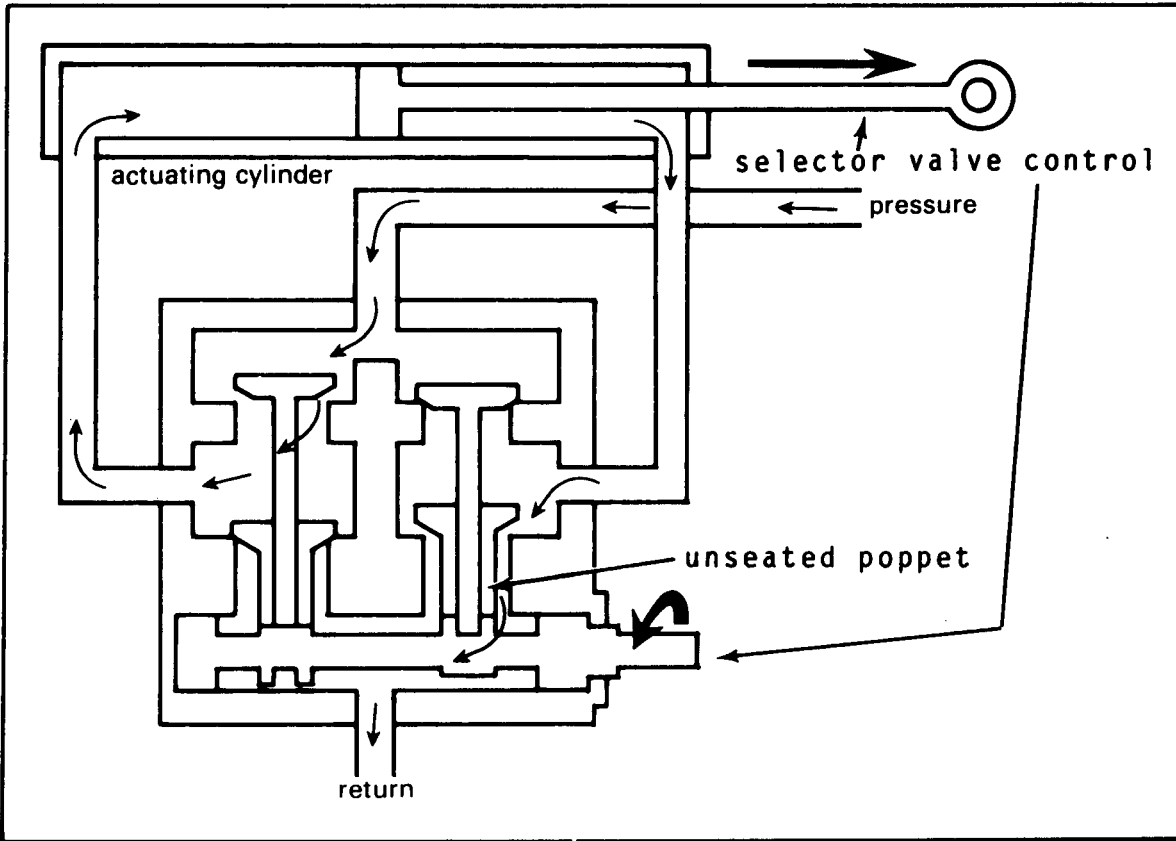
Poppet-type and ball-type selector valves are operated by cams that lift the poppet or ball off its seat. Purpose, use, and operation of the two types are the same: One controls fluid flow by using poppets; the other uses a ball-shaped valve. The piston-type selector valve may also be cam-operated. In this case, flow is directed by the sliding action of a piston, which is a spool-shaped plunger within a housing.

In-line, cam-operated selector valve (poppet-type). The poppets of an in-line selector valve are similar to the pistons of an in-line aircraft engine. In the neutral position, all four poppets are closed. With this type of valve, a pressure rise caused by an increase in temperature in either cylinder line can unseat an upper poppet. This will relieve the pressure into the return line. An integral temperature relief valve that relieves pressure from the pressure manifold into the return line is used in several models of this valve. Figure 8-10 illustrates a condition in which fluid pressure is forcing the actuating cylinder piston inward, permitting fluid to flow from the actuating cylinder through the lower unseated poppet to the return line.



**Figure 8-10. In-line, cam-operated selector valve with fluid pressure forcing the actuating cylinder piston inward.**

Figure 8-11 shows the selector valve control placed in the opposite direction. Fluid pressure is forcing the actuating cylinder piston outward, and fluid from the actuating cylinder flows through the other unseated poppet to the return line.

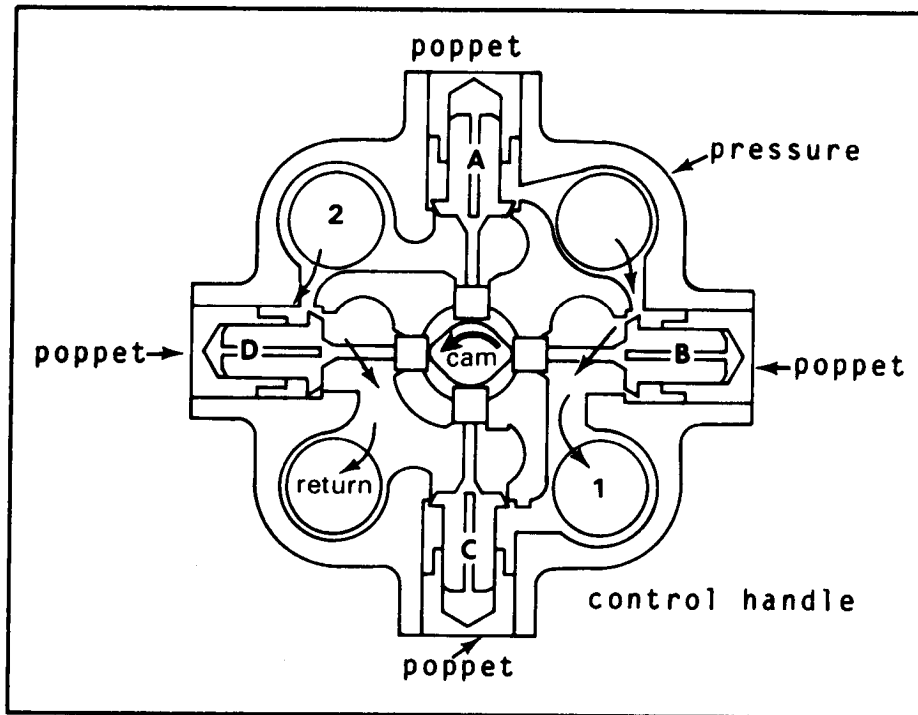


**Figure 8-11. In-line, cam-operated selector valve with fluid pressure forcing the actuating cylinder piston outward.**

Radial, cam-operated selector valve. The two types of radial selector valves are the poppet-type selector valve and the spool-type selector valve.

In the typical poppet-type, radial selector valve, the cam in the center is attached to a control handle. (See Figure 8-12.) Moving the control handle causes the cam to rotate and to move the poppets on or off their seats. In Figure 8-12, poppets A and C are seated, and poppets B and D are unseated. Fluid entering the inlet pressure port flows around poppet B to the actuator unit through the cylinder 1 port. Fluid returning from the actuator unit enters through the cylinder 2 port, flows around poppet D, and exits through the return line. If the cam is rotated 90°, poppets A and C will unseat, and poppets B and D will seat. Fluid entering the inlet pressure port then passes around poppet A to the actuator unit through the cylinder 2 port. Fluid returning from the actuator unit flows to the return line by entering the selector valve through the cylinder 1 port,

flowing around poppet C, and exiting through the return port. If the cam is rotated 45° from the position shown in Figure 8-12, all the poppets are seated, and the selector valve is in a neutral position.



**Figure 8-12. Poppet-type, radial, cam-operated selector valve.**

The spool-type, radial selector valve operates in the same manner as the poppet type. The spools are plungers within the valve housing. Drilled or cutaway passages in the spools are aligned with drilled passages in the valve housing when the spools are raised by the cam.

**Compound Selector Valve.** To conserve space and to make installation easy when banks of units must be controlled, several selector valves are compounded into one unit. Each selector valve is controlled independently, but only one connection is needed for the pressure line and one for the return line.

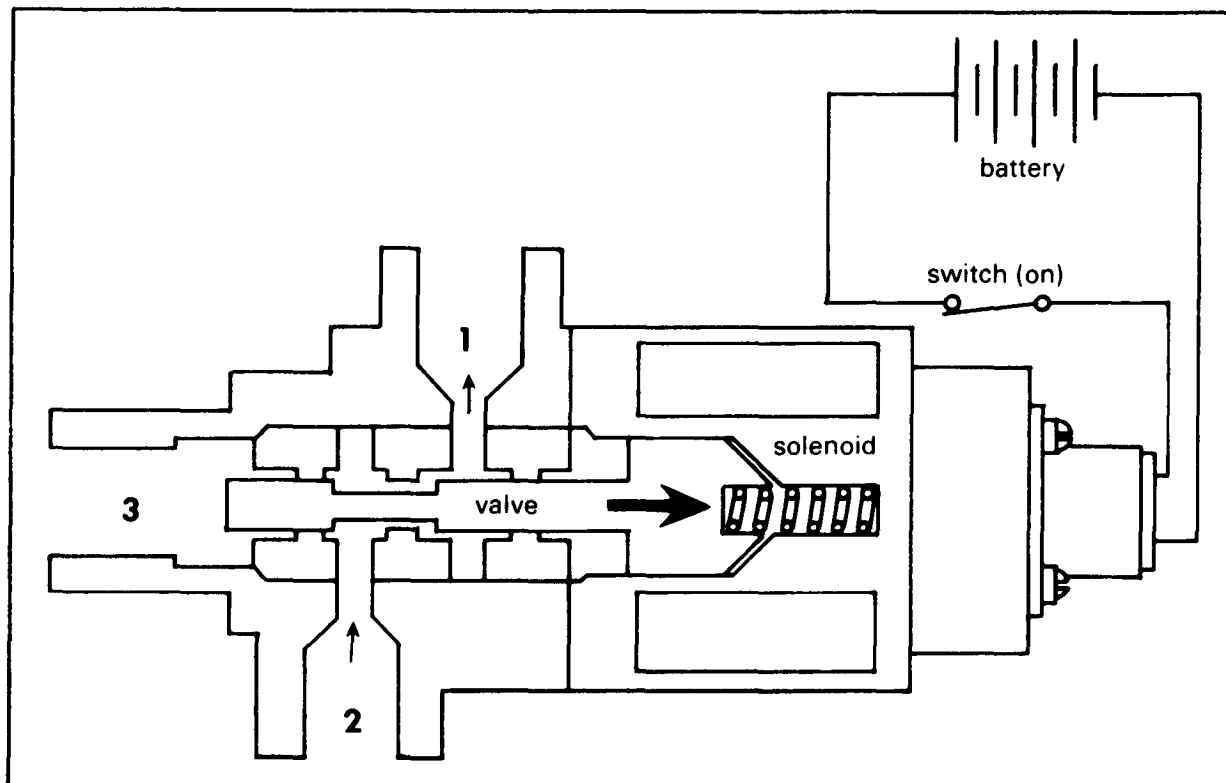
## CONTROL VALVES

**Purpose.** Hydraulic valves control movement or pressure of fluids in hydraulic systems. Generally, all valves are control valves; however, for some Army aircraft, the term "control valve" identifies a valve that controls the direction of flow through alternate channels. Such a valve does not do quite as much in the control of fluid flow as the selector valve does; the control valve functions more like a shutoff valve.

**Operation.** Although some control valves have more than three ports, the valve most commonly referred to in Army aircraft as a control valve is

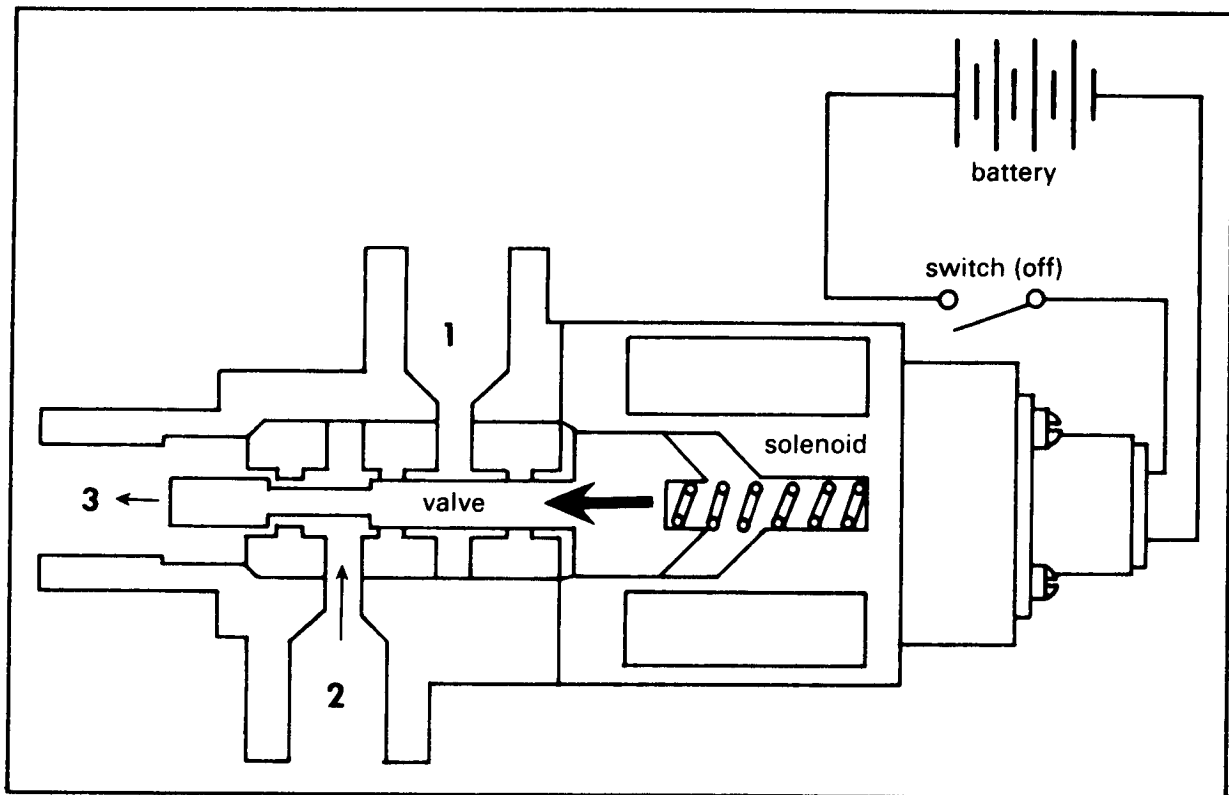


one having three ports and providing pathways for fluid flow. However, the nomenclature is not standardized. For some aircraft, this type of valve is called a three-way, solenoid-actuated control valve. (See Figure 8-13.)



**Figure 8-13. Three-way, solenoid-actuated control valve (solenoid energized).**

Some control valves are actuated manually; others, electrically. Electrical actuation may be by either a solenoid or a motor. A solenoid-actuated valve is shown in Figure 8-14. The valving device of the solenoid-actuated valve is spring-loaded to one position and solenoid-actuated to the other position. However, some solenoid-actuated valves have three operating positions. In such valves, a spring holds the valving device in one position, and a solenoid moves the valving device to either of the other two positions against the resistance of the spring. In Figure 8-14, the control valve ports are identified by numbers rather than by function (pressure, return, system, and so forth). Identifying the ports by numbers provides different patterns of flow through a control valve by varying the interconnection of lines to ports. The line to be interconnected with a port depends on the desired pattern of flow through a valve.



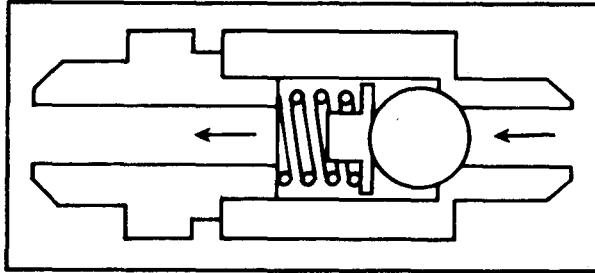
**Figure 8-14. Solenoid-actuated control valve (solenoid de-energized).**

## CHECK VALVES

**Purpose.** For hydraulic components and systems to operate as they should, the flow of fluid must be rigidly controlled. Fluid must be made to flow according to the needs of the system. Many kinds of valve units are used for exercising such control. One of the simplest and most commonly used is the check valve. The check valve allows free flow of fluid in one direction but no flow or a restricted flow in the other direction.

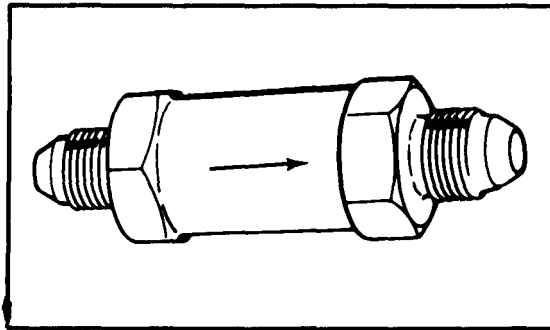
**Operation.** Check valves are made in two general designs to serve two different needs. In one design, the check valve is complete within itself; it is interconnected by tubing or hose with other components. This type of check valve is commonly called an in-line check valve. The two types of in-line check valves are the simple type and the orifice type. In the other design, the check valve does not have a housing of its own; this type is commonly called an integral check valve. This valve is actually an integral part of some major component and shares the housing of that component. Integral check valves are similar to the in-line type. They come in simple and orifice designs and operate on the same general principles as the in-line valves. Check valves may use any one of several types of valving devices: balls, disks, needles, and poppets.

**Simple-Type, In-Line Check Valve.** (See Figure 8-15.) These valves are used when a flow of fluid is desired in only one direction. Fluid entering the inlet port of the check valve forces the valving device off its seat and against the spring. This permits fluid to flow through the open passageway. When the fluid stops moving in this direction, the valving device is returned to its seat by the spring. This blocks the opening in the valve seat and the flow of fluid through the valve.



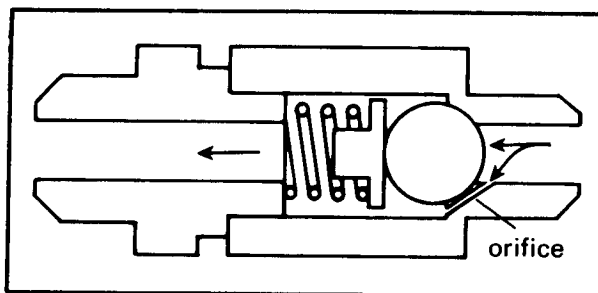
**Figure 8-15. Simple-type, in-line check valve.**

The direction of fluid flow through in-line check valves is indicated by stamped arrow markings on the housing. On the simple-type, in-line check valve, a single arrow shows the direction of fluid flow. (See Figure 8-16.)



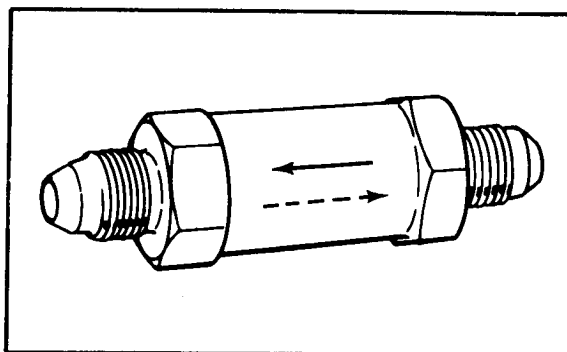
**Figure 8-16. Simple-type, in-line check valve marked with a single arrow.**

**Orifice-Type, In-Line Check Valve.** (See Figure 8-17.) These valves (sometimes called damping valves) are used to allow the normal operating speed of a mechanism by providing free flow of fluid in one direction, while allowing limited operating speed through restricted flow of fluid in the opposite direction. The operation of this check valve is the same as that of the simple type except for the restricted flow allowed when closed. This is accomplished by having a second opening in the valve seat. This second opening is never closed and is where some reverse flow can take place through the valve. The second opening is much smaller than the opening in the valve seat. As a rule, this opening is a specified size to control the rate at which fluid can flow through the valve in reverse.



**Figure 8-17. Orifice-type, in-line check valve.**

The orifice-type, in-line check valve is usually marked with two arrows. (See Figure 8-18.) One arrow is more pronounced than the other; it indicates the direction of unrestricted flow. The other arrow is either smaller than the first or has a broken-line construction; it points in the direction of restricted reverse fluid flow.



**Figure 8-18. Orifice-type, in-line check valve marked with two arrows.**

## SEQUENCE VALVES

**Purpose.** Sequence valves (sometimes called timer check valves) set up a sequence of operation. In Army aircraft, these valves are used in such mechanisms as landing gear doors, landing gear uplocks and downlocks, cargo doors, ramps, locks, and ejection seats to cause hydraulic operations to occur in a specific order.

**Operation.** Two major types of sequence valves used are the mechanically actuated type and the pressure-actuated type.

**Mechanically Actuated Sequence Valve.** This valve is commonly used in Army aircraft. It consists of a housing with two ports, a ball valving device, two springs, a plunger that extends through one end of the housing, and the necessary seals to prevent leakage. In Figure 8-19, the input pressure line is connected to port 1. The unit operated by the fluid

passing through the sequence valve is connected to port 2. The passage interconnecting ports 1 and 2 is blocked when the spring-loaded ball is seated.

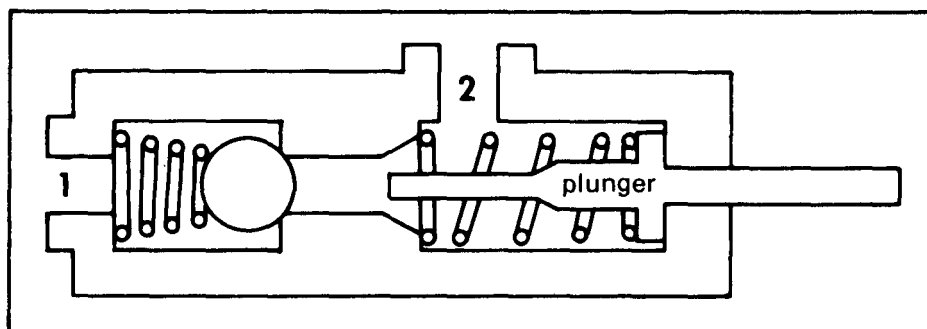


Figure 8-19. Mechanically actuated sequence valve (closed).

When the spring-loaded plunger is depressed, the ball is lifted off its seat. Fluid can then flow in through port 1 and out through port 2 to activate the actuating unit connected to port 2. (See Figure 8-20.) Reverse flow through the sequence valve can take place with or without the plunger being depressed since the reverse moving fluid can easily lift the ball off its seat against the relatively light resistance of the ball spring.

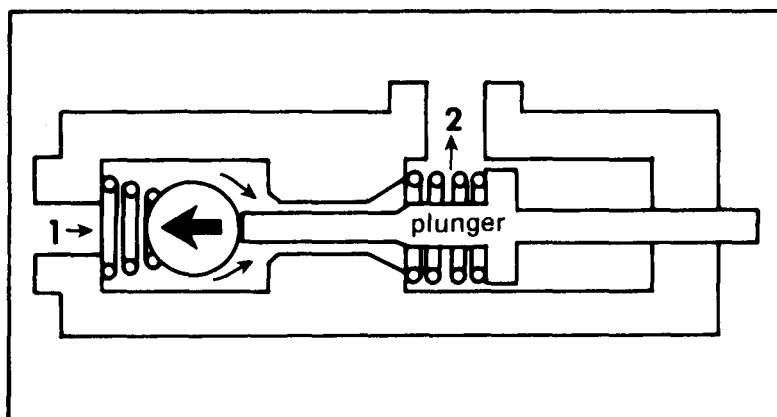
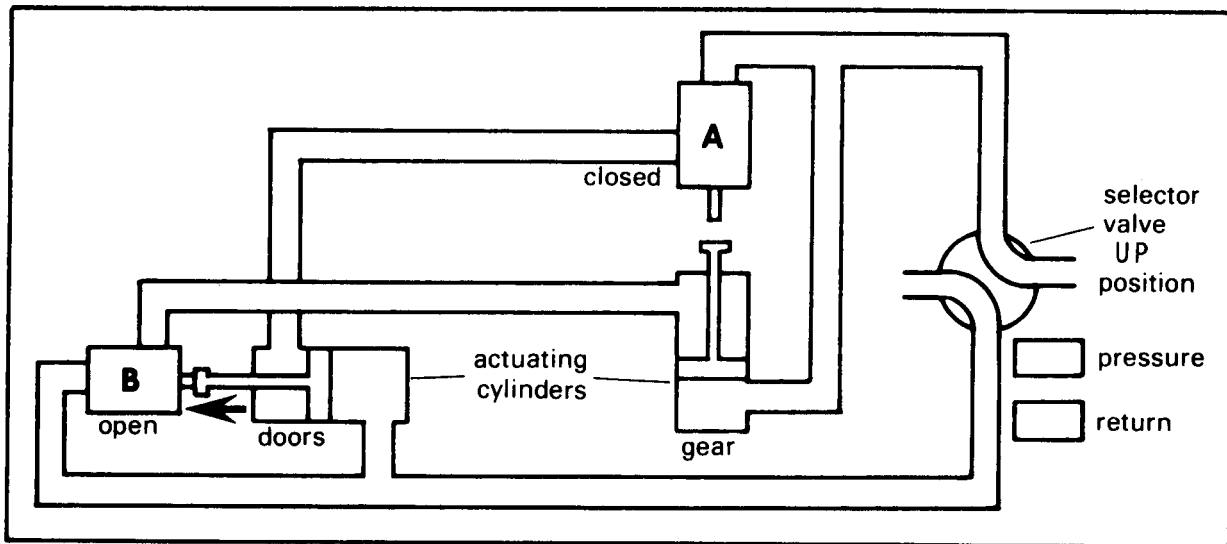


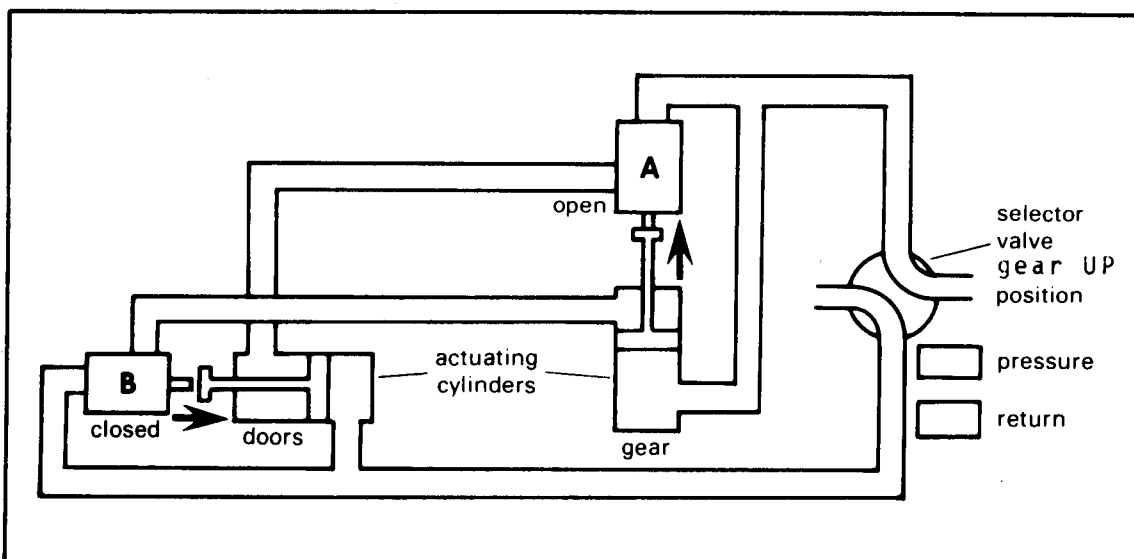
Figure 8-20. Mechanically actuated sequence valve (open).

Figure 8-21 shows a landing gear system where mechanically actuated sequence valves are used. In this simple landing gear system using landing gear well doors, the doors must open before the landing gear is extended and must close after the gear is retracted. With the landing gear selector valve in the UP position, pressure is directed to the UP side of the landing gear actuating cylinder and to sequence valve A. At this point, sequence valve A is closed; sequence valve B is open because the landing gear door is open and is depressing the plunger of sequence valve B. This allows return fluid from the gear actuating cylinder to pass through sequence valve B, through the selector valve, and back to the reservoir.



**Figure 8-21. Landing gear system using mechanically actuated sequence valves with gear retracting.**

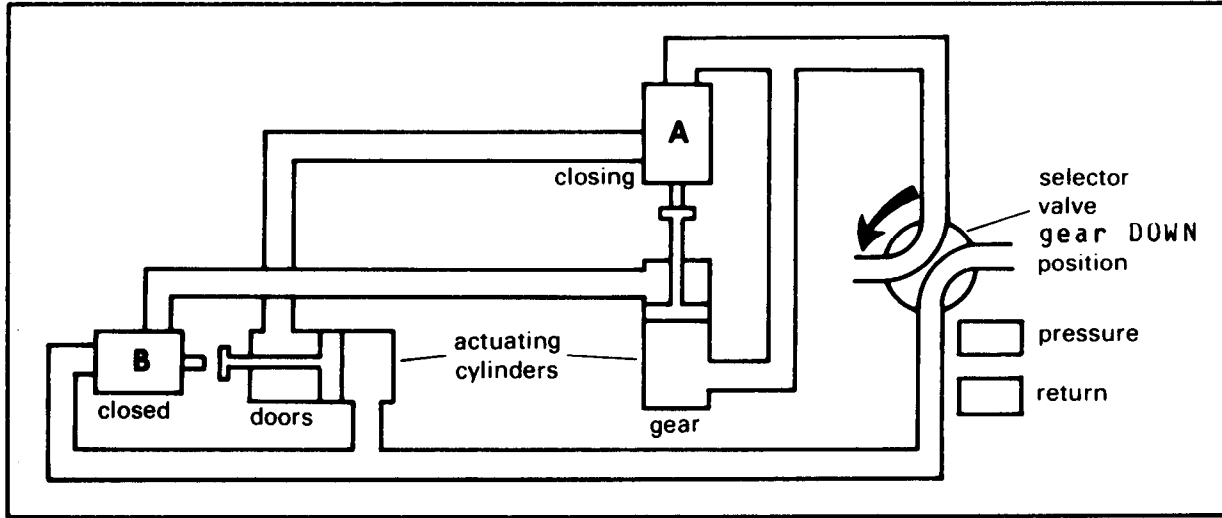
As retraction of the landing gear nears completion, the gear actuating cylinder piston rod extends far enough to contact and depress the plunger of sequence valve A. (See Figure 8-22.) As the plunger moves, it pushes the ball off its seat, allowing fluid to flow through the valve to the closing side of the door actuating cylinder. As the door actuating cylinder closes the door, the cylinder piston rod releases the spring-loaded plunger of sequence valve B and the valve closes.



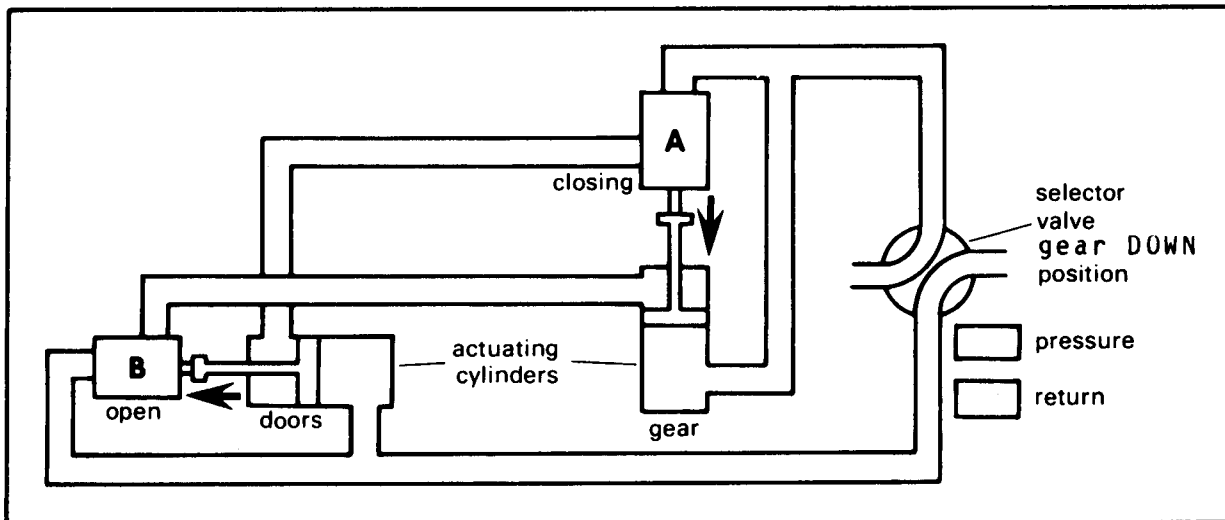
**Figure 8-22. Landing gear system using mechanically actuated sequence valves with gear retraction near completion.**

When the landing gear selector valve is moved for gear extension, pressure is directed to the opening side of the door actuating cylinder and

to sequence valve B. Since sequence valve B is now closed, fluid cannot pass through it. (See Figure 8-23.)

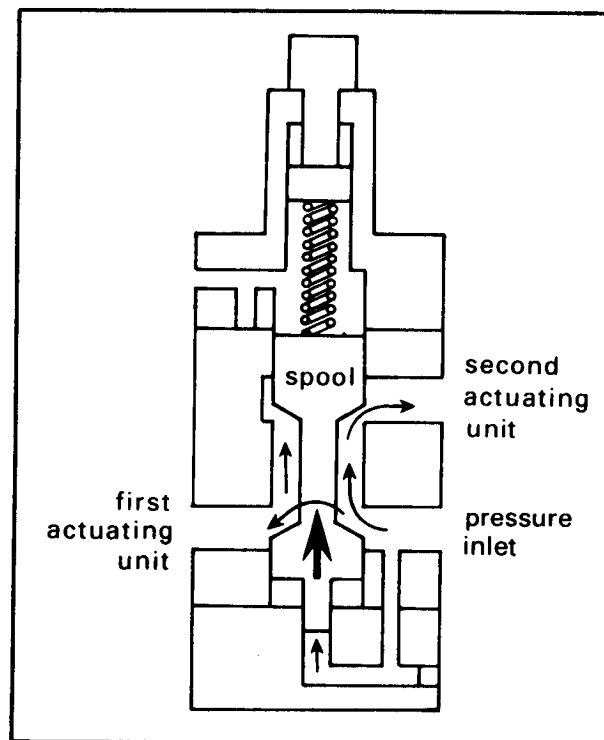


When the door is opened, the door actuating cylinder piston rod extends far enough to contact and depress the plunger of sequence valve B. (See Figure 8-24.) This opens sequence valve B and allows fluid pressure to pass through to the DOWN side of the landing gear actuating cylinder, extending the gear. Return fluid from the door actuating cylinder is routed to the reservoir through sequence valve A while the landing gear is still retracted and the sequence valve is still open.



**Figure 8-24. Landing gear system using mechanically actuated sequence valves with gear extension near completion.**

**Pressure-Actuated Sequence Valve.** This valve consists of a three-port housing, a spool-type valving device, and an adjustable spring. The operation of this valve depends upon the movement of the spring-loaded spool. (See Figure 8-25.) Unlike the mechanically operated type, no mechanical contact with any other unit is necessary to operate a pressure-actuated sequence valve. When the selector valve is positioned, fluid pressure is directed to the pressure inlet port of the sequence valve and passes through the valve to the first unit to be actuated. The pressure necessary to operate this unit is less than that required to move the spool against the restraint of its spring. After the operation of the first unit is completed and the flow ceases, pressure in the passage between the pressure inlet port and the first unit port increases. This pressure is conducted through a special passage to the underside of the pilot piston on the lower end of the spool, forcing the spool upward until the passage between the pressure inlet port and the port to the second unit becomes unblocked. Fluid then flows into the second unit, causing it to operate.



**Figure 8-25. Pressure-actuated sequence valve.**

## PRIORITY VALVES

**Purpose.** Priority valves are installed in hydraulic systems to provide adequate fluid flow to units requiring immediate completion of action. The valve is installed in the line between an actuating unit--where completion of action can be delayed--and its source of operating pressure. As long as system pressure is normal, the flow of fluid to the delayable unit is unrestrained. When system pressure drops below normal, the priority valve



automatically reduces the rate of flow to the unit not requiring immediate completion of action. Priority valves give operating priority to such units as brakes, landing gear, and flaps.

**Operation.** A priority valve having a full-flow capacity of 4 gallons per minute (GPM) at 1,500 psi (Figure 8-26) and a reduced-flow capacity of 1 GPM at 1,000 psi (Figure 8-27) controls fluid flow to an actuating cylinder that can use as much as 3 GPM. Flow capacity of the orifice is 1 GPM at 1,000 psi and 1.5 GPM at 1,500 psi. Flow capacity past the valve seat is 2.5 GPM at 1,500 psi. When fluid pressure entering the priority valve exceeds 1,000 psi, the force of the fluid on the spring-loaded valving device is enough to overcome the spring tension. This causes the spring-loaded valving device to move toward the outlet port. Fluid then flows through both the orifice and the valve seat. As fluid pressure increases, the spring-loaded valving device moves farther toward the outlet port, causing a greater rate of fluid flow. When fluid pressure within the priority valve drops below 1,000 psi, spring tension overcomes fluid pressure. This seats the spring-loaded valving device against the valve seat. The orifice then becomes the only path for the fluid, cutting the flow rate to 1 GPM.

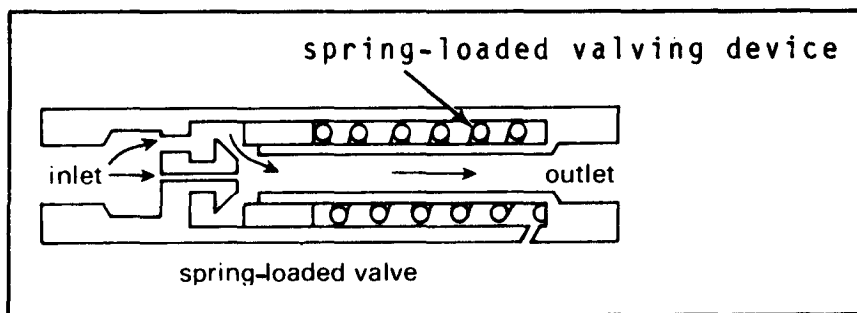


Figure 8-26. Full-flow priority valve with 4 GPM at 1,500 psi.

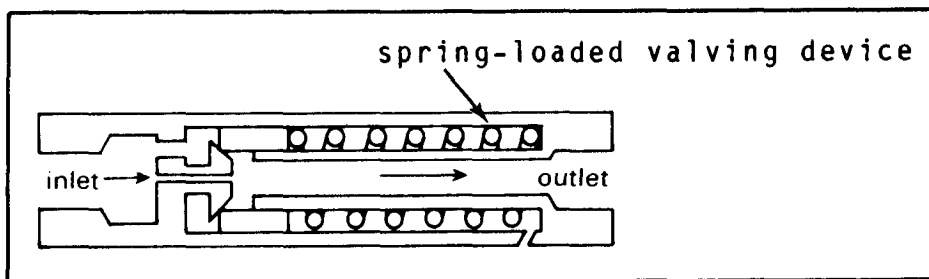


Figure 8-27. Flow-reduced priority valve with 1 GPM at 1,000 psi.

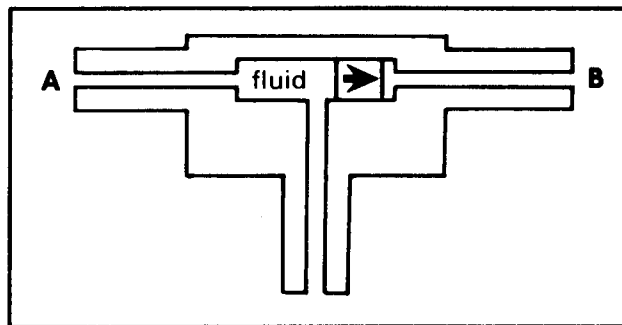
## SHUTTLE VALVES

**Purpose.** In some cases, two sources of operating pressure are connected to a single component or system. One of the pressure sources will be reserved for emergency use. In such cases, shuttle valves are

usually used to eliminate any possible transfer of fluid from one pressure source to the other. Army aircraft equipped with dual brake systems use shuttle valves to isolate the pilot and copilot master cylinders from each other to allow optional operation of the brakes by either set of master cylinders. Also, Army aircraft having compressed-air equipment for emergency use of landing gear and wheel brakes use shuttle valves to isolate the system hydraulic fluid from the compressed air or other authorized gas used in emergencies.

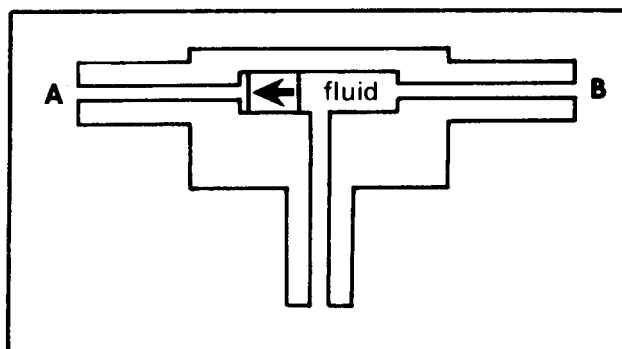
Operation. The two types of shuttle valves used are the floating-piston type and the detent type.

**Floating-Piston-Type Shuttle Valve.** In this type valve, fluid entering the shuttle valve from pressure source A moves the piston to block the flow from pressure source B so that fluid flows to the unit being actuated from pressure source A only. (See Figure 8-28.)



**Figure 8-28. Floating-piston-type shuttle valve with fluid entering from pressure source A.**

Conversely, fluid entering from pressure source B would reposition the piston to block the flow from pressure source A; fluid would then flow to the unit being actuated from pressure source B only. (See Figure 8-29.) The piston is restrained against random movement by the slight drag of the O-ring against the cylinder walls.



**Figure 8-29. Floating-piston-type shuttle valve with fluid entering from pressure source B.**

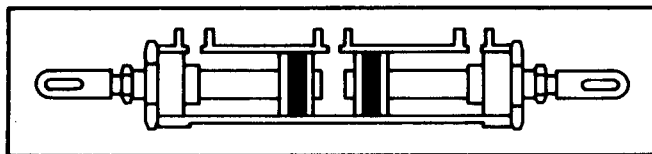
**Detent-Type Shuttle Valve.** This type valve operates on the same general principles as the floating-piston type except that a spring-loaded detent ball holds the piston in the position dictated by the pressure source.

## ACTUATING CYLINDERS

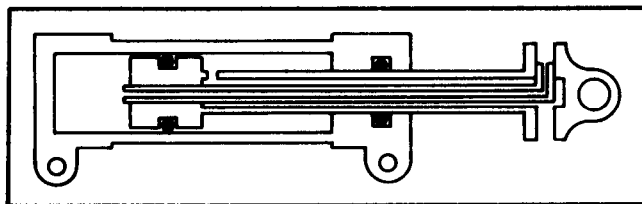
**Purpose.** Actuating cylinders transform energy in the form of fluid pressure into mechanical force so that the energy can perform work. They give powered linear motion to some movable object or mechanism.

**Operation.** A typical actuating cylinder is made of a cylinder housing, one or more pistons and piston rods, and the necessary seals to prevent leakage between the piston rods and the end of the cylinder. The cylinder housing contains a polished bore in which the piston operates and one or more ports where fluid enters and leaves the bore. The piston and rod form an assembly. The piston moves forward and backward within the cylinder bore; the rod moves in and out of the cylinder housing through an opening in one end of the housing. Both the cylinder housing and piston rod have provisions for attachment to the mechanism to be moved by the actuating cylinder.

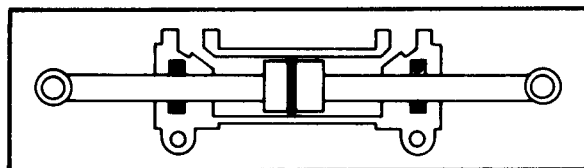
The two major types of actuating cylinders are the single-action type and the double-action type. Several other types are shown in Figures 8-30 through 8-32. However, only the single-action and double-action types will be discussed since they are the ones commonly used in Army aircraft.



**Figure 8-30. Three-port actuating cylinder.**

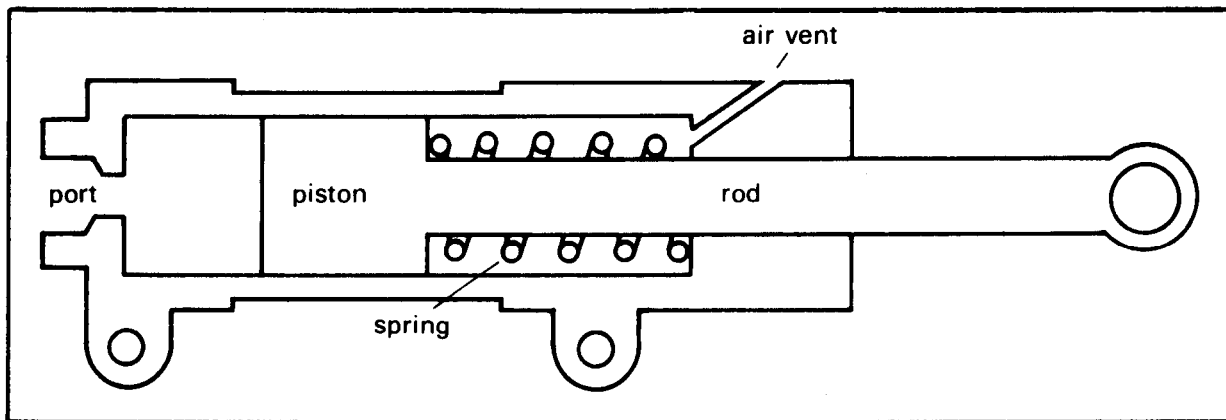


**Figure 8-31. Actuating cylinder with ports in the piston rod.**



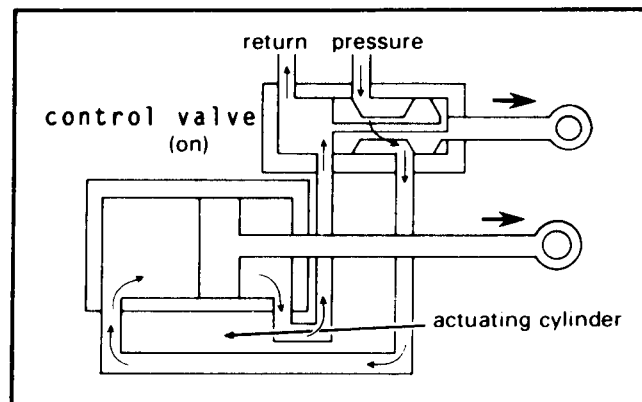
**Figure 8-32. Double-action actuating cylinder with two piston rods.**

**Single-Action (Single-Port) Actuating Cylinder.** This cylinder causes movement in one direction only. The operation of this type of cylinder is controlled by a three-way control valve. In the single-action cylinder, fluid under pressure enters the port at the left and pushes against the face of the piston, forcing the piston to the right. (See Figure 8-33.) As the piston moves, air is forced out of the spring chamber through the vent, and the spring is compressed. When pressure on the fluid is released to a point less than the force in the compressed spring, the spring pushes the piston toward the left. As the piston moves to the left, fluid is forced out of the fluid port and air enters the spring chamber through the vent.



**Figure 8-33. Single-action actuating cylinder (single-port).**

**Double-Action (Two-Port) Actuating Cylinder.** This cylinder causes movement in two directions. The operation of this type of cylinder is usually controlled by a four-way control valve. Placing the control valve in the ON position admits fluid pressure to the left-hand chamber of the actuating cylinder, forcing the piston to the right. (See Figure 8-34.) As the piston moves to the right, it pushes return fluid out of the right-hand chamber and through the control valve to the reservoir.



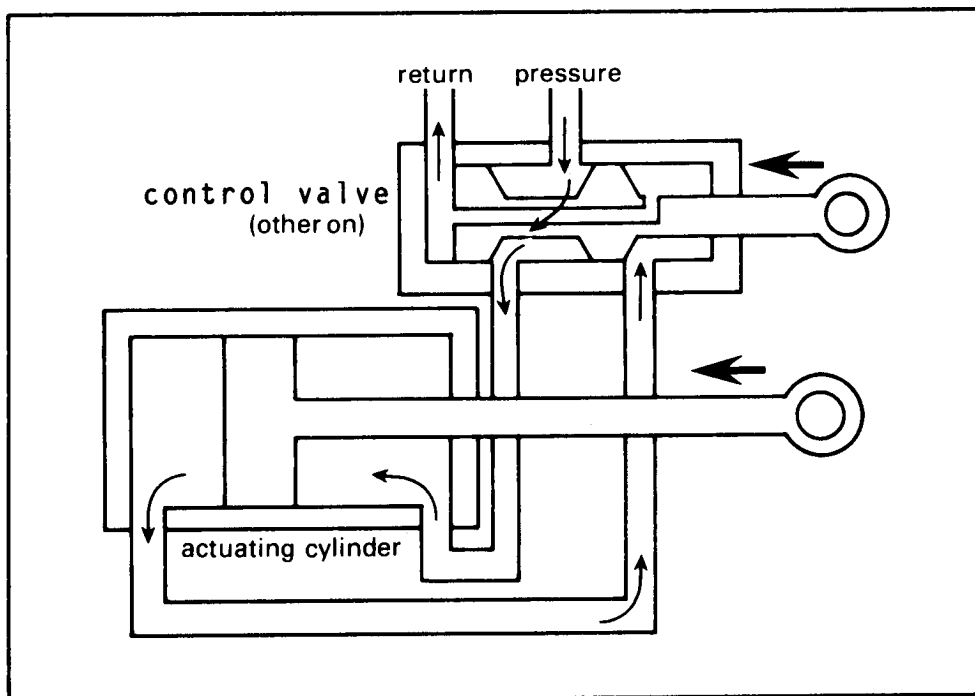
**Figure 8-34. Control valve and double-action cylinder forcing the piston to the right.**

When the control valve is placed in its other ON position, fluid pressure enters the right-hand chamber and forces the piston to the left. (See Figure 8-35.) As the piston moves to the left, it pushes return fluid out of the left-hand chamber through the control valve to the reservoir. Besides having the ability to move a load into position, a double-action cylinder can hold a load in position in opposition to any force which may tend to displace it. This capability exists because when the control valve is placed in the OFF position, fluid is trapped in the chambers on both sides of the actuating cylinder piston. This locks it against movement in either direction.

Sizes. Actuating cylinders are made in various lengths and diameters. Selecting a particular size for a particular job is based on several factors, the most important being--

- How much force the actuating cylinder will be required to put out.
- What length of travel the actuating cylinder must be capable of.
- How much fluid pressure is needed to operate the actuating cylinder.

Because the aircraft's weight must be kept as low as possible, care must be taken not to select actuating cylinders with capabilities exceeding those actually required. Excess capabilities carry the penalty of excess size and weight; the higher the pressure available to operate an actuating cylinder, the smaller its diameter can be.



**Figure 8-35. Control valve and double-action cylinder forcing the piston to the left.**

Maintenance. The seepage of some fluid past shaft end seals and bearings is necessary for their lubrication; however, through normal wear, seepage develops into leakage. A small leakage at piston rod end bearings and seals during operation is normal in actuating cylinders that have been used for some time. Limits have been established as to the amount of leakage permitted at such points. The general military specification for allowable external leakage at each shaft seal and bearing is one drop per 25 cycles of operation (25 full or partial strokes in each direction). This specification always applies except where a different leakage limitation is specifically stated in the publications for the equipment concerned.

Wipers are used to clean and lubricate the exposed portions of piston shafts. They prevent foreign matter from entering the system and scoring internal surfaces. They are used in practically all landing gear shock struts and in most actuating cylinders. Wipers are manufactured for a specific hydraulic component and must be ordered for that application. They are inspected and, if necessary, changed while the component is being repaired.

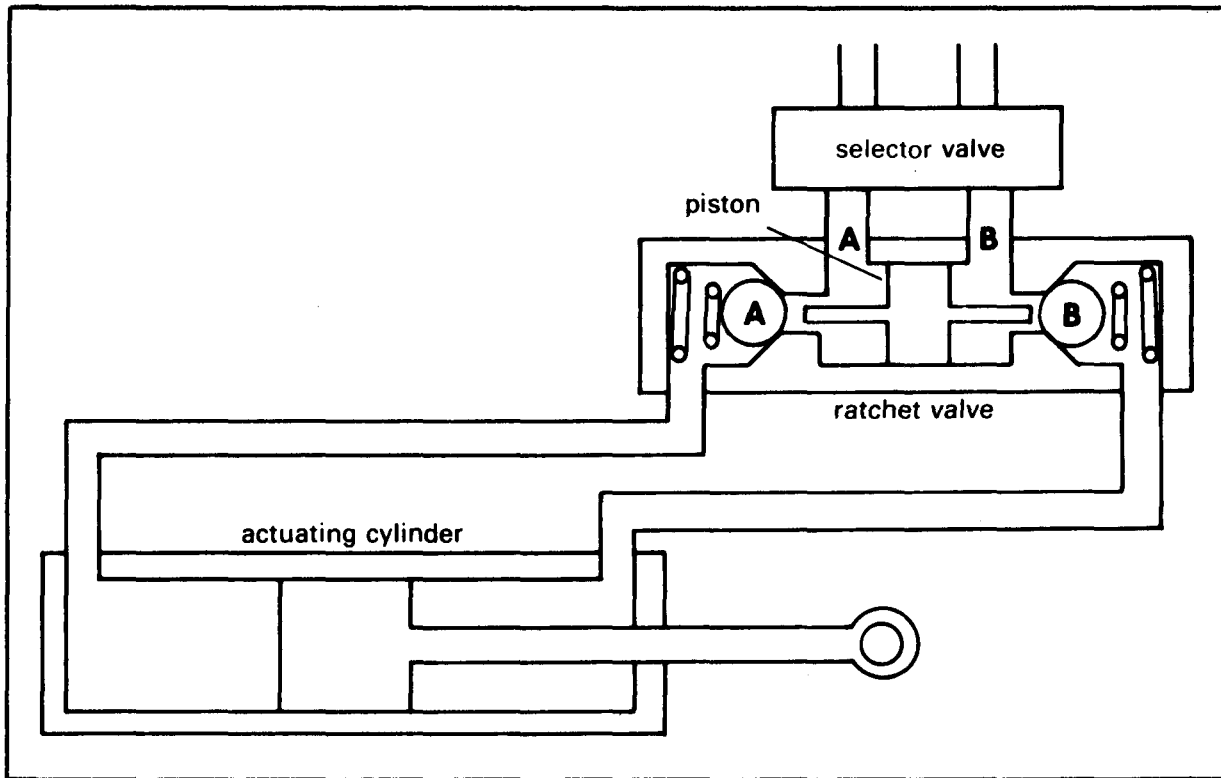
Wipers are made of metal (usually copper-base alloy) or felt. At times, felt and metallic wipers are used together; the felt wiper is installed behind the metallic one. In this type of installation, the felt wiper is normally lubricated with system hydraulic fluid from a drilled bleed passage or an external fitting. Metallic wipers are formed in split rings for easy installation and are manufactured slightly under size to ensure a tight fit. One side of the metallic wiper has a lip which should face outward upon installation. Metallic wipers are inspected for foreign matter and condition; then they are installed by sliding them over the piston shaft in the proper order as directed in the applicable maintenance manual. The felt wiper may be a continuous felt ring or a length of felt with enough material to overlap its ends. During installation, it must be kept clean and soft and well soaked in hydraulic fluid.

## RATCHET VALVES

Purpose. Hydraulic ratchet valves are used as companion devices to double-action actuating cylinders. The ratchet valve helps an actuating cylinder hold a load in the position into which it was moved by the operation of a hand pump. It also ensures that fluid will be trapped on each side of the actuating cylinder piston. This is necessary for the actuating cylinder to lock a load against movement in either direction; it is especially vital should the selector valve which controls the actuating cylinder be left in the ON position or have internal leakage. The ratchet valve does not affect actuating cylinder piston movements that are intentionally produced by the system's operating pressure. Ratchet valves are optional equipment; they are only used when a load must be locked in position.

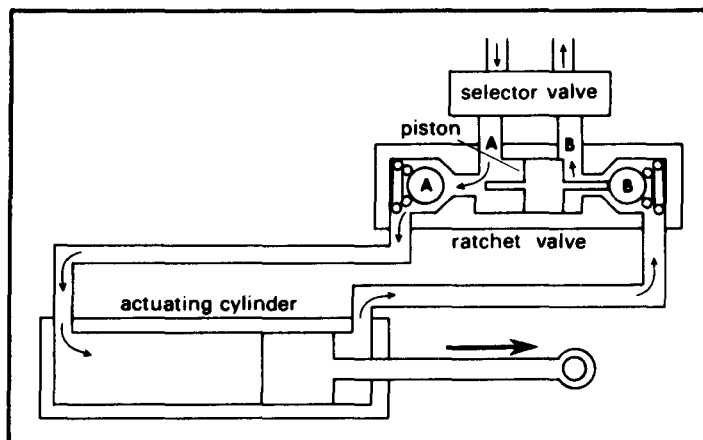
Operation. Figure 8-36 shows the ratchet valve with no pressure applied (selector valve off). The piston is centered in its bore with both

check valves (balls A and B) closed. This locks the actuating cylinder in position by trapping all fluid in the cylinder.



**Figure 8-36. Ratchet valve (off) and actuating cylinder (static).**

Figure 8-37 shows the ratchet valve with pressure applied to port A. This forces the piston to the right where it unseats ball check B. Pressure entering port A unseats ball check A on the left side. Fluid then flows through the ratchet valve; the piston moves to the right, unseating ball check B.

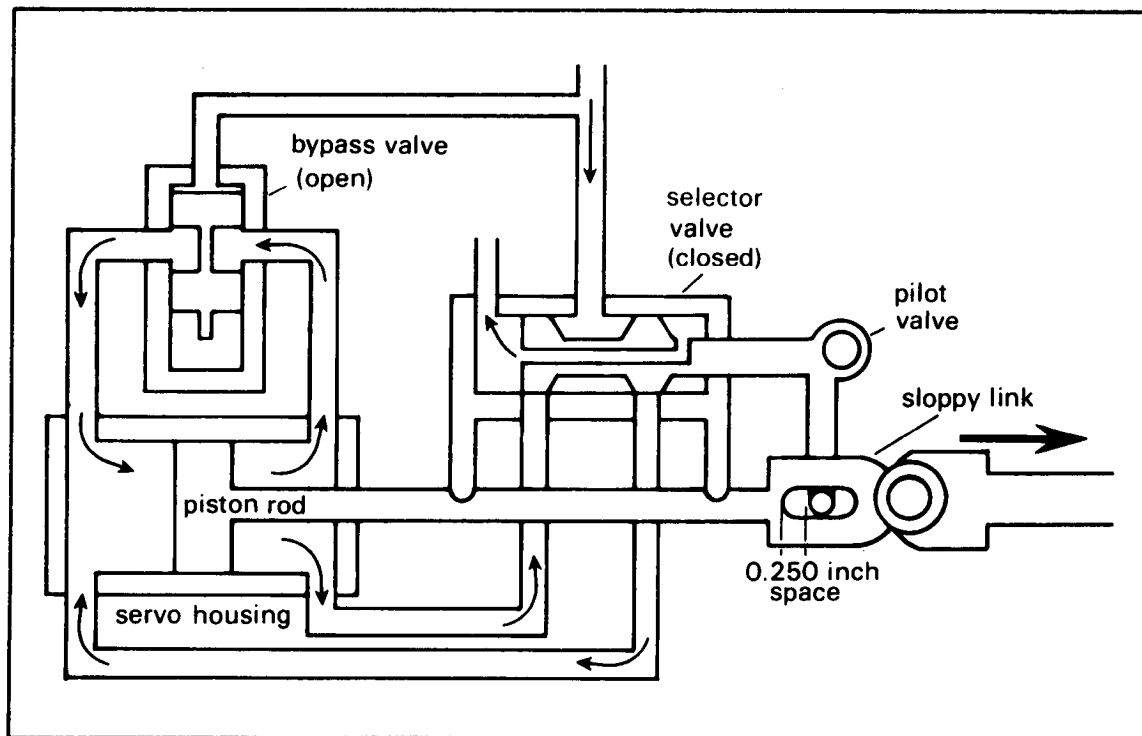


**Figure 8-37. Ratchet valve (on) and actuating cylinder (moving).**

## HYDRAULIC SERVOS

**Purpose.** Many situations exist where powered movements must be consistently made with accuracy within thousandths of an inch; such exact control cannot be effected by an actuating cylinder connected with a selector valve. Hydraulic servos perform this function. Hydraulic servos are used in airplanes and helicopters to multiply the physical effort personnel expend in operating the aircraft. Servos enable a pilot to use fingertip force in controlling the actions of a flight control system that may actually require hundreds of pounds of force to actuate.

**Operation.** In effect, a hydraulic servo is a combination of an actuating cylinder and a selector valve in a single unit. The servo selector valve is manually opened by the operator and is automatically closed by the servo's movement. The spool-shaped valving device of the servo selector valve is commonly referred to as a pilot valve. Servos are made in two general designs. In one design, the servo cylinder housing is stationary and the piston rod moves. In the other design, the piston rod is stationary and the cylinder housing moves. For convenience, a servo in which the cylinder housing is stationary and the piston moves is used in the following explanation of basic servo functions and of servo sloppy links and bypass valves. Such a servo is shown in Figure 8-38.



**Figure 8-38. Hydraulic servo.**

Assume that the servo pilot valve has been moved a given distance to the right from the OFF position and is to be held there. If the given distance is 0.250 inch, the following will result:



- Fluid under pressure will flow through the now unblocked selector valve cylinder port and will enter the left chamber of the servo cylinder housing.
- The piston will be forced to the right and will carry the selector valve housing with it since that housing is welded to the piston rod.
- When the piston has moved to the right exactly 0.250 inch, the selector valve housing will have moved to the right over the now stationary pilot valve. This action will return the selector valve to the OFF position. Since the flow of fluid is now stopped, the piston will travel no farther.

If it is necessary to move the servo piston to the limit of its possible travel within the cylinder bore, continue moving the pilot valve ahead so that the selector valve housing is unable to catch up with the pilot valve.

In most cases, the pilot valve is operated by remote control. The servo sloppy link is the point of interconnection between the control linkage, the servo pilot valve, and the servo piston rod. It provides a limited amount of slack between them. This enables the pilot valve to be moved to the ON position without the linkage directly moving the piston rod. The slack provided by the sloppy link is necessary for the normal powered movement of the servo to take place. The limitation in the amount of movement that can take place in the sloppy link provides two benefits: a stop is provided for the pilot valve movement, and the manual movement of the servo piston can be made without any strain on the pilot valve. All servos used in aircraft systems incorporate some form of sloppy link.

In some servos, a bypass valve is provided to reduce the servo's resistance to movement whenever it has to be moved manually. The bypass valve automatically opens a free-flow pathway between the chambers on each side of the piston when no operating pressure is available to the servo. It automatically closes the free-flow pathway whenever the servo has operating pressure. Fluid can be forced in and out of the servo chambers during manual operation without much manual effort.

In some hydraulic servos, the selector valve is actuated by an electrical input control signal rather than by a manual input control signal. Such signals can be provided by some aircraft flight-position-sensitive sensing device (for example, a gyro or an aneroid altimeter) that permits the servo to provide semiautomatic control of an aircraft's flight. Two types of electroservos are used in some late model cargo helicopters: extensible links and stability augmentation servos. However, these electroservos will not be discussed here because their complex design and operation are beyond the scope of this manual.

## IRREVERSIBLE VALVES

Purpose. Irreversible valves assist hydraulic servos the same as ratchet valves assist actuating cylinders; both ratchet and irreversible valves guard against the movement of the unit by an externally applied

force. Irreversible valves are used with hydraulic servos in a helicopter flight control system to block the travel of feedback forces from their point of origin in the rotor head and blades to the control stick.

**Operation.** Figure 8-39 illustrates the basic functions of the irreversible valve. The check valve in this mechanism allows fluid from the pump to flow in the normal direction shown by the arrows. However, feedback force tends to move the servo piston in the opposite direction to the pump-produced pressure. This tends to force fluid backward through the irreversible valve. The check valve blocks this rearward flow of fluid and keeps the servo piston from yielding to the feedback force. The relief valve serves as a safety device to limit the pressure produced by the feedback-induced movement of the servo piston. It opens to allow fluid to bypass to the return line if the feedback-produced pressure exceeds a preset safe limit.

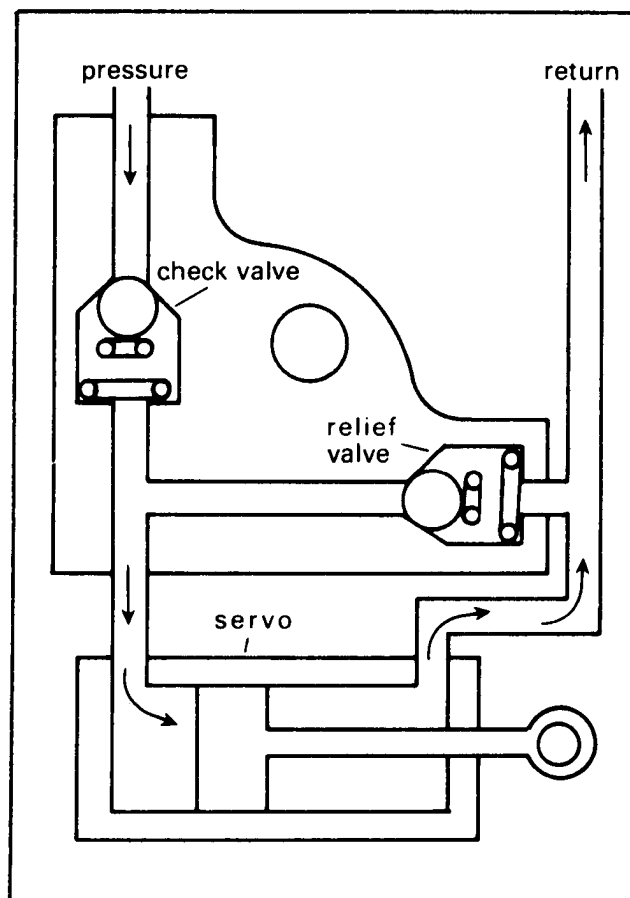


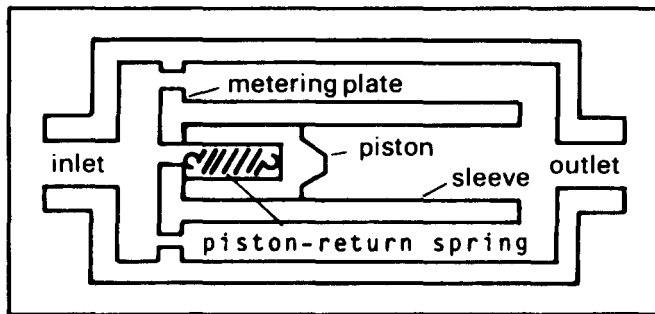
Figure 8-39. Irreversible valve.

## HYDRAULIC FUSES

**Purpose.** Fuses are incorporated in hydraulic systems to prevent continued loss of fluid in cases of serious leakage. Fuses are safety devices; they are not needed for operation of the system.

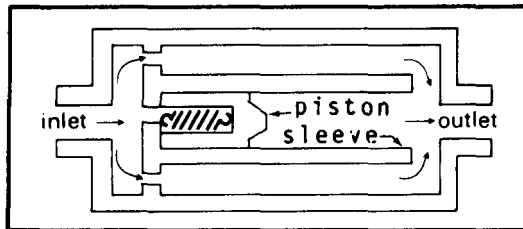
**Operation.** Hydraulic fuses are usually installed in lines that run in hazardous locations or that conduct fluid to components located in such places. They can only be used in lines through which fluid flows in one direction but not continuously or in lines through which flow is reversed at intervals. A hydraulic fuse permits only a limited quantity of fluid to pass through it. When this limit is reached, the fuse automatically shuts off further flow.

Figure 8-40 shows a typical hydraulic fuse that consists essentially of a housing, sleeve, piston, piston-return spring, and metering plate. The housing has a pressure port at one end and a return port at the other. The sleeve is attached to the housing and is centered on the axis of the housing. It has a polished bore in which the piston operates. Holes in the end of the sleeve nearest the outlet port open the bore of the sleeve to a space between the sleeve and the housing. The metering plate divides whatever fluid enters the fuse into streams of unequal size. The larger streams flow around the outside of the sleeve; the smaller streams, through the inside.



**Figure 8-40. Hydraulic fuse.**

Whenever the fuse is not transmitting fluid, its piston is pulled to the inlet end of the fuse by the piston-return spring. As soon as fluid begins flowing through the fuse, the stream of fluid that enters the sleeve reacts against the piston. (See Figure 8-41.) This causes a slow movement of the piston toward the outlet end of the sleeve. Meanwhile, the stream of fluid that flows on the outside of the sleeve passes through the communication holes in the sleeve and then out of the fuse outlet port. As long as the quantity of fluid passing through the fuse is equal to or less than the fuse's rated flow capacity, the piston travels less distance within the sleeve than its travel limit.



**Figure 8-41. Hydraulic fuse (full flow).**

If the flow of fluid through the fuse becomes greater than its rated flow capacity, the increased pressure causes the piston to travel until the needle on its end plugs the opening at the outlet end of the housing; this action blocks further fluid flow through the fuse. (See Figure 8-42.) The piston is held in the blocking position until the pressure is relieved. When the pressure is relieved, the piston-return spring retracts the piston, and fluid again flows through the fuse.

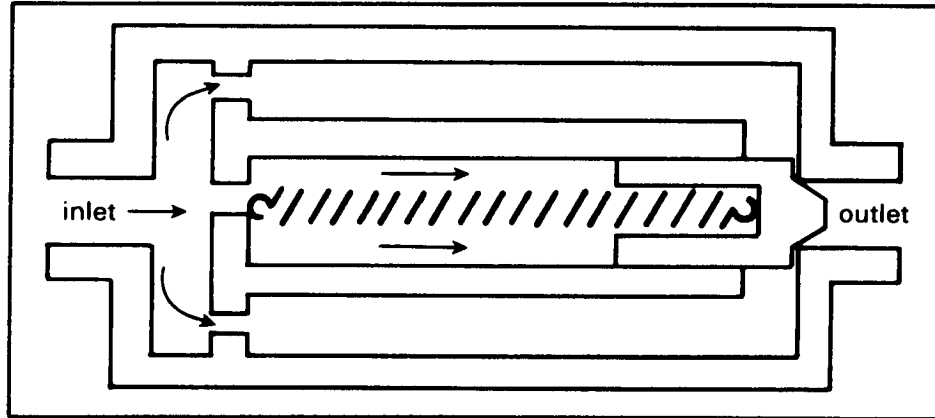


Figure 8-42. Hydraulic fuse (blocked flow).

## CHAPTER 9

## PNEUDRAULIC SYSTEMS

## OPEN-CENTER HYDRAULIC SYSTEM

Description. An open-center hydraulic system has hydraulic fluid flow but no pressure until some actuating unit is operated. A basic open-center system consists primarily of a reservoir, a constant-delivery-type pump, a relief valve, one or more selector valves, and one or more actuating units. This system does not require a pressure regulator. The system relief valve limits system pressure when the selector valve is in the ON position and an actuating unit is operating.

When all selector valves are in the neutral (OFF) position, fluid flows from the reservoir into the pump, and from the pump into the main pressure line. (See Figure 9-1.) Because all selector valves are in the OFF position, the fluid passes back to the reservoir through the open-center passage of these valves. Since no restrictions exist in the system, no pressure is in the system other than that caused by friction.

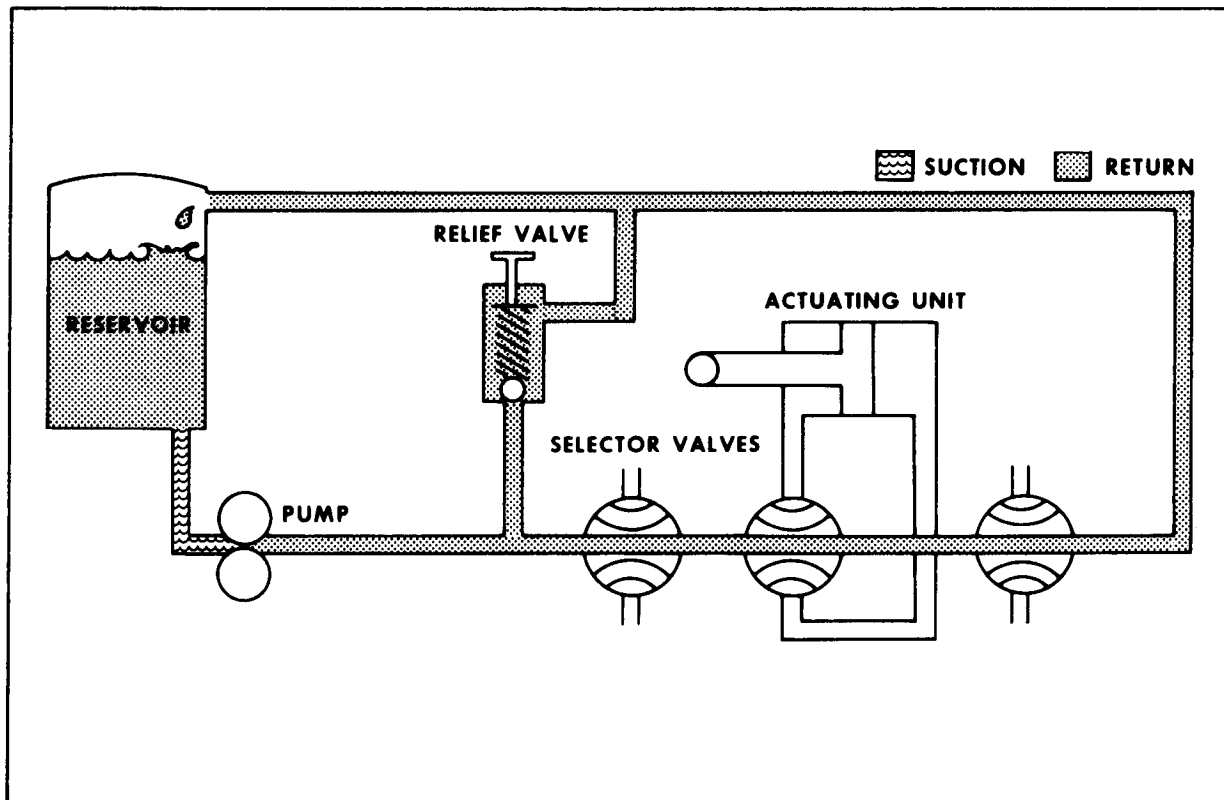


Figure 9-1. Open-center hydraulic system (valve closed).

When one selector valve is in the operating (ON) position, fluid flows under pressure to the actuating unit. (See Figure 9-2.) As the actuating unit moves, it forces residual fluid from the piston through the open selector valve and back to the reservoir. At the end of the stroke of the actuating unit, fluid flow becomes blocked, and pressure increases within the system. Eventually the pressure builds up to the setting of the relief valve; then it is bypassed to the return line and back to the reservoir. This condition exists until the selector valve is returned to the neutral (OFF) position.

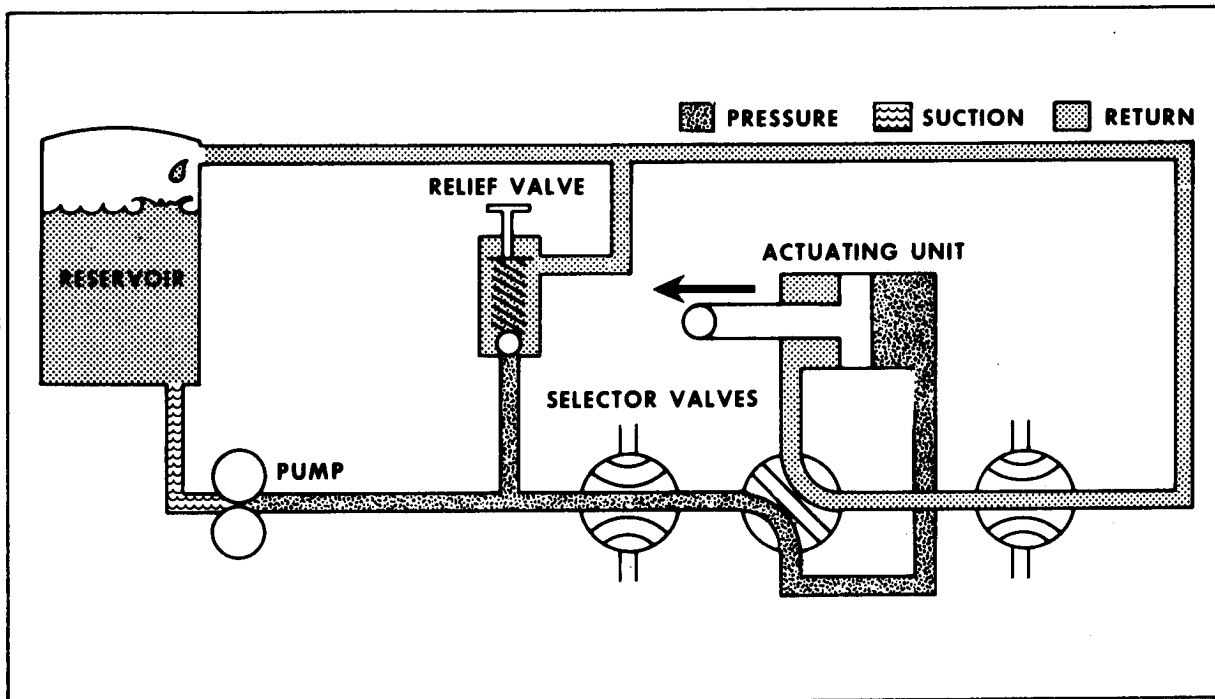


Figure 9-2. Open-center hydraulic system (valve open).

### CLOSED-CENTER HYDRAULIC SYSTEM

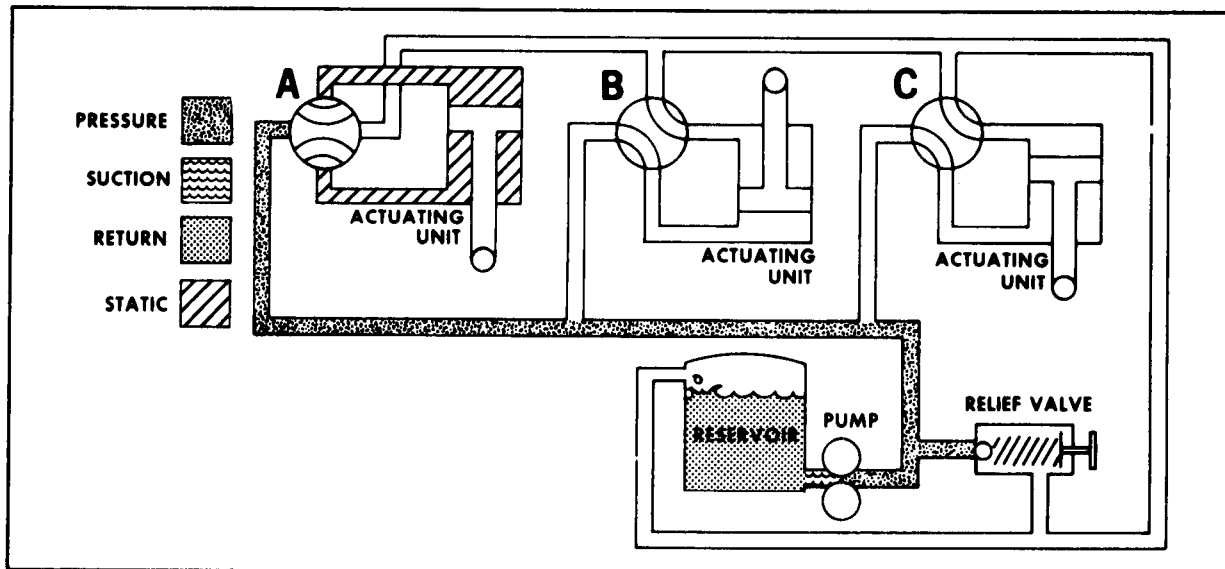
Description. A closed-center hydraulic system is sometimes called a direct-pressure system because the hydraulic fluid is under pressure throughout the system when the pump is operating. A basic closed-center hydraulic system consists of a reservoir, a pump, a relief valve, one or more selector valves, and one or more actuating units.

#### Functions.

Basic System. Three selector valves are depicted in Figures 9-3, 9-4, and 9-5. Each is in a different position, and each valve controls a different actuating unit. Hydraulic fluid is drawn from the reservoir to the pump, which forces the fluid to selector valves A, B, and C with the following results:

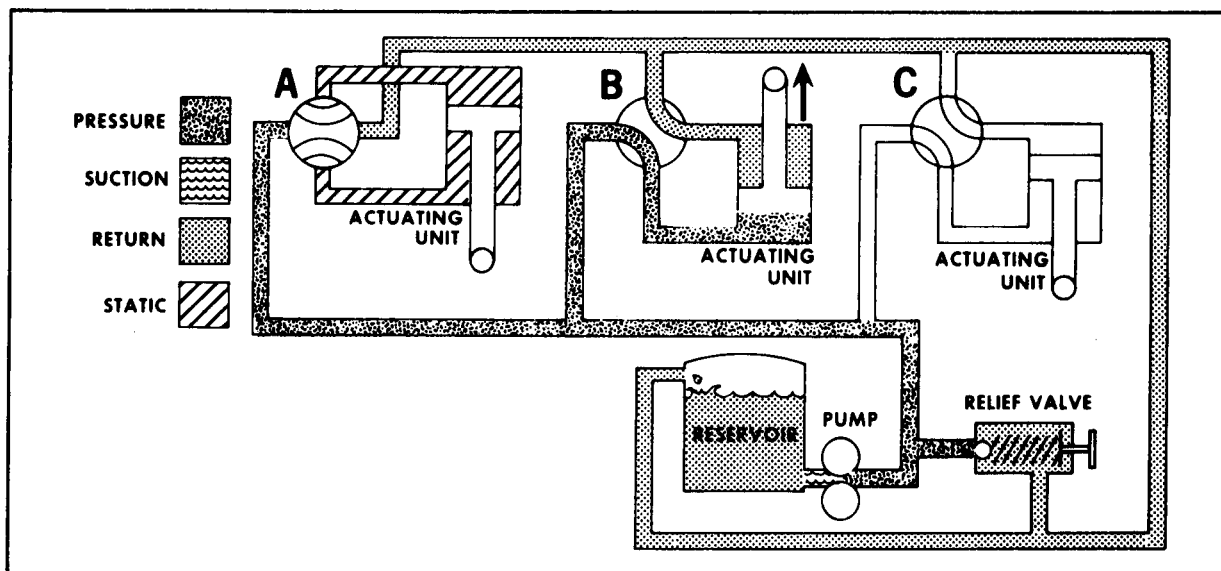
- The rotor of selector valve A (Figure 9-3) is positioned so that the valve ports are closed. The hydraulic fluid is trapped in the lines

leading from the selector valve to each side of the piston in the actuating unit; the fluid cannot move in any direction. This holds the piston in a locked position and any attached mechanism in a fixed position.



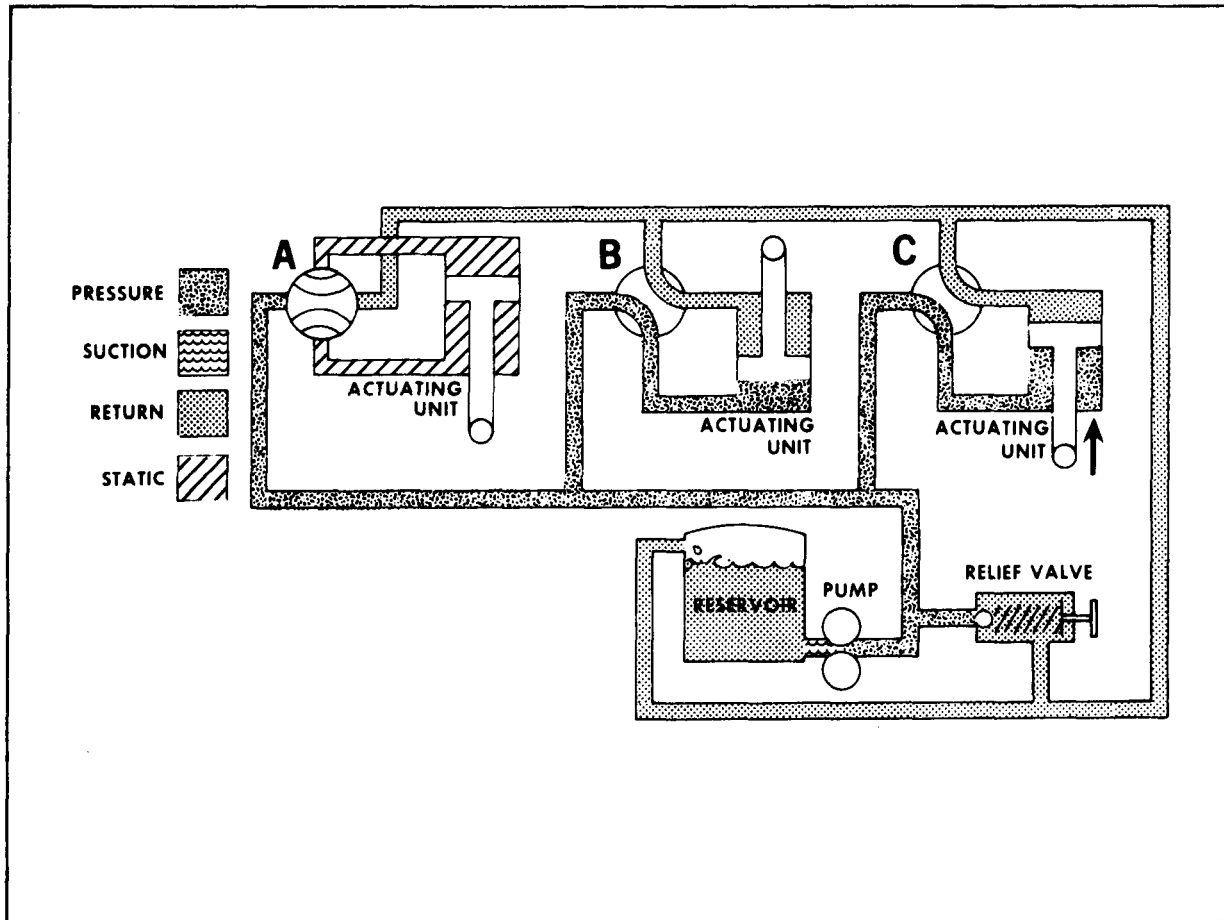
**Figure 9-3. Closed-center hydraulic system (selector valve A).**

- The rotor of selector valve B (Figure 9-4) is positioned to direct the fluid flow from the selector valve to the face of the piston in the actuating unit. This pressure forces the piston to move outward flows causing any mechanism attached to the piston rod to function. Fluid moving out of the actuating unit as the piston moves outward flows into the return line to the reservoir.



**Figure 9-4. Closed-center hydraulic system (selector valve B).**

The rotor of selector valve C (Figure 9-5) is positioned to direct the fluid flow to the rod side of the piston, forcing the piston to move inward. Fluid moving out of the actuating unit as the piston moves inward flows into the return line to the reservoir.



**Figure 9-5. Closed-center hydraulic system (selector valve C).**

**Complete System.** Figure 9-6 shows a closed-center hydraulic system with all of the components discussed in Chapters 4 through 8 of this manual. Note that fluid flows from the reservoir into the power-driven pump or hand pump. The pressure created by either pump moves the fluid through the shuttle valve and the system filter into the pressure lines. If the hand pump is operated instead of the power-driven pump, the shuttle valve blocks off the power-driven pump and pressure regulator from the pressure lines. A hydraulic pressure gage is installed in the pressure line to indicate system pressure. The system relief valve is interconnected between the pressure and return lines. From the pressure lines, any number of units or subsystems may be supplied with fluid under pressure. The control valves and selector valves are used to isolate and operate any unit or subsystem independently of other units or subsystems.



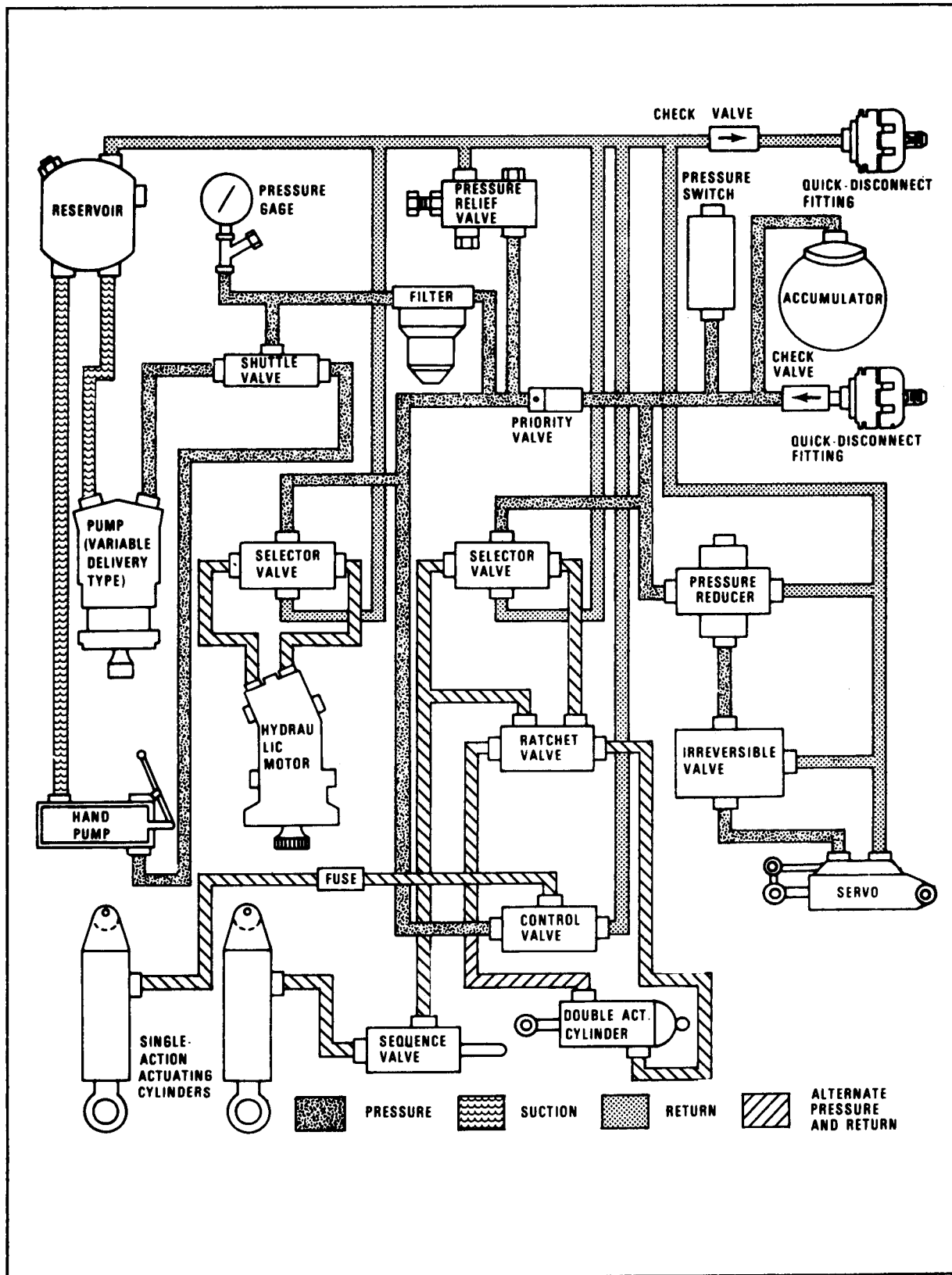


Figure 9-6. Complete closed-center hydraulic system.

## MODULE AND MANIFOLD SYSTEMS

Each of these systems consists of multiple hydraulic components that function as one complete unit. Figure 9-7 illustrates the module system with multiple components combined into one unit. Figure 9-8 illustrates the Rosan fittings which are used to connect the module and manifold systems to the tubing and hoses of the hydraulic system. (Information on installation and removal of Rosan fittings can be found in TM 43-0104.) Figure 9-9 illustrates the manifold system with multiple components combined into one unit.

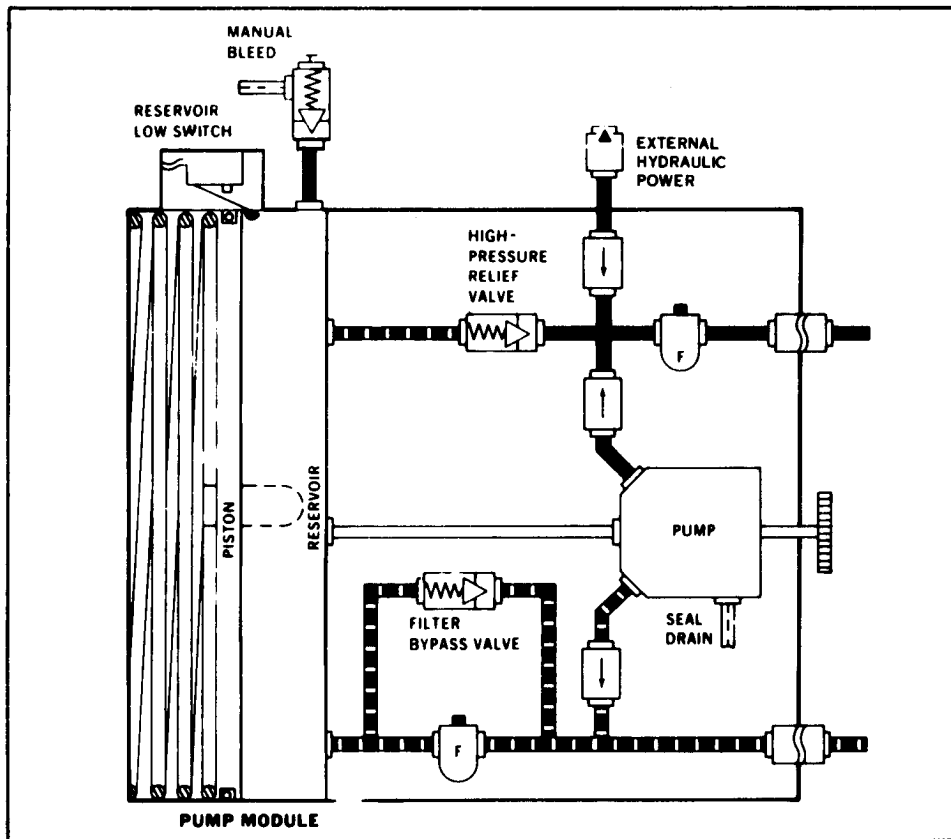


Figure 9-7. Module system.

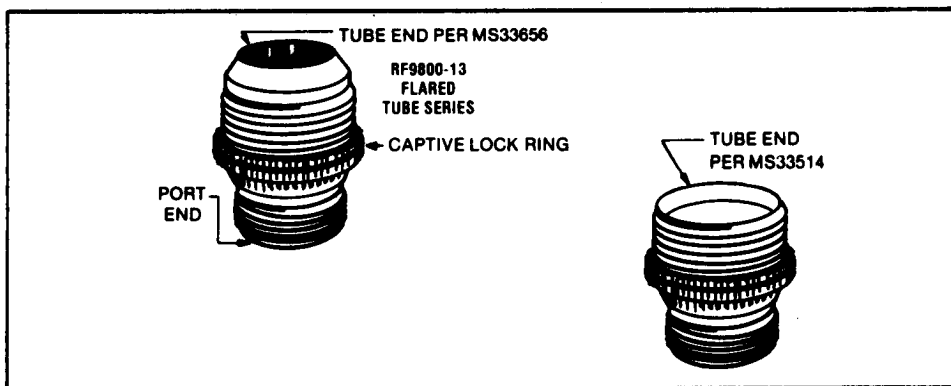
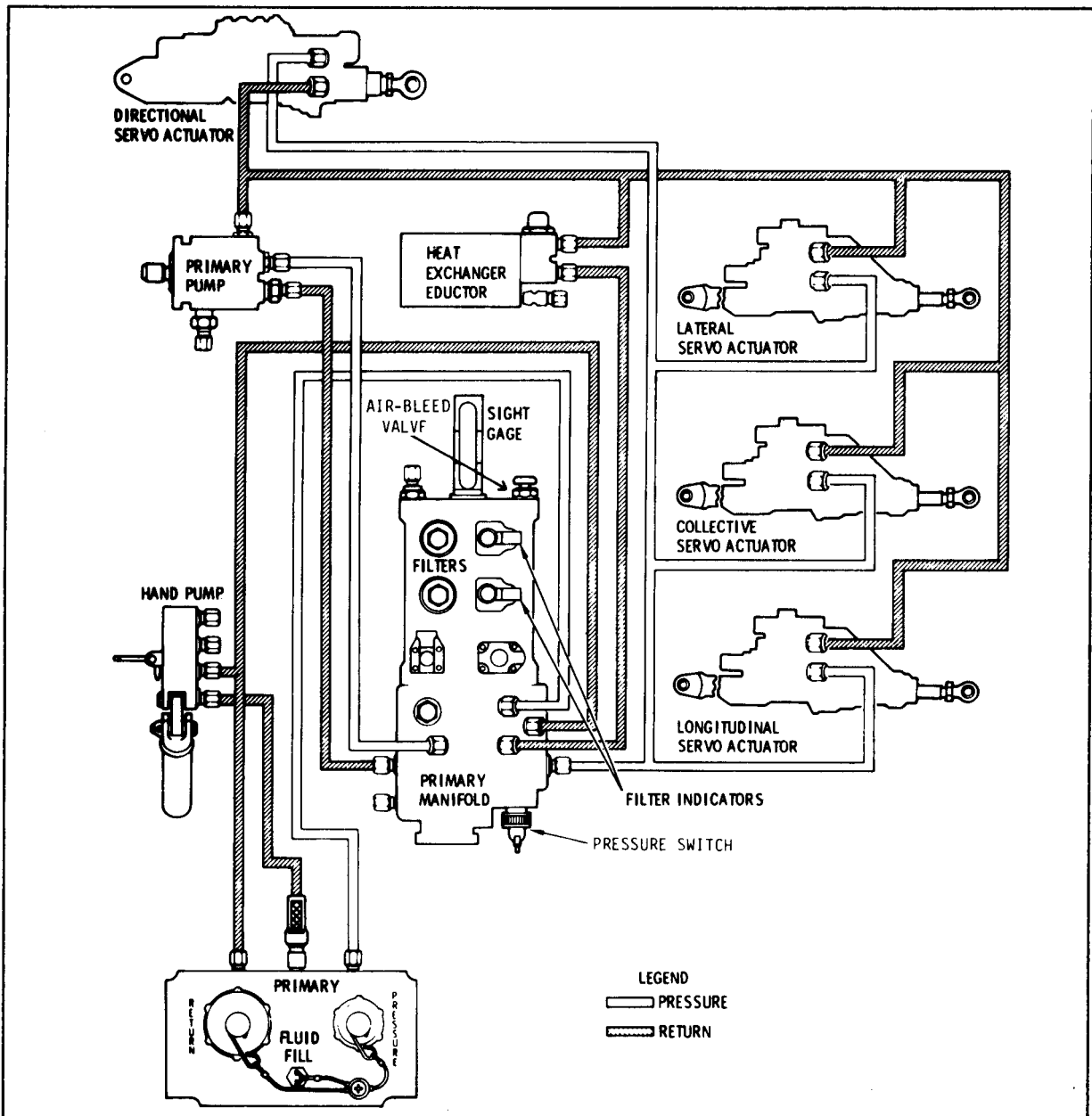


Figure 9-8. Rosan fittings.



**Figure 9-9. Manifold system.**

## PNEUMATIC SYSTEM

**Description.** Aircraft pneumatic systems are primarily used as emergency sources of pressure for hydraulically operated subsystems. The pneumatic power system usually consists of one or more high-pressure air cylinders, pressure gages, and pressure warning lights. Since the pneumatic power source does not replenish itself during flight, the compressed-air supply is only good for a certain number of operations.

**Operation.** High-pressure pneumatic systems operate much the same as hydraulic systems. A shuttle valve connects the pneumatic system to the hydraulic system. This allows the same tubing and units to be used for

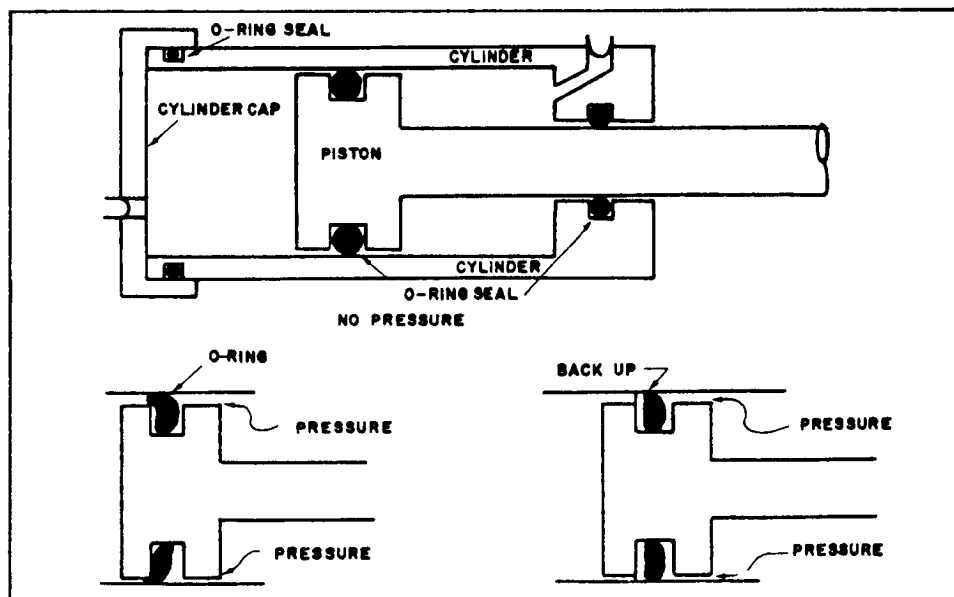


Figure 9-10. O-ring seals and grooves.

both systems. The shuttle valve separates the normal hydraulic system from the pneumatic system. Pneumatic system selector valves control the air to the subsystems. Each subsystem is connected to the high-pressure air source through a pressure regulator, relief valve assembly, and selector valve. Since pneumatic selector valves are installed in parallel, air pressure is immediately available to all subsystems for instant operation. When connected in this manner, more than one system can operate at the same time.

In a pneumatic system, the pressure regulator, the relief valve assembly, and the return lines from the selector valves are vented to the atmosphere. The air cylinders are charged through a ground-test filler connection by a portable nitrogen cart or a high-pressure air compressor. All nitrogen or air is filtered by a filter in the service line.

**Lubrication of Pneumatic Seals.** Lubrication of pneumatic seals is more difficult to control than lubrication of hydraulic seals. Pressurized air from the system does not lubricate the seals as the hydraulic fluid does. Actually, the air dries out the seals and any lubricant that may be on them. To prevent this from happening, use MIL-G-4343 grease for pneumatic systems. This grease has qualities that are better suited for pneumatic systems; it should not be substituted unless specifically stated in the technical order. This grease will not harden and jam solenoids of valves and orifices when it gets cold. Applying the grease to a pneumatic unit is different from applying grease to a hydraulic component. For example, on a pneumatic actuating cylinder, the O-ring seals and seal grooves (Figure 9-10) should be packed with pneumatic grease. The felt wiper should also be thoroughly impregnated with the grease. After the unit is assembled and greased, it should be operated through several complete cycles to spread the grease over all working surfaces. This may be the only lubrication this unit may receive for years to come, so be sure to grease it properly.

## CHAPTER 10

# AIRCRAFT BRAKE SYSTEMS

### WHEEL BRAKE SYSTEMS

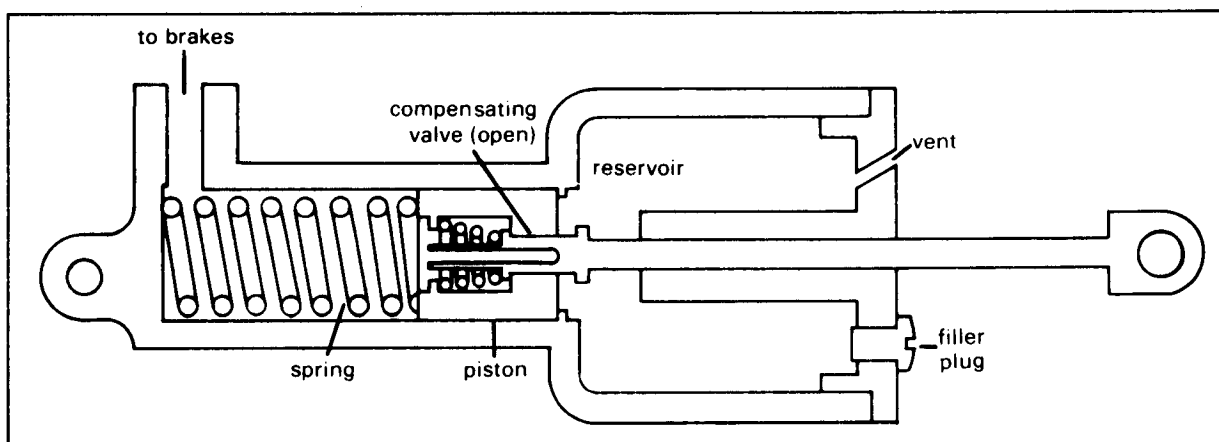
Operation. All hydraulic brake systems operate on the same basic principle. When the operator moves a brake pedal or other brake operating control, the movement is transmitted to a master cylinder or power brake control valve. Then fluid pressure is delivered through connecting lines to a brake assembly connected to the wheel or shaft to be braked. The fluid pressure acting on the brake assembly pushes brake linings into contact with surfaces of a rotating disk or drum. The resulting friction slows and finally stops the continued rotation of the wheel or shaft to which the disk or drum is connected. When the brake pedal or brake control is returned to the OFF position, brake operating pressure is relieved; the brake lining loses contact with the disk or drum; and the wheel or shaft is free to turn again.

Aircraft wheel brake systems are composed of two identical subsystems that can be operated independently of each other to provide separate braking action for the landing gear on each side of the aircraft. Each subsystem is operated by a toe plate (brake pedal) that is hinge-mounted to the top of the aircraft rudder (directional) pedal. Since each brake pedal can be operated independently, the brakes can also be used to steer the aircraft.

Components. A list of brake system components, which may be found in varying combinations to make up different wheel brake systems, includes the following: master cylinder (or a power brake control valve), wheel brake assemblies, deboosters, parking brake valves, shuttle valves, accumulators, connecting lines, and bottles charged with compressed air. The minimum parts needed to perform the function of a simple wheel brake system are a master cylinder (or a power brake control valve), wheel brake assembly, and connecting lines.

Master Cylinders. Master cylinders are used in some wheel brake systems to transform force applied by the operator's foot into fluid pressure; the greater the force applied to the pedal, the higher the fluid pressure. This pressure actuates the brake system and stops the rotation of the wheels. Master cylinders fall into three general classifications: simple, compound, and power boost. They vary in shape, size, and design, depending on the manufacturer and on how the cylinder functions in the brake system. Brake systems incorporating simple and compound master cylinders operate independently of any other hydraulic system within the aircraft and are sometimes called independent brake systems. When a power booster master cylinder is used, some of the power needed for braking is supplied by a power-driven pump.

**Simple master cylinder.** These cylinders are restricted to light aircraft. Some have integral reservoirs; others are connected with in-line reservoirs by a hose. In some designs, a push rod actuates the piston; in others a pull rod performs this function. Figure 10-1 shows an integral reservoir; the piston is actuated by a push rod. Note that the illustration shows the cylinder in the released position with the compensating valve open. This allows any thermally expanded fluid within a connected wheel brake assembly to pass freely into the reservoir; from the reservoir, the fluid passes back into the assembly to replace fluid that may have been lost due to minor leakage. When the brake pedal is depressed, the first few thousandths of an inch of travel of the master cylinder push rod closes the compensating valve and traps the fluid that lies between the underface of the piston and the wheel brake assembly. Further depression of the brake pedal moves the piston within its bore and forces fluid out of the master cylinder into the wheel brake assembly. Releasing the brake pedal retracts the master cylinder push rod. This action allows the piston spring to open the compensating valve and to hold it open until the pedal is depressed again.

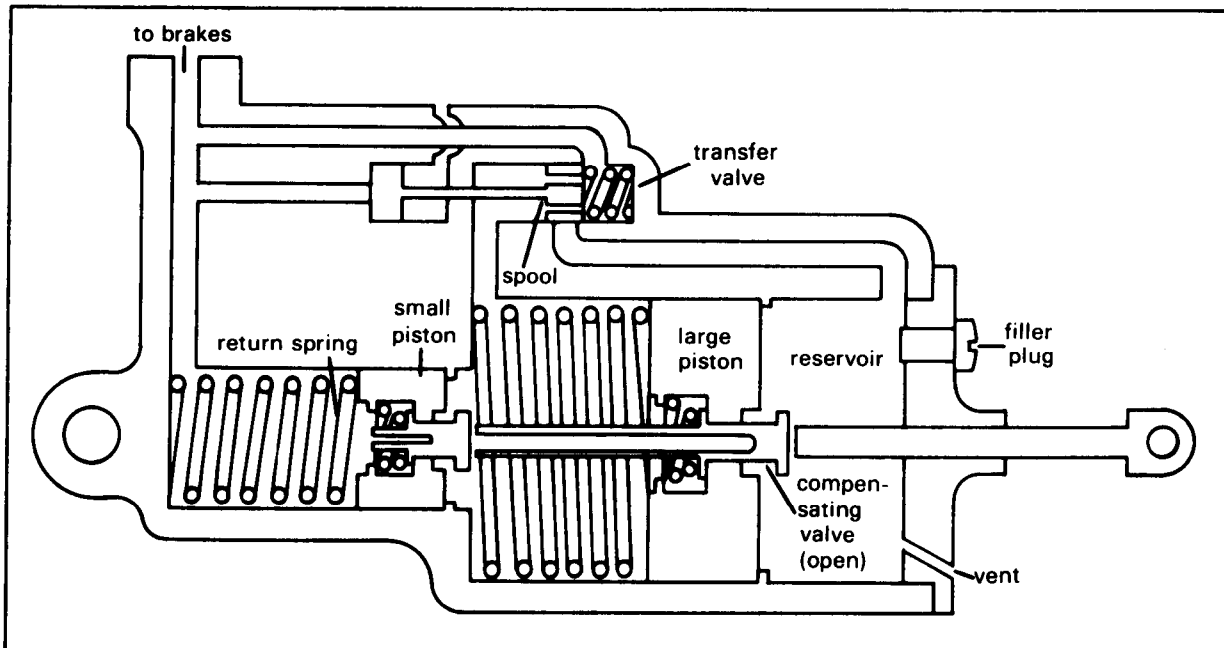


**Figure 10-1. Simple master cylinder in the released position.**

**Compound master cylinder.** Some heavy aircraft require wheel brake systems that operate with more fluid flow and higher fluid pressure than is possible with a simple master cylinder. In some types of aircraft, a compound master cylinder is used for this purpose. This type of master cylinder can deliver a large quantity of fluid at low pressure by a relatively short pedal travel. It can also develop high operating pressure by a moderate pedal pressure. This dual capability is achieved by two pistons: a large one for producing a large fluid flow with short travel and a small one for developing high pressure from a lightly applied force.

In Figure 10-2, the compound master cylinder is in the released position, meaning the compensating valves of both pistons are open to the reservoir. As the brake pedal is depressed, both compensating valves close, and the pistons are forced ahead in their cylinder bores. The fluid displaced jointly by the two pistons flows into the wheel brake assembly and moves the linings into contact with the disk. A slight additional movement of the brake pedal and pistons raises the pressure in the system

for a few pounds. This rise in pressure moves the spring-loaded spool in the transfer valve within the master cylinder. The new position of the spool blocks the flow of fluid from the large cylinder to the wheel brake assembly. It opens a passage between the large cylinder bore and the reservoir, which allows any fluid displaced by the large piston to flow without resistance into the reservoir. The small cylinder bore remains open to the passage within the master cylinder where fluid is delivered to the wheel brake assembly.



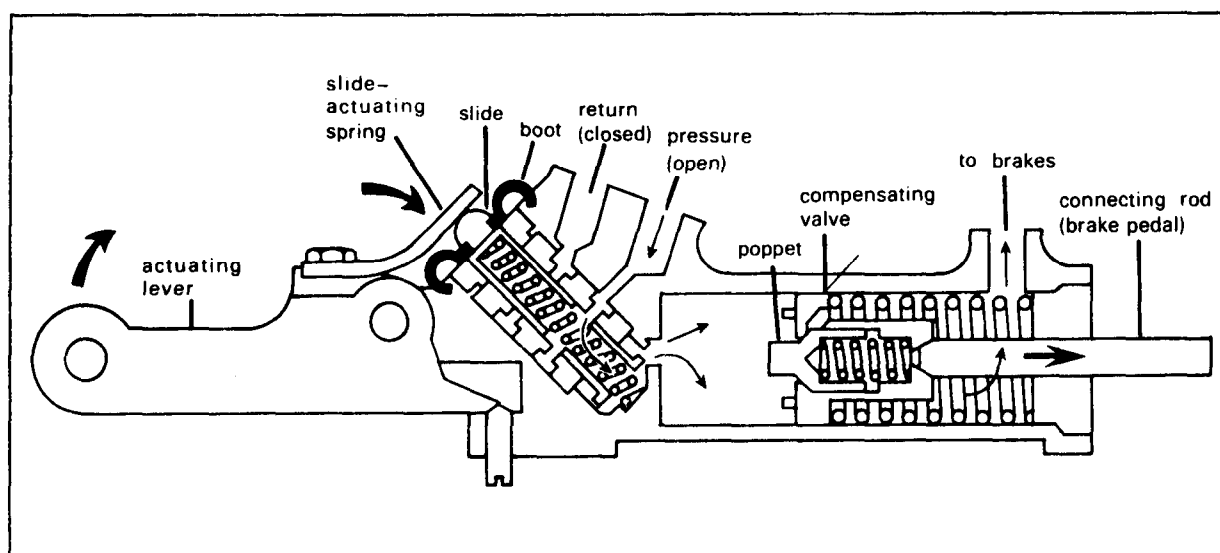
**Figure 10-2. Compound master cylinder in the released position.**

As the force applied to the brake pedal is increased to push the linings into contact with the brake disk, the two pistons move slightly farther into their bores. Since any fluid displaced from its bore by the large piston flows to the reservoir without resistance, practically all the force exerted on the brake pedal is applied to the small piston. When the brake pedal is released, the transfer valve spool returns to the spring-loaded position; the pistons return to their released positions; the compensating valves open; and the fluid that was forced into the wheel brake assembly when the brake was applied returns to the master cylinder.

**Power-boost master cylinder.** Some aircraft are too heavy or land at speeds too great to permit control by a brake system powered entirely by an operator's foot and leg muscles; the brake system requires power produced by a power-driven pump. In some aircraft, the pump-produced power does the job alone and is merely controlled by the operator. In other aircraft, the pump-produced power is used as a supplement (or boost) to the power supplied by the muscles of the operator; the power-boost master cylinder is used in this case. If a loss of pump-produced power to the master cylinder occurs, some brake application by muscle power alone is possible. However, considerably more force than normal has to be applied to the brake pedal to achieve the necessary braking action. In heavy aircraft, the most vigorous

manual application is still completely inadequate; an emergency source of boost pressure such as an accumulator or a compressed-air bottle must be provided.

Figure 10-3 shows a typical power-boost master cylinder. Note that two interconnected chambers make up the cylinder body. The upper chamber houses a spring-loaded sleeve and slide and pressure and return ports for the main system lines. The lower chamber contains a spring-loaded piston, a poppet, and the port to the brake line. This chamber also serves as a reservoir for fluid that energizes the brake when pressure is applied. An actuating lever and two slide-actuating springs are mounted on top of the cylinder. One end of the actuating lever is secured to the aircraft; the other end, to the cylinder housing. The master cylinder illustrated has a piston rod that is pulled outward from the housing as the brake is applied. However, there is another design in which applying the brake pushes the piston rod inward.



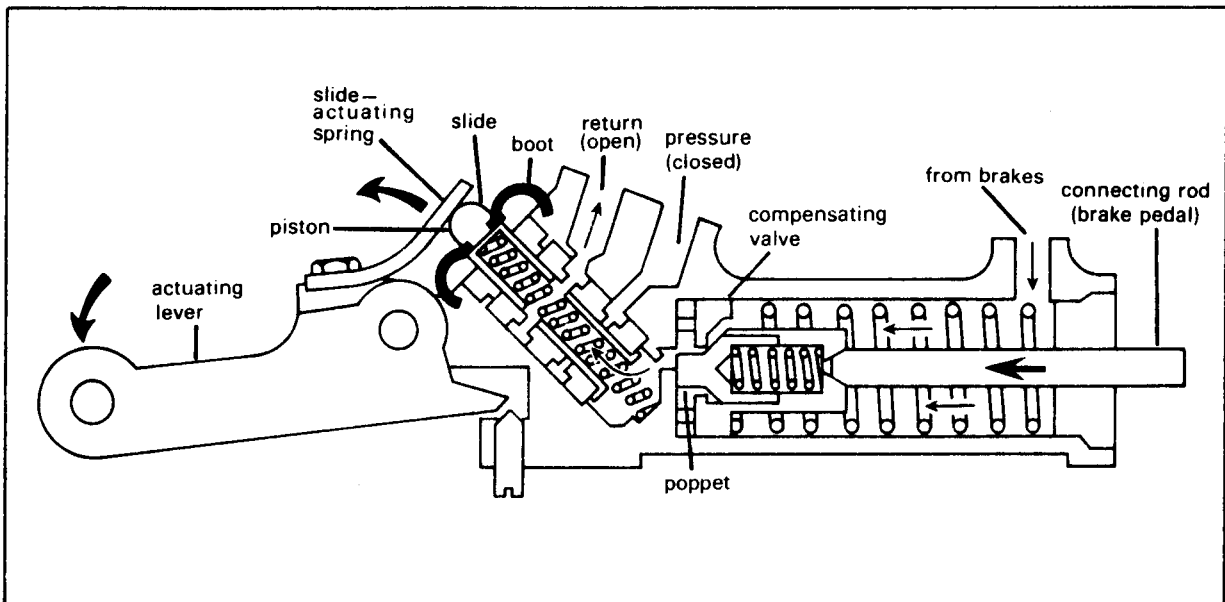
**Figure 10-3. Power-boost master cylinder with brake applied.**

Applying pressure to the brake pedal creates a pull on the piston rod that results in the piston's downward movement. When the piston's movement releases the poppet extension from its contact with the housing, the poppet seats and closes the compensating valve. Fluid trapped between the underside of the piston and the wheel brake assembly then becomes pressurized. This fluid pressure, acting with the force exerted by the piston retracting spring, creates a downward pull on the master cylinder housing. When the pull becomes sufficiently great, it causes the pivoted actuating lever to move from its previously angled position. The new position forces the attached slide-actuating spring to retract the slide, causing the slide to block the return port and open the pressure port. This allows pressure from the system pump to pass through the pressure port and slide and enter the chamber above the piston. This pressure exerts a downward push on the piston, which aids the muscle-produced (operator) pull on the piston in developing the brake application pressure within the lower chamber and the connected wheel brake assembly.



Whatever pressure is present in the chamber above the piston is also present within the slide. This pressure tends to force the slide upward against the resistance of the slide-actuating springs. When the pressure-produced force acting on the slide becomes slightly greater than the force exerted by the slide-actuating springs, the slide moves upward to the extent that it blocks both the pressure and return ports. Since no pressure can then be relieved or increased within the chamber above the piston, brake application remains constant as long as the operator does not change the force applied to the brake pedal. The degree of brake application is under the operator's complete control and is determined by the amount of pressure applied to the brake pedal.

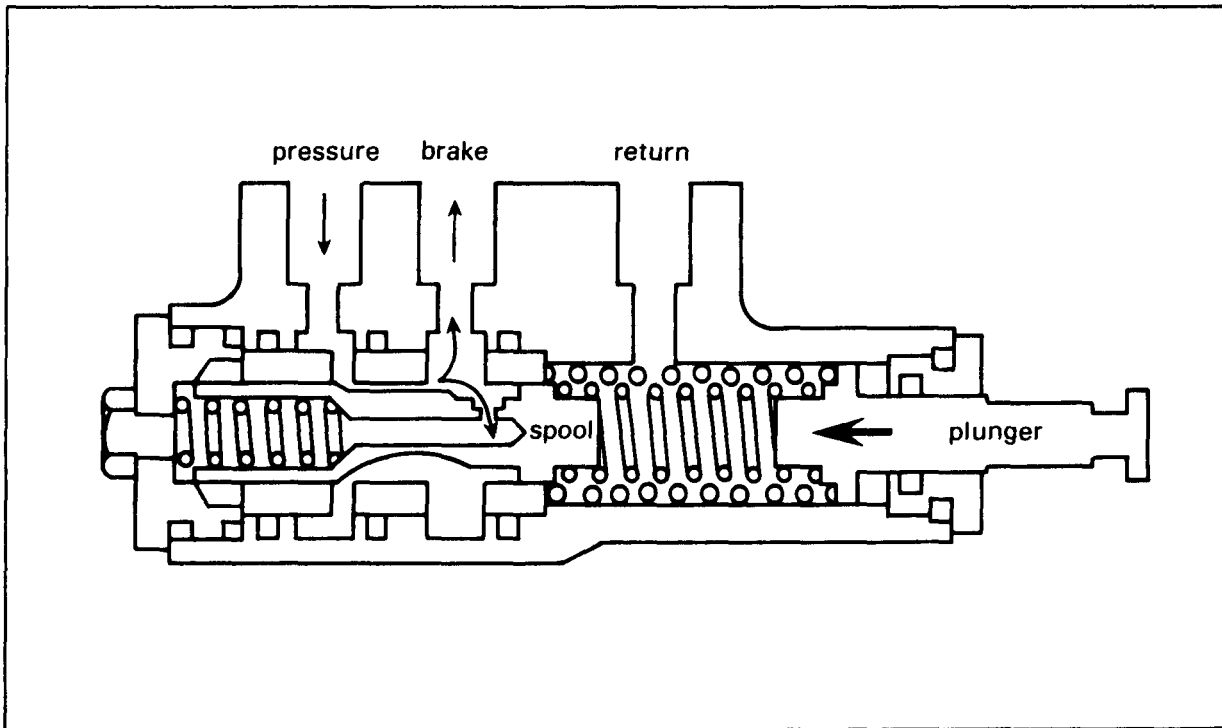
Releasing pressure on the brake allows the piston spring to retract the piston, which reopens the compensating valve. (See Figure 10-4.) This allows the actuating lever to return to its angled position and permits the slide to return to the position which blocks the pressure port and opens the return port. Fluid that was forced into the wheel brake assembly during brake application can then return to the chamber on the underside of the piston and release the brake.



**Figure 10-4. Power-boost master cylinder with brake released.**

**Power Brake Control Valves.** In many large aircraft that land at high speeds, power brake control valves are used instead of master cylinders to provide the wheel brake assemblies with fluid pressure. The main difference between a power brake control valve and a master cylinder is the pressure source. A power brake control valve produces no pressure; it is, in effect, a variable pressure reducer. The control valve receives fluid pressure from the power-driven pump of some major aircraft hydraulic system and meters the pressure to a wheel brake assembly. Since it does not produce pressure, a brake system using this type of valve must be supplied with an emergency source of input pressure such as an air bottle in case the regular pressure source fails.

When the brake pedal is depressed, the plunger moves toward the left. (See Figure 10-5.) This movement is transmitted to the spool by the spool pressure spring, causing the spool to move toward the left. If the brake pedal is slightly depressed, the spool's leftward movement is just enough to barely unblock the pressure port. This movement of the spool interconnects the pressure and brake lines and isolates the brake line from the return line. As a result, fluid flows out of the brake port into the brake assembly, raising the pressure in the wheel brake assembly and causing the brake to be applied. The rise in pressure in the wheel brake assembly takes place gradually because of the very small opening between the spool and pressure port.



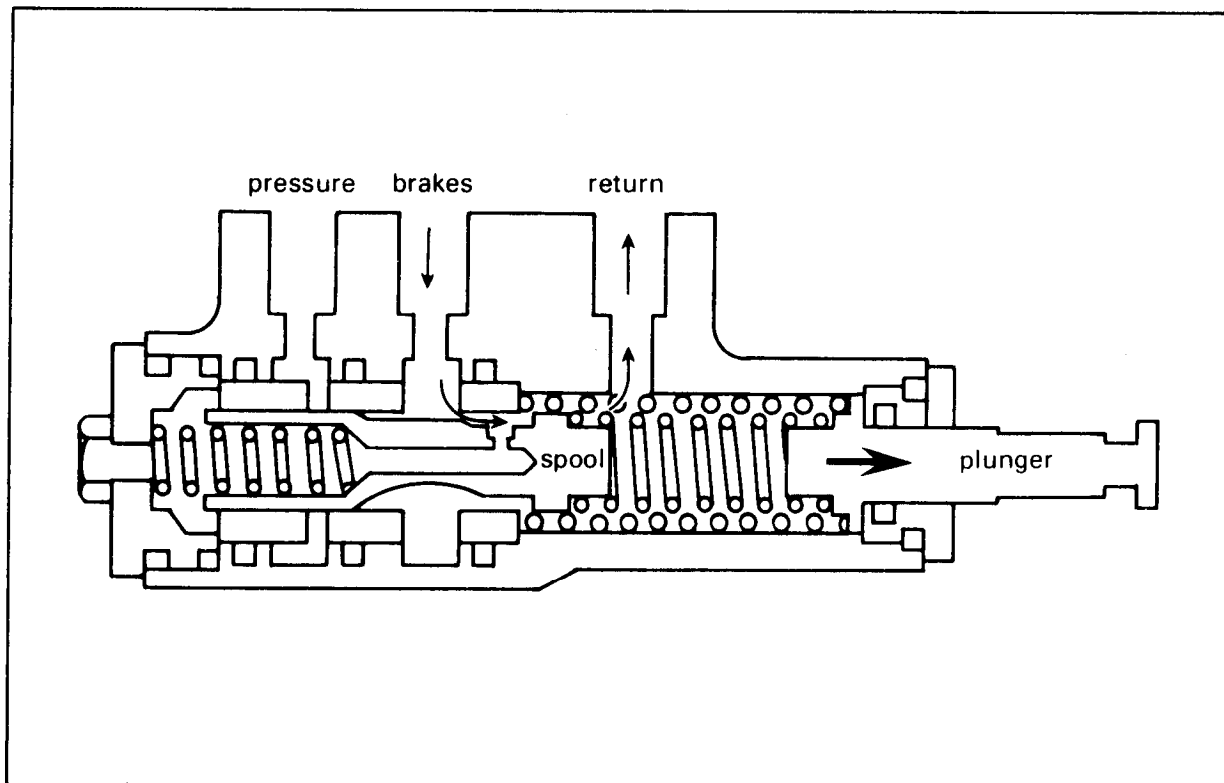
**Figure 10-5. Power brake control valve with brakes applied.**

Whatever amount of pressure is present in the wheel brake assembly at any time is also present in the hollow of the spool, having entered the spool through a cross-drilled hole. This pressure within the spool tends to move it toward the right. This is in opposition to the force exerted by the spool pressure spring and reblocks the pressure port. The amount of fluid pressure that has to be present at any given time in the wheel brake assembly and in the spool to cause reblocking of the pressure port depends on the amount of force in the spool pressure spring at that time. Since the amount of force exerted by the spool pressure spring is in proportion to the distance the brake pedal is depressed, the degree of pressure with which the brake is applied depends on how far the pedal is depressed.

Once a given degree of braking effort has been obtained by depressing the pedal a given distance, it will remain unchanged as long as the pedal

is not moved. This is because the spool's movement to the right in blocking the pressure port leaves the brake line isolated from both the pressure and return lines. No fluid can enter or leave the wheel brake assembly and change the amount of pressure unless the spool's position is changed by the moving pedal. When the brakes are in this static condition, the operator may feel that he is still applying the brakes. The fluid pressure within the spool that tends to move the spool toward the right is transmitted back to the brake pedal through the spool pressure spring and the plunger; this results in a push of the pedal against the operator's foot.

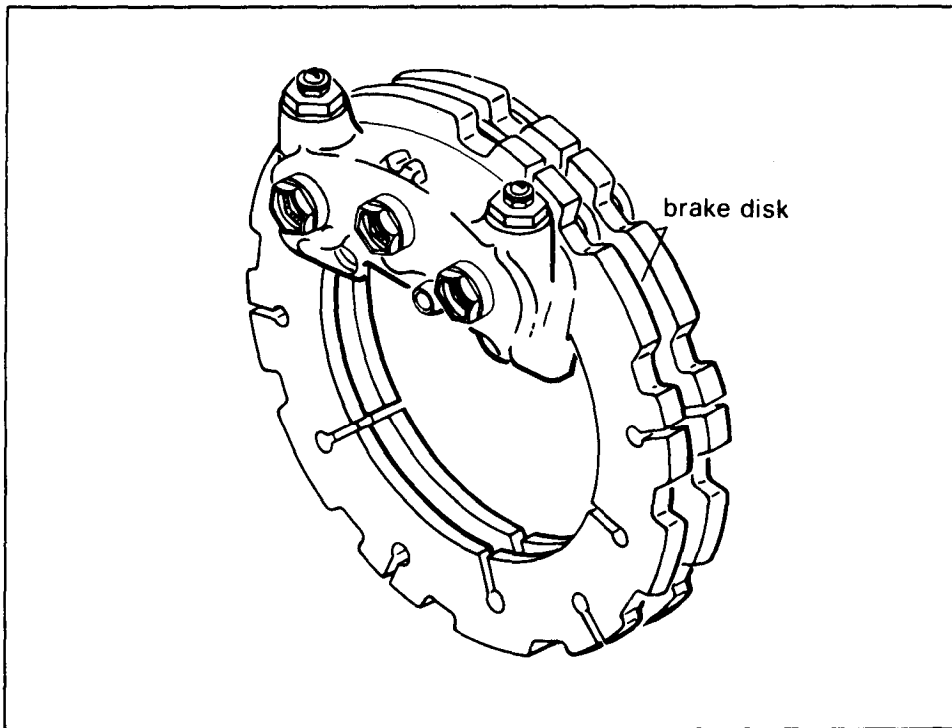
Releasing the brake causes the plunger spring to move the plunger toward the right. (See Figure 10-6.) This releases pressure on the spool pressure spring and permits the spool return spring to move the spool toward the right. Under these conditions, the pressure port is blocked, and the brake line and return line are interconnected. Fluid that was forced into the wheel brake assembly when the brake was applied now returns to the reservoir.



**Figure 10-6. Power brake control valve with brakes released.**

**Wheel Brake Assemblies.** The wheel brake assembly is that portion of a wheel brake system that receives pressure from a master cylinder or a power brake control valve; it converts the pressure into a retarding force that stops wheel rotation. Two major types of wheel brake assemblies used on Army aircraft are the disk type and the expander-tube type.

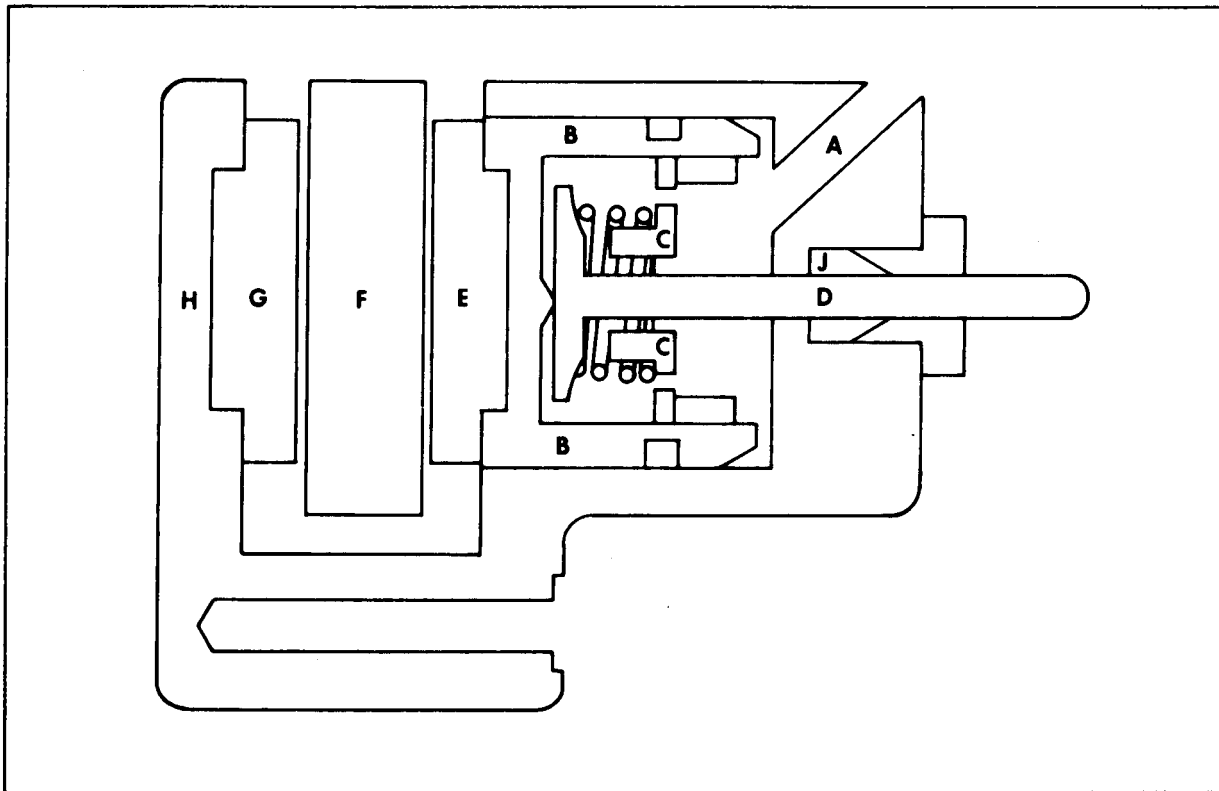
Disk brake. (See Figure 10-7.) In a disk assembly, one or two steel disks are generally used, depending on the type and size of the aircraft on which the brakes are installed. These disks are keyed to the wheel and rotate with the wheel. The brake piston housing, which is securely bolted to the torque plate of the aircraft landing gear, contains from one to four brake-actuating pistons, the number depending on the type and size of the aircraft. Depressing a brake pedal forces hydraulic fluid through connecting lines to the wheel brake assembly and into each piston cavity. This forces the piston and outboard brake lining against the brake disk. Since the disk is free to move from side to side along the lugs in the wheel, it is forced against the inboard brake lining. The friction that results from this clamping of the rotating disk between a pair of linings retards the continued rotation of the disk and the wheel to which it is attached.



**Figure 10-7. Disk brake assembly.**

A single-disk, hydraulically operated brake, like most hydraulically operated disk brakes, is self-adjusting. (See Figure 10-8.) The illustration shows a cutaway of only one piston cavity; however, all piston assemblies of this type of brake are nearly identical. Applying the brake pedal causes increased hydraulic pressure to enter through port (A) and activate the single-disk brake. This pressure forces the piston (B) to the left against the spring pressure until the spring guide (C) contacts the flanged side of the adjusting pin (D). In moving this distance, the piston has forced the outboard brake lining (E) against the steel disk (F), which then moves sideways on its keys and contacts the inboard brake lining (G) supported by the backing plate (H). The brake running clearance is taken up by the piston's first movement. However, to obtain full braking

friction between the rotating disk and the lining pucks, the piston must move farther to the left. The disk must be firmly pinched between the lining pucks. The spring guide is already contacting the face of the adjusting pin, which is held firmly by the friction of the adjusting pin grip (J). However, pressure on the piston provides enough force to overcome this friction, allowing the piston and pin to move farther to the left. If the brakes are held in this applied position, the lining wears away. The pin continues to move inward slowly to compensate for the small amount of lining wear. Each time the brakes are released, the piston backs away from the outboard lining block. It can move until the back of the piston head contacts the face of the adjusting pin. The piston always releases to give the same running clearance. The self-adjusting pin grip prevents the pin from moving to the right.



**Figure 10-8. Single-disk brake assembly.**

Dual-disk brakes, which are always multiple-piston types, are used on aircraft requiring more braking friction at lower pressure than single-disk brakes provide. Pressure applied to the pistons of this type of brake pushes their attached linings against the brake disk nearest the pistons. That disk is then forced against the brake linings on its side of the center carrier assembly. This forces the center carrier assembly and its second set of brake linings against the second disk. The second disk is then forced against the brake linings in the anvil. In this manner, each brake disk receives equal braking action on both sides when the brake is operated. When brake pressure is released, the return springs within the self-adjusting mechanism in each cavity retract the pistons.

Expander-tube brake. (See Figure 10-9.) This type of brake assembly consists of three main parts: brake frame, expander tube, and brake blocks.

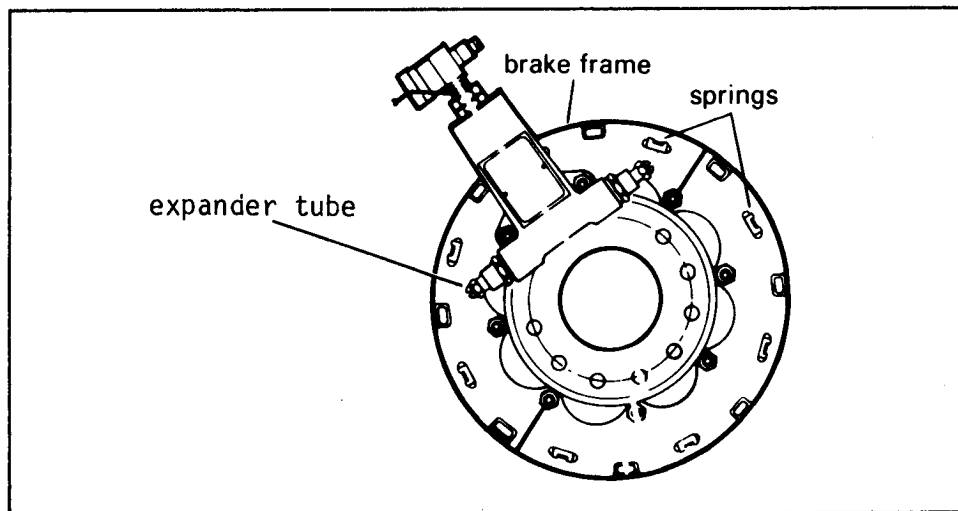


Figure 10-9. Expander-tube brake.

Figure 10-10 shows that braking takes place when fluid pressure is directed through the fluid inlet (A) into the expander tube (B). The tube, restrained from inward and sideward movement by the brake frame (C), expands outward. This forces the brake blocks (F) outward against the brake drum, causing the friction which stops wheel rotation. Torque lugs on the brake frame prevent the brake blocks from turning with the drum. When the brake pedal is released, fluid pressure is relieved from the tube. This causes the curved retractor springs (E) fitted through the slots in the ends of the brake blocks to retract the blocks. The expander tube then deflates, and the brake returns to the OFF position. Expander-tube shields (D) under the ends of adjoining brake blocks prevent the tube from squeezing out between the brake blocks where it could be pinched as the blocks move.

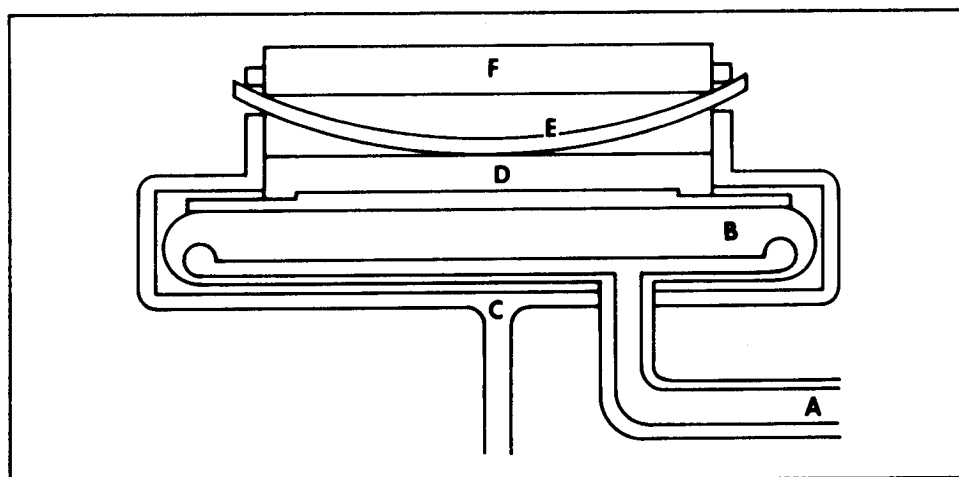
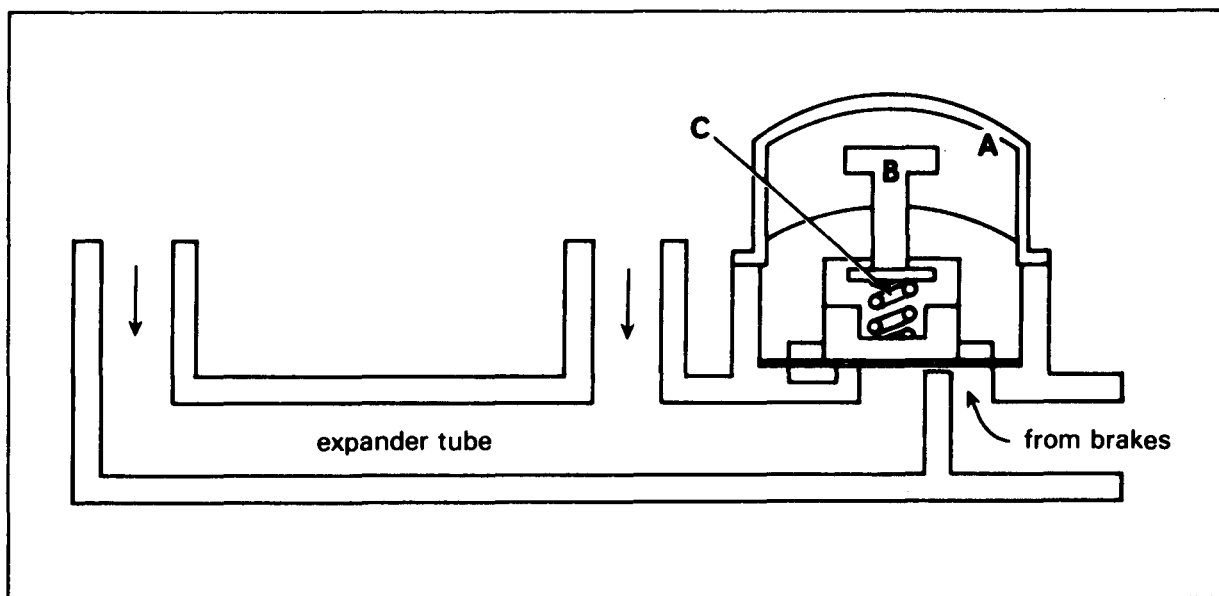


Figure 10-10. Expander-tube brake assembly.

Some expander-tube brakes have a brake adjuster valve (Figure 10-11); without this valve, brakes cannot be adjusted. The first step in adjusting the brakes is to release them and remove the brake adjuster valve cap (A). Then turn the brake adjusting screw (B) several turns clockwise to tighten the spring (C). In this position, the adjusting screw will cause the maximum quantity of fluid to remain in the expander tube. Now depress the brake pedal several times to fully expand the expander tube. If this puts the brake blocks against the drum, release the brakes and slowly turn the adjusting screw counterclockwise. This permits the brake blocks to retract from the drum. Keep checking with a feeler gage inserted between the brake blocks and the drum. When the minimum clearance specified in the aircraft technical manual is obtained, stop turning the screw. Then, with the weight of the aircraft on the wheels, reapply the brakes several times, and recheck for a uniform minimum clearance. Make clearance checks about 30 seconds after brakes are released to ensure that the brake blocks are retracted completely.



**Figure 10-11. Brake adjuster valve.**

**Deboosters.** A debooster is used in an aircraft brake system Pressurized by power-boost master cylinders or power brake control valves to ensure rapid application and release of brakes. This action reduces excessive heating and wear of the brakes caused by the extra drag on them before and after effective braking takes place. The main aircraft system fluid supply coming from the power-boost master cylinder or the power brake control valve is high in pressure but small in volume. Most aircraft do not need such high pressure going into the brake to lock the wheels; however, large aircraft with many wheel brakes require a large volume of fluid. The debooster solves this problem; it reduces the pressure but increases the volume to the brakes.

The basic elements of a typical brake debooster include a housing which has two fluid ports and two cylinder bores that are considerably different

in size and a stepped piston that fits the two bores. Figure 10-12 illustrates how the deboost器 operates. Assume that a master cylinder is connected to the upper port and a wheel brake assembly to the lower port; also that the small end of the piston is 1 inch square and the large end, 3 inches square. If the master cylinder delivers fluid under 1,200-psi pressure to the 1-square-inch bore, a thrust of 1,200 pounds will act on the piston and force it downward. As the 3-square-inch end of the piston pushes on the fluid in the lower cylinder bore, a pressure of 400 psi will be produced. This is because the total force of 1,200 pounds which the piston puts on the fluid spreads over the 3-square-inch area. It is evident then that a pressure of 1,200 psi delivered by the master cylinder results in a pressure of only 400 psi delivered to the wheel brake assembly. If the master cylinder delivers 1 cubic inch of fluid to the small end of the deboost器, the piston will move downward 1 inch. The resulting 1-inch movement of the larger piston will cause 3 cubic inches of fluid to be forced out of the lower port and into the wheel brake assembly. This three-to-one increase in fluid movement during brake application results in faster braking. On the other hand, the movement of 3 cubic inches of fluid out of the wheel brake assembly, while only 1 cubic inch of fluid is being returned to the master cylinder, speeds up the brake's release. The spring-loaded ball check in the small section of the piston serves as a compensating valve to release fluid out of the wheel brake assembly and the lower chamber of the deboost器 in the event of thermal expansion of the fluid. It also serves to replenish fluid lost because of leakage.

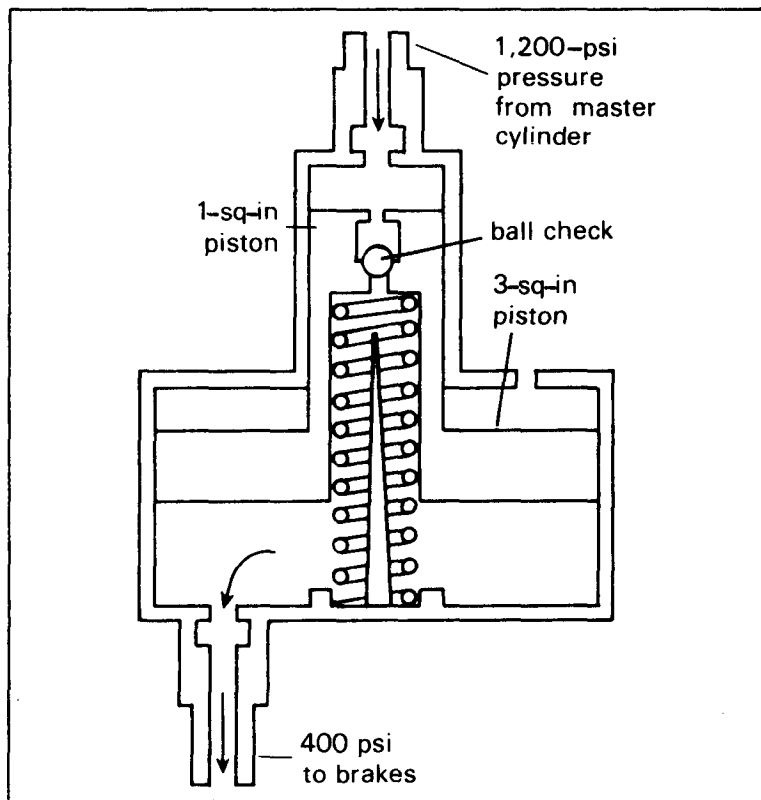
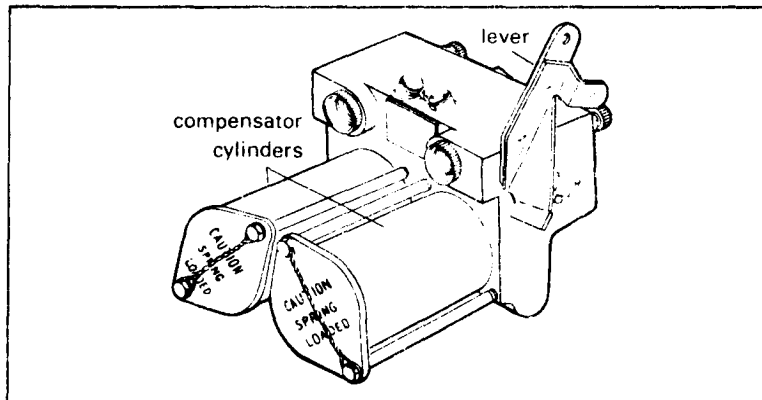


Figure 10-12. Brake deboost器.

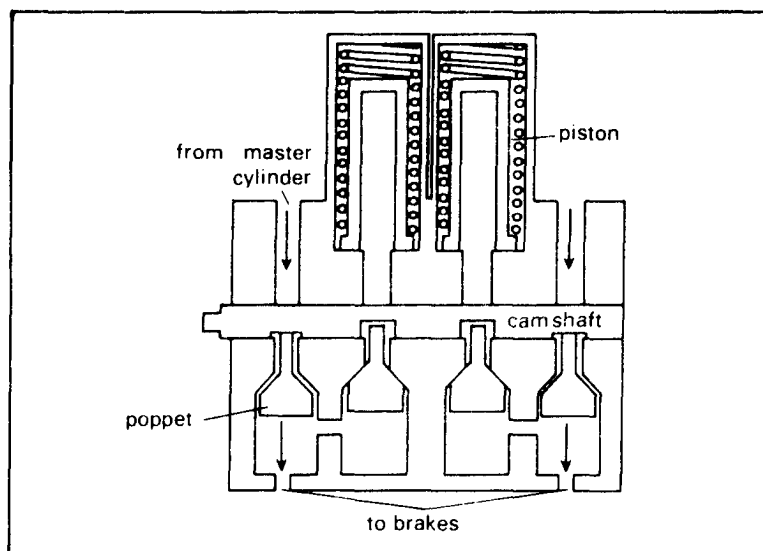


**Parking Brake Valves.** These valves are used as a means of trapping fluid pressure in the wheel brake assemblies to keep the brakes applied after parking. Individual and dual valves are commonly used. Since the dual valve is basically a combination of two individual valves, the following explanation of dual valves will serve for individual valves as well. (See Figure 10-13.)



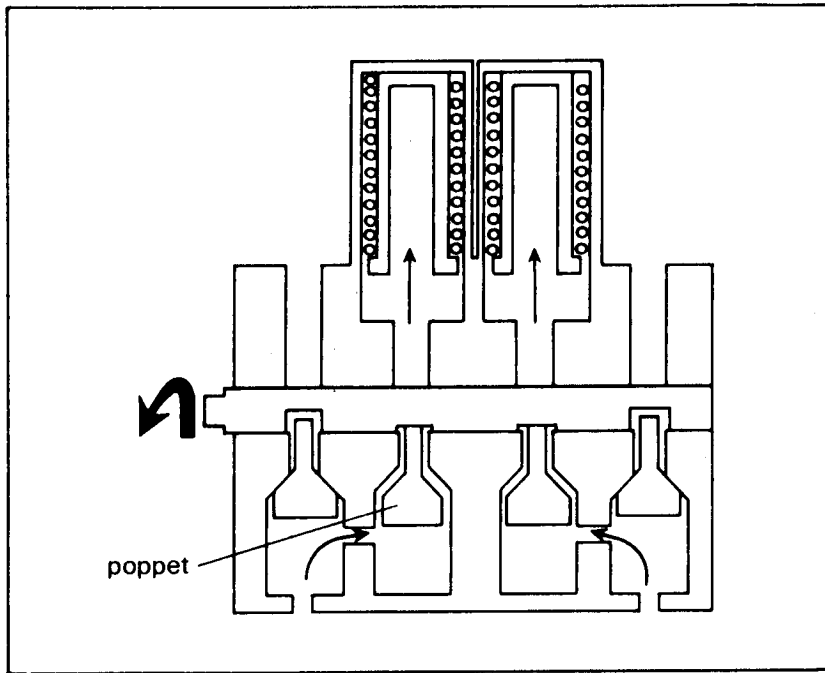
**Figure 10-13. Dual parking brake valve.**

The typical dual-type parking brake valve (Figure 10-14) incorporates two spring-loaded pistons in compensator cylinders, which provide an automatic means of compensating for changes in hydraulic oil volume caused by temperature changes or minor leakage. During normal braking of the aircraft by pedal actuation, the lever of the parking brake valve is held in the OFF position by a spring. The camshaft to which the lever is attached holds the two outer poppets of the valve unseated. This permits fluid pressure from the master cylinder or power brake control valve to pass straight through the parking brake valve to the wheel brake assemblies. In this position, the inner poppets are seated and the spring-loaded pistons are inoperative.



**Figure 10-14. Dual parking brake valve in the OFF position.**

To set the brake for parking, leave the parking brake valve in the OFF position until the brake pedals are depressed. (See Figure 10-15.) While the brake pedals are still depressed, pull the parking brake control handle to the PARK position. This rotates the camshaft of the valve, causing the outer poppets to seat; fluid pressure is now locked within the wheel brake assemblies. At the same time the rotating camshaft unseats the inner poppets, thereby opening the compensator cylinders to the wheel brake assemblies. As a result, the compensator cylinders become charged, the pistons become partially retracted, and the springs become partially compressed. Spring tension on the spring-loaded pistons maintains constant braking pressure by compensating for volume changes caused by temperature changes and minor leaks.

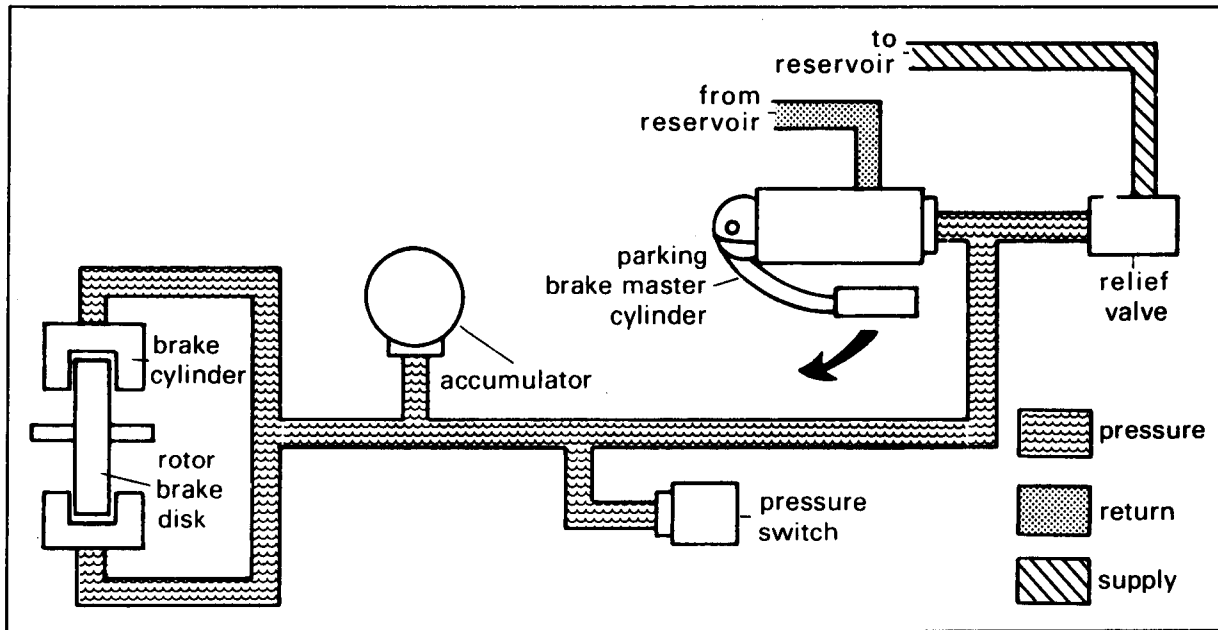


**Figure 10-15. Dual parking brake valve in the ON position (parked).**

After the parking brake has been set in the PARK position, release the brake pedals. The parking brake lever then becomes locked in the PARK position by a locking pin, which is extended to the locking position by a spring. The locking pin is retracted, permitting the release of the lever by fluid pressure when the brake system is pressurized by operating the brake pedals.

## ROTOR BRAKE SYSTEMS

Purpose. Rotor brake systems are installed on some helicopters to shorten the time required to bring their rotor assemblies to rest after the power has been shut off. They also prevent the rotor assemblies of parked helicopters from windmilling. Figure 10-16 shows a basic hydraulic rotor brake system. Newer helicopters have more complex systems, but the same basic principles apply.



**Figure 10-16. Hydraulic rotor brake system.**

**Operation.** To apply the rotor brake, slowly push the master cylinder handle downward and forward. (See Figure 10-16.) This results in a movement of the master cylinder piston that forces fluid out of the master cylinder and into the rotor brake cylinders. The fluid's movement causes the pistons and brake linings of each pair of brake cylinders to move toward each other. This produces a clamping action on the rotor brake disk which stops its rotation. The master cylinder handle is automatically locked in the brake ON position for parking the aircraft by a spring-loaded latch. To release the brake, the spring-loaded latch has to be pulled outward to disengage it from the handle. A spring-loaded detent helps to hold the handle in the released position.

## MAINTENANCE

**Inspections.** Inspections must be conducted at frequent intervals, and maintenance work must be performed promptly and carefully. The system should be under operating pressure when it is being checked for leaks, but loose fittings must be tightened with the pressure off. All flexible hoses should be carefully checked for swelling, cracking, and soft spots; they should be replaced if any deterioration is noted. The proper fluid level must be maintained at all times to prevent brake failure and to prevent air from entering the system. Air in the system is indicated by a spongy action of the brake pedals. If air is present, remove it by bleeding the system.

**Bleeding Operations.** There are two general methods of bleeding brake systems--from the bottom upward (pressure method) and from the top downward (gravity method). The method used generally depends on the type and design of the brake system to be bled and the bleeding equipment that is available.

Pressure Method. In the pressure method, air is expelled through the brake system reservoir or some other specially provided location. Some aircraft have a bleeder valve located in the upper brake line. In this method of bleeding, pressure is supplied by a pressurized hydraulic fluid dispenser. (See Figure 10-17.) A fluid dispenser is a portable tank filled with hydraulic fluid which is then put under pressure with compressed air. The fluid dispenser is equipped with an air valve, an air gage, and a connector hose. The connector hose is provided with a shutoff valve. This connector hose is normally connected to the lowest bleed fitting on the brake assembly. With the brake bleed fitting opened, opening the fluid dispenser shutoff valve allows pressurized fluid to flow from the fluid dispenser through the brake system until all trapped air is expelled. The brake bleeder valve is then secured, and the hose is disconnected.

NOTE: Only fully trained and authorized personnel will operate and service the hydraulic fluid dispenser.

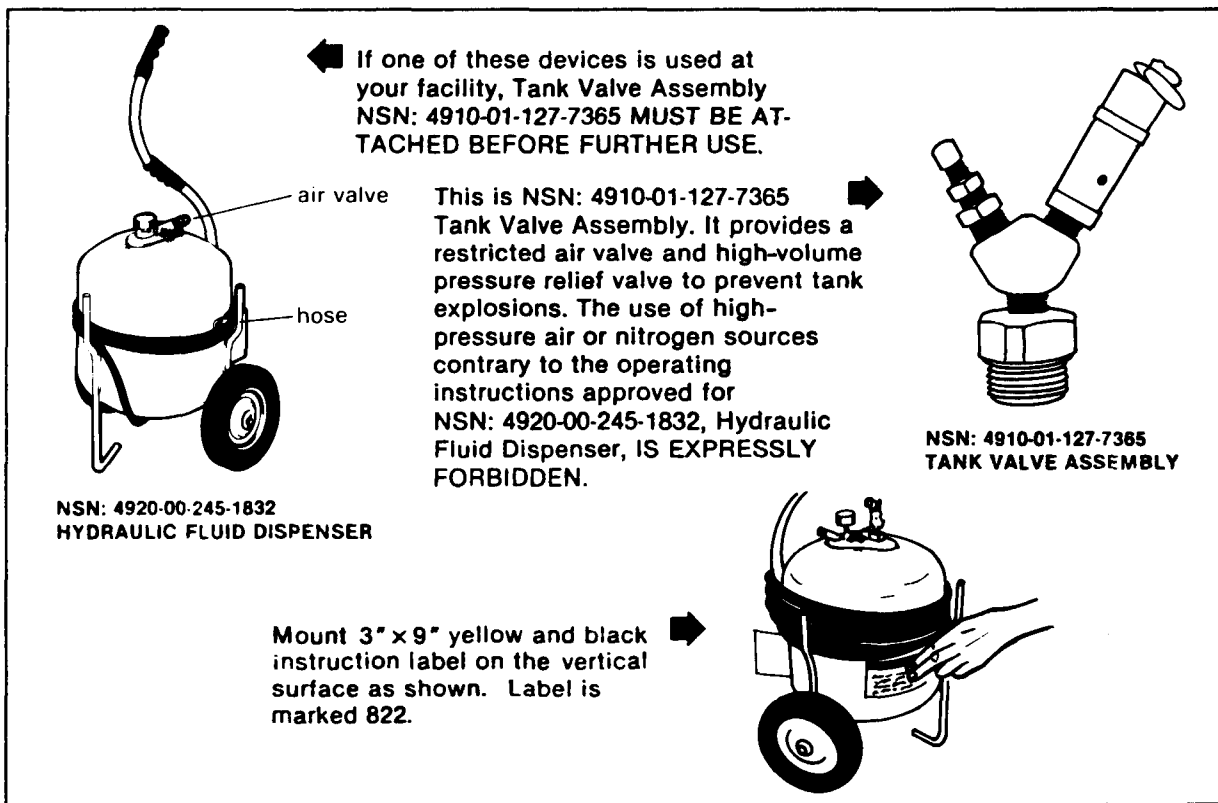


Figure 10-17. Hydraulic fluid dispenser and tank valve assembly.

CAUTION

USE OF HYDRAULIC FLUID DISPENSER NSN 4920-00-245-1832 IS EXPRESSLY FORBIDDEN UNLESS RETROFITTED WITH TANK VALVE ASSEMBLY NSN 4910-01-127-7365 AND PROPERLY LABELED AS SHOWN IN FIGURE 10-17.

## CAUTION

NEVER EXCEED 50 PSI WHEN CHARGING THE FLUID DISPENSER.

## CAUTION

MAKE SURE A SUFFICIENT AMOUNT OF FLUID IS MAINTAINED IN THE FLUID DISPENSER DURING BLEEDING OPERATIONS.

After bleeding, always check the system reservoir to ensure that it is full of hydraulic fluid.

**Gravity Method.** In the gravity method, the air is expelled from the system through one of the bleeder valves on the brake assembly. To bleed the system using this method, attach a bleeder hose to the bleeder valve. (See Figure 10-18.) Then place the free end of the hose in a container holding enough hydraulic fluid to cover the end of it. The air-laden fluid is then forced from the system by applying the brakes. If the brake system is part of the main hydraulic system, use a portable hydraulic test stand to supply the pressure. If the system is an independent master cylinder system, use the master cylinder to supply the necessary pressure. In either case, close the bleeder valve each time the brake pedal is released; otherwise air will be drawn back into the system. Bleeding should continue until no more air bubbles come through the bleeder hose into the container.

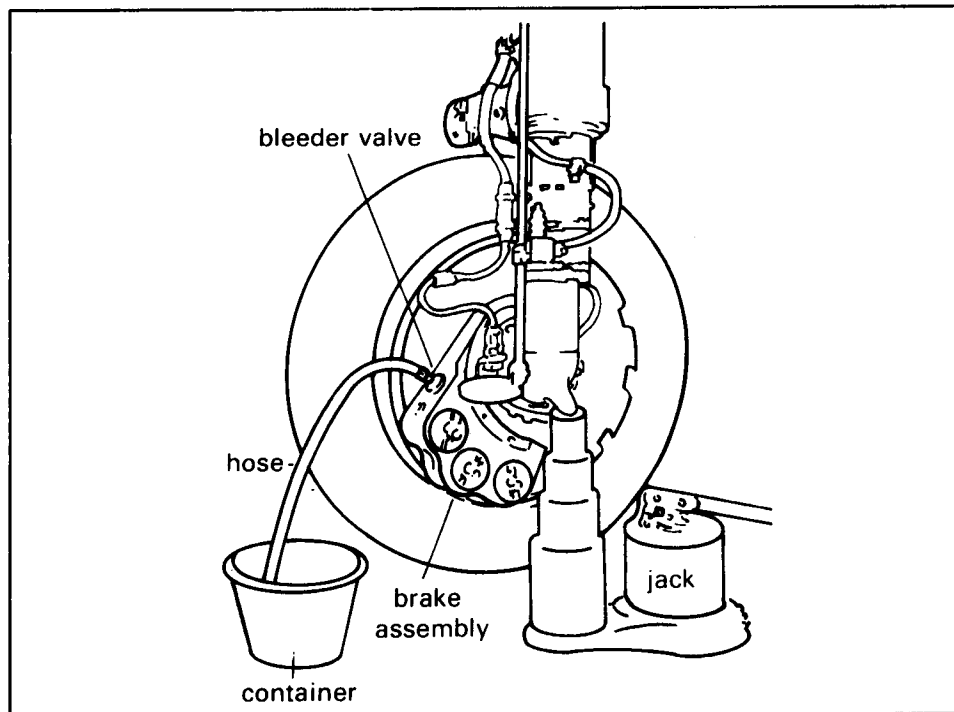


Figure 10-18. Gravity method.

Troubleshooting Procedures. Table 10-1 lists common problems found in wheel brake systems used on Army aircraft. Table 10-2 lists common problems found in rotor brake systems used on Army aircraft.

**Table 10-1. Troubleshooting Wheel Brake Systems**

TROUBLE	PROBABLE CAUSE	REMEDY
Brakes do not hold	Air in system Leaks in system Worn brake linings Oil or grease on brake linings Leak in master cylinder or power brake control valve	Bleed system. Check for leaks and tighten all fittings. Replace brake linings as necessary. Replace brake linings as necessary. Replace master cylinder or power brake control valve and bleed system.
Brakes grab	Stones or other foreign matter locking brake disk Warped or bent brake disk	Clean brake disk brake linings Replace brake disk.
Brakes will not release	Parking brake stuck Blockage in master cylinder or power brake control valve	Replace parking valve and bleed system. Replace master cylinder or power brake control valve; bleed system.
Dragging brakes	Warped disk Automatic adjusting mechanism faulty	Replace disk. Replace adjusting mechanism or brake assembly.
Excessive force required on brake pedals of power-boost brake system to apply brakes.	Power-boost master cylinder inoperative. Excessively worn brake linings Failure of main or utility hydraulic system pressure	Replace power-boost master cylinder and bleed system. Replace brake linings. Check main or utility hydraulic system; correct defect.
Parking brake will not hold	Air in system Defective parking brake valve Parking brake valve control out of adjustment	Bleed brakes. Replace parking brake valve; bleed system. Adjust parking valve control.
Pedals bottom, no brakes	Broken or leaking brake line Master cylinder or power brake control valve defective Excessively worn brake linings Air in system Too little fluid in system	Replace damaged line and bleed system. Replace master cylinder or power brake control valve; bleed system. Replace brake linings. Bleed brakes. Replenish supply and bleed brakes.
Solid pedal and no brakes	Excessively worn brake linings or grease on brake linings	Replace brake linings.
Spongy brakes	Air in system Low hydraulic fluid level	Bleed brakes. Replenish supply.
Unable to hold pressure	Leak in brake system Master cylinder or power brake control valve defective	Visually check entire system for evidence of leaks. Replace master cylinder or power brake control valve; bleed system.
Uneven braking	Worn brake linings Worn brake disk Air in system Leaking line connection Worn or damaged pressure relief valve	Replace brake linings. Replace brake disk. Bleed system. Tighten connection and bleed system. Replace pressure relief valve and bleed system.
Weak braking	Air in system Master cylinder or power brake control valve defective Insufficient supply of hydraulic fluid Brake linings worn excessively	Bleed system. Replace master cylinder or power brake control valve; bleed system. Replenish supply. Replace brake linings.

**Table 10-2. Troubleshooting Rotor Brake Systems**

TROUBLE	PROBABLE CAUSE	REMEDY
<p>Brake does not hold .</p>	<p>Brake cylinders improperly adjusted .                      Leakage in lines .....                      Defective accumulator .....                        Accumulator air pressure escaping into brake lines (brake off over a prolonged period).....                      Internal or external leakage in master cylinder.....                      Low oil level in utility reservoir.....</p>	<p>Adjust cylinders.                      Repair or replace as necessary.                      Check air pressure; replace accumulator if necessary.                        Service accumulator and bleed air out of brake lines.                      Replace master cylinder.                      Service reservoir.</p>
<p>Brake does not release (lining drags on disk).</p>	<p>Improper internal adjustment of brake cylinder.....                        Brake disk warped.....</p>	<p>Replace brake cylinder.                        Replace disk.</p>
<p>Clutch pump operates with rotor brake on.</p>	<p>Defective rotor brake limit switch...                        Open circuit breaker.....                      Defective clutch control relay.....</p>	<p>Check prime power source and continuity; replace switch if necessary.                      Reset circuit breaker.                      Replace relay.</p>
<p>Spongy brake</p>	<p>Air in lines .....                        Brake cylinders improperly adjusted.</p>	<p>Bleed air at master cylinder and/or brake cylinders.                      Adjust brake cylinders.</p>
<p>Master cylinder handle does not lock in parked position (when not made inoperative by latch).</p>	<p>Defective latch.....</p>	<p>Replace master cylinder.</p>
<p>Master cylinder handle does not release.</p>	<p>Defective latch.....</p>	<p>Replace handle.</p>

## CHAPTER 11

### DAMPENING AND ABSORBING UNITS

#### HYDRAULIC DAMPERS

Purpose. A damper is a device that controls the speed of relative movement between two connected objects. Usually one end of the damper is connected to a fixed member; the other end, to a movable part. The reacting parts of the damper move against considerable resistance, which slows the speed of relative movement between the objects.

Types. Hydraulic dampers used in Army aircraft operate either by displacing fluid (displacement dampers) or by shearing fluid (shear dampers).

Displacement Dampers. The two types of displacement dampers are the piston type (Figure 11-1) and the vane type (Figure 11-2). Though different in construction, both types have the same basic design characteristics--a sturdy metal container with a sizable inner space divided into two or more chambers. The chambers vary in size according to the position of the parts within the damper. The chambers must be completely filled with fluid to operate properly.

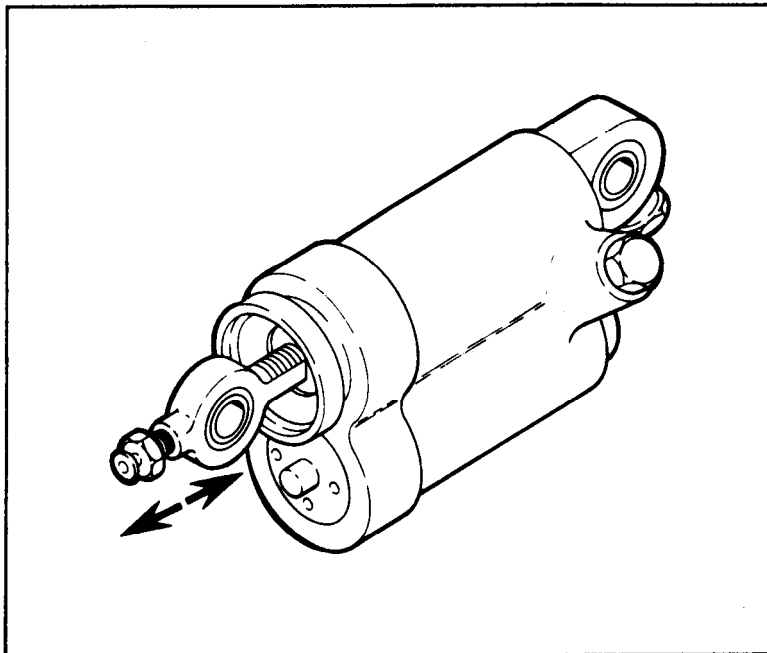
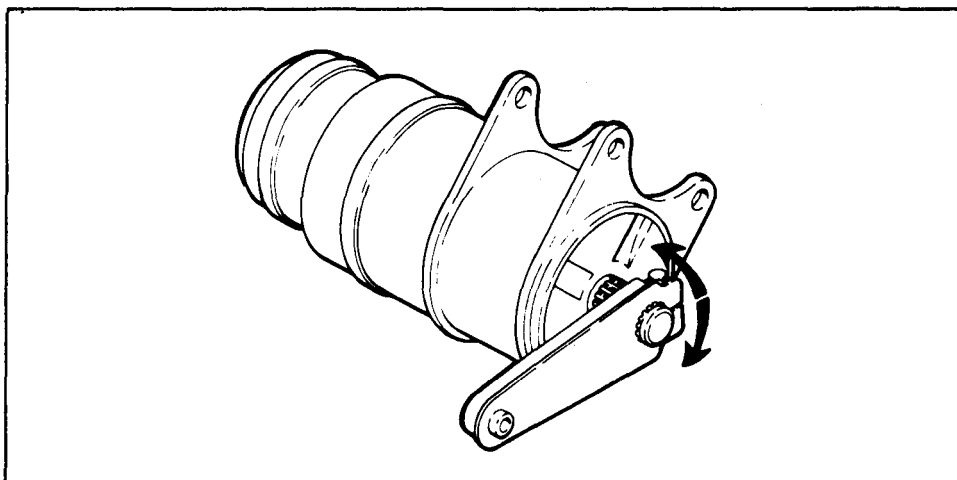


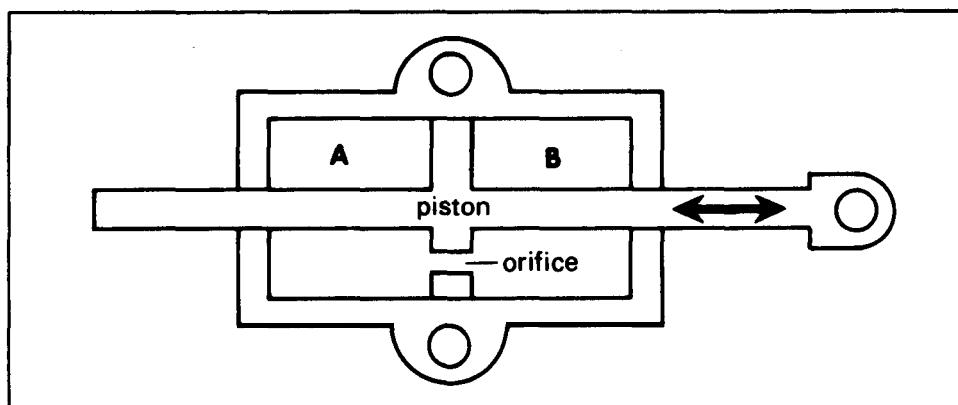
Figure 11-1. Piston-type displacement damper.





**Figure 11-2. Vane-type displacement damper.**

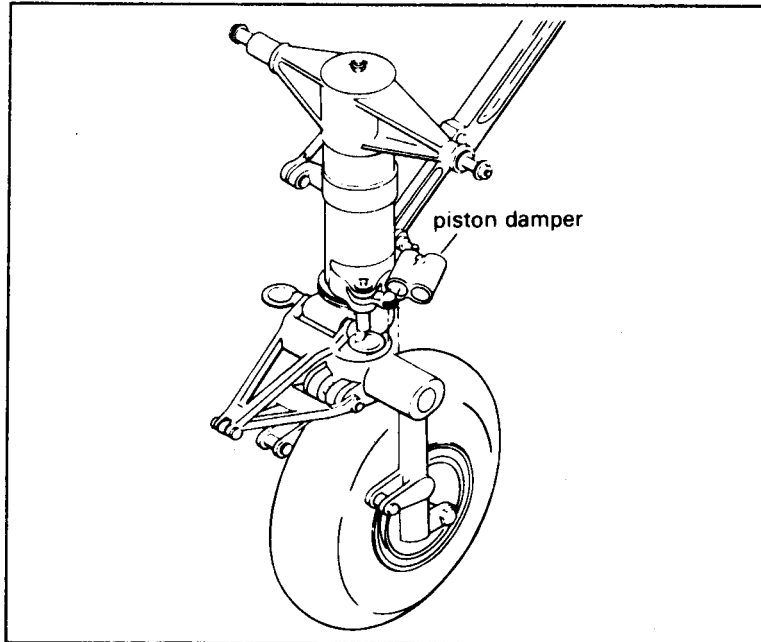
**Piston-type displacement dampers.** In this type damper, the piston and rod assembly divides the space within the damper housing into two chambers. (See Figure 11-3.) Seal rings on the piston prevent fluid leakage between the chambers. An orifice permits fluid to pass with restricted flow from one chamber to the other. A filler port (not shown) services the damper with fluid.



**Figure 11-3. Piston-type displacement damper.**

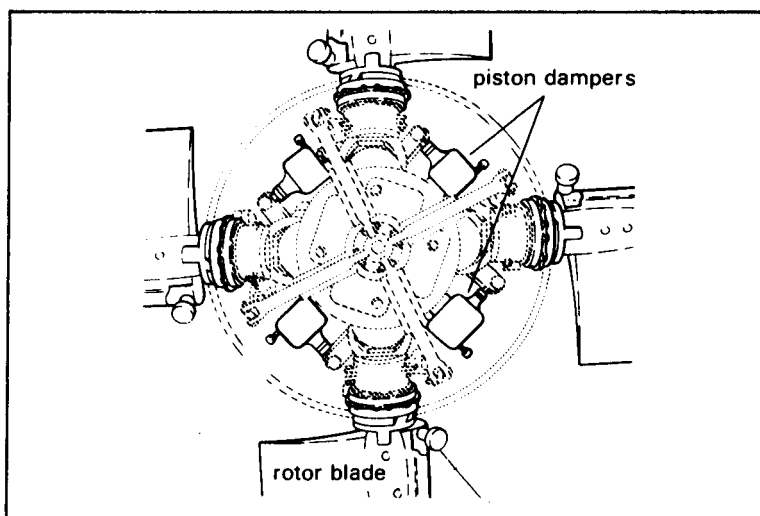
As the piston is forced to the right, chamber B decreases in proportion to the distance the piston is moved. Simultaneously, chamber A increases by a comparable size. The hydraulic fluid displaced from chamber B flows through the restricting orifice into chamber A. When the piston is moved toward the left, reverse changes occur in the chamber sizes and in the direction of fluid flow. The restriction of the fluid flow by the orifice slows the rate of speed at which a given amount of force can move the damper piston. The rate at which a damper moves in response to a force is called damping rate or timing rate. In some dampers, the opening is a fixed size, and the timing rate is not adjustable. In other dampers, the orifice size is adjustable to allow for timing adjustments. The three types of piston dampers are the nose landing gear damper, the tail rotor pedal damper, and the rotor blade damper:

- **Nose landing gear damper.** The nose landing gear of an aircraft has a tendency to shimmy when the aircraft is taxiing at any appreciable speed. This type damper is used to eliminate wheel shimmy without interfering with the normal steering movements on the nose wheel. (See Figure 11-4.)



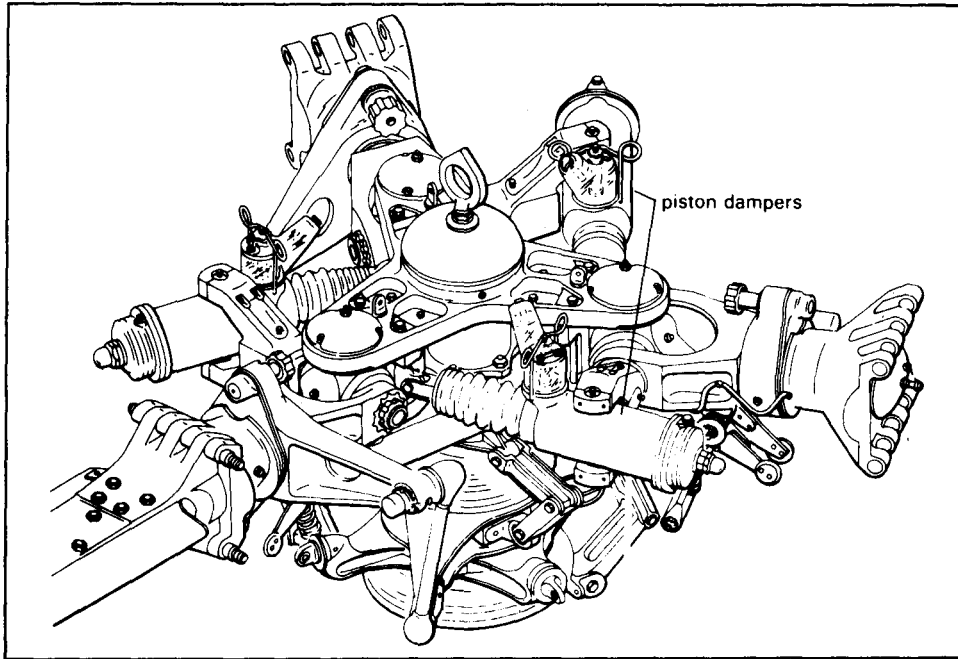
**Figure 11-4. Nose landing gear with piston damper.**

- **Tail rotor pedal damper.** Piston-type dampers are used on some helicopters that have power-assisted tail rotor control systems. The dampers are connected to the pedals to prevent rapid pedal movement. (See Figure 11-5.) If the pedals move too rapidly, an excessively fast yaw movement of the aircraft results; this could cause structural damage.



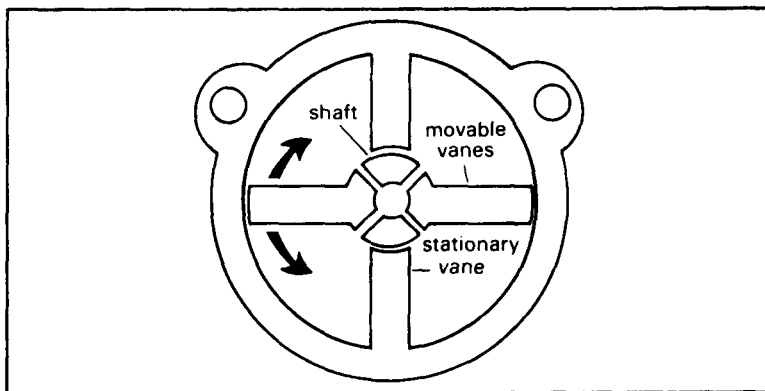
**Figure 11-5. Tail rotor assembly with piston dampers.**

- Rotor blade damper. Piston-type dampers are used on helicopter rotor head assemblies and tail rotor hub assemblies to control lead-lag movements of rotor blades. Note how the dampers are connected in the illustration at Figure 11-6. Lead-lag movements occur when three or more blades are in a set, and they are hinged to the rotor head.



**Figure 11-6. Main rotor assembly with piston-type rotor blade dampers.**

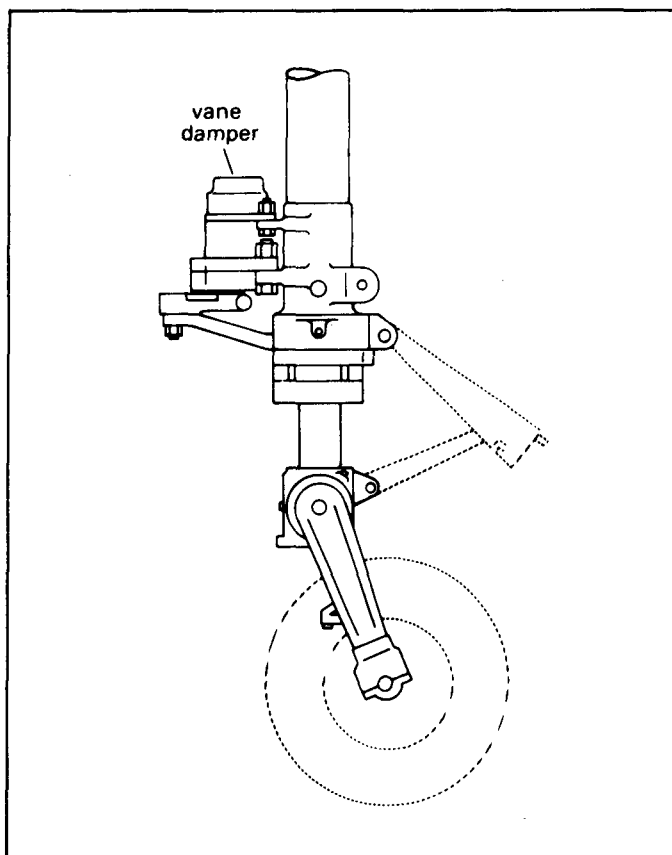
Vane-type displacement dampers. A typical vane-type damper consists basically of a cylindrical housing having a polished bore with two stationary vanes (called abutments) and a shaft supporting two movable vanes. (See Figure 11-7.) Together, the four vanes split the cylinder bore lengthwise into four chambers. The two stationary vanes are attached to the damper housing. The two movable vanes, along with the shaft, make up a unit called a wing shaft, which rotates between the abutments. One end of the wing shaft is splined and protrudes through the damper housing. A lever arm attached to the splined end rotates the wing shaft.



**Figure 11-7. Vane-type displacement damper.**

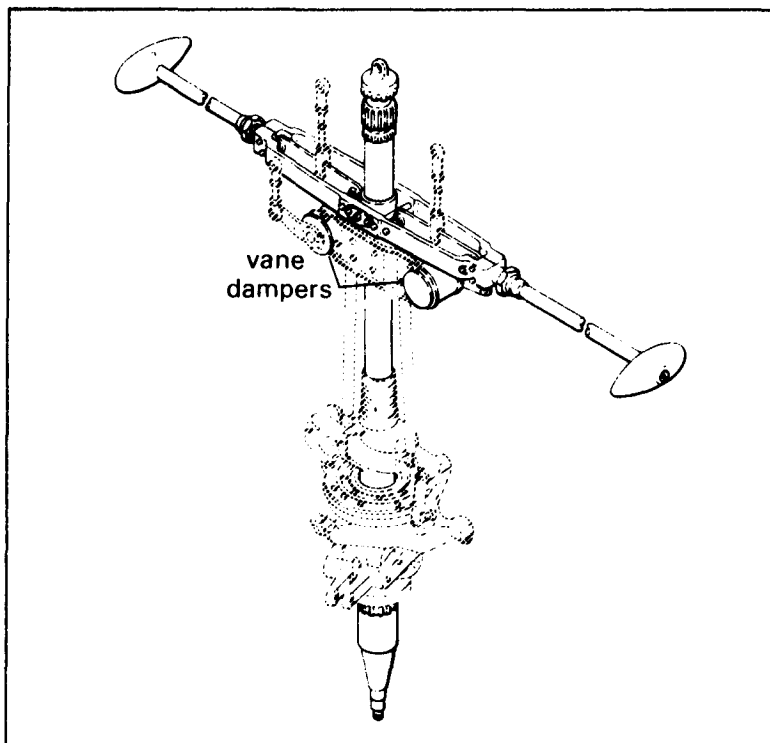
The damper chambers are completely filled with fluid. At any instant of damper motion, the fluid is subjected to forced flow. As the wing shaft rotates, fluid between the chambers flows through an opening within the wing shaft, which interconnects the four chambers. Then a restraining force is developed in the damper, dependent on the velocity of fluid flow through the orifice. Slow relative movement between the wing shaft and damper housing causes a low-velocity flow through the opening and little resistance to damper arm rotation. A more rapid motion of the wing shaft increases the speed of fluid flow and thus increases resistance to damper arm rotation. The timing rate of vane-type dampers can be adjusted by a timing adjustment centrally located in the exposed end of the wing shaft. This adjustment sets the effective size of the opening through which fluid flows between chambers; it determines the speed of movement with which the damper will respond to an applied force. The vane-type mechanism is sensitive to changes in fluid viscosity caused by changes in fluid temperature. Most vane-type dampers have a thermostatically operated compensating valve to provide consistent timing rate performance over a wide range of temperatures. The two types of vane-type dampers are the nose landing gear damper and the stabilizer bar damper.

- Nose landing gear damper. A vane-type damper is used on the nose landing gear of some aircraft to eliminate the shimmy tendency. (See Figure 11-8.)



**Figure 11-8. Nose landing gear with vane damper.**

- **Stabilizer bar damper.** Some helicopters have vane-type dampers that control the degree of sensitivity with which a helicopter responds to movements made by the pilot on the flight controls. (See Figure 11-9.) These dampers are mounted on a bracket attached to the helicopter mast (main shaft). The damper arms are interconnected with other parts of the flight control system.

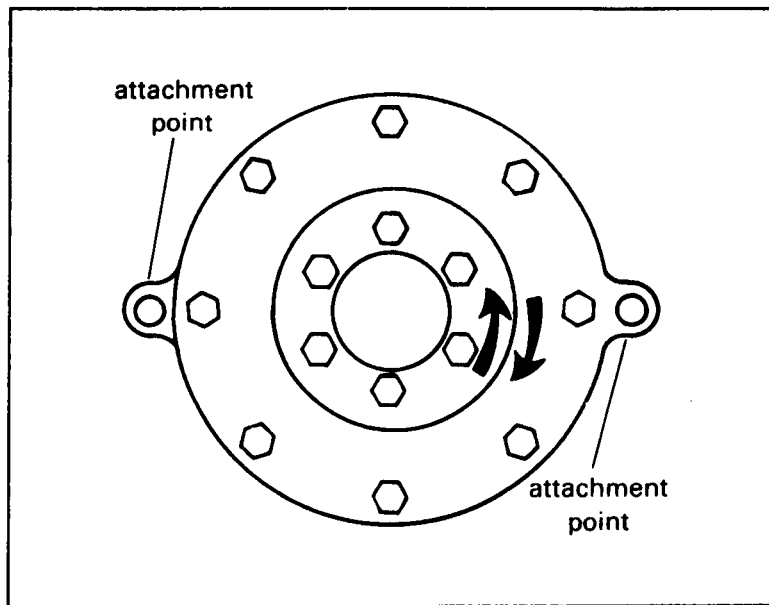


**Figure 11-9. Stabilizer bar with vane dampers.**

**Shear Dampers.** In dampers operating on the shear principle, fluid is not forced out of one space and into another space within the damper as it is in displacement dampers. Instead, action on the fluid involves tearing (shearing) a thick film of highly viscous fluid into two thinner films that move with resistance in opposite directions. Highly viscous fluid is thick-bodied, syrupy, and sticky.

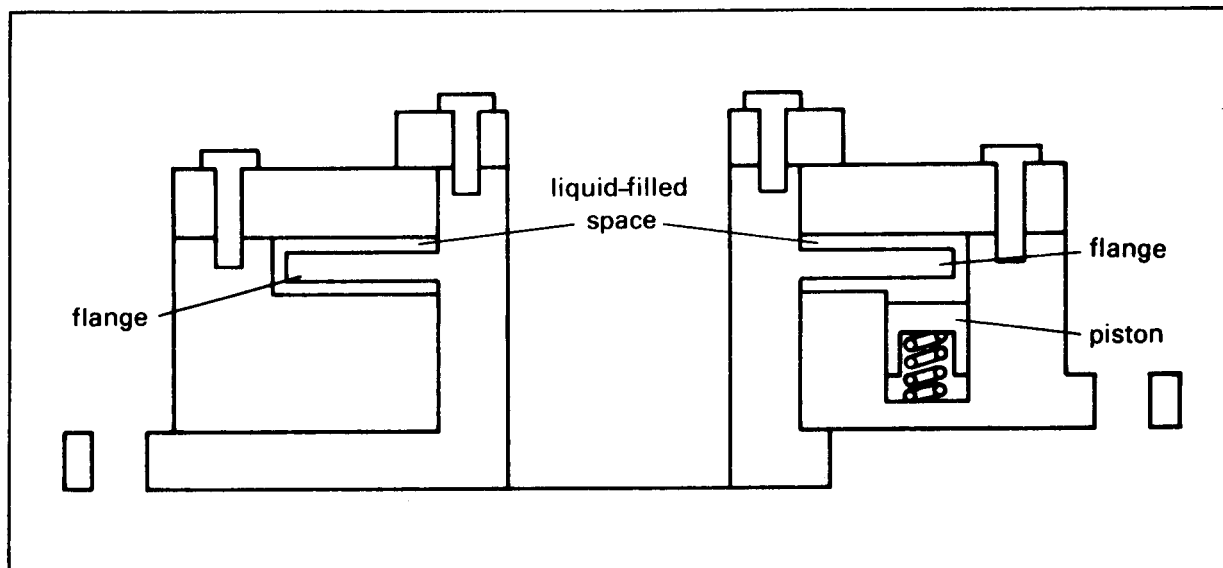
In a shear damper, two reacting parts are free to slide or rotate past each other as the damper operates. The surfaces facing each other are relatively smooth; between them is a preset gap of a few thousandths of an inch. This gap is filled with highly viscous fluid. As the parts of the damper move relative to each other, the film of fluid in the gap between them shears into two thinner films. Each film sticks to and moves along with one of the parts. It is the friction within the fluid itself that causes resistance to movement of the parts to which the films stick. To better understand this principle, imagine a puddle of syrup spilled on a relatively smooth table top. A sheet of paper placed on top of the puddle would move with considerable drag. This is very much like what happens between the parts of a shear damper as the damper operates. The two types of shear dampers on Army aircraft are the rotary type and the linear type.

Rotary-type shear damper. A typical rotary-type, shear damper consists of two members that are free to rotate together. (See Figure 11-10.) Each of the members is attached to one of the two objects whose relative movement the damper will restrain.



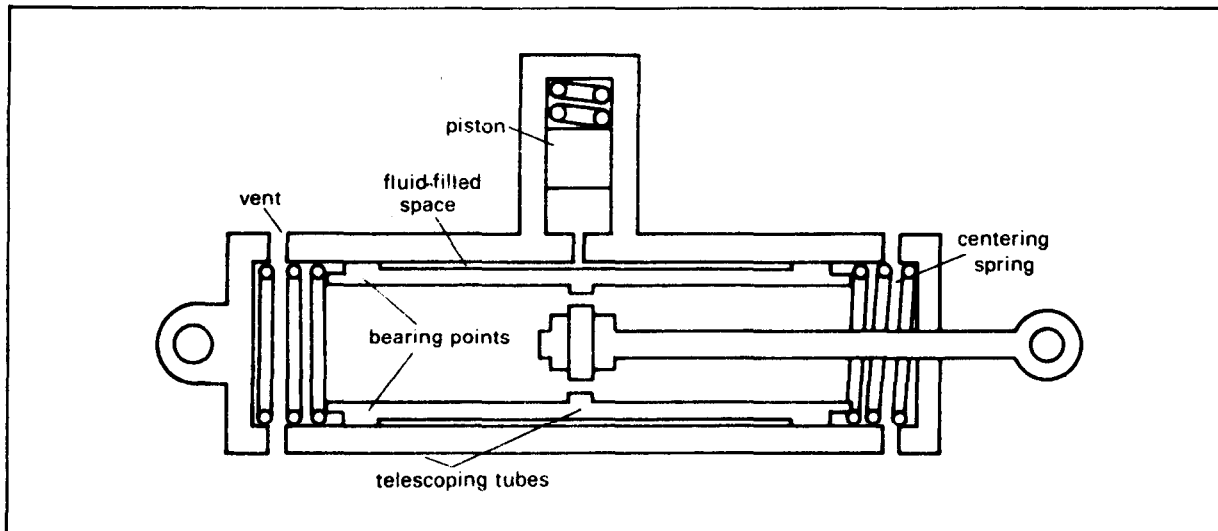
**Figure 11-10. Rotary-type shear damper.**

One of the damper members has a flange-like section that fits between these two objects. (See Figure 11-11.) Bearing points ensure that the flange is centered between the two surfaces. The spaces between the flange surfaces and the other two surfaces are filled with highly viscous fluid. A spring-loaded piston applies pressure to a supply of replenishment fluid to ensure that the spaces are always completely filled with fluid.



**Figure 11-11. Schematic of a rotary damper.**

**Linear-type shear damper.** A typical linear-type, shear damper consists of two telescoping tubular members that can be connected to the two objects whose movement will be restrained. (See Figure 11-12.) Between the telescoping tubes, bearing points hold a preset space to a uniform thickness. The springs at the ends of the inner tubular member provide a centering tendency that makes the damper double-acting. The spring-loaded piston keeps the space between the tubular members filled with fluid.



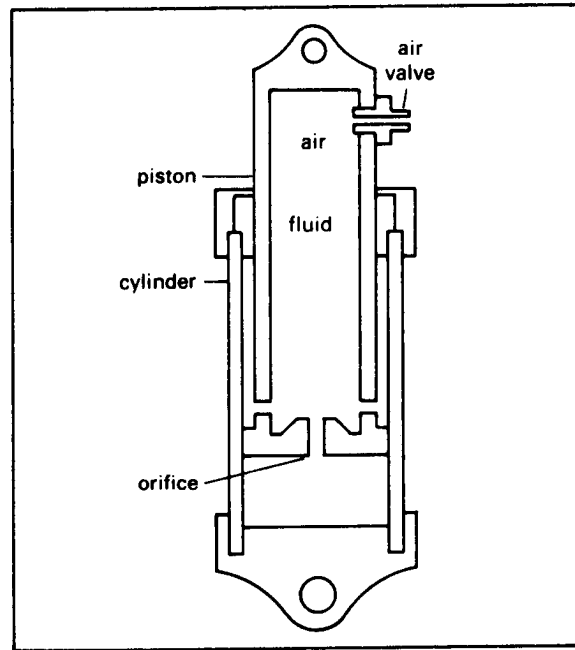
**Figure 11-12. Schematic of a linear damper.**

## SHOCK STRUTS

**Purpose.** A shock strut can be thought of as a combination suspension unit and shock absorber. It performs functions in an aircraft similar to those performed in an automobile by the chassis spring and the shock absorber.

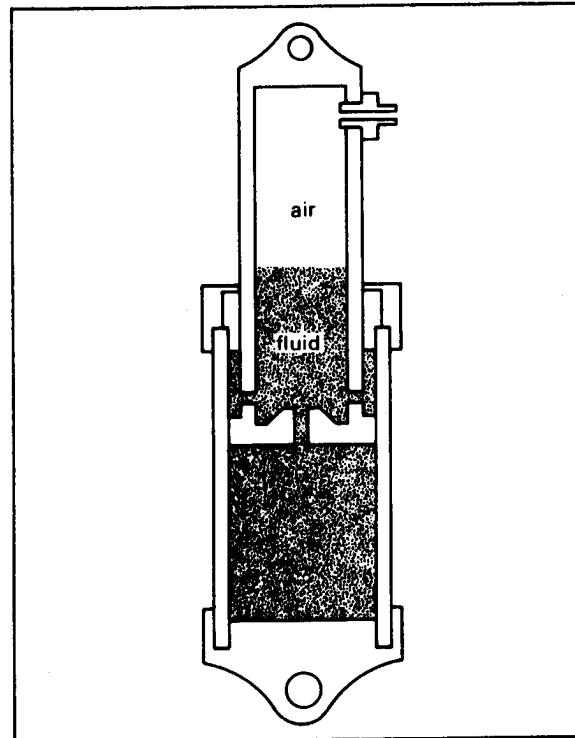
**Types.** The two major types of shock struts are the mechanical type and the pneudraulic type. In the mechanical type, a rubber or spring mechanism performs the cushioning operation. In the pneudraulic type, air and hydraulic fluid accomplish this. Since pneudraulic struts are the ones most commonly used in Army aircraft, they are the only type discussed in this manual. The two types of pneudraulic struts are the simple type and the complex type.

**Simple Shock Struts.** The basic parts of a simple shock strut are two telescoping tubes: a piston and a cylinder. A simple shock strut is installed in an aircraft with the piston uppermost and the cylinder filled with fluid. (See Figure 11-13.) An orifice in the piston head permits fluid to pass from one chamber to the other. When a shock strut has sufficient fluid above the piston head, the above above the fluid is filled with air. When the aircraft is landing and the shock strut is compressing, fluid is forced through the orifice into the piston. The movement of fluid through the orifice, together with the compression of the air, absorbs the energy of the descending aircraft's motion.



**Figure 11-13. Simple shock strut (compressed).**

When the load on the shock strut is lightened, the shock strut extends. (See Figure 11-14.) This extension is caused by the force exerted by the compressed air in the shock strut and, during takeoff, by the weight of the lower tube and attached landing gear. When the shock strut is extending, fluid in the piston passes through the orifice into the cylinder.

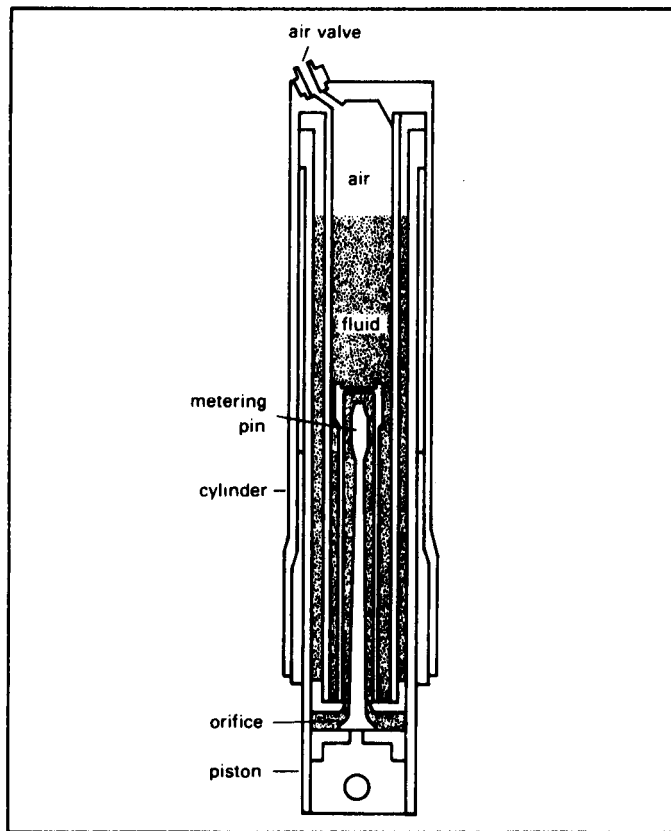


**Figure 11-14. Simple shock strut (extended).**



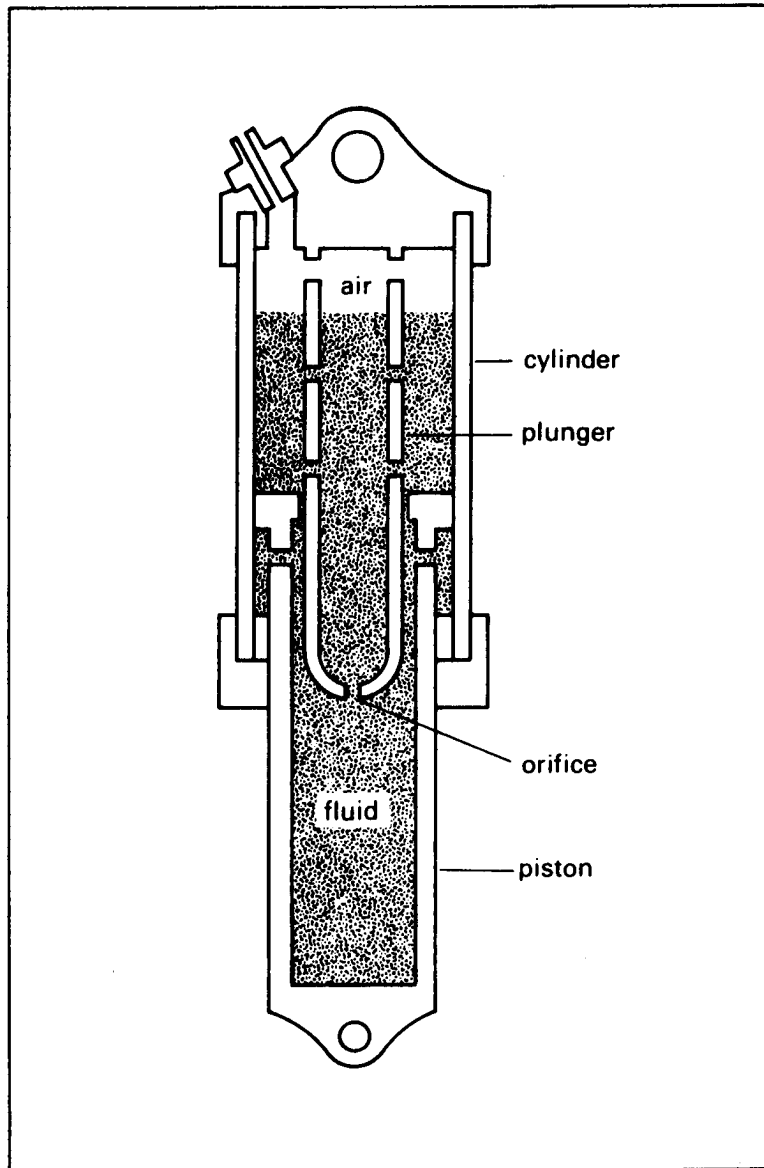
**Complex Shock Struts.** A complex shock strut (Figure 11-15) works in essentially the same manner as a simple one; however, it contains, besides two telescoping tubes, a number of parts that provide a more effective damping action than a simple strut. Design features found singly or in combination in complex-type shock struts are the metering pin, plunger, and floating piston.

**Metering pin.** The metering pin changes the effective size of the orifice to vary the rate of fluid flow from one chamber of the shock strut to the other. The diameter of the metering pin varies along its length; it is almost equal at the ends and smaller in the middle. The unanchored end of the metering pin is located in the orifice when the shock strut is fully extended. The large diameter of the pin at this end provides a high resistance to fluid flow, a condition that is required during landing. The small diameter portion of the metering pin is located within the orifice when the shock strut is in the taxi position (partially compressed). This provides the low resistance to fluid flow that is required for taxiing. The portion of the metering pin nearest its anchored end lies within the orifice when the shock strut is completely compressed. The large diameter of the metering pin at this end provides increased resistance to fluid flow. The design of the pin at this end ensures against bottoming of the shock strut during unusually hard landings. The gradual increase in the diameter of the pin toward the anchored end prevents a sudden change in resistance to fluid flow.



**Figure 11-15. Metering pin-type complex shock strut.**

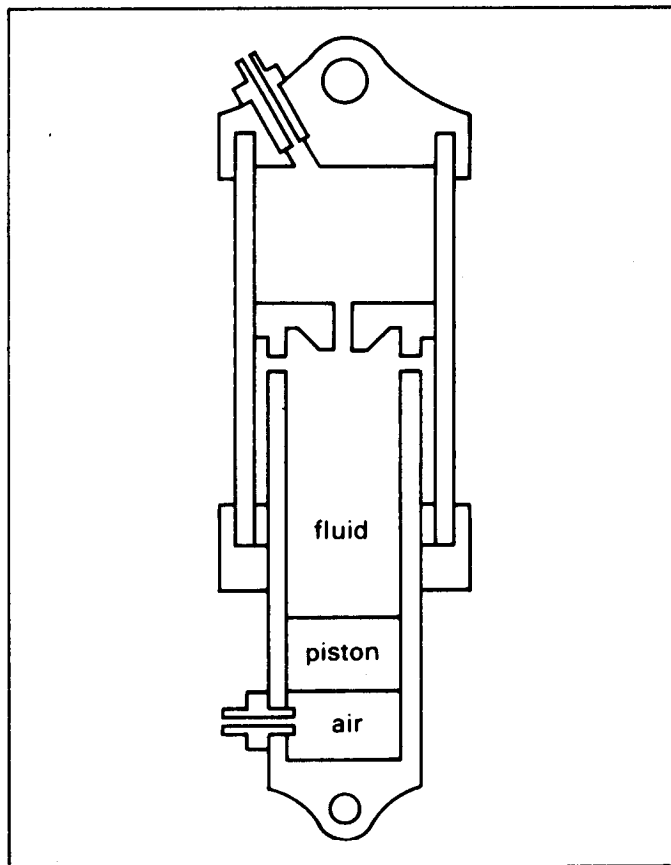
**Plunger.** Some complex shock struts are mounted on the aircraft with their cylinders uppermost. (See Figure 11-16.) In such a unit, a plunger anchored in the cylinder extends downward into the piston. The plunger forces fluid out of the piston and into the cylinder during the shock strut compression. The plunger is hollow; fluid enters and leaves its interior through an orifice and holes in its walls.



**Figure 11-16. Plunger-type complex shock strut.**

**Floating piston.** In some shock struts, the air charge is carried at the bottom of the shock strut instead of at the top. Since air normally rises to the top of a liquid, a device must be provided to keep the air below the liquid. A floating piston serves this purpose. In the floating-piston-type shock strut, the upper chamber of the strut decreases

in size as the strut compresses. (See Figure 11-17.) This is because the compression forces fluid downward out of the upper chamber into the lower fluid chamber. The increase in the lower fluid chamber's size, necessary for accommodating the inflow of fluid, is obtained by the floating piston's downward movement. Besides holding the air below the fluid, the floating piston contributes to the movement of fluid through the orifice as the shock strut compresses and extends.



**Figure 11-17. Floating-piston-type complex shock strut (compressed).**

Functions. Shock struts perform three major functions. They support the static load (deadweight) of the aircraft, cushion the jolts during taxiing or towing of the aircraft, and reduce shock during landing.

Supporting Static Loads. The normal load of a parked aircraft is static, meaning the force present is fixed. The pressure of the air and fluid within a shock strut tends to keep the shock strut fully extended. However, air pressure in a shock strut is not enough to keep the strut fully extended while supporting the static load of an aircraft. Therefore, a shock strut gives under load and compresses until the air pressure builds enough to support the aircraft.

Cushioning Jolts. As an aircraft taxis, the uneven surface of the runway causes the aircraft to bob up and down as it moves forward (sometimes air currents contribute to this effect). The inertia of the

aircraft fuselage in opposition to such up-and-down movement causes the force of the taxi load to fluctuate. This bouncing motion is held within limits by the damper-like action of the shock strut. This dampening results from resistance created by the back-and-forth flow of fluid through the orifice as the shock strut extends and compresses.

**Reducing Shock.** The aircraft will continue to descend at a high rate when landing, even after the wheels touch the ground. In the few remaining inches that the fuselage can move toward the ground after the wheels touch, the descent of the aircraft must be stopped. To do this, the shock strut must remove a great amount of energy from the downward movement of the aircraft. The impact force is very great compared to the force exerted by the mere weight of the aircraft. The shock strut removes some of the energy of motion and impact force by converting energy into heat and dissipating the heat into the atmosphere. The resistance to fluid flow offered by the orifice is the principal means of developing the heat. Also, the temperature of the air inside the strut rises as the air is compressed.

The speed of a descending aircraft while landing causes overcompression of the air in the shock strut. As a result, the air pressure is greater than that needed to support the static load of the aircraft. The excess pressure tends to extend the shock strut and bounce the aircraft back into the air. For comfort and control of the aircraft, this rebound has to be held to the lowest level possible. The most common means of counteracting rebound involves the use of a shock strut annular space. The annular space is a chamber that surrounds the polished piston surface that lies within the cylinder. The space has no definite volume; the volume depends on the amount the shock strut is extended or compressed. The annular space is at minimum size when the shock strut is completely extended and at maximum size when the strut is completely compressed. As the shock strut extends, fluid passes from the piston into the annular space. Compression of the shock strut forces fluid from the annular space back into the piston. Transfer of fluid into or out of the annular space takes place through transfer passages in the wall of the piston. The fluid moves with some resistance, which varies with the size of the transfer passages. In simple shock struts, the transfer passages are merely holes. In many complex shock struts, the passages are provided with a snubber valve or rebound control valve. Such a valve allows fluid to flow more freely into the annular space during shock strut compression than it flows out during extension.

**Maintenance.** Shock struts should be frequently checked for leakage, proper air pressure, secure attachment, and cleanliness. The exposed portion of the shock strut piston should be cleaned frequently with a clean, lint-free cloth moistened with hydraulic fluid. Specific instructions for servicing with hydraulic fluid and air pressure are stamped on the nameplate of the shock strut and are given in the applicable aircraft manual. With a few exceptions, a single port in the shock strut serves as a filler hole for both hydraulic fluid and air. An air valve assembly screws into the port.

## CAUTION

ALWAYS BE SURE TO RELEASE THE AIR PRESSURE BEFORE ATTEMPTING TO REMOVE THE AIR VALVE CORE OR ASSEMBLY. ROCK THE AIRCRAFT AND DEPRESS THE VALVE CORE SEVERAL TIMES WITH A SUITABLE METAL TOOL TO ENSURE THAT ALL PRESSURE IS RELEASED. AIR PRESSURE COULD BLOW OUT THE AIR VALVE CORE OR ASSEMBLY WHEN EITHER OF THEM IS LOOSE.

## LIQUID SPRINGS

Functions. The liquid spring contains hydraulic fluid under pressure. The cushioning effect of the spring is produced by a slight compression in the fluid. In Figure 11-18, note that the piston rod fits into the inner space of the cylinder.

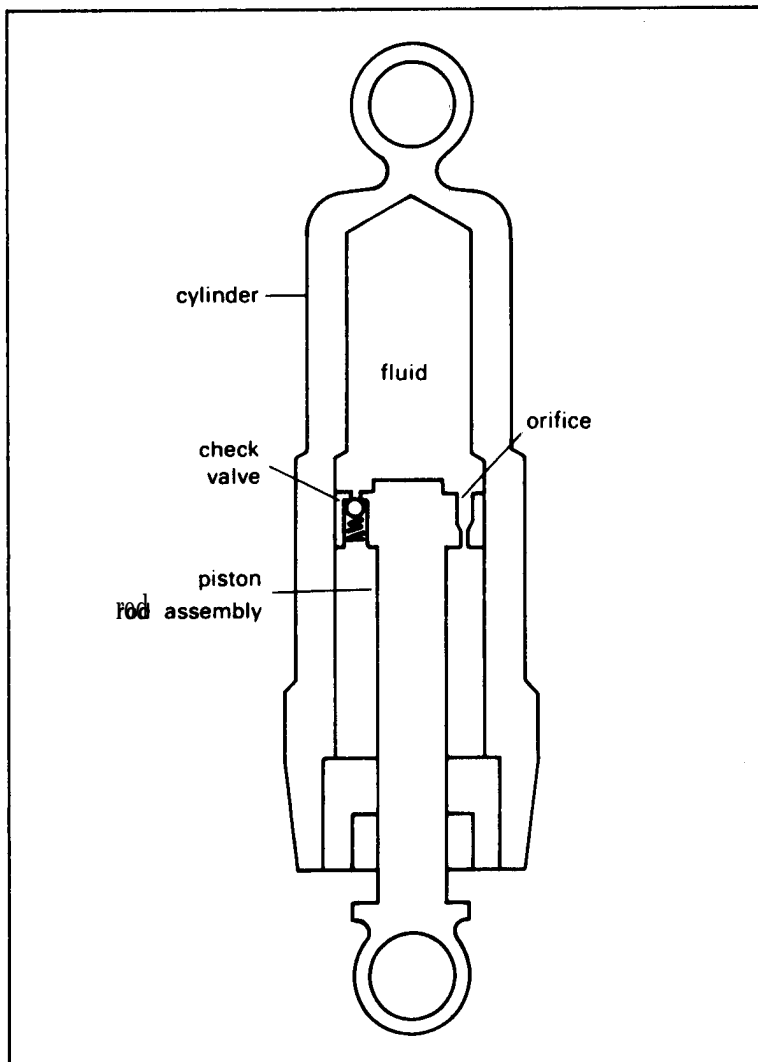
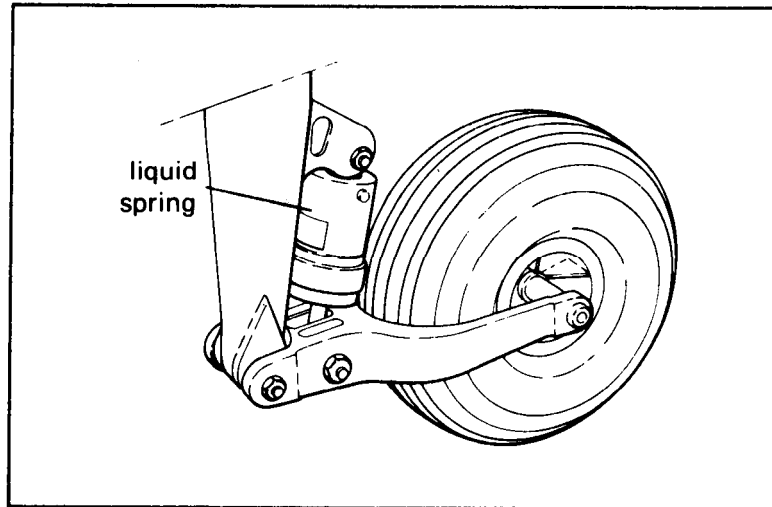


Figure 11-18. Liquid spring.

A gland seal is provided to prevent fluid leakage as the piston rod moves in and out of the housing. The housing is attached to a stationary part of the aircraft; the piston rod is connected to a movable part of the landing gear. Figure 11-19 shows a liquid spring installed on the tail landing gear of an Army aircraft.



**Figure 11-19. Liquid spring installed on tail landing gear.**

Liquid springs support static loads of the aircraft, cushion the jolts during taxiing and towing of the aircraft, and reduce shock during landing. Liquid springs perform the same functions as shock struts, but their operations differ.

**Supporting Static Loads.** The weight of the parked aircraft moves the liquid spring housing downward over the piston rod. The inward movement of the piston rod decreases the space occupied by the fluid; it compresses the fluid and increases its pressure. The movement continues until fluid pressure puts a force on the shaft equal to the force that moves the shaft inward. When this force is reached, no further inward movement of the shaft takes place; the aircraft is held in a stationary position.

**Cushioning Jolts.** The liquid spring controls the bouncing motion of the aircraft in the same manner as shock struts. As the piston in the liquid spring moves in and out of the housing, fluid moves back and forth through an orifice in the piston. This fluid flow restrains the rate at which the piston moves and dampens the up-and-down movements of the aircraft fuselage.

**Reducing Shock.** In the liquid spring, the resistance to fluid flow necessary to convert motion energy to heat energy is effected by a check valve in the piston. As the liquid spring compresses, fluid flows through the check valve and orifice. During extension of the liquid spring, the check valve closes, and fluid then passes through the orifice only. The additional restraint that is set up to the movement of fluid from one side of the piston to the other provides rebound control during landing.

Maintenance. The exposed portion of the liquid spring shaft should be cleaned with a clean, lint-free cloth moistened with hydraulic fluid. When the liquid spring is filled to the correct level with the proper type of hydraulic fluid, the fluid will be under pressure. A special gun which looks like a hand-grease gun is used to force the fluid inside the spring. Specific servicing instructions are stamped on the nameplate of the spring and are given in the applicable manual for the aircraft.

## CHAPTER 12

# SHOP SAFETY

### GENERAL WORK AREA

Every effort should be made to improve safety conditions in the shop. Always be on the alert for unsatisfactory conditions that could injure personnel or damage equipment. Conduct preventive maintenance and periodic inspections to keep the shop safe and efficient. The following are some general guidelines to remember:

- Keep your work area clean, orderly, and free of obstructions; you may trip or injure yourself because of a misplaced extension cord or dropped tool. A cluttered bench makes effective work almost impossible.
- Reassemble units properly. Some units that you will disassemble consist of small parts that can easily be lost, broken, or mixed with other parts. A unit improperly reassembled or one reassembled with defective parts is the starting place for an aircraft accident.
- Dispose of worn-out parts in designated places--not on the floor.
- Keep toolboxes in their designated places and keep the lids closed.
- Use tools for their designed purposes only, and keep them in a good state of repair. Common hand tools are a frequent source of injury. For guidance on use and care of hand tools, see TM 9-243.
- Use the proper guards when working in the shop. Whenever possible, guards should be permanently installed. Machines with movable guards should have a power cutoff switch installed.
- Become familiar with the color codes used on power equipment--red indicates danger or identifies emergency stop-devices, yellow indicates caution, and green identifies safety equipment facilities. Black and white are used for informational signs.

### HAZARDOUS WORK AREA

Although hazards exist in some areas where you work, you can reduce the danger to yourself by being careful. Observe the following precautions:

- Do not stand in line with the turbine wheel during engine run-up.



- Do not pass close behind an aircraft when its engine is running. The high-velocity, high-temperature exhaust blast of a turbine engine is especially hazardous to personnel.
- Do not approach jet intakes when the engine is operating. The intake ducts should be free of all objects.
- Protect yourself against harmful noise levels. Noise endangers a person's hearing, makes speech communication almost impossible, and is tiring. All of these factors contribute to faulty maintenance which, in turn, contributes to maintenance errors. Noise levels above 85 decibels are extremely hazardous. Do not expose yourself to such high-level noise unless absolutely necessary; if you must do so, keep the period of exposure as short as possible. Wear a headset and earplugs. Earplugs alone will not give you enough protection at these high levels. You should know the physical symptoms that indicate overexposure to loud noise. A person who has worked too long under high-noise-level conditions will show symptoms of sickness: pain, a feeling of fullness, a ringing sound, or a burning sensation in the ear; dizziness, slowed mental concentration, nausea, vomiting, or weakness of the knees. When any of these symptoms occur, remove the affected person from the noise area immediately. A medical officer should examine him before the effects wear off.
- When working around radar equipment and other microwave equipment, be sure that the power is turned off; otherwise, you run a high risk of radiation burns, which can damage body tissue.
- Even though you will be performing only limited maintenance on armed aircraft, be extremely careful when performing these duties. Observe and obey all armament warning signs. Be careful when using external power. Don't operate any armament switches or remove their safety devices. Before beginning work on armed aircraft, study the applicable aircraft technical manual to become familiar with the safety precautions.
- When working around ejection seats, be careful to avoid accidental arming and firing. High-level heat or movement of the actuating mechanisms can fire the ejection seat. Know how and where the safety pins are installed. Do not place tools in your pockets while working in the cockpit.
- Make sure that operating systems are clear of personnel and equipment when you are checking them. Have someone stand by to make sure that everyone stays clear of the danger areas. Aircraft with power-operated devices, such as flight control mechanisms and landing gear, present a possible danger. These devices are hydraulically operated. Careless operation can damage equipment and injure people.
- When repair work makes it necessary to walk or step on the aircraft, use the designated walkways. These are covered with nonskid material. You must not walk or step on areas designated as no-step

areas. Doing so could damage the aircraft, and you could slip and fall when stepping on slick surfaces.

- When using high-pressure air, be extremely careful. Air pressure strong enough to blow away dust or dirt is also strong enough to blow it into eyes and ears. Pressure as low as 10 to 15 psi has been known to cause serious injuries.

## FIRE PREVENTION

Many fires are caused by carelessness and poor housekeeping. To prevent shop fires, observe the following precautions:

- Do not allow large quantities of rags to accumulate. Be sure that all oil rags are kept in approved, closed containers.
- Never smoke in areas marked with NO SMOKING signs.
- When your clothing becomes saturated with fuel or oil, change it as soon as possible. Besides being a fire hazard, clothing saturated with flammables may cause skin problems.
- Store combustible fluids in closed containers.
- Always make sure that static lines are in place and that the aircraft is properly grounded before working on it.
- Never deposit cigarettes or matches in a wastebasket even if they appear to be extinguished.
- Be careful with hydraulic fluid; it is not a highly flammable liquid but it will burn.
- Use only approved cleaning solvents.

Know the telephone number of the post fire department and the location of the fire extinguishers in the shop. See Table 12-1 for the types of fires that might occur and the extinguishers to be used on each.

### CAUTION

THOUGH FIRE EXTINGUISHERS MAY LOOK ALIKE, THE EXTINGUISHING AGENTS INSIDE MAY VARY. A FIRE MAY BE MADE WORSE IF THE THE WRONG TYPE OF EXTINGUISHER IS USED.

Table 12-1. Types of Fire Extinguishers and Their Uses

TYPE OF EXTINGUISHER	TYPE OF FIRE	APPLICATION	EFFECTIVE RANGE	CHARACTERISTICS	WARNING
Pump tank	Type A fires: wood, trash, paper, waste.	Direct stream at base of flames.			Never use on charged electrical equipment, varnish, oils, or other fuels. Protect from freezing.
Soda acid	Type A fires: wood, trash, paper, waste.	Work close for penetration; direct stream at base of flames.	30 to 40 feet	Cools burning surfaces below ignition point. Any stream tends to smother flames.	Never use on charged electrical equipment, varnish, oils, or other fuels. Protect from freezing.
Foam type	Type B fires: gasoline, oil, oil-base materials, varnishes, wood, trash, and paper waste.	Apply complete blanket of foam over surface. Avoid a direct stream on oil surfaces.	30 to 40 feet	Blankets burning material with froth or foam, which excludes oxygen. Cools and insulates surface from heat. Blanket prevents flashbacks.	Never use on charged electrical equipment. Protect from freezing.
Carbon dioxide (CO <sub>2</sub> )	Types A, B, and C fires: electrical fires, confined oil fires, ordinary combustibles.	Working with draft, apply so that gas floods material in a wave (extinguisher lasts only a few seconds).	3 to 6 feet	Flame is smothered by heavy blanket of nonflammable gas.	Avoid extended exposure in area where CO <sub>2</sub> has been used, especially in pits. CO <sub>2</sub> will not support life.
Chlorobromomethane	Type C fires: electrical and small fires.	Direct stream on base of fire or hot surface.	15 to 30 feet	Upon contact with flame or hot surface, converts into a heavy smothering vapor.	Do not use in closed areas. If liquid comes into contact with skin or eyes, wash immediately with water and get medical treatment immediately.

## GLOSSARY

### ACRONYMS AND ABBREVIATIONS

AC	alternating current
ATTN	attention
DC	direct current
GPM	gallons per minute
ID	inside diameter
lb	pound
MACOM	major Army command
MOS	military occupational specialty
MS	military standard
NC	normally closed
NO	normally open
OD	outside diameter
PRESS	pressure
psi	per square inch
RET	return
RPM	revolutions per minute
sq in	square inch
W	width

### TERMS

accumulator	A device used to store liquid under pressure; usually consists of a chamber separated into a gas compartment and a liquid compartment separated by a piston or a diaphragm; smooths out pressure surges in a hydraulic system.
actuating cylinder	An actuator that converts fluid power into linear mechanical force and motion.
actuator	A device that converts fluid power into mechanical force and motion.
additive	A chemical compound added to a fluid to change its properties.
air bleeder	A device (needle valve, capillary tubing to the reservoir, or bleed plug) used to remove air from a hydraulic system.
back pressure	Pressure exerted against the pressure producing the main flow.
boss	A protruding part or body, such as a stud or propeller hub.

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Boyle's law	A statement in physics: the product of the pressure and the specific volume of a gas at constant temperature is constant.
calibrate	To make adjustments to a meter or other instrument so that it will give the correct indications with respect to its inputs.
centrifugal force	The force that a rotating object exerts on the body constraining the object and that acts outwardly away from the center of rotation.
check valve	A valve that permits fluid to flow in one direction but prevents a return flow.
circuit	An arrangement of interconnected component parts.
compressed air	Air under pressure greater than that of the atmosphere.
condensation	The change from a gaseous (or vapor) state to a liquid state.
contamination	Harmful foreign matter in a fluid.
corrosion	Slow destruction of materials by chemical agents and electromechanical reactions.
diaphragm	A dividing membrane or a thin partition.
directional control valve	A valve that selectively directs or prevents flow to or from desired channels; also referred to as selector valve, control valve, or transfer valve.
double-acting cylinder	An actuating cylinder in which both strokes are produced by pressurized fluid.
energy	The ability or capacity for doing work.
feedback	A transfer of energy from the output of a device back to its input.
fixed displacement pump or motor	A pump or motor in which the volume of fluid per cycle cannot be varied.
flash point	The lowest temperature at which vapors above a volatile substance ignite in air when exposed to flame.

flow control valve	A valve used to control the rate of flow of fluid in a system.
flow meter	An instrument used to measure the velocity of flow of a liquid in a pipe; an instrument used to indicate pressure, velocity of flow, and rate of discharge of a gas or vapor.  flowing in a pipe.
fluid	Any liquid, gas, or mixture thereof.
fluid flow	The stream or movement of a fluid or the rate of its movement.
fluid power	Power transmitted and controlled through the use of fluids, either liquids or gases, under pressure.
force	The action of one body on another, tending to change the state of motion of the body acted upon (force is usually expressed in pounds).
free flow	Flow that encounters negligible resistance.
friction	The action of one body or substance rubbing against another, such as fluid flowing against the walls of a pipe; the resistance to motion caused by this rubbing.
gage snubber	A device installed in the line to the pressure gage used to dampen pressure surges, thus providing a steady reading and protecting the gage.
gas	A fluid that has neither independent shape nor volume but tends to expand indefinitely.
gasket	A seal used to pack pistons or to make pipe or other joints fluid-tight.
horsepower	A unit equal to a rate of 33,000 foot-pounds per minute (used to measure the power of motors or engines); the force required to raise 33,000 pounds at a rate of 1 foot per minute.
hydraulics	A branch of science that deals with the action or use of liquids forced through tubes and orifices under pressure to operate various mechanisms.

inhibitor	Any substance that slows or interferes with a chemical reaction such as corrosion or oxidation.
line	A tube, pipe, or hose that is used as a conductor of fluid.
liquid	A fluid that has a definite volume without a definite shape except such as is temporarily given by its container.
micron (micrometer)	A millionth of a meter or about 0.00004 inch.
motor	An actuator that converts linear power to rotary mechanical force and motion.
ozone	Form of oxygen formed from an electrical charge.
packing	A type of seal used to provide a leakproof connection between two parts of a unit that move in relation to each other.
Pascal's law	A statement in physics: when external pressure (force) is applied to any confined fluid at rest, the pressure is increased at every point in the fluid by the amount of external pressure.
pilot valve	A relay valve that controls the operation of another valve.
pneumatics	A branch of mechanics that deals with the mechanical properties of gases under pressure.
port	An opening for the intake or exhaust of a fluid.
pressure	The amount of force distributed over an area (usually expressed in pounds per square inch).
pressure differential	The difference in pressure between any two points of a system or a component.
pressure switch	An electrical switch operated by the increase and decrease of fluid pressure.
proof pressure	Approximately one and one-half times normal operating pressure.

pump	A device used to convert mechanical energy into fluid energy.
relief valve	A pressure control valve used to limit system pressure.
reservoir	A container that serves primarily as a supply source of the liquid for a hydraulic system.
sequence valve	An automatic valve in a fluid power system that causes operations to occur in a definite order.
servo	An automatic device used to control large amounts of power by very small amounts of power.
servo control	A control, actuated by a feedback system, which compares the output with a reference signal and makes corrections to reduce the differences.
shutoff valve	A valve that operates fully open or fully closed.
shuttle valve	A valve used to direct fluid automatically to the actuator from either the normal source or an alternate source.
single-acting cylinder	An actuating cylinder in which one stroke is produced by pressurized fluid and the other stroke by some other force such as gravity or spring tension.
solid	The form of matter that has definite shape and volume.
surge	A momentary rise of pressure in a system.
thermal expansion	An increase in the volume of a substance due to temperature change.
torque	A force or combination of forces that produces or tends to produce a twisting or rotary motion.
turbulence	A state of flow in which the fluid particles move in a random manner.
vacuum	Pressure less than atmospheric pressure.



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variable displacement pump  
or motor

A type of pump or motor in which  
the volume of fluid per cycle can be varied.

viscosity

The internal resistance of a fluid that tends  
to retard its flow.

volume of flow

The quantity of fluid that passes a certain  
point in a unit of time (usually expressed in  
gallons per minute for liquids and cubic feet  
per minute for gases).

## REFERENCES

### REQUIRED PUBLICATIONS

Required publications are sources that users must read to understand or comply with this publication.

NAVY PERSONNEL (NAVPERS) TRAINING MANUAL:\*

NAVPERS 10310-B      Aviation Structural Mechanic H3 & 2

TECHNICAL BULLETINS (TBs):

55-1500-334-25      Conversion of Aircraft to Fire Resistant Hydraulic Fluid  
750-103              Maintenance and Care of Common Type Machine Tools and  
Shop Equipment Before, During, and After Operation  
750-125              Assembly and Inspection of Medium-Pressure Hose and  
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