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# **FUNDAMENTALS OF AIRCRAFT PNEUDRAULICS**

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# FUNDAMENTALS OF AIRCRAFT PNEUDRAULICS

## PREFACE

Military personnel holding MOS 68H (aircraft pneudraulics repairer) will use this manual as a general guide in the repair of pneumatic systems (using gases such as air) and of hydraulic systems (using liquids such as oil). The manual covers basic hydraulic principles and describes the hydraulic systems used in US Army aircraft. It discusses aircraft in general-not specific types of aircraft. For instructions on the repair of hydraulic systems on a particular aircraft, refer to the technical manual written for that aircraft. Additional general 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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The words "he," "him," "his," and "men," when used in this publication, represent both the masculine and feminine genders, unless otherwise specifically stated.

## CHAPTER 1 INTRODUCTION

This chapter gives a general introduction to the subject of hydraulics as it pertains to US Army aircraft. The topics covered are--

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### ————— USES OF HYDRAULIC SYSTEMS IN ARMY AIRCRAFT —————

Hydraulic systems perform a variety of functions in Army aircraft. They are used in fixed-wing aircraft for such purposes as changing propeller pitch and operating landing gear, wing flaps, wheel brakes, and shock struts. In helicopters, hydraulic systems start engines and operate brakes, shock struts, dampers, flight control systems, loading ramps, folding pylons, winch hoists, and hydraulic clutches. There are a number of reasons why hydraulic systems have been designed for so many uses in aircraft:

- A hydraulic system is almost 100 percent efficient. The slight loss of efficiency (a fraction of 1 percent) is due to internal friction in the system machinery.
- The moving parts of a hydraulic system, being light in weight, can be quickly put into motion or brought to rest. The valves used in a hydraulic

system are capable of quickly starting or stopping the flow of fluid under pressure, and 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 be easily bent around obstructions. The major parts of hydraulic systems can be located in a wide variety of places.
- Since the components of a hydraulic system are small in comparison with 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.

### ————— BASIC PRINCIPLES CONCERNING USE OF LIQUIDS IN HYDRAULIC SYSTEMS —————

#### *Characteristics of Liquids.*

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, you must first understand certain characteristics of liquids, the primary one

being its fluid quality. Fluids--substances that flow--can be liquids or gases. However, there is a difference in the degree of fluidity of these two states of matter in that liquids cannot expand indefinitely to fill containers as gases do.

We can further describe liquids in terms of three physical qualities:

**Incompressibility.** For practical purposes, liquids are incompressible. This means that even under extremely high pressure a liquid cannot be made much smaller. The brake system in your 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 have to 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, the liquid 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. Let us again use your car's brake system to show how this principle works. When a force (your 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.

### ***Resistance to Liquid Flow.***

Resistance to flow is a factor that must be reckoned 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 arises as liquids flow through tubing. This movement creates a shearing action between the wall of the tube and the liquid--an action that results in a turbulent flow along the walls. A turbulent flow is a nonsmooth, whirling flow. Turbulence working against the smooth flow of a liquid causes resistance, which causes the temperature to rise, and 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. The 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. When the liquid is not moving in the system, there is no resistance. When it starts to move, resistance begins and, as the speed of flow increases, resistance increases. For this reason, an orifice plate or restriction is sometimes installed in a line to limit the rate of flow. As an example, a landing gear when being extended 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 reduces the speed at which the landing gear comes down and prevents possible structural damage.

### ***How To Compute Force, Area, and Pressure.***

Hydraulic systems are designed to take advantage of the characteristics of liquids 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. The force applied to a piston head, for example, is the energy applied to the total area of the piston head. In this manual, we measure force in pounds.

**Area** is the measurement of a surface. In the aircraft hydraulic system, we are concerned with the areas of piston heads. If we know this area, we can compute the amount of force needed 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. The pressure on a piston head develops the force that operates a mechanism. In our work, we measure pressure in pounds per square inch (psi).

If you know any two of these factors, you can easily compute the third by using the equation illustrated in the accompanying triangle. To apply this equation, multiply the two lower factors together to get the top factor, and divide the top factor by the known

lower factor to get the unknown lower factor. That is to say, if you know the area in square inches and the pressure in pounds per square inch, simply multiply the area (A) times the pressure (P) to obtain the force (F) in pounds. Similarly, if you know the force in pounds and the area in square inches, divide F by A to obtain pressure (P) in pounds per square inch. Finally, to obtain area in square inches, divide force in pounds by pressure in pounds per square inch. For example, a pressure of 50 pounds per square inch acts on a piston whose surface area is 5 square inches. What force is acting on the piston? Using the equation set up in the triangle, multiply P (50 psi) times A (5 square inches) to obtain F--a force of 250 pounds acting on the surface of the piston.

#### ***How To Compute Volume, Area, and Length of Stroke.***

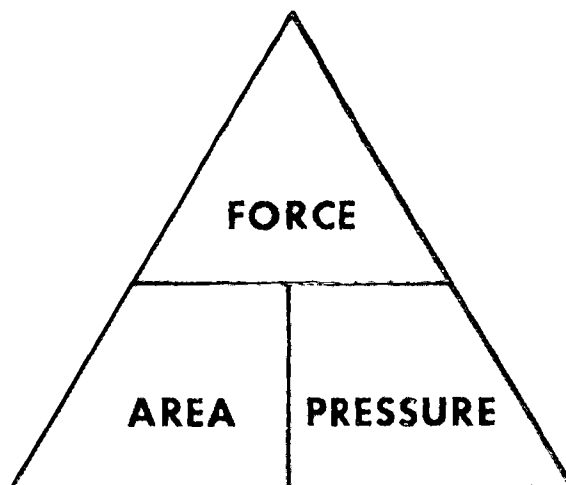
You can use the same type of triangular equation to compute volume, area, and length of stroke. The following definitions apply for this manual:

*Volume* is a measurement of quantity expressed in cubic inches; for example, the amount of liquid in a cylinder or the amount of liquid displaced by a pump or an actuating cylinder.

As in the previous equation, *area* is a surface measurement expressed in square inches.

*Length of stroke* is a measurement of distance expressed in inches. The stroke length with which you will be concerned in this manual is the distance a piston moves in a cylinder.

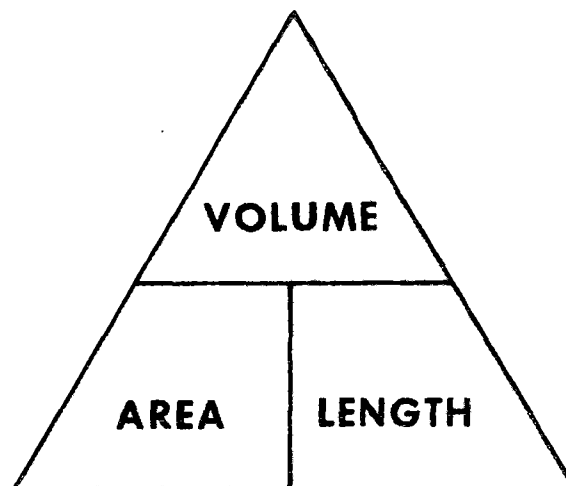
If you know any two of these factors, you can compute the third. As in the previous equation, multiply the two lower factors together to obtain the top factor and divide the top factor by the known lower factor to obtain the unknown lower factor. For example, a piston having an area of 8 square inches moves a distance of 10 inches within a cylinder. To find the volume of liquid moved, multiply the two lower factors together--8 square inches (A) times 10 inches (L)--to obtain V: 80 cubic inches.



$$A \times P = \text{FORCE}$$

$$\frac{F}{A} = \text{PRESSURE}$$

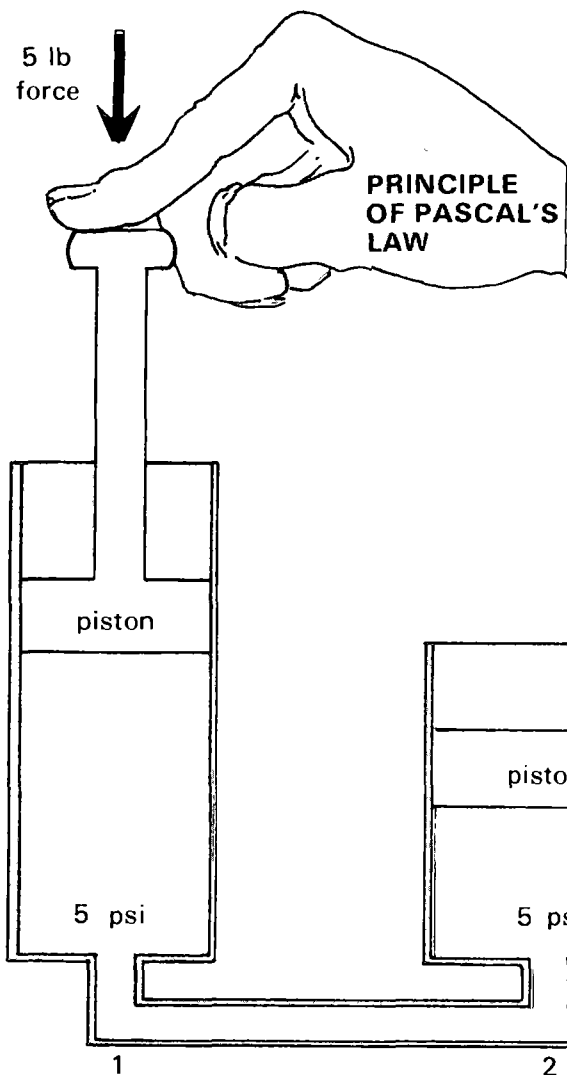
$$\frac{F}{P} = \text{AREA}$$



$$A \times L = \text{VOLUME}$$

$$\frac{V}{A} = \text{LENGTH}$$

$$\frac{V}{L} = \text{AREA}$$



### ***Pascal's Law.***

Practical applications of hydraulic principles are based on Pascal's law, which may be stated in simple terms as follows: When a force is applied to a confined fluid, the pressure is transmitted equally in all directions. Check the definitions of *force* and *pressure* already given. An understanding of Pascal's law depends on a strict interpretation of these terms. Note that Pascal's law applies for confined fluids only. It follows then that the law does not apply for fluids in motion since moving fluid is *not confined* in the true sense of the word. Here is a graphic illustration of how Pascal's law applies in an aircraft hydraulic system. Note that when a

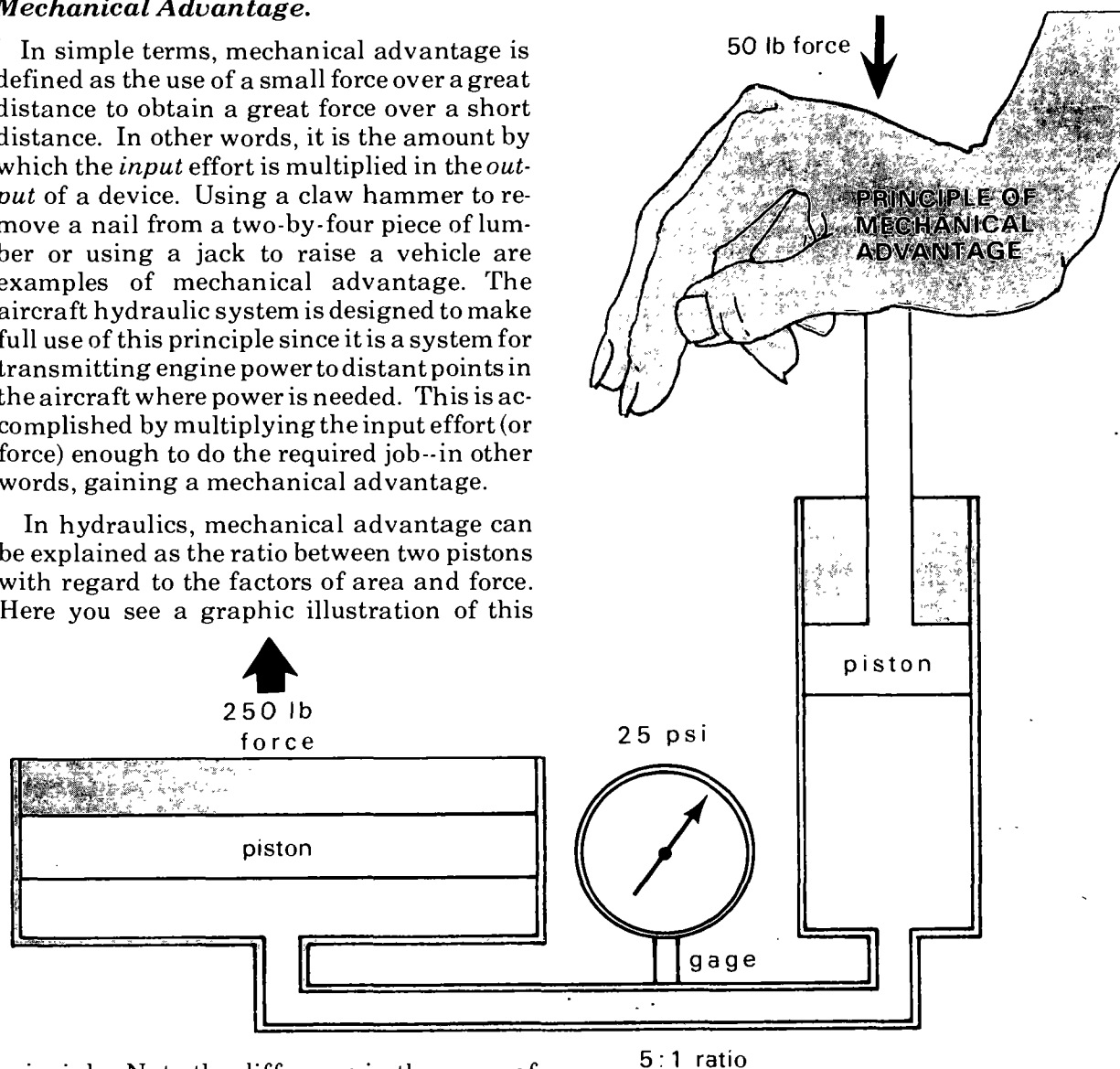
force is applied to the piston in cylinder 1, it is transmitted to all portions of the confined fluid. If, for example, the applied force is 5 psi, the pressure in cylinders 1, 2, and 3 and in the tubing will be 5 psi. But suppose a change takes place in which a lack of resistance causes either piston 2 or 3, or both, to move upward. This momentarily lowers the pressure in cylinders 2 and 3 while in cylinder 1 it is still 5 psi. This unbalanced condition cannot last. Fluid will flow from cylinder 1 to cylinders 2 and 3. This is 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 again equalizes--Pascal's law applies once more.



### Mechanical Advantage.

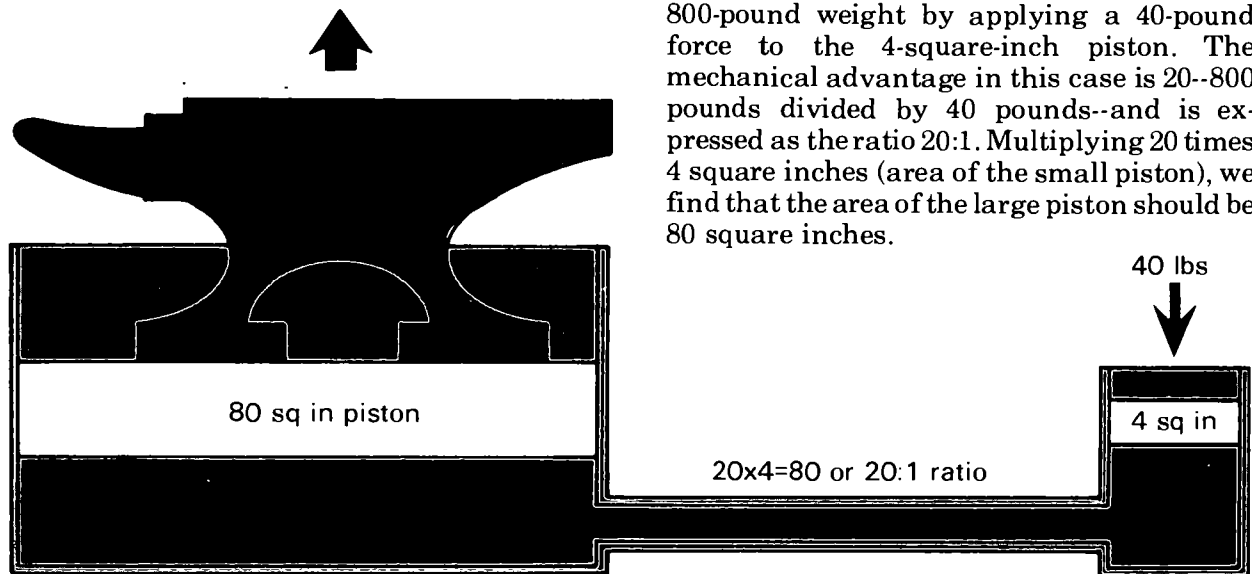
In simple terms, mechanical advantage is defined as the use of a small force over a great distance to obtain a great force over a short distance. In other words, it is the amount by which the *input* effort is multiplied in the *output* of a device. Using a claw hammer to remove a nail from a two-by-four piece of lumber or using a jack to raise a vehicle are examples of mechanical advantage. The aircraft hydraulic system is designed to make full use of this principle since it is a system for transmitting engine power to distant points in the aircraft where power is needed. This is accomplished by multiplying the input effort (or force) enough to do the required job--in other words, gaining a mechanical advantage.

In hydraulics, mechanical advantage can be explained as the ratio between two pistons with regard to the factors of area and force. Here you see a graphic illustration of this



principle. Note the difference in the areas of the small and large pistons. This difference in size is the means by which mechanical advantage is obtained. When a 50-pound force is applied to the small piston, the fluid pressure shows 25 psi on the gage, but 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. It is important to note that this 5-to-1 ratio does not change if the pounds per square inch change. If, for example, the input force were 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.

## APPLICATION OF MECHANICAL ADVANTAGE



An example of how to apply mechanical advantage is shown in the accompanying illustration. Here we want to find just how big the large piston must be to raise an 800-pound weight. Let us assume that we must raise the 800-pound weight 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 the ratio 20:1. Multiplying 20 times 4 square inches (area of the small piston), we find that the area of the large piston should be 80 square inches.

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, it would not be feasible for the small piston to move that far on a single stroke. Therefore, the small piston must move through a series of short repeated strokes.

## - BASIC PRINCIPLES CONCERNING USE OF AIR IN HYDRAULIC SYSTEMS -

### *Characteristics of Gases.*

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 a 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, and emergency systems and for pressurizing 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 for atmospheric air in hydraulic systems, and it is the only substitute authorized.

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 or, if the volume doubles, the pressure is halved. This characteristic of gases is known as Boyle's law and is expressed by the equation

$$V \times P = V^1 \times P^1$$

where

**V = initial volume**

**P = initial pressure**

**V' = changed volume**

**P' = changed pressure**

If the measurements of any three of these factors are known, the fourth factor can be determined. To illustrate, let us assume that 30 cubic inches of gas (V) at a constant

temperature and under 90-psi pressure (P) is forced into a 15-cubic-inch space (V'). To find the changed pressure (P') we substitute in the equation as follows:

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

$$2700 = 15P'$$

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

$$180 = P'$$

## ———— TYPES OF HYDRAULIC FLUID USED IN ARMY AIRCRAFT ————

Hydraulic fluids are classified generally as petroleum base, synthetic base, and vegetable base. Vegetable base fluid is no longer authorized for use in Army aircraft, and 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 that help stop oxidation and corrosion. MIL-H-83282 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 that of MIL-H-5606 by greater than 200° F, and 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 and may be combined with the latter fluid with no bad effect except a reduction of its fire-resistant properties. 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 temperature, the viscosity of MIL-H-83282 increases at low temperature; for this reason, MIL-H-5606 is still used for cold weather operation.

Petroleum base fluid MIL-H-6083 is still authorized for certain uses 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. It should not be used in composite aircraft hydraulic systems.

You must be extremely careful to use only the fluid authorized for a particular component or system. To determine the correct fluid, consult the applicable technical manual. In addition, 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 FOR USE IN ARMY AIRCRAFT, THERE IS A CHANCE OF ITS GETTING INTO THE MAINTENANCE SHOP. NEVER USE THIS FLUID IN 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.

## ———— FLUID CONTAMINATION ————

Contamination in a hydraulic system is the presence of any material other than the hydraulic fluid being used. This includes

water and metal, dust, and other solids. Contamination sources may be internal or external. Internal contamination can cause

normal wear of the pump or of 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, etc., 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 in order to help control contamination in aircraft. Contamination checks should become a routine part of your work. You should 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 a pump failure, require flushing of the system. Here are some ways you can help 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.
- Before installing a pump, fill it with hydraulic fluid.
- Take good care of test stands and ground equipment.
- Handle flexible hydraulic hoses carefully. Particles from their walls enter the system when hoses are kinked or run over or when quick disconnects are not cleaned before being joined.

In addition to the above-mentioned checks, 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, presence of water, hydrolytic stability, viscosity-temperature coefficient, neutralization number, and pour point.

### CAUTION!

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

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## CLEANING HYDRAULIC UNITS

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A hydraulic unit, when disassembled and overhauled, should always be cleaned with 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 no particular type of solvent is specified, you may use PD-680 to clean units operating with petroleum base fluid; denatured alcohol, for units using vegetable base fluid; trichloroethylene for units using some types of synthetic base fluid.

Whatever the type of solvent used, the unit and its internal parts should be soaked and washed thoroughly in the cleaner. Use a small brush on the inside passageways and chambers, but be sure that its bristles are not so stiff as to scratch the metal. All parts must be completely dry before being assembled. You may use compressed air or a lint-free cloth for drying. Since some solvents are very flammable, proper precautions should be taken in storing them. Keep such cleaners in a tightly sealed container and, when using cleaners indoors, be sure that the work area is well ventilated.

## CHAPTER 2

# PNEUDRAULIC LINES

Aircraft have hundreds of feet of fluid lines running through their fuselages. Hydraulic repairers are responsible for maintaining most of these fluid lines. This involves making and replacing tubing and hose assemblies, which are broadly classified as--

RIGID TUBING .....	2-1
FLEXIBLE HOSE .....	2-3

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### RIGID TUBING

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

**Tubing sizes.** The tubing used in the manufacture of rigid tubing assemblies is sized by outside diameter 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. Thus, No. 6 tubing is 6/16 or 3/8 inch, No. 8 tubing is 8/16 or 1/2 inch, etc. Wall thickness is specified in thousandths of an inch. Most aircraft maintenance manuals contain a table of acceptable substitutes which lists the original material and substitutes and gives the wall thickness for each.

#### ***Removal and Replacement of Damaged Tubing.***

All tubing is pressure tested before installation and is designed to withstand several times the operating pressure to which it will be subjected. Generally, when a tube bursts or cracks, it is the result of excessive vibration, improper installation, or damage caused by collision with an object. When tubing fails, the cause of the failure should be determined. Replacements should be of the same size and material as the original, or you may find an acceptable substitute listed in the applicable maintenance manual.

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, you can make a pattern. Do this by placing one end of a piece of soft wire into one of the fittings where the tube is to be connected and then forming the bends 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. A tube cannot be cut or flared accurately enough so that it can be installed satisfactorily without bends. Bends are also necessary to permit the tubing to expand or contract under temperature changes and to absorb vibration. If the tube is small (under 1/4 inch) and can be hand formed, casual bends may be made to allow for this. If the tube must be machine formed, definite bends must be made to avoid a straight assembly. Care must be taken to start all bends a reasonable distance from the end fittings. This is because the sleeves and nuts must be slipped back along the tube during fabrication of flares and during inspections. In all cases, the new tube assembly should be so formed before installation that it is not necessary to pull or deflect the assembly into alignment by means of the coupling nuts.

**Cutting tubing.** The ideal objective when cutting tubing is to produce a square end that

is free from burrs. Tubing may be cut with a tube cutter or with a fine-tooth hacksaw.

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 as to apply light cutter pressure on the tube. Then rotate the cutter toward 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. 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 tubing with a hacksaw, all saw marks must be removed by filing. After filing, remove all burrs and sharp edges from the inside and outside of the tube. Then clean out the tube and make sure that no foreign particles remain.

**Bending tubing.** The objective in tube bending is to obtain a smooth bend without flattening the tube. Usually tube bending is done with a tube bender. Only in an extreme emergency would you try to bend a tube without using a hand-held or mechanical bending tool.

The hand-held tube bender has a hand clip handle, a radius block, and a slide bar handle. The two handles act as levers to provide the mechanical advantage necessary to bend the tubing.

The mechanical tube bender is issued as a kit. The kit contains the necessary equipment and instructions for bending tubing from 1/4 to 3/4 inch in diameter. This tube bender is designed for use with metal tubing such as aircraft high-strength stainless steel.

### **Flaring Tubing.**

The flaring tool used by the Army is suitable for producing tubing flares having a 74° angle. It will produce 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. Use the operating instructions furnished with the tool when making flares.

Single-flared tubing is used for tubing joints on all sizes of steel tubing, on 6061 aluminum alloy tubing, and on all sizes of 5052 aluminum alloy tubing above 1/2-inch outside diameter. Double-flared tubing is used for tubing joints on all sizes of 5052 aluminum alloy having 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. Consult TM 55-1500-204-25/1 for more detailed information on bending and flaring tubing.

### **Installation of Tube Assemblies.**

**General.** Before installing a tubing 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. The tubing assembly must be clean and free of all foreign matter. Hand-screw nuts to the mating connector and then tighten with the proper wrench--never use pliers for this purpose. Avoid pulling the tubing assembly into place with the nut; line up the assembly before tightening.

Tubing that runs through cutouts must be installed with care so that it will not be scarred when worked through the hole. When the tubing assembly is long, the edges of any cutouts are taped before the tubing is installed.

**Installing flared-tube assemblies.** After tightening an aluminum alloy tube assembly to the required torque, check for leaks. If the assembly leaks, it must not be tightened further. Overtightening can badly damage or completely cut off the tubing flare, or it can damage the sleeve or nut. The leaking connection should be disassembled and the fault corrected. Common faults that cause leaking are as follows:

- Flare distorted into the nut threads.

- Sleeve cracked.
- Flare out of round.
- Flare cracked or split.
- Inside of flare rough or scratched.
- Connector mating surface rough or scratched.
- Threads of connector or nut dirty, damaged, or broken.

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

Undertightening of connections may also be serious as this can allow the tubing to leak at the connector because of insufficient grip on the flare by the sleeve. The use of a torque wrench will prevent undertightening.

A nut should never be tightened when there is pressure in the line as this will tend to damage the connection without adding any appreciable torque.

*Installing flareless-tube assemblies.* When installing flareless-tube assemblies, inspect to insure that there are 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, and 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 it is impossible to run the nut down with the fingers, 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. There is no specific torque setting for flareless-tube fittings; therefore, care should be used in finding the exact point where the nut begins to bottom and in applying the required amount of turn on the nut.

After the tube assembly is installed, the system should be pressure tested. If a connection leaks, it is all right to tighten the nut an additional one-sixth turn (making a total of one-third turn). If the connection still leaks after tightening the nut a total of one-third turn, the assembly should be removed. After removal, the components of the assembly should be inspected for scores, cracks, presence of 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 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.

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## FLEXIBLE HOSE

---

Hose is used where flexibility is required in the connections between moving parts and where a line is subject to vibration. Hose is made of a flexible leakproof inner tube and of 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 of Hose.*

*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 usability with certain fluids or operability within certain ranges of

temperature. The kind of braid and the number of layers depend on intended operating pressure range. The outer covering of most rubber hose is 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 hose there is also a lay strip, which provides an easy method to determine whether an installed hose is twisted.

Rubber hose is used in aircraft hydraulic systems only in the form of 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 and gives operating pressure and pressure test data. Refer to chapter 7 of TM 55-1500-204-25/1 for information on fabrication of 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 a very long shelf life as compared 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 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, bear the military specification number, the manufacturer's code number, and the 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 such information as national stock number, part number, and date of pressure test. 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.

### ***General Information on Installation of Hose.***

**Pretesting hose.** Prior to installation, all field-fabricated hose assemblies must be pressure tested. This applies regardless of whether they were just made or were previously made, tested, and placed in storage. All factory- or depot-made assemblies should be pressure tested before use.

**Connecting hose.** When connecting hose remember--

- Fittings must be lubricated with hydraulic fluid before hose assemblies are connected. Never connect dry fitting parts.
- Avoid making a straight hose connection between two rigid connection points. Slack equal to at least 5 percent of the hose length must be allowed for operation and shrinkage.
- If a hose is to be installed with only a slight bend, add 5 percent to the hose length to make up for contraction of the hose under pressure. Where a hose is attached to an engine-mounted hydraulic component, provide at least 1 1/2-inches of hose slack between the component and the hose support nearest the engine.
- Tighten fittings to exact torque specifications given in the applicable technical manuals. Avoid guesswork.

**Hose supports.** Teflon hose requires a different kind of support from that used for rubber hose. However, the following principles in the use of supports apply to both rubber and Teflon hose:

- Supports should be spaced at 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.

*Hose protection.* To protect hose against damage from chafing, you must provide adequate clearance between the hose and other objects. For example, grommets are used to protect hose passing through bulkheads.

Hose must be protected from extreme temperatures. For example, shrouding or relocation will provide protection from engine exhaust or from hot engine parts.

Vibration is harmful to hose. When a hose is connected to a unit that moves in a direction opposite to movement of the airframe, the hose must be installed 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.

*Identification of lines.* 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 blue and spaced 1/6-inch apart identify the hydraulic lines. With either system, additional white tapes with arrows printed on them to indicate direction of flow may run adjacent to the colored tape to identify a pressure line or a return line.



## CHAPTER 3

## SEALS AND FITTINGS

This chapter will familiarize you in a general way with the types of seals and fittings used in Army aircraft and will give you general guidance in their maintenance. Topics covered are--

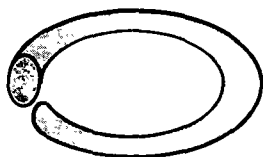
TYPES OF SEALS .....	3-1
O-RINGS .....	3-3
BACKUP RINGS .....	3-9
HYDRAULIC FITTINGS .....	3-11
QUICK-DISCONNECT COUPLINGS ...	3-17
WIPERS .....	3-17
SAFETYING DEVICES .....	3-17

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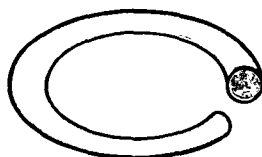
**TYPES OF SEALS**


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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. A 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, but elliptical seals are used in some landing gear struts.



elliptical ring



o-ring

**HYDRAULIC SEALS**

Advances in aircraft design have created a need for new O-ring compositions to meet changing conditions. Newer compounds developed under military standard (MS)

specifications give improved low temperature performance without sacrificing high temperature performance. These superior materials are used in the MS28775 O-ring, which is replacing the AN6227 and AN6230 O-rings. The MS28775 and MS8778 O-rings are used for MIL-H-5606 systems where the operating temperatures may vary from -65° to +275° F.

**Gaskets.**

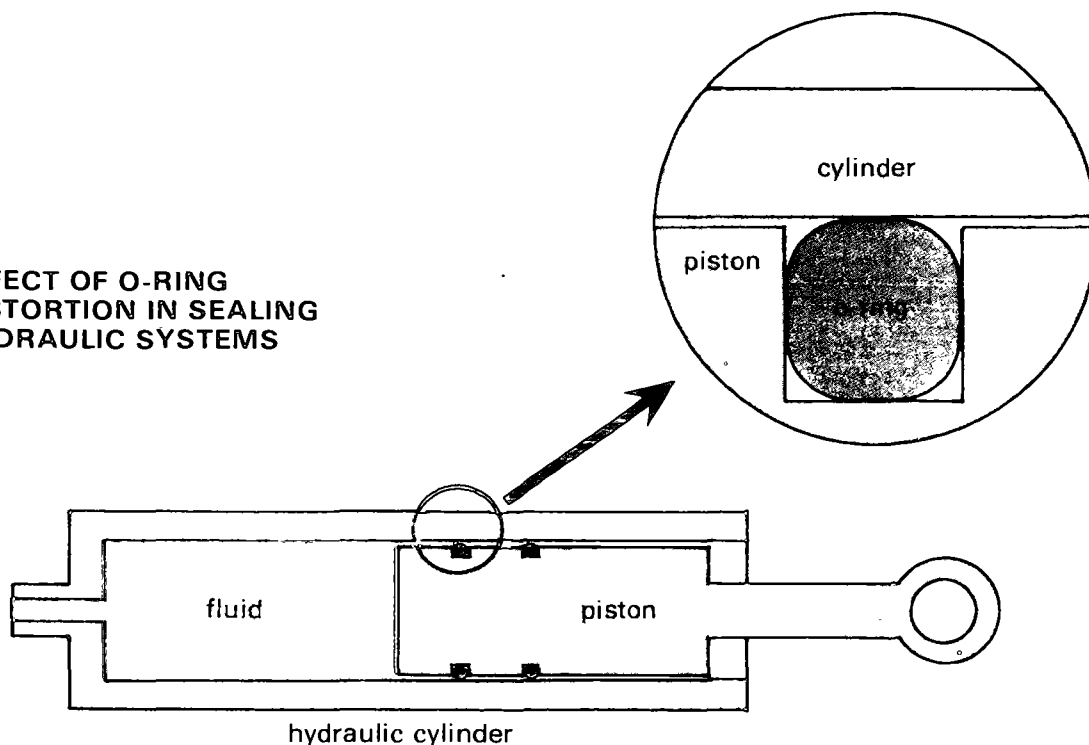
Gaskets are used in the sealing of boss fittings, end caps of actuators, piston accumulators, and other installations where moving parts do not come in contact with the seal. Normally, the type of gasket used is an O-ring. In some case it might be the same type of seal that is used as a packing in other installations, but it may be one that is manufactured only for use as a gasket. In hydraulic systems where the operating temperature ranges from -65° to +160° F, the O-rings AN6290, MS28778, AN6230B-1 through -25, and MS28775-013 through -028, -117 through -149, and -223 through -247 are intended for use as gaskets. In systems where temperature limits range from -65° to +275° F, MS28778 and designated sizes of MS28775 O-rings are used as gaskets. Normally, O-rings designated as MS28778 should be used only in connections with straight thread tube fittings such as end caps of check valves.

### *Packings.*

Packings used in Army aircraft hydraulic installations are made of synthetic rubber. They are used in units that contain moving parts, such as actuating cylinders and selector valves. Although packings are made in various forms, the O-ring type is most widely used. The U-rings, V-rings, and various other types are obsolete in most cases and are not discussed in this manual.

The O-ring packings effectively seals in all directions by distortion of its elastic compound. The clearance for the O-ring is less than its free outer diameter so that the O-ring is squeezed out of round. The ring contacts the inner and outer walls of the passage under both static (no pressure) and when pressure is applied. Note that backup

#### **EFFECT OF O-RING DISTORTION IN SEALING HYDRAULIC SYSTEMS**



rings are not installed. In hydraulic systems where components are subject to 1,500 psi pressure and below, AN6226B, AN6230B, and MS28775 packings are used. In such installations backup rings, although desirable, are not required. In most modern aircraft with hydraulic system pressures up to 3,000 psi, backup rings are used in conjunction with the MS28775 packings.

## O-RINGS

**O-Ring 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 by visual examination 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.

**Replacement schedules for O-rings.** Note the manufacturer's cure date given in this illustration: 2Q80 indicates that the O-ring

K25330-833-7491  
PACKING PREFORMED SYN. RUBBER  
1 EACH (MS28778-5)  
DISC-38329  
A-5/80  
SR 810-B-90  
MFD. DATE 4-80; CURE DATE 2Q80  
STILLMAN RUBBER CO. (MFR/CONTR)  
MIL-G-5510A

was manufactured during the second quarter of calendar year 1980. Age limitation of synthetic rubber O-rings is based on the fact that the material deteriorates with age. O-ring service life (estimated time of trouble-free service) is computed from the cure date. Service life also depends on use, physical stress, and exposure to certain elements. Operational conditions imposed on O-rings in one component may necessitate more frequent replacement than for identical O-rings in other components. Therefore, it is necessary to follow the recommended replacement schedule for each individual component. The age of O-rings in a spare part is determined from the assembly date recorded on the service or identification plate and/or on the outside of the container. All O-rings over 24 months old should be replaced, and rings nearing their age limit (24 months) should not be used for replacement.

**O-Ring 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. Their enemies are heat, light, oil, grease, fuels, solvents, thinners, moisture, 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. Conditions to be avoided include the following:

- Defects in shape resulting from improper stacking of parts and from storage in improper containers.
- Creasing caused by force applied to corners and edges and by squeezing rings between boxes and storage containers.
- Compression and flattening as a result of storage under heavy parts.
- Punctures caused by staples used in attaching identification.
- Hanging O-rings from nails or pegs where they are apt to become dirty and to develop defective shapes (O-rings should be kept in their original envelopes).
- Allowing rings to become oily or dirty by 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 a pressure-sensitive, moistureproof tape, but the tape must not contact the O-ring surface).
- Keeping over-age parts as a result of improper storage arrangements or unreadable identification. O-rings should be arranged so that older seals are used first.

### **Remove and Install O-Rings.**

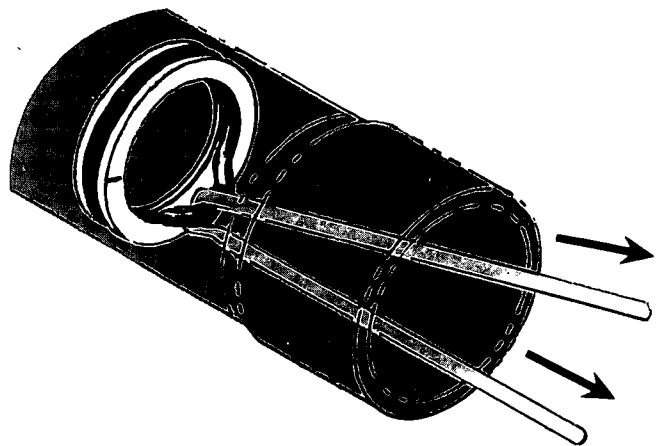
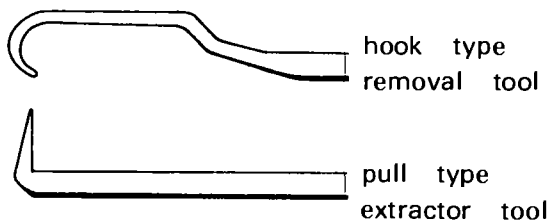
A hydraulic system cannot operate successfully if hydraulic seals are not handled and installed properly. These seals are comparatively soft and should not be nicked, scratched, or dented. They should be kept free of dirt and foreign matter and

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.

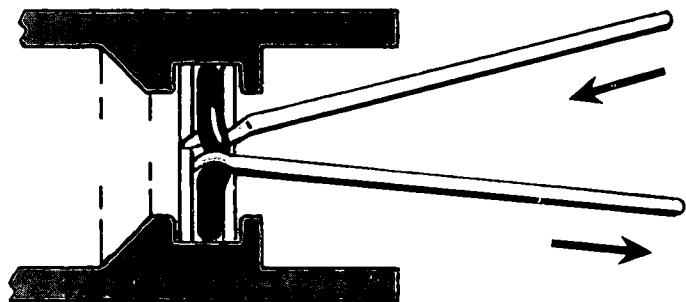
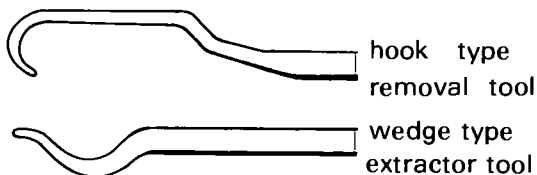
*Tools for removing and installing O-rings.* When removing and installing hydraulic seals, you must be careful to choose the correct tool. A variety of these tools may be used on any given job. They should be made from soft metal such as brass and aluminum; however, tools made from phenolic rod, plastics, and wood may also be used. Avoid using pointed or sharp-edged tools that might scratch or mar surfaces or damage the O-rings.

*Removing internal O-rings.* Notice how the hook type removal tool is put under the O-ring and then lifted to allow the extractor tool, as well as the removal tool, to pull the O-ring

#### INTERNAL O-RING REMOVAL



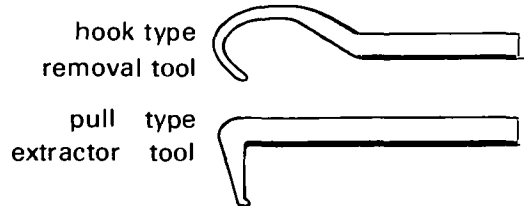
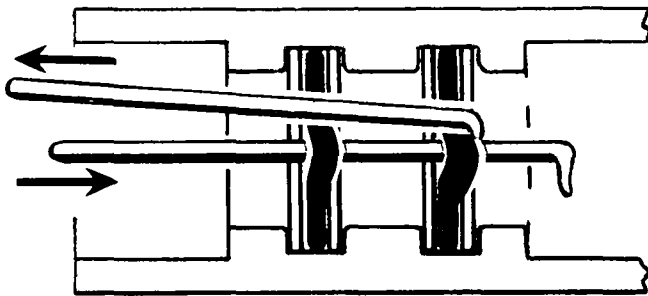
#### INTERNAL O-RING REMOVAL



from its place. The pull method may be used to remove dual O-rings. Notice that the

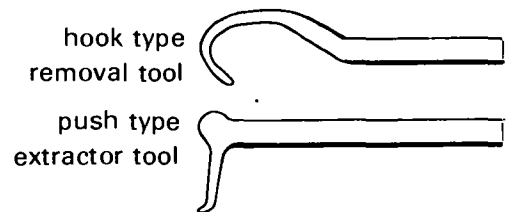
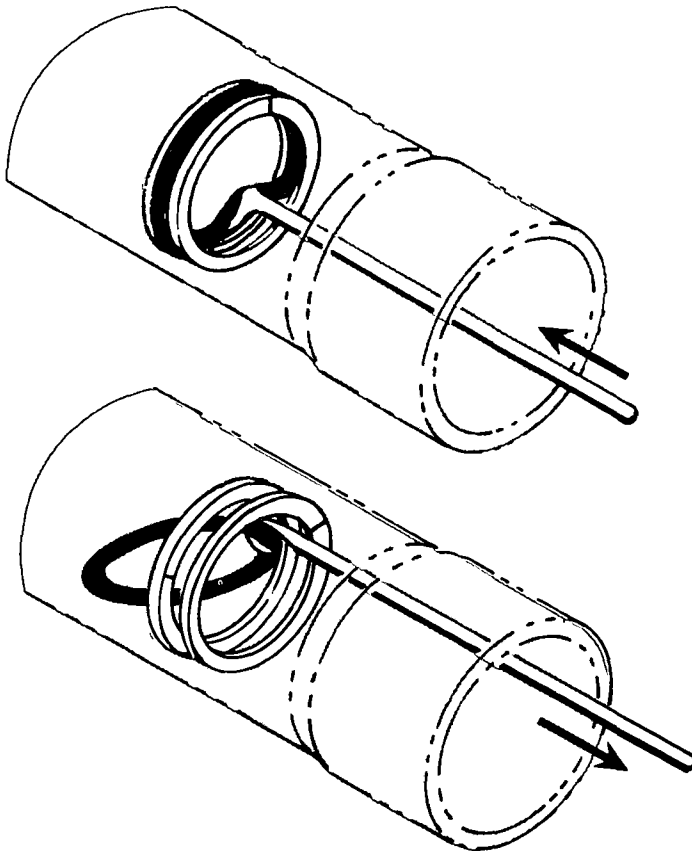
extractor tool's position under both O-rings allows the hook type removal tool to extract

### DUAL INTERNAL O-RING REMOVAL



both O-rings with minimum effort. Here is a similar method for removing internal O-rings. The difference in this case is that the extractor tool pushes, rather than pulls, the O-ring from its place.

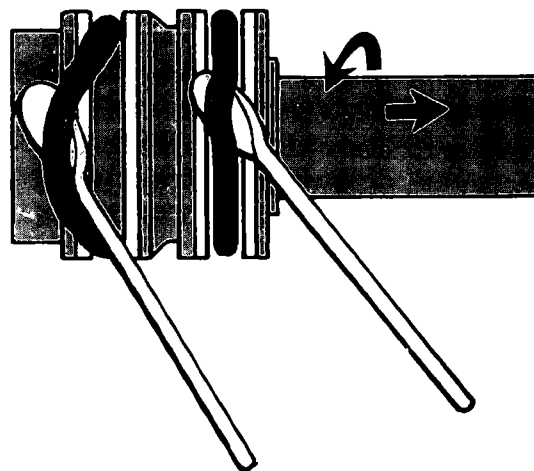
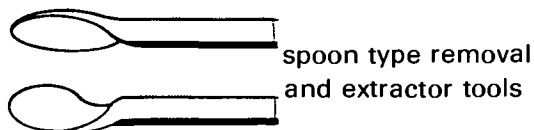
### INTERNAL O-RING REMOVAL



*Removing external O-rings.* It is less difficult to remove external O-rings than internal ones. Two accepted removal methods are shown here.

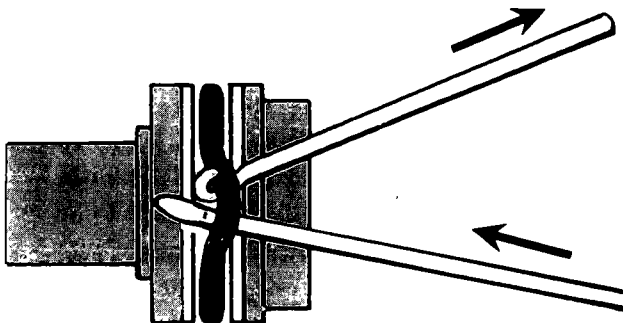
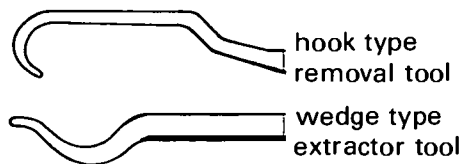
1. A spoon type extractor is positioned under the seal. After the O-ring is taken from its cavity, the spoon is held still while the piston is rotated and withdrawn.

#### EXTERNAL O-RING REMOVAL



2. A wedge type extractor tool is inserted under an O-ring and the hook type removal tool hooks the O-ring. A slight pull on the hook removes the O-ring from its cavity.

#### EXTERNAL O-RING REMOVAL





### ***Cleaning and Inspecting O-rings.***

After all O-rings are removed, cleaning of the parts that will receive new O-rings is mandatory. Insure that the area used for such installations is clean and free from all contamination.

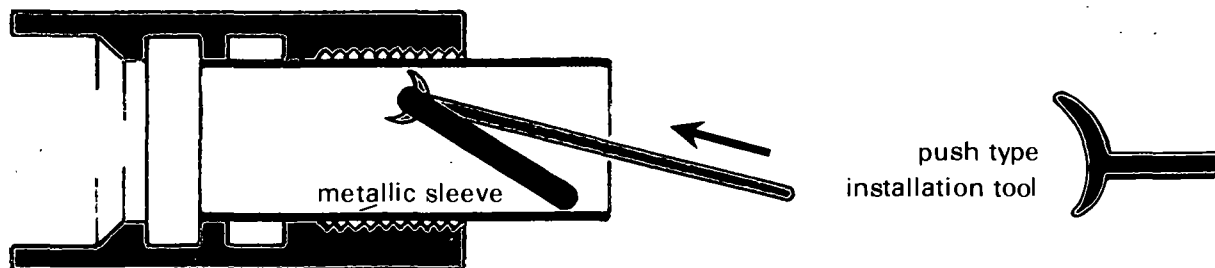
Each replacement O-ring should be removed from its sealed package and inspected for defects such as blemishes, abrasions, cuts, or punctures. Although an O-ring may appear perfect at first glance, slight surface flaws may exist. These can prevent satisfactory O-ring performance under the variable operating pressures of aircraft systems. O-rings having flaws that will affect their performance should be rejected.

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

### ***Installing O-rings.***

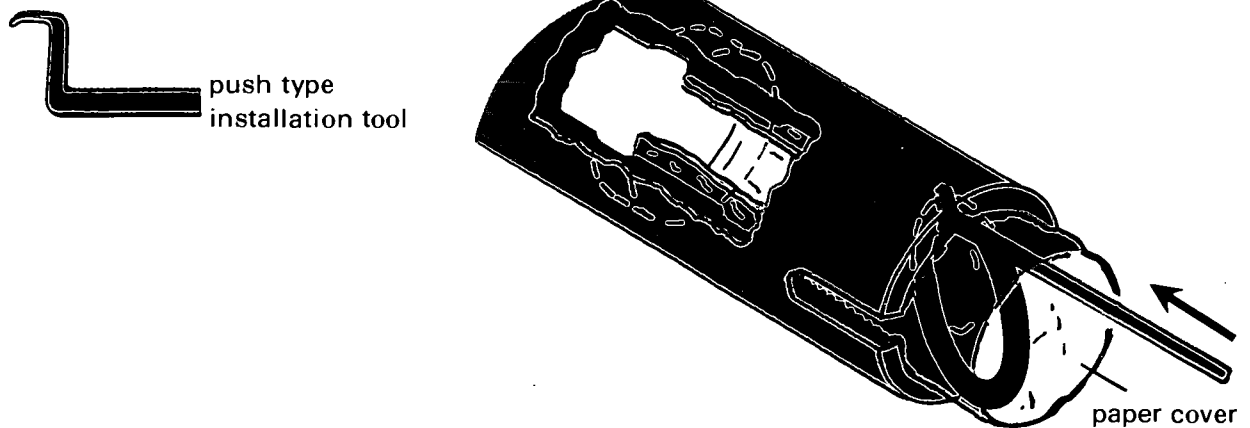
After inspection and before installing an O-ring, immerse it in clean hydraulic fluid. During installation, avoid rolling and twisting the O-ring to put it into place. If possible, keep the position of the O-ring's mold line constant. When the O-ring installation requires spanning or inserting through sharp threaded areas, ridges, slots, and edges, use protective measures such as the O-ring entering sleeves shown here. If the

#### **INTERNAL O-RING INSTALLATION**

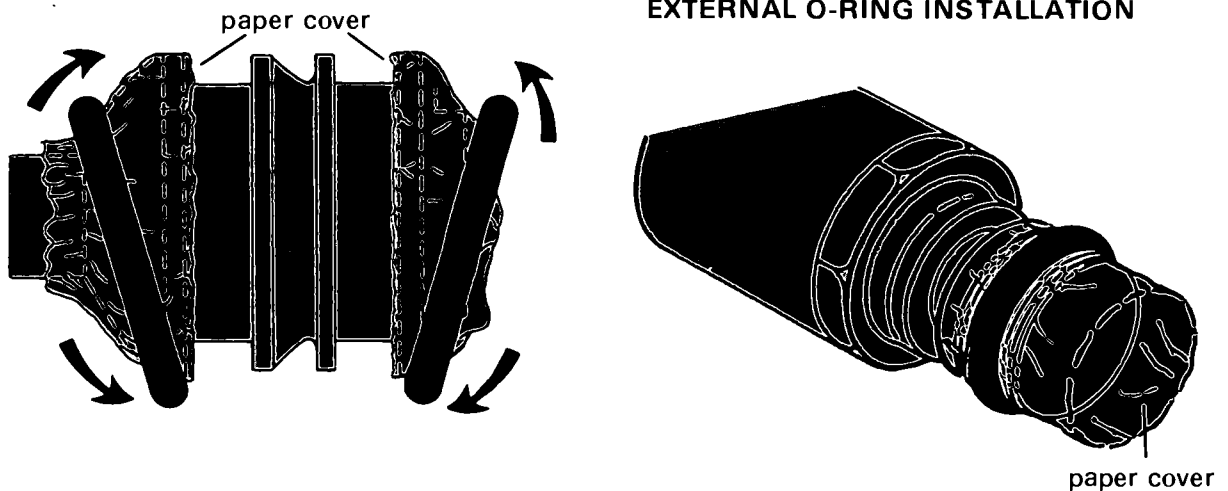


recommended O-ring entering sleeve (soft thin-wall metallic sleeve) is not available, paper sleeves and covers may be made by using seal package (gloss side out) or lint-free bond paper.

### INTERNAL O-RING INSTALLATION



### EXTERNAL O-RING INSTALLATION



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 cavity provided, gently roll the O-ring with the fingers to remove any twist that might have occurred during installation.

## BACKUP RINGS

### *Types of Backup Rings.*

Backup rings are used to support O-rings and to prevent them from wearing, thus causing leakage. Teflon backup rings are generally used with both 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 and friction resistant and which is more durable than leather. Backup rings made from Teflon do not deteriorate with age, they are unaffected by any other system fluid or vapor, and they tolerate temperature extremes greater than those encountered in high-pressure hydraulic systems. Precautions similar to those applicable to O-rings must be taken to avert contamination of backup rings and damage to hydraulic components.

Teflon backup rings may be stocked in individual sealed packages similar to those in which O-rings are packed, or several may be stored on a cardboard mandrel. If unpackaged rings are stored for a long time without the use of mandrels, overlap may develop. In order 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.

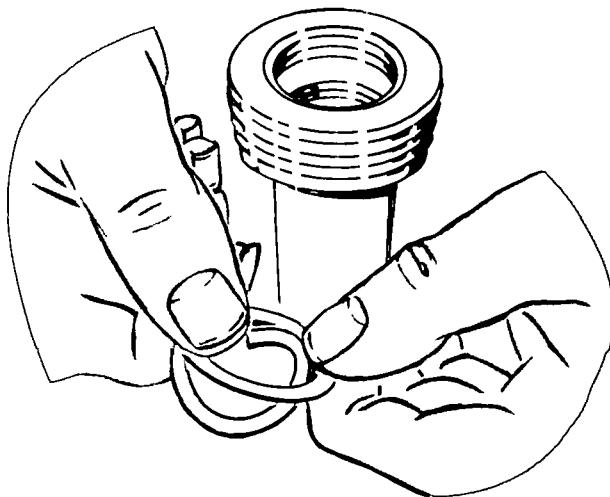
*Identification of backup rings.* Backup rings are not color coded or otherwise marked and must be identified from package labels. The dash number, which follows the specification number on the package, shows the size and in some cases relates directly to the dash number of the O-ring for which the backup 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 of backup rings.* Care must be taken during handling and installation of backup rings. If possible, backup rings should be put on by hand and without the use of sharp tools.

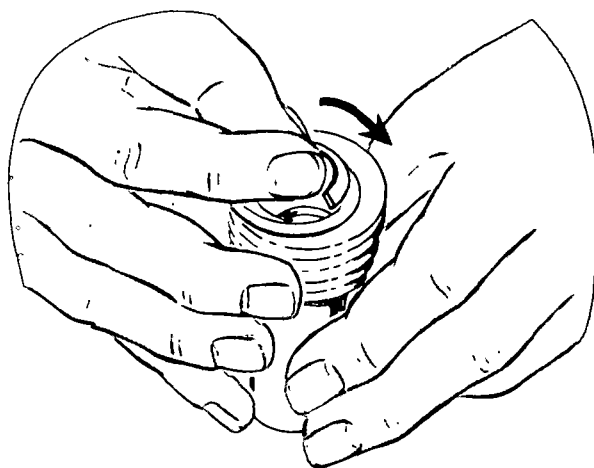
### *Installing Teflon Backup Rings.*

Teflon backup rings must be inspected before reuse and must be discarded if there is evidence of compression damage, scratches, cuts, nicks, and fraying conditions.

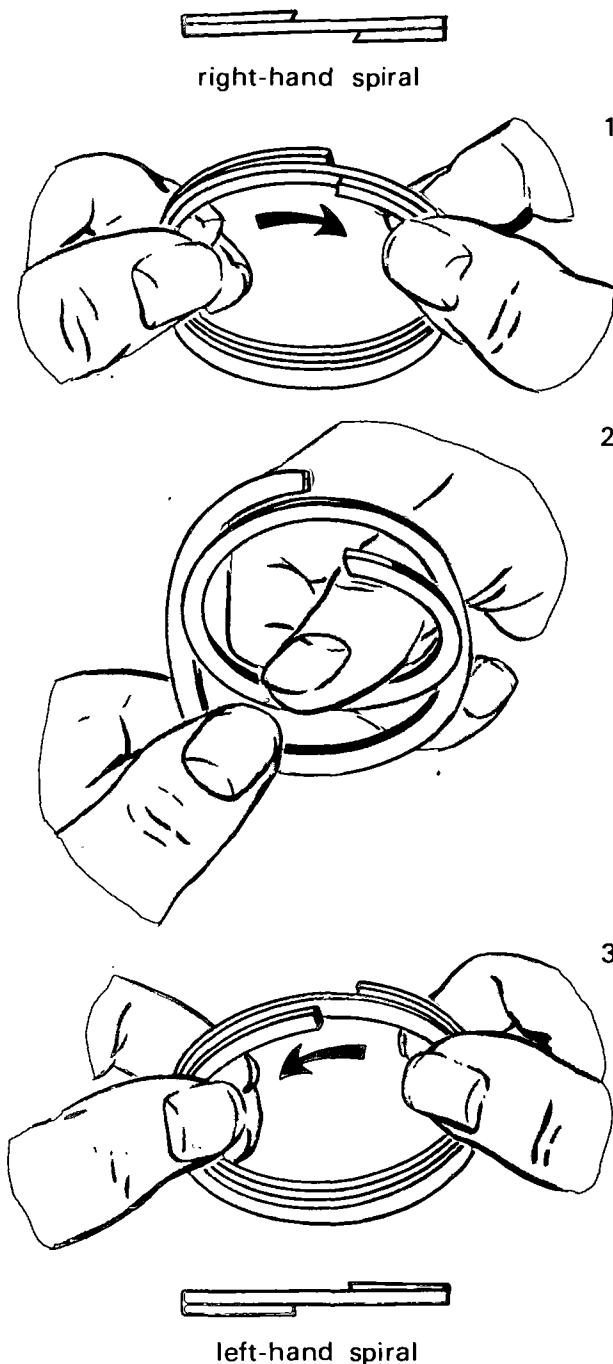
Before installing a Teflon spiral ring in an internal groove, stretch it slightly as shown here. While the Teflon ring is being put in the



groove, turn the component in a clockwise direction. This will tend to expand the ring diameter and will reduce the possibility of damage to the ring.

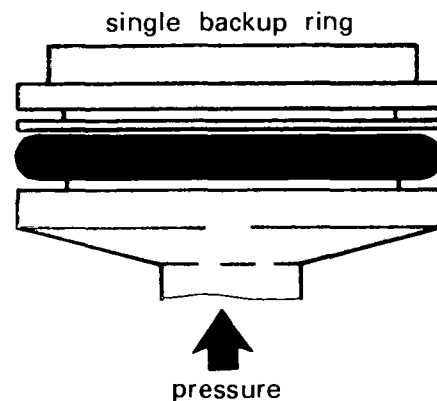


Before installing a Teflon spiral ring in an external groove, you must change the ring's right-hand spiral to a left-hand one as shown here. As you put the ring into the groove, turn

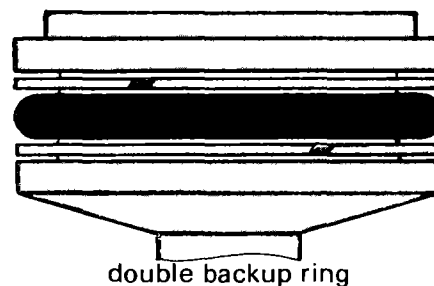


the component in a clockwise direction. This will tend to contract the ring diameter and will reduce the possibility of damage to the ring.

Backup rings may be installed singly if pressure acts on only one side of the seal. In this case, the backup ring is installed next to the O-ring and opposite to the pressure force.



When dual backup rings are installed, the split scarfed ends must be staggered as shown here.

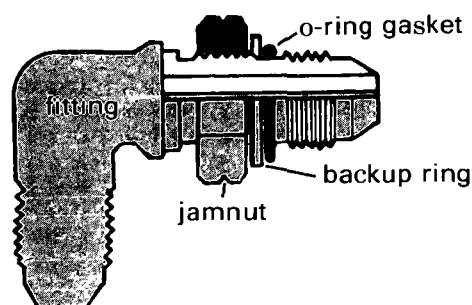


### *Installing Leather Backup Rings.*

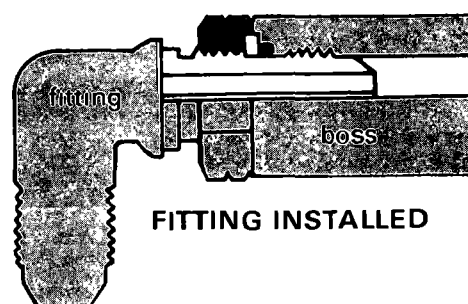
Leather backup rings also must be inspected before reuse for defects. Defective rings must be discarded. To install a leather backup ring, proceed as follows:

- Soak 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 as that used in the hydraulic system.
- Examine the fitting groove for roughness that might damage the seal.
- Position the jamnut well above the fitting groove, and coat the male threads of the fitting sparingly with hydraulic fluid.

- Install the backup ring in the fitting groove with the smooth side away from the jamnut, and work the backup ring into the counterbore of the jamnut.
- Install the gasket in the fitting groove against the backup ring.
- Turn the jamnut down until the packing is pushed firmly against the threaded portion of the fitting.
- Install the fitting into the boss and turn until the packing has contacted the boss (the jamnut must turn with the fitting).
- While holding the jamnut 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.



**INSTALLING LEATHER  
BACKUP RINGS**



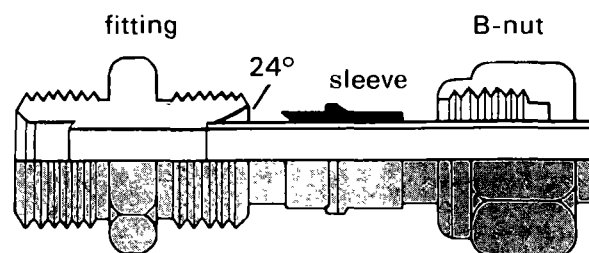
**FITTING INSTALLED**

## HYDRAULIC FITTINGS

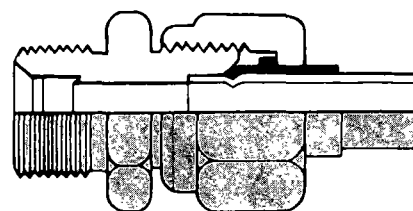
Hydraulic fittings are used throughout the hydraulic system to provide simple connections between hydraulic components and tubing. Standard MS (flareless) and AN (flared) fittings are used in Army aircraft. Both types are made in many different shapes and designs. They may be ordered in either male or female design or in a combination design (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 to be used in an aircraft hydraulic system are selected according to the design of the system. The hydraulic repairer repairs fitting failures by duplicating the original installation.

*Flareless fittings (MS).* The main feature of MS fittings is that they can be used to connect unflared tubing. An MS fitting has a counterbore in which the tube end is installed. In this 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 tube or of a tube to a component, and the beveled area causes the tube connector sleeve to seal the connection as the tube B-nut is tightened.



**COMPONENTS OF  
MS FITTINGS**



**MS FLARELESS FITTING  
INSTALLED**

*Identification of flareless fittings.* 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, which 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.

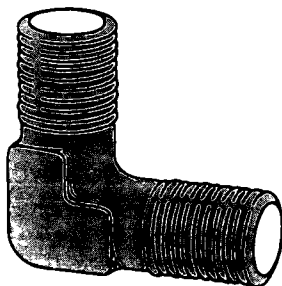
MS21900-8-D is made from aluminum alloy.

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

*Types of flareless fittings.* MS fittings may be procured in many styles.

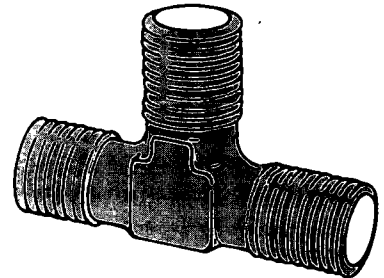
Note the 90° angle of the MS21904 elbow. This design adapts the fitting for use where the routing of tubing requires a 90° change in direction in a limited area. The flat surface between the threaded ends allows an open-end wrench to be used to hold the fitting in position while tube connections are being made.

**MS21904  
ELBOW**

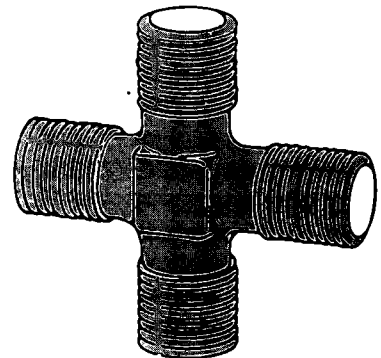


The MS21905 tee and the MS21906 cross fittings are designed for connecting common-purpose lines that come together within the hydraulic system. They, like the 90° fittings, have flat surfaces on which an open-end wrench may be placed to assist in maintaining the fitting in the correct position.

**MS21905  
TEE**

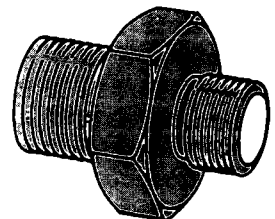


**MS21906  
CROSS**

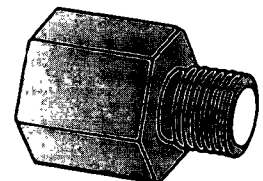


At times it may be necessary to reduce or expand a hydraulic connection. An MS21916 reducer is normally used in the first case; an MS21915 bushing in the latter. Both bushings and reducers are usually necessary when connecting components to hydraulic test equipment.

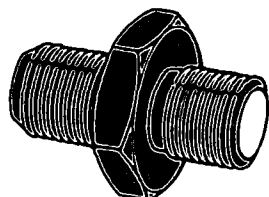
**MS21916  
REDUCER**



**MS21915  
BUSHING**

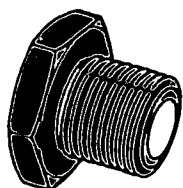


The MS21902 flareless tube union is used for straight connections of tube to tube or tube to component.

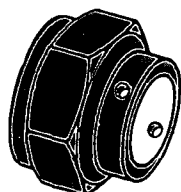


**MS21902  
UNION**

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



**MS21913  
PLUG**

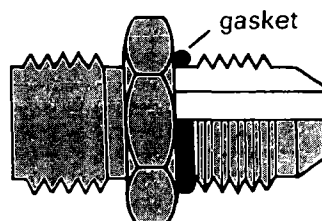


**MS21914  
CAP**

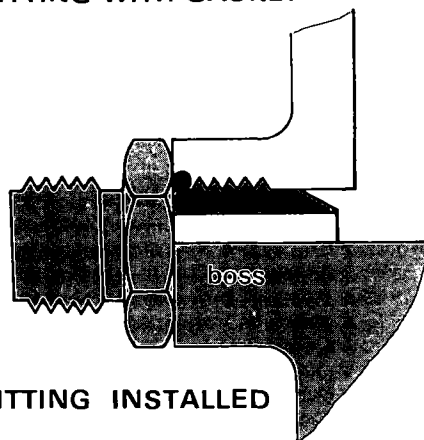
### ***Installation of Flareless Fittings.***

MS fittings must be inspected before installation. If it is impossible to see through a fitting or tube, 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 type of 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 tubing and a component, the proper gasket is selected, lubricated, and installed in position as shown here. The fitting is screwed into the boss of the component until it bottoms on the boss.

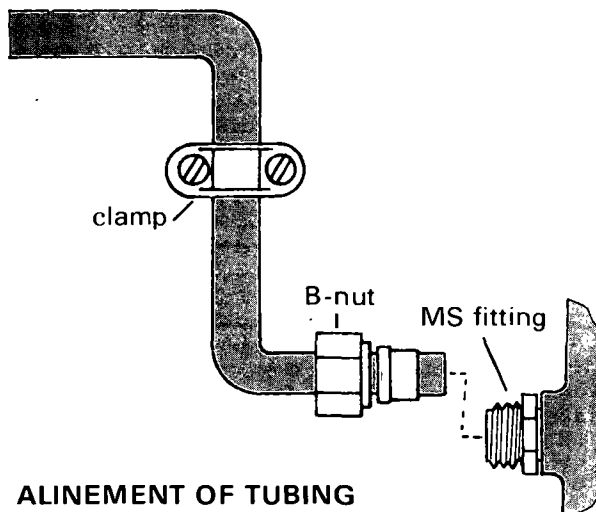


**MS FITTING WITH GASKET**



**MS FITTING INSTALLED**

When you are connecting tubing to an MS fitting, the tube should be aligned with the fitting and the nut should be started by hand without excessive strain on the line. Do not use force to align tubing. Tube alignment can often be obtained by loosening clamps on connecting lines or by rotating fittings. Both

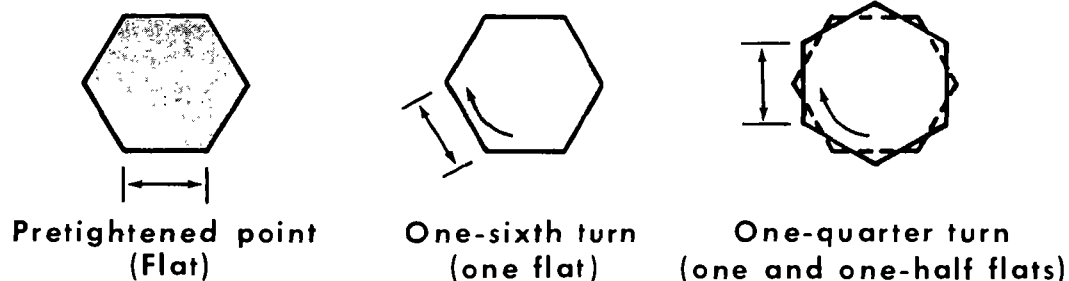


**ALINEMENT OF TUBING**

ends of the tubing should be connected and tightened until a decided increase in resistance to turning of the B-nut is encountered. At this point, tighten the clamps, insuring that they do not pull the tubing out of alinement and place it 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 will stop the leak, but if it does not you must replace the assembly.

When connecting tubing to an MS fitting, consult the accompanying illustration for torque and flat turn values for nuts on flareless tubing.

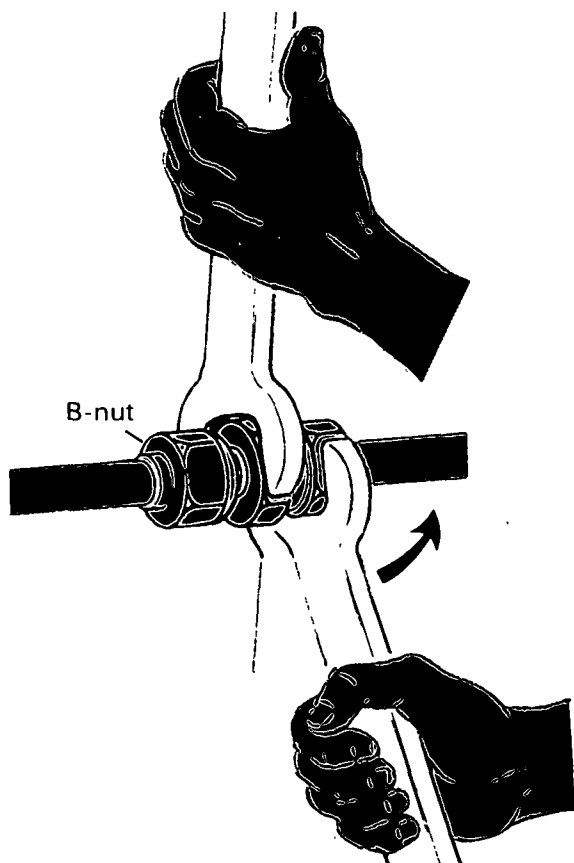
**TABLE OF  
TORQUE AND FLAT TURN  
VALUES FOR MS FITTINGS**



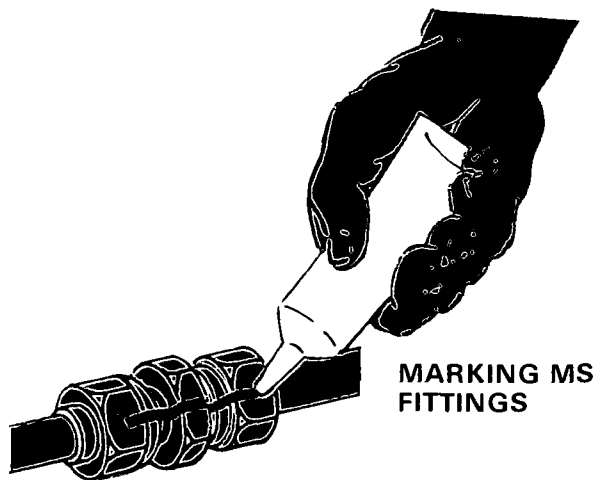
Tubing	Size	Torque (inch pounds)	Tightening — rule of thumb (Flat turns after pretightening)	
			Normal tight	Extra tight
Aluminum or steel	— 3	65 To 95	1 To 1 1/2	2 Maximum
	— 4	100 To 150		2 Maximum
	— 6	175 To 300		2 Maximum
	— 8	325 To 500		2 Maximum
	— 10	400 To 700		2 Maximum
	— 12	500 To 800		2 Maximum
Aluminum	— 16	500 To 800	1 To 1 1/2	2 Maximum
	— 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, the tube B-nut is tightened until a definite resistance is felt and is then turned one-sixth of a turn farther. The upper wrench is held stationary while the lower wrench is moved upward

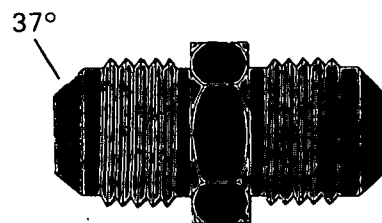


**TIGHTENING AN MS FITTING**

until the B-nut is tightened a sufficient amount. On this tube connection, like most others, a 1/8-inch colored stripe may be painted across the completed assembly so that loosening can be readily detected.

**MARKING MS FITTINGS**

*Flared fittings (AN).* Flared fittings, like flareless (MS) fittings, come in many different shapes. 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. 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.

**STANDARD AN FITTING (UNION)**

*Identification of flared fittings.* 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, which 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 the size number or by the addition of a letter at this location; for example:

AN6289-4 is made from carbon steel.

AN6289-D4 is made from aluminum alloy.

AN6289-S4 is made from corrosion-resistant steel, classes 304L and 347.

***Installation of Flared Fittings.***

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

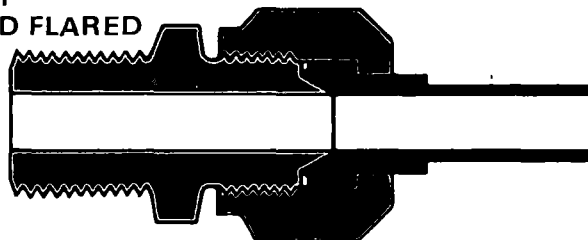
Before installation, lubricate all male fittings and the outside of the tube flare and sleeve with the type of hydraulic fluid used in the system. During installation, insure that the tube assembly is aligned and that the B-nut starts freely by hand. The nut should be fitted and started with at least 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 values as specified in the following table:

**TABLE FOR  
B-NUT TORQUE VALVE**

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 for misalignment of the tube assembly. A correctly torqued fitting is shown here.

**PROPERLY  
INSTALLED FLARED  
FITTING**



**CAUTION!**

HYDRAULIC FITTINGS SHOULD NEVER BE TIGHTENED WHEN THE HYDRAULIC SYSTEM IS PRESSURIZED.

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**QUICK-DISCONNECT COUPLINGS**


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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, allowing fluid to flow in either direction through the coupling. When the coupling is disconnected, a spring in each half closes the valves, preventing loss of fluid and entrance of air. The union nut has a quick lead thread

which permits 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 disconnects must be installed in accordance with the instructions in the applicable maintenance manual.

---

**WIPERS**


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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 of felt. At times, felt and metallic wipers are used together, the felt wiper being 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 from an external fitting. Metallic wipers are formed in split rings for easy installation and are manufactured slightly undersize to insure 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 for condition and are then 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 is well soaked in hydraulic fluid.

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**SAFETYING DEVICES**


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Aircraft vibration tends to loosen or change the adjustment of various parts, such as nuts, turnbuckles, and screws. Therefore, parts that are intended for disassembly or adjustment are safetyed by some device. The safetying devices commonly used on aircraft are cotter pins, checknuts, lockwashers,

safety pins, lockrings, and safety wire. An incorrectly installed safetying device or failure to install one where it is needed can cause a component to fail.

Detailed information on safetying devices is contained in TM 55-1500-204-25/1.



## CHAPTER 4

**SYSTEM RESERVOIRS**

This general description of reservoirs used in the hydraulic systems of Army aircraft will acquaint you with--

**USES OF RESERVOIRS IN**

**HYDRAULIC SYSTEMS** ..... 4-1

**TYPES OF RESERVOIRS USED IN**

**HYDRAULIC SYSTEMS** ..... 4-1

**STANDPIPES** ..... 4-4

**AIR CYLINDERS** ..... 4-4

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**USES OF RESERVOIRS IN HYDRAULIC SYSTEMS**

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The system reservoir holds enough fluid for use in operation of the system and to replace fluid lost through minor leakage or evaporation. Reservoirs may be installed for other purposes such as--

- Providing a space for increase in fluid volume over the initial amount; for

example, that which might occur through thermal expansion or foaming.

- Providing a place for escape of air trapped in the system.
- Helping to cool the system fluid.

---

**TYPES OF RESERVOIRS USED IN HYDRAULIC SYSTEMS**

---

*General.* Two types of reservoirs are used in aircraft hydraulic systems: the *in-line* 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 merely of a space set aside within some major component for the purpose of holding a supply of operational fluid; such a reservoir has no housing of its own. Since the in-line reservoir is the type commonly used in Army aircraft, it will be the one discussed here.

A space is provided in the reservoir above the normal level of the fluid for fluid expansion and for escape of entrapped air. 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 somewhat below the top of the reservoir. Most reservoirs have a dipstick or a glass sight gage by which fluid level can be easily and accurately checked. All reservoirs are either vented to the at-

mosphere or are closed to the atmosphere and pressurized.

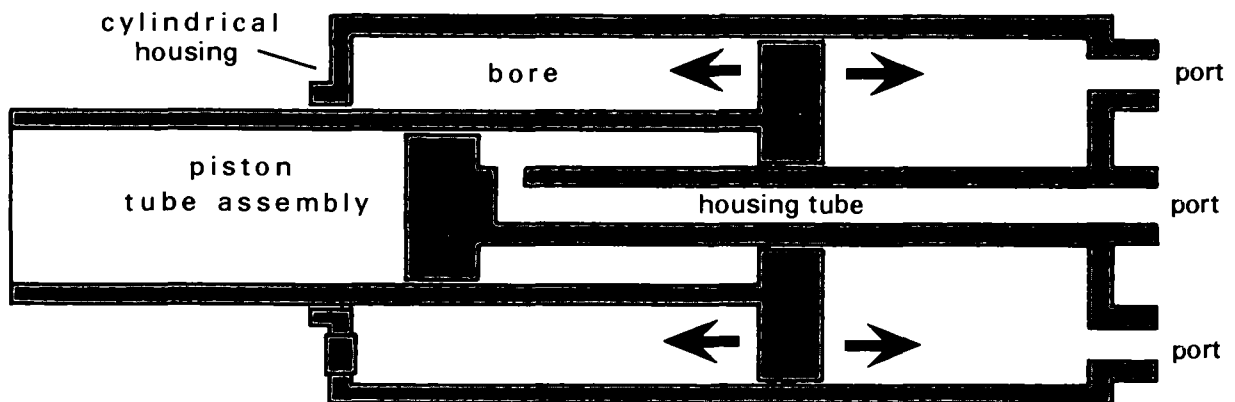
*Vented reservoirs.* In vented reservoirs, atmospheric pressure and gravity are the forces which together cause fluid to flow out of the reservoir and into the pump. In order to supply a pump with fluid, a vented reservoir must be positioned at a higher location than the pump. If the reservoir and the 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 the hydraulic systems of some aircraft, it is necessary to mount the reservoir at a level below the pump. In this case, the weight of the fluid obviously deters rather than aids the flow of fluid into the pump. A reservoir so located has to have the fluid it contains under greater than atmospheric pressure to force the fluid upward into the pump. Another reason for

pressurizing reservoirs is to enable 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. Two general methods of pressurizing reservoirs are employed. One method employs air; the other, fluid.

*Pressurized by fluid.* This method makes use of fluid pressure bled from the pressure lines of the system in which the reservoir is incorporated. The reservoir is designed in such a way as to develop a relatively low pressure on the supply fluid contained in the reservoir by use of a stream of fluid fed into the reservoir at a much higher pressure. Such a reservoir is commonly called an airless reservoir. This schematic shows 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, and a piston and piston tube assembly. The piston and piston tube assembly are free to slide back and forth relative to the housing. The housing tube and

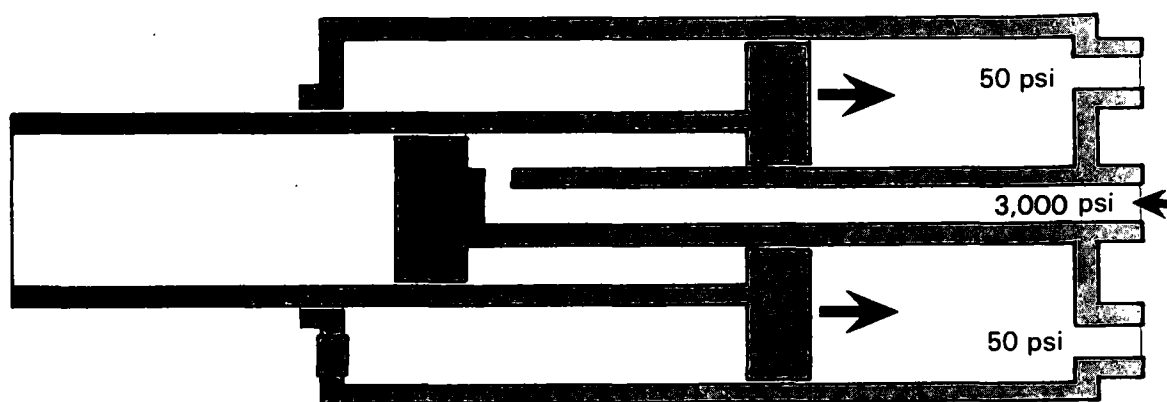
**SCHEMATIC OF  
FLUID PRESSURIZED RESERVOIR**



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 and thus developing 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  $\div$  60) is built up in the supply fluid.

**HYDRAULIC RESERVOIR  
PRESSURIZED WITH FLUID**



*Pressurized by air.* Pressurizing with air is done by forcing 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 accomplished by passing the air through an air pressure regulator.

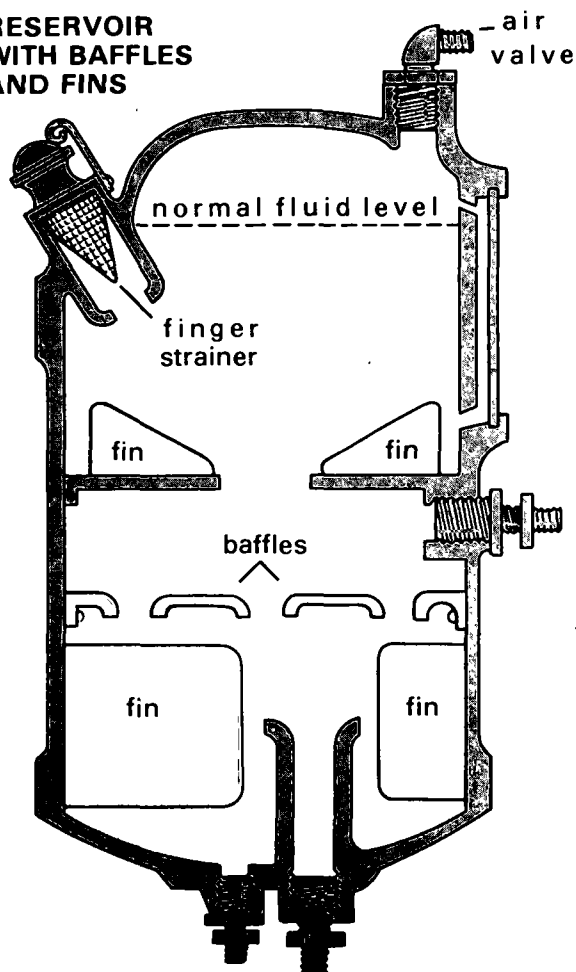
### ***Baffles and Fins Used In Reservoirs***

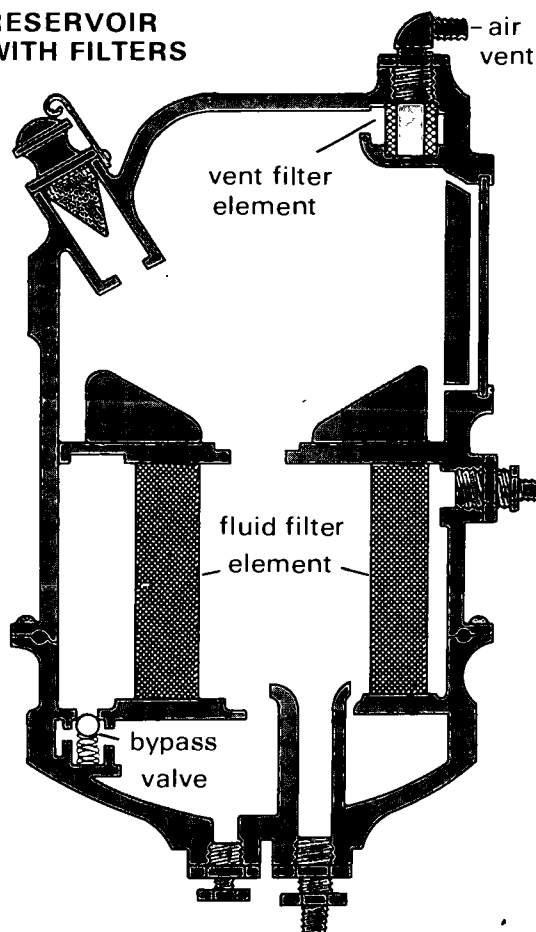
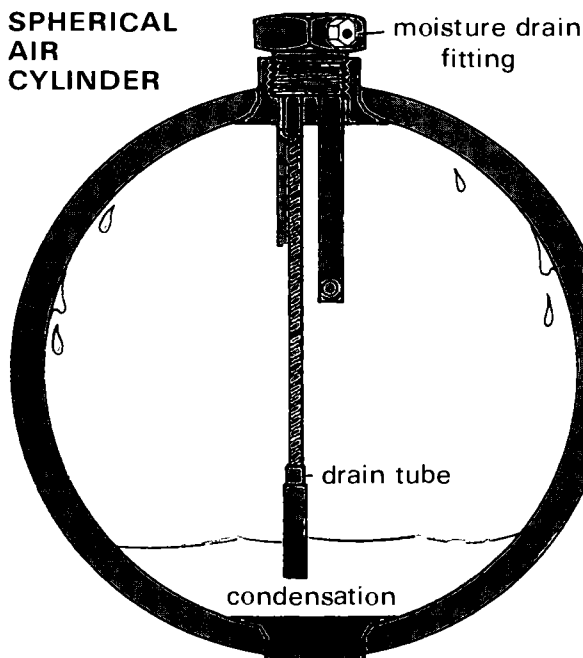
Baffles and/or fins are used in most reservoirs to prevent the fluid within the reservoir from swirling and surging. These conditions could cause fluid to foam and air to enter the pump along with the fluid.

### ***Finger Strainers Used In Reservoirs***

Many reservoirs have strainers in the filler neck to keep foreign matter from entering 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 as a means of speeding up the pouring of fluid into the reservoir.

**RESERVOIR  
WITH BAFFLES  
AND FINS**



**RESERVOIR  
WITH FILTERS****SPHERICAL  
AIR  
CYLINDER*****Filter Elements Used In Reservoirs***

Filter elements are incorporated in some reservoirs either to filter air before it enters the reservoir or to filter fluid before it leaves the reservoir. When an air vent filter element is used, it is located in the upper part of the reservoir above the fluid level. When a fluid filter element is used, it 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 insure that the pump will not be without fluid even if the filter element becomes clogged. This valve is normally held closed by a spring that would be opened by the stronger partial vacuum that would develop if the element became badly clogged.

**STANDPIPES**

Some aircraft have emergency hydraulic systems that take over if the main system fails. In many such 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 and the main system draws its fluid through a standpipe located at a higher elevation. With this arrangement, operation of the emergency system is insured should the main system fail.

**AIR CYLINDERS**

Air cylinders are the pneumatic reservoirs in an aircraft's pneumatic system, which serves as an emergency source of pressure for the hydraulic system. These cylinders are made of steel and may have a cylindrical or a spherical shape. Cooling of the high-pressure air in the storage cylinders will cause some condensation to collect in them. To insure positive operation of systems, storage cylinders must be purged of moisture periodically. This is done by slightly cracking the moisture drain fitting located on the cylinder manifold.



## CHAPTER 5

# SYSTEM FILTERS

In chapter 1 you learned about the importance of keeping the aircraft's hydraulic systems clean. In this chapter you will learn about safeguards built into the system to insure a clean fluid and air supply. Some very general guidelines concerning servicing of this equipment are included. Topics covered are--

FLUID FILTERS .....	5-1
AIR FILTERS .....	5-4
SERVICING FILTERS .....	5-4

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### FLUID FILTERS

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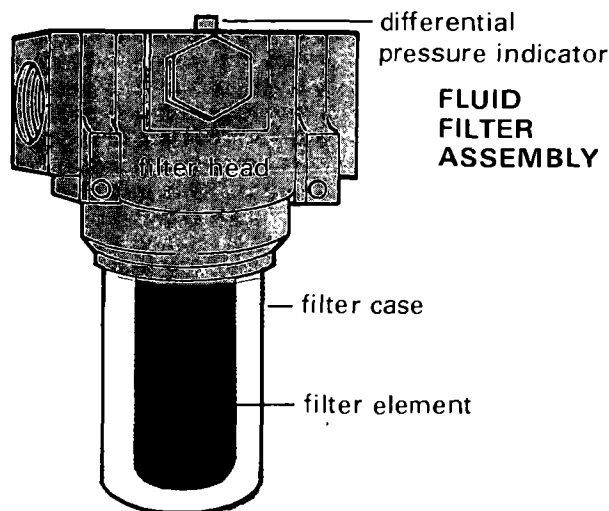
Practically all foreign particles found in hydraulic fluid can be removed by filters. The degree of filtration needed depends on the acceptance level desired. Most high pressure hydraulic systems use filters having a 10- to 15-micron capability, but many later model aircraft have 5-micron filters; and 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 wear and tear of parts in the system. They cannot handle large quantities of foreign matter from outside the system.

We have already mentioned that filters are sometimes used in reservoirs. In addition, they 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.

The filtering elements in fluid filters are normally made of paper or of 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 line filter assemblies are made up of three basic units: filter head, filter case, and filter element. Illustrated here is a typical line filter assembly in which 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 case is the housing that holds the element to the



head assembly and is the part that is removed during replacement of the filter element.

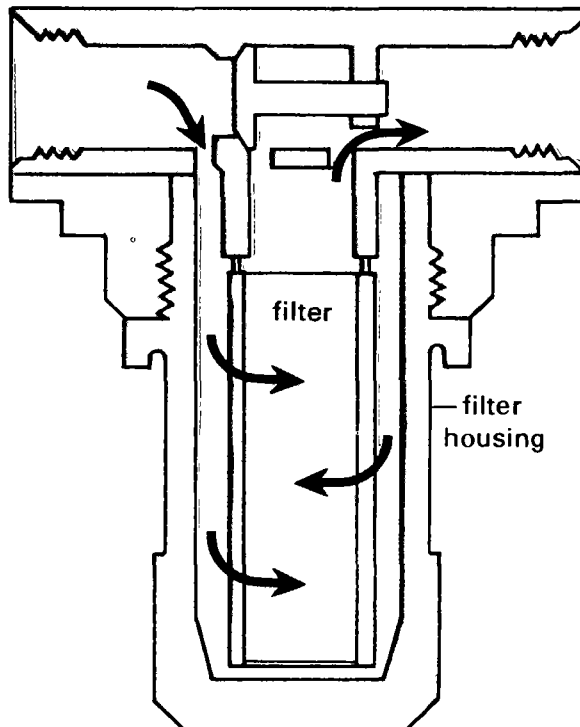
### ***Fluid Filters With Paper Elements.***

A typical fluid filter with a paper element is designed to remove 99 percent of all particles 10 microns (0.000394 inch) in diameter and larger. To define this capability in meaningful terms, let us take the following 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 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. A groove machined around the base of the threads provides the location for the packing between the filter bowl and the body assembly.

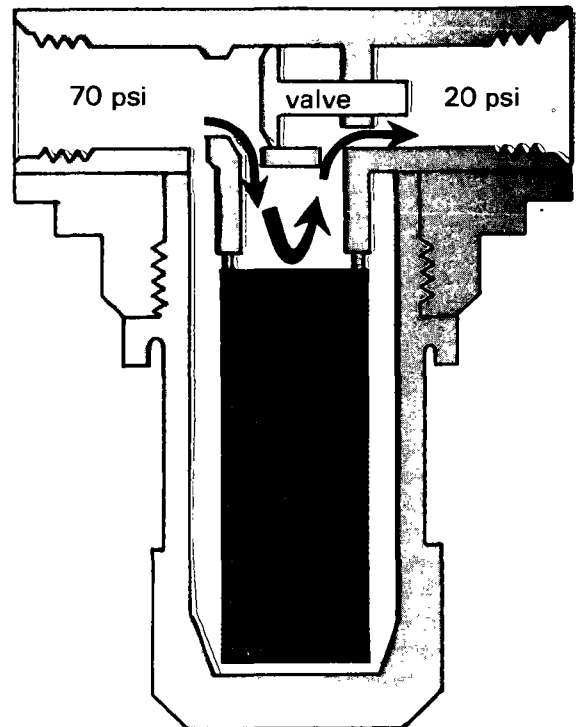
Hydraulic fluid enters the filter through the inlet port in the body and flows around the element inside the filter bowl. This element, like those used in the reservoir, is made of specially treated cellulose paper formed in accordion-like pleats to present the maximum

#### **FLUID FILTER NORMAL FLOW**



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. 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,

#### **FLUID FILTER CLOGGED**



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.

Paper filter elements are replaced on a scheduled basis, depending on the needs of the specific aircraft system. Unscheduled replacement of filter elements is also required following removal of certain components. One should 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, for example, and 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 lies in the fact that, while elements may seem identical in outward appearance and in physical dimensions, there are internal differences peculiar to different types of filters. 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.

The following procedure for removing and replacing paper filter elements is typical of most Army aircraft:

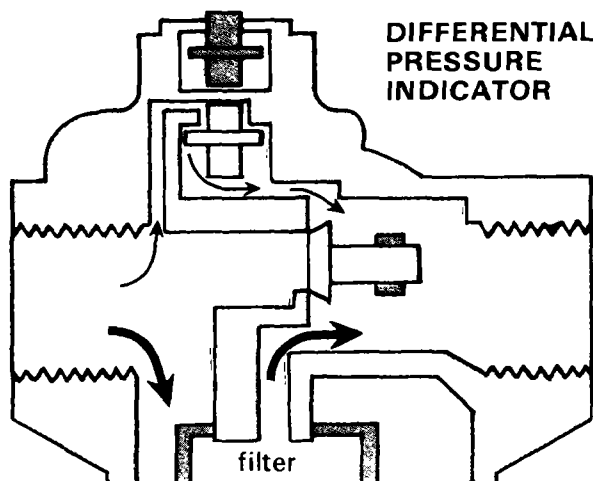
- Relieve system pressure by operating the main system bypass valve or by actuating a hydraulically operated unit.
- Depressurize reservoir (if necessary).
- Cut lockwire.
- Unscrew the filter case and remove it from the filter head, using a slight rocking and downward pull on the case after the case threads are free from the filter.
- Extract the retaining ring and remove the filter element from the cases.
- After insuring that a replacement filter element is available, cut the filter element as indicated by the dash lines in the illustration and inspect internally for evidence of system contamination.
- Before installing the new filter, clean the filter head and the filter 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 handtight plus one-eighth of a turn, but always check the specific 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 the head assembly.

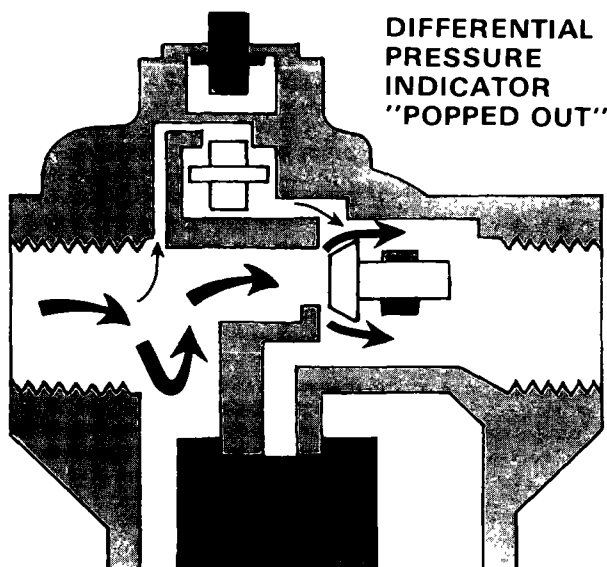
### ***Stainless Steel Fluid Filters.***

Stainless steel filter elements are used in most modern aircraft. Filter elements 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 at 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 operate on the principle of difference in pressure entering the element and pressure after it leaves the element. As 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 to pop out, showing that the element must be cleaned. 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. The use of a nonbypassing type filter eliminates the possibility of contaminated fluid passing the filter element and



contaminating the entire system. This type of filter will minimize the need for flushing the entire system and will lessen the chance for failure of pumps and other components in the power system.

*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. As long as the first-stage element is unclogged and functioning, there will be no foreign matter left for the second-stage element to remove. However, 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 then 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 safely used until the first-stage element is unclogged.

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## AIR FILTERS

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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 is designed to open and

bypass 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 screen mesh type, which requires periodic cleaning. The screen mesh type may be returned to the system after being cleaned and dried.

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## SERVICING FILTERS

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Filters should be serviced in accordance with schedules and procedures contained in technical manuals pertaining to the specific aircraft involved. However, the following general guidelines apply to the servicing 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 help keep dirt and other foreign particles from entering the system while the filter is being serviced.
- Do not leave a disassembled filter housing unprotected as this may cause contamination.
- Remove wrappings from a replacement element only when the element is to be inspected or installed.

- The filter bowl should only be hand-tightened to the head. Always safety the bowl and head together.

Be sure that a popped-out indicator button is indicating 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 by means of ultrasonic cleaning equipment only. No other known method is successful. If ultrasonic equipment is not available in the organization, the contaminated element must be replaced by one obtained from supply by direct exchange. The replaced element is not an expendable item: it must be turned in for cleaning and reissue.



## CHAPTER 6

# HYDRAULIC PUMPS AND MOTORS

The hydraulic pump is the mechanism for transferring and pressurizing the aircraft's hydraulic fluid. Aircraft systems use engine-driven power pumps for this purpose. Hand pumps are also provided as emergency equipment and for ground checking the hydraulic system. Hydraulic motors in Army aircraft perform such functions as starting landing gear wheels and powerplant turbines and operating cargo ramp doors and winch hoists. This chapter is subdivided as follows:

POWER PUMPS.....	6-1
HAND PUMPS .....	6-10
MOTORS .....	6-12

## POWER PUMPS

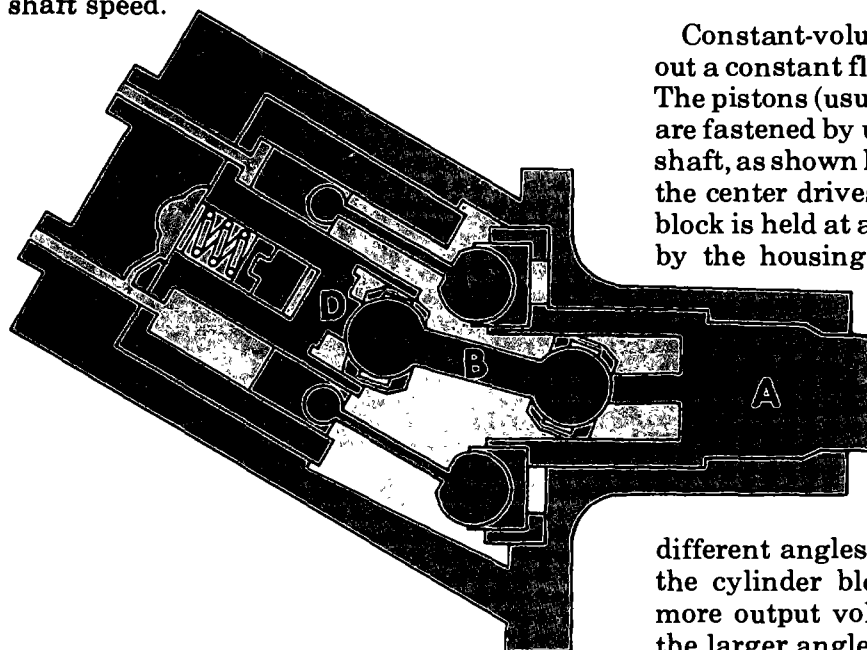
The primary energizing unit of the hydraulic system is the power pump. It is the unit that normally delivers hydraulic fluid under pressure to the actuators. Power pumps may be driven by an electric motor, a turbine unit, or the aircraft engine; however, engine-driven pumps are used in all Army aircraft at this time. The piston type power pumps used in modern hydraulic systems run at a rated speed of about 1-1/2 times engine crankshaft speed.

In the drive shafts of all power pumps there is a thinned portion that provides for a shearing action. If the pump seizes, the shaft will break at this point, thus preventing damage to the engine or the transmission.

Piston type power pumps have common constructional features, but there are variations in volume output and in methods of operation.

### *Constant-Volume Pumps.*

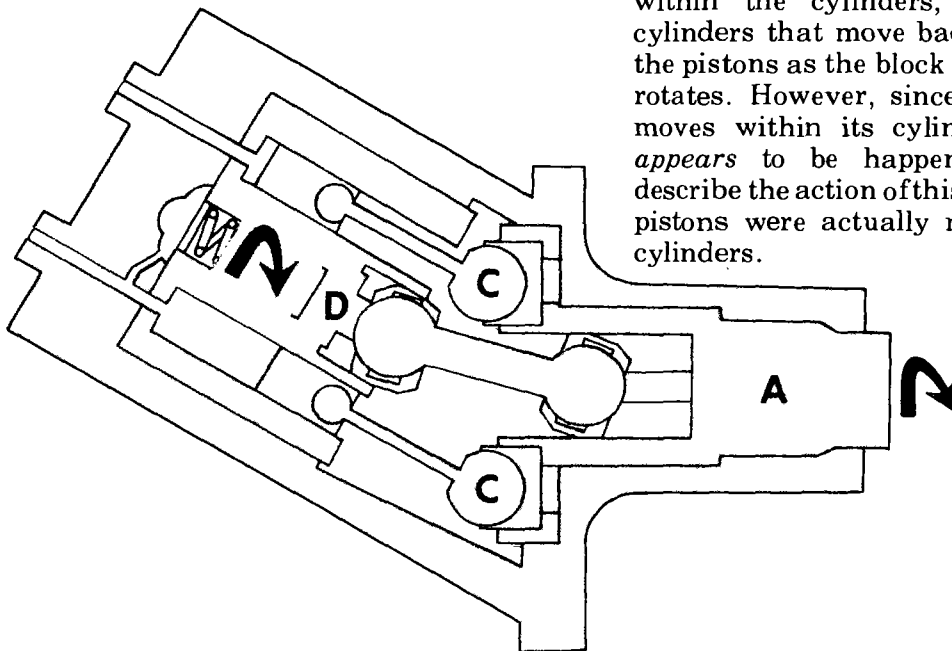
Constant-volume piston type pumps put out a constant flow of fluid for any given rpm. The pistons (usually seven or nine in number) are fastened by universal linkage to the drive shaft, as shown here. The universal link (B) in the center drives the cylinder block (D). This block is held at an angle to the drive shaft (A) by the housing. Pumps are available with



**SCHEMATIC  
OF A  
CONSTANT  
VOLUME PUMP**

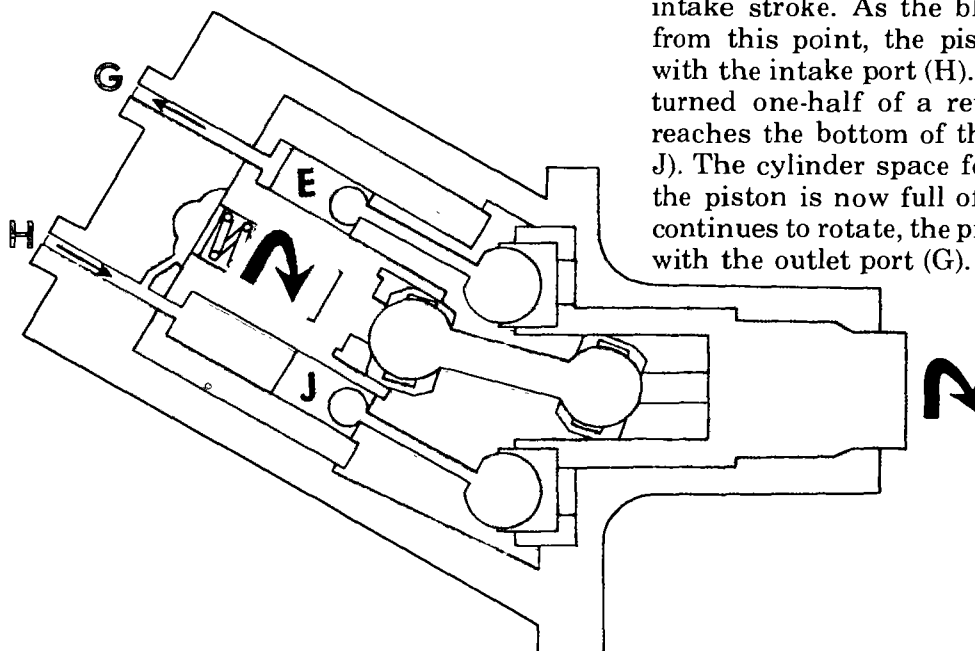
different angles between the drive shaft and the cylinder block; a large angle provides more output volume per revolution because the larger angle increases the piston stroke.

**SCHEMATIC  
OF A CONSTANT VOLUME PUMP**



As the drive shaft (A) rotates the cylinder block (D) and the piston assemblies, all the pistons are always the same distance from their points of attachment (C) on the drive shaft. Although the pistons appear to move within the cylinders, it is actually the cylinders that move back and forth around the pistons as the block and piston assembly rotates. However, since a piston normally moves within its cylinder and since this *appears* to be happening here, we will describe the action of this pump as though the pistons were actually moving within their cylinders.

**SCHEMATIC  
OF A CONSTANT VOLUME PUMP**



To clarify this operation, let us follow a piston through one complete revolution. We will begin with the piston at the top of its cylinder (position E), having just completed its pressure stroke and ready to begin its intake stroke. 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). Having now moved

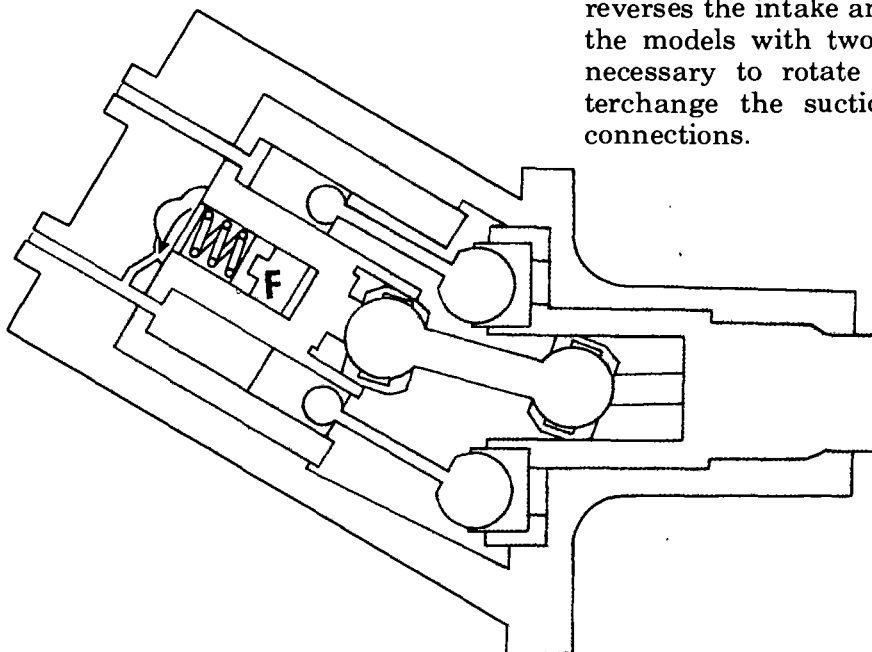


through the last 180° of rotation, it has exhausted all fluid from the cylinder and is ready to make another cycle. Since several pistons are operating as described here and since the cylinder block and piston assembly rotate rapidly, there are always pistons somewhere between the upper and lower positions. This insures a constant intake and a constant output of fluid.

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. This is done 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 the pump model shown here, 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, both located in the head. The direction in which the accessory drive rotates determines the direc-

tion 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 do so, 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. For the models with two foot valves, it is not necessary to rotate the head. Simply interchange the suction and pressure line connections.



**SCHEMATIC  
OF A  
CONSTANT  
VOLUME PUMP**

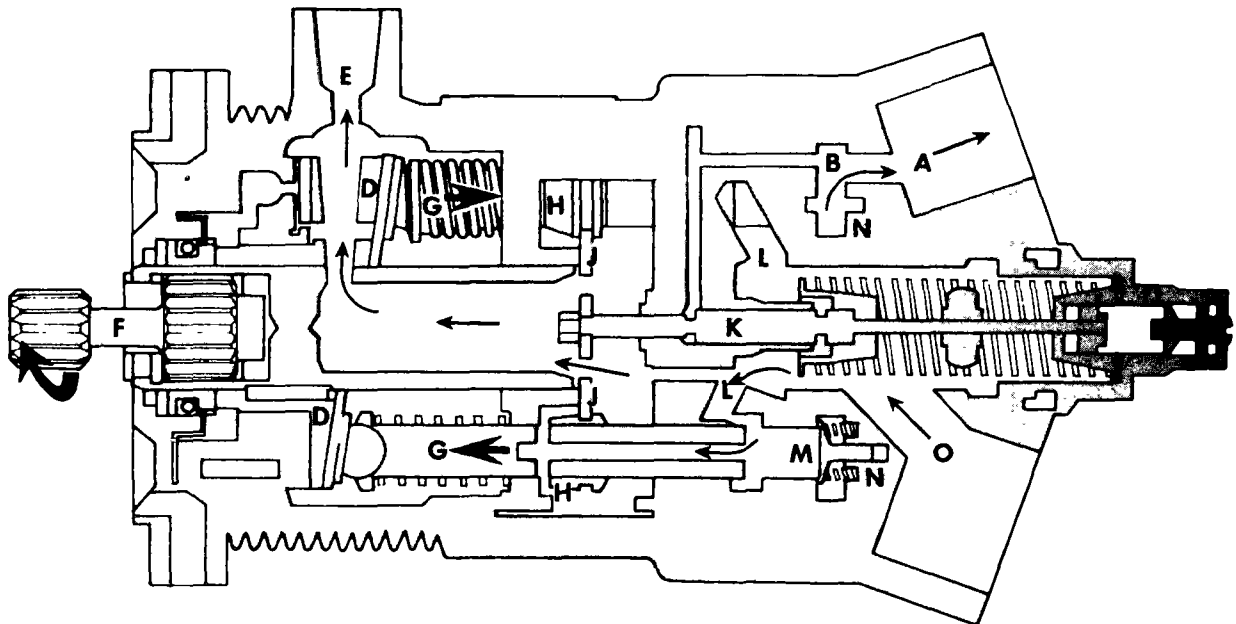
**Variable-volume pumps.** A variable-volume pump has some advantages. One is that its use does away with the need for a pressure regulator or an unloading valve: Integral flow control valves regulate the pressure according to the demands made on the system. A second advantage is that pressure surges are reduced. Accumulators are not needed to smooth out surges with systems using variable-volume pumps, but they are retained to aid the pump when peak loads occur. Three types of variable-volume pumps are described here.

***Stratopower Effective Stroke Pumps (Variable Volume).***

As shown in the stratopower pump full-flow illustration, 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

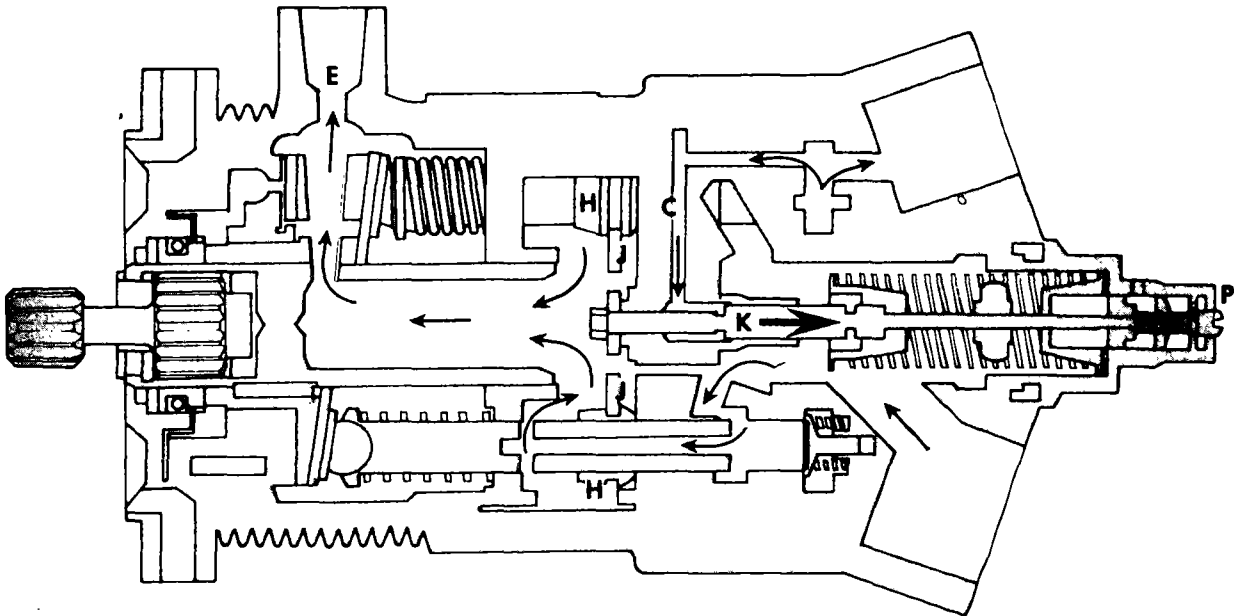
each piston there is a sleeve (H) attached to a spider (J), which in turn is attached to the compensator (K). An increase in pressure moves the compensator to the right. Decreased pressure allows it to move to the left because of the valve spring tension. As the pistons travel to the left, fluid drawn 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 and on to the pump's return port (E) on the drive end of the pump. As the pistons are forced to the right by the cam (D), the cross-drilled hole of each piston is 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 condition traps the fluid in the piston and cylinder. As the piston continues on 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.

**SCHEMATIC OF A  
STRATOPOWER EFFECTIVE  
STROKE PUMP (FULL FLOW)**



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. 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. There is always fluid being pumped through the inlet port. But fluid will not be pumped through the outlet port until system pressure drops low enough to demand it. Always connect the proper lines to the ports marked IN, OUT, and RETURN.

**SCHEMATIC OF A  
STRATOPOWER EFFECTIVE  
STROKE PUMP (ZERO FLOW)**



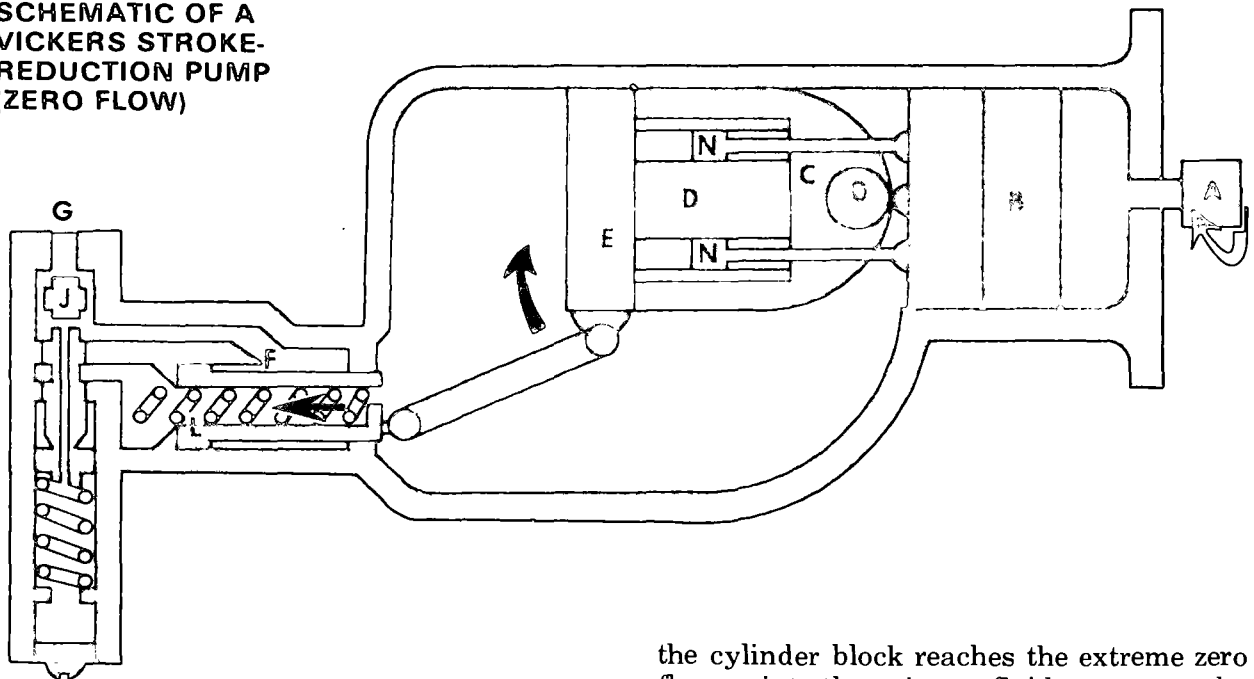
The stratopower pump does not require a pressure regulator. The compensator serves nearly the same purpose. Pressure can be increased by turning the adjusting screw (P) clockwise or decreased by turning it counterclockwise.

This pump, like the constant volume one, can be rotated in either direction.

### ***Vickers Stroke-Reduction Pump (Variable Volume).***

As the accompanying illustration shows, the Vickers stroke-reduction pump operates somewhat like the constant volume piston type pump. The main difference between the two types 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 varies automatically to satisfy the pressure-volume demands of the system.

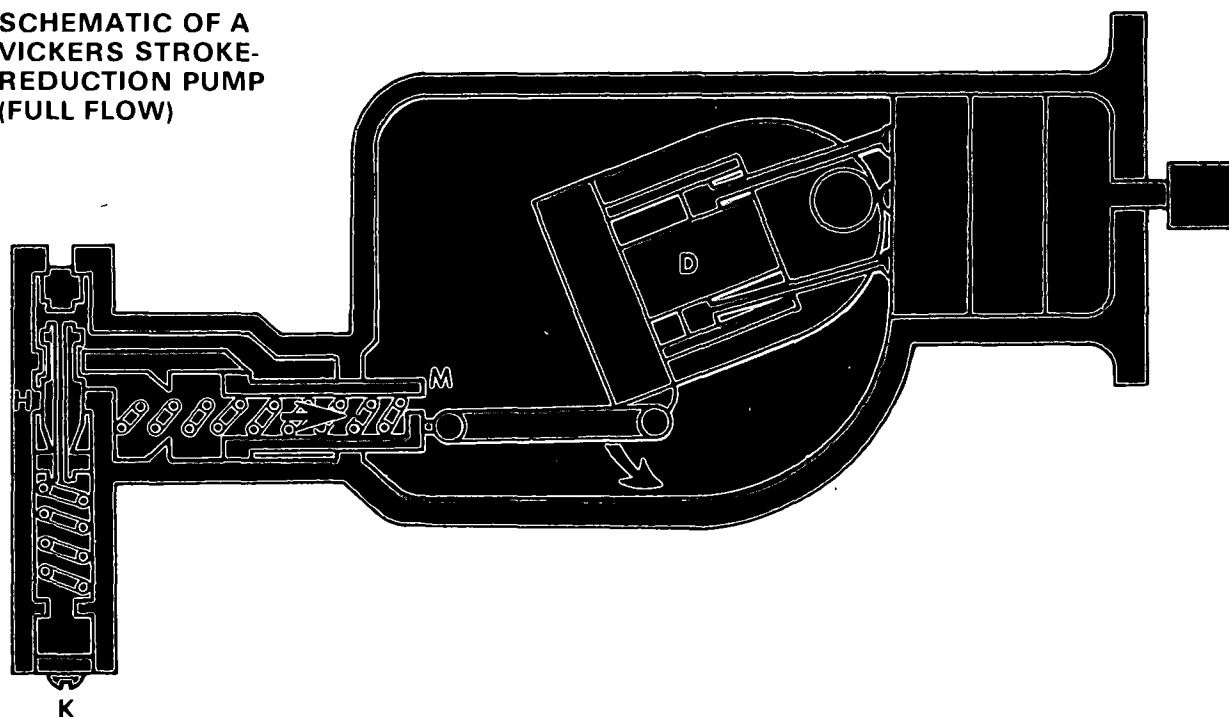
#### **SCHEMATIC OF A VICKERS STROKE-REDUCTION PUMP (ZERO FLOW)**



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.

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 it 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, thereby causing the stroke of the pistons to increase. The pressure and volume output again start to increase until the system's demands are met. Thus the action of the pressure control valve (H) stabilizes the position of the cylinder block (D): Its angle adjusts to meet the system 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.

**SCHEMATIC OF A  
VICKERS STROKE-  
REDUCTION PUMP  
(FULL FLOW)**



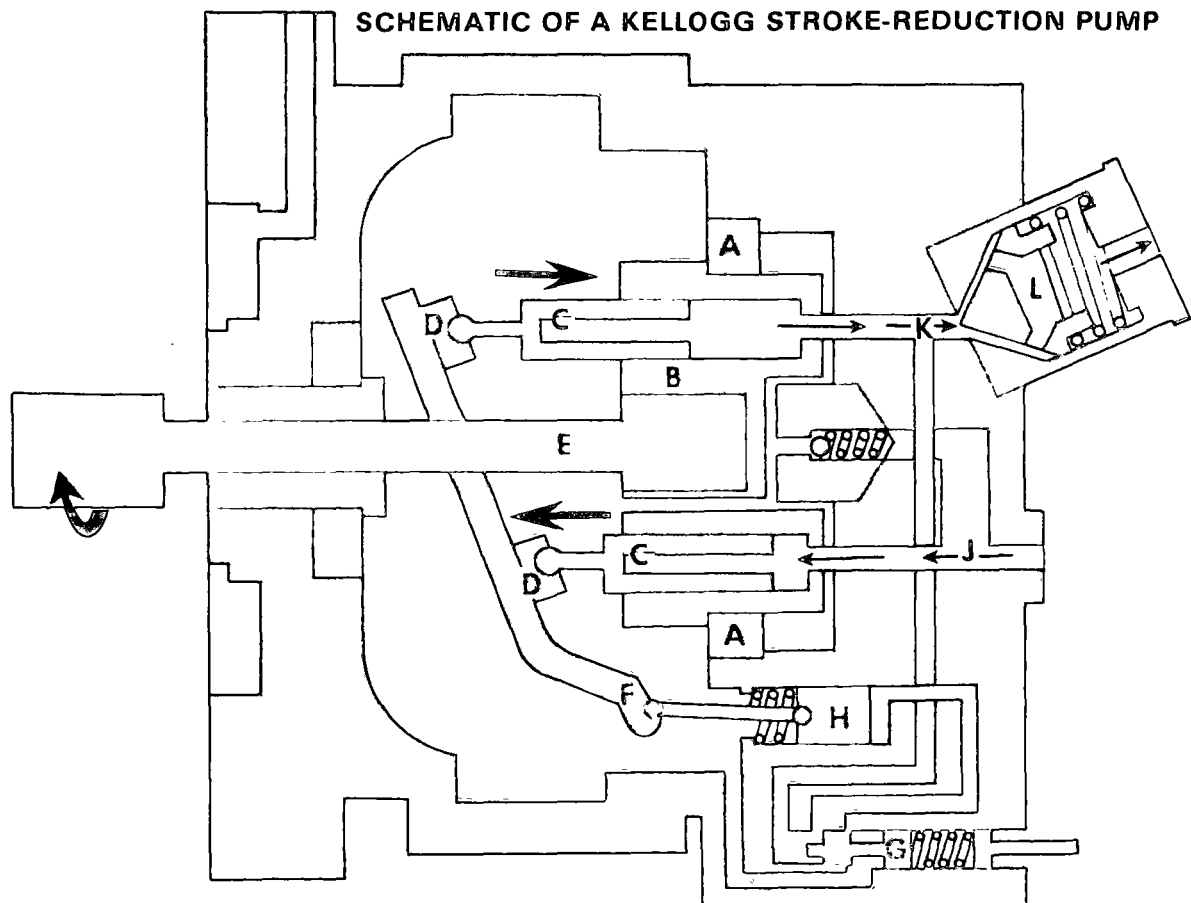
Direction of rotation of this pump cannot be changed. Therefore, you must be sure to check the direction arrow on the mounting flange before installing the pump. Pressure is increased or decreased by turning the adjusting screw (K). An internal relief valve prevents damage in case the pressure control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

### ***Kellogg Stroke-Reduction Pump (Variable Volume).***

The Kellogg pump is made up of two major component groups: the rotating group and the pressure-compensating group. The rotating group consists of the drive shaft (E), the cylinder barrel (B), 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 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.

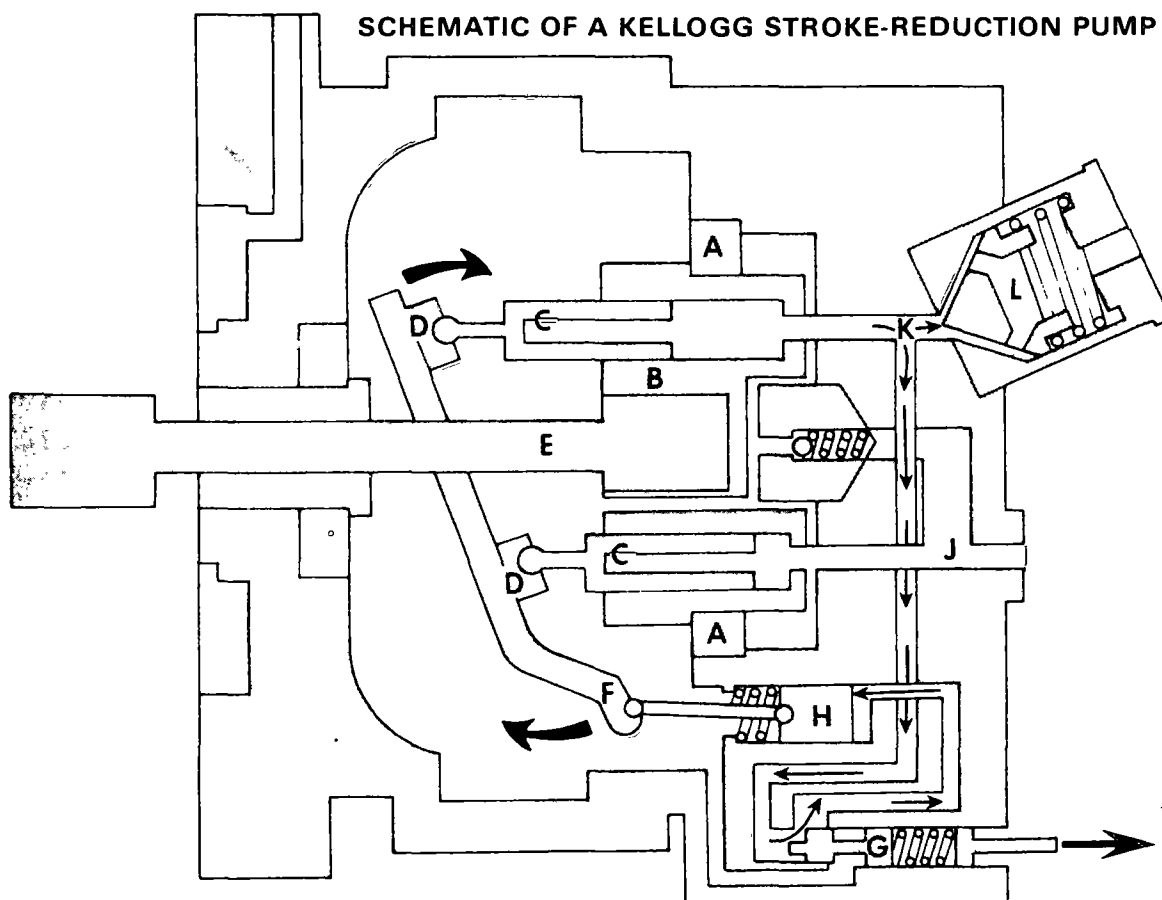
In the illustration, the lower piston is shown near the beginning of the intake stroke. As the cylinder unit is rotated, the piston moves to the left in its cylinder. For nearly one-half of a revolution, the face port of this cylinder is alined with the annulus connected to the fluid inlet (J). Hydraulic fluid is sucked into the cylinder as the piston is withdrawn just after passing the end of the inlet annulus. Further rotation forces the piston to the right and alines the cylinder with the annulus connected to the outlet port (K) and to the compensator valve (G). In this position, fluid is forced from the piston. This discharge stroke lasts until the cylinder and piston reach the bottom position and are ready to begin another intake stroke.

We have described the intake and discharge strokes of one piston during 360° of cylinder rotation. At the same time, there are eight other pistons on the intake and discharge strokes, all doing the same thing. Their pumping action continues until the



fluid needs of the system are satisfied. For example, when a subsystem actuator completes its travel, the 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, thus decreasing 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 (L) installed in the pump outlet line prevents return flow into the pump during operation of the system with a portable test stand. Reverse flow of hydraulic fluid would motorize the pump.

*Maintenance of power pumps.* Repair and overhaul of hydraulic power pumps is done at depots. This work requires special tools and equipment.



## HAND PUMPS

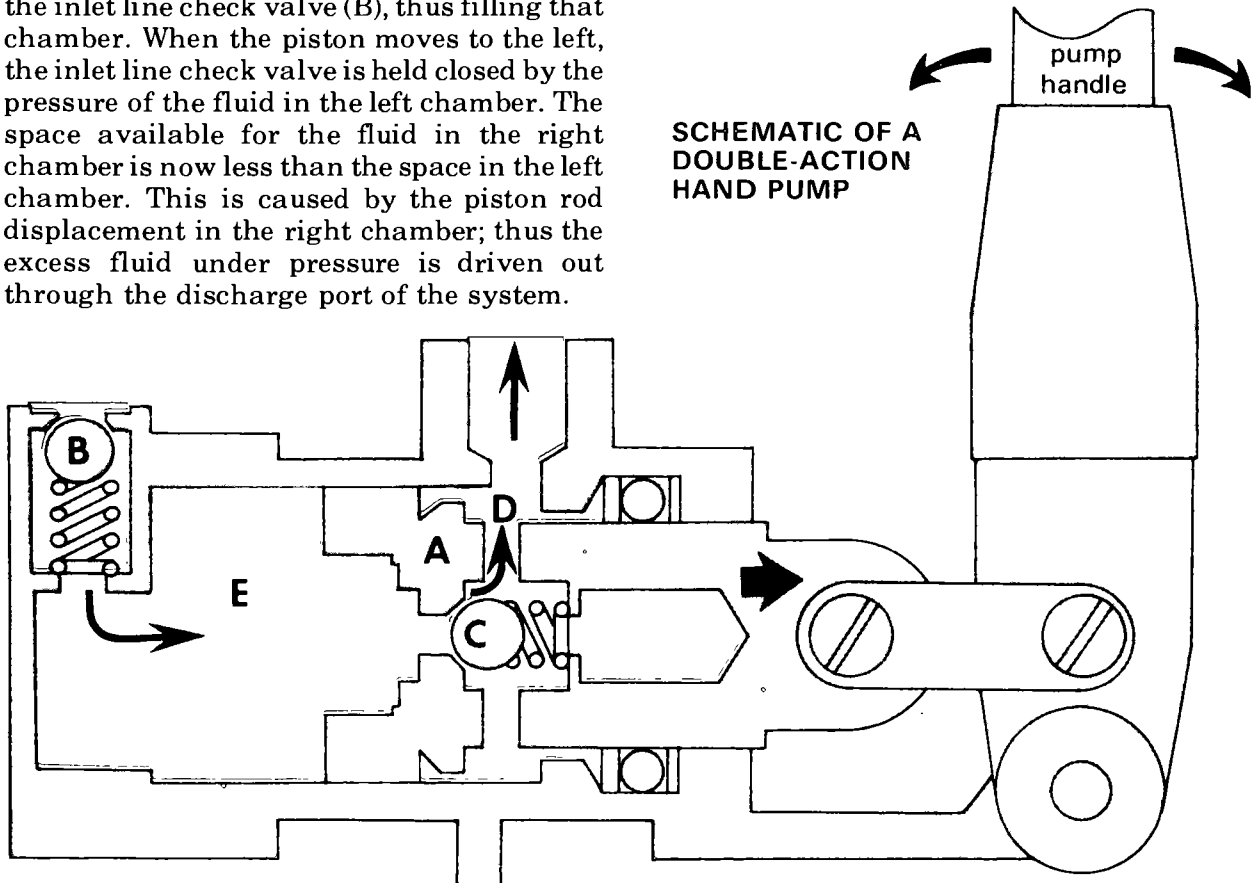
**Operation.**

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; however, most are the double-action type. Such pumps deliver fluid under pressure on both the fore and aft strokes of the piston. The accompanying schematic shows the construction of this type of pump.

Note that the hand pump consists essentially 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 through the check valve. At the same time, the suction effect created in the left chamber (E) by the moving piston draws fluid through the inlet line check valve (B), thus 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; thus the excess fluid under pressure is driven out through the discharge port of the system.

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 normal operation of the system. 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.

**SCHEMATIC OF A  
DOUBLE-ACTION  
HAND PUMP**





If the pressure (out) line check valve leaks, there will be no immediate indication that this is happening. 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. Cure-dated parts (natural or synthetic rubber items) must be replaced anytime the pump is disassembled. Minor scratches and corrosion may be removed or polished 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 with the proper size die. Before reassembly, all internal parts should be coated with clean hydraulic fluid of the type used in the system.

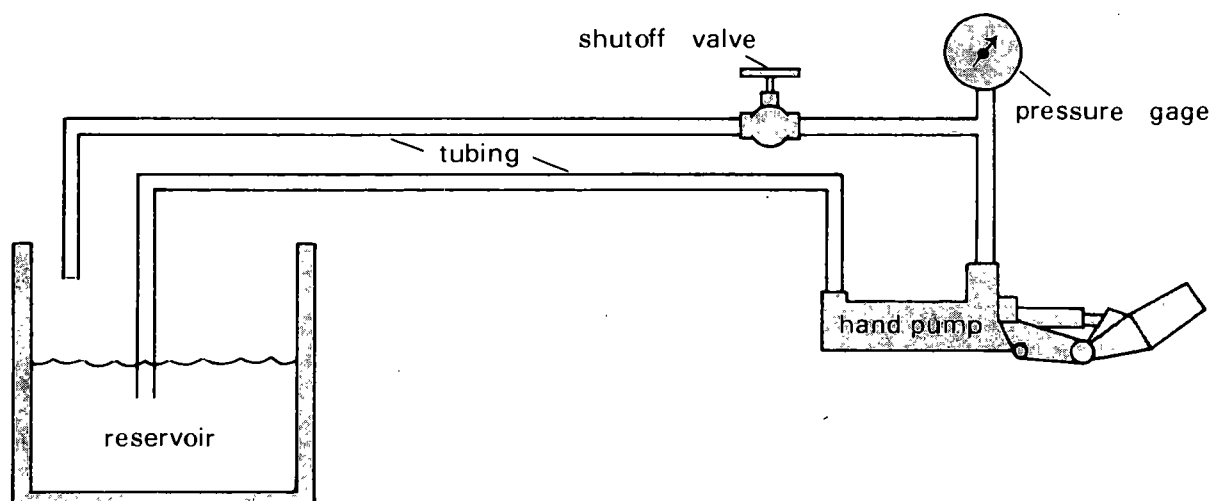
After the pump has been reassembled, test it for proof pressure and leakage. The accompanying illustration shows a setup for testing the hand pump. Basically it consists of a gage, a shutoff valve, a reservoir, and tubing.

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 1-1/2 times normal operating pressure. You should control the strokes so that the final stroke will leave the piston in the retracted position, after which pressure should be maintained for a specified time (usually 2 to 5 minutes). Repeat the preceding step, this time controlling 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 period of time (approximately 2 minutes). There should be no piston creep, and the pressure drop should not exceed the specified amount (usually 50 to 100 psi).

After completion of testing, 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.

**TEST CIRCUIT FOR  
HAND PUMPS**



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 HYDRAULIC MOTORS
 

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**Operation.** Motors operate on the same principle as pumps, but in reverse.

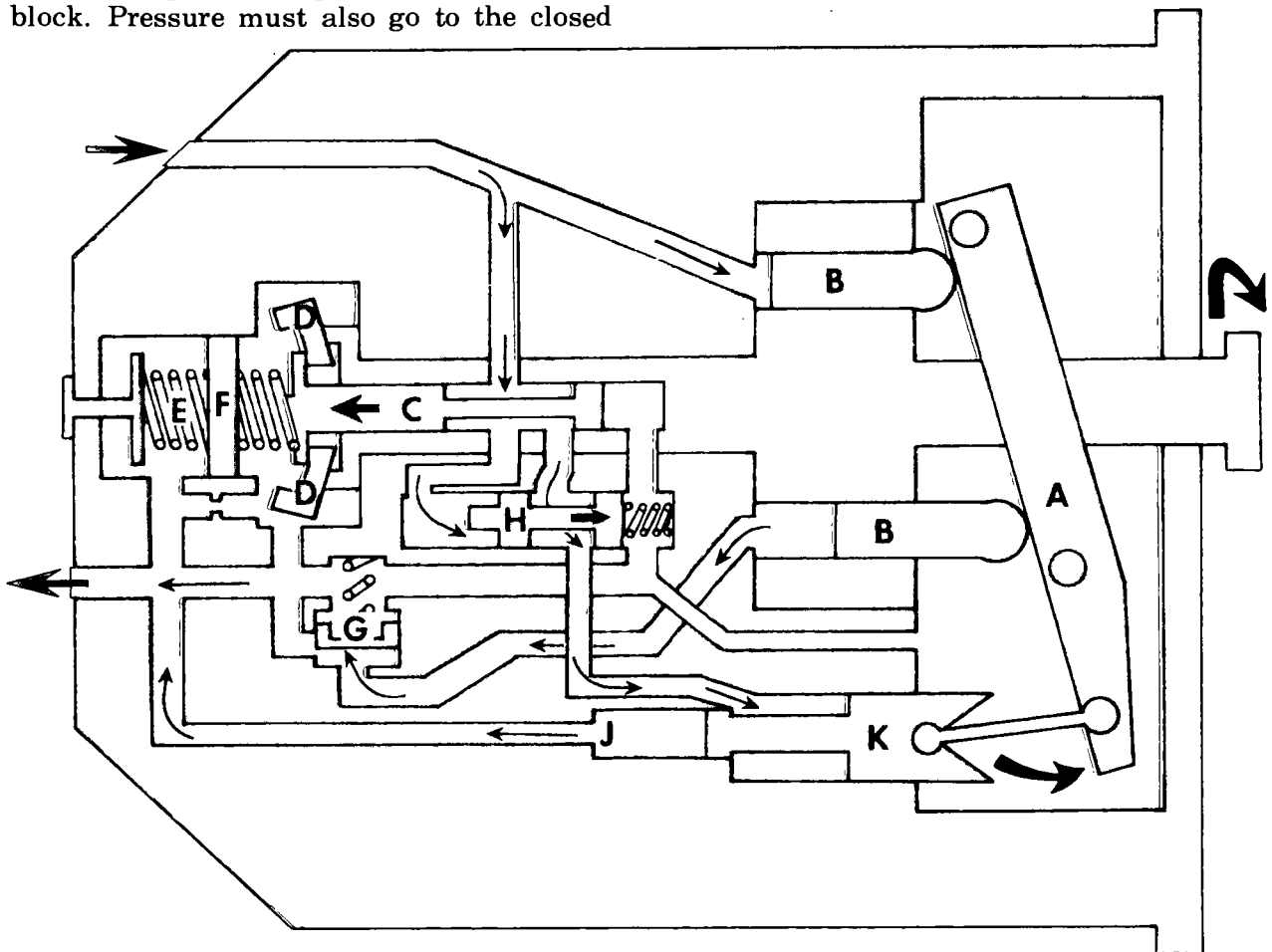
The hydraulic motor shown here is a variable-displacement, axial-piston, rotating-cylinder-block unit. It delivers a minimum of 16.6 horsepower at 8,000 rpm. This particular motor is used to drive an AC-DC generator at a constant rpm. Since an AC generator or alternator must put out the same number of 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.

If you understand the operation of the motor shown here, you should have little trouble with other motors. 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.

Starting is accomplished by the starting valve (H). When system pressure builds up to 1,800-2,200 psi, the starting valve is moved to the right as shown. This action permits fluid under pressure to move the control piston (K). The control piston moves the bottom of the wobbler plate (A) to the right with sudden force. Movement of the wobbler kicks the upper and lower pistons (B) to give the cylinder block an initial spin. Thereafter, system pressure maintains rotation of the cylinder block.

**SCHEMATIC OF A HYDRAULIC MOTOR**



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. When the passage is completely blocked, pressure is no longer put on the control piston and 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. Let us assume that the motor tends to overspeed. The overspeeding 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 blocked 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, thus reducing the angle of the wobbler plate. The reduced angle reduces the torque output and consequently the speed of the motor. Movement of the wobbler plate also momentarily activates the preact piston (F) of the flyweight governor. This prevents overtravel 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 passage and holding the wobbler plate in its new position. These events occur almost instantly to match 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 depth of maintenance you will perform on hydraulic motors will depend on the equipment you have. 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

# DEVICES FOR REGULATING PRESSURE

Devices for regulating pressure in the aircraft's hydraulic system are described in a general way in this chapter. General maintenance guidelines are given for each device. Pressure regulating devices include--

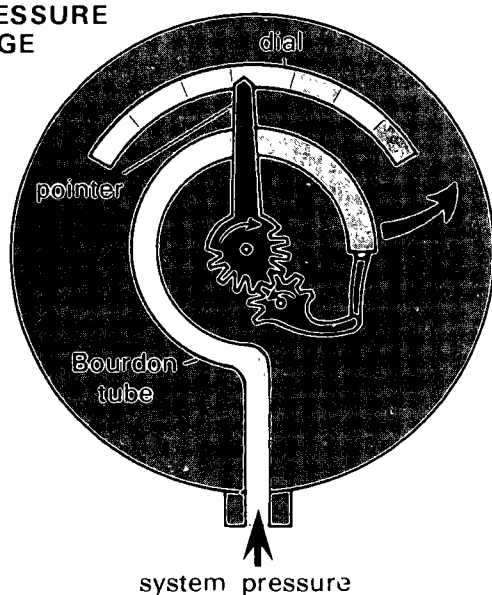
HYDRAULIC PRESSURE GAGES .....	7-1
PRESSURE SWITCHES .....	7-2
PRESSURE RELIEF VALVES .....	7-3
PRESSURE REDUCING VALVES .....	7-4
ACCUMULATORS .....	7-5

## HYDRAULIC PRESSURE GAGES

Hydraulic pressure gages (sometimes called pressure indicators) indicate the amount of pressure in hydraulic systems. Gage dials are calibrated to show this pressure in pounds per square inch. Direct-reading and remote-indicating gages are the types used.

The *direct-reading* gage consists essentially of a Bourdon tube, a pointer, a dial, and a

### SCHEMATIC OF A PRESSURE GAGE



raintight case. The Bourdon tube and the pointer are interconnected by gearing so as to cause them to 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 curvature of the tube reacts on the gearing, causing the pointer to move to a correspondingly higher reading on the dial. As hydraulic system pressure decreases, the Bourdon tube curls back toward its original shape a corresponding amount. This causes the pointer to fall back to a correspondingly lower dial reading. Pressure gage snubbers are usually used with hydraulic pressure gages to dampen oscillations of the pointer.

In the *remote-indicating* gage, the gage transmitter contains a Bourdon tube diaphragm, or bellows, to which hydraulic system pressure is admitted through a connecting line. The Bourdon tube diaphragm reacts to pressure changes in a manner similar to that of the direct-reading type gage. Movements of the diaphragm produce electrical signals that are transmitted through connecting wiring to the indicator unit, where they cause the indicator pointer to move.

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 PRESSURE SWITCHES
 

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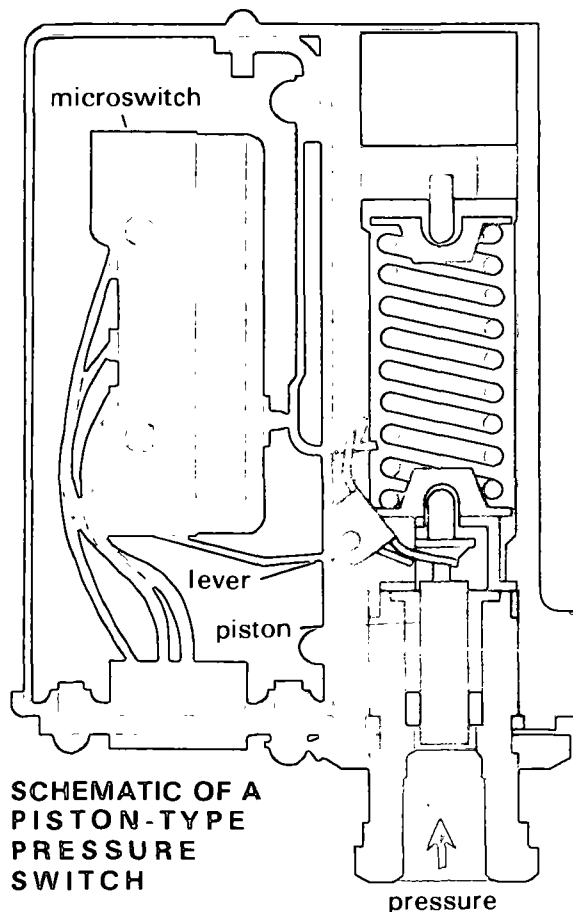
*Types of Pressure Switches.* A pressure switch is designed to open or close an electrical circuit in response to a predetermined hydraulic pressure entering the switch from a connected source. Piston-type and diaphragm-type pressure switches are the types commonly used in Army aircraft.

The *piston-type* pressure switch consists of a rectangular-shaped housing, a cylinder bore and piston, an adjustable spring for loading the piston, a microswitch, and a linkage for transmitting movement of the piston 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.

The *diaphragm-type* pressure switch consists of a cylindrical-shaped housing, a diaphragm, an adjustable spring to load the diaphragm, a microswitch, and linkage for transmitting movements of the diaphragm 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 of pressure switches.* The operation described here covers the piston-type pressure switch. However, the diaphragm switch operates on essentially 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, movement of the piston causes the pivoted lever of the connecting linkage between the piston and the microswitch to rotate. The movement of the pivoted lever is transmitted through the idler spring to the actuating button of the microswitch. When the microswitch actuating button has moved a sufficient amount, the microswitch contacts move into the pressure-induced position. Some pressure switches are designed so that their contacts remain open until closed by the action of fluid pressure against the switch position. Such switches are specified as

NORMALLY OPEN (NO). Other switches are designed for their contacts to remain closed until opened by the reaction of fluid pressure against the switch piston. These are specified as NORMALLY CLOSED (NC).



**SCHEMATIC OF A  
PISTON-TYPE  
PRESSURE  
SWITCH**

*Uses of pressure switches.* Pressure switches on Army aircraft serve two 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 in such a manner 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 so as to provide control for both the warning light and the solenoid valve.

## PRESSURE RELIEF VALVES

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

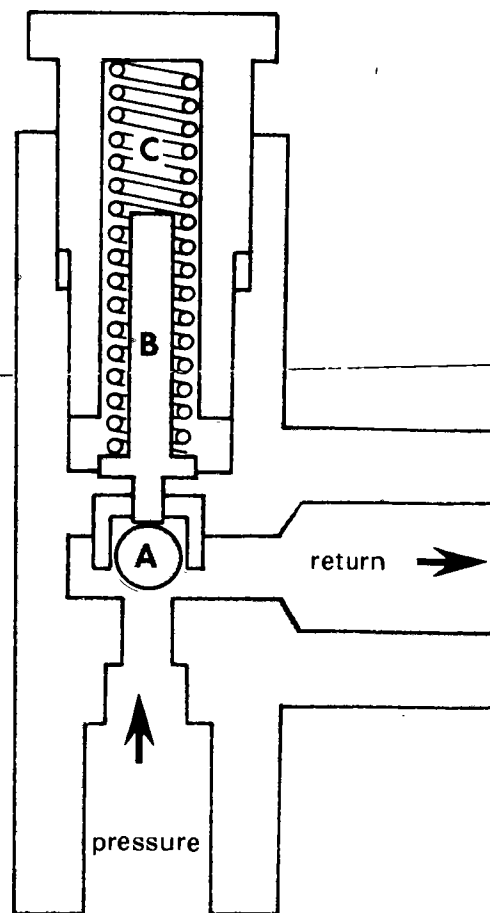
### *Main System Relief Valves.*

Main system relief valves are set to open and close at pressures determined by the system in which they are 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 be different from one aircraft to another. When the relief valve is in the open position, it sends excess pressurized fluid to the reservoir return line.

A typical main system relief valve and a breakdown of its component parts is shown here. 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 installation of 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. Thus, the passage through the piston is opened, 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 and fluid flow through the relief valve ceases. Should the pressure at the outlet port exceed 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.

*Thermal relief valves.* Thermal relief valves are usually smaller than system relief valves. They are 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 in which it is installed 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.

**SCHEMATIC OF A  
MAIN SYSTEM RELIEF VALVE**



*Maintenance of relief valves.* Relief valve maintenance is limited to adjusting the valve for proper relieving pressure and checking the valve for leakage. If it is thought that a relief valve is leaking internally, a flexible hose may be connected to the return port of the valve and the drippings, if any, caught in a container. The opening and closing pressure of the valve may also be checked in this manner provided an external source of power is used.

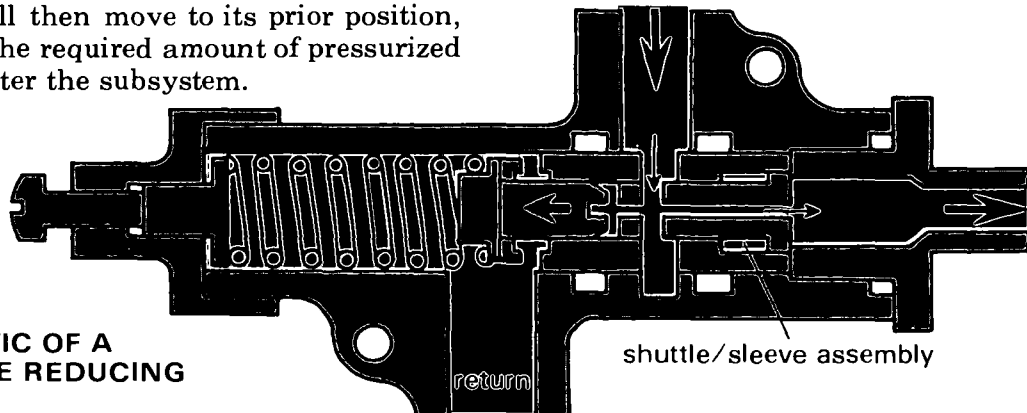
### CAUTION!

DO NOT ATTEMPT TO ADJUST A RELIEF VALVE WHILE IT IS INSTALLED ON AN AIRCRAFT. THE VALVE MUST BE REMOVED AND ADJUSTED 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

Pressure reducing valves are used in hydraulic systems where it is necessary to lower the normal system operating pressure to a specified amount. This schematic shows how this type of valve operates. Here, 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 the shuttle to move to the left after reaching a set pressure and thus 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 normal operation of the subsystem, the pressure reducing valve continuously meters fluid to the system. The pressure reducing valve is also designed to act as a relief valve. 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 causes a passage to be opened 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.



**SCHEMATIC OF A  
PRESSURE REDUCING  
VALVE**



## ACCUMULATORS

The purpose of an accumulator in a hydraulic system is to store a volume of fluid under pressure. This storage capability has several uses, some of which are listed below:

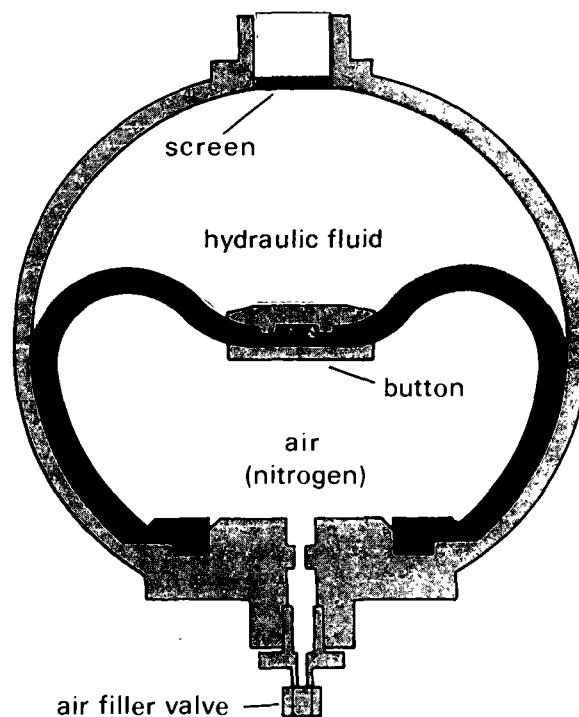
- An accumulator acts as a cushion against pressure surges that may be caused by pulsating fluid delivery from the pump or from system operation.
- The accumulator supplements the pump's output when the pump is under a peak load by storing energy in the form of fluid under pressure.
- The energy stored in the accumulator may be used to actuate a unit in case the normal hydraulic system fails. For example, enough energy can be stored in the accumulator for several applications of the collective flight control on the AH-1G.

### *Types of Accumulators.*

Two general types of accumulators are used in Army aircraft: spherical and cylindrical. Until recently, the spherical type was the one more commonly used; however, the cylindrical type has proved better for high pressure hydraulic systems. Schematics of both types are shown here.

**Spherical type.** The spherical accumulator is made up of two halves screwed together. A synthetic rubber diaphragm divides the accumulator into two chambers. The assembled component has two threaded openings. Note that the opening at the top contains a screen disk. This prevents the diaphragm from coming up through the threaded opening when system pressure is depleted, a condition that could rupture the diaphragm. On some designs the screen is replaced by a button type protector fastened to the center of the diaphragm. The top threaded opening provides a means for connecting the fluid chamber of the accumulator to the hydraulic system. The bottom threaded opening provides a means for installation of 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.

### SCHEMATIC OF A SPHERICAL ACCUMULATOR



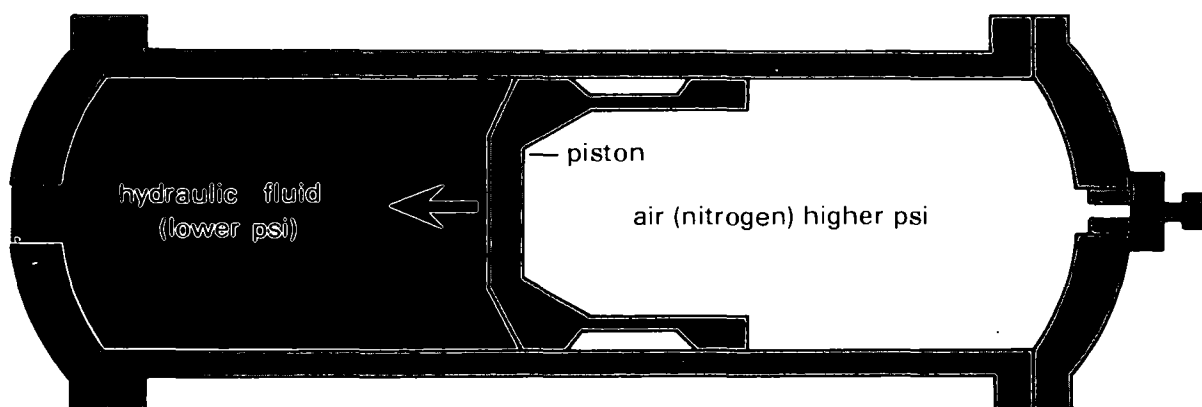
**Cylindrical type.** Cylindrical accumulators consist of a cylinder and piston assembly. Caps are attached to both ends of the cylinder. The internal piston separates the fluid chamber from the air (or nitrogen) chamber. The end caps and the piston are sealed by gaskets and packing to prevent external leakage around the caps and internal leakage between the chambers. A hydraulic fitting in the end cap on the fluid side is used to attach 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 of Accumulators.*

Spherical and cylindrical accumulators operate in essentially the same manner. In operation, the compressed-air chamber is charged to a set pressure somewhat lower than the system operating pressure. This initial charge is referred to as the accumulator preload. To illustrate operation of

the accumulator, let us assume that the cylindrical accumulator illustrated here 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. Thus, 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

**SCHEMATIC OF A  
CYLINDRICAL ACCUMULATOR**



it occupies a space less than one-half the length of the cylinder. When use of hydraulic units lowers system pressure, it is evident that the compressed air will cause the piston to move, forcing fluid from the accumulator and thus supplying fluid to the hydraulic system.

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

***Maintenance of Accumulators.***

Visually examine accumulators for indications of external hydraulic fluid leaks. Examine for external air leaks by brushing the exterior with soapy water; bubbles will form wherever air is leaking. Examine the accumulator for internal leaks by loosening the air valve assembly. If hydraulic fluid comes out of the air valve, the accumulator should be removed and replaced.

Check the preload pressure after relieving the hydraulic system pressure by operating a hydraulically actuated unit. The majority of the accumulators installed in Army aircraft are equipped with air pressure gages for this purpose. When the accumulator is not so

equipped, a high-pressure air gage may be installed at the air preload fitting for this purpose. The required pressure will be stated in the maintenance manual for each aircraft.

Insure that the air preload has been completely exhausted before disassembling any accumulator. This may be accomplished by loosening the swivel nut on the air filler valve until all air is out and then removing 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**

Numerous valving devices are used in aircraft hydraulic systems to control the flow of fluid within the system. These devices perform such functions as controlling direction, sequence, and priority of flow; transforming fluid pressure into mechanical energy; holding loads in position against feedback-induced forces; and preventing leaks. The devices that perform these functions are--

SELECTOR VALVES .....	8-1
CONTROL VALVES .....	8-9
CHECK VALVES .....	8-10
SEQUENCE VALVES.....	8-11
PRIORITY VALVES.....	8-15
SHUTTLE VALVES.....	8-16
ACTUATING CYLINDERS.....	8-16
RATCHET VALVES.....	8-19
HYDRAULIC SERVOS.....	8-20
IRREVERSIBLE VALVES .....	8-22
HYDRAULIC FUSES.....	8-22

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**SELECTOR VALVES**


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The purpose of a hydraulic selector valve is to control 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 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 for reversing the direction of movement of the actuating unit).

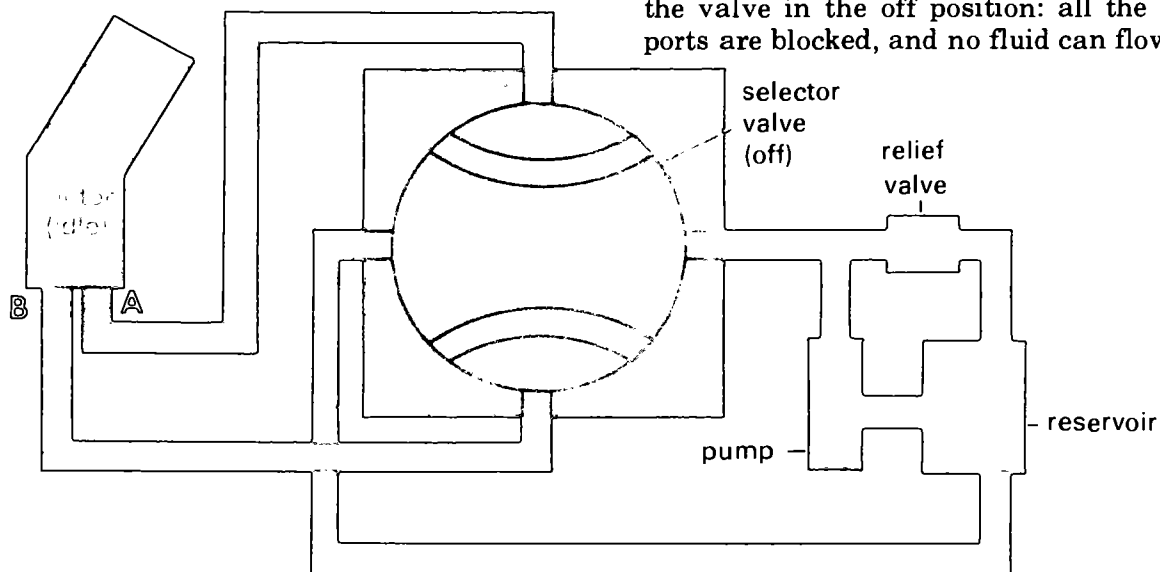
Selector valves are classified as *closed-center* and *open-center* types. These classifications are based on what happens to the flow of fluid when the selector valve is placed in the off position. When a closed-center selector valve is placed in the off position, its pressure

passage is blocked to the flow of fluid and 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 and fluid can flow into the pressure port and out of the return port.

Selector valves may be further classified on the basis of design characteristics as *cam-operated*, *in-line*, *radial*, and *compound*. Valving devices common to all types include rotors, spools, poppets, and balls. Selector valve spools are sometimes called pilot valves.

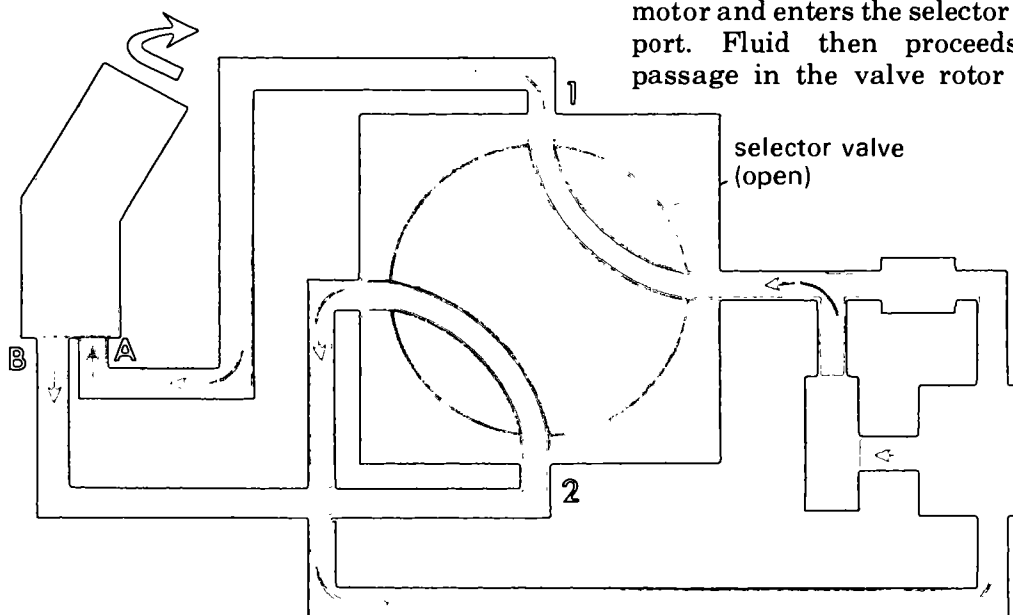
*Closed-center selector valves.* The four-way, closed-center type selector valves are the ones most commonly used in aircraft hydraulic systems. Rotor and spool type valving devices are used in these valves. The valves operate in one off position and in two on positions.

**SCHEMATIC OF A CLOSE CENTER ROTOR-TYPE SELECTOR VALVE OPERATING IN A HYDRAULIC SYSTEM**



The *rotor-type* selector valve has a thick circular disk-shaped rotor as its valving device. A typical four-way, closed-center selector valve is shown here. This view shows the valve in the off position: all the valve ports are blocked, and no fluid can flow into

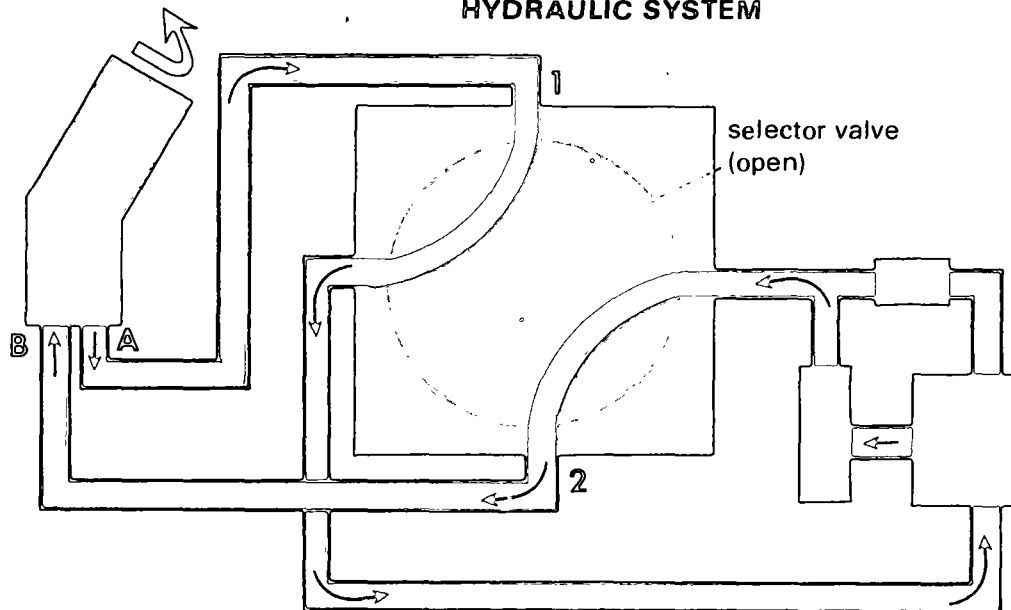
**SCHEMATIC OF A CLOSE CENTER ROTOR-TYPE SELECTOR VALVE OPERATING IN A HYDRAULIC SYSTEM**



or out of the valve. Here the valve is in one of its on positions. In this position, the pressure port and the 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 of the motor and enters the selector valve cylinder 2 port. Fluid then proceeds through the passage in the valve rotor and leaves the

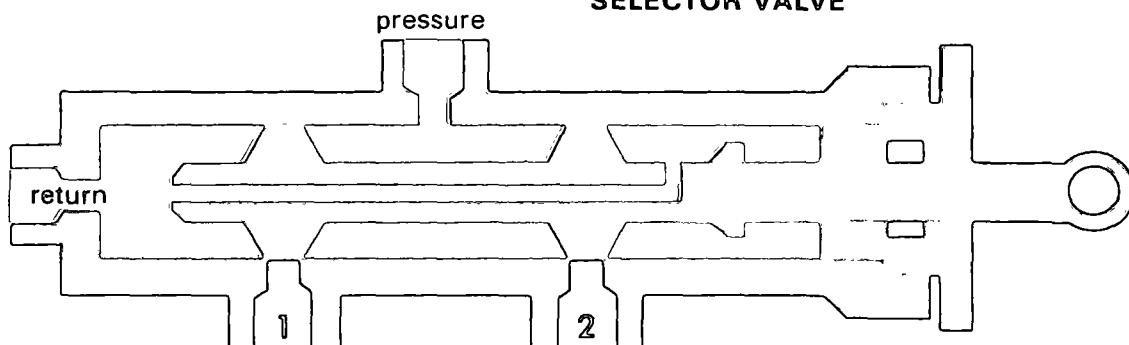
valve through the return port. Here the pressure port and the cylinder 2 port become interconnected. This causes fluid pressure to be delivered to port B of the motor with the result that the motor turns counterclockwise. Return fluid leaves port A of the motor, enters the selector valve cylinder 1 port, and leaves through the selector valve return port.

**SCHEMATIC OF A CLOSE  
CENTER ROTOR-TYPE SELECTOR  
VALVE OPERATING IN A  
HYDRAULIC SYSTEM**

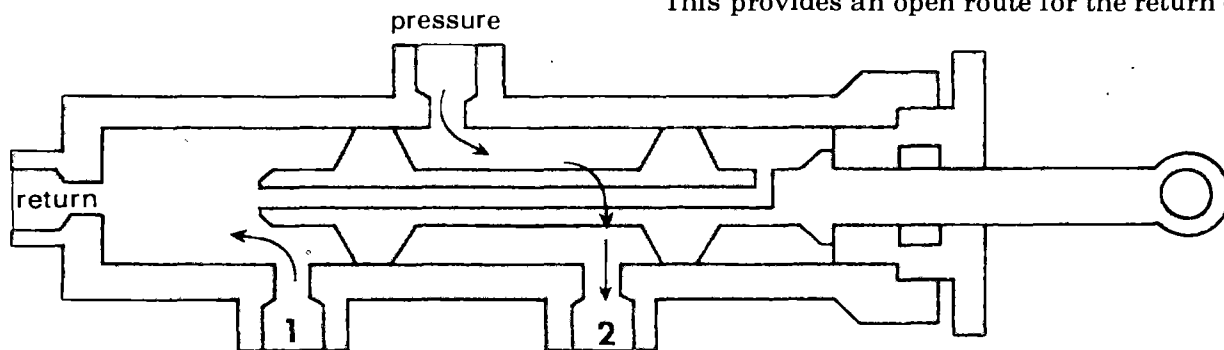


In selector valves having a *spool-shaped* valving device, the spool is a one-piece, leaktight, free-sliding fit in the valve housing. The spool can be moved lengthwise in the housing by means of the extended end which sticks out through the housing. A drilled hole in the spool connects the two end chambers of the selector valve. In the off position the two cylinder ports are directly blocked by the seats of the spool. This indirectly blocks the pressure and return ports, and no fluid can flow into or out of the

**SCHEMATIC OF A  
SPOOL-TYPE CLOSED-CENTER  
SELECTOR VALVE**

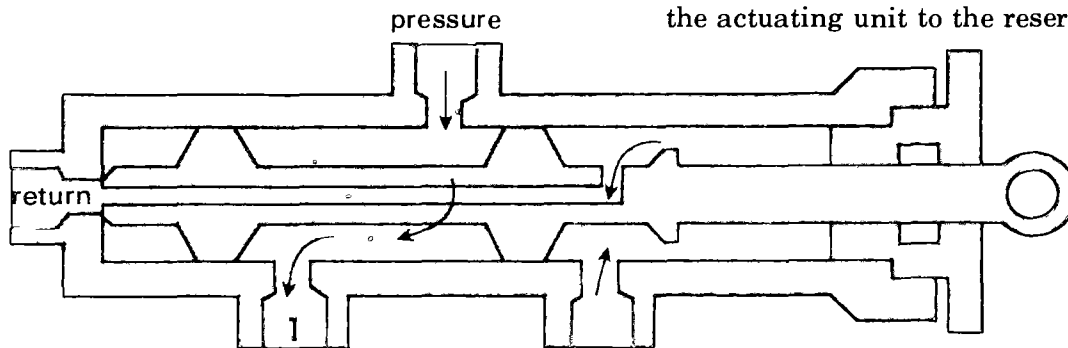


### SCHEMATIC OF A SPOOL-TYPE CLOSED-CENTER SELECTOR VALVE



valve. Moving the spool toward the right moves the spool seats away from the cylinder 1 and 2 ports. The pressure port and the cylinder 2 port then become interconnected. 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

### SCHEMATIC OF A SPOOL-TYPE CLOSED-CENTER SELECTOR VALVE



fluid from the actuating unit to the system reservoir. 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. 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.

*Open-center selector valves.* 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 important differences between the two types 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

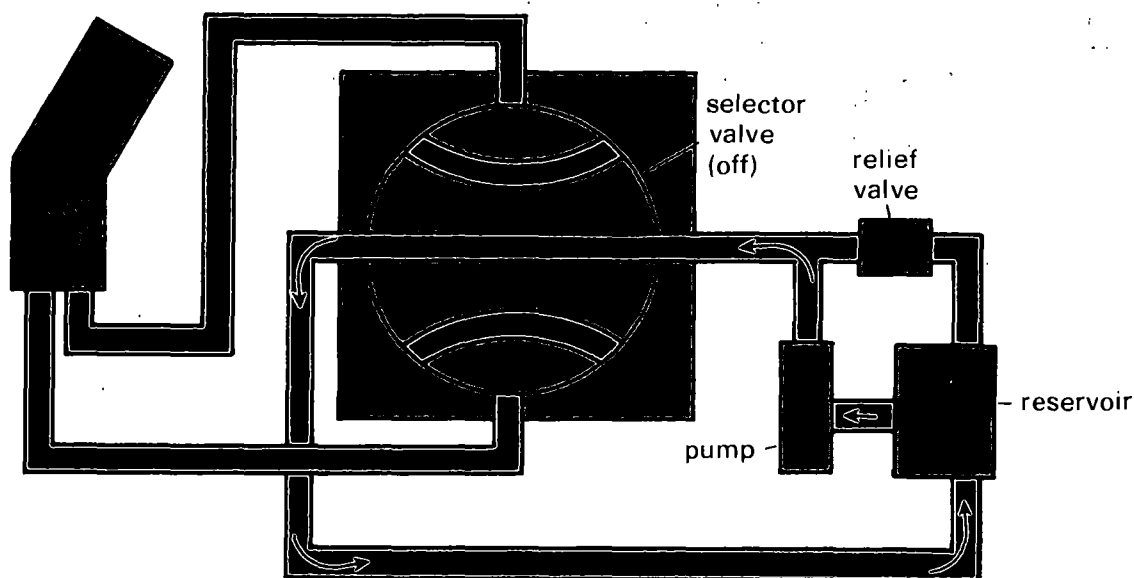


points to remember about hydraulic systems incorporating an open-center selector valve are--

- 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. Thus in an open-center system, operating pressure is present only when an actuating unit is being used. Because of this, in some open-center systems there is a slight delay in the response of an actuating unit after the selector valve has been placed in the on position.
- Only open-center type selector valves are suitable for use in open-center systems.
- No more than one actuating unit can be efficiently used at a time in an open-center system.

In open-center selector valves having *rotor-type* valving devices, two passages in the rotor serve to 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 as shown here, fluid from the pump enters the selector valve pressure port

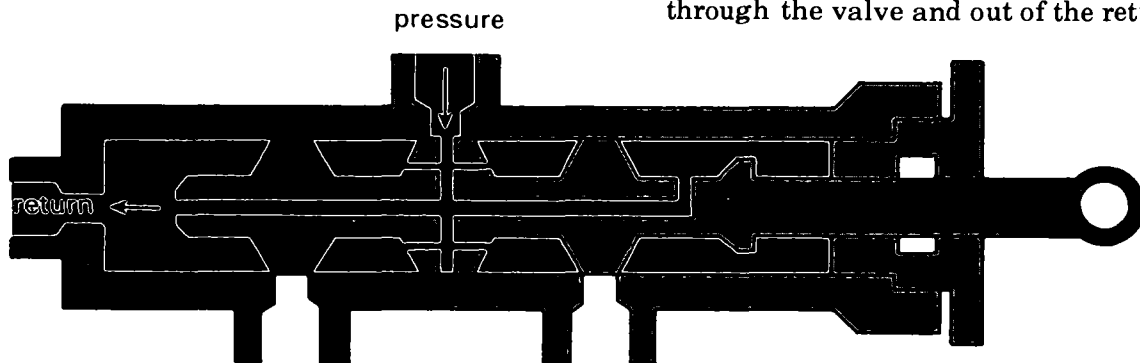
**SCHEMATIC OF AN  
OPEN CENTER ROTOR-TYPE  
SELECTOR VALVE OPERATING  
IN A HYDRAULIC SYSTEM**



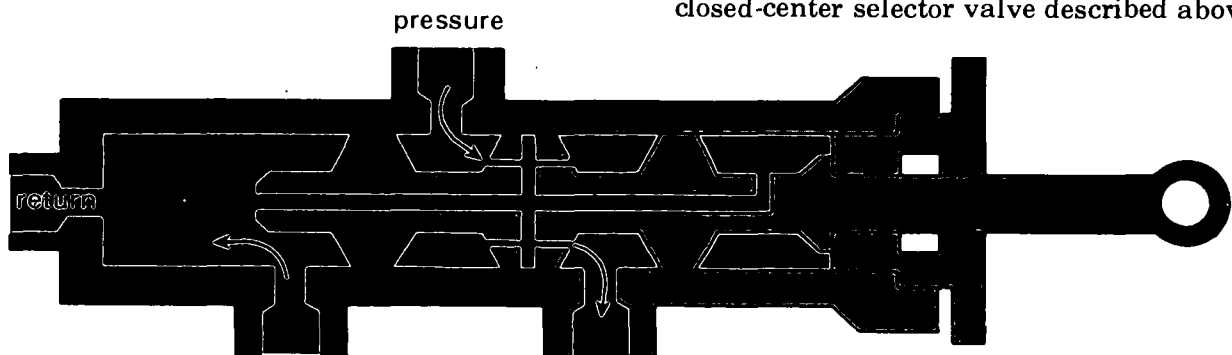
and passes through the open-center passage in the rotor, through the selector valve return port, and back to the reservoir. When the selector valve is moved to the on positions, its operation is identical to that of the closed-center type selector valve as described in the previous paragraph.

Operation of open-center *spool-type* selector valves is generally similar to that of the rotor-type valve just described. In this schematic, a typical spool-type open-center selector valve is shown in the off and in one on 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.

**SCHEMATIC OF A  
SPOOL-TYPE OPEN-CENTER  
SELECTOR VALVE (CLOSED)**



**SCHEMATIC OF A  
SPOOL-TYPE OPEN-CENTER  
SELECTOR VALVE (OPEN)**



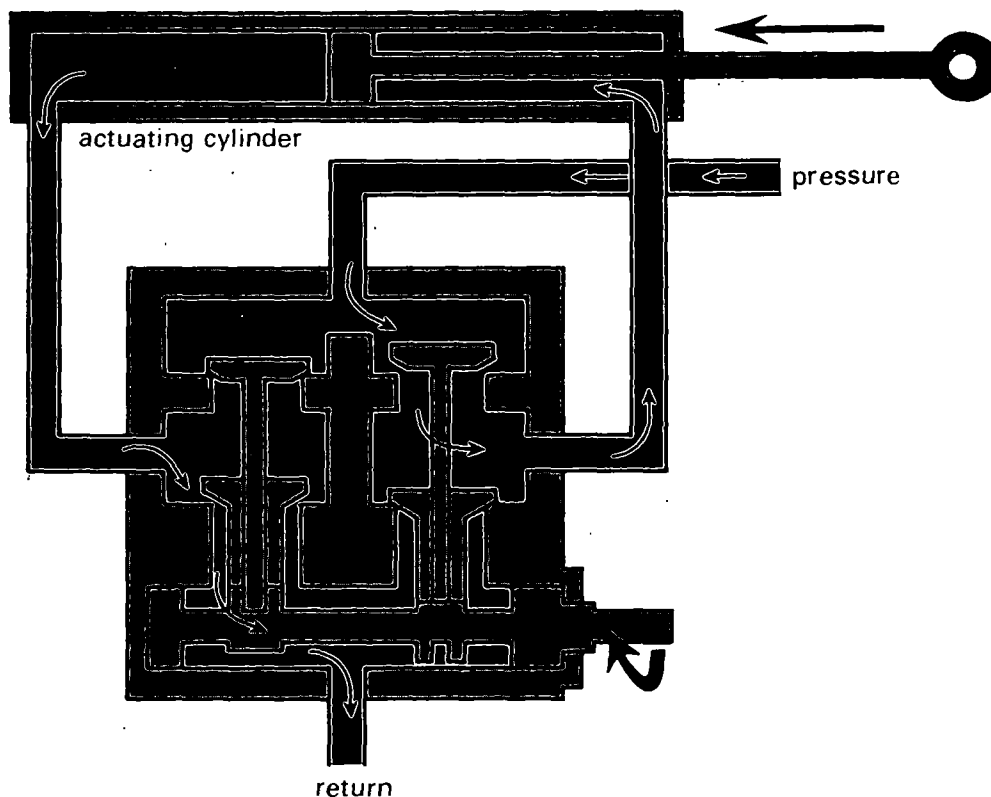
When the valve is placed in either of the on positions, the groove in the center seat is blocked by the bore well of the valve housing and fluid cannot pass through it as it does in the off position. Under these conditions, fluid flows in the same direction as in the corresponding on positions of the spool-type closed-center selector valve described above.

*Cam-operated selector valves (open-center or closed-center). Poppet-type and ball-type selector valves are operated by cams that lift*

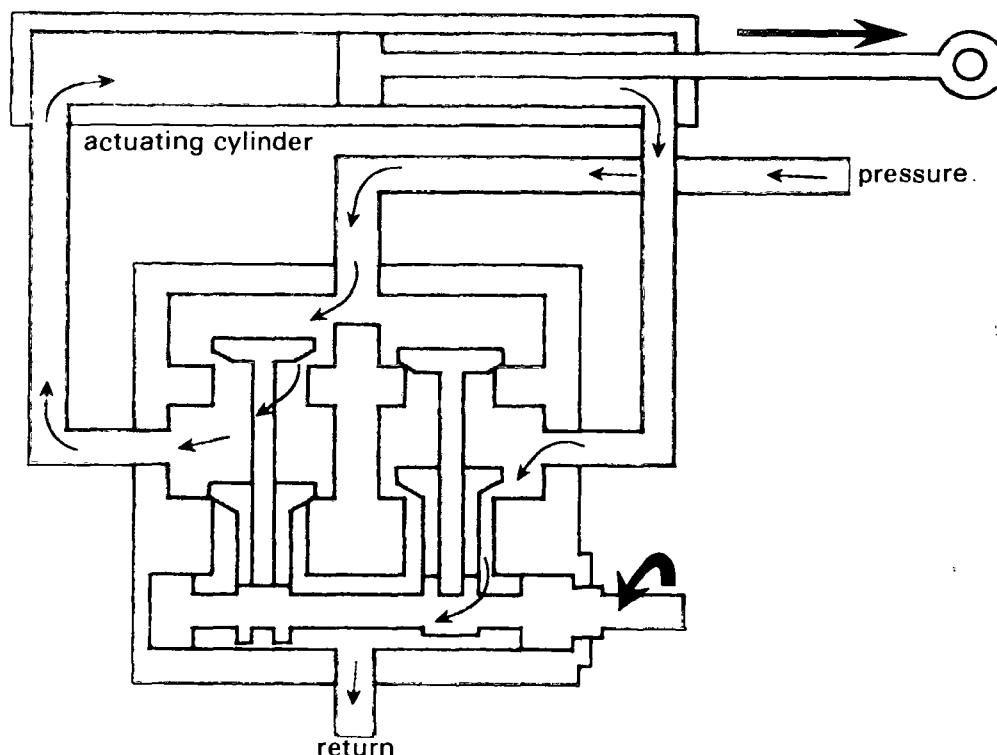
the poppet or ball off its seat. Purpose, use, and operation of the two types are the same: One controls fluid flow by the use of poppets; the other employs a ball-shaped valve. The piston-type selector valve may also be cam-operated. In this case, flow is directed by the sliding action of a piston,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

*In-line cam-operated selector valves (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, relieving from the pressure manifold into the return line is used in several models of this valve. This schematic shows a condition in which fluid pressure is forcing the actuating cylinder piston inward, permitting fluid to flow from the actuating cylinder through the lower

**SCHEMATIC OF AN  
IN-LINE CAM-OPERATED  
SELECTOR VALVE**

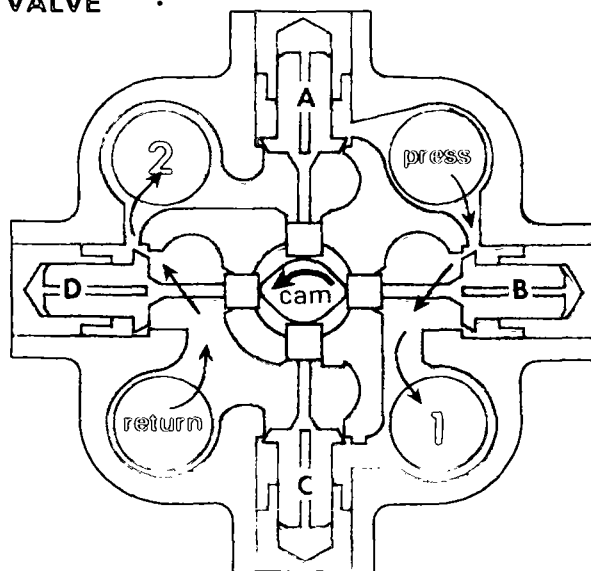


# **SCHEMATIC OF AN IN-LINE CAM-OPERATED SELECTOR VALVE**



unseated poppet to the return line. Here the selector valve control has been 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.

# **SCHEMATIC OF A RADIAL CAM-OPERATED SELECTOR VALVE**



## ***Radial Cam-Operated Selector Valves.***

*Poppet type.* In the typical poppet-type radial selector valve shown here, the cam in the center is attached to a control handle. Moving the control handle causes the cam to rotate and moves the poppets on or off their seats. In the position shown here, poppets A and C are seated and poppets B and D are unseated. Fluid entering the inlet pressure port flows around poppet B and 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 and 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 the schematic, all the poppets are seated and the selector valve is in a neutral position.

**Spool type.** The *spool-type* radial selector valve operates in the same manner as the poppet-type valve just described. The spools are plungers within the valve housing. Drilled or cutaway passages in the spools are

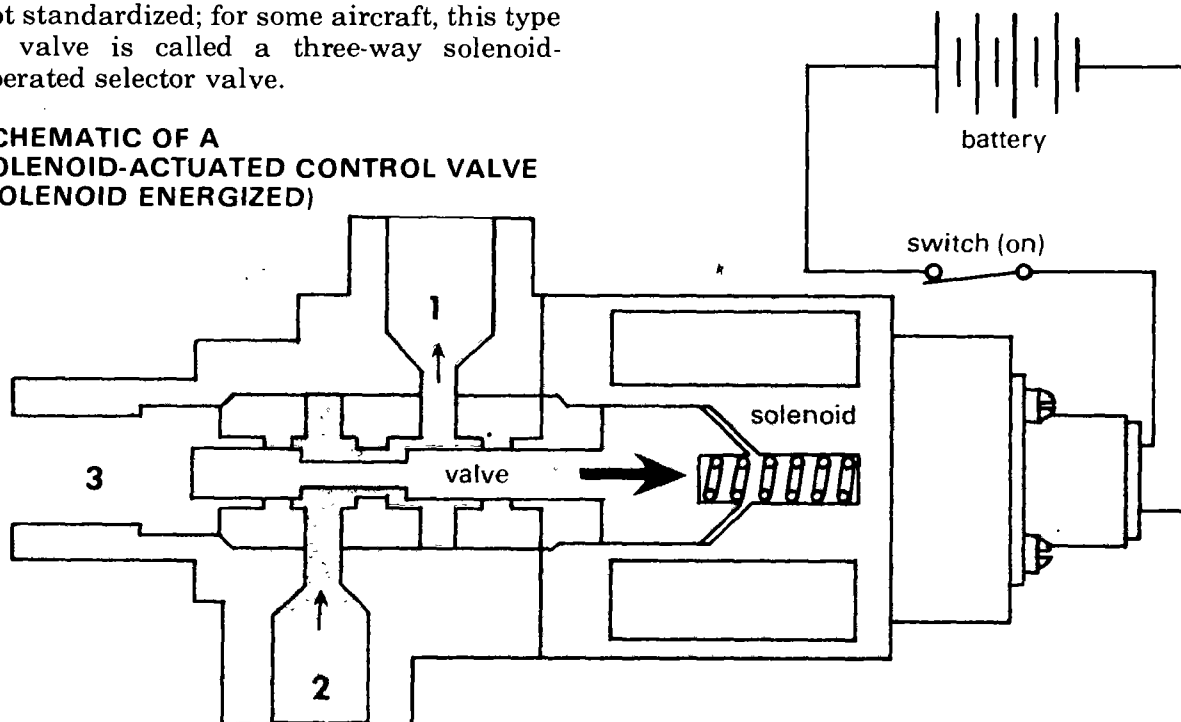
aligned with drilled passages in the valve housing when the spools are raised by the cam.

**Compound selector valves.** To conserve space and make installation easy when banks of units are to 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

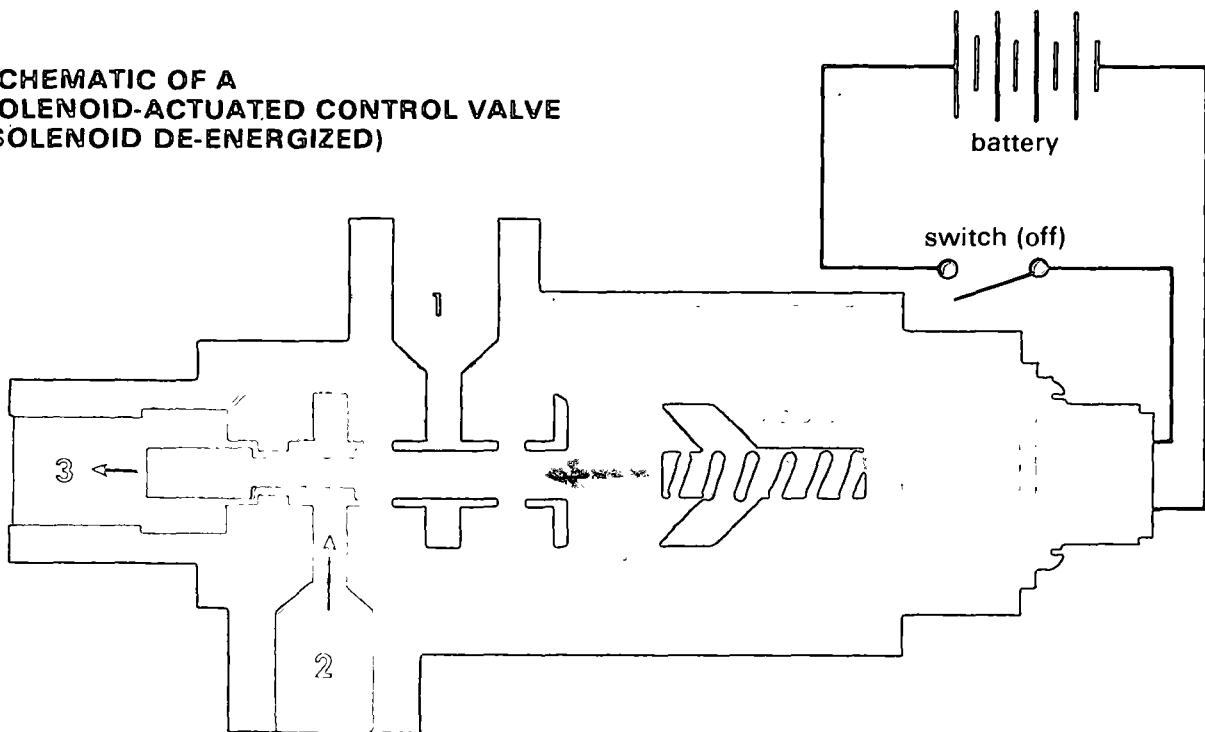
The purpose of any hydraulic valve is to control movement or pressure of fluids in hydraulic systems. Generally, all valves are control valves. However, for some Army aircraft, the term *control valve* identifies a valve that controls direction of flow through alternate channels. Such a valve does not do quite as much in the control of fluid flow as does the selector valve: it functions more like a shutoff valve. Although some of these 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 as shown here. However, the nomenclature is not standardized; for some aircraft, this type of valve is called a three-way solenoid-operated selector valve.

**SCHEMATIC OF A  
SOLENOID-ACTUATED CONTROL VALVE  
(SOLENOID ENERGIZED)**



fied by numbers rather than by function (pressure, return, system, etc.). The reason for identifying the ports in this manner is that it is possible to provide different patterns of flow through a control valve by varying the interconnection of lines to ports. Thus, the line to be interconnected with a port depends in each case on the desired pattern of flow through a valve.

**SCHEMATIC OF A  
SOLENOID-ACTUATED CONTROL VALVE  
(SOLENOID DE-ENERGIZED)**



## CHECK VALVES

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 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.

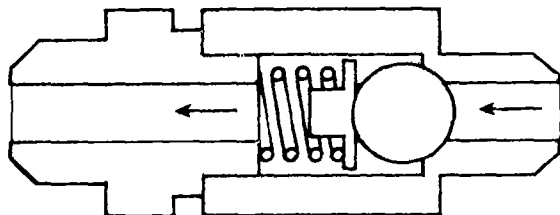
Check valves are made in two general designs to serve two different needs. In one design, the check valve is complete within itself. It is interconnected by means of tubing or hose with other components with which it operates. This type of check valve is common-

ly called an *in-line* check valve. There are two types of in-line check valves: 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. Such a 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 both simple and orifice designs, and they 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* check 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 against the spring. This permits fluid to flow through

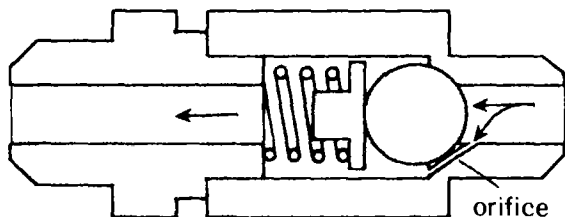
#### SIMPLE TYPE CHECK VALVE



the passageway thus opened. The instant that 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, thus blocking the flow of fluid through the valve.

The *orifice type* check valve (sometimes called a damping valve) is used to allow 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 the orifice type 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

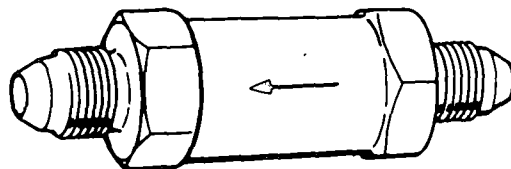
#### ORIFICE TYPE CHECK VALVE



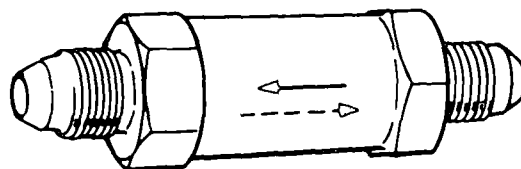
second opening is never closed and is the means by which some reverse flow can take place through the valve. The second opening is much smaller than the opening in the valve seat. As a rule, this opening is a specified size in order to maintain close control over the rate at which fluid can flow through the valve in reverse.

The direction of fluid flow through in-line check valves is indicated by stamped arrow markings on the housing as shown in the schematic. On the simple type in-line check valve, a single arrow shows the direction in which fluid can flow. The orifice type in-line check valve is usually marked with two arrows. One arrow is more pronounced than the other, and indicates the direction of unrestricted flow. The other arrow is either smaller than the first or of broken-line construction and points in the direction of restricted reverse fluid flow.

#### SIMPLE IN-LINE CHECK VALVE



#### ORIFICE TYPE IN-LINE CHECK VALVE



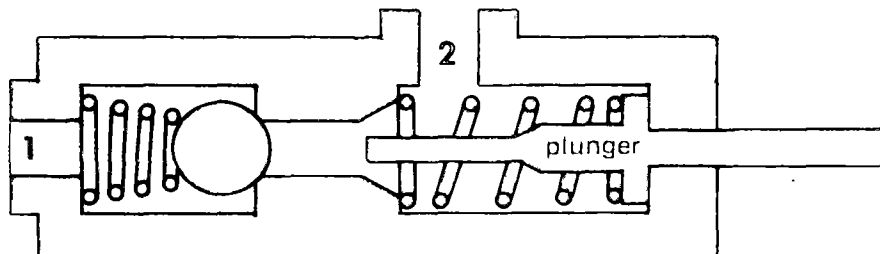
### SEQUENCE VALVES

The purpose of sequence valves (sometimes called timer check valves) is to 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, and locks; and ejection seats to cause hydraulic operations to occur in a specific order. Two major types are used: mechanically actuated and pressure actuated.

#### *Mechanically Actuated Sequence Valves.*

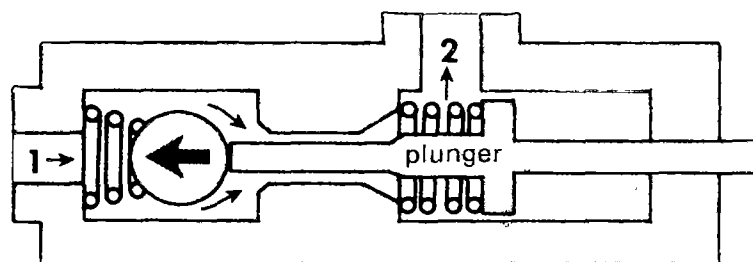
The mechanically actuated sequence valve is the type commonly used in Army aircraft. A typical valve of this type consists of a housing in which there are two ports, a ball valving device, two springs, a plunger that extends through one end of the housing, and the necessary seals to prevent leakage. The input pressure line is connected to port 1. The

**SCHEMATIC OF A  
MECHANICALLY-ACTUATED SEQUENCE  
VALVE (CLOSED)**



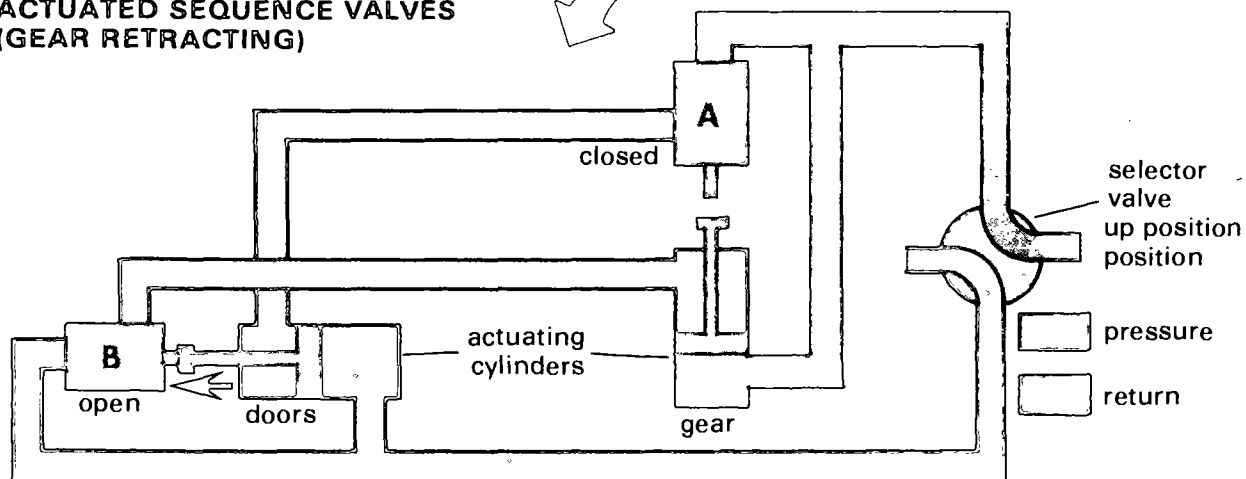
unit to be operated by means of fluid passing through the sequence valve is connected to port 2. The passage interconnecting ports 1 and 2 is blocked when the spring-loaded ball

**SCHEMATIC OF A  
MECHANICALLY-ACTUATED SEQUENCE  
VALVE (OPEN)**



is seated. 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 cause operation of the

**SCHEMATIC OF A LANDING GEAR  
SYSTEM USING MECHANICALLY-  
ACTUATED SEQUENCE VALVES  
(GEAR RETRACTING)**



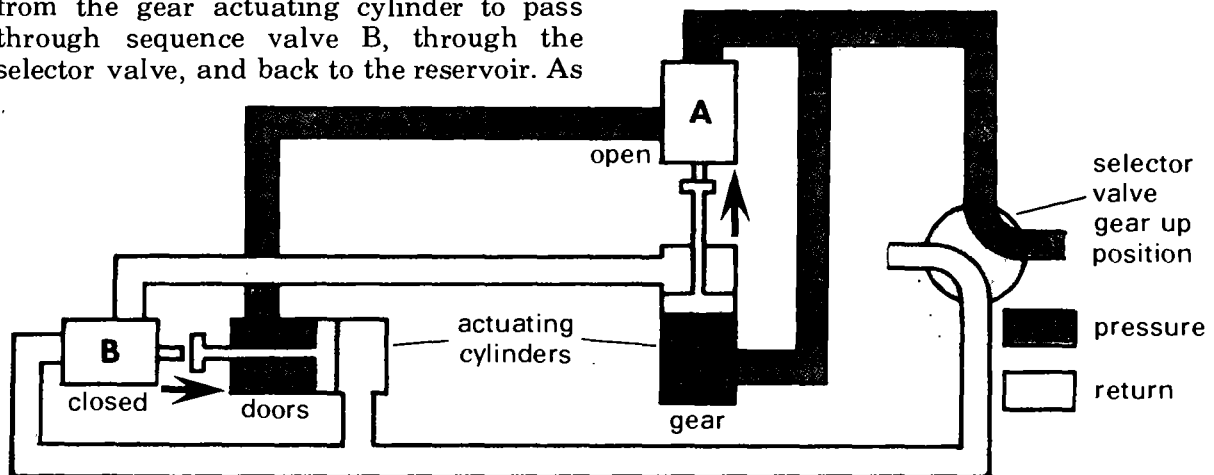
actuating unit connected to port 2. Reverse flow through the sequence valve can take place with or without the plunger being depressed since the reverse moving fluid can easily lift the ball off its seat against the relatively light resistance of the ball spring.

An example of operation of a system in which mechanically-actuated sequence valves are used is shown here. In this simple landing gear system using landing gear well



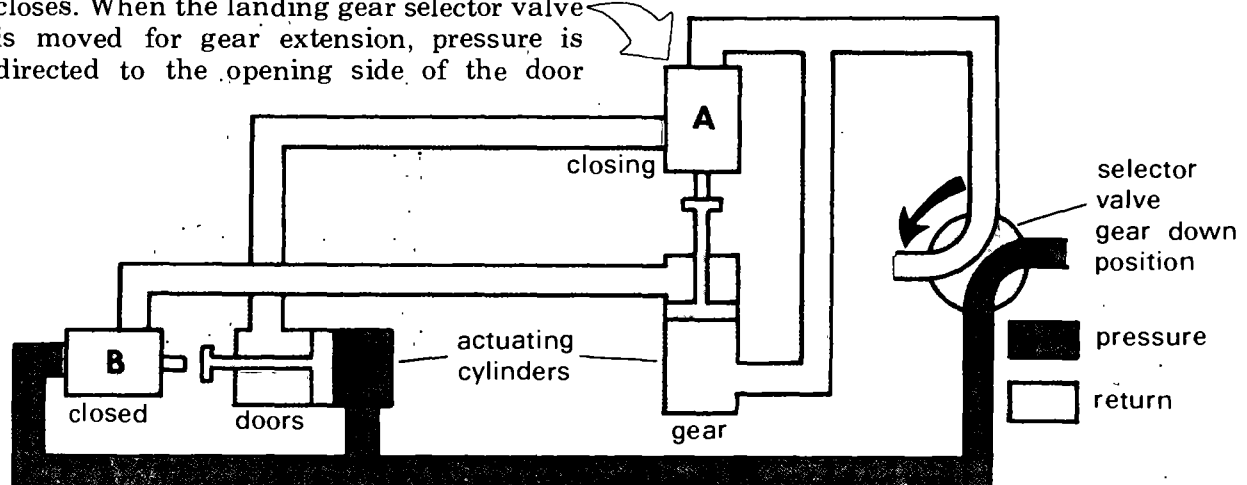
doors, the doors must open before the landing gear is extended and must close after the gear is retracted. With the landing gear selector valve in the up position as shown, pressure is directed to the up side of the landing gear actuating cylinder and to sequence valve A. At this point in the operation, sequence valve A is closed. Sequence valve B is in the open position at this time 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. As

**SCHEMATIC OF A LANDING GEAR SYSTEM USING MECHANICALLY-ACTUATED SEQUENCE VALVES (GEAR RETRACTION NEAR COMPLETION)**

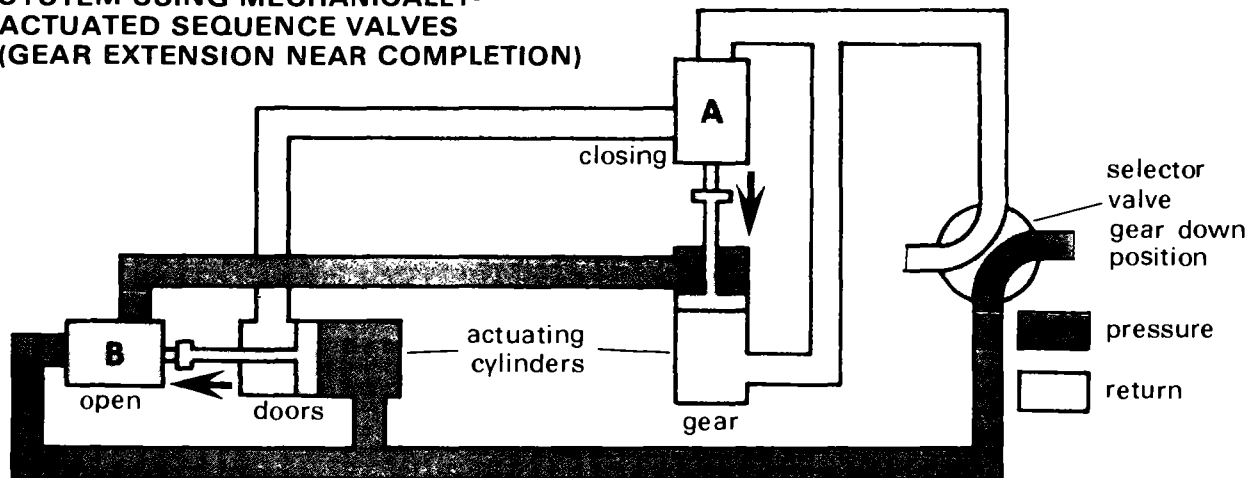


retraction of the landing gear nears completion, the gear actuating cylinder piston rod extends far enough to contact and depress the plunger of sequence valve A. As the plunger moves, it pushes the ball off its seat, allowing fluid to flow through the valve to the closing side of the door actuating 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. When the landing gear selector valve is moved for gear extension, pressure is directed to the opening side of the door

**SCHEMATIC OF A LANDING GEAR SYSTEM USING MECHANICALLY-ACTUATED SEQUENCE VALVES (GEAR EXTENDING)**

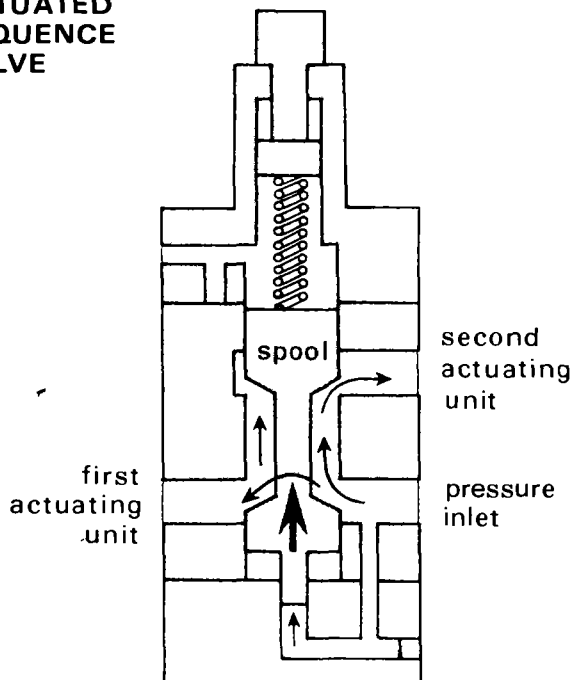


**SCHEMATIC OF A LANDING GEAR SYSTEM USING MECHANICALLY-ACTUATED SEQUENCE VALVES (GEAR EXTENSION NEAR COMPLETION)**



actuating cylinder and to sequence valve B. Since sequence valve B is now closed, fluid cannot pass through it. When the door is opened, the door actuating cylinder piston rod extends far enough to contact and depress the plunger of sequence valve B. This opens sequence valve B and allows fluid pressure to pass through to the down side of the landing gear actuating cylinder, thus extending the gear. Return fluid from the door actuating

**SCHEMATIC OF A PRESSURE-ACTUATED SEQUENCE VALVE**



cylinder is routed to the reservoir through sequence valve A while the landing gear is still retracted and the sequence valve is still open.

*Pressure-actuated sequence valves.* The typical pressure-actuated sequence valve consists of a three-port housing, a spool-type valving device, and an adjustable spring. Operation of the pressure-actuated sequence valve shown here is dependent upon movement of the spring-loaded spool. 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 operation of the first unit is completed and flow to it 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.

## PRIORITY VALVES

Priority valves are installed in hydraulic systems to provide adequate fluid flow to units requiring immediate completion of action. The priority valve is installed in the line between an actuating unit in which 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 are used in hydraulic systems to give operating priority to such units as brakes, landing gear, and flaps.

To illustrate how this operation is accomplished, let us assume that a priority valve having a full-flow capacity of 4 gallons per minute (gpm) at 1,500 psi and a reduced-flow capacity of 1 gpm at 1,000 psi controls fluid flow into 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.

**SCHEMATIC OF A  
PRIORITY VALVE (FULL FLOW)  
4 GPM AT 1,500 PSI**



spring loaded valve

**SCHEMATIC OF A  
PRIORITY VALVE (FLOW REDUCED)  
1 GPM AT 1,000 PSI**



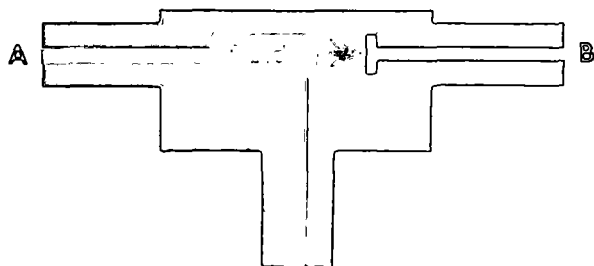
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## SHUTTLE VALVES

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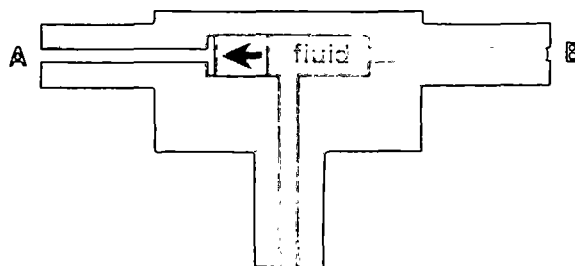
In some cases, two sources of operating pressure are connected to a single component or system. One of the pressure sources will be reserved for emergency use. Provisions are usually made in such cases to eliminate any possible transfer of fluid from one pressure source to the other. This is done by means of shuttle valves. Army aircraft equipped with dual brake systems use shuttle valves to isolate the pilot and copilot master cylinders from each other so as to allow optional operation of the brakes by either set of master cylinders. Also, Army aircraft having compressed-air equipment for emergency operation of landing gears and wheel brakes use shuttle valves to isolate the system hydraulic fluid from the compressed air or other authorized gas used in emergency operation. Two types of shuttle valves are used in Army aircraft.

### FLOATING-PISTON TYPE SHUTTLE VALVE (PRESSURE SOURCE A)



In the *floating-piston* type shown here, 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. Conversely, fluid entering from

### FLOATING-PISTON TYPE SHUTTLE VALVE (PRESSURE SOURCE B)



source B would reposition the piston to block the flow from source A; fluid would then flow to the unit being actuated from pressure source B only. The piston is restrained against random movement by the slight drag of the O-ring against the cylinder walls.

The *detent-type* shuttle valve operates on the same general principles as the floating-piston type, with the exception that a spring-loaded detent ball holds the piston in the position dictated by the pressure source.

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## ACTUATING CYLINDERS

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Actuating cylinders transform energy in the form of fluid pressure into mechanical force so that the energy can perform work. They impart powered linear motion to some movable object or mechanism. 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 through which fluid enters and leaves the bore. The piston and rod form an assembly. The piston moves forward and backward within the cylinder bore. The piston rod moves into and out of the cylinder housing through an opening in one end of the housing. Both the cylinder housing and the

piston rod have provisions for attachment to the mechanism to be moved by the actuating cylinder.

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

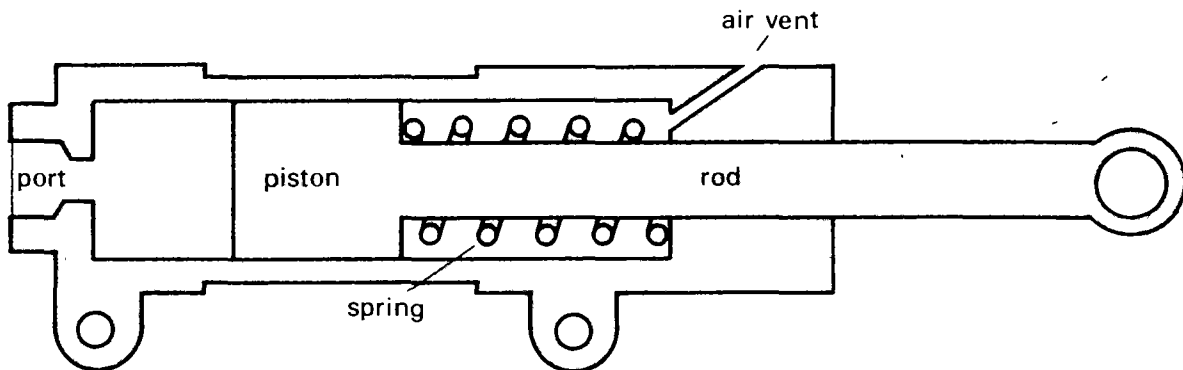
- How much force will the actuating cylinder be required to put out?
- What length of travel will the actuating cylinder have to be capable of?
- How high a fluid pressure is needed to operate the actuating cylinder?

Because of the need to keep aircraft weight as low as possible, care must be taken not to

select actuating cylinders with capabilities exceeding those actually required. Excess capability carries with it the penalty of excess size and weight. The higher the pressure available for operation of an actuating cylinder, the smaller its diameter can be.

Actuating cylinders come in two major types--single action and double action--as shown here. Several other types are also shown. However, only the single-action and double-action types are discussed here since they are the ones commonly used in Army aircraft.

The *single-action* (single port) actuating cylinder causes movement in one direction only. 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. 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.

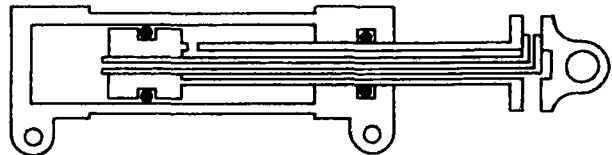


The *double-action* (two port) actuating cylinder causes movement in two directions. Operation of this type of cylinder is usually controlled by a four-way selector valve.

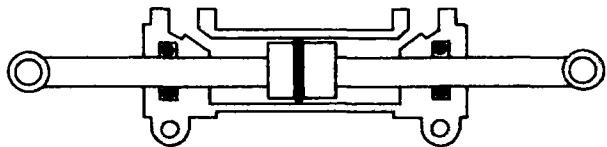
**SCHEMATIC OF A  
3-PORT ACTUATING CYLINDER**



**SCHEMATIC OF AN  
ACTUATING CYLINDER WITH  
PORTS IN THE PISTON ROD**

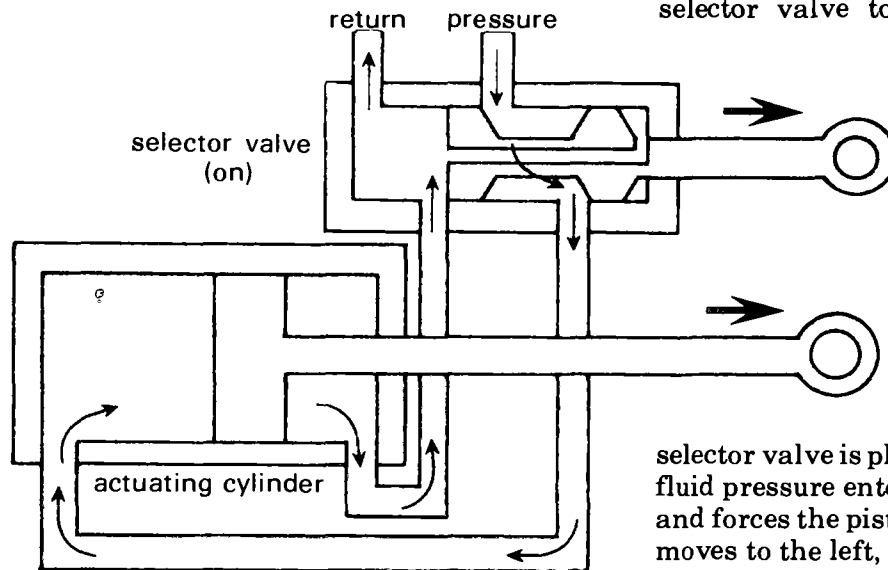


**SCHEMATIC OF A  
DOUBLE-ACTION ACTUATING CYLINDER  
WITH TWO PISTON RODS**



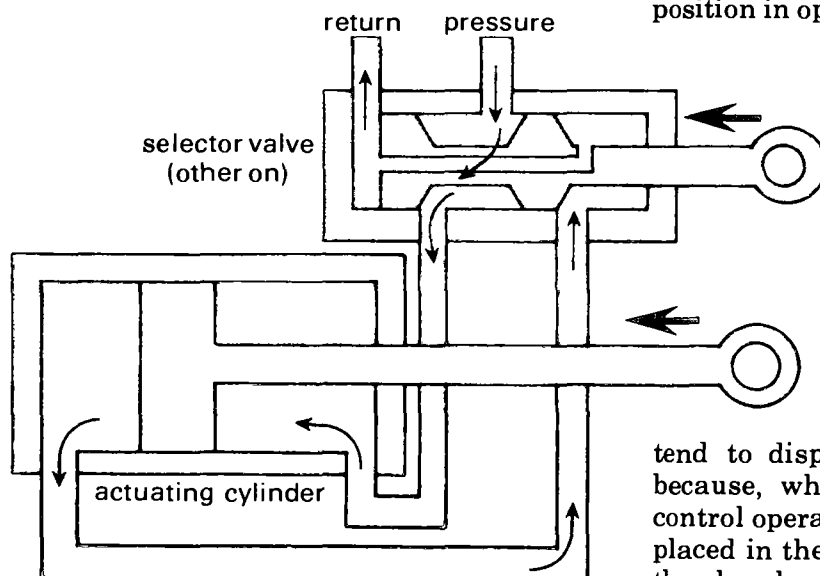
**SCHEMATIC OF A  
SINGLE-ACTION ACTUATING CYLINDER  
(SINGLE PORT)**

# **SCHEMATIC OF A CONTROL VALVE AND DOUBLE-ACTION CYLINDER**



Placing the selector valve in the on position admits fluid pressure to the left-hand chamber of the actuating cylinder, thus forcing the piston to the right. As the piston moves to the right, it pushes return fluid out of the right-hand chamber and through the selector valve to the reservoir. When the

# **SCHEMATIC OF A CONTROL VALVE AND DOUBLE-ACTION CYLINDER**



selector valve is placed in its other on position fluid pressure enters the right-hand chamber and forces the piston to the left. As the piston moves to the left, it pushes return fluid out of the left-hand chamber and through the selector 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 selector valve used to control operation of the actuating cylinder 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.

The seepage of some fluid past shaft end seals and bearings is necessary for their lubrication. However, through normal wear,

seepage develops into leakage. Moderate leakage at piston rod end bearings and seals during operation is normal in actuating cylinders which have been in use for some time. There are established limits as to the amount of leakage permitted at such points. The general military specification for

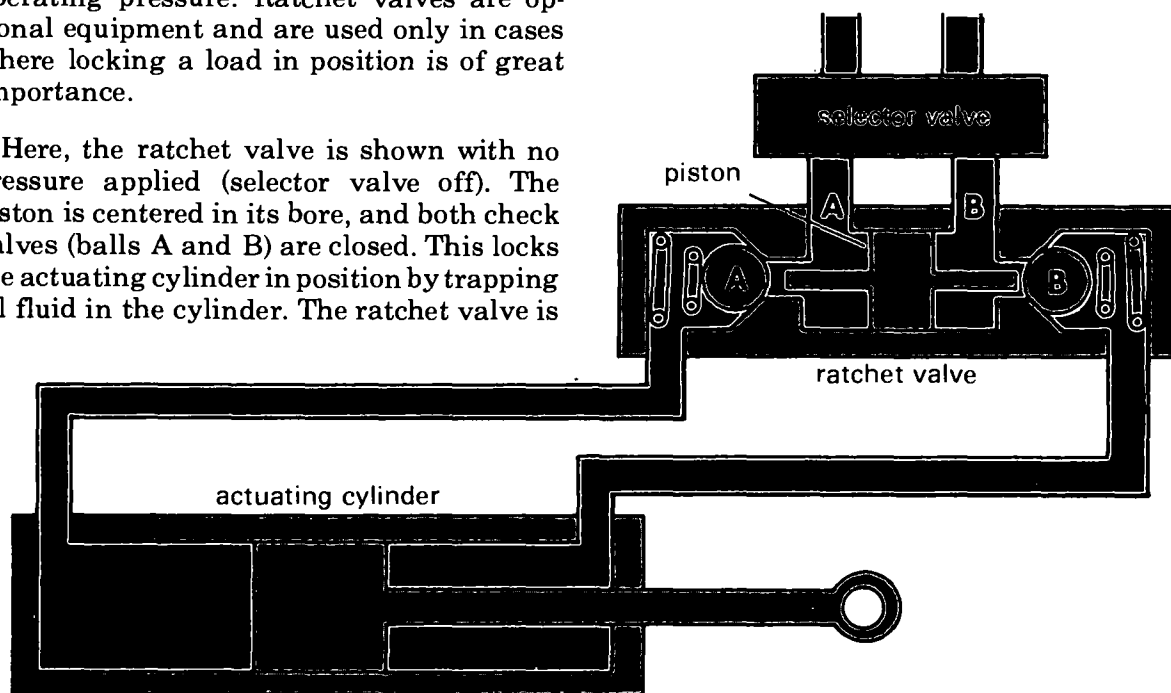
allowable external leakage at each shaft seal and bearing is one drop per 25 cycles of operation (25 full or partial strokes in each direction). This specification is applicable except where a different leakage limitation is specifically stated in publications for the equipment concerned.

## RATCHET VALVES

Hydraulic ratchet valves are used as companion devices to double-action actuating cylinders. The purpose of a ratchet valve is to aid an actuating cylinder in holding a load in the position into which it has been moved by operation of a hand pump. The ratchet valve insures that there will be trapped fluid on each side of the actuating cylinder piston. This is necessary for the actuating cylinder to lock a load against movement in either direction, and 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 means of system operating pressure. Ratchet valves are optional equipment and are used only in cases where locking a load in position is of great importance.

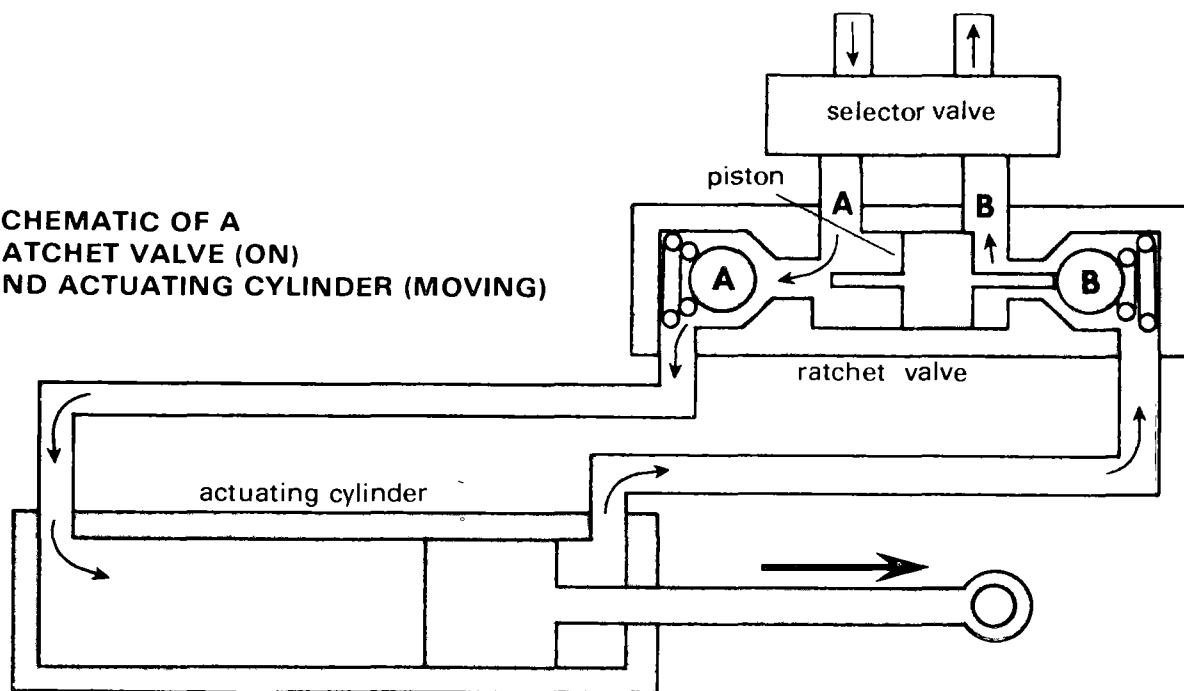
Here, the ratchet valve is shown with no pressure applied (selector valve off). The piston is centered in its bore, and both check valves (balls A and B) are closed. This locks the actuating cylinder in position by trapping all fluid in the cylinder. The ratchet valve is

SCHEMATIC OF A  
RATCHET VALVE (OFF)  
AND ACTUATING CYLINDER (STATIC)



shown here 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, and the piston moves to the right, unseating ball check B.

**SCHEMATIC OF A  
RATCHET VALVE (ON)  
AND ACTUATING CYLINDER (MOVING)**



## HYDRAULIC SERVOS

**Use.** Many situations exist in which powered movements must be consistently made with accuracy within thousandths of an inch; such exact control cannot be effected by an actuating cylinder merely connected with a selector valve. Hydraulic servos perform this function. Hydraulic servos are used in both airplanes and helicopters to multiply the physical effort expended by personnel 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.

**Types.** 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 for the following explanation of basic servo operation and of servo sloppy links and bypass valves. Such a servo is shown here.

**Operation.** To exemplify servo operation, let us 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 will result in returning the selector valve to the off position. Since the flow of fluid is now stopped, the piston will travel no farther.

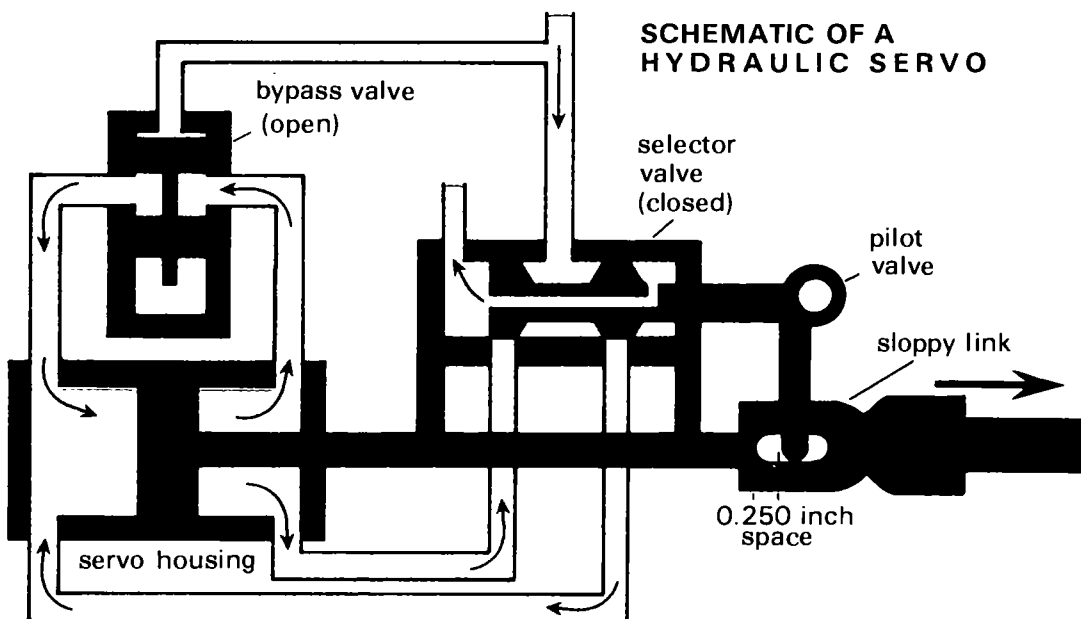
Should it be necessary to move the servo piston to the limit of its possible travel within the cylinder bore, all that is required is to continue moving the pilot valve ahead so that the selector valve housing is unable to catch up with the piston valve.

In most cases the pilot valve will be 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 and 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 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 pilot valve movement, and 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 minimize the resistance to movement of the servo whenever it has to be moved manually. The bypass valve is designed to automatically open a free-flow pathway between the chambers on each side of the piston at times when there is no operating pressure available to the servo. It automatically closes the free-flow pathway whenever the servo has operating pressure. Thus fluid can be forced into 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), thus permitting the servo to provide semiautomatic control of an aircraft's flight. Two types of electro servos are used in some late model cargo helicopters--extensible links and stability augmentation servos--but these will not be discussed here because their complex design and operation are beyond the scope of this manual.

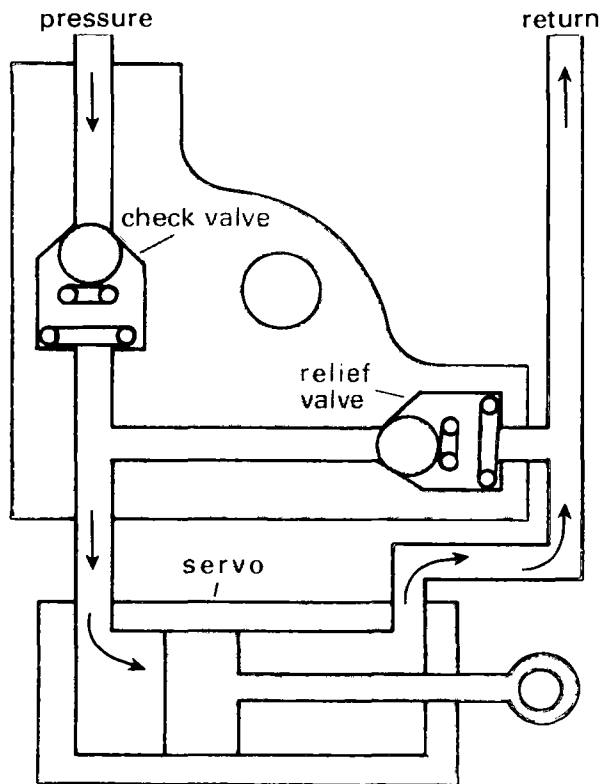


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## IRREVERSIBLE VALVES

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### SCHEMATIC OF A SIMPLE IRREVERSIBLE VALVE



Irreversible valves assist hydraulic servos in a manner similar to that in which ratchet valves assist actuating cylinders. Both ratchet valves and irreversible valves provide defense against 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. The simple schematic shown here illustrates basic operation of the irreversible valve. The check valve in this mechanism allows fluid from the pump to flow in the normal direction as 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 feedback force. The relief valve serves as a safety device to limit the pressure produced by 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.

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## HYDRAULIC FUSES

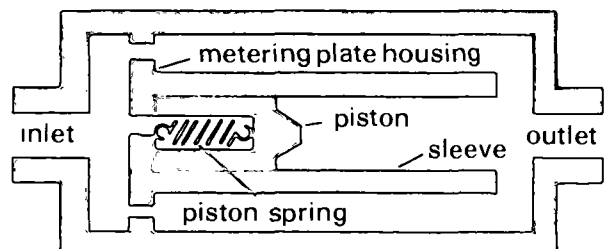
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Fuses are incorporated in hydraulic systems to prevent continued loss of fluid in cases of serious leakage. Fuses are strictly safety devices: They are not needed for operation of the system. Hydraulic fuses are usually installed in lines that are 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.

An hydraulic fuse is designed to permit only a limited quantity of fluid to pass through it. When this limit is reached, the fuse automatically shuts off further flow. The typical fuse shown here consists essentially of a housing, a sleeve, a piston, a piston return spring, and a metering plate. The housing has a port at each end—one pressure; the other, return. 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.

### SCHEMATIC OF A HYDRAULIC FUSE



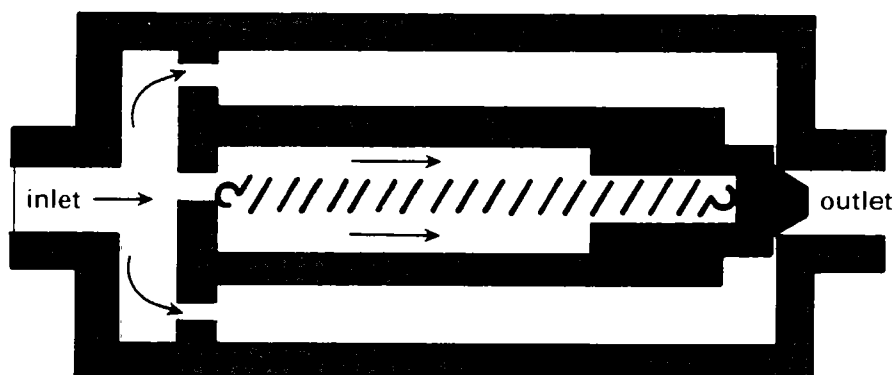
Whenever the fuse is not transmitting fluid, its piston is pulled to the inlet end of the fuse by the piston return spring. As soon as fluid begins flowing through the fuse, the stream of fluid that enters the sleeve reacts against the piston. This causes a slow movement of the piston toward the outlet 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. If the

**SCHEMATIC OF A  
HYDRAULIC FUSE  
(FULL FLOW)**



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, thus blocking further fluid flow through the fuse. 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.

**SCHEMATIC OF A  
HYDRAULIC FUSE  
(BLOCKED FLOW)**





## CHAPTER 9

# TYPES OF PNEUDRAULIC SYSTEMS

The arrangement of components within the hydraulic systems varies among the different types of aircraft. However, all aircraft hydraulic systems incorporate the components described in chapters 4 through 8. The hydraulic system may be an open-center or a closed-center type and may be interconnected with a pneumatic system that serves as an emergency pressure source in case the main system fails. These systems are discussed in this chapter under the following headings:

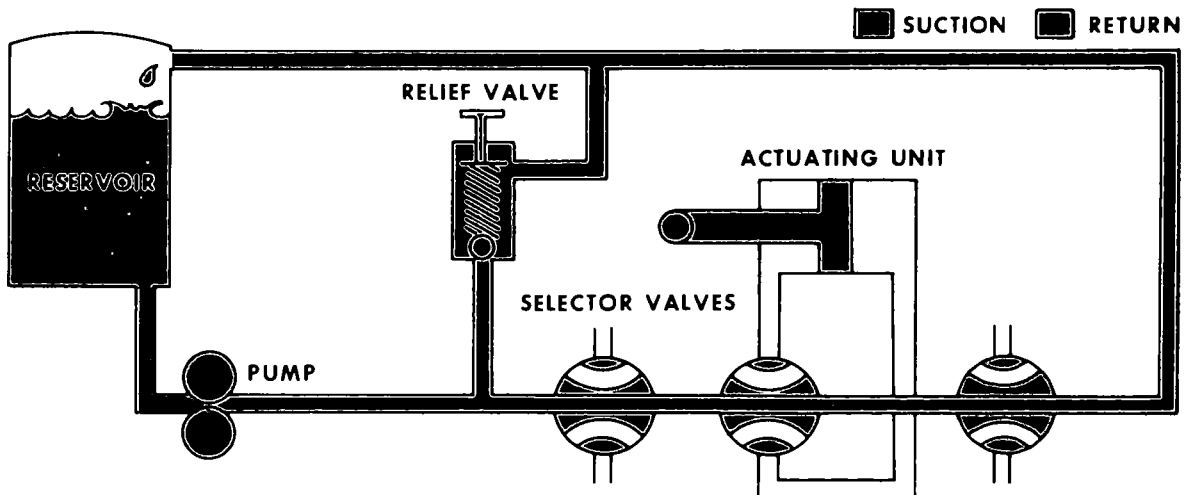
OPEN-CENTER HYDRAULIC SYSTEM .....	9-1
CLOSED-CENTER HYDRAULIC SYSTEM .....	9-2
PNEUMATIC SYSTEM .....	9-5

## OPEN-CENTER HYDRAULIC SYSTEM

An open-center hydraulic system has hydraulic fluid flow but no pressure until some actuating unit is operated. A typical basic open-center system such as the one shown here 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 an on position and an actuating unit is operating.

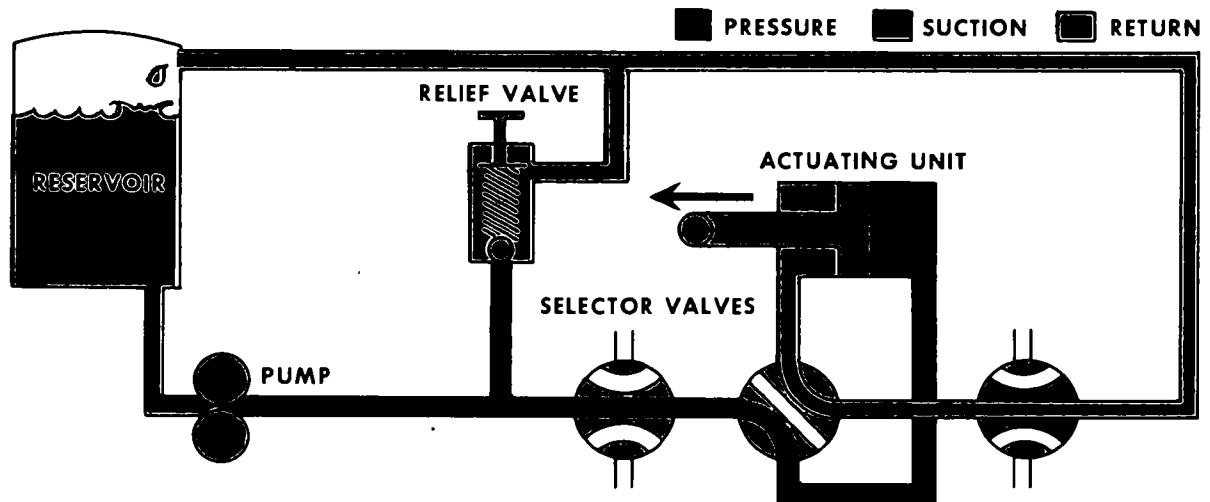
*Operation of open-center system with all selector valves in neutral (off) position.* Fluid flows from the reservoir into the pump and from the pump into the main pressure line. Because all selector valves are in the off position, the fluid passes back to the reservoir through the open-center passage of these valves. Since no restrictions exist in the system, there is no pressure in the system other than that caused by friction.

### SCHEMATIC OF AN OPEN-CENTER HYDRAULIC SYSTEM (VALVE CLOSED)



*Operation of open-center system with one selector valve in operating position. With one selector valve in the operating position, fluid flows under pressure to the actuating unit. 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, at which point 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.*

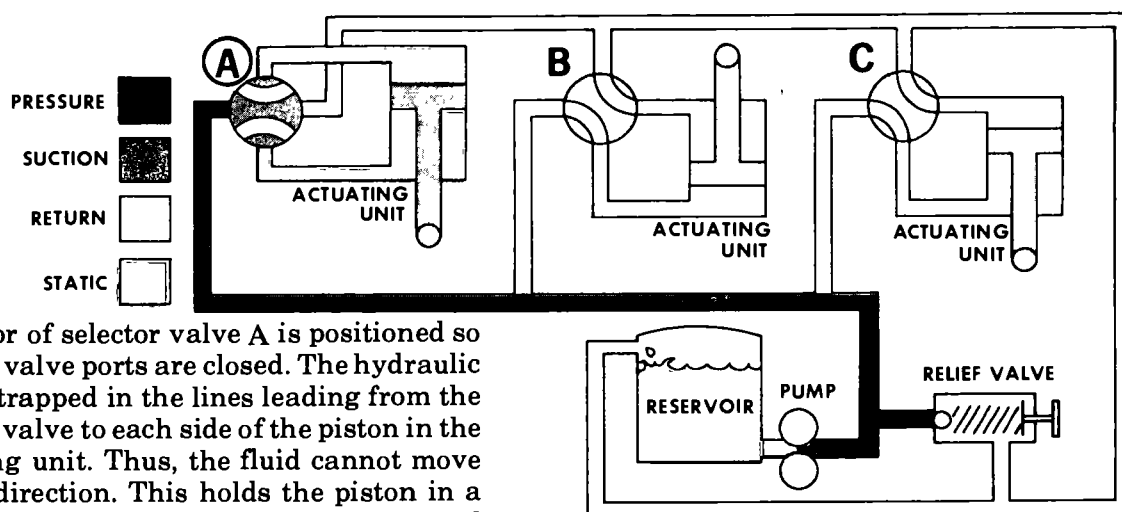
**SCHEMATIC OF AN OPEN CENTER HYDRAULIC SYSTEM (VALVE OPEN)**



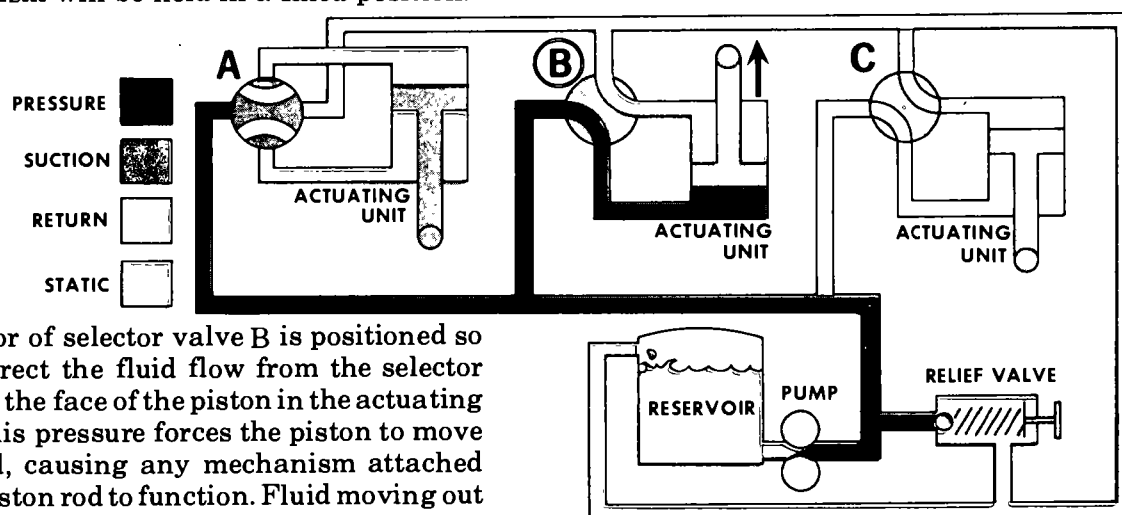
## — CLOSED-CENTER HYDRAULIC SYSTEM —

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 primarily of a reservoir, a pump, a relief valve, one or more selector valves, and one or more actuating units.

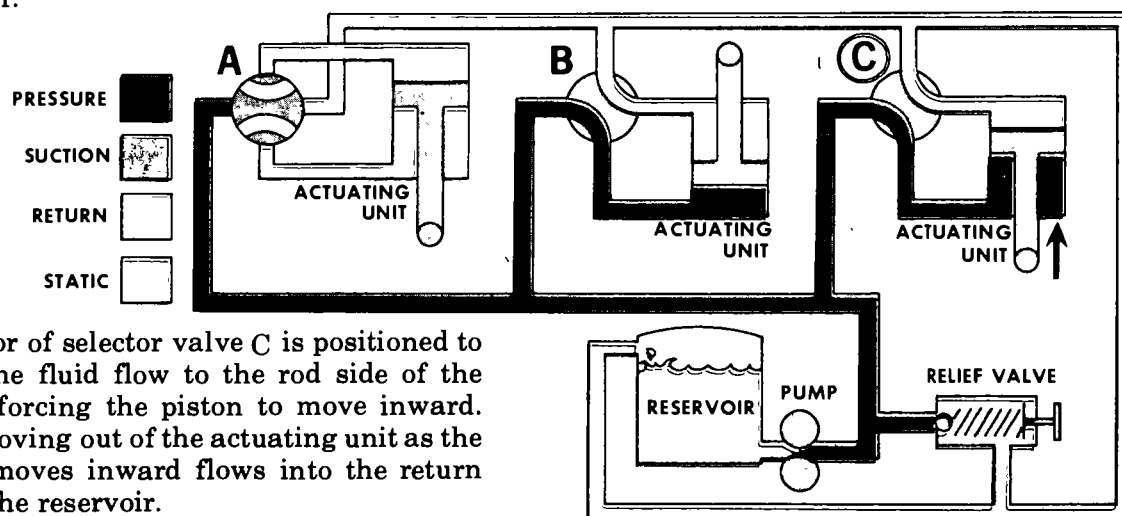
*Basic closed-center hydraulic system.* In the schematic shown here, each of the three selector valves controls a different actuating unit and each valve is in a different position. Hydraulic fluid is drawn from the reservoir to the pump, which forces the fluid on to the selector valves A, B, and C with results as follows:



The rotor of selector valve A 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. Thus, the fluid cannot move in any direction. This holds the piston in a locked position, and any attached mechanism will be held in a fixed position.



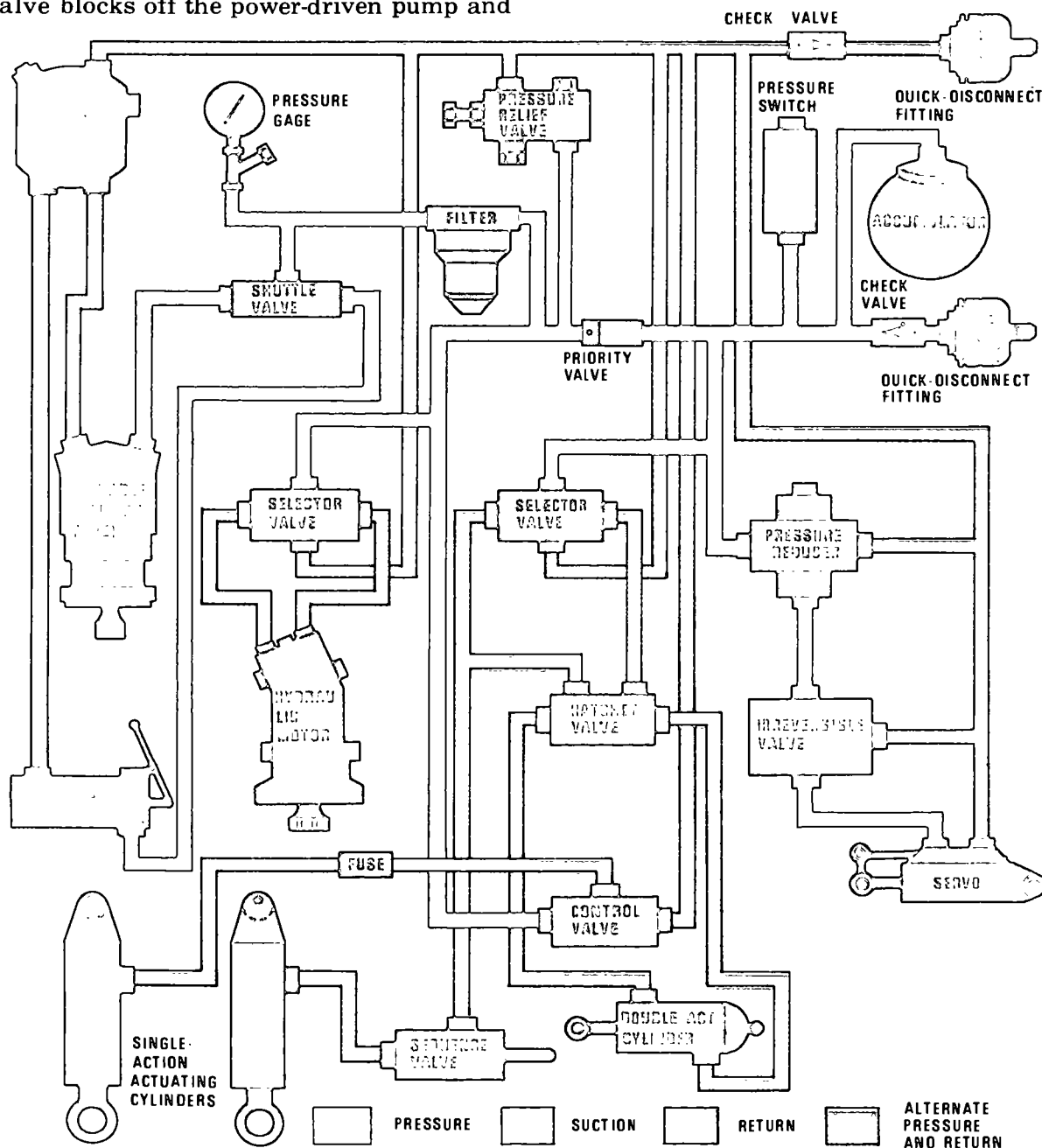
The rotor of selector valve B is positioned so as to direct the fluid flow from the selector unit to the face of the piston in the actuating unit. This pressure forces the piston to move outward, causing any mechanism attached to the piston rod to function. Fluid moving out of the actuating unit as the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



The rotor of selector valve C 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.

*Complete closed-center hydraulic system.* This schematic shows a closed-center hydraulic system containing 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 the hand pump. Pressure created by operation of 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.





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## PNEUMATIC SYSTEM

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Aircraft pneumatic systems are mostly used as an emergency source 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 good for only a certain number of operations.

High pressure pneumatic systems are constructed to operate in much the same manner as hydraulic systems. A shuttle valve connects the pneumatic system to the hydraulic system. This allows the use of the same tubing and units for both systems. The shuttle valve separates the normal hydraulic system from the pneumatic system. Pneu-

matic system selector valves control the air to the subsystems. Each subsystem is connected to the high pressure air source through a pressure regulator and relief valve assembly and a selector valve. Since pneumatic selector valves are installed in parallel, air pressure is immediately available to all subsystems for instant operation. Connected in this manner, more than one system can be operated at the same time.

In a pneumatic system, the pressure regulator and 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.



## CHAPTER 10

# AIRCRAFT BRAKE SYSTEMS

In this chapter you will learn the uses of aircraft brake systems and how these systems can be arranged in different ways. Arrangement depends upon such factors as the landing gear layout and size and the type of aircraft. General maintenance guidance is included. The following headings identify the sections in this chapter:

WHEEL BRAKE SYSTEMS .....	10-1
HELICOPTER ROTOR BRAKE SYSTEMS .....	10-12
MAINTENANCE OF BRAKE SYSTEMS .....	10-13

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### WHEEL BRAKE SYSTEMS

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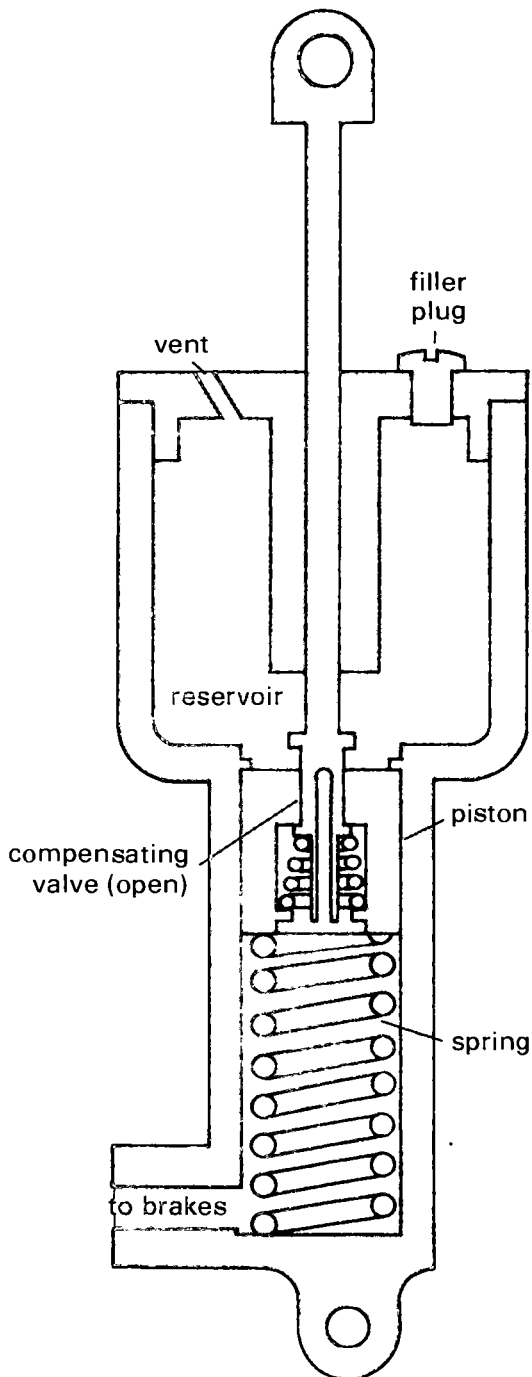
All hydraulic brake systems operate on the same basic principle. When the operator moves a brake pedal or other brake operating control, the movement is transmitted to a master cylinder or to a power brake control valve from which fluid pressure is delivered through connecting lines to a brake assembly connected to a wheel or shaft whose movement is 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 dual in nature in that they 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 be used for steering the aircraft.

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

*Master cylinders.* Master cylinders are used in some wheel brake systems as the means of transforming 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, thus stopping rotation of the wheels. Master cylinders fall into three general classifications: *simple*, *compound*, and *powerboost*. Within these classifications, there are many variations 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

**SCHEMATIC OF A  
SIMPLE MASTER CYLINDER  
(RELEASED POSITION)**



independent brake systems. In brake systems using a power boost master cylinder, some of the power needed for braking is supplied by a power-driven pump.

### ***Simple Master Cylinders.***

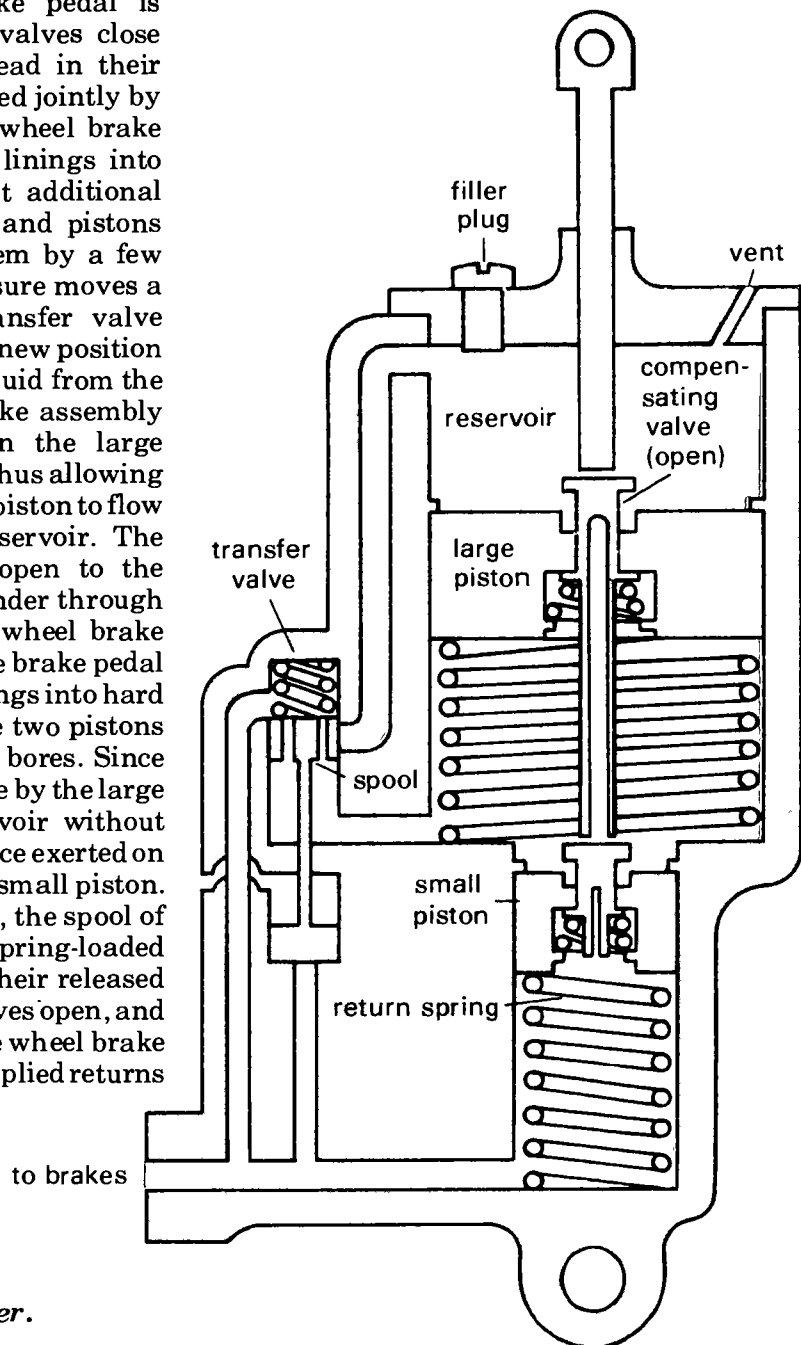
The use of simple master cylinders is restricted to light aircraft. Some simple cylinders have integral reservoirs; others are connected with in-line reservoirs by means of a hose. In some designs, a push rod actuates the piston; in others a pull rod performs this function. The design shown here has an integral reservoir, and the piston is actuated by a push rod. Note that the illustration shows the cylinder in 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 and from the reservoir 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, thus trapping 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, allowing the piston spring to open the compensating valve and to hold it open until the pedal is depressed again.

### ***Compound Master Cylinders.***

Some heavy aircraft require wheel brake systems that operate with more fluid flow and higher fluid pressure than is within the capability of 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 means of relatively short pedal travel. It can also develop high operating pressure by means of moderate pedal pressure. This dual capability is achieved by means of 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.

The compound master cylinder shown here is in released position, which means that 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, where it moves the linings into contact with the disk. A slight additional movement of the brake pedal and pistons raises the pressure in the system by a few pounds. This slight rise in pressure moves a 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 bore and the reservoir, thus allowing any fluid displaced by the large piston to flow without resistance into the wheel brake assembly. The small cylinder bore remains open to the passage within the master cylinder through which fluid is delivered to the wheel brake assembly. As force applied to the brake pedal is increased so as to push the linings into hard contact with the brake disk, the two pistons move slightly farther into their bores. Since any fluid displaced out of its bore by the large piston is flowing to the reservoir without resistance, practically all the force exerted on the brake pedal is applied to the small piston. Upon release of the brake pedal, the spool of the transfer valve returns to its 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.

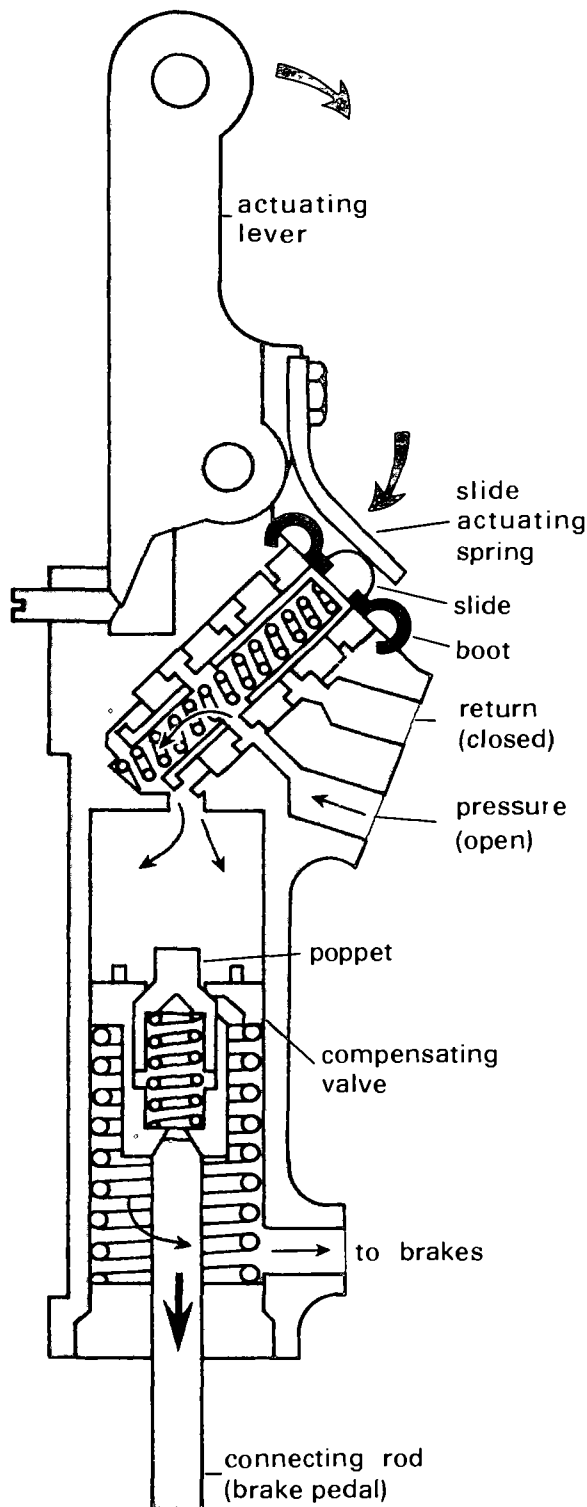
**SCHEMATIC OF A  
COMPOUND MASTER CYLINDER  
(RELEASED POSITION)**



### ***Power-Boost Master Cylinder.***

Some aircraft are too heavy or land at speeds too great to permit control of the aircraft by a brake system powered entirely by an operator's foot and leg muscles. The brake systems of such aircraft require power produced by a power-driven pump. In some aircraft, the pump-produced power does the

**SCHEMATIC OF A  
POWER-BOOST MASTER CYLINDER  
(BRAKE APPLIED)**



job alone and is merely controlled by the operator (this is discussed in the next paragraph, *power brake control valves*). 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 these brake systems. In the event of loss of pump-produced power to the master cylinder, 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 and an emergency source of boost pressure, such as an accumulator or a compressed-air bottle, has to be provided.

A typical power-boost master cylinder is shown here. Note that two interconnected chambers make up the cylinder body. The upper chamber houses a spring-loaded sleeve and slide and the pressure and return ports for the main system lines. The lower chamber contains a spring-loaded piston and poppet and the port to the brake line. This chamber also serves as a reservoir for the 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. It should be noted that the master cylinder described here has a piston rod that is pulled outward of the housing as the brake is applied. However, there is another design in which applying the brake pushes the piston rod inward.

Applying pressure to the brake pedal creates a pull on the piston rod that results in downward movement of the piston. When sufficient movement of the piston occurs to release the poppet extension from its contact with the housing, the poppet seats, thereby closing 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

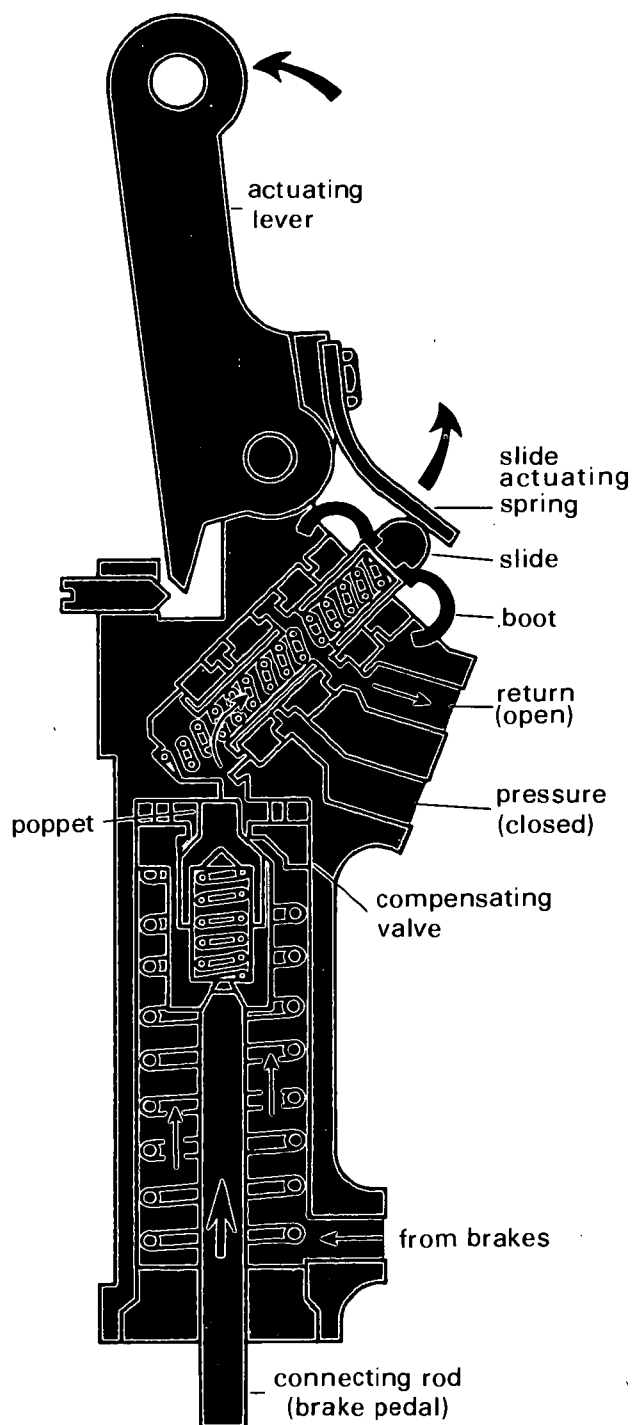
pivoted actuating lever to move from its previously angled position. The new position of the actuating lever forces the attached slide actuating springs to retract the slide, thereby causing the slide to block the return port and to open the pressure port. This allows pressure from the system pump to pass through the pressure port and the slide and to enter the chamber above the piston. This pressure exerts a downward push on the piston, which aids the muscle (operator) produced pull on the piston in developing 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 and 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 complete control of the operator and is determined by the amount of pressure he applies to the brake pedal.

Release of pressure on the brake allows the piston spring to retract the piston, which results in reopening the compensating valve. This allows the actuating lever to return to its angled position, thereby permitting the slide to return to the position in which it 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 thus release the brake.

### ***Power Brake Control Valves.***

In many large aircraft that land at high speed, 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 lies in the pressure source. A power brake control valve

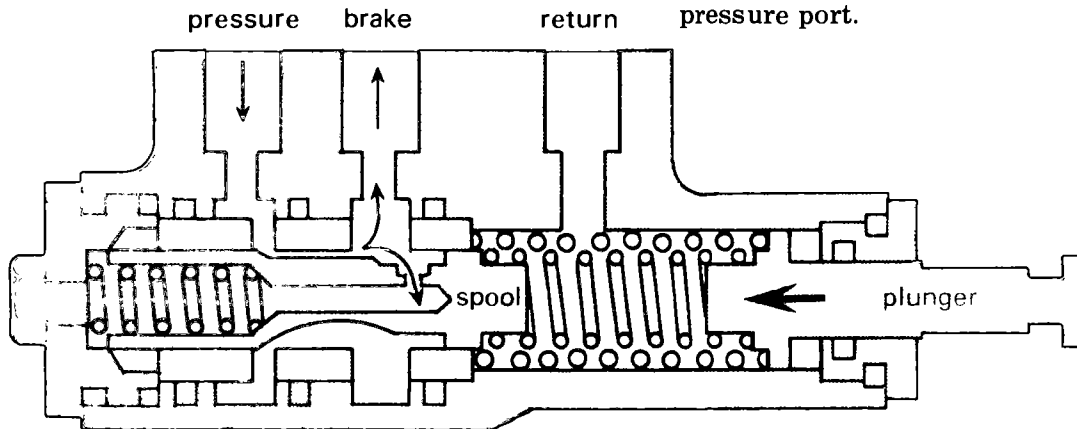
**SCHEMATIC OF A  
POWER-BOOST MASTER CYLINDER  
(BRAKE RELEASED)**



produces no pressure. It is, in effect, a variable pressure reducer, receiving fluid pressure from the power-driven pump of some major hydraulic system of the aircraft and metering the pressure to a wheel brake assembly. Since the power brake control valve 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, for use in the event that the regular pressure source fails.

*Brake application.* When the brake pedal is depressed, the plunger moves toward the left as shown here. 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 depressed only a minimum amount, 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, thus 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 the pressure port.

**SCHEMATIC OF A  
POWER BRAKE CONTROL VALVE  
(BRAKES APPLIED)**



Whatever amount of pressure is present in the wheel brake assembly at any given moment 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



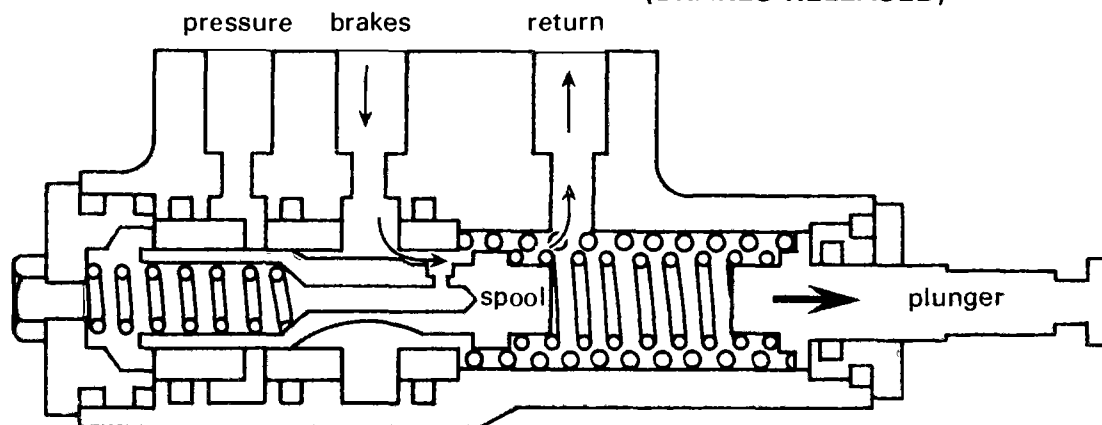
port. The amount of fluid pressure that has to be present at any given time in the wheel brake assembly and in the spool to cause reblocking of the pressure port depends on the amount of force in the spool pressure spring at that time. Since the amount of force exerted by the spool pressure spring is 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 movement of the spool to the right in blocking the pressure port leaves the brake line isolated from both the pressure and the return lines. Thus, no fluid can enter or leave the wheel brake assembly and change the amount of pressure therein unless the position of the spool is changed by moving the pedal. When the brakes are in this static condition, the operator may experience the illusion that he is still applying the brakes. The reason for this is that 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, giving him the feeling that he is applying the brakes.

Releasing the brake causes the plunger spring to move the plunger toward the right. 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 the return line are interconnected. The fluid that was forced into the wheel brake assembly when the brake was applied now returns to the reservoir.

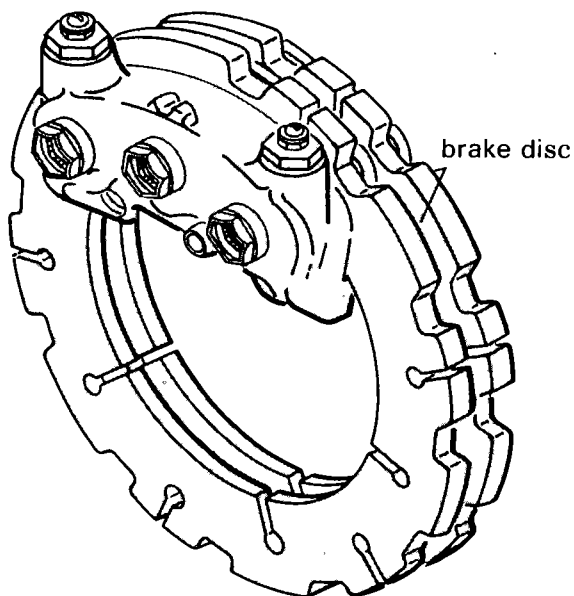
#### SCHEMATIC OF A POWER BRAKE CONTROL VALVE (BRAKES RELEASED)



### 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 and converts the pressure into a retarding force that stops wheel rotation. Two major types of wheel brake assemblies are used on Army aircraft: the disc type and the expander tube type.

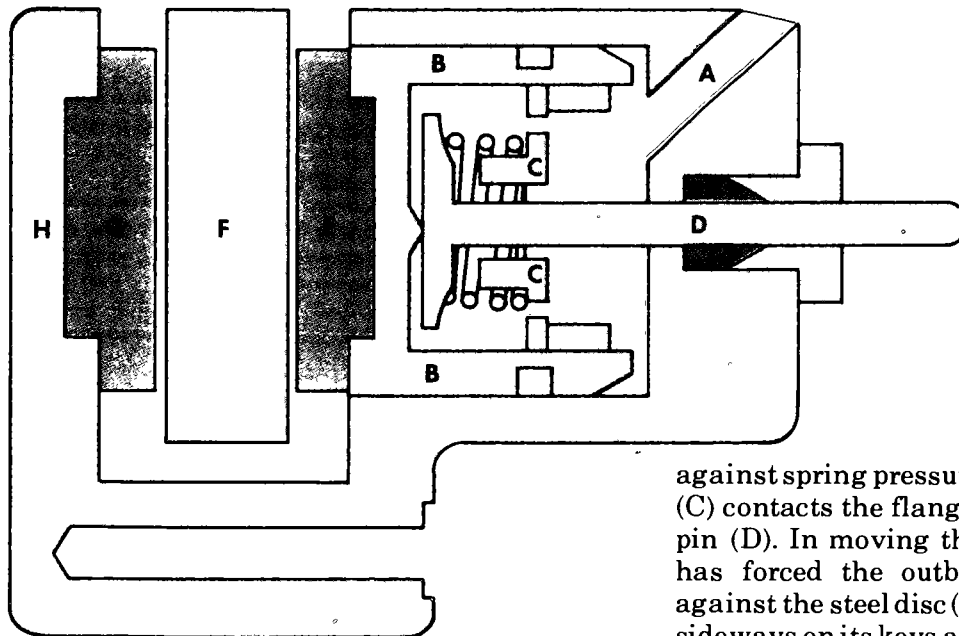
#### DISC BRAKE ASSEMBLY



*Disc brakes.* In a disc assembly, one or two steel discs are generally used, depending on the type and size of the aircraft on which the brakes are installed. These discs 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 the outboard brake lining against the brake disc. Since the disc 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 disc between a pair of linings retards the continued rotation of the disc and of the wheel to which it is attached.

A schematic cross section of a *single-disc* hydraulically operated brake is shown here. This brake, like most hydraulically operated disc brakes, is self-adjusting. The illustration shows a cutaway of only one piston cavity. However, all piston assemblies of this type of brake are nearly identical. Application of the single-disc brake occurs when hydraulic fluid under pressure enters the fluid port (A). This pressure forces the piston (B) to the left

#### SCHEMATIC OF A DISC BRAKE ASSEMBLY



against 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 disc (F), which in turn moves sideways on its keys and contacts the inboard

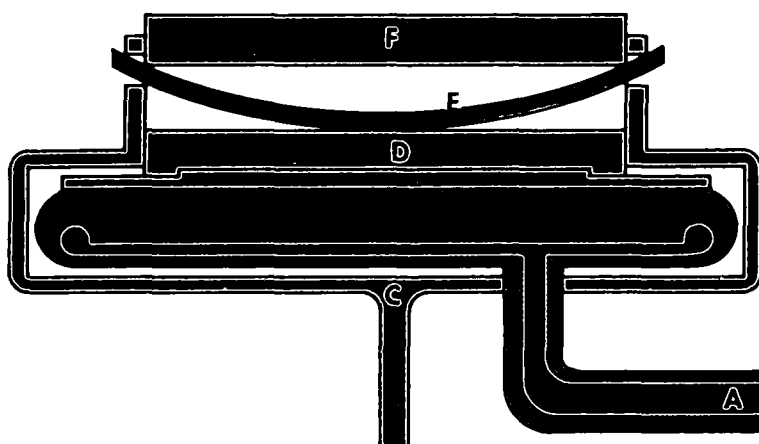
brake lining (G) supported by the backing plate (H). The brake running clearance is thus taken up by this first movement of the piston. However, to obtain full braking friction between the rotating disc and the lining "pucks," the piston must move farther to the left. The disc must be firmly pinched between the lining "pucks." The spring guide is already contacting the face of the adjusting pin, and the adjusting pin 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.

*Dual-disc brakes*, which are always multiple piston types, are used on aircraft requiring more braking friction at lower pressure than single disc brakes provide. Pressure applied to the pistons of this type of brake pushes their attached linings against the brake disc nearest the pistons. That disc is then forced against the brake linings on its

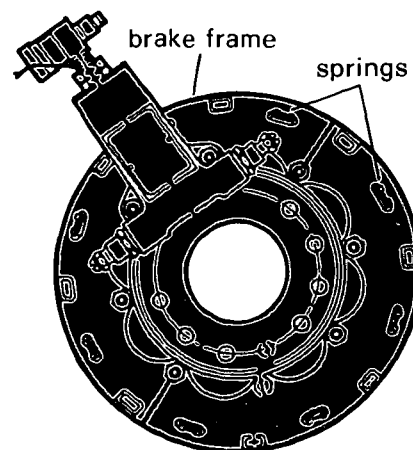
side of the center carrier assembly. This forces the center carrier assembly and its second set of brake linings against the second disc. The second disc is then forced against the brake linings in the anvil. In this manner, each brake disc receives equal braking action on both sides when the brake is operated. When brake pressure is released, the return springs within the self-adjusting mechanism in each cavity retract the pistons.

*Expander tube brakes.* An expander tube brake is shown here. This type of brake assembly consists of three main parts: the brake frame, the expander tube, and the brake blocks. Braking takes place when fluid pressure is directed through the fluid inlet (A) into the expander tube (B). The tube, being 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 slots in the ends of the brake blocks to retract the blocks. The expander tube then deflates and the brake returns to its 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.

**SCHEMATIC OF AN  
EXPANDER TUBE BRAKE ASSEMBLY**



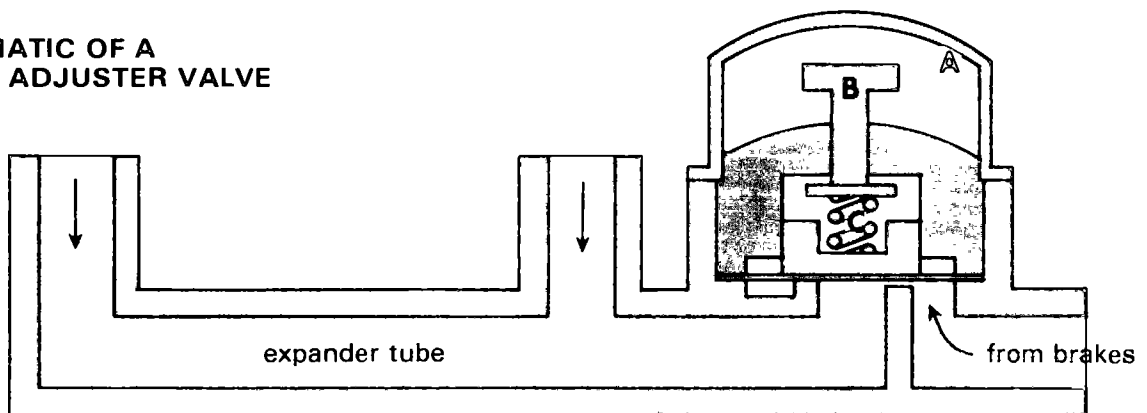
**EXPANDER TUBE  
BRAKE ASSEMBLY**



Some expander tube brakes have a brake adjuster valve; brakes without this valve cannot be adjusted. A typical adjuster valve is shown here. The first step in the adjustment is to release the brakes and remove the brake adjuster valve cap (A). Then turn the brake adjusting screw (B) several turns clockwise to tighten the spring (C). This position of 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 insure complete retraction of the brake blocks.

**SCHEMATIC OF A  
BRAKE ADJUSTER VALVE**



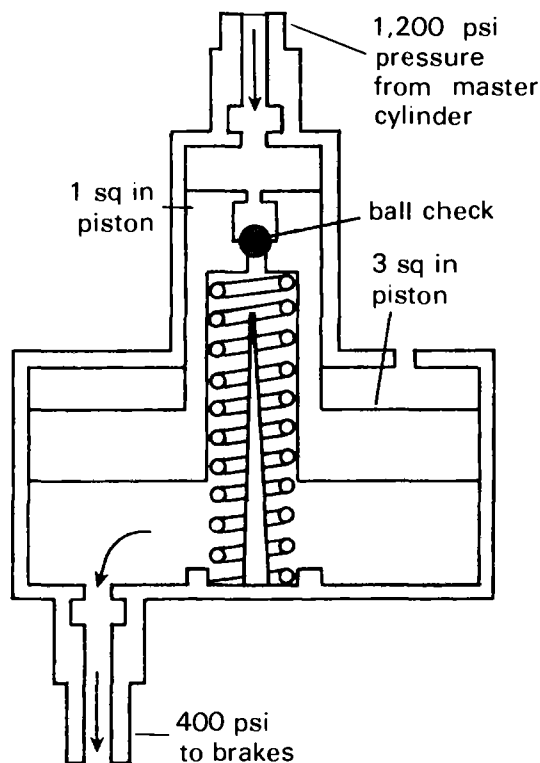
### ***Brake Deboosters.***

A deboost器 is used in an aircraft brake system pressurized by power boost master cylinders or power brake control valves to insure rapid application and release of brakes. This reduces excessive heating and wear of the brakes caused by the extra drag on the brakes 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 deboost器 solves this problem: It reduces the pressure but increases the volume to the brakes.

The basic elements of a typical brake deboost器 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. To illustrate how the deboster operates, let us assume that a master cylinder is connected to the upper port and a wheel brake assembly to the lower port and that the small end of the piston is 1 square inch in area and the large end, 3 square inches. 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

#### SCHEMATIC OF A BRAKE DEBOOSTER



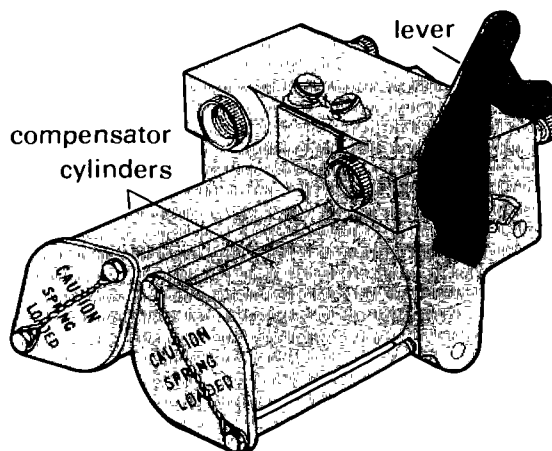
to the wheel brake assembly. If the master cylinder delivers 1 cubic inch of fluid to the small end of the deboster, the piston will move downward 1 inch. The resulting 1-inch movement of the larger piston will cause 3 cubic inches of fluid to be forced out of the lower port and into the wheel brake assembly.

This 3-to-1 increase in fluid movement during brake application results in faster braking. On the other hand, during release of the brake, 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 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 deboster in the event of thermal expansion of the fluid. It also serves to replenish fluid lost because of leakage.

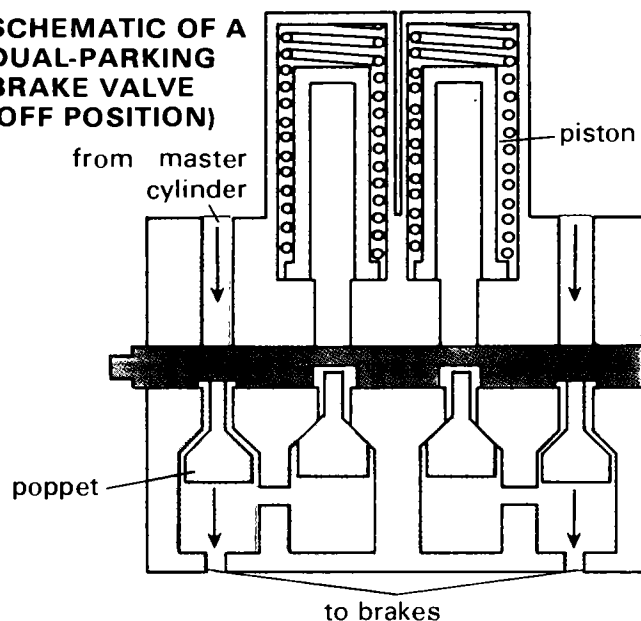
**Parking brake valves.** Parking brake valves are used on some aircraft wheel brake systems as a means of trapping fluid pressure in the wheel brake assemblies to keep the brakes applied for parking. Individual and dual type valves are commonly used. Because the dual type is basically a combination of two individual valves, this explanation of the dual valve will illustrate the operation of both types.

The typical dual parking brake valve shown here 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 means of a spring. The camshaft to which the

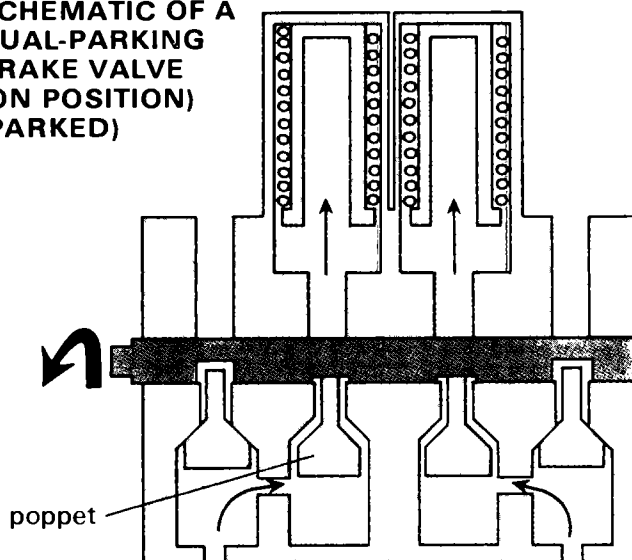
#### DUAL PARKING BRAKE VALVE



### SCHEMATIC OF A DUAL-PARKING BRAKE VALVE (OFF POSITION)



### SCHEMATIC OF A DUAL-PARKING BRAKE VALVE (ON POSITION) (PARKED)



lever is attached holds the two outer poppets of the valve unseated as shown here. 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.

To set the brakes for parking, the parking brake valve is left in the off position until the brake pedals are depressed. While the brake pedals are still depressed, the parking brake control handle is pulled to the park position. This rotates the camshaft of the valve, causing the outer poppets to seat as shown here; 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 produced by changes in temperature and by minor leaks.

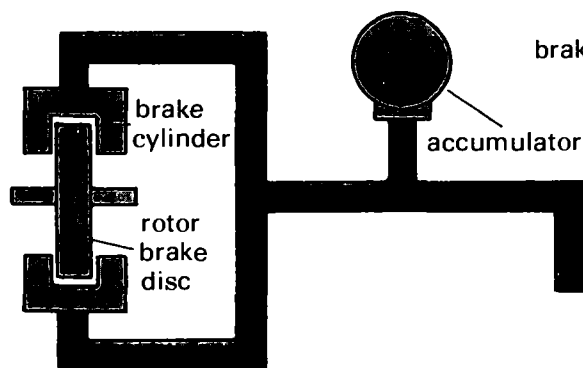
After the parking brake has been set in the park position, the brake pedals are released. The parking brake lever then becomes locked in the park position by means of a locking pin, which is extended to the locking position by a spring. The locking pin is retracted, permitting release of the lever by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

## HELICOPTER ROTOR BRAKE SYSTEMS

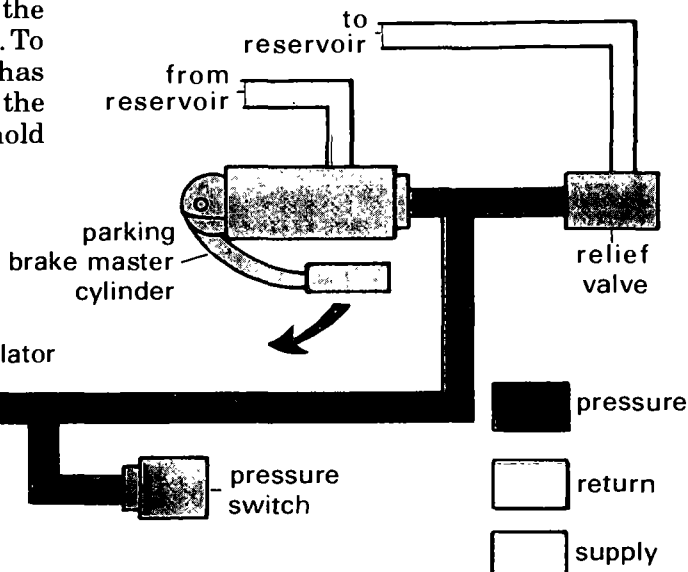
Rotor brake systems are installed on some helicopters as a means of shortening the time required to bring their rotor assemblies to rest after power has been shut off. They also prevent the rotor assemblies of parked helicopters from windmilling. A basic hydraulic rotor brake system is shown here. Newer helicopters have more complex systems, but the same basic principles apply.

To apply the rotor brake, the master cylinder handle is slowly pushed downward and forward. This results in a movement of the master cylinder piston that forces fluid out of the master cylinder and into the rotor brake cylinders. Movement of the fluid 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 means of 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.



### SCHEMATIC OF A ROTOR BLADE HYDRAULIC SYSTEM



## MAINTENANCE OF BRAKE SYSTEMS

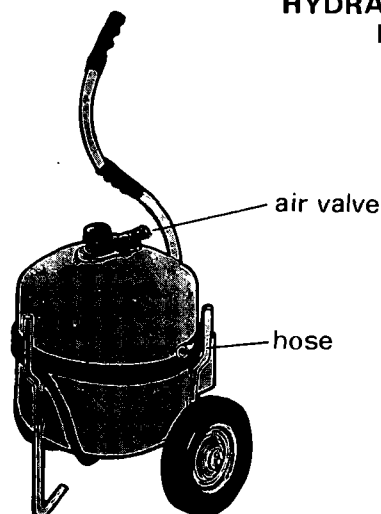
**Inspecting brake systems.** Proper functioning of the brake system is of utmost importance. Inspections must be conducted at frequent intervals, and maintenance work which might be indicated must be performed promptly and carefully. The system should be under operating pressure when it is being checked 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 and should be replaced if evidence of deterioration is noted. The proper fluid level must be maintained at all times to prevent brake failure or the introduction of air into the system. Air in the system is indicated by a spongy action of the brake pedals. If air is present in the system, it must be removed by bleeding.

### Bleeding Brake Systems.

There are two general methods of bleeding brake systems—from the bottom upward (pressure) and from the the top downward (gravity method). The method used generally depends on the type and design of the brake system to be bled, but it sometimes depends on the bleeding equipment available.

**Bleeding by the 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 (bleeder bomb) such as the one shown here. A bleeder bomb is a portable tank

### HYDRAULIC FLUID DISPENSER



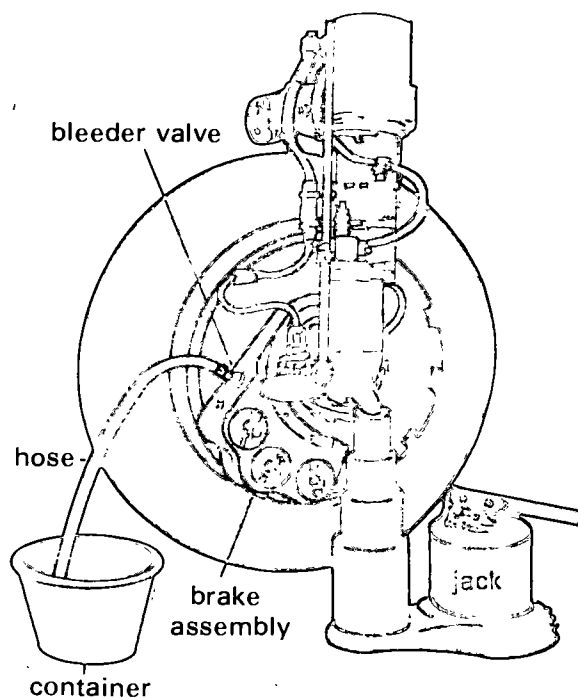
which is filled with hydraulic fluid that is then put under pressure with compressed air. The bleeder bomb is equipped with an air valve, an air gage, and a connector hose. The connector hose is provided with a shutoff valve. This connector hose is normally connected to the lowest bleed fitting on the brake assembly. With the brake bleed fitting opened, opening the bleeder bomb shutoff valve allows pressurized fluid to flow from the bleeder bomb through the brake system until all trapped air is expelled. The brake bleeder valve is then secured, and the bleeder bomb hose is disconnected.

### CAUTION!

INSURE THAT A SUFFICIENT AMOUNT OF FLUID IS MAINTAINED IN THE BLEEDER BOMB DURING BLEEDING OPERATIONS:

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

### THE GRAVITY METHOD FOR BLEEDING BRAKE SYSTEM



*Bleeding by the gravity method.* In the gravity method, the air is expelled from the system through one of the bleeder valves on the brake assembly. As shown here, a bleeder hose is attached to the bleeder valve and the free end of the hose is placed in a container holding enough hydraulic fluid to cover the end of the hose. 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, a portable hydraulic test stand may be used to supply the pressure. If the system is an independent master cylinder system, the master cylinder will supply the necessary pressure. In either case, each time the brake pedal is released, the bleeder valve must be closed; 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.

*Troubleshooting brake systems.* Table 10-1 lists common troubles found in wheel brake systems used on Army aircraft. Table 10-2 lists common troubles 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 .....	Bleed system.
	Leaks in system .....	Check for leaks and tighten all fittings.
	Worn brake linings .....	Replace brake linings as necessary.
	Oil or grease on brake linings .....	Replace brake linings as necessary.
	Leak in master cylinder or power brake control valve.	Replace master cylinder or power brake control valve and bleed system.
Brakes grab .....	Stones or other foreign matter locking brake disc.	Clean brake disc brake linings.
	Warped or bent brake disc .....	Replace brake disc.
Brakes will not release .....	Parking brake stuck .....	Replace parking valve and bleed system.
	Blockage in master cylinder or power brake control valve.	Replace master cylinder or power brake control valve and bleed system.
Dragging brakes .....	Warped disc .....	Replace disc.
	Automatic adjusting mechanism faulty	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.	Replace power-boost master cylinder and bleed system.
	Excessively worn brake linings .....	Replace brake linings.
	Failure of main or utility hydraulic system pressure.	Check main or utility hydraulic system and correct defect.
Parking brake will not hold .....	Air in system .....	Bleed brakes.
	Defective parking brake valve .....	Replace parking brake valve and bleed system.
	Parking brake valve control out of adjustment.	Adjust parking valve control.
Pedals bottom, no brakes .....	Broken or leaking brake line .....	Replace damaged line and bleed system.
	Master cylinder or power brake control valve defective.	Replace master cylinder or power brake control valve and bleed system.
	Excessively worn brake linings .....	Replace brake linings.
	Air in system .....	Bleed brakes.
	Too little fluid in system .....	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 .....	Bleed brakes.
	Low hydraulic fluid level .....	Replenish supply.
Unable to hold pressure .....	Leak in brake system .....	Visually check entire system for evidence of leaks.
	Master cylinder or power brake control valve defective.	Replace master cylinder or power brake control valve and bleed system.
Uneven braking .....	Worn brake linings .....	Replace brake linings.
	Worn brake disc .....	Replace brake disc.
	Air in system .....	Bleed system.
	Leaking line connection .....	Tighten connection and bleed system.
	Worn or damaged pressure relief valve.	Replace pressure relief valve and bleed system.
Weak braking .....	Air in system .....	Bleed system.
	Master cylinder or power brake control valve defective.	Replace master cylinder or power brake control valve and bleed system.
	Insufficient supply of hydraulic fluid	Replenish supply.
	Brake linings worn excessively .....	Replace brake linings.

**TABLE 10-2. TROUBLESHOOTING  
ROTOR BRAKE SYSTEMS**

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

## CHAPTER 11 DAMPENING AND ABSORBING UNITS

The units discussed in this chapter all serve the same general purpose: They retard the motion of moving objects to which they are attached. These units perform this function by removing some of the energy of motion from the moving objects and converting this energy to heat. The heat is then dissipated into the surrounding atmosphere. Dampening and absorbing units used in Army aircraft fall into the following general categories:

HYDRAULIC DAMPERS .....	11-1
SHOCK STRUTS .....	11-6
LIQUID SPRINGS .....	11-10

### HYDRAULIC DAMPERS

A damper is a device for controlling 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. This resistance slows the speed of relative movement between the objects. Hydraulic dampers used in Army aircraft operate either by displacing fluid or by shearing fluid.

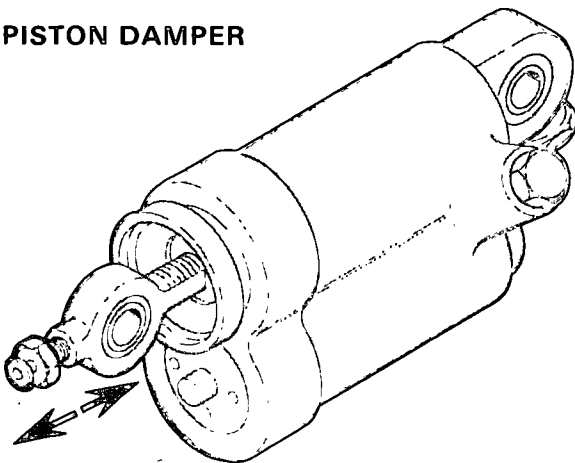
#### ***Displacement-Principle Dampers.***

Displacement-principle dampers used in Army aircraft are of two types—piston and

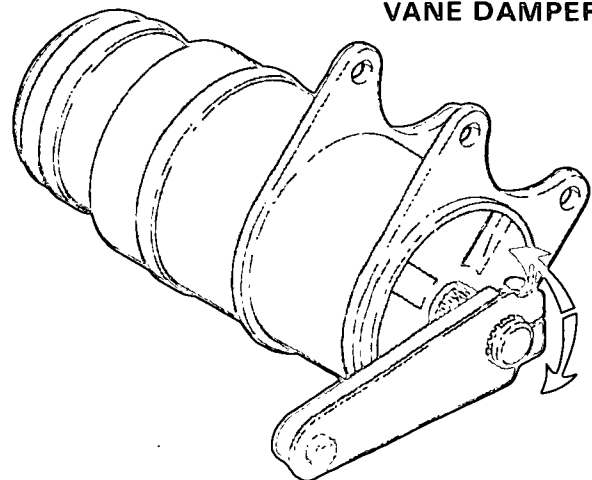
vane. Though different in construction, both types have the same basic design characteristics—a sturdy metal container with a sizeable inner space divided into two or more chambers. The chambers vary in size according to the position of parts within the damper. The chambers must be completely filled with fluid in order to operate properly.

*Piston-type displacement dampers.* Note that in the piston-type damper the piston and rod assembly divides the space within the damper housing into two chambers. Seal rings on the piston prevent fluid leakage

**PISTON DAMPER**



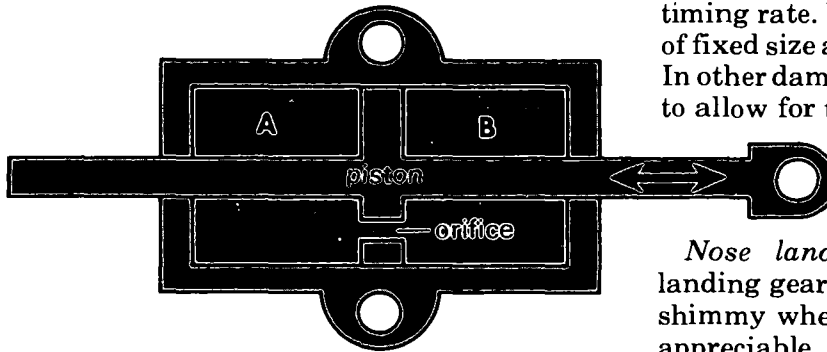
**VANE DAMPER**



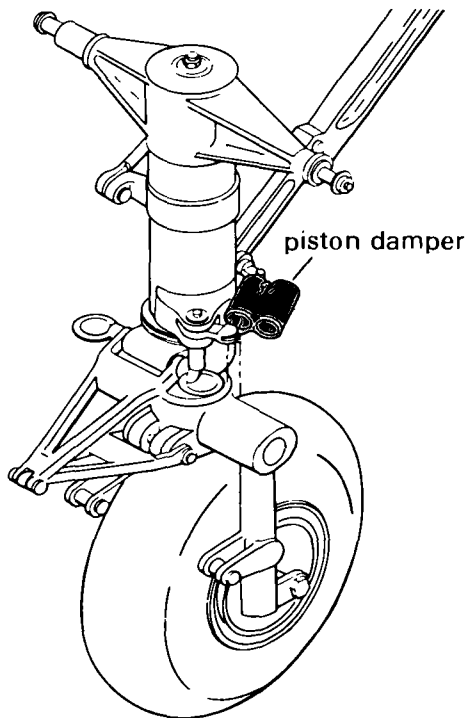
between the chambers. An orifice permits fluid to pass with restricted flow from one chamber to the other. A filler port (not shown) provides for servicing the damper with fluid.

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

#### SCHEMATIC OF PISTON DAMPER



#### NOSE LANDING GEAR WITH PISTON DAMPER

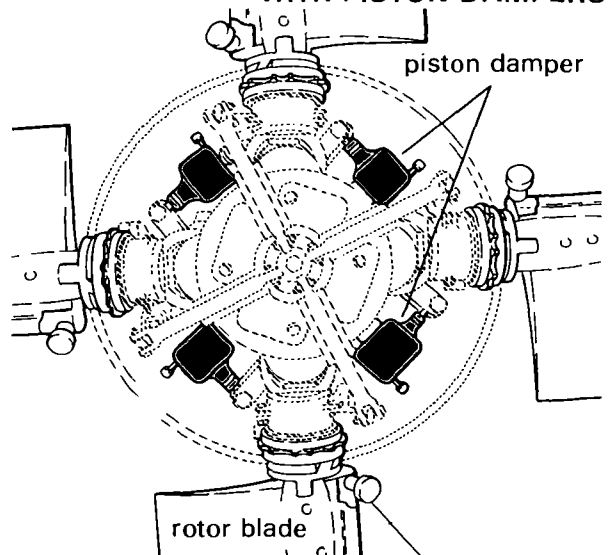


hydraulic fluid displaced from chamber B flows through the restricting orifice into chamber A. When the piston is moved toward the left, reverse changes occur in the chamber sizes and in the direction of fluid flow. The restriction of the fluid flow by the orifice slows the rate of speed at which a given 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 of fixed size and timing rate is not adjustable. In other dampers, the orifice size is adjustable to allow for timing adjustments.

*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. A damper is used as shown here to eliminate wheel shimmy without interfering with the normal steering movements on the nose wheel.

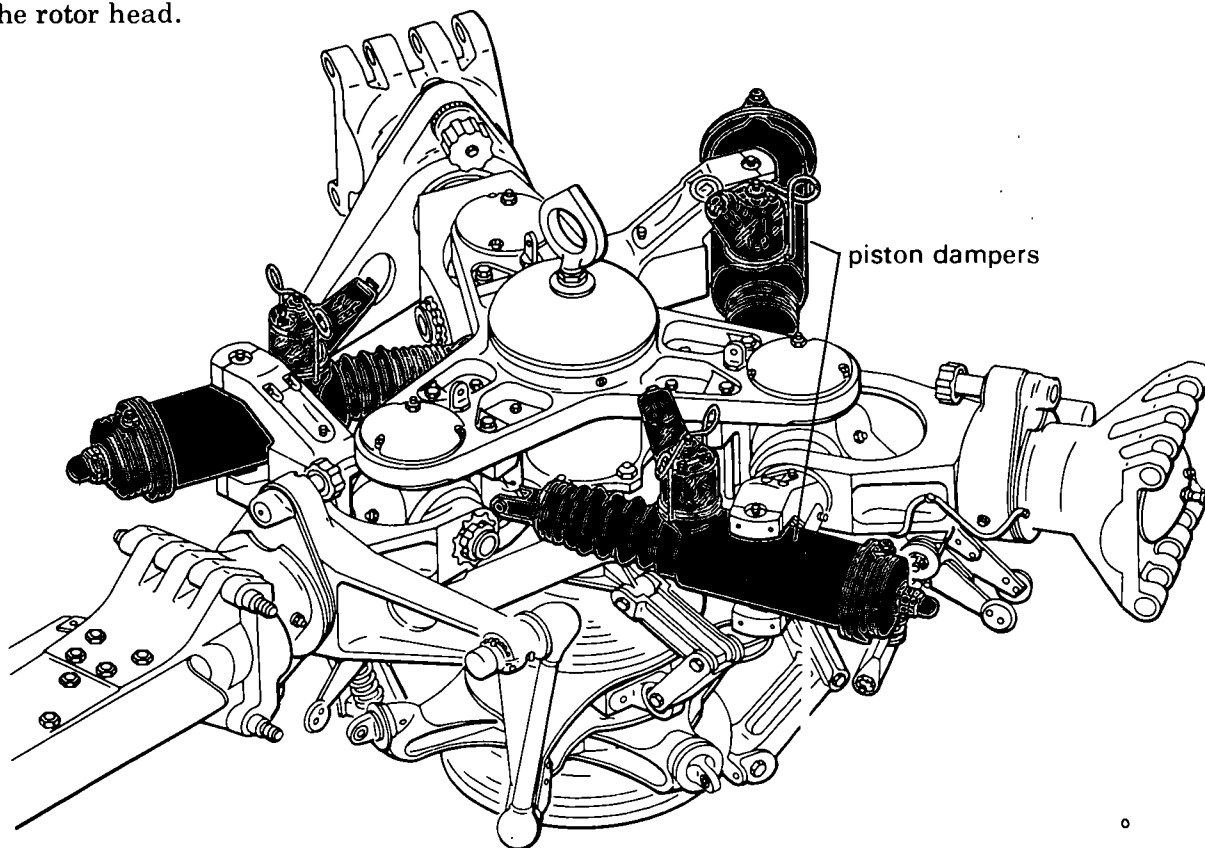
*Tail rotor pedal damper.* Piston-type dampers are used on some helicopters that have power-assisted tail rotor control systems. The dampers are connected to the pedals to prevent too rapid movement of the pedals. If the pedals move too rapidly, excessively fast yaw movement of the aircraft results and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

#### TAIL ROTOR ASSEMBLY WITH PISTON DAMPERS



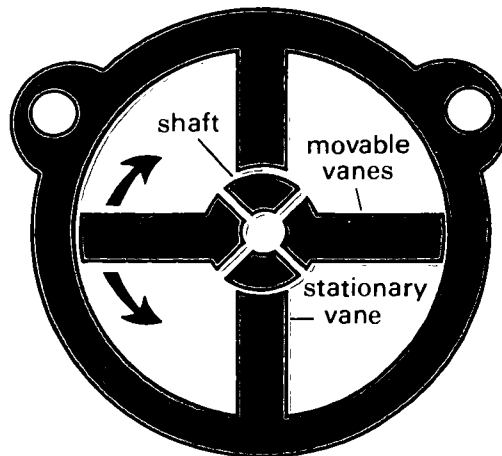
**Rotor blade damper.** Piston-type dampers are used on helicopter rotor head assemblies and on tail rotor hub assemblies to control lead-lag movements of rotor blades. Note how the dampers are connected in this illustration. Lead-lag movements of rotor blades occur in cases in which there are three or more blades in a set and the blades are hinged to the rotor head.

**MAIN ROTOR ASSEMBLY WITH PISTON-TYPE ROTOR BLADE DAMPERS**



**Vane-type displacement dampers.** A diagram of a typical vane-type damper is shown here. This type of damper consists basically of a cylindrical housing having a polished bore with two stationary vanes (called abutments) and having a shaft supporting two movable vanes. 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. The wing shaft rotates between the abutments. One end of the wing shaft is splined and protrudes through the damper housing. A lever arm,

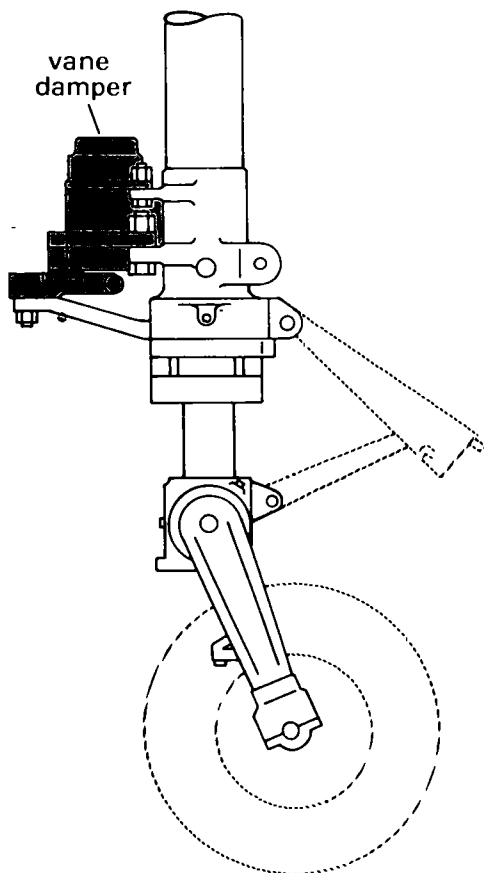
**SCHEMATIC OF A VANE DAMPER**



attached to the splined end, is the means of rotating the wing shaft.

The damper chambers are completely filled with fluid, and at any instant of damper motion the fluid is subjected to forced flow. As the wing shaft rotates, fluid flow between the chambers takes place through an opening within the wing shaft, which interconnects the four chambers. Thus 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 the damper housing causes a low velocity flow through the opening and little resistance to damper arm rotation. 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

#### NOSE LANDING GEAR WITH VANE DAMPER



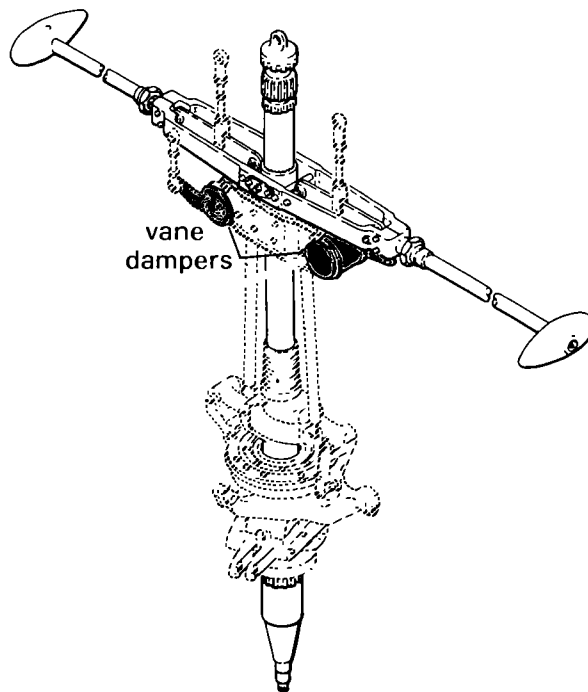
the wing shaft. This adjustment (not shown) sets the effective size of the opening through which fluid flows between chambers and thus determines the speed of movement with which the damper will respond to an applied force.

The vane-type mechanism is sensitive to changes in fluid viscosity caused by changes in fluid temperature. In order to provide consistent timing rate performance over a wide range of temperatures, most vane-type dampers have a thermostatically operated compensating valve (not shown).

*Nose landing gear damper.* Vane-type dampers such as the one shown here are used on the nose landing gear of some aircraft to eliminate the shimmy tendency.

*Stabilizer bar damper.* Some helicopters have vane-type dampers such as the one shown here that serve to control the degree of sensitivity with which a helicopter responds to movements made by the pilot on the flight controls. 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.

#### HELICOPTER STABILIZER BAR WITH VANE DAMPERS



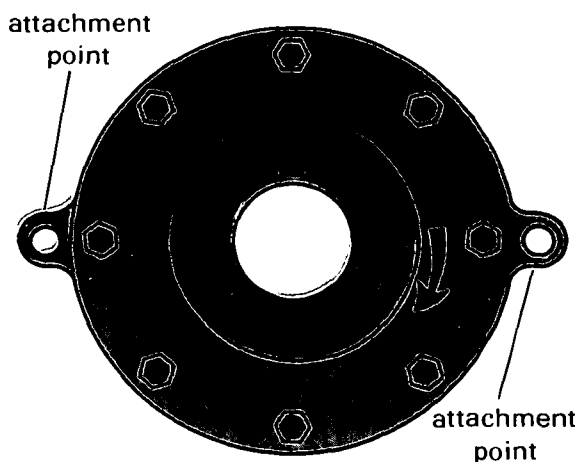
### Shear-Principle Dampers.

In dampers operating on the shear principle, fluid is not forced out of one space and into another within the damper as in the case of 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. A highly viscous fluid is thick-bodied, syrupy, and sticky.

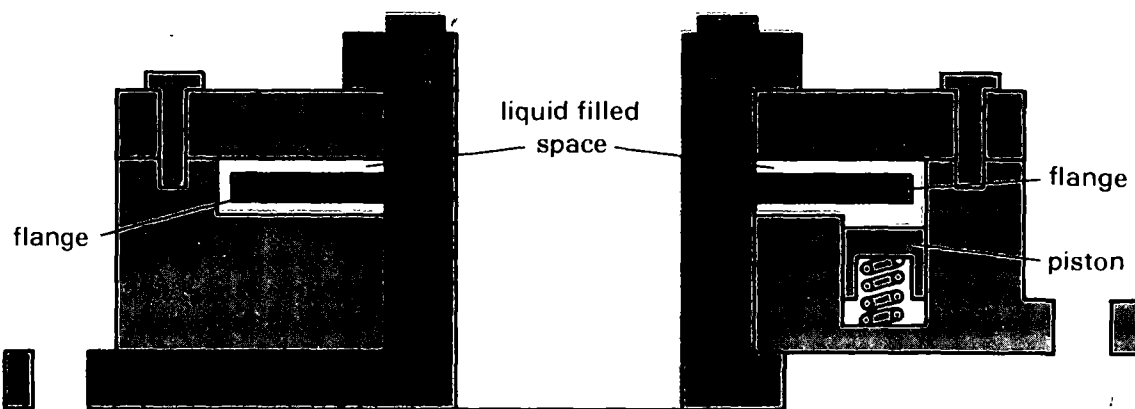
In a shear-principle damper, two reacting parts are free to slide or rotate past each other as the damper operates. The surfaces facing each other are relatively smooth, and between them there is a preset gap of a few thousandths of an inch. This gap is filled with a highly viscous fluid. As the parts of the damper move relative to each other, the film of fluid in the gap between them shears into two thinner films. Each film adheres 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 adhere. 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-principle damper as the damper operates. You will work with two types of shear principle dampers on Army aircraft: rotary and linear.

*Rotary-type shear-principle dampers.* A typical rotary-type shear-principle damper such as the one shown here consists of two members that are free to rotate together. Each of the members is connected to one of the two objects whose relative movement the damper is to restrain. One of the damper members has a flange-like section that fits between these two objects. Bearing points insure that the flange is centered between the two surfaces. The spaces between the flange surfaces and the other two surfaces are filled with a highly viscous fluid. A spring-loaded piston applies pressure to a supply of replenishment fluid to insure that the spaces are always completely filled with fluid.

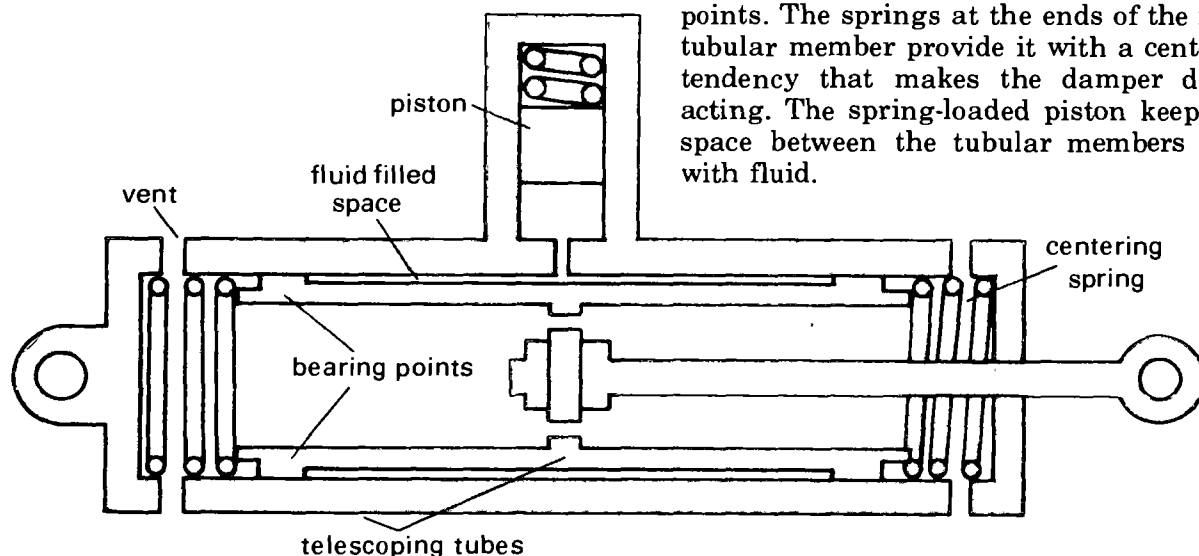
### ROTARY DAMPER



### SCHEMATIC OF A ROTARY DAMPER



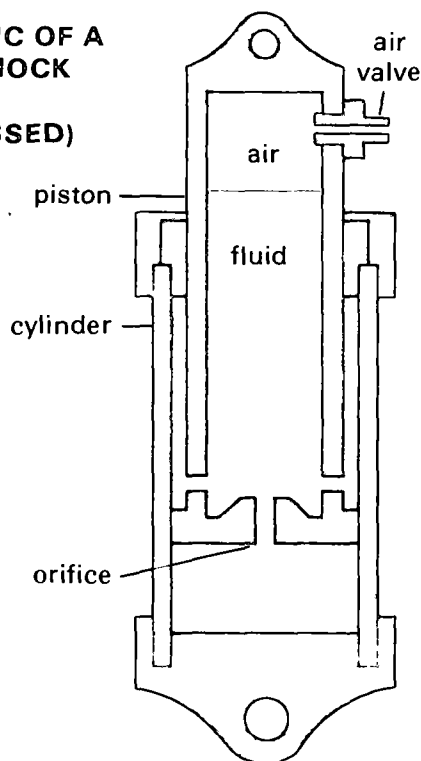
### SCHEMATIC OF LINEAR-TYPE SHEAR PRINCIPLE DAMPER



*Linear-type shear-principle dampers.* A typical linear-type shear-principle damper such as the one shown here consists of two telescoping tubular members that can be connected to the two objects between which movement is to be restrained. Between the telescoping tubes, there is a preset space that is held to a uniform thickness by bearing points. The springs at the ends of the inner tubular member provide it with a centering tendency that makes the damper double acting. The spring-loaded piston keeps the space between the tubular members filled with fluid.

### SHOCK STRUTS

### SCHEMATIC OF A SIMPLE SHOCK STRUT (COMPRESSED)



A shock strut can be thought of as a combination suspension unit and shock absorber. The shock strut performs functions in an aircraft similar to those performed in an automobile by the chassis spring and the shock absorber. There are two major types of shock struts, the classification depending on construction and operation. 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, we will discuss only that type in this manual.

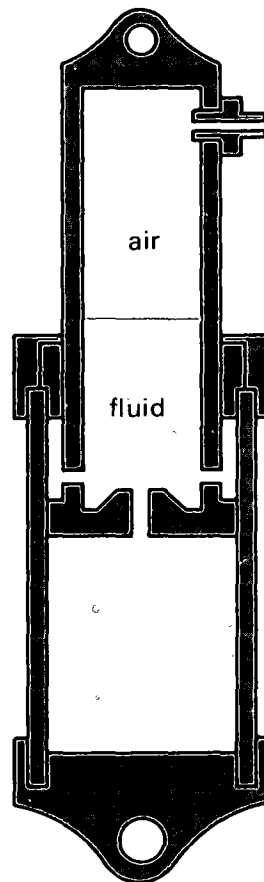
*Simple shock struts.* The basic parts of a simple shock strut are two telescoping tubes: a piston and a cylinder. A simple shock strut is installed in an aircraft as shown here--with the piston uppermost and with the cylinder filled with fluid. An orifice in the piston head permits fluid to pass from one chamber to the other. When a shock strut has sufficient fluid above the piston head, the



space 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 motion of the descending aircraft. When the load on the shock strut is lightened, the shock strut extends. 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 the attached landing gear. When the shock strut is extending, fluid in the piston passes through the orifice from the piston into the cylinder.

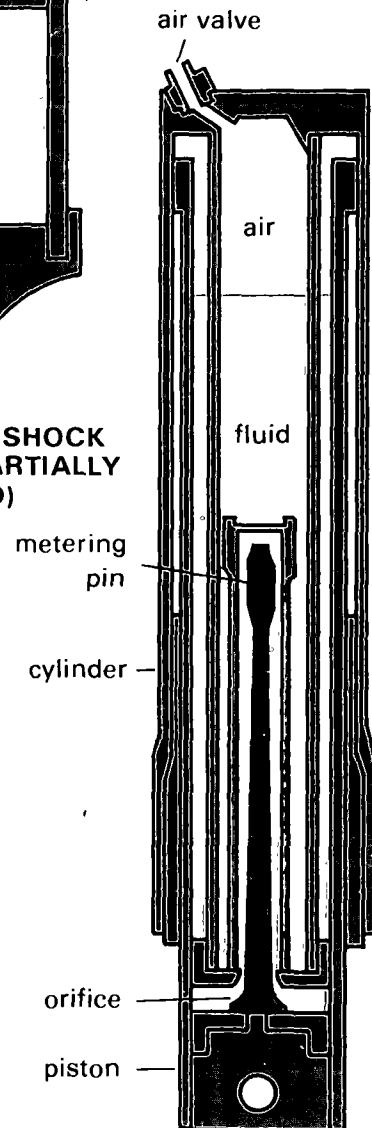
**Complex shock struts.** Complex shock struts work in essentially the same manner as simple ones. However, they contain, in addition to two telescoping tubes, a number of parts that make for more effective damping action than is possible with simple struts. Design features found singly or in combination in complex-type shock struts are as follows:

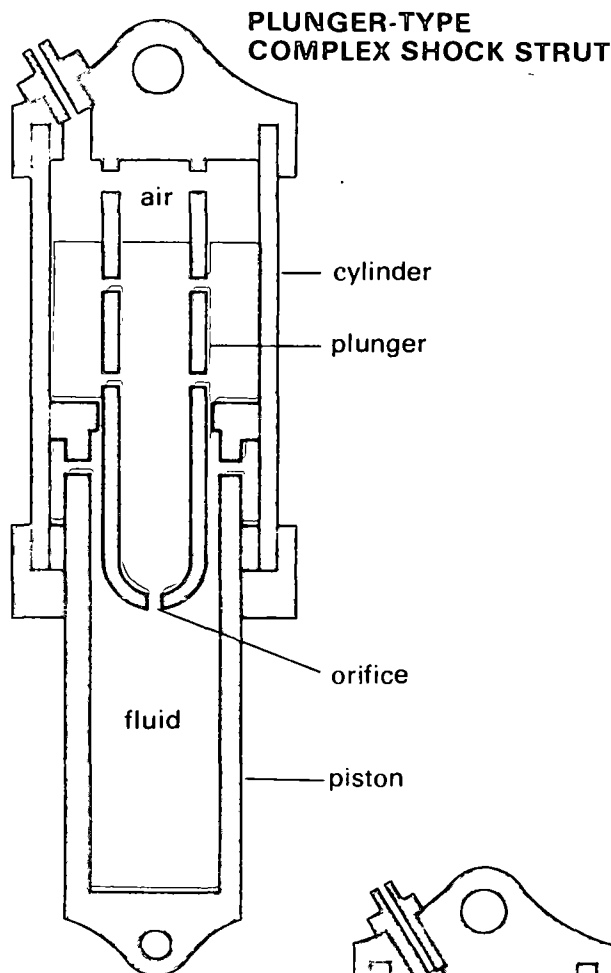
**Metering pin.** The metering pin is a means of changing the effective size of the orifice so as to vary the rate of fluid flow from one chamber of the shock strut to the other. The diameter of the metering pin varies along its length, being almost equal at the ends and smaller in the middle. Note that 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 its 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 insures 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.



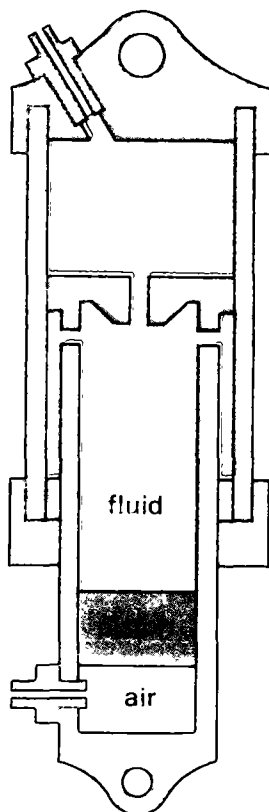
**SCHEMATIC OF  
A SIMPLE SHOCK  
STRUT  
(EXTENDED)**

**COMPLEX SHOCK  
STRUT (PARTIALLY  
EXTENDED)**





**FLOATING  
PISTON-TYPE  
SHOCK STRUT  
(COMPRESSED)**



*Plungers.* Some complex shock struts are mounted on the aircraft with their cylinders uppermost as shown here. 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 compression of the shock strut. The plunger is hollow, and fluid enters and leaves its interior through an orifice and through holes in its walls.

*Floating pistons.* 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, some means 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 as shown here. This is because compression of the shock strut forces fluid downward out of the upper chamber into the lower fluid chamber. The increase in size of the lower fluid chamber, necessary for accommodating the inflow of fluid, is obtained by downward movement of the floating piston. Thus, in addition to 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.

### *Uses of Shock Struts.*

Shock struts perform three major functions:

- They support the static load (deadweight) of the aircraft.
- They cushion the jolts during taxiing or towing of the aircraft.
- They reduce shock during landing.

*Supporting static loads.* The normal load of a parked aircraft is static; that is, 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 during taxiing.* As an aircraft taxis, the unevenness of the runway surface 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 movements causes the force of the taxi load to fluctuate. This bouncing motion is held within limits by the damperlike 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 during landing.* 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 perform this task, 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 thus some 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 to bounce the aircraft back into the air. For reasons of 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 annular 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, the resistance varying 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 a 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.

*Servicing shock struts.* Shock struts should be frequently checked for leakage, proper air pressure, security of attachment, and cleanliness. The exposed portion of the shock strut piston should be cleaned frequently with a clean, lintfree 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!

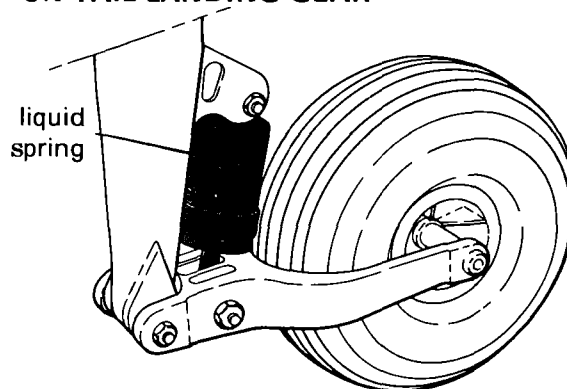
ALWAYS BE SURE TO RELEASE THE AIR PRESSURE BEFORE ATTEMPTING TO REMOVE THE AIR VALVE CORE OR THE AIR VALVE ASSEMBLY. ROCK THE AIRCRAFT AND DEPRESS THE VALVE CORE SEVERAL TIMES WITH A SUITABLE METAL TOOL TO INSURE THAT ALL PRESSURE IS RELEASED. AIR PRESSURE COULD BLOW OUT THE AIR VALVE ASSEMBLY OR THE VALVE CORE WHEN THEY ARE LOOSENED.

## LIQUID SPRINGS

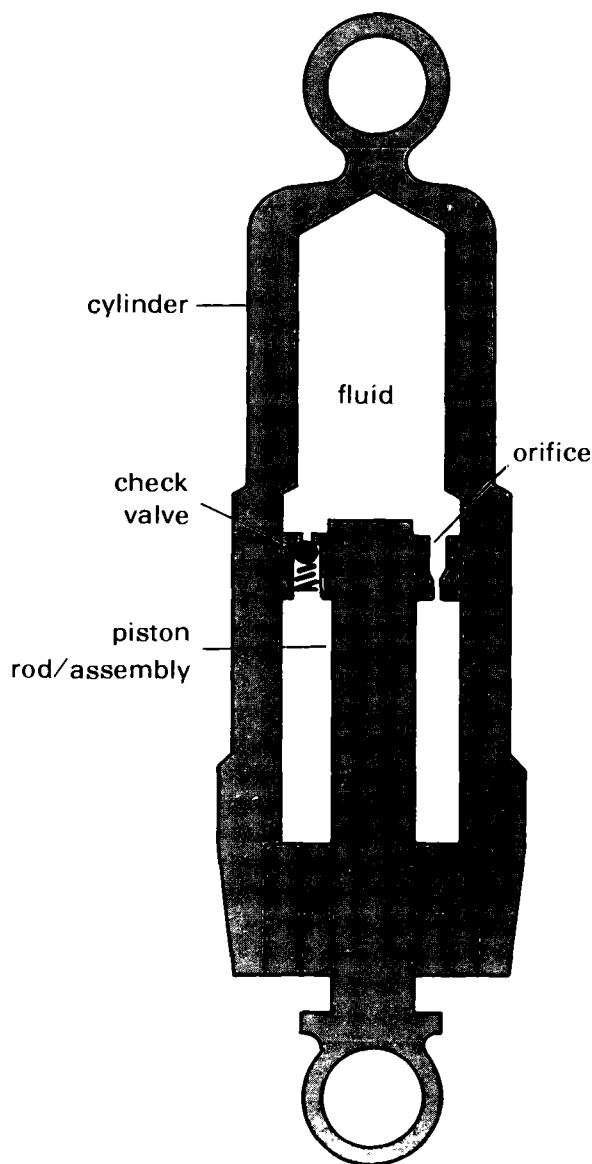
**Operation.** The liquid spring contains hydraulic fluid under pressure. The cushioning effect of the spring is produced by effecting a slight compression in the fluid. Note that the piston rod fits into the inner space of the cylinder and that a gland seal is provided to prevent fluid leakage as the piston rod moves into and out of the housing. The housing is attached to a stationary part of the aircraft, and the piston rod is connected

to a movable part of the landing gear. A typical installation of a liquid spring on a tail landing gear of an Army aircraft is shown here.

### LIQUID SPRING INSTALLED ON TAIL LANDING GEAR



### SCHEMATIC OF A LIQUID SPRING



**Uses.** The liquid spring performs the same functions as the shock struts just discussed, but there are differences in operation. The manner in which the liquid spring performs these functions is described below:

**Supporting static loads.** The weight of the parked aircraft tends to move the housing of the liquid spring downward over the piston rod. The inward movement of the piston rod decreases the space occupied by the fluid. This compresses the fluid, thus increasing its pressure. The movement continues until fluid pressure puts a force on the shaft equal to the force tending to move the shaft inward. When this point is reached, no further inward movement of the shaft takes place and the aircraft is held in a stationary position.

**Cushioning during taxiing.** The liquid spring controls the bouncing motion of the aircraft in much the same way as the shock strut does. As the piston in the liquid spring moves inward and outward in relation to its housing, there is a back-and-forth movement of fluid through an orifice in the piston. This fluid flow restrains the rate at which the piston moves, thus dampening the up-and-down movements of the aircraft fuselage.

*Reducing shock during landing.* In the liquid spring, the resistance to fluid flow necessary to convert motion energy to heat energy is effected by means of a check valve in the piston. As the liquid spring compresses, fluid flows through the check valve in addition to flowing through the orifice. During extension, 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.

### ***Servicing Liquid Springs.***

The exposed portion of the liquid spring shaft should be cleaned by using a clean, lintfree cloth moistened with hydraulic fluid.

When the liquid spring is serviced to the correct level with the proper type of hydraulic fluid, the fluid is 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 also included in the manual for the aircraft.



## CHAPTER 12

**SHOP SAFETY**

If all of us would practice safety continuously, we could greatly reduce the number of accidents. It is estimated that 88 percent of all accidents are caused by acts of people. All such accidents could be prevented. You can help to prevent accidents at work by observing the safety reminders given in this chapter under the headings:

WORK AREA HOUSEKEEPING ..... 12-1

FIRE PREVENTION ..... 12-1

WORKING IN DANGEROUS AREAS .. 12-3

---

**WORK AREA HOUSEKEEPING**


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Everyone assigned to the shop should make an effort to improve safety conditions. Always be on the alert for unsatisfactory conditions that could result in injury to personnel or damage to equipment. Preventive maintenance and periodic inspections of shop equipment are important factors in keeping the shop safe and efficient. Some general guidance follows:

- Keep your work area clean, orderly, and free of obstructions. An extension cord or a dropped tool may cause you to trip and injure yourself. A cluttered bench makes effective work almost impossible.
- Some units that you will disassemble are made up 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.
- Wornout parts should be disposed of promptly in the correct places--not on the floor.
- Every shop has a designated place for toolboxes. Keep them in their place and keep the lid closed. This is not only a good safety practice: It makes you work more efficiently.
- Common handtools are a frequent source of injury. Use tools for their designed purposes and keep them in a good state of repair. (See TM 9-243 for guidance in the use and care of handtools.)
- 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 coding used on power equipment. Red is used to indicate danger or to identify emergency stop devices; yellow, to indicate caution; green, to identify safety equipment facilities. Black and white are used for informational signs.

---

**FIRE PREVENTION**


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Many fires are caused by carelessness and by poor housekeeping. Here are a few precautions that you should observe to prevent shop fires:

- 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. In addition to 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 you work 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.

You should know the telephone number of the post fire department and the location of the fire extinguishers in the shop. Types of fires and the extinguishers to be used on each are shown in table 12-1.

### CAUTION!

THOUGH FIRE EXTINGUISHERS MAY LOOK ALIKE, THE EXTINGUISHING AGENTS INSIDE MAY VARY. A FIRE MAY BE MADE WORSE IF 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 and oil base material, varnishes, wood, trash, 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.	CO <sub>2</sub> will not support life. Avoid extended exposure in area where it has been used, especially in pits.
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, the liquid 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.



## WORKING IN DANGEROUS AREAS

Although hazards exist in some areas in which you work, you can minimize the danger to yourself by being careful. Some general precautions follow:

- Do not stand in line with the turbine wheel during engine runup.
- The high-velocity, high-temperature exhaust blast of a turbine engine is especially hazardous to personnel. Do not pass close behind an aircraft when its engine is running.
- Do not approach jet intakes when the engine is operating. The intake ducts should be free of all objects.
- Noise endangers a person's hearing and makes speech communication almost impossible, and is fatiguing. 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 and wear a headset in addition to 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. In the ear area, he may have pain, a feeling of fullness, a ringing sound, or a burning sensation. He may experience dizziness, slowed mental concentration, nausea, vomiting, or weakness of the knees. When any of these symptoms are noted, the affected person should be taken from the noise area immediately and 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.
- You will perform only limited maintenance on armed aircraft, but be extremely careful when performing these duties. Observe and obey all armament warning signs, and be careful in the use of external power. Don't operate any armament switches or remove their safety devices. Before you begin work on armed aircraft, study the applicable aircraft technical manual in order to be completely familiar with the safety precautions.
- When working in an ejection seat area, be careful to avoid accidental arming and firing. High-level heat or movement of the actuating mechanisms can fire the ejection seat. Know where the safety pins are installed and how they should be installed. Do not place tools in your pockets while working in the cockpit.
- Aircraft with power-operated devices, such as flight control mechanisms and landing gear, present a possible danger. Most such devices are hydraulically operated. Careless operation can damage equipment and injure people. When operating systems to check them out, make sure that they are clear of personnel and equipment. Have someone stand by to make sure that everyone stays clear of the danger areas.
- 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 under any circumstances 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



## APPENDIX A

# REFERENCES

### ARMY REGULATIONS

**AR 310-50** Authorized Abbreviations and Brevity Codes.

### DEPARTMENT OF THE ARMY PAMPHLETS

**DA Pam 310 series** Military publications indexes.

### TECHNICAL MANUALS

**TM 9-243** Use and Care of Handtools and Measuring Tools.

**TM 55-1500-204-25/1** General Aircraft Maintenance Manual.

**TM 55-1510 series** Operator's, direct support, general support, and depot maintenance manuals (fixed-wing aircraft).

**TM 55-1520 series** Operator's, direct support, general support, and depot maintenance manuals (rotary-wing aircraft).

### TECHNICAL BULLETINS

**TB 55-1500-334-25** Conversion to Fire Resistant Hydraulic Fluid.

**TB 750-103** Maintenance and Care of Common Type Machine Tools and Shop Equipment Before, During, and After Operation.

**TB 750-125** Assembly and Inspection of Medium Pressure Hose and Hose Assemblies, Tetrafluoroethylene (Teflon).

### NAVY RATE TRAINING MANUAL\*

**NAVPERS 10310-B** Aviation Structural Mechanic H 3 & 2.

\*This publication can be obtained from--

Navy Publication and Forms Center  
5801 Tabor Avenue  
Philadelphia, Pennsylvania 19120



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## APPENDIX B

# GLOSSARY

The words in this glossary are defined in terms of their use in hydraulics.

**accumulator**--a device for storing liquid under pressure, usually consisting of a chamber separated into a gas compartment and a liquid compartment by a piston or a diaphragm; an accumulator also serves to smooth 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 used to remove air from a hydraulic system; it may be a needle valve, capillary tubing to the reservoir, or a bleed plug.

**back pressure**--pressure exerted against the pressure producing the main flow.

**boss**--a protruding part or body, such as a stud or the hub of a propeller.

**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 a body constraining the object and that acts outwardly away from the center of rotation.

**check valve**--a valve that permits fluid flow in one direction but prevents a return flow.

**circuit**--an arrangement of interconnected component parts.

**compressed air**--air under pressure greater than the local atmospheric pressure.

**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 to do 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 for controlling the rate of flow of fluid in a system.

**flowmeter**--an instrument for measuring the velocity of flow of a liquid in a pipe; an instrument for indicating 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 for packing pistons or for making pipe or other joints fluid tight.

**horsepower**--a unit equal to a rate of 33,000 foot-pounds per minute (used for measuring the power of motors or engines); the force required to raise 33,000 pounds at the rate of 1 foot per minute.

**hydraulics**--a branch of mechanics or engineering 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.

**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: whenever an external pressure is applied to any confined fluid at rest, the pressure is increased at every point in the

fluid by the amount of the external pressure.

**pilot valve**--a relay valve that controls the operation of another valve.

**pneumatics**--that branch of physics pertaining to the pressure and flow of gases.

**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.

**pump**--a device for converting 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 for controlling large amounts of power by means of very small amounts of power.

**servocontrol**--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 a definite shape and a definite volume.

***surge***--a momentary rise of pressure in a system.

***thermal expansion***--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.

***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).





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**FM 55-409**

**29 DECEMBER 1980**

By Order of the Secretary of the Army:

**E. C. MEYER**  
*General, United States Army*  
*Chief of Staff*

Official:

**J. C. PENNINGTON**  
*Major General, United States Army*  
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