SUBCOURSE
AL0926

EDITION
A

BASIC HYDRAULIC SYSTEMS AND COMPONENTS

READINESS/PROFESSIONALISM THRU GROWTH

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

BASIC HYDRAULIC SYSTEMS AND COMPONENTS

Subcourse Number AL 0926

EDITION A

US Army Aviation Logistics School
Fort Eustis, Virginia 23604-5439

4 Credit Hours

Edition Date: September 1994

SUBCOURSE OVERVIEW

This subcourse is designed to provide instruction on the concept and operation of the basic components of the hydraulic system. It also describes the various components of a typical hydraulic system, their construction and functions, and their relationship to each other.

When the term hydraulics is applied to aircraft, it means a method of transmitting power from one location to another through the use of a confined fluid. The functions performed by hydraulic systems in aircraft include assisting in flight control, extending and retracting landing gear, positioning flaps, operating hoists, raising and lowering cargo doors, and starting engines.

The hydraulic systems used in Army aircraft are dependable and relatively trouble-free. The maintenance requirements are small in comparison to the work the system performs.

This subcourse is to be completed on a self-study basis. You will grade your lessons as you complete them using the lesson answer keys which are enclosed. If you have answered any question incorrectly, study the question reference shown on the answer key and evaluate all possible solutions.

There are no prerequisites for this subcourse.

This subcourse reflects the doctrine which was current at the time it was prepared. In your own work situation, always refer to the latest official publications.

Unless otherwise stated, the masculine gender of singular pronouns is used to refer to both men and women.

<u>TERMINAL LEARNING OBJECTIVE</u>

ACTION: You will demonstrate a knowledge of the basic components of the hydraulic system, including the devices which actuate, discharge, and control the flow of hydraulic fluid and those devices which sense, control, and limit hydraulic pressure.

CONDITIONS: You will use the material in this subcourse.

STANDARD: You must correctly answer 70 percent of the questions on the subcourse examination to pass this subcourse.

TABLE OF CONTENTS

GRADING AND CERTIFICATION INSTRUCTIONS

Examination: This subcourse contains a multiple-choice examination covering the material contained in this subcourse. After studying the lessons and working through the practice exercises, complete the examination. Mark your answers in the subcourse booklet, then transfer them to the ACCP Examination Response Sheet. Completely black out the lettered oval which corresponds to your selection (A, B, C, or D). Use a number 2 lead pencil to mark your responses. When you complete the ACCP examination response sheet, mail it in the preaddressed envelope you received with this subcourse. You will receive an examination score in the mail. You will receive **Four** credit hours for successful completion of this examination.

LESSON 1

HYDRAULIC RESERVOIRS, FILTERS, PUMPS, ACCUMULATORS, AND MOTORS

STP Tasks: 552-758-1063
552-758-1071

OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn the basic operation of the hydraulic reservoirs, filters, pumps, accumulators, and motors.

TERMINAL LEARNING OBJECTIVE:

ACTION: After this lesson you will demonstrate knowledge of hydraulic reservoirs, filters, pumps, accumulators, and motors.

CONDITIONS: You will study the material in this lesson in a classroom environment or at your home.

STANDARD: You will correctly answer all the questions in the practice exercise before you proceed to the next lesson.

REFERENCES: The material contained in this lesson was derived from the following publications: AR 310-25, AR 310-50, FM 1-500, FM 1-509, TM 1-1500-204-23 Series, TM 55-1510-Series (Fixed Wing Maintenance Manuals), TM 55-1520-Series (Rotary wing Maintenance Manuals) and TM 4301A 05 0267 (Air Force)

INTRODUCTION

A means of storing hydraulic fluid and minimizing contamination is necessary to any aircraft hydraulic system. These functions are performed by reservoirs and filters. The component which causes fluid flow in a hydraulic system--the heart of any hydraulic system--can be a hand pump, power-driven pump, accumulator, or any combination of the three. Finally, a means of converting hydraulic pressure to mechanical rotation is sometimes necessary, and this is accomplished by a hydraulic motor.

HYDRAULIC RESERVOIRS

The hydraulic reservoir is a container for holding the fluid required to supply the system, including a reserve to cover any losses from minor leakage and evaporation. The reservoir can be designed to provide space for fluid expansion, permit air entrained in the fluid to escape, and to help cool the fluid. Figure 1-1 shows two typical reservoirs. Compare the two reservoirs item by item and, except for the filters and bypass valve, notice the similarities.

Filling reservoirs to the top during servicing leaves no space for expansion. Most reservoirs are designed with the rim at the filler neck below the top of the reservoir to prevent overfilling. Some means of checking the fluid level is usually provided on a reservoir. This may be a glass or plastic sight gage, a tube, or a dipstick. Hydraulic reservoirs are either vented to the atmosphere or closed to the atmosphere and pressurized. A description of each type follows.

Vented Reservoir. A vented reservoir is one that is open to atmospheric pressure through a vent line. Because atmospheric pressure and gravity are the forces which cause the fluid to flow to the pump, a vented reservoir is mounted at the highest point in the hydraulic system. Air is drawn into and exhausted from the reservoir through a vent line. A filter is usually installed in the vent line to prevent foreign material from being taken into the system.

Pressurized Reservoir. A pressurized reservoir is sealed from the atmosphere. This reservoir is pressurized either by engine bleed air or by hydraulic pressure produced within the hydraulic system itself. Pressurized reservoirs are used on aircraft intended for high altitude flight, where atmospheric pressure is not enough to cause fluid flow to the pump.

In reservoirs pressurized by engine bleed air, the amount of air pressure is determined by an air pressure regulator--usually 10 to 15 pounds per square inch (psi) gage. An example of a hydraulically pressurized reservoir used in the CH-47 hydraulic system is shown in Figure 1-2.

This reservoir, or tank as it is referred to by Boeing-Vertol, is constructed of a metal housing with two internal pistons, one fixed and the other a floating piston which slides along a central tube. Attached to the floating piston is a larger tube that projects through the forward end of the tank and is calibrated to indicate FULL and REFILL fluid levels for ramp-up and ramp-down positions.

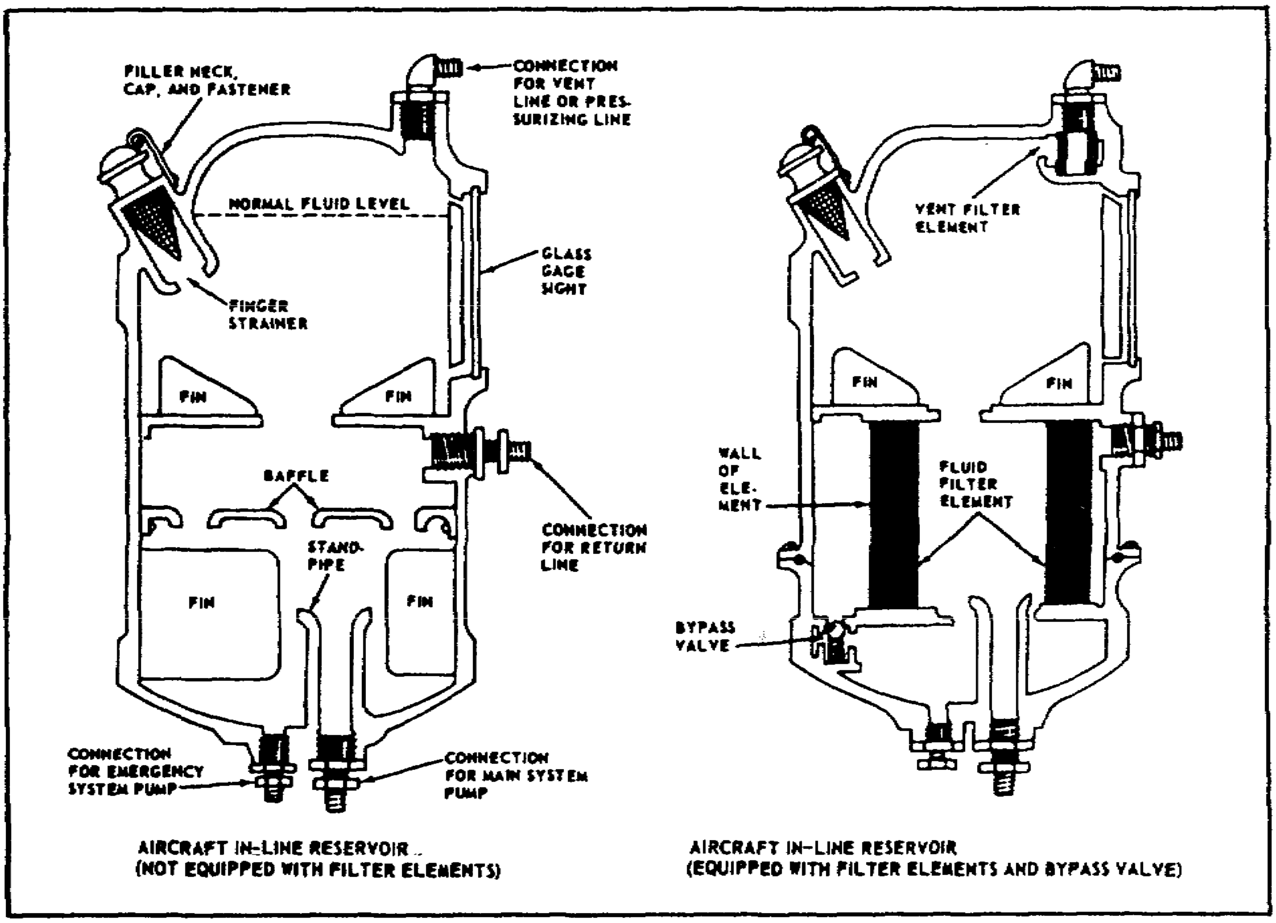


Figure 1-1. Typical Hydraulic Reservoirs.

Hydraulic fluid at 3,000 psi flows into the central tube as shown in Figure 1-2, passes through two outlet holes, and applies pressure at the piston area between the two tubes. Because the smaller piston has a .5-square-inch (sq in) exposed surface and the floating piston has a 30-sq-in exposed surface, the 3,000-psi pressure acting upon the smaller forward area produces an opposing pressure of 50 psi on the return fluid stored at the rear of the piston.

Additional Reservoir Components. Many reservoirs, as shown in Figure 1-1, are constructed with baffles or fins to keep the fluid from swirling and foaming. Foaming can cause air to become entrained in the system.

Filters are incorporated in some reservoirs to filter the fluid before it leaves the reservoir.

A bypass valve is used to ensure that the pump does not starve if the filter becomes clogged.

A standpipe is used in a reservoir which supplies a normal and an emergency system. The main system draws its fluid from the standpipe, which is located at a higher elevation. This ensures an adequate fluid supply to the secondary system if the main system fails.

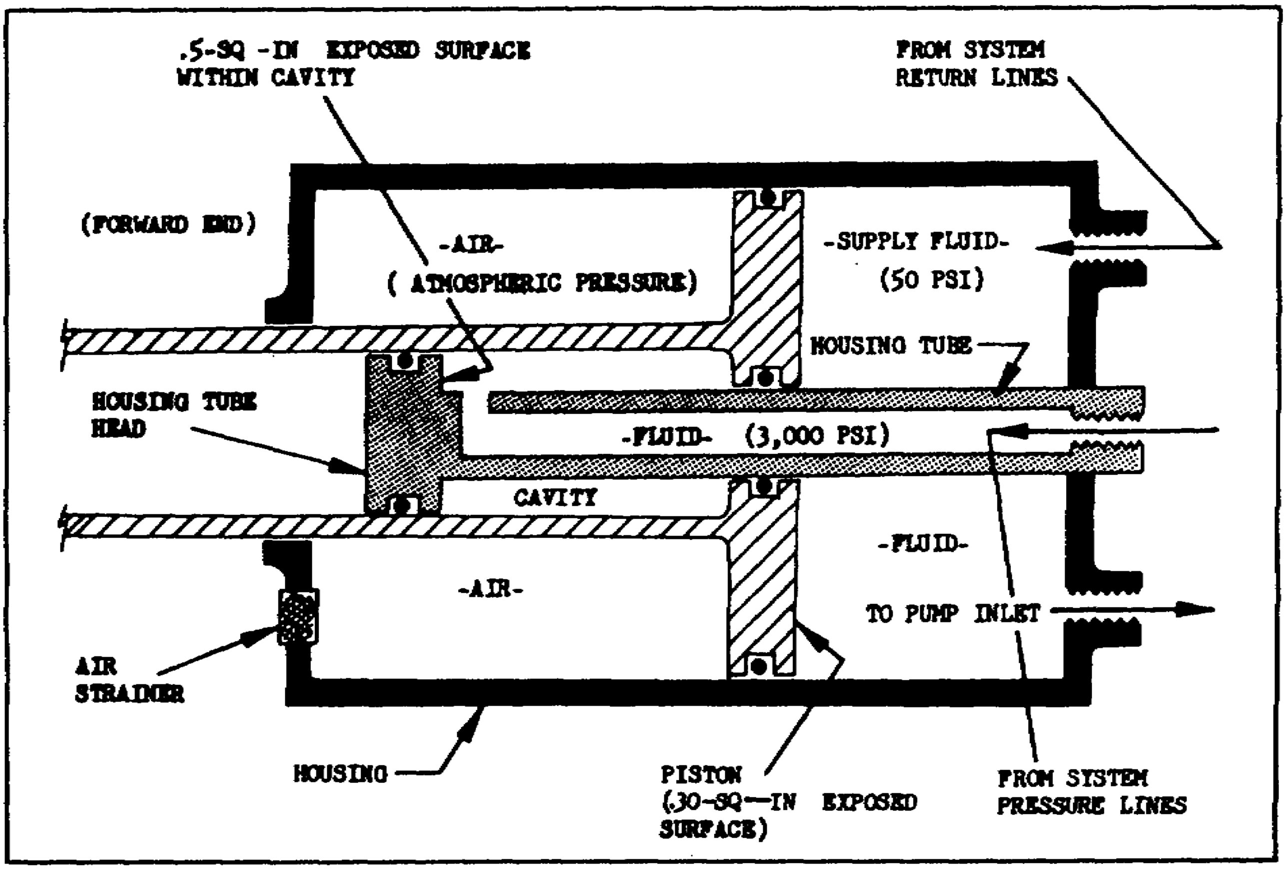


Figure 1-2. Hydraulic Reservoir Pressurized With Hydraulic Fluid.

HYDRAULIC FILTER

Contamination of hydraulic fluid is one of the common causes of hydraulic system troubles. Installing filter units in the pressure and return lines of a hydraulic system allows contamination to be removed from the fluid before it reaches the various operating components. Filters of this type are referred to as line filters.

Line Filter Construction. A typical line filter is shown in Figure 1-3. It has two major parts--the filter case, or bowl, and the filter head. The bowl holds the head that screws into it. The head has an inlet port, outlet port, and relief valve. Normal fluid flow is through the inlet port, around the outside of the element, through the element to the inner chamber, and out through the outlet port. The bypass valve lets the fluid bypass the filter element if it becomes clogged.

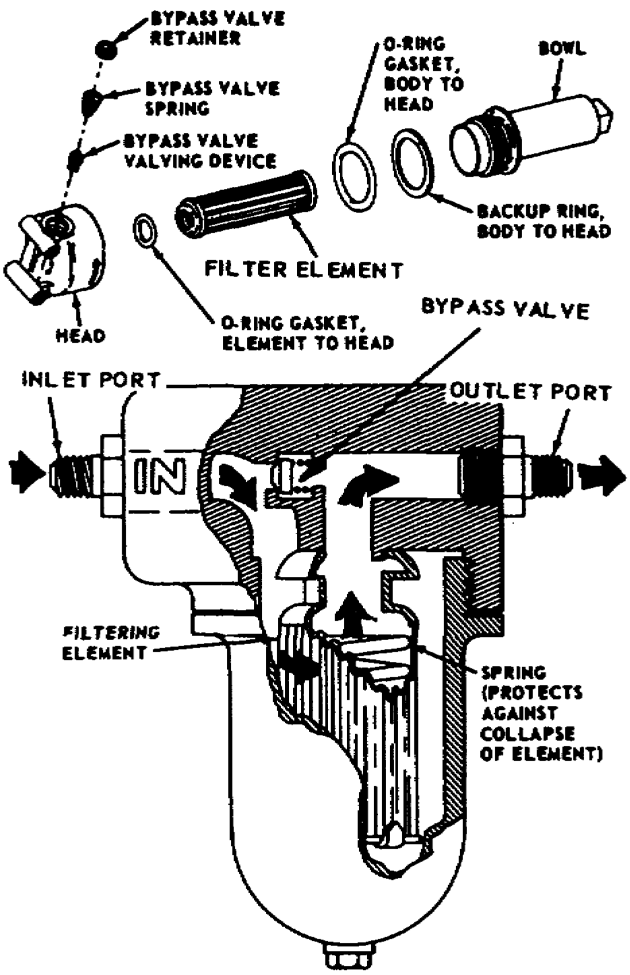


Figure 1-3. Typical Line Filter Assembly.

Types of Filter Elements. The most common filtering element used on Army aircraft is the micronic type. It is a disposable unit made of treated cellulose and is formed into accordion pleats, as shown in Figure 1-3. Most filter elements are capable of removing all contaminants larger than 10 to 25 microns (1 micron equals 0.00004 inch).

Another type is the cuno filter element. It has a stack of closely spaced disks shaped like spoked wheels. The hydraulic fluid is filtered as it passes between the disks.

HAND-OPERATED HYDRAULIC PUMP

The heart of any hydraulic system is the pump which converts mechanical energy into hydraulic energy. The source of mechanical energy may be an electric motor, the engine, or the operator's muscle.

Pumps powered by muscle are called hand pumps. They are used in emergencies as backups for power pumps and for ground checks of the hydraulic system. The double-action hand pump produces fluid flow with every stroke and is the only type used on Army aircraft.

Handle to the Right. The double-action hand pump, shown in Figure 1-4, consists of a cylinder piston with built-in check valve, piston rod, operating handle, and a check valve built into the inlet port. As the handle is moved to the right, the piston and rod also move to the right. On this stroke, the inlet check valve opens as a result of the partial vacuum caused by the movement of the piston, allowing fluid to be drawn into the left chamber. At the same time, the inner check valve closes. As the piston moves to the right, the fluid in the right chamber is forced out into the system.

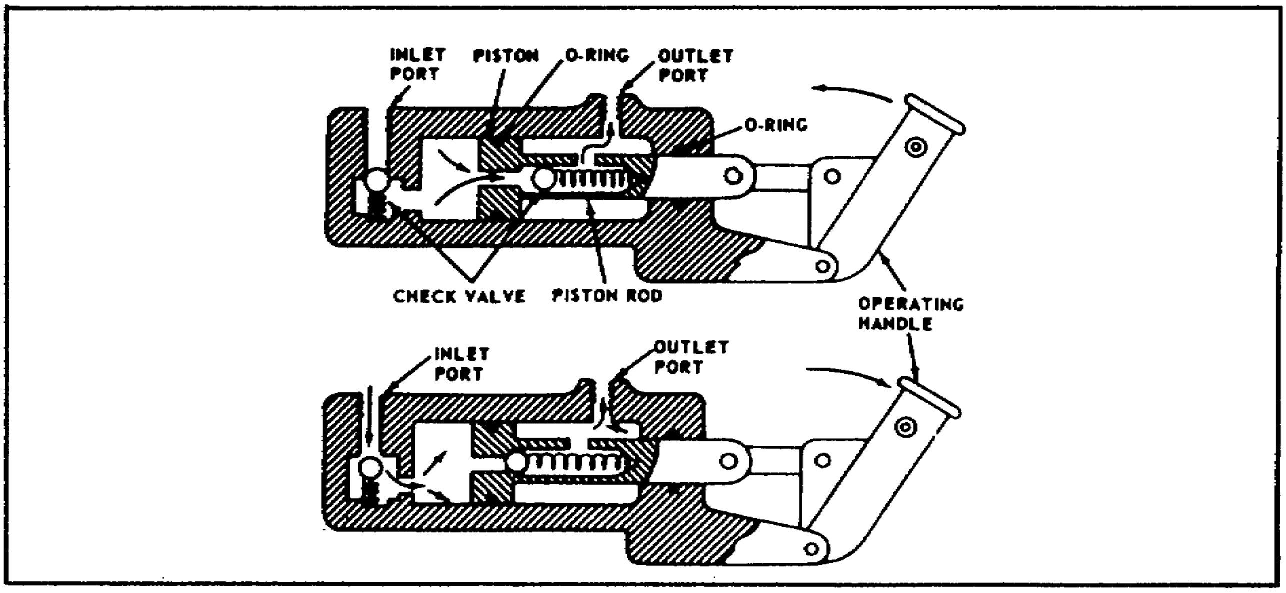


Figure 1-4. Double-Action Hand Pump.

Handle to the Left. When the handle is moved to the left, the piston and rod assembly also move to the left. The inlet check valve now closes, preventing the fluid in the left chamber from returning to the reservoir. At the same time, the pistonhead check valve opens, allowing the fluid to enter the right chamber.

Fluid Into the System. The pump produces pressure on both strokes because of the difference in volume between the right and left chambers. The piston rod takes up a good share of the space in the right chamber. Therefore, the excess fluid is forced out of the pump and into the hydraulic system, creating fluid pressure.

PUMP-DRIVEN HYDRAULIC PUMPS

Power-driven pumps receive their driving force from an external power source, such as the aircraft engine. This force is converted into energy in the form of fluid pressure. The four basic types of power-driven hydraulic pumps are gear, vane, diaphragm, and piston. Of these, the piston type is most commonly found in Army aircraft. The reason for this is that it operates more efficiently at higher pressures and has a longer life than any of the others. Piston pumps are further categorized as either constant delivery or variable delivery.

Pumps are coupled to their driving units by a short, splined coupling shaft, commonly called a drive coupling. As shown in Figure 1-5, the shaft is designed with a weakened center section called a shear section, with just enough strength to run the pump under normal circumstances. Should some trouble develop within the pump causing it to turn unusually hard, the shear section will break. This prevents damage to the pump or driving unit.

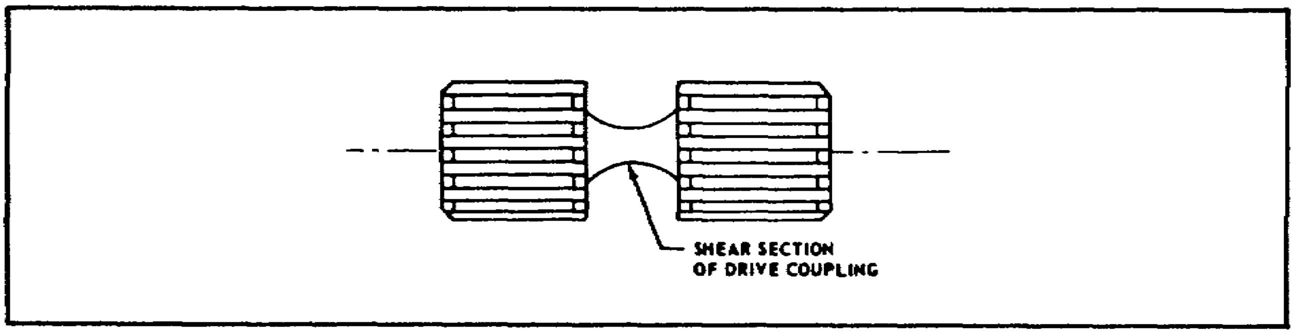


Figure 1-5. Pump Drive Coupling.

Constant-delivery piston pumps deliver a given quantity of fluid per revolution of the drive coupling, regardless of pressure demands. The quantity of fluid delivered per minute depends on pump revolutions per minute (rpm). In a system requiring constant pressure, this type of pump must be used with a pressure regulator. The two types of constant-delivery piston pumps used in Army aircraft are the angular and cam.

Angular Piston Pump Construction. The basic components of an angular piston pump are shown in Figure 1-6. They are--

- (1) A rotating group consisting of a coupling shaft, universal link, connecting rods, pistons, and cylinder block.
- (2) A stationary group consisting of the valve plate and the pump case or housing.

The cylinder bores lie parallel to, and are evenly spaced around, the pump axis. For this reason, a piston pump is often referred to as an axial piston pump.

Packings on seals are not required to control piston-to-bore leakage. This is controlled entirely by close machining and accurate fit between piston and bore. The clearance is only enough to allow for lubrication by the hydraulic fluid and slight expansion when the parts become heated. Pistons are individually fitted to their bores during manufacture and must not be changed from pump to pump or bore to bore.

Pump Operation. As the coupling shaft is turned by the pump power source, the pistons and cylinder block turn along with it because they are interconnected. The angle that exists between the cylinder block and coupling shaft causes the pistons to move back and forth in their respective cylinder bores as the coupling is turned:

- During the first half of a revolution of the pump, a cylinder is aligned with the inlet port in the valve plate. At this time the piston is moving away from the valve plate and drawing hydraulic fluid into the cylinder. During the second half of the revolution, the cylinder is lining up with the outlet port in the valve plate. At this time, the piston is moving toward the valve plate, thus causing fluid previously drawn into the cylinder to be forced out through the outlet port.
- Fluid is constantly being drawn into and expelled out of the pump as it turns. This provides a multiple overlap of the individual spurts of fluid forced from the cylinders and results in delivery of a smooth, nonpulsating flow of fluid from the pump.

Cam-Piston Pumps. A cam is used to cause the stroking of the pistons in a cam-piston pump. Two variations are used: in one the cam rotates and the cylinder block is stationary, and in the other the cam is stationary and the cylinder block rotates. Both cam-piston pumps are described below:

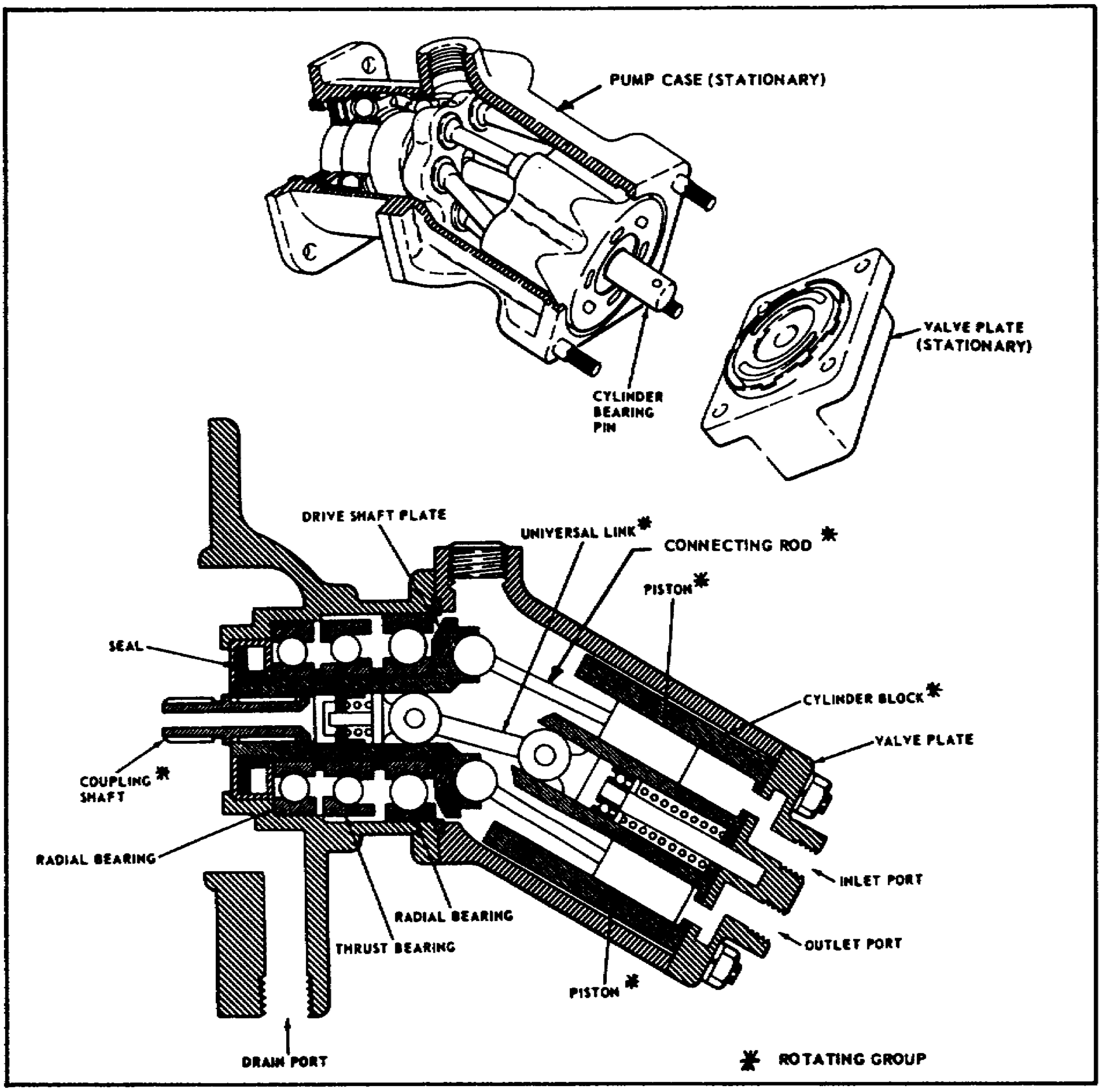


Figure 1-6. Typical Angular Piston Pump.

- Rotating-cam pump. The rotating-cam pump is the one most commonly used in Army aviation. As the cam turns in a rotating-cam pump (Figure 1-7), its high and low points pass alternately and in turn under each piston. It pushes the piston further <u>into</u> its bore, causing fluid to be <u>expelled</u> from the bore. When the falling face of the cam comes under a piston, the piston's return spring pulls the piston down in its bore. This causes fluid to be drawn <u>into</u> the bore.

Each bore has a check valve that opens to allow fluid to be expelled from the bore by the piston's movement. These valves are closed by spring pressure during inlet strokes of the pistons. This fluid is drawn into the bores only through the central inlet passages. The bores only through the central inlet passages. The movement of the pistons in drawing in and expelling fluid is overlapping, resulting in a nonpulsating fluid flow.

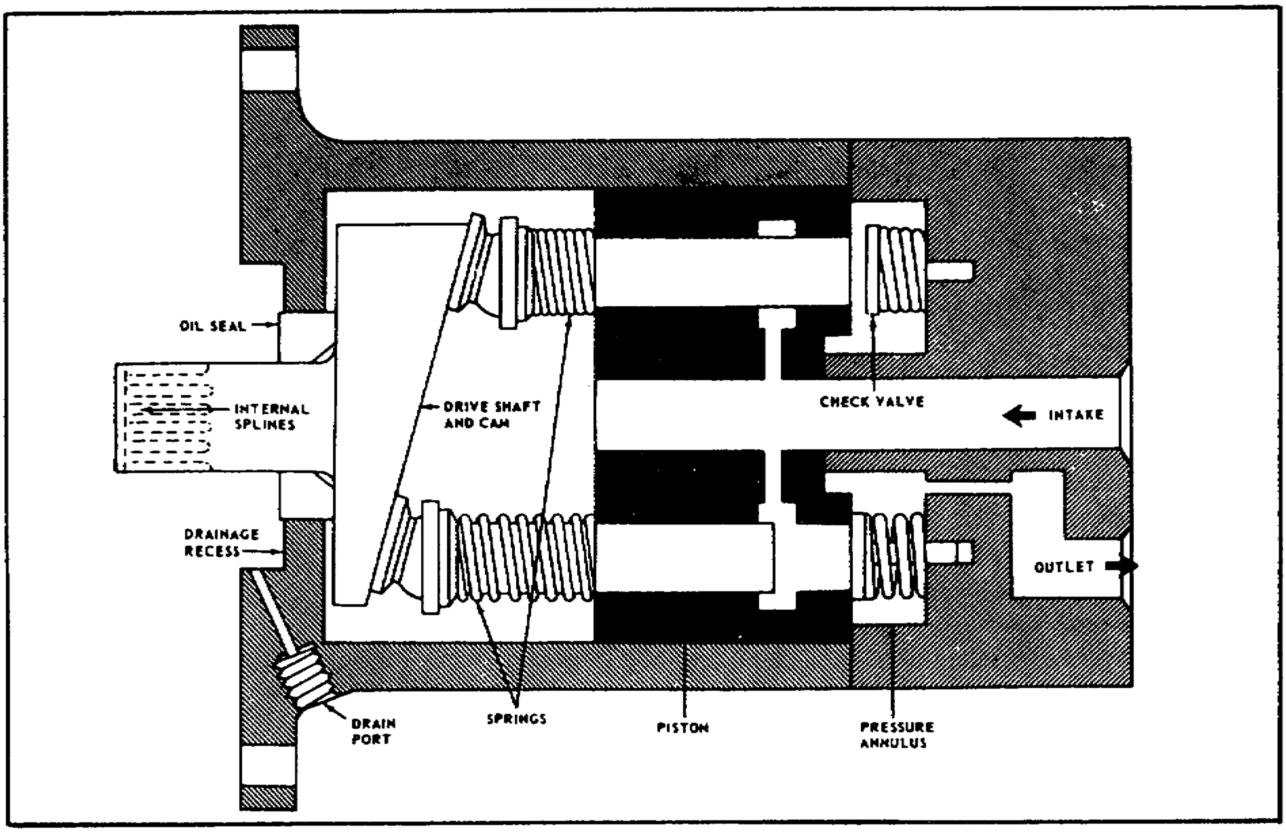


Figure 1-7. Typical Rotating-Cam Piston Pump.

- <u>Stationary-cam pump</u>. The operation and construction of a stationary-cam pump are identical to that of the rotating cam except that the cylinder block turns, not the cam. The stationary-cam pump is not used on the Army's OV-1, AH-1G, and UH-1C.

VARIABLE-DELIVERY PISTON PUMPS

A variable-delivery piston pump automatically and instantly varies the amount of fluid delivered to the pressure circuit of a hydraulic system to meet varying system demands. This is accomplished by using a compensator, which is an integral part of the pump. The compensator is sensitive to the amount of pressure present in the pump and in the hydraulic system pressure circuit. When the circuit pressure rises, the compensator causes the pump output to decrease.

Conversely, when circuit pressure drops, the compensator causes pump output to increase. There are two ways of varying output--demand principle (cam) and stroke-reduction principle (angular).

Demand Principle. The demand principle (Figure 1-8) is based on varying pump output to fill the system's changing demands by making the piston stroke effective in varying degrees.

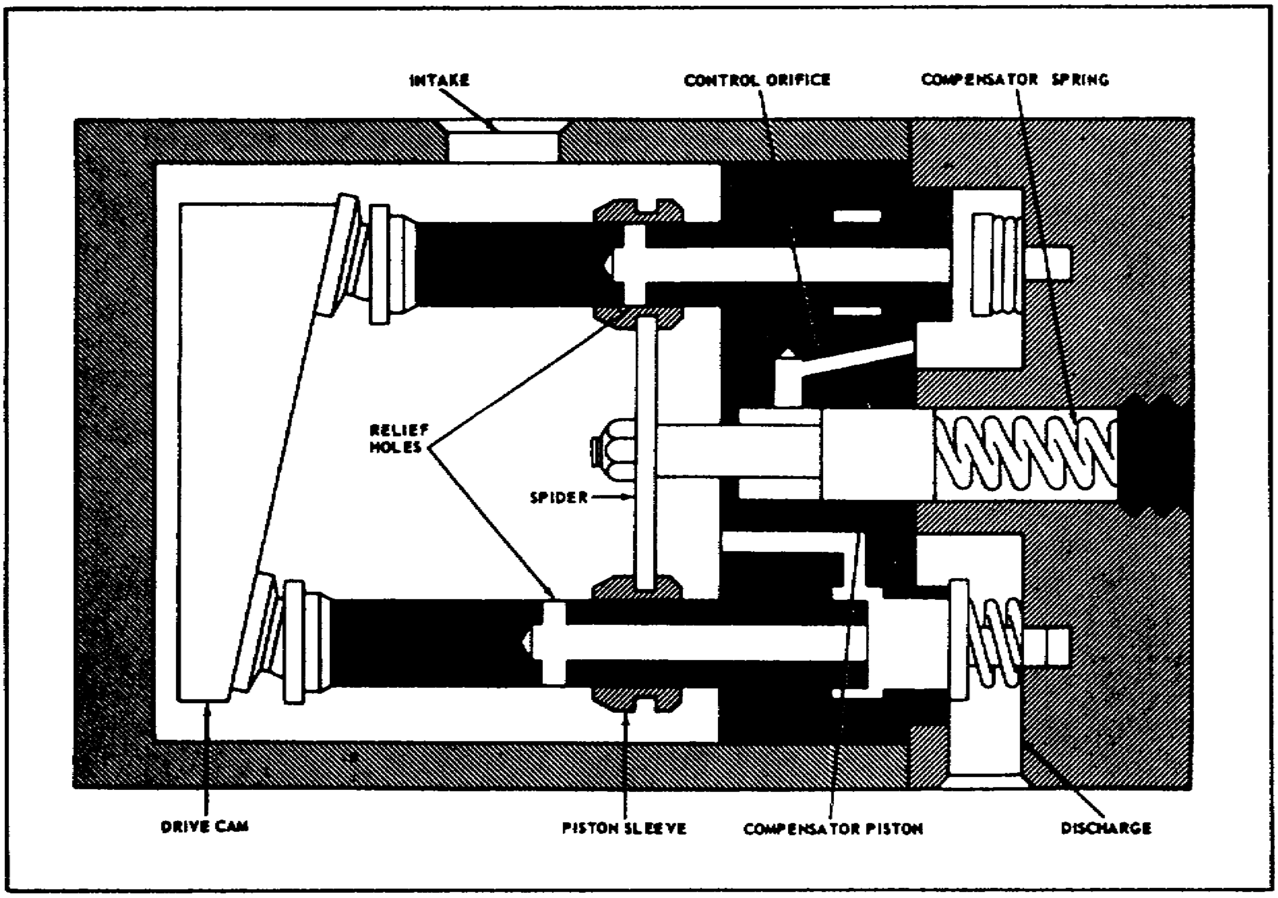


Figure 1-8. Variable-Delivery Demand-Principle Cam Pump.

The pistons are designed with large hollow centers. The centers are intersected by cross-drilled relief holes that open into the pump case. Each piston is equipped with a movable sleeve, which can block the relief holes. When these holes are not blocked, fluid displaced by the pistons is discharged through the relief holes into the pump case, instead of past the pump check valves and out the outlet port.

When full fluid flow is required, the sleeves are positioned to block the relief holes for the entire length of piston stroke. When zero flow is required, the sleeves are positioned not to block the flow during any portion of the piston stroke. For requirements between zero and full flow, the relief holes are uncovered or blocked accordingly.

The sleeves are moved into their required positions by a device called a pump compensator piston. The sleeves and compensator piston are interconnected by means of a spider. Fluid pressure for the compensator piston is obtained from the discharge port (system pressure) through a control orifice.

Stroke-Reduction Principle. The stroke-reduction principle (Figure 1-9) is based on varying the angle of the cylinder block in an angular pump. This controls the length of the piston's stroke and thus the volume per stroke.

The cylinder block angle change is achieved by using a yoke that swivels around a pivot pin called a pintle. The angle is automatically controlled by using a compensator assembly consisting of a pressure-control valve, pressure-control piston, and mechanical linkage that is connected to the yoke.

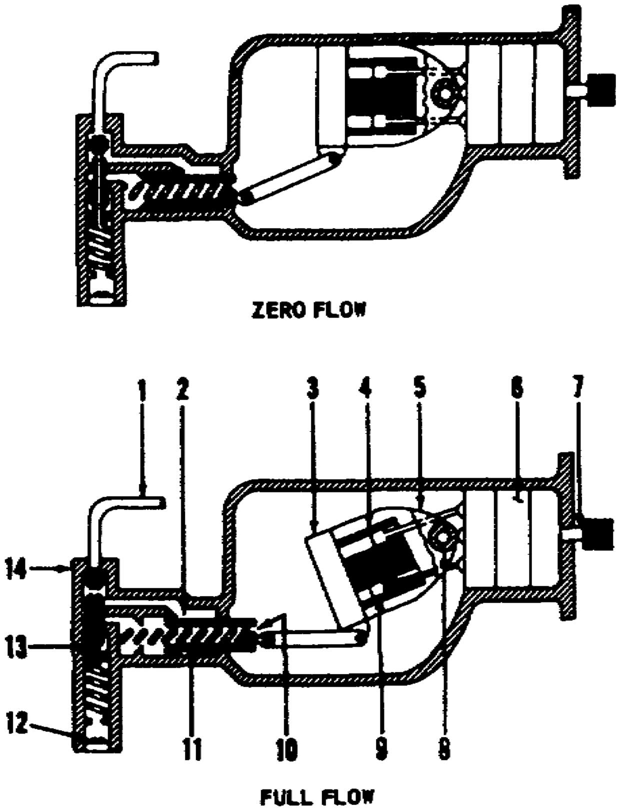
As system pressure increases, the pilot valve opens a passageway allowing fluid to act on the control piston. The piston moves, compressing its spring, and through mechanical linkage moves the yoke toward the zero flow (zero angle) position. As system pressure decreases, the pressure is relieved on the piston, and its spring moves the pump into the full flow position.

HYDRAULIC ACCUMULATORS

The purpose of a hydraulic accumulator is to store hydraulic fluid under pressure. It may be used to--:

- Dampen hydraulic shocks which may develop when pressure surges occur in hydraulic systems.
- Add to the output of a pump during peak load operation of the system, making it possible to use a pump of much smaller capacity than would otherwise be required.

- Absorb the increases in fluid volume caused by increases in temperature.
- Act as a source of fluid pressure for starting aircraft auxiliary power units (APUs).
- Assist in emergency operations.



1 Pressure outlet line
2 Passageway
3 Valve plate
4 Block assembly
5 Yoke
6 Bearing
7 Drive shaft
8 Pintle
9 Piston
10 Piston end opening
11 Pressure control piston
12 Adjusting screw
13 Pilot valve
14 Pressure control valve

Figure 1-9. Variable Stroke-Reduction Pump.

Accumulators are divided into types according to the means used to separate the air fluid chambers; these are the diaphragm, bladder, and piston accumulators.

Diaphragm Accumulator. The diaphragm accumulator consists of two hollow, hemispherical metal sections bolted together at the center. Notice in Figure 1-10 that one of the halves has a fitting to attach the unit to the hydraulic system; the other half is equipped with an air valve for charging the unit with compressed air or nitrogen. Mounted between the two halves is a synthetic rubber diaphragm that divides the accumulator into two sections. The accumulator is initially charged with air through the air valve to a pressure of approximately 50 percent of the hydraulic system pressure. This initial air charge forces the diaphragm upward against the inner surface of the upper section of the accumulator.

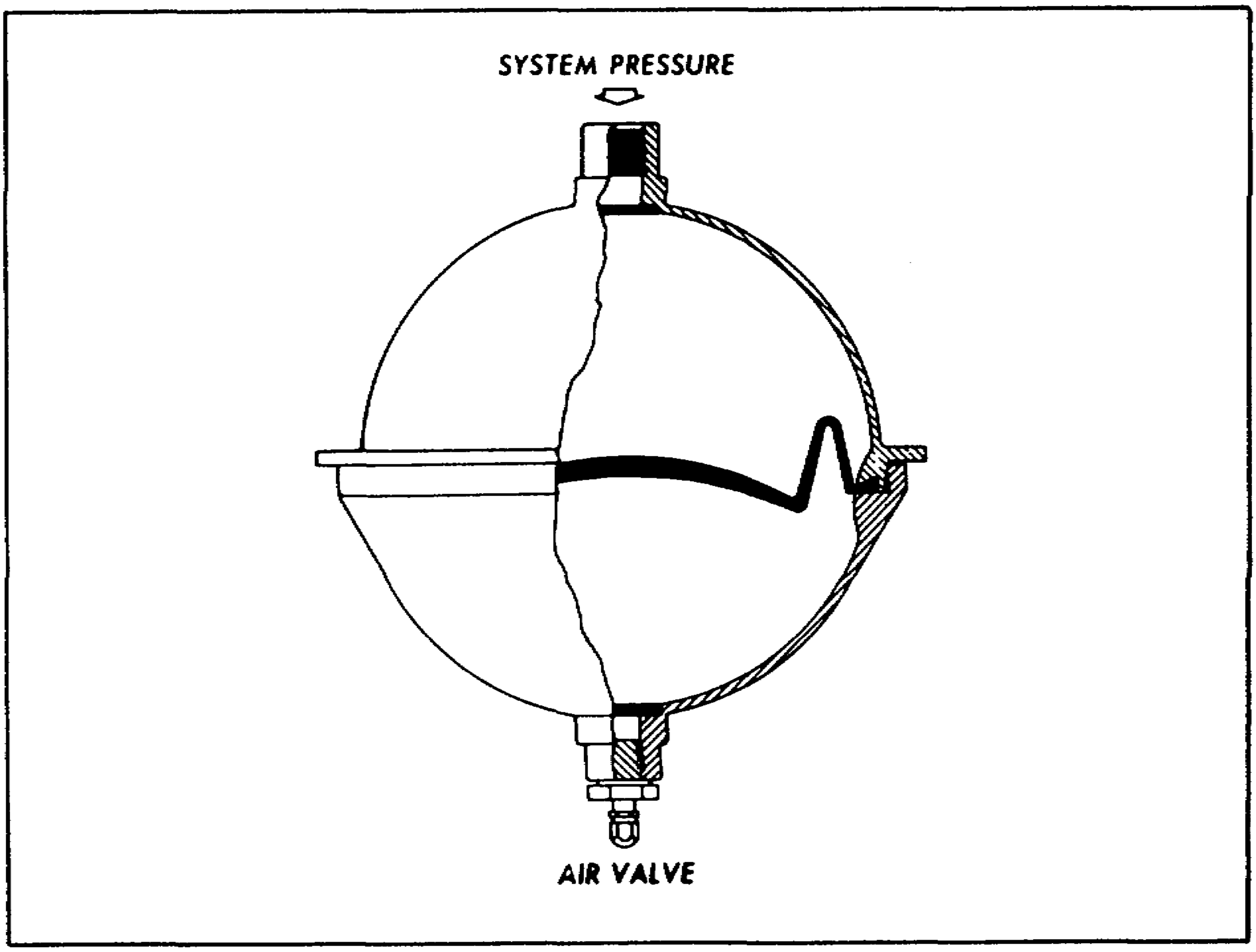


Figure 1-10. Diaphragm Accumulator.

When fluid pressure increases above the initial air charge, fluid is forced into the upper chamber through the system pressure port, pushing the diaphragm down and further compressing the air in the bottom chamber. Under peak load, the air pressure in the lower chamber forces fluid back into the hydraulic system to maintain operating pressure. Also, if the power pump fails, the compressed air forces a limited amount of pressurized fluid into the system.

Bladder Accumulator. The bladder accumulator operates on the same principle and for the same purpose as the diaphragm accumulator but varies in construction, as shown in Figure 1-11. The unit is a one-piece metal sphere with a fluid pressure inlet at the top and an opening at the bottom for inserting the bladder. A large screw-type plug at the bottom of the accumulator is a retainer for the bladder that also seals the unit. A high-pressure air valve is also incorporated in the retainer plug. Fluid enters through the system pressure port. As fluid pressure increases above the initial air charge of the accumulator, it forces the bladder downward against the air

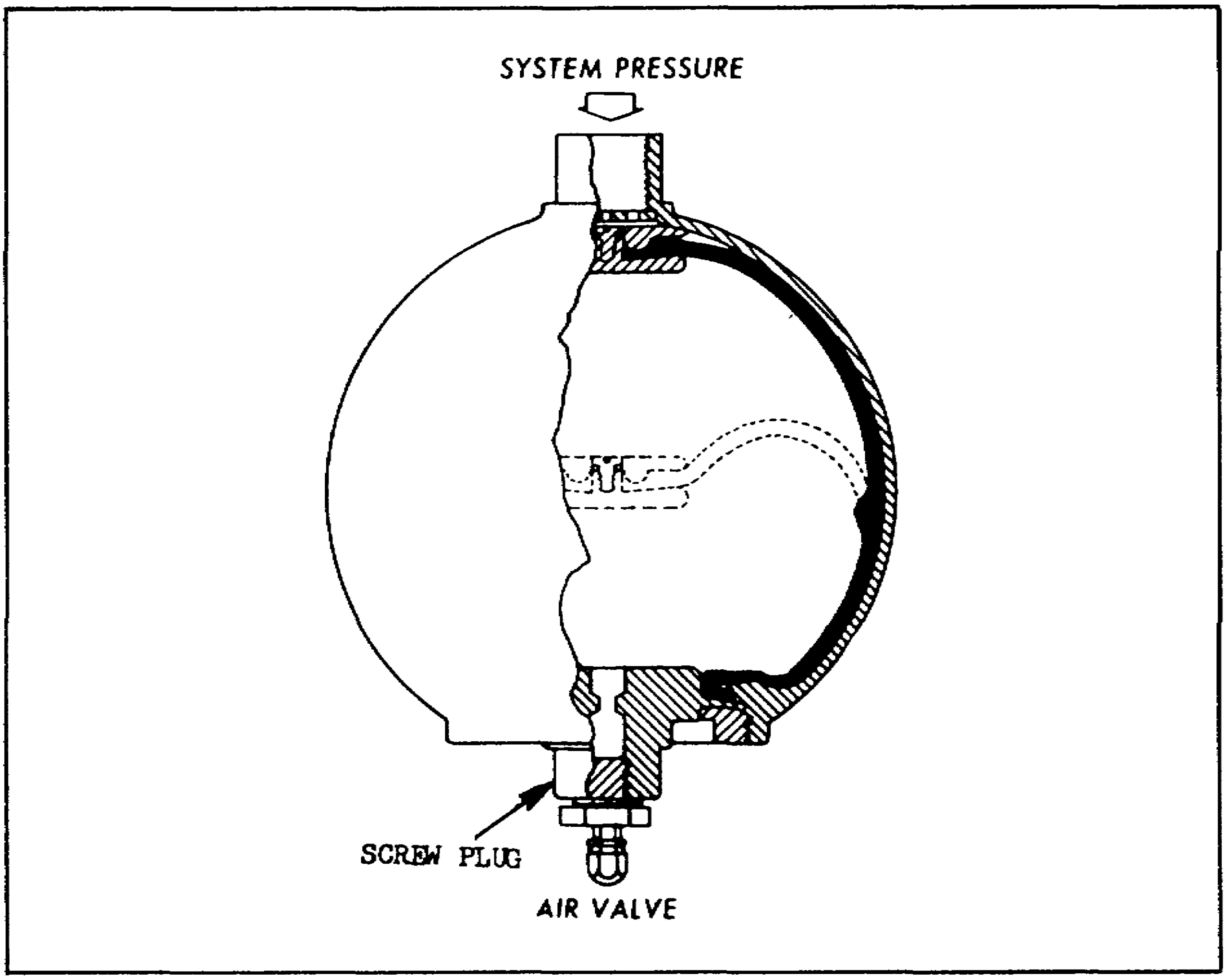


Figure 1-11. Bladder Accumulator.

charge, filling the upper chamber with fluid pressure. The broken lines in Figure 1-11 indicate the approximate position of the bladder at the time of the initial air charge.

Piston Accumulator. The piston accumulator serves the same purpose and operates by the same principles as do the diaphragm and bladder accumulators. As shown in Figure 1-12, the unit consists of a cylinder and piston assembly with ports on each end. Fluid pressure from the system enters the left port, forcing the piston down against the initial air charge in the right chamber of the cylinder. A high-pressure air valve is located at the right port for charging the unit. A drilled passage from the fluid side of the piston to the outside of the piston provides lubrication between the cylinder walls and the piston.

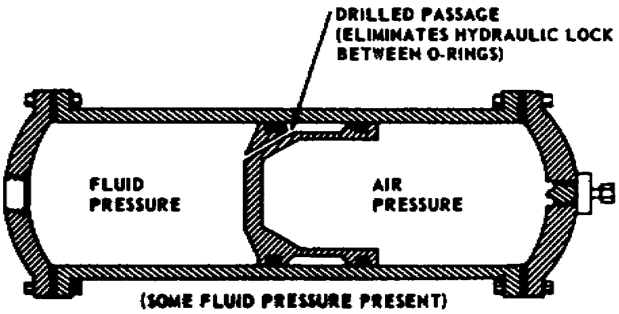


Figure 1-12. Piston Accumulator.

HYDRAULIC MOTORS

Hydraulic motors are installed in hydraulic systems to use hydraulic pressure in obtaining powered rotation. A hydraulic motor does just the opposite of what a power-driven pump does. A pump receives rotative force from an engine or other driving unit and converts it into hydraulic pressure. A hydraulic motor receives hydraulic fluid pressure and converts it into rotative force.

Figure 1-13 shows a typical hydraulic motor. The two main ports through which fluid pressure is received and return fluid is discharged are marked A and B, respectively. The motor has a cylinder block-and-piston assembly in which the bores and pistons are in axial arrangement, the same as in a hydraulic pump. Hydraulic motors can be instantly started, stopped, or reversed under any degree of load; they can be stalled by overload without damage. The direction of rotation of a hydraulic motor can be changed by reversing the flow of fluid into the ports of the motor.

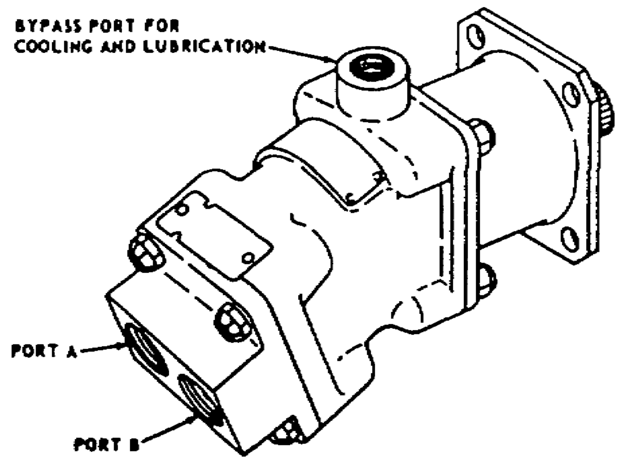


Figure 1-13. Typical Hydraulic Motor.

SUMMARY

The basic components of any hydraulic system are reservoirs, filters, and pumps (hand or power-driven). The reservoir holds the fluid supply for the system and helps cool the fluid. Filters are used to ensure that no contamination reaches the components in a hydraulic system. The pleated micronic filter is the most common.

The pump converts mechanical energy to fluid flow. The most common power-driven pump is the piston pump. In all but the simplest hydraulic systems, variable-delivery pumps are used. A variable-delivery pump delivers only the amount of fluid demanded by the system. This is accomplished through the use of a compensator.

Depending on the type of aircraft, hydraulic accumulators and hydraulic motors can also be found in the system. Accumulators are used primarily to supply pressure for starting auxiliary power units and emergency hydraulic pressure. Hydraulic motors perform a variety of functions, including raising and lowering cargo doors, operating rescue hoists, and positioning wing flaps.

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LESSON 1

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you have completed the exercise, check your answers with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. The pistons and cylinder block rotate at what RPM?

___ A. The same.
___ B. 500 RPM.
___ C. 750 RPM.
___ D. 1500 RPM.

2. How many types of hydraulic reservoirs are there?

___ A. One.
___ B. Two.
___ C. Three.
___ D. Four.

3. The stationary-cam pump is NOT used on what three Army aircraft?

___ A. UH-1H, AH-1S, and OV-1B.
___ B. UH-1D, AH-1H, and OV-1.
___ C. OV-1A, AH-1G, and UH-1E.
___ D. OV-1, AH-1G, and UH-1C.

4. What type of pump is often used in Army aviation?

___ A. Piston pump.
___ B. Rotating-cam pump.
___ C. Demand-principle compensator pump.
___ D. Rotating-compensator pump.

5. What is used to control piston-to-bore leakage in piston pumps?

___ A. Wiper rings.
___ B. O-rings.
___ C. Seals.
___ D. Close machining.

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6. What type hydraulic pump would you most likely find on an Army AH-1?

___ A. Compensator pump.
___ B. Drive pump.
___ C. Piston pump.
___ D. Auxiliary pump.

7. The angular pump uses what type of compensator?

___ A. Stroke-reduction.
___ B. Reduction-stroke.
___ C. Cam-reduction.
___ D. Piston-reduction.

8. What component in a hydraulic system protects against pressure surges?

___ A. Double-check valve.
___ B. Stationary-cam pump.
___ C. Accumulator.
___ D. Hand-operated pump.

9. What type of pump has a check valve built into the piston?

___ A. Double-action hand pump.
___ B. Single-action hand pump.
___ C. Single-action cam pump.
___ D. Double-action cam pump.

10. What valve opens as the handle is moved to the right?

___ A. Double check valve.
___ B. Single check valve.
___ C. Outlet check valve.
___ D. Inlet check valve.

LESSON 1

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	A. The same RPM.
	Both operate alike because they are connected. (Page 8)
2.	B. 2.
	The two types of reservoirs are classified as vented and pressurized. (Page 2)
3.	D. OV-l, AH-1G, and UH-1C.
	All Army aircraft do not have the stationary-cam pump as an operating component. (Page 10)
4.	B. Rotating-cam pump.
	More Army aircraft use the rotating-cam pump than any type. (Page 9)
5.	D. Close machining.
	The piston and bore fit so closely that no other component is necessary to stop leakage. (Page 8)
6.	C. Piston pump.
	The Army has selected the most efficient, longest-lasting hydraulic pump to be used on its aircraft. (Page 7)
7.	A. Stroke-reduction principle.
	The length of the stroke can be controlled by angling the cylinder block. (Page 12)
8.	C. Accumulator.
	The accumulator can absorb increases in fluid volume to prevent damage to the system. (Page 12)

9. A. Double-action hand pump.

The double-action hand pump has two check valves which allow fluid to be drawn into the left and right chambers. (Page 6)

10. D. Inlet check valve.

Moving the handle to the right results in a slight vacuum, which opens the inlet check valve as a result of the partial vacuum caused by the movement of the piston, allowing fluid to be drawn into the left chamber. (Page 6)

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LESSON 2

BASIC CONSTRUCTION AND OPERATION OF HYDRAULIC ACTUATING DEVICES, FLOW CONTROL, AND DIRECTIONAL DEVICES

STP Tasks: 552-758-1003
552-758-1071

OVERVIEW

<u>LESSON DESCRIPTION</u>:

In this lesson you will learn the basic construction and operation of hydraulic actuating devices, flow control, and directional devices.

<u>TERMINAL LEARNING OBJECTIVE</u>:

ACTION: After this lesson you will demonstrate a knowledge of the basic construction and operation of hydraulic actuating devices, flow control, and directional devices.

CONDITIONS: You will study the material in this lesson in a classroom environment or at home.

STANDARD: You will correctly answer all the questions in the practice exercise before you proceed to the next lesson.

REFERENCES: The material contained in this lesson was derived from the following publications: AR 310-25, AR 310-50, FM 1-500, FM 1-509, TM 1-1500-204-23 Series, TM 55-1510-Series, TM 55-1520-Series and TM 4301A 05 0267 (Airforce).

INTRODUCTION

So that fluid pressure produced by a pump can be used to move some object, the pressure must be converted to usable forces by means of an actuating unit. A device called an actuating cylinder is used to impart powered straight-line motion to a mechanism.

Hydraulic systems must also have devices to control or direct the fluid pressure to the various components. Such devices include selector valves, check valves, ratchet valves, irreversible valves, sequence valves, and priority valves. Each is described in the paragraphs that follow.

ACTUATING CYLINDERS

A basic actuating cylinder consists of a cylinder housing, one or more pistons and piston rods, and one or more seals. 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 which moves forward and backward within the cylinder bore. The piston rod moves into and out of the cylinder housing through an opening in one or both ends. The seals are used to prevent leakage between the piston and cylinder bore, and between the piston rod and housing. The two major types of actuating cylinders are single-action and double-action.

Single-Action Actuating Cylinder. The single-action actuating cylinder, shown in Figure 2-1, consists of a cylinder housing with one fluid port, a piston and rod assembly, a piston return spring, and seals.

When no pressure is applied to the piston, the return spring holds it and the rod assembly in the retracted position. When hydraulic pressure is applied to the inlet port, the piston, sealed to the cylinder wall by an O-ring, does not allow the fluid to pass. This causes the piston to extend.

As the piston and rod extend, the return spring compresses. A vent on the spring side of the piston allows air to escape. When pressure is relieved, the return spring forces the piston to retract, pushing the fluid out of the cylinder. A wiper in the housing keeps the piston rod clean.

The cylinder can be pressure-operated in one direction only. A three-way control valve is normally used to control cylinder operation.

Double-Action Actuating Cylinder. The double-action actuating cylinder consists of a cylinder with a port at either end and a piston and rod assembly extending through one end of the cylinder (Figure 2-2).

Pressure applied at port A causes the piston to extend, forcing the fluid on the opposite side of the piston out of port B. When pressure is applied to port B, the piston and rod retract, forcing the fluid in the opposite chamber out through port A.

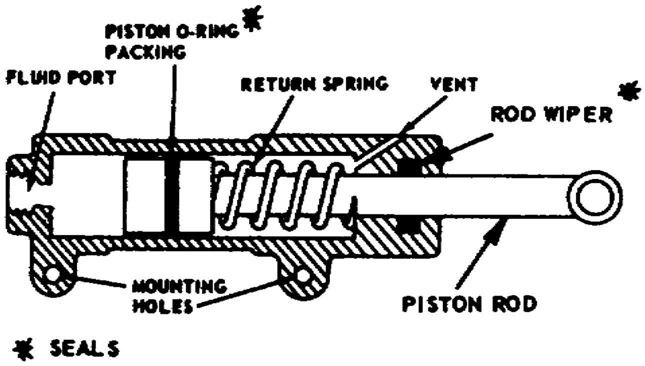

Figure 2-1. Single-Action Actuating Cylinder.

This type of cylinder is powered in both directions by hydraulic pressure. A selector valve is normally used to control a double-action actuating cylinder. Selector valves are discussed in the next paragraph.

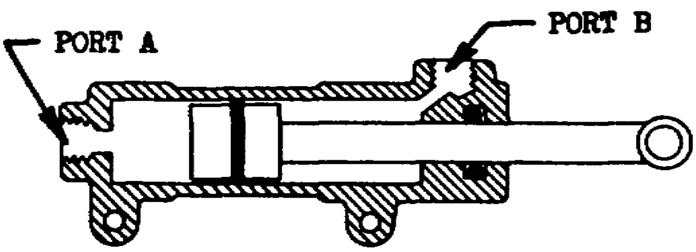

Figure 2-2. Double-Action Actuating Cylinder.

SELECTOR VALVES

Used in hydraulic systems to control the direction of operation of a mechanism, selector valves are also referred to as directional control valves or control valves. They provide pathways for the simultaneous flow of two streams of fluid, one under pressure into the actuating unit, and the other, a return stream, out of the actuating unit. The selector valves have various numbers of ports determined by the requirements of the system in which the valve is used. Selector valves with four ports are the most commonly used; they are referred to as four-way valves. Selector valves are further classified as closed-center or open-center types.

Closed-Center Selector Valve. When a closed-center selector valve is placed in the the OFF position, its pressure passage is blocked to the flow of fluid. Therefore, no fluid can flow through its pressure port, and the hydraulic system stays at operating pressure at all times. The four-way, closed-center selector valve is the most commonly used selector valve in aircraft hydraulics. There are two types:

- The rotor-type, closed-center selector valve is shown in Figure 2-3. It has a rotor as its valving device. The rotor is a thick circular disk with drilled fluid passages. It is placed in its various operating positions by relative movement of the valve control handle. In the OFF position, the rotor is positioned to close all ports. In the first ON position, the rotor interconnects the pressure port with the number 1 cylinder port. The number 2 cylinder port is open to return. In the second ON position the reverse takes place.

- The spool-type, closed-center selector valve, is shown in Figure 2-4. This valve has a housing containing four ports and a spool (pilot valve). The spool is made from a round shaft having machined sections forming spaces to allow hydraulic fluid to pass. A drilled passage in the spool interconnects the two end chambers of the selector valve. The large diameters of the spool are the bearing and sealing surfaces and are called "lands" (see Glossary). In operation, the spool valve is identical to the rotor type.

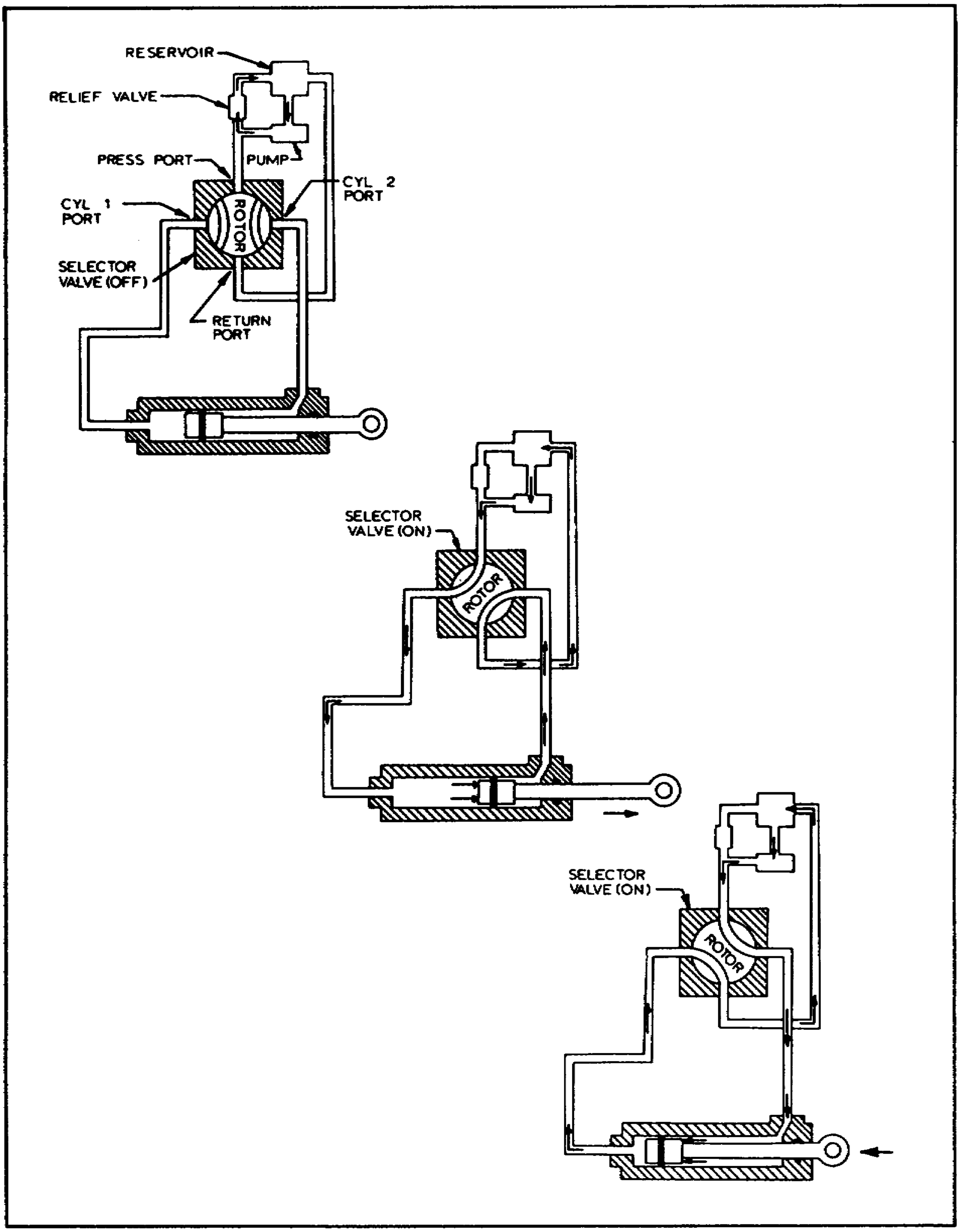

Figure 2-3. Typical Rotor Closed-Center Selector Valve.

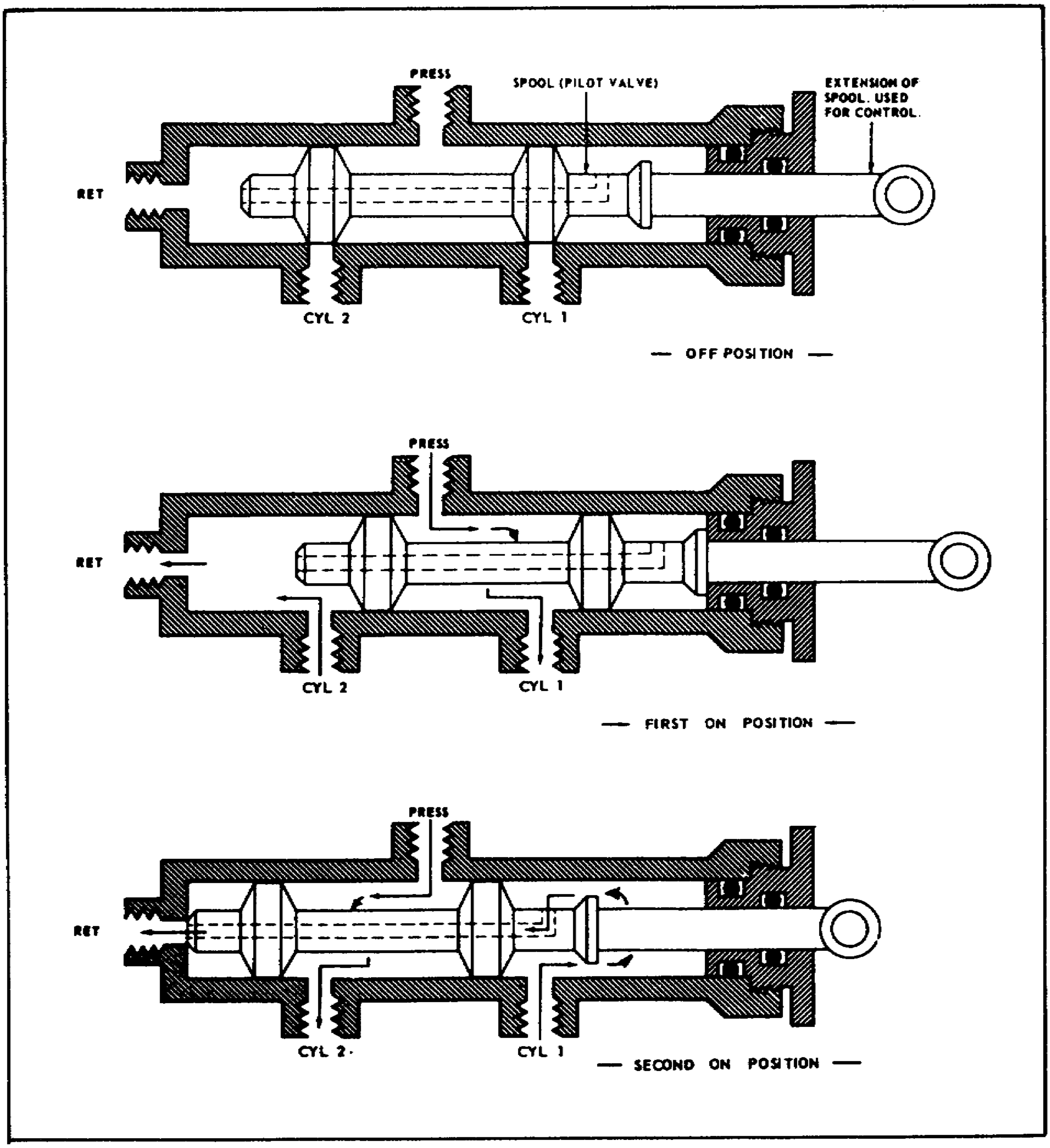

Figure 2-4. Typical Spool Closed-Center Selector Valve.

Open-Center Selector Valve. In external appearance, the open-center selector valve looks like the closed-center one. Like closed-center valves, open-center selector valves have four ports and operate in one OFF and two ON positions. The difference between the closed-center and open-center valves is in the OFF position. In the closed-center valve none of the ports are open to each other in the OFF position. In the open-center valve, the pressure and return ports are open to each other when the valve is OFF. In this position, the output of the system pump is returned through the selector valve to the reservoir with little resistance. Hence, in an open-center system, operating pressure is present only when the actuating unit is being operated.

An open-center, rotor-type selector valve is shown in Figure 2-5. As you can see, when the valve is in the OFF position, fluid from the pump enters the pressure port, passes through the open center passage in the rotor, and back to the reservoir. When the valve is in either of the two ON positions, it functions the same as a closed-center valve.

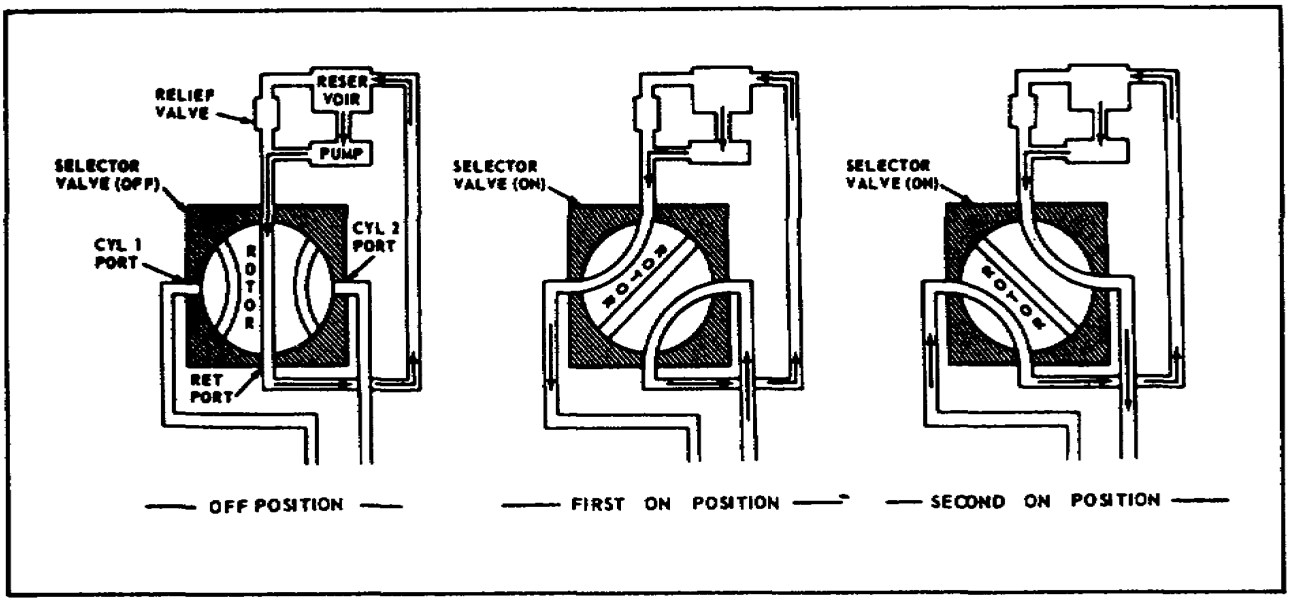

Figure 2-5. Typical Open-Center Rotor Selector Valve.

An open-center, spool-type selector valve is shown in Figure 2-6. Notice that this valve differs from the closed-center type in that a third land is machined on the spool. This land is used to cover the pressure port when the valve is in the OFF position. It provides an inter-passage in the spool which allows fluid from the pump to return to the reservoir. Operation in both of the ON positions is the same as the closed-center selector valve.

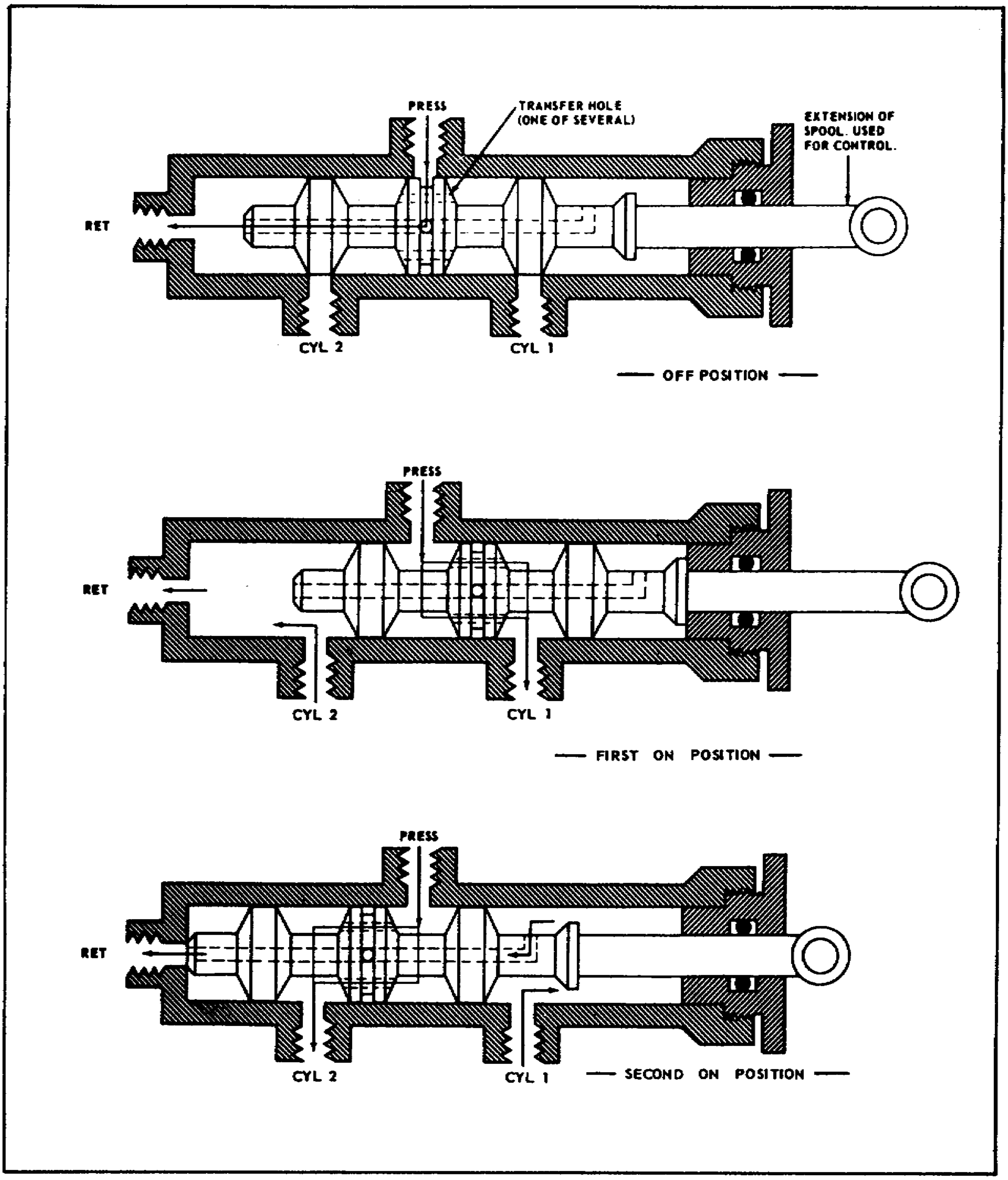

Figure 2-6. Typical Open-Center Spool Selector Valve.

Hydraulic systems are classified as open-center or closed-center depending upon the type of selector valves used. In an open-center system that has more than one selector valve, the valves are arranged one behind the other (in series).

In a closed-center system, the valves are arranged parallel to each other. An open-center system has fluid flow but no pressure in the system when the selector valve is off.

In a closed-center system, fluid is under pressure throughout the system when the hydraulic pump is operating. Both systems are discussed in the paragraphs that follow.

Open-Center System. Figure 2-7 shows a basic open-center hydraulic system which uses a relief valve to limit system pressure. As was mentioned earlier, this type of system

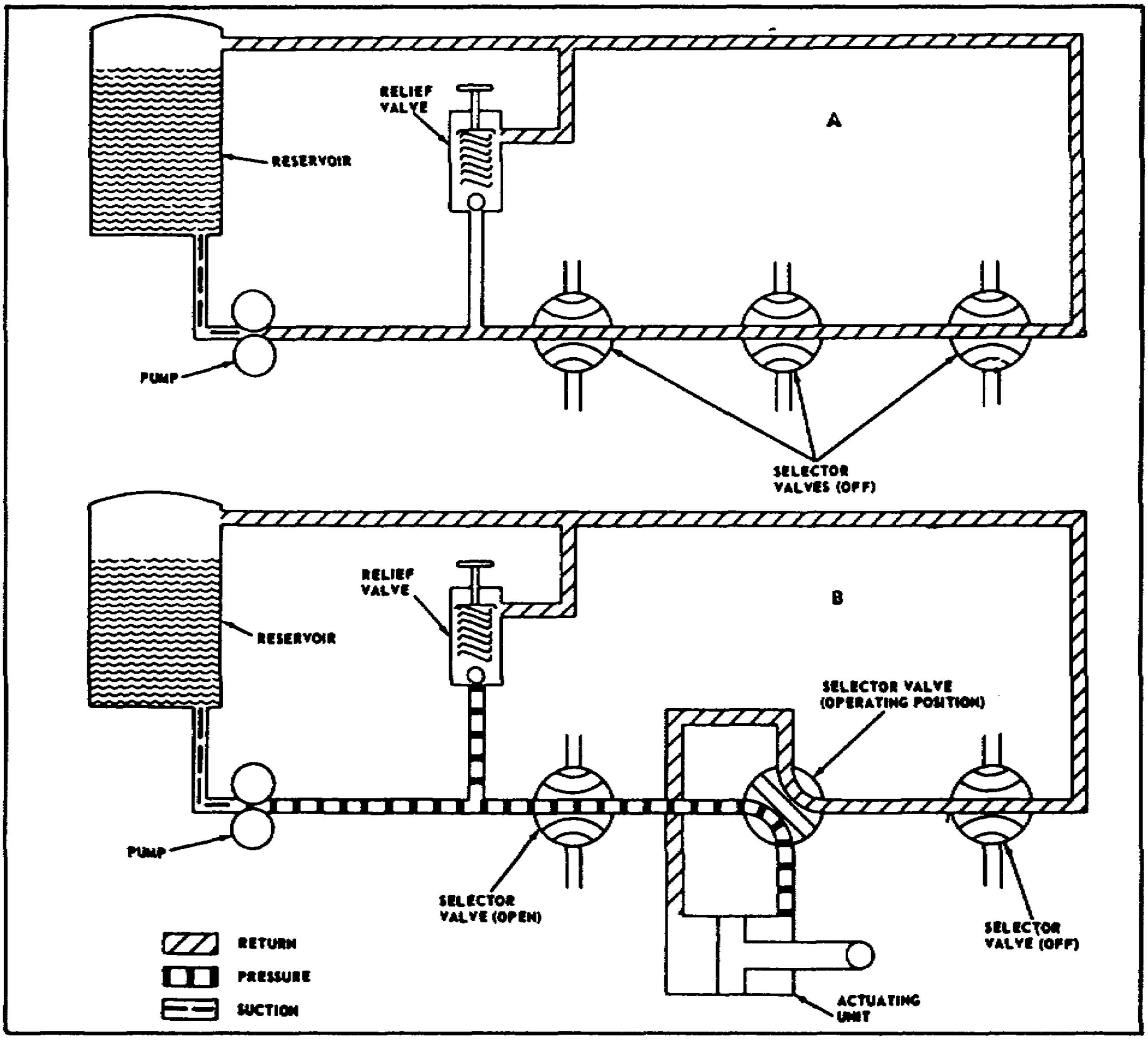

Figure 2-7. Basic Open-Center Hydraulic System.

has fluid flow but no pressure until some hydraulic device is operated. When the selector valves are OFF, fluid flows from the reservoir to the pump through the open-center passage of each valve, then back to the reservoir. No restrictions exist in the system; therefore, no pressure is present. When one valve is placed in the operating position, a restriction is created by the device the valve controls. Fluid then flows under pressure to that hydraulic device.

Closed-Center System. Figure 2-8 shows a basic closed-center system. Fluid is under pressure throughout a closed-center system when the pump is operating. When the selector valves are in the OFF position, fluid cannot flow through the closed centers. This causes pressure to build in the system; it is available at any time a selector valve is turned on. A relief valve is used to keep system pressure from going above a predetermined amount when all valves are off.

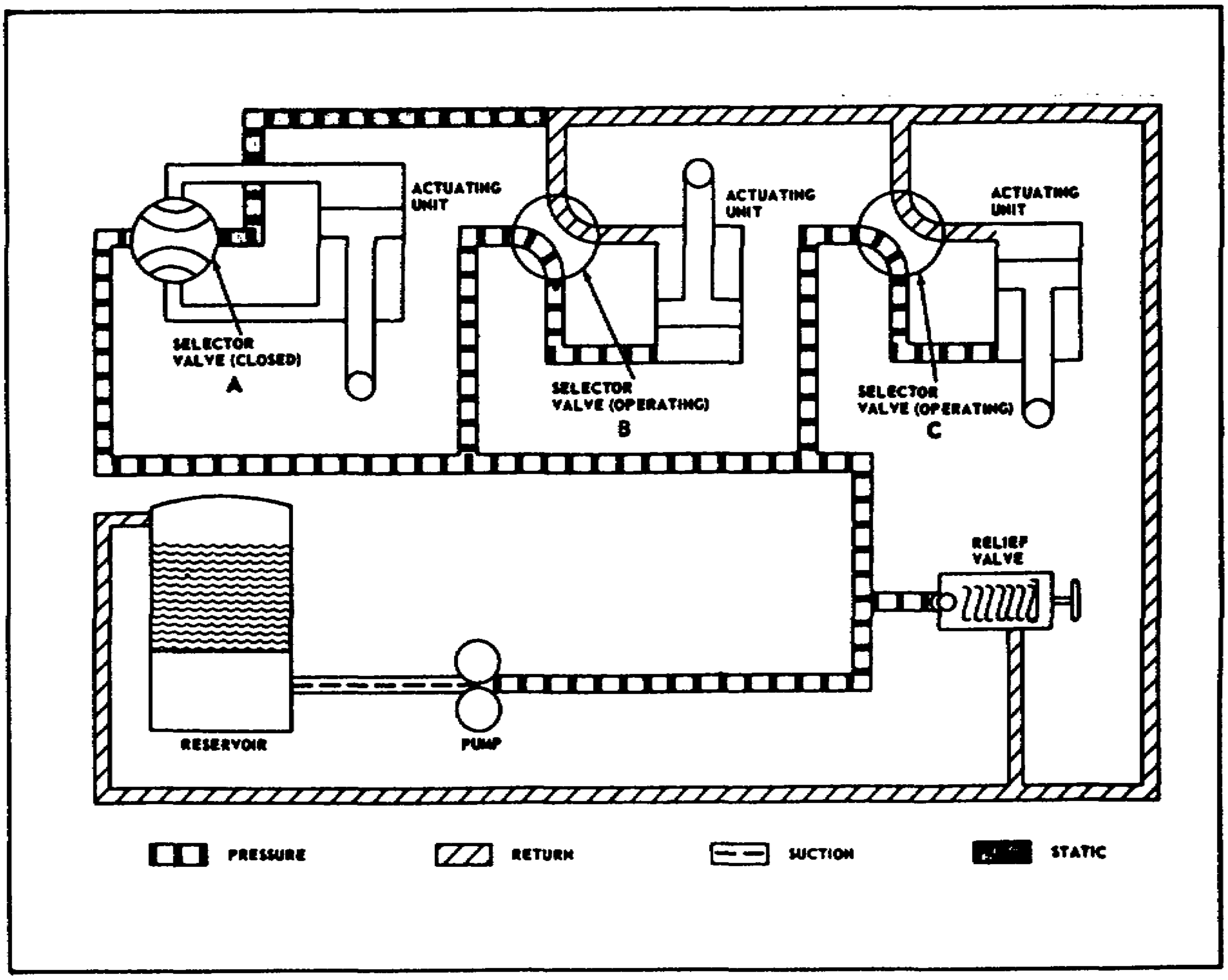

Figure 2-8. Basic Closed-Center System.

HYDRAULIC SERVO

A servo is a combination of a selector valve and an actuating cylinder in a single unit. When the pilot valve of a servo is opened by the operator, it is automatically closed by movement of the servo (or actuating) unit as explained below. Hydraulic servos are used in aircraft when precise control is necessary over the distance a component moves.

Typical Hydraulic Servo. Figure 2-9 shows a typical hydraulic servo. In operation, when the pilot valve is displaced from center, pressure is directed to one chamber of the power piston. The other chamber is open to return flow. As the power piston travels the pilot valve housing travels because the two are attached. The pilot valve itself is being held stationary by the operator, and the ports again become blocked by the lands of the pilot valve stopping the piston when it has moved the required distance.

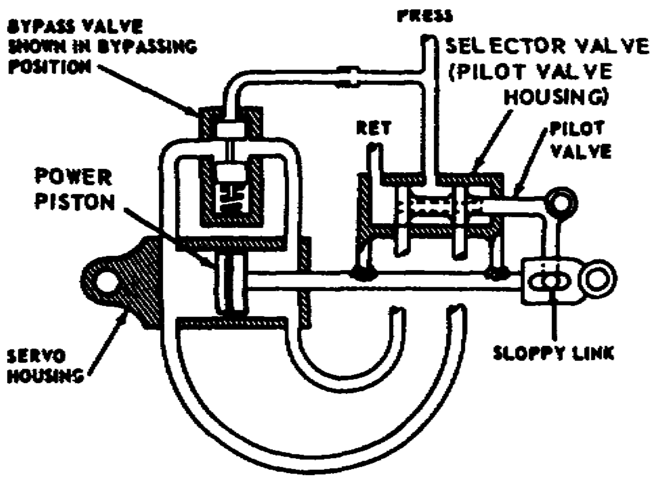

Figure 2-9. Hydraulic Servo Incorporating Sloppy Link and Bypass Valve.

Servo Sloppy Link. Notice the servo sloppy link in Figure 2-9. It is the connection point between the control linkage, pilot valve, and servo piston rod. Its purpose is to permit the servo piston to be moved either by fluid pressure or manually. The sloppy link provides a limited amount of slack between connecting linkage and pilot valve. Because of the slack between the piston rod and the connecting linkage, the pilot valve can be moved to an ON position by the connecting linkage without moving the piston rod.

Bypass Valve. A bypass valve is provided to minimize the resistance of the servo piston to movement when it must be moved manually. The valve opens automatically when there is no operating pressure on the servo. This allows fluid to flow freely between the chambers on each side of the piston.

IRREVERSIBLE VALVE

During normal aircraft operation, external forces from an aircraft's control surfaces, such as rotor blades and ailerons, tend to move servo cylinders. This movement creates a pumplike action in the servo called feedback. The irreversible valve prevents feedback through the servo to the control stick.

Figure 2-10 is a simplified schematic version of an irreversible valve. The broken-line block represents the housing of the

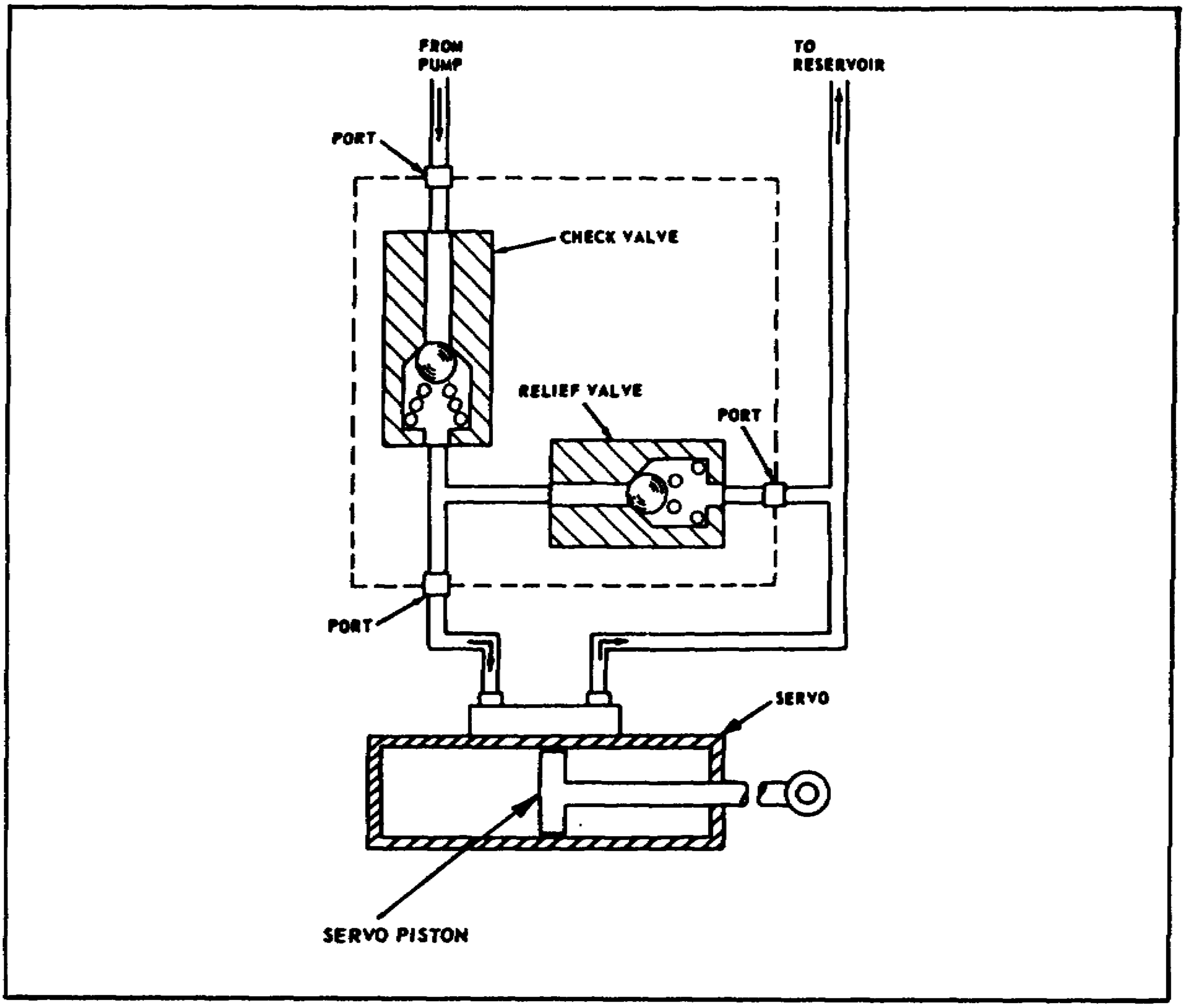

Figure 2-10. Simplified Irreversible Valve.

valve. The check valve allows fluid from the pump to flow in the normal direction as shown by the arrow. Feedback forces tend to move the servo piston opposite to the direction of pump-produced pressure. This tends to force fluid backward through the irreversible valve. The check valve keeps the servo piston from yielding to feedback by locking the rear-ward flow of fluid. The relief valve is 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 pressure exceeds a predetermined safe limit.

RATCHET VALVE

A ratchet valve is used with a double-action actuating cylinder to aid in holding a load in the position where it has been moved. The ratchet valve ensures that there is trapped fluid on each side of the actuating cylinder piston. This is necessary for the cylinder to lock a load against movement in either direction.

A typical ratchet valve is shown in Figure 2-11. It consists of a housing with four ports, a polished bore, two ball check valves and a piston. The piston has extensions on either end to unseat the two ball check valves. Springs keep these valves on their seats when no pressure is applied to the system.

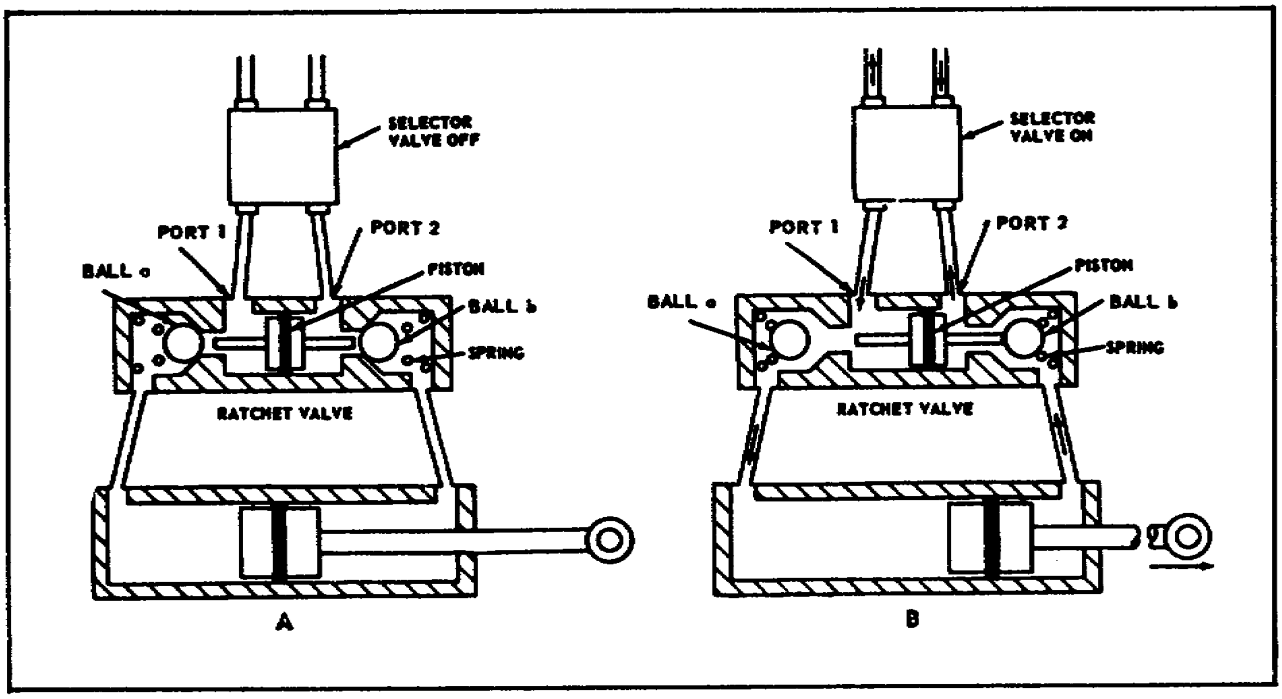

Figure 2-11. Typical Application of Ratchet Valve.

Valve Operation With no Pressure. In A, Figure 2-11, the ratchet valve is shown with no pressure applied. The piston is centered in its bore and both ball check valves are closed. This locks the actuating cylinder in position by trapping all fluid in the cylinder.

Valve Operation With Pressure Applied. In B, Figure 2-11, the ratchet valve is shown with pressure applied to port 1. This forces the piston to the right where it unseats ball check valve b. Pressure entering port 1 also unseats ball check valve a on the left side. Fluid then flows through the ratchet valve and the piston moves to the right.

CHECK VALVES

A check valve is installed in a hydraulic system to control the direction flow of hydraulic fluid. The check valve allows free flow of fluid in one direction, but no flow or a restricted one in the other direction.

There are two general designs in check valves. One has its own housing and is connected to other components with tubing or hose. Check valves of this design are called in-line check valves. In the other design, the check valve is part of another component and is called an integral check valve. It will not be covered because its operation is identical to the in-line check valve. The two types of in-line check valves, simple and orifice, are described in the following paragraphs.

Simple In-Line Check Valve. As illustrated in Figure 2-12, the simple inline check valve consists of a casing, inlet and outlet ports, and a ball-and-spring assembly. The ball and spring permit full fluid flow in one direction and block flow completely in the opposite direction. Fluid pressure forces the ball off its seat against the spring pressure, permitting fluid flow. When flow stops, the spring forces the ball against its seat, blocking reverse flow.

Orifice In-Line Check Valve. The orifice check valve shown in Figure 2-13 is used to allow free flow in one direction and limited flow in the opposite direction. This is accomplished by drilling a passage in the valve seat connecting the inlet side of the valve to the outlet side.

SEQUENCE VALVE

A sequence valve, shown in Figure 2-14, is placed in a hydraulic system to delay the operation of one portion of that system until another portion of the same system has functioned. For

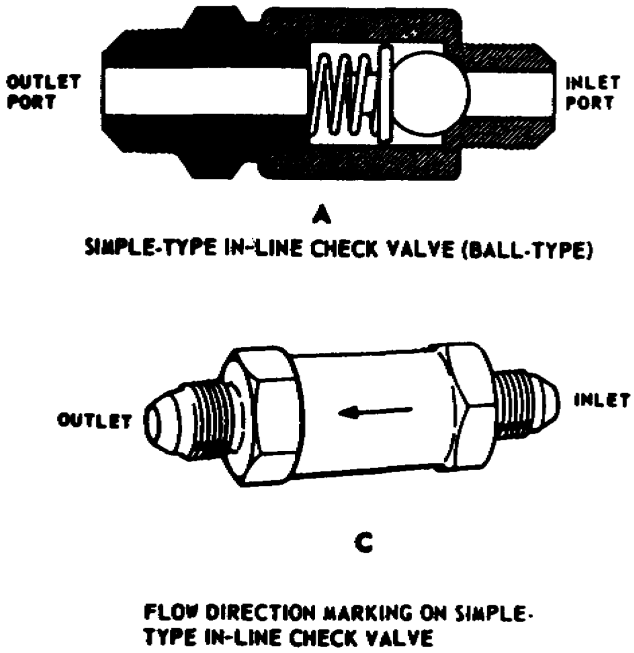

Figure 2-12. Simple In-Line Check Valve.

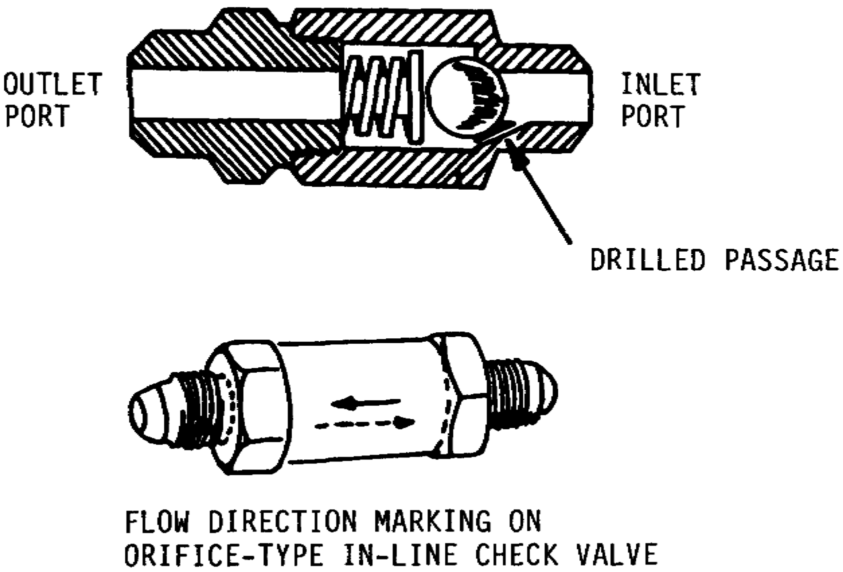

Figure 2-13. Orifice In-Line Check Valve.

example, it would be undesirable for the landing gear to retract before the gear compartment doors are completely open. A sequence valve actuated by the fully open door would allow pressure to enter the landing gear retract cylinder.

The sequence valve consists of a valve body with two ports, a ball and seal spring-loaded to the closed position, and a spring-loaded plunger. Compressing the plunger spring off-seats the ball and allows the passage of fluid to the desired actuator. The typical sequence valve is mechanically operated, or it can be solenoid-operated by means of microswitches. In either case, the valve is operated at the completion of one phase of a multiphase hydraulic cycle.

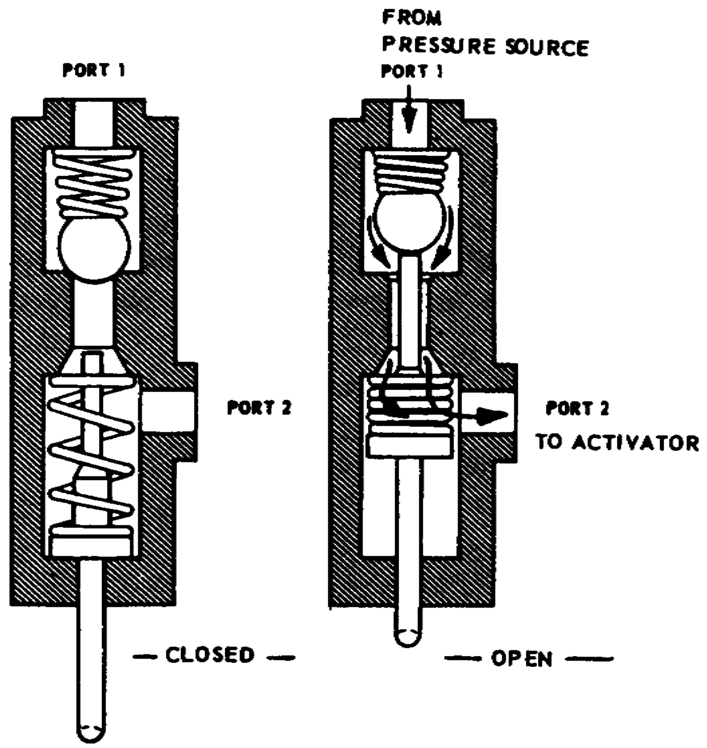

Figure 2-14. Mechanically Actuated Sequence Valve.

PRIORITY VALVE

A priority valve is installed in some hydraulic systems to provide adequate fluid flow to essential units. The valve is installed in the line between a nonessential actuating unit and its source of pressure. It permits free, unrestrained flow of fluid to nonessential units as long as system pressure is normal. When system pressure drops below normal, the priority valve automatically reduces the flow of fluid to the nonessential units.

The priority valve (Figure 2-15) resembles a check valve in both external appearance and internal operation. A spring acts against a hollow piston to maintain contact with a valve seat. With no system pressure, the priority valve is in the Spring-loaded position, closed. The piston is against the valve seat. As pressure is applied to the system, fluid passes through the valve seat and also through drilled passages to act against the face of the piston. With normal flow and pressure, the piston moves against the spring tension and allows passage of fluid. If pressure decreases, the spring forces the piston to seat, assuring a supply of fluid for the essential portion of the system.

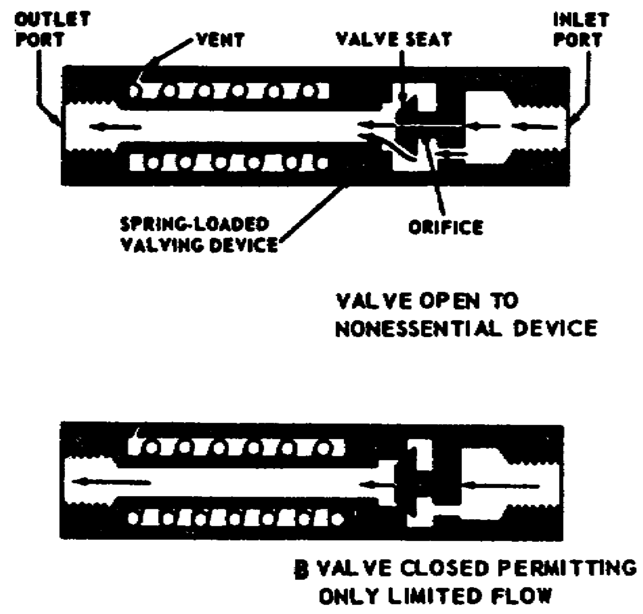

Figure 2-15. Typical Priority Valve.

SUMMARY

The hydraulic actuating cylinder is used to convert fluid pressure to straight-line motion. The two types are single-and double-acting.

Selector valves are used with actuating cylinders to control their operation. The typical selector valve has two ON positions to extend and retract the cylinder and one OFF position.

Hydraulic systems are classified as either open-center or closed-center. Open-center systems have only open-center selector valves and closed-center systems only closed-center valves.

Hydraulic servos are physical combinations of actuators and selector valves. They are used when precise control of movement is required and normally found in the flight control system of an aircraft. Irreversible valves are used in line with servos to prevent feedback to the flight controls.

Ratchet valves are locking devices for actuating cylinders; they
hold the cylinders in any desired position.

If full fluid flow in one direction only is required, a simple in-line check valve is used. When full flow in one direction and restricted flow in the opposite direction is desired, an orifice check valve is used.

When more than one function must be performed in a hydraulic system and a definite order must be followed, sequence valves are used. Sequence valves ensure that the proper order of operations is maintained. In a reduction of pressure or fluid flow, certain components can be cut out of the hydraulic system to ensure an adequate supply of fluid for the essential components, such as flight controls. Priority valves are used to automatically shut off the supply of fluid to nonessential components.

LESSON 2

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you have completed the exercise, check your answers with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. The piston in a double-action actuating cylinder can--

___ A. retract only.
___ B. extend only.
___ C. retract and extend.
___ D. neither extend nor retract.

2. What type of valve prevents feedback through the servo to the control stick?

___ A. Ratchet valve.
___ B. Spool selector valve.
___ C. Orifice check valve.
___ D. Irreversible valve.

3. What is used to limit system pressure?

___ A. Relief valve.
___ B. Check valve.
___ C. Ratchet valve.
___ D. Selector valve.

4. What type of valve is installed in a closed-center hydraulic system?

___ A. Return valve.
___ B. Check valve.
___ C. Ratchet valve.
___ D. Selector valve.

5. What controls the direction of fluid flow?

___ A. Relief valve.
___ B. Check valve.
___ C. Ratchet valve.
___ D. Selector valve.

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6. What valve resembles a check valve in appearance and operation?

___ A. Selector valve.
___ B. Priority valve.
___ C. Sequence valve.
___ D. Ratchet valve.

7. What is used to prevent leakage in the single-action actuating cylinder?

___ A. Polished bore.
___ B. Close-tolerance machining.
___ C. Wiper rings.
___ D. Seals.

8. What holds the piston in the retracted position in a single-action actuating cylinder?

___ A. Fluid pressure.
___ B. Static pressure.
___ C. Spring pressure.
___ D. Return pressure.

9. What is used with double-action cylinders to hold loads?

___ A. Relief valve.
___ B. Check valve.
___ C. Ratchet valve.
___ D. Selector valve.

10. What permits limited flow in one direction and full flow in the other direction?

___ A. Sequence valve.
___ B. Selector valve.
___ C. Orifice check valve.
___ D. Priority valve.

LESSON 2

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	C. Retract and extend.
	The piston of a double-action actuating cylinder can move in either direction, depending on which of the two ports has pressure applied. (Page 27)
2.	D. Irreversible valve.
	The irreversible valve prevents the shock and vibration of the rotor blades from feeding back to the pilot's hands through the control stick. (Page 36)
3.	A. Relief valve.
	A relief valve does just what the name implies. It releases pressure at a predetermined pressure level. (Page 33)
4.	D. Selector valve.
	The selector valve determines the flow of fluid. (Page 34)
5.	B. Check valve.
	A check valve basically allows fluid to flow only in one direction. When fluid flow tries to reverse its direction, the reverse direction of fluid pushes a ball against its seat and shuts off any reverse fluid flow. (Page 38)
6.	B. Priority valve.
	Allows flow of fluid to nonessential parts as long as the pressure remains normal. As soon as there is a pressure drop, it immediately reduces pressure to any nonessential components. (Page 41)

7. D. Seals.

Seals are used to prevent leakage in fluid-operated components. (Page 26)

8. C. Spring pressure.

The spring prevents the piston from moving until an overriding fluid force is applied against it. (Page 26)

9. C. Ratchet valve.

This valve allows enough trapped fluid on both sides of the piston to lock a load against movement in either direction. (Page 37)

10. C. Orifice check valve.

A small passage is formed in the valve seat which connects the inlet side to the outlet side. When fluid tries to reverse the flow, the ball closes against the seat and only a small portion is allowed to flow through the small passage. (Page 38)

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LESSON 3

HYDRAULIC PRESSURE-LIMITING, CONTROLLING, AND SENSING DEVICES

STP Tasks: 552-758-1003
552-758-1006
552-758-1071

OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn the basic construction and operation of hydraulic pressure-limiting, controlling, and sensing devices.

TERMINAL LEARNING OBJECTIVE:

ACTION: After this lesson unit you will demonstrate knowledge of the basic construction and operation of hydraulic controlling, pressure-limiting, and sensing devices.

CONDITIONS: You will study the material in this lesson in a classroom environment or at home.

STANDARD: You will correctly answer all the questions in the practice exercise before you proceed to the subcourse examination.

REFERENCES: The material contained in this lesson was derived from the following publications. AR 310-25, AR 310-50, FM 1-500, FM 1-509, TM 1-1500-204-23 Series, TM 55-1510-Series, TM 55-1520-Series, and TM 4301A 05 0267 (Airforce).

INTRODUCTION

The hydraulic systems in modern Army aircraft operate at pressures up to 3,000 psi. These systems must be protected against excessively high pressure that can cause seals and lines to fail. Pressure relief valves are used to keep system pressure from exceeding a predetermined safe limit.

A complex hydraulic system can use any number of components: actuators, servos, irreversible valves, selector valves, check valves, accumulators, hydraulic motors, etc. Each of these various components in one hydraulic system can operate most efficiently at a different pressure. In systems having a single hydraulic pump, pressure reducers are used to vary operating pressures to the different components.

If hydraulic pressure becomes too low for safe operation, a hydraulic pressure switch can be used to close an electrical circuit. This actuates a warning light in the cockpit or turns on a secondary system, or does both.

In this chapter you will learn of the devices used to limit, control, and sense hydraulic pressure.

PRESSURE RELIEF VALVES

A relief valve is installed in any system containing a confined liquid subject to pressure. The use of relief valves falls into one or more of three categories:

- In the first category, a relief valve is used to protect a hydraulic system if the pump compensator fails. The relief valve is adjusted to open at a pressure slightly higher than normal system operating pressure.

- In the second category, a relief valve is used to protect a system subject to pressure increases caused by thermal expansion.

- In the third category, a relief valve is used as the sole means of pressure control in a hydraulic system.

Relief Valves. The configurations for relief valves are either two-port or four-port. Both types operate in the same way. The main reason for additional ports is convenience in connecting the plumbing. For simplicity, only the two-port pressure relief valve is described in this text.

Two-Port Relief Valve. A typical two-port relief valve is shown in Figure 3-1. It consists of a housing with an inlet and an outlet port, a valving device, a compression spring, and an adjustment screw. When the hydraulic system is pressurized, the pressure acts against the valving device; in this case, a ball. The ball is held against its seat by a coil spring. When the fluid pressure is great enough against the ball to overcome the force of the spring, the ball is unseated and allows fluid to pass.

The exact pressure at which this takes place is called the cracking pressure. This pressure can be adjusted to any desired pressure by means of the pressure adjustment screw. Fluid passing the valving ball flows into return lines and back to the reservoir.

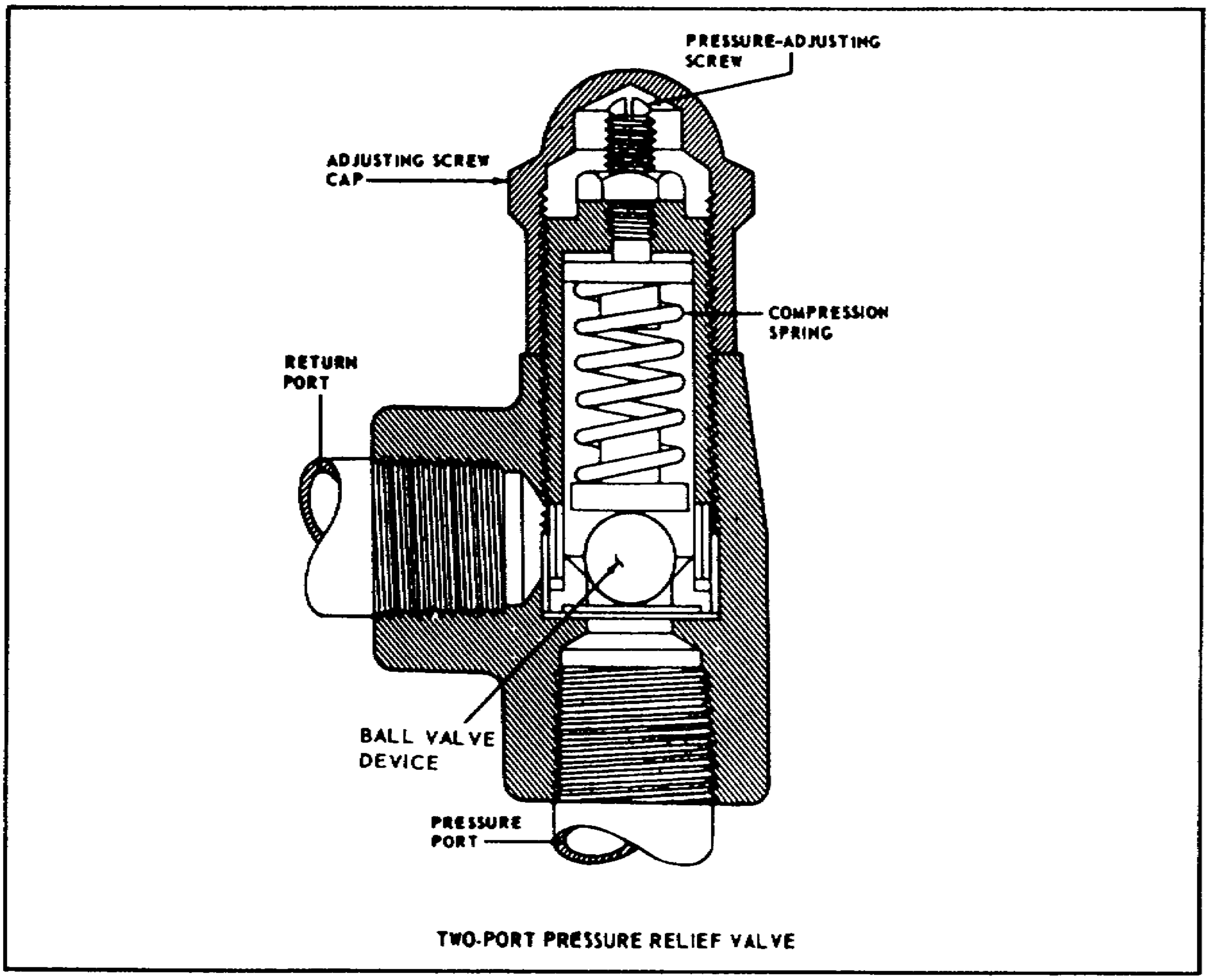

Figure 3-1. Pressure Relief Valve.

PRESSURE REDUCER

A pressure reducer provides more than one level of pressure in a system that has a single hydraulic pump. The reducer (Figure 3-2) consists of a three-port housing, piston, poppet and spring, adjusting spring, and adjusting screw. A poppet is a valving device with a flat face. The three ports of the housing are input pressure port, reduced-pressure port, and return port.

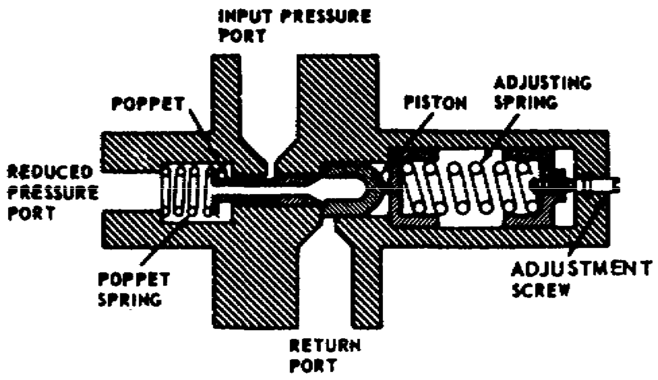

Figure 3-2. Pressure Reducer.

Withholding Pressure. The pressure reducer operates on the principle of withholding pressure rather than relieving it. With no pressure in the system, the adjusting spring tension holds the poppet open. As system pressure builds up, fluid passes through the poppet to the reduced-pressure port. When the pressure acting against the piston exceeds the force of the adjusting spring in the pressure reducer, the poppet moves to close the inlet port. Further buildup of system pressure does not affect the reduced pressure until it decreases enough to allow the inlet to be opened by spring tension.

Relieving Pressure. Pressure reducers also relieve increased pressure resulting from thermal expansion. As the pressure at the reduced pressure port increases, the piston moves against the adjusting spring, opening the return port and relieving the excessive pressure.

PRESSURE SWITCHES

A pressure switch is designed to open or close an electrical circuit in response to a predetermined hydraulic pressure; the switch activates a warning or protective device. At a set minimum pressure, the switch can turn on a light to warn the pilot, turn a pump off, or activate a solenoid-controlled valve. The types of pressure switches, piston and diaphragm, commonly used in Army aircraft are described in the following paragraphs.

Piston Pressure Switch. The piston pressure switch (Figure 3-3) consists of a housing, a cylinder bore and piston, an adjustable spring for loading the piston, a microswitch and linkage for transmitting movements of the piston to the microswitch. The housing has a pressure port for connection to system pressure and an electrical receptable for connecting the switch to an electrical circuit.

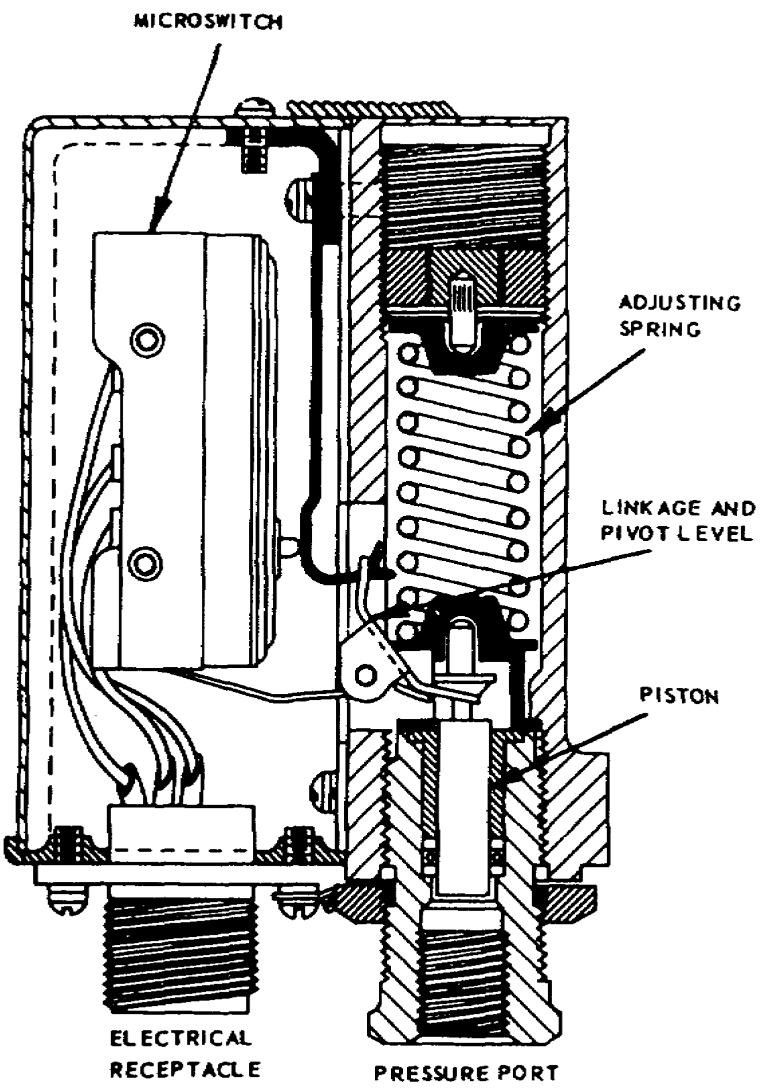

Figure 3-3. Piston Pressure Switch.

Diaphragm Pressure Switch. The diaphragm pressure switch consists of a 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 ports for the same functions as those in the piston switch.

Pressure Switch Operation. The two types of pressure switches have the same operating principles; only the piston one is covered here. Fluid pressure enters the pressure port and moves the face of the piston against the adjustment spring.

When the pressure becomes great enough to overcome the force of the spring, the piston moves and causes the pivot lever to rotate. The movement of the lever is transmitted through the linkage to the microswitch button. This closes the electrical circuit.

SUMMARY

Hydraulic systems have devices to protect against excessive pressure. These are called pressure relief valves. The valves are adjustable and are set to open at a point slightly above maximum system pressure. When this occurs, the fluid is returned to the system reservoir.

Pressure reducers are used to deliver the correct pressure to each component in a hydraulic system. This makes it possible to use one hydraulic pump, delivering one set pressure in a system that requires several different pressures.

Pressure switches are physical combinations of a hydraulic device (pressure port, piston, and sprint) and an electrical device (microswitch and wiring). Pressure switches are used to sense hydraulic pressure. Depending on the switch, if the pressure is too high or too low, the microswitch closes and energizes a valve, stops or starts a pump, or illuminates a warning light.

LESSON 3

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you have completed the exercise, check your answers with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. What are the configurations for relief valves?

___ A. One and two ports.
___ B. One and four ports.
___ C. Two and four ports.
___ D. Two and three ports.

2. What part of a single hydraulic pump provides more than one level of pressure in a hydraulic system?

___ A. Return port.
___ B. Pressure reducer.
___ C. Pressure port.
___ D. Compression spring.

3. How many types of pressure switches are most often used on Army aircraft?

___ A. One.
___ B. Two.
___ C. Three.
___ D. Four.

4. What device is used to protect against excessive pressure?

___ A. Pressure relief valve.
___ B. Pressure reducer valve.
___ C. Pressure sequence valve.
___ D. Pressure selector valve.

5. Pressure switches are used to sense--

___ A. excessive pressure.
___ B. electrical current.
___ C. hydraulic pressure.
___ D. electrical voltage.

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6. What is used to relieve increased pressure from thermal expansion?

___ A. Pressure sequential valve.
___ B. Pressure selector valve.
___ C. Pressure relief valve.
___ D. Pressure reducer valve.

7. When a pressure switch senses a drop in system fluid pressure, what does the switch activate?

___ A. Warning device.
___ B. Sensing device.
___ C. Pressure device.
___ D. Sequential device.

8. What are the two types of pressure switches commonly used in Army aircraft?

___ A. Sensing and warning.
___ B. Piston and diaphragm.
___ C. Warning and diaphragm.
___ D. Diaphragm and sensing.

9. What does the piston pressure switch consist of?

___ A. Cylinder housing, bore and piston, microswitch.
___ B. Housing, cylinder bore and piston, microswitch, spring.
___ C. Piston, cylinder bore and switch spring, microswitch.
___ D. Warning device, cylinder bore and piston.

10. What is the term used to describe the action of fluid pressure in a valve becoming high enough against the ball to overcome the force of the spring?

___ A. Spring pressure.
___ B. Reducing pressure.
___ C. Cylinder pressure.
___ D. Cracking pressure.

LESSON 3

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answers and Feedback
1.	C. Two and four ports.
	There are two configurations for relief valves. They are two- and four-port and are used to relieve pressure. A four-port relief valve is for connecting additional plumbing that may be incorporated into a more complex hydraulic system. (Page 50)
2.	B. Pressure reducer.
	A pressure reducer provides the different pressures which are required to operate some components. (Page 51)
3.	C. Two.
	There are only two types of pressure switches used in Army aircraft. (Page 52)
4.	A. Pressure relief valve.
	In a pressure relief valve, when fluid pressure reaches a certain point, the relief valve opens to relieve excessive fluid pressure, allowing it to return to the system reservoir. (Page 50)
5.	C. hydraulic pressure.
	This switch senses any under- or over-pressurization of hydraulic fluid. (Page 52)
6.	D. Pressure reducer valve.
	The pressure reducer valve senses abnormal pressure buildup and opens to relieve the excessive pressure. (Page 52)
7.	A. Warning device.
	A pressure switch activates a warning device at a predetermined fluid pressure. (Page 52)

8. B. Piston and diaphragm.

There are two types of pressure switches used in Army aircraft. (Page 52)

9. B. Housing, cylinder bore and piston, microswitch, spring.

The main components of a pressure switch are housing, cylinder bore and piston, microswitch, spring. (Page 52)

10. D. Cracking pressure.

The cracking pressure is the pressure above normal at which the relief valve will-open. (Page 51)

APPENDIX
GLOSSARY

Accumulator--device for storing liquid under pressure, usually consisting of a chamber separated into a gas compartment and a liquid compartment by a bladder, piston, or diaphragm. An accumulator also smooths out pressure surges in a hydraulic system.

Actuating cylinder--device that converts fluid power into linear mechanical force and motion.

Actuating cylinder, double-action--actuating cylinder in which both strokes are produced by pressurized fluid.

Actuating cylinder, single-action--actuating cylinder in which one stroke is produced by pressurized fluid and the other stroke is produced by some other force, such as gravity or spring tension.

Angular piston pump--hydraulic pump that has the cylinder block placed at an angle to the drive shaft plate where the pistons are attached. The angular configuration causes the pistons to stroke as the pump shaft is turned.

Baffle--metal plate installed in a reservoir to keep the fluid from swirling and surging.

Bladder--synthetic rubber bag inserted in an accumulator to hold the air charge.

Bypass valve--valve used to allow fluid to go around a filtering element if the element becomes clogged.

Cam pump--type of hydraulic pump that utilizes a cam to cause stroking of the pistons.

Check valve--valve that permits fluid flow in one direction, but prevents flow in the reverse direction.

Closed-center valve--type of valve that has its pressure passage blocked to fluid flow when the valve is in the OFF position.

Cracking pressure--pounds per square inch pressure at which the valving device of a pressure relief valve clears its seat just enough to permit fluid to seep through.

Diaphragm--synthetic rubber device that divides an accumulator into two separate compartments, one for air and the other for fluid.

Displacement--volume of fluid that can pass through a pump, motor, or cylinder in a single revolution or stroke.

Double-action actuating cylinder--See Actuating cylinder, double-action.

Drive coupling--device that transmits torque from a driving unit to a hydraulic pump drive shaft.

Efficiency--ratio of output power to input power, generally expressed as a percentage.

Energy--ability or capacity to do work.

Filter--device used to remove contaminants from hydraulic fluid.

Fixed-displacement pump--pump in which the volume of fluid per cycle cannot be varied.

Fluid--any liquid, gas, or mixture thereof.

Hydraulics--that branch of mechanics or engineering that deals with the action or use of liquids forced through tubes or lines under pressure to operate various mechanisms.

Irreversible valve--device used in conjunction with a servo to block feedback.

Land--smooth machined surface on the spool of a spool selector valve.

Micron--millionth of a meter, or about 0.00004 inch.

Open-center valve--type of valve that has its pressure passage open to return when the valve is in the OFF position.

Orifice--device used to restrict the flow of fluid in order to slow the operation of a component.

Pilot valve--valve used to control the operation of another valve, the spool in a selector valve.

Piston--that part of an actuating cylinder, servo, or motor that the hydraulic fluid works against. In a pump, the pistons work against the fluid.

Poppet--valving device similar to the valves found in an automobile engine.

Port--opening for the intake or exhaust of fluid.

Power--rate of doing work or expending energy.

Pressure--amount of force distributed over each unit area expressed in pounds per square inch (psi).

Pressure reducer--device for lowering the pressure in a hydraulic system to allow a component to operate at a lower pressure than the rest of the system.

Pressure relief valve--pressure control valve used to keep system pressure from exceeding predetermined limits.

Pressure switch--electrical switch operated by the increase or decrease of fluid pressure.

Priority valve--valve used to route fluid to those components requiring immediate completion of action when a reduction in normal system flow and pressure occurs.

Pump--device that converts mechanical energy into fluid energy.

Ratchet valve--valve used with double-action actuator cylinders to aid the cylinder in holding a load in the position selected by the operator.

Reservoir--container that serves primarily as a supply source of the fluid for a hydraulic system.

Selector valve--valve used to control the direction of movement of an actuating unit.

Servo--device used to convert a small movement into a greater movement or force.

Sloppy link--point of interconnection between control linkage, pilot valve, and servo piston rod in a servo.

Standpipe--pipe located in a reservoir where the main hydraulic system draws its fluid.

Stroke--distance a piston moves in its bore from bottom to top, a single movement of a piston from one end of its range to the other.

Thermal expansion--increase in volume of a substance due to temperature change.

Variable-delivery pump--type of pump in which the volume of fluid per cycle can be varied.

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