LESSON 2

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

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OVERVIEW

LESSON DESCRIPTION:

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

TERMINAL LEARNING OBJECTIVE:

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 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.
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.](image)

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.
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.](image-url)
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.](image)

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.](image)
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.](image-url)
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.

![Mechanically Actuated Sequence Valve](image)

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.
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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.
THIS PAGE IS INTENTIONALLY LEFT BLANK.
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.
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### PRACTICE EXERCISE

### ANSWER KEY AND FEEDBACK

<table>
<thead>
<tr>
<th>Item</th>
<th>Correct Answer and Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>C. Retract and extend.</td>
</tr>
<tr>
<td></td>
<td>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)</td>
</tr>
<tr>
<td>2.</td>
<td>D. Irreversible valve.</td>
</tr>
<tr>
<td></td>
<td>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)</td>
</tr>
<tr>
<td>3.</td>
<td>A. Relief valve.</td>
</tr>
<tr>
<td></td>
<td>A relief valve does just what the name implies. It releases pressure at a predetermined pressure level. (Page 33)</td>
</tr>
<tr>
<td>4.</td>
<td>D. Selector valve.</td>
</tr>
<tr>
<td></td>
<td>The selector valve determines the flow of fluid. (Page 34)</td>
</tr>
<tr>
<td>5.</td>
<td>B. Check valve.</td>
</tr>
<tr>
<td></td>
<td>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)</td>
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<tr>
<td>6.</td>
<td>B. Priority valve.</td>
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<td>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)</td>
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</tbody>
</table>
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)


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)