CONSTRUCTION-EQUIPMENT REPAIRER (HYDRAULIC SYSTEMS)

Subcourse EN 5260

EDITION B

United States (US) Army Engineer School
Fort Leonard Wood, Missouri 65473

4 Credit Hours

Edition Date: November 1999

SUBCOURSE OVERVIEW

This subcourse is designed to teach the basic skills required to adjust and repair hydraulic pumps and valves used on engineer construction equipment. Information is provided on positive-displacement pumps and control valves and the procedures required to disassemble, adjust or repair, and reassemble them. This subcourse is presented in two lessons, each corresponding to a terminal learning objective.

There are no prerequisites for this course.

This subcourse reflects the doctrine which was current at the time it was prepared. In your own work, 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.

TERMINAL LEARNING OBJECTIVE:

ACTION: You will learn to identify, disassemble, adjust or repair, and reassemble hydraulic pumps and valves used on engineer construction equipment.

CONDITION: You will be given this subcourse and an ACCP examination response sheet.

STANDARD: To demonstrate competency of this task, you must attain a minimum score of 70 percent on the subcourse examination.

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ADMINISTRATIVE INSTRUCTIONS

1. Number of lessons in this subcourse: Two.

2. Materials you will need in addition to this booklet are a number two pencil, the ACCP examination response sheet, and the preaddressed envelope you received with this subcourse.

3. Supervisory requirements: None.

4. The following publications provide additional information about the material in this subcourse. You do not need these publications to complete this subcourse.

- FM 5-499. *Hydraulics*. 1 August 1997.

- Soldier Training Publication (STP) 5-62B1-SM. *Soldier's Manual, MOS 62B, Construction Equipment Repairer Skill Level 1*. 25 September 1990.

- STP 5-62B24-SM-TG. *Soldier's Manual and Trainer's Guide: MOS 62B, Construction Equipment Repairer (Skill Level 2/3/4)*. 15 October 1990.

- TM 5-2350-262-20-1. *Unit Maintenance Manual Vol 1 of 2 for Armored Combat Earthmover (ACE), M9 (NSN 2350-00-808-7100) (This Item is Included on EM 0035)*. 3 January 1997.

- TM 5-2350-262-20-2. *Unit Maintenance Manual, Vol 2 of 2 for Armored Combat Earthmover (ACE), M9 (NSN 2350-00-808-7100) (This Item is Included on EM 0035)*. 3 January 1997.

- TM 5-2410-237-20. *Unit Maintenance Manual for Tractor, Full Tracked, Low Speed: DED, Medium Drawbar Pull, SSN M061, Tractor With Ripper, (NSN 2410-01-223-0350) Tractor With Winch, (2410-01-223-7261) Tractor With Ripper and Winterized Cab, (2410-01-253-2118) Tractor With Winch and Winterized Cab, (2410-01-253-2117) (This Item is Included on EM 0119).* 30 March 1993.

- TM 5-2410-237-34. *Direct Support and General Support Maintenance Manual for Tractor, Full Tracked, Low Speed: DED, Medium Drawbar Pull, SSN M061 Tractor With Ripper, (NSN 2410-01-223-0350) Tractor With Winch, (2410-01-223-7621) Tractor With Ripper and Winterized Cab, (2410-01-253-2118) Tractor With Winch and Winterized Cab, (2410-01-253-2117) (This Item is Included on EM 0119*). 30 March 1993.

- TM 5-3805-262-20. *Organizational Maintenance, Loader, Scoop Type, DED, 4 x 4, Articulated Frame Steer, 2-1/2 Cubic Yard (J. I. Case Model MW24C) (NSN 3805-01-150-4814) (This Item is Included on EM 0115*).
  1 September 1987.

- TM 5-3805-262-34. *Direct Support and General Support Maintenance Manual For Loader, Scoop Type, DED, 4 x 4, Articulated Frame Steer, 2-1/2 Cubic Yard (J. I. Case Model MW24C) (NSN 3805-01-150-4814) (This Item is Included on EM 0115).* 1 September 1987.

GRADING AND CERTIFICATION INSTRUCTIONS

Examination: This subcourse contains a multiple-choice examination covering the material in the two lessons. 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 that corresponds to your selection (A, B, C, or D). Use a number two 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.

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LESSON 1

HYDRAULIC PUMPS

Critical Tasks: 051-235-1180
051-235-2186

OVERVIEW

LESSON DESCRIPTION:

This lesson will introduce you to positive-displacement pumps used on engineer construction equipment. Included are the steps required to disassemble pumps, repair or replace components, and reassemble pumps.

TERMINAL LEARNING OBJECTIVE:

ACTION:	You will learn the types of positive-displacement pumps commonly used on engineer construction equipment and the procedures required to disassemble, repair, and reassemble them.
CONDITION:	You will be given the material contained in this lesson. You will work at your own pace and in your own selected environment with no supervision.
STANDARD:	You will correctly answer the practice exercise questions at the end of the lesson.
REFERENCES:	The material contained in this lesson was derived from STP 5-62B1-SM, STP 5-62B24-SM-TG, TM 5-2350-262-20-1, TM 5-2350-262-20-2, TM 5-2410-237-34, TM 5-3805-262-20, and TM 5-3805-262-34.

INTRODUCTION

Hydraulics is the science of using force and motion to move confined liquid. In a hydraulic device, a transfer of energy takes place when liquid is subject to pressure. The following four basic principles govern hydraulics:

- Liquids have no shape of their own; they conform to the shape of their container.

- Liquids are incompressible.
- Liquids transmit applied pressure in all directions.

- Liquids provide increased force.

The following key facts will help you gain an understanding of hydraulics:

- Hydraulic power is generated from mechanical power.

- Hydraulic energy is achieved by converting hydraulic power to mechanical energy.

- Hydraulic energy consists of potential (pressure energy), kinetic (energy of moving liquids), and heat (energy of resistance to fluid flow [friction]).

- Hydraulic energy is neither created nor destroyed, only converted to another form.

- Energy in a hydraulic system is considered either work (gain) or heat (loss).

- Heat is created and energy is lost when a moving liquid is restricted.

PART A: POSITIVE-DISPLACEMENT PUMPS

1-1. General. Pumps are used to lift or transport liquid. They may raise the liquid level or force the liquid through a hydraulic system.

a. Pumps in a hydraulic system are used to convert mechanical energy to hydraulic energy. Mechanical power creates a partial vacuum at the pump's inlet port so that atmospheric pressure in the reservoir can force liquid through the inlet line and into the pump. Mechanical power then delivers this liquid to the outlet port, forcing the liquid into the hydraulic system.

b. Positive-displacement pumps are the most common hydraulic pumps on engineer construction equipment. These pumps have a rotary motion that carries liquid from the inlet port to the outlet port. They produce a pulsating flow of liquid. Because these pumps have a positive internal seal to prevent leakage, their output is relatively unaffected by system variations. For example, if an outlet port is blocked, pressure in the pump will increase until the equipment stalls or the pump's motor fails. Positive- displacement pumps are classified according to the element that transmits the liquid—gear, vane, or piston.

1-2. Gear Pump. The gear pump (Figure 1-1) consists of a driving gear and a driven gear enclosed in a fitted housing. The gears rotate in opposite directions, and the gear teeth mesh in the housing between the inlet and outlet ports. As the teeth of the two gears separate, a partial vacuum is formed, which draws liquid through the inlet port into chamber A. Liquid in chamber A is then trapped between the teeth of the two gears and the housing and is carried through two paths to chamber B. As the teeth mesh again, liquid is forced through the outlet port.

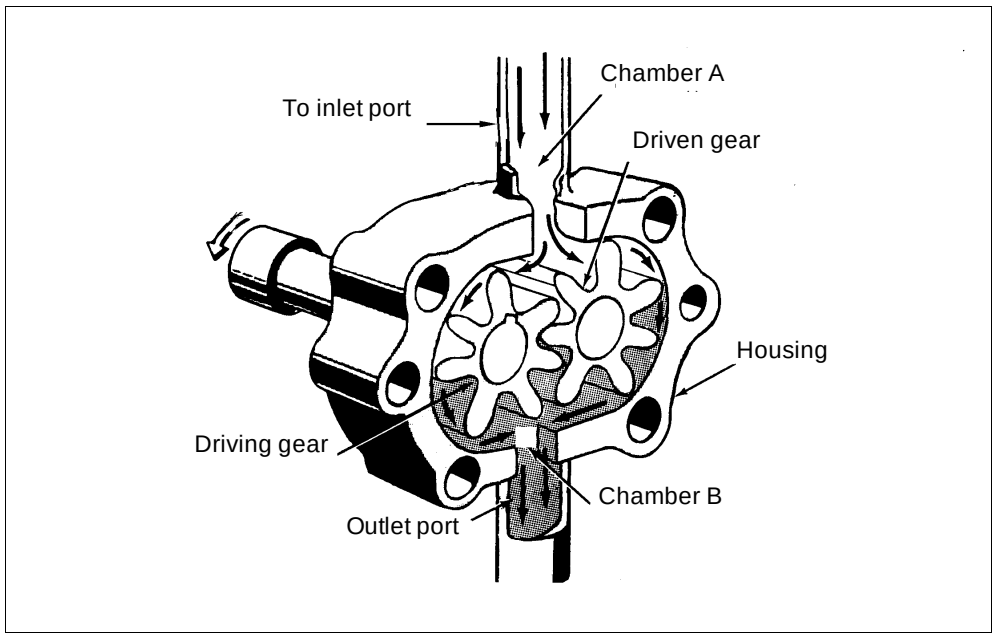


Figure 1-1. Gear pump

1-3. Vane Pump. In a vane pump, a slotted rotor splined to the drive shaft rotates between fitted side plates inside an elliptical- or circle-shaped ring (Figure 1-2, page 1-4). Polished, hardened vanes slide in and out of the rotor slots and follow the ring's contour by centrifugal force. Chambers formed between succeeding vanes carry oil from the inlet port to the outlet port. A partial vacuum is created at the inlet as the space between the vanes increases, forcing oil through the outlet as the area in the pumping chamber decreases. Because the normal wear points on a vane pump are the tips and the ring surface, these parts are specially hardened and ground.

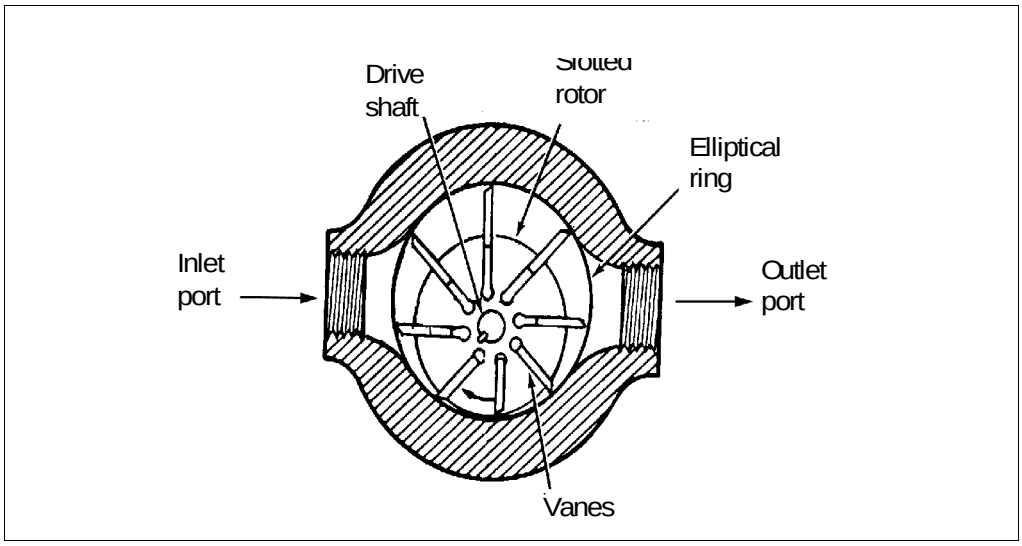


Figure 1-2. Vane pump

a. The vane pump is the only pump designed with automatic wear compensation. As wear occurs, the vanes slide out of the rotor slots and continue to follow the ring's contour. Thus, efficiency remains high throughout the life of the pump.

b. Vane pumps can be assembled to rotate either left or right. Corresponding arrows stamped on the pump's body and cartridge indicate rotation direction. Rotation is also indicated in the model number. Pumps assembled for left-hand rotation (counterclockwise when viewed from the drive-shaft end) have the letters "LH" added to the model number. Pumps assembled for right-hand rotation have no markings.

1-4. Piston Pump. On an in-line piston pump, the drive shaft and the cylinder block are on the same centerline (Figure 1-3). Reciprocation of the pistons occurs when the pistons run against a swash plate as the cylinder block rotates. The drive shaft turns the cylinder block, which carries the pistons around the shaft. The piston shoes slide against the swash plate and are held against it by the shoe-retainer plate. The angle of the swash plate causes the cylinders to reciprocate in their bores. When a piston begins to retract, the opening on the end of the bore slides over the inlet slot in the valve plate and oil is drawn into the bore through less than one-half a revolution of the cylinder block. A solid area is created in the valve plate, and the piston retracts. As the piston begins to extend the opening, the cylinder barrel moves over the inlet port and oil is forced through the outlet port.

a. The major components of a piston pump consist of a housing, a bearing-supported drive shaft, a rotating group, a shaft seal, and a valve plate. The valve plate contains the inlet and outlet ports and functions as the back cover. The rotating group includes a cylinder block, which is splined to the drive shaft; a splined spherical washer; a cylinder-block spring; nine pistons with shoes; a swash plate; and a shoe-retainer plate. When this group is assembled, the cylinder-block spring forces the cylinder block against the valve plate and the spherical washer against the shoe-

retainer plate. The nine piston shoes are held positively against the swash plate, ensuring that the pistons reciprocate as the cylinder turns. In fixed-displacement pumps, the swash plate is stationary.

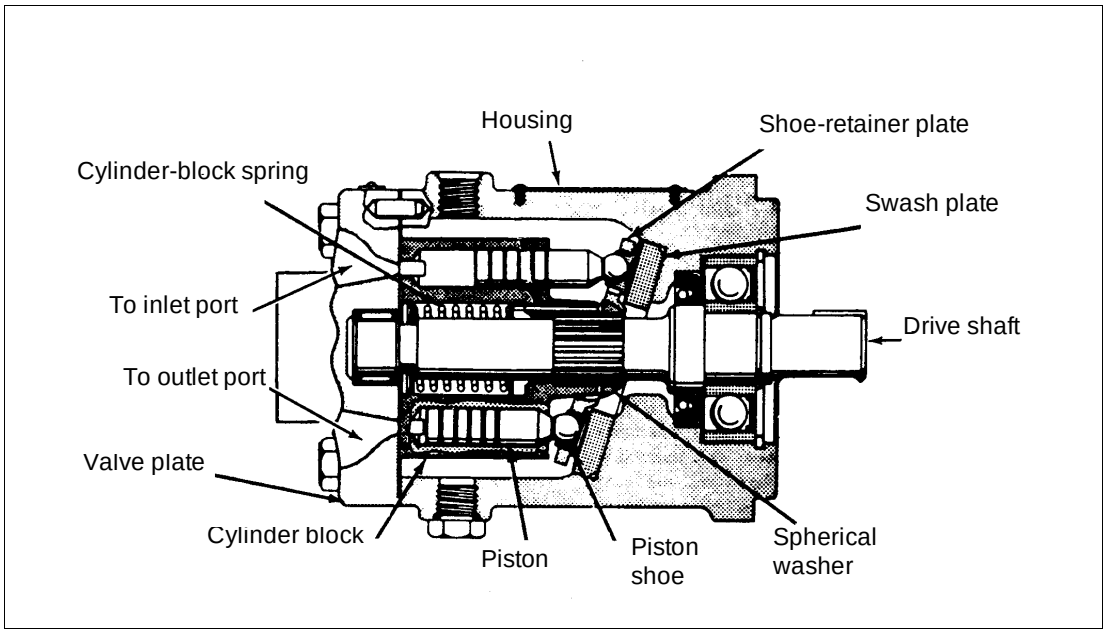


Figure 1-3. Piston pump

b. Displacement (outflow) from the piston pump depends on the number of pistons, their bore, and their stroke. The swash plate's angle determines the stroke; therefore, the stroke can be changed by altering the angle (Figure 1-4).

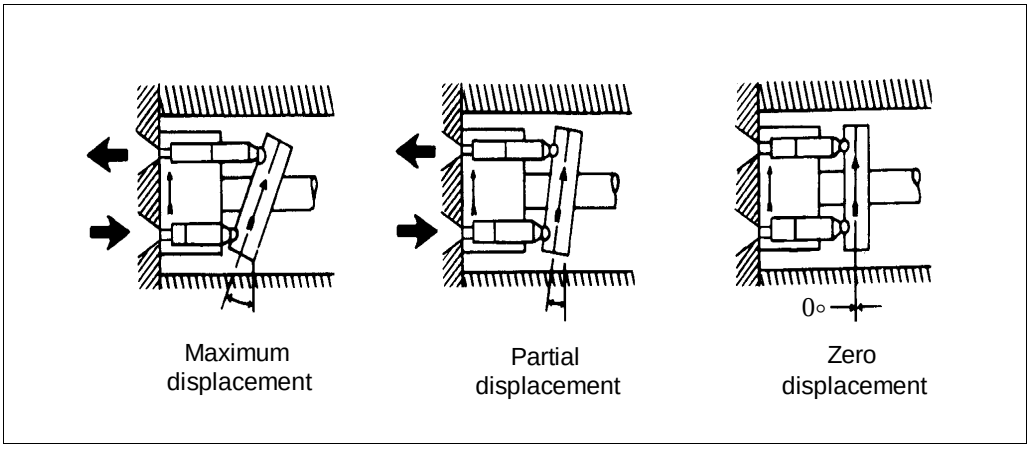


Figure 1-4. Piston-pump displacement

PART B: GEAR PUMP

1-5. General. The J. I. Case Model MW24C scoop loader has a two-section pump—one section provides hydraulic power for the steering system; the other section

provides power for the loader system. This model has a gear-type, fixed-displacement pump located on the rear of, and it is driven by the transmission. Hydraulic lines carry fluid from the reservoir to the pump and from the pump to the control, demand, and relief valves.

1-6. Removal and Repair of the Gear Pump. When the gear pump breaks down or does not operate properly, the maintenance supervisor instructs the construction-equipment repairer in the procedures necessary to determine the extent of damage and possible repairs. The first step in this process is to drain the reservoir. The pump is then removed from the transmission and completely disassembled before cleaning or repairs begin. The removal-and-disassembly process requires several steps; each step must be performed in the order listed.

a. Refer to Figure 1-5 and use the following steps to drain the reservoir on the gear pump:

- Remove the filler plug (1) on the hydraulic reservoir slowly to relieve air pressure.
- Remove the drain plug (2), and drain the fluid from the reservoir into a container.
- Turn the front-end loader fully to the left or right, and engage the locking bar.

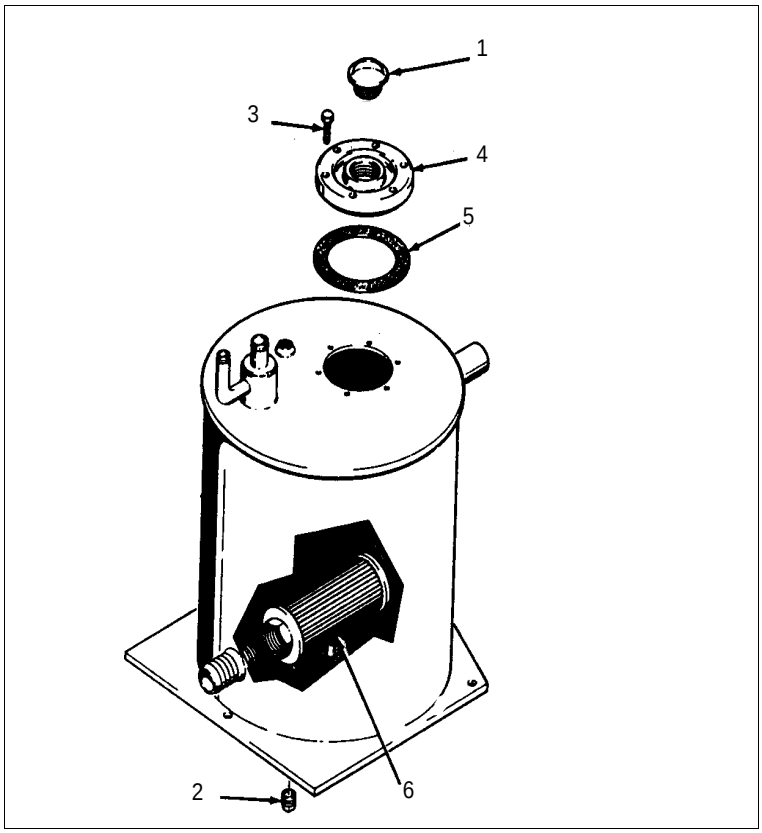


Figure 1-5. Hydraulic reservoir of a J. I. Case Model MW24C scoop loader

b. Refer to Figure 1-6 and use the following steps to remove the gear pump:

- Remove the hose assemblies from the gear pump, and drain the hydraulic fluid into a container.

- Support the hydraulic pump (3), and remove the two cap screws (1) and lock washer (2).

- Remove the pump (3) and bracket (4) from the transmission carefully. Place a protective cover over the splined drive shaft on the pump and the mounting pad to prevent foreign material from entering the transmission.

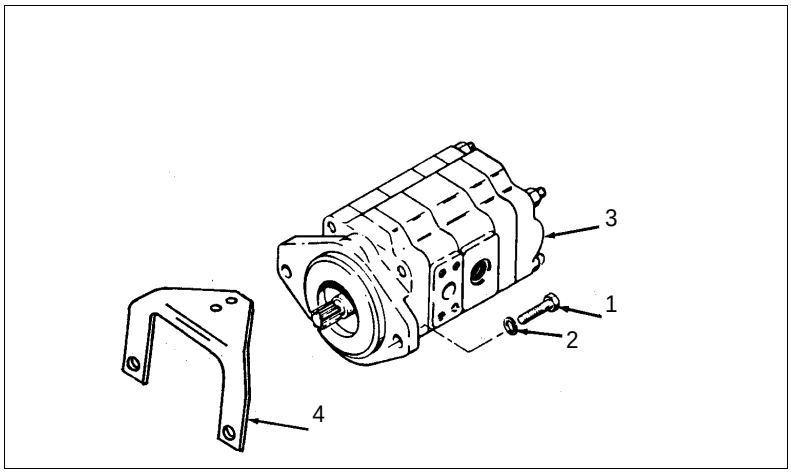


Figure 1-6. Hydraulic gear pump

c. Refer to Figure 1-7, page 1-8, and use the following steps to disassemble the gear pump:

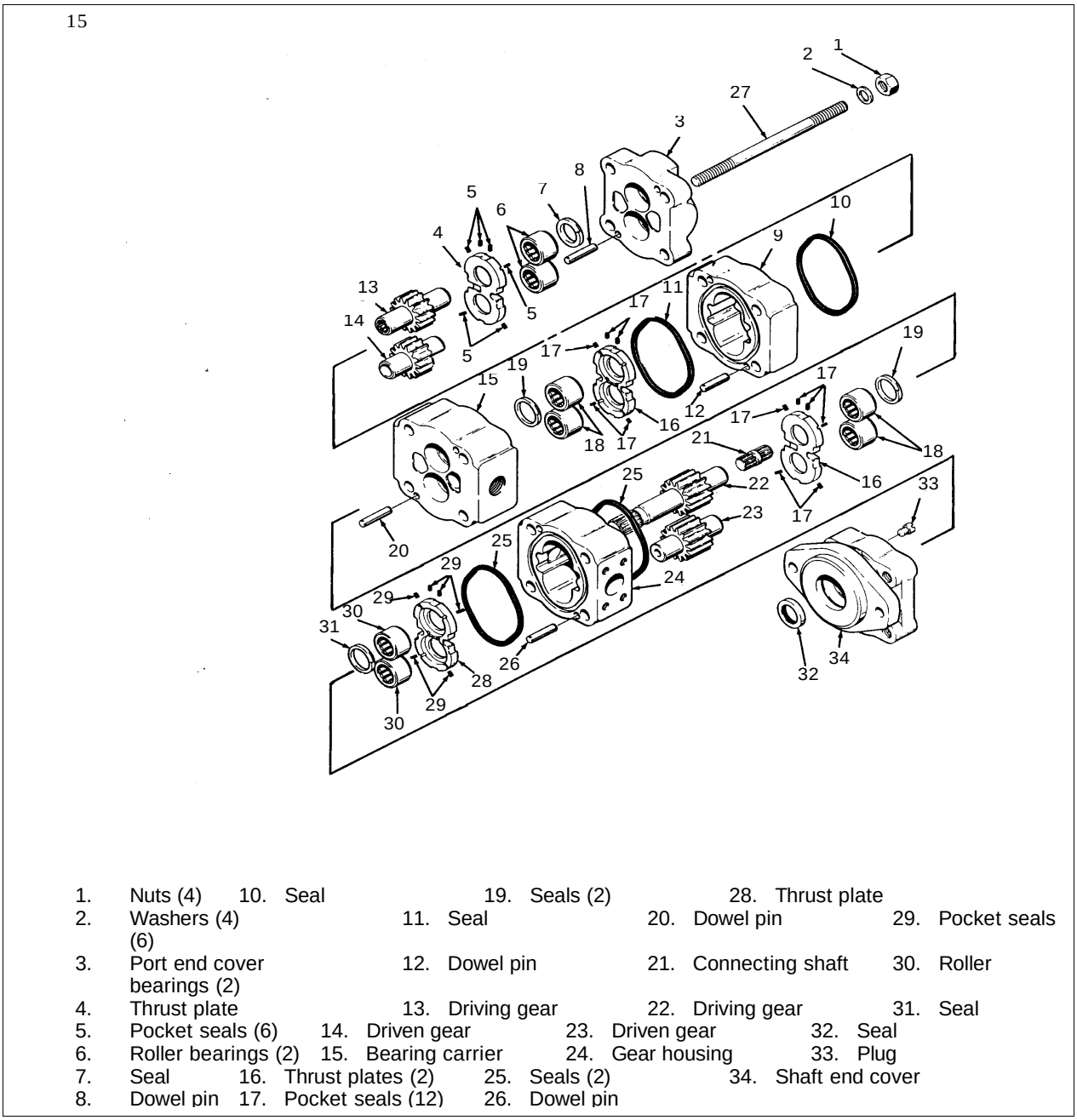
- Scribe a line lengthwise along the pump to aid in alignment during reassembly.

- Remove the roller bearings (6, 18, and 30) with a bearing puller. Replace them as necessary.

- Remove the seals (7, 10, 11, 19, 25, and 31) and discard.

- Remove the seal (32) from the shaft end cover (34).

- Discard the preformed packing and the seal (32).



1.	Nuts (4)	10.	Seal	19.	Seals (2)	28.	Thrust plate
2.	Washers (4)	11.	Seal	20.	Dowel pin	29.	Pocket seals (6)
3.	Port end cover	12.	Dowel pin	21.	Connecting shaft	30.	Roller bearings (2)
4.	Thrust plate	13.	Driving gear	22.	Driving gear	31.	Seal
5.	Pocket seals (6)	14.	Driven gear	23.	Driven gear	32.	Seal
6.	Roller bearings (2)	15.	Bearing carrier	24.	Gear housing	33.	Plug
7.	Seal	16.	Thrust plates (2)	25.	Seals (2)	34.	Shaft end cover
8.	Dowel pin	17.	Pocket seals (12)	26.	Dowel pin		

Figure 1-7. Gear pump, exploded view

d. Clean all metal parts using cleaning solvent (specification P-D-680) and allow parts to air dry. Do not use cloths to dry parts.

1-7. Inspection of the Gear Pump. Refer to Figure 1-7, and complete the following steps to inspect the gear pump:

a. Inspect the gear surfaces and the edges of the gear teeth for burrs, scoring, or wear. Remove burrs with a fine stone. Replace the gears if they are worn or badly scored.

NOTE: Gears must be replaced in sets.

b. Inspect the driving gear (22), and replace it if it is rough or damaged near the seal or if wear at the bearing surfaces has caused the shaft diameter to differ from the designated diameter by more than 0.001 inch.

c. Inspect the roller bearings (6, 18, and 30) for free rollers, pitting, or wear. Replace the bearings as needed.

d. Inspect the gear housings (9 and 24) for wear and damage, and replace them as needed. Inspect the mating surfaces of the gear housings (9 and 24), bearing carrier (15), port end cover (3), and shaft end cover (34) for burrs and damage. Remove burrs with a fine file or stone. Replace the entire part if the surface is badly damaged.

e. Inspect the thrust plates (4, 16, and 28) for wear and scoring. Replace the plates as needed.

1-8. Reassembly of the Gear Pump. Refer to Figure 1-7, and complete the following steps to reassemble the gear pump:

a. Coat the preformed packing, the pocket seals (5, 17, and 29), and the seals (7, 10, 11, 19, 25, 31, and 32) with an oil-soluble grease before installing them.

b. Press the seal (32) into the shaft end cover (34) with the lip facing the inside of the bore.

c. Use soft jaws to place the shaft end cover (34) in a vise. Install the preformed packing and roller bearings (30) in the shaft end cover (34).

d. Grease the six pocket seals (17) and install them in the two middle slots of the thrust plates (16). Install the thrust plate (4) on the drive shaft with the pocket seal facing the shaft end cover (34). Tap the thrust plate (4) in place. Leave a clearance of 0.03125 inch between the thrust plate (4) and the shaft end cover (34).

e. Install the six outer pocket seals (5) in the thrust plate (4). Push the pocket seals (5) into the slots until the ends make contact with the roller bearings (18). Tap the thrust plate (4) solidly into position on the port end cover (3). Use a razor blade or a sharp knife to trim the exposed ends on the pocket seals (5) so that they are flush with the sides of the thrust plate (4).

f. Use soft jaws to place the gear housing (24) in a vise. Install the thrust plate (16) as described in paragraph 1-8d.

g. Place the port end cover (3) in a vise. Install the seal (7), the roller bearings (6), and the thrust plate (4).

h. Place the bearing carrier (15) in a vise. Install the seals (19), the roller bearings (18), and the thrust plates (16).

i. Place the assembled shaft end cover (34) in a vise. Coat the thrust plate (28) with engine oil. Install the driving gear (22) and the driven gear (23) in the shaft end cover (34).

j. Install the seals (25) in the grooves on the gear housing (24). Install the housing over the gears on the shaft end cover (34). Tap the gear housing (24) with a leather hammer to seat it on the cover. Lubricate the gears with engine oil to provide initial lubrication.

k. Install the connecting shaft (21) in the bore of the pump shaft and driving gear (22). Install the bearing carrier (15) on the gear housing (24), and align the scribe marks. Tap the bearing carrier (15) in place.

l. Install the driving gear (13) on the connecting shaft (21) and install the driven gear (14) in the bore of the bearing carrier (15). Insert seals (10 and 11) in the grooves on the gear housing (9). Place the gear housing (9) over the gears and tap the housing in place. Lubricate gears with engine oil.

m. Place the port end cover (3) on the gear housing (9) and tap in place. Thread four studs through the port end cover (3) and into the shaft end cover (34) until the stud's ends extend above the port end cover (3). Insert the four washers (2) and nuts (1). Tighten the nuts (1) to a snug fit.

n. Rotate the connecting shaft (21) and the driving gear (22) with a 6-inch wrench. Check the ease of operation. If the connecting shaft (21) rotates freely, tighten the nuts (1) to a torque of 200 foot-pounds. Rotate the connecting shaft (21), and check the ease of operation a second time. The pump should rotate freely with no evidence of binding.

o. Coat the splines of the connecting shaft (21) and the driving gear (22) with grease.

1-9. Installation of the Gear Pump. Complete the following steps to install the assembled gear pump:

a. Refer to Figure 1-7, page 1-8. Remove the protective cover from the splined connecting shaft (21) of the gear pump, and coat the shaft with grease. Install the pump on the mounting pad.

b. Refer to Figure 1-6, page 1-7. Install the gear pump and secure it with two screws (1) and lock washers (2). Connect the hydraulic lines to the pump.

c. Refer to Figure 1-5, page 1-6, and continue with the following steps to install the assembled gear pump:

- Replace the drain plug (2) and strainer assembly (6) in the reservoir.
- Replace the cover (4) and the gasket (5) on the reservoir, and secure the cover with screws (3).
- Refill the reservoir with hydraulic fluid, and replace the filler plug (1).
- Start the engine, and check the pump and lines for leaks. Operate the hydraulic controls and check pump operation.

PART C: VANE PUMP

1-10. General. A double-section, insert, hydraulic vane pump is used on Caterpillar D7G tractors. The pump is bolted on the engine's rear-power-takeoff housing and is driven by the rear-power-takeoff idler gear.

a. A vane pump consists of a small and a large section, both of which share a common inlet. The large section provides hydraulic power for the blade-lift and scraper circuits. The blade-lift circuit is controlled by a valve located in the hydraulic tank. The scraper circuit is controlled by a valve located in the equipment operator's compartment. The small section powers the blade-tilt circuit and is controlled by a valve mounted in the hydraulic tank.

b. The vane pump requires a continuous flow of clean oil to lubricate the closely fitted parts. If inlet oil is not available, the pump may seize or sustain damage when the engine is started. Insufficient oil supply may result from clogged or leaking inlet lines or a low oil level. The pump may need to be removed for cleaning or repair.

1-11. Removal of the Vane Pump. To remove the vane pump from its mounting, complete the following steps:

a. Close the shut-off valve located on or near the reservoir.

b. Disconnect the suction (intake) and pressure (outlet) hoses.

c. Remove the vane pump from its mounting bracket or housing.

1-12. Disassembling the Vane Pump. Refer to Appendix D, pages D-7 through D-10, to disassemble the vane pump.

1-13. Cleaning, Inspecting and Repairing the Vane Pump. After the vane pump is disassembled, thoroughly clean and dry all parts (refer to Appendix D, pages D-3 through D-6 and D-10). Carefully inspect and repair cleaned parts according to the following procedures:

a. Discard the intake and exhaust plate seals and O-rings. Wash all metal parts in mineral oil solvent, and dry them with filtered, compressed air. Place the parts on a clean surface for inspection.

b. Inspect the surfaces of the pump housing, rotor ring, and rotor for scoring and wear. Remove light scoring marks by lapping with an extra-fine emery cloth or lapping compound. Replace all heavily scored or badly worn parts.

c. Check the intake and exhaust end plates for scoring and wear. Replace badly worn or heavily scored end plates.

d. Inspect the vanes for burrs, wear, or play in the rotor slots. If too much play is noted, replace the rotor and vanes. Refer to the repair and replacement standards listed in the appropriate TM to determine if replacement is necessary.

e. Check the slip ring and slip-ring washer for scoring and wear. Replace heavily scored or badly worn parts.

f. Check the bearings for wear and fit. To check for pitted or cracked balls or race, apply pressure and slowly rotate the bearing. Replace the bearing if it is worn or scored. Place the drive shaft into the pilot bearing and check for excessive play. Replace the pilot bearing if necessary. Refer to the repair and replacement standards listed in the appropriate TM to determine when replacement is necessary.

g. Inspect the oil-seal-mating surface of the drive shaft for scoring and wear. If marks on the drive shaft cannot be removed with light polishing, replace the drive shaft.

h. Coat O-rings with a small amount of petroleum jelly to hold them in place during reassembly.

1-14. Lubricating and Assembling the Vane Pump. Lubricate all parts with clean oil. Refer to Appendix D, pages D-10 through D-14 to assemble the vane pump.

1-15. Testing the Vane Pump. Refer to Appendix D, pages D-14 through D-18, to test the vane pump.

PART D: PISTON PUMP

1-16. General. The piston pump is used on the ACE. The compensating hydraulic pump is a ten-piston, variable-displacement, constant-pressure, radial pump.

WARNING

The ACE's hydraulic system is under high pressure. Relieve pressure before disconnecting any hydraulic components. After pressure is relieved, wait at least 4 minutes before disconnecting any hose or fitting. Failure to comply may result in severe injury.

1-17 Removing the Piston Pump. Complete the following steps to remove the piston pump from its mounting:

a. Refer to Figure 1-12 and disconnect the piston pump using the following steps:

- Disconnect the hoses (1, 2, and 3) from elbows (4, 5, and 6).
- Loosen the screw (8) on the clamp (9), and remove the clamp from the pump (7).

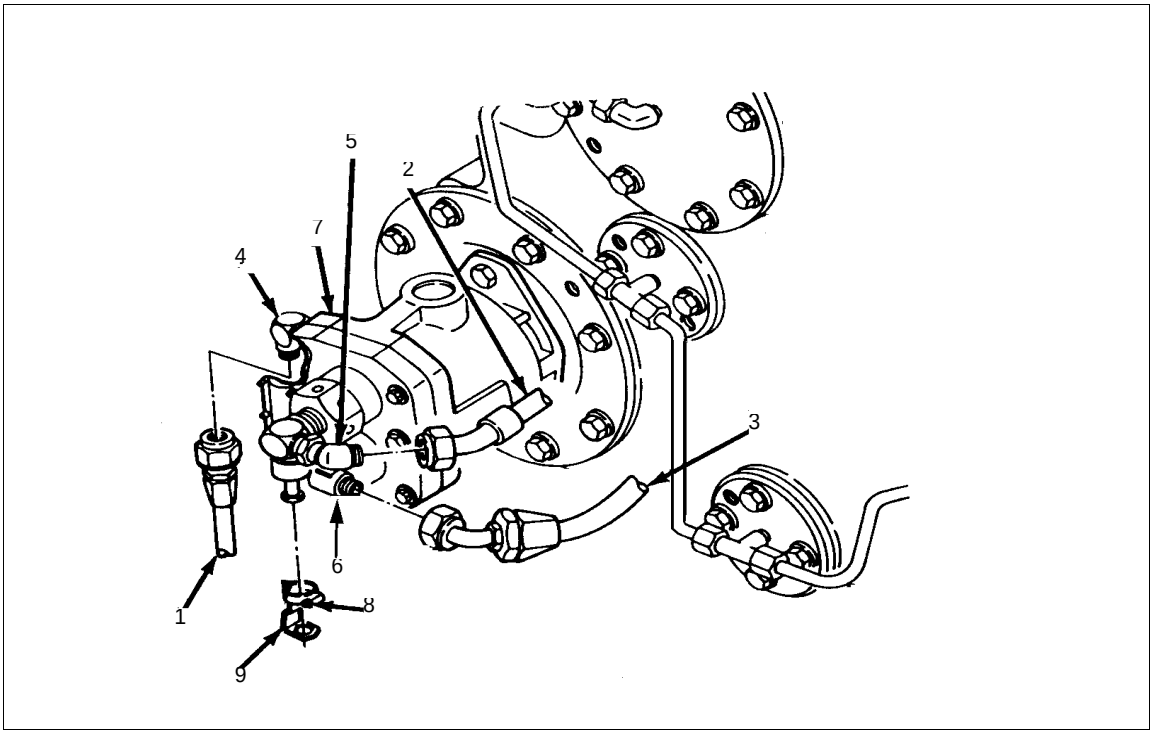


Figure 1-12. Disconnecting the piston pump

b. Refer to Figure 1-13, page 1-14, to remove the piston pump. Remove the two self-locking screws (10), washers (11), pump (7), and gasket (12) from the transfer case (13). Discard the screws (10) and the gasket (12).

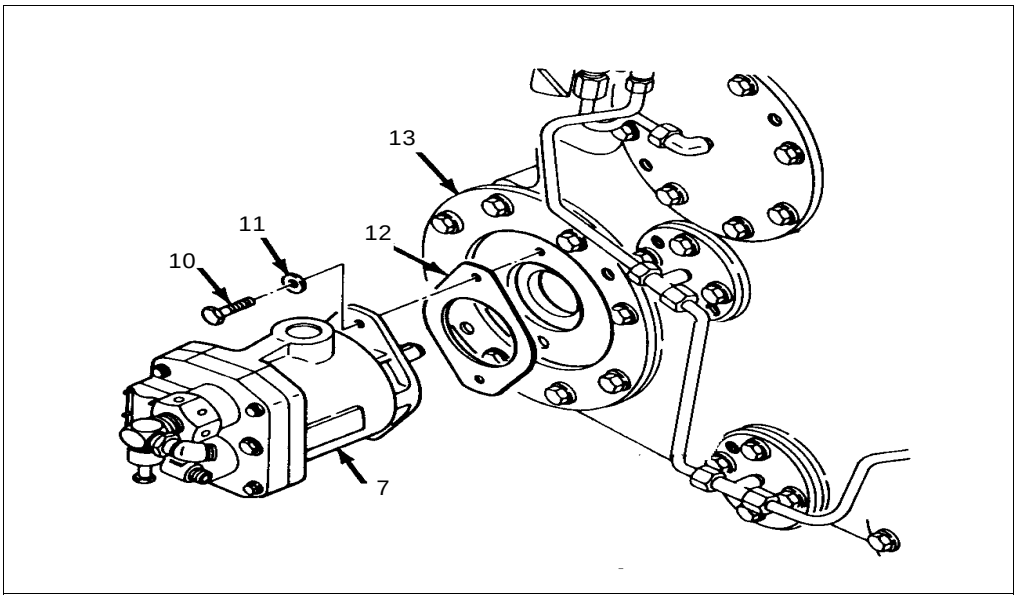


Figure 1-13. Removing the piston pump

1-18. Disassembling the piston pump. Complete the following steps to disassemble the piston pump:

a. Refer to Figure 1-14, and disassemble the piston pump using the following steps:

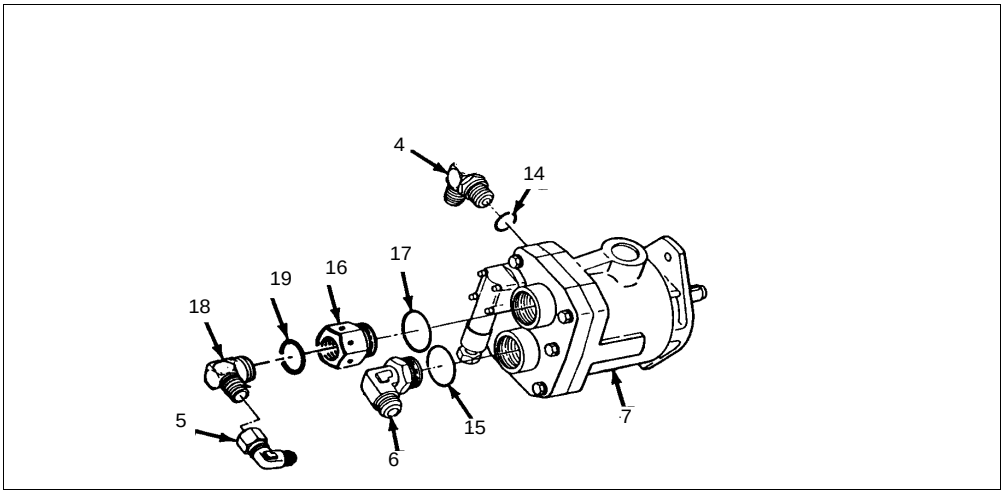


Figure 1-14. Disassembling the piston pump, part I

- Remove the elbows (4 and 6) and the seals (14 and 15) from the pump (7). Discard the packing.

- Remove the elbow (5), the reducer (16), the seal (17), the elbow (18), and the seal (19) from the pump (7). Discard the seals (17 and 19).

b. Refer to Figure 1-15, and disassemble the piston pump using the following steps:

- Remove the four cap screws (1), compensator (2), gasket (3), and seal (4) from the cover (5). Discard the gasket (3) and the seal (4).

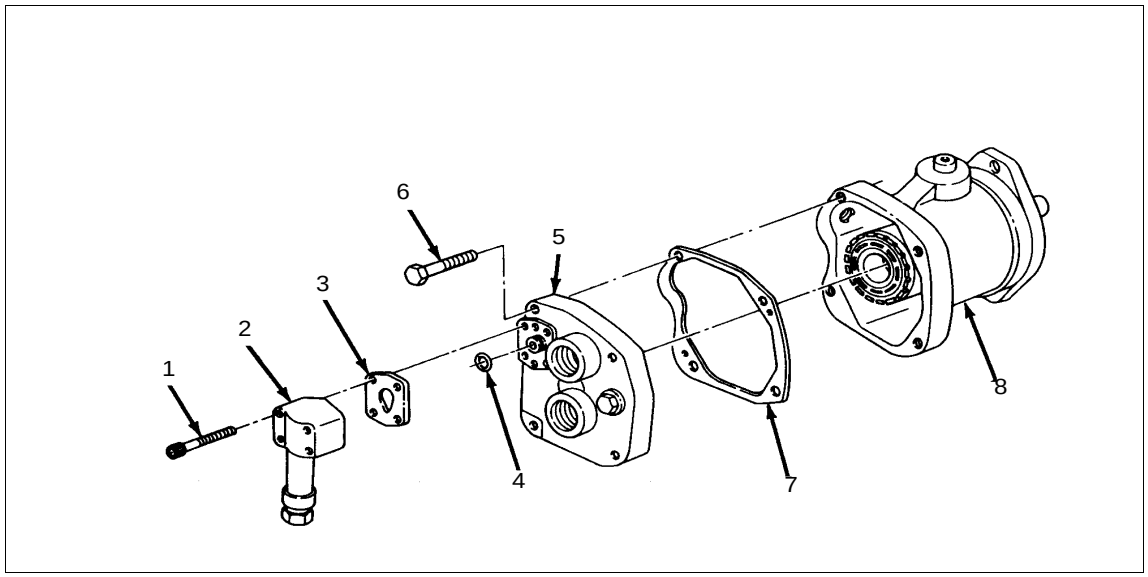


Figure 1-15. Disassembling the piston pump, part II

- Remove the four screws (6), cover (5), and gasket (7) from the housing (8). Discard the gasket.

WARNING

Remove the rotating group as an assembly. Failure to comply may result in damage to equipment.

c. Refer to Figure 1-16, page 1-16, and disassemble the piston pump using the following steps:

- Tip the housing (8) forward and remove the rotating group (9) from the shaft (10).

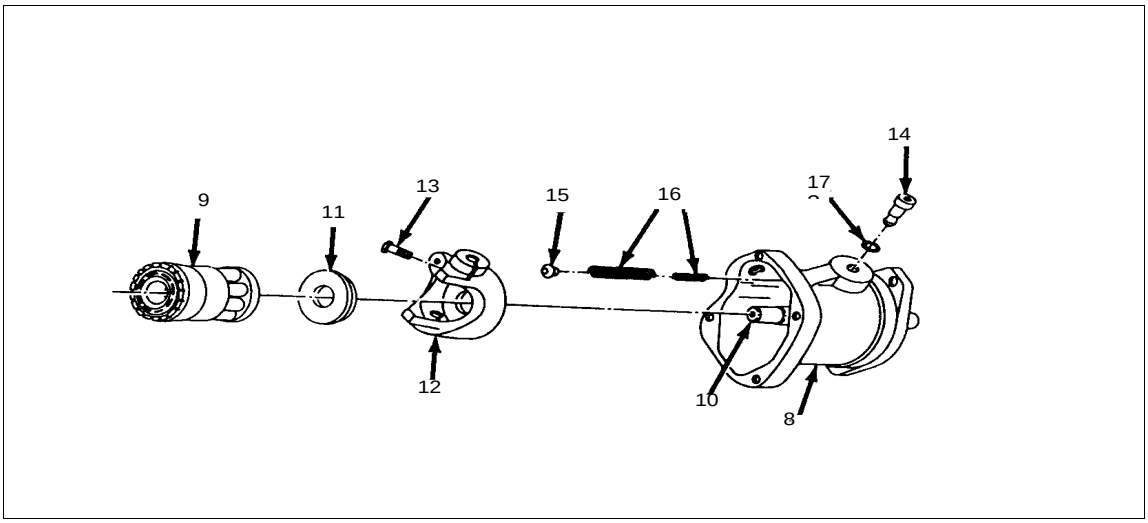


Figure 1-16. Disassembling the piston pump, part III

- Remove the swash plate (11) and the two screws (13) from the yoke (12).
- Apply pressure to the yoke (12) and use a wood dowel to drive out the two pintles (14).
- Remove the yoke (12), seat (15), and two springs (16) from the shaft (10) and housing (8).
- Remove the packing (17) from the pintles (14). Discard the seal (17).

1-19. Reassembling the Piston Pump. Complete the following steps to reassemble the piston pump:

NOTE: Lightly coat all parts with lubricating oil before assembly. Apply lubricating oil to packing before installation.

a. Refer to Figure 1-16, and reassemble the piston pump using the following steps:

- Install the seal (17) on the pintles (14).
- Install the two springs (16), seat (15), and yoke (12) on the housing (8).
- Press down on the yoke (12) and align the screw holes with the holes in the pintle (14) seat. Install two pintles on the housing (8) and the yoke (12).

NOTE: The pintle grooves must align in the center of the yoke's screw holes.

- Install the two screws (13) on the yoke (12). Tighten the screws (13) to 75 to 80 foot-pounds.

- Install the swash plate (11) on the yoke (12), chamfered side first. Coat the face of the swash plate (11) with lubricating oil.

- Lay the housing (8) on its side and carefully slide the rotating group (9) on the shaft (10), aligning the splines. Coat the face of the rotating group (9) with lubricating oil.

NOTE: The cover will not fit flush until the screws are tightened.

b. Refer to Figure 1-15, page 1-15, and reassemble the piston pump using the following steps:

- Install the gasket (7) and cover (5) on the housing with the four screws (6). Tighten the screws (6) to 25 to 35 foot-pounds.

- Install the packing (4), gasket (3), and compensator (2) on the cover (5) with four screws (1). Tighten the screws (1) to 60 to 70 foot-pounds.

1-20. Installing the Piston Pump. Complete the following steps to install the piston pump:

NOTE: New pumps are delivered with a 0.25 by 0.25-inch key installed on the shaft. Discard this key and use a 0.25 by 0.225-inch key.

a. Refer to Figure 1-12, page 1-13. Install the clamp (8) on the pump (7).

b. Refer to Figure 1-13, page 1-14, and install the piston pump using the following steps:

- Clean the mounting surfaces of the pump (7) and transfer case (13).

NOTE: Apply lubricating oil to the screw threads and packing before installation.

- Install the gasket (12) and the pump (7) on the transfer case (13) with the washer (11) and self-locking screws (10).

c. Refer to Figure 1-14, page 1-14. Install the packing (14), elbow (4), packing (15), elbow (6), packing (17), reducer (16), packing (19), elbow (18), and elbow (5) on

pump (7). The position of the elbow (6) should point slightly downward to prevent the hose from interfering with the ejector.

d. Refer to Figure 1-12, page 1-13, and install the piston pump using the following steps:

WARNING

Ensure that the pump is primed with lubricating oil. Failure to comply may result in damage to equipment.

- Connect SPNSN PUMP-7 hose (3) to the elbow (6).
- Turn the elbow (4) to an upright position. Fill the pump (7) with lubricating oil through the upright elbow (4) until oil overflows from the elbow (5).
- Turn the elbow (5) to a downward position.
- Connect SPNSN PUMP-9 hose (2) to the elbow (5) and connect SPNSN DRAIN-7V hose (1) to the elbow (4).

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 answer with the answer key that follows. If you answer any item incorrectly, study again that part which contains the portion involved.

1. Hydraulic energy is achieved by converting hydraulic power to _____ energy.

   A. Electrical
   B. Mechanical
   C. Solar
   D. Kinetic

2. Positive-displacement pumps are classified according to the element that transmits the liquid. What are the three classifications?

   A. Plunger, vane, and rotary
   B. Centrifugal, rotary, and suction
   C. Gear, vane, and rotary
   D. Gear, vane, and piston

3. Following disassembly of a gear pump, you should _____ old seals and preformed packing?

   A. Reuse
   B. Discard
   C. Turn in
   D. Store

4. Scribe a line lengthwise along the gear pump to aid in alignment during _____.

   A. Replacement
   B. Removal
   C. Reassembly
   D. Disassembly

5. Following gear pump disassembly, use _____ to clean all metal parts.

A. Kerosene
B. Solvent
C. Gasoline
D. Diesel fuel

6. All preformed packing, pocket seals, and seals on a gear pump should be coated with _____ before installation.

A. Motor oil
B. Hydraulic fluid
C. Oil-soluble grease
D. Gear oil

7. What should be used to remove burrs from the bearing carrier of a gear pump?

A. Grinder
B. Rough file
C. Fine file
D. Steel wool

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LESSON 1

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	B. Mechanical Hydraulic energy is achieved by converting ... (page 1-2, Introduction)
	D. Gear, vane, and piston Positive-displacement pumps are classified ... (page 1-2, para 1-1b)
	B. Discard Remove the seals ... (page 1-7, para 1-6c)
4.	C. Reassembly Scribe a line lengthwise along the pump ... (page 1-7, para 1-6c)
5.	B. Solvent Clean all metal parts using ... (page 1-8, para 1-6d)
6.	C. Oil-soluble grease Coat all preformed packing ... (page 1-9, para 1-8a)
7.	C. Fine file Remove burrs with a ... (page 1-9, para 1-7d)

LESSON 2

HYDRAULIC VALVES

Critical Task: 051-235-2188

OVERVIEW

LESSON DESCRIPTION:

In this lesson, you will learn the steps required to test, adjust, and repair hydraulic valves on engineer construction equipment.

TERMINAL LEARNING OBJECTIVE:

ACTION:	You will learn to repair hydraulic valves on engineer construction equipment.
CONDITION:	You will be given the material contained in this lesson. You will work at your own pace and in your own selected environment with no supervision.
STANDARD:	You will correctly answer practice exercise questions at the end of the lesson.
REFERENCES:	The material contained in this lesson was derived from FM 5-499 STP 5-62B24-SM-TG, TM 5-3805-262-20, and TM 5-3805-262-34.

INTRODUCTION

Hydraulic systems use valves to move hydraulic fluid or oil from one point to another. To ensure the efficient operation of equipment, the construction-equipment repairer must be knowledgeable in control and repair procedures. In a hydraulic system, valves control the actuators. An actuator is a cylinder that converts hydraulic energy to mechanical energy. For example, the tilt cylinder on a Caterpillar D7 or D8 dozer is an actuator that controls the blade direction.

a. Valves are often referred to as the "control" of the hydraulic system, particularly when several are built into a single assembly. Valves assert control in the hydraulic system to—

- Regulate pressure and create special pressure conditions.
- Regulate the flow rate and direction of fluid to parts of the hydraulic system.

b. Valves are rated by their size, pressure capabilities, and pressure drop versus flow capabilities. Most are named for their function, but some are named for their construction. For example, a pressure-relief valve is named for its function, and a poppet valve is named for its construction.

c. Valve construction ranges from a simple ball-and-seat arrangement to a multielement, spool-type valve with jet-pipe pilot stage and electrical control. General construction classification begins with simple valves and builds to complex designs.

PART A: PRESSURE-CONTROL VALVES

2-1. General.

a. Pressure-control valves are the most common valves on engineer construction equipment with hydraulic systems. They are used to—

- Regulate pressure.
- Create specific pressure conditions.
- Control the order in which actuators operate.

b. Pressure-control valves operate in hydraulic balance. Hydraulic balance occurs when pressure on one side or end of a ball, poppet, or spool is opposed by a spring on the opposite end. During operation, the position of the valve causes the hydraulic pressure to balance with the force of the spring. Because spring force differs with compression distance, the amount of pressure can differ. The pressure-control valve has infinite positioning. It can control conditions from a large to a small volume of fluid flow, or it can completely restrict fluid movement.

2-2. Classification.

a. Pressure-control valves are classified as normally closed or normally open. The most common type, the normally closed, blocks the flow of fluid from the inlet port to the outlet port until pressure builds high enough to cause unbalanced operation. Flow in a normally open valve moves freely until the valve operates in balance. The flow is then partly restricted or completely cut off.

b. Pressure override occurs when a normally closed valve operates in balance. Because pressure increases as the height of the compression spring is reduced, the pressure when the valve cracks or begins to pass flow through the outlet port is less than when it passes a large volume (full flow). The difference between full-flow pressure and cracking pressure is called override.

2-3. Pressure-Relief Valve.

a. The relief valve is the most common pressure-control valve. Relief valves have two functions. They provide overload protection for circuit components, and they limit the force (torque) exerted by a linear actuator or rotary motor. The function of the relief valve may change, depending on the system's needs. These valves are classified as simple or compound, depending on their design.

b. The internal design of all pressure-relief valves is similar. The valves have two sections—a body and a cover. The body contains a piston, which is retained on its seat by one or more springs. The cover, also called the pilot-valve section, contains the adjusting screw. The adjusting screw controls fluid movement to the pump's body and controls the pressure (expressed in pounds per square inch [psi]) within range of the valve's rated capacity.

2-4. Simple Pressure-Relief Valve.

a. A simple pressure-relief valve has only one spring. The valve is installed so that one port connects to the pressure line (inlet) and the other connects to the reservoir (outlet). The ball on the simple pressure-relief valve is held on its seat by the thrust of the spring. The amount of thrust exerted can be modified by turning the adjusting screw. When pressure at the inlet is insufficient to overcome the spring force, the ball remains on its seat and the valve is closed as shown in Figure 2-1, page 2-4. The position of the ball prevents the flow of fluid through the valve. When the pressure at the inlet exceeds the adjusted spring's force, the ball moves off its seat and the valve opens, allowing hydraulic fluid or oil from the pressure line to flow through the valve to the reservoir. This flow prevents a pressure increase in the pressure line. When pressure decreases below the adjusted spring's force, the ball is reseated and the valve closes.

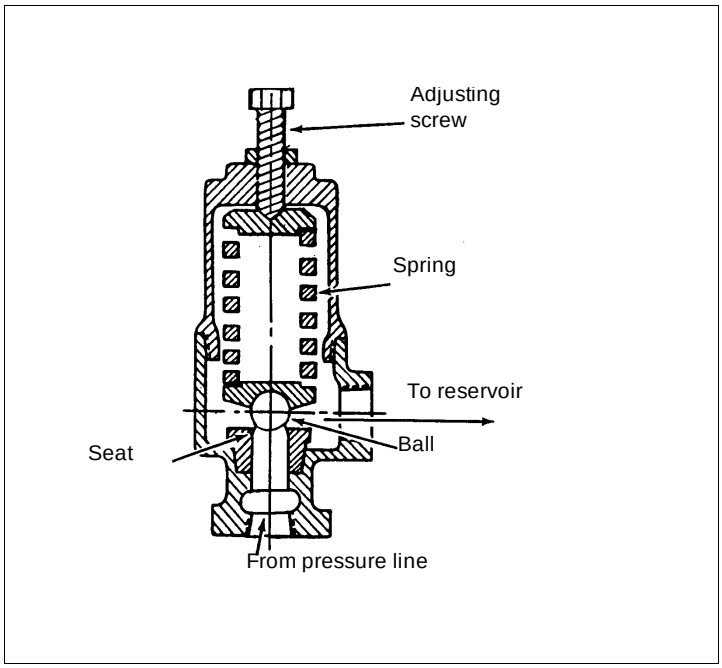


Figure 2-1. Simple pressure-relief valve

b. The spring force in a simple pressure-relief valve causes greater full-flow pressure than cracking pressure. When operating at full-flow capacity, the high pressure causes the valve to operate in an override mode. In some cases, the override pressure is almost as high or higher than the valve's rated capacity.

2-5. Compound Pressure-Relief Valve.

a. A compound pressure-relief valve has a poppet and a spring to adjust fluid flow (Figure 2-2). The closed view in Figure 2-2 shows that passage 1 is used to maintain the hydraulic balance in the piston when the valve's inlet pressure is less than the pressure setting. The valve setting is determined by the thrust of the adjusting spring against the poppet. When the pressure at the valve inlet reaches the valve setting, the pressure in passage 2 rises to overcome the thrust of spring 1. When the flow through passage l creates sufficient pressure drop to overcome the thrust of spring 2, the piston rises off its seat as shown in the open view. This allows hydraulic fluid or oil to pass through the drainage port to the reservoir and prevents any further increase in pressure.

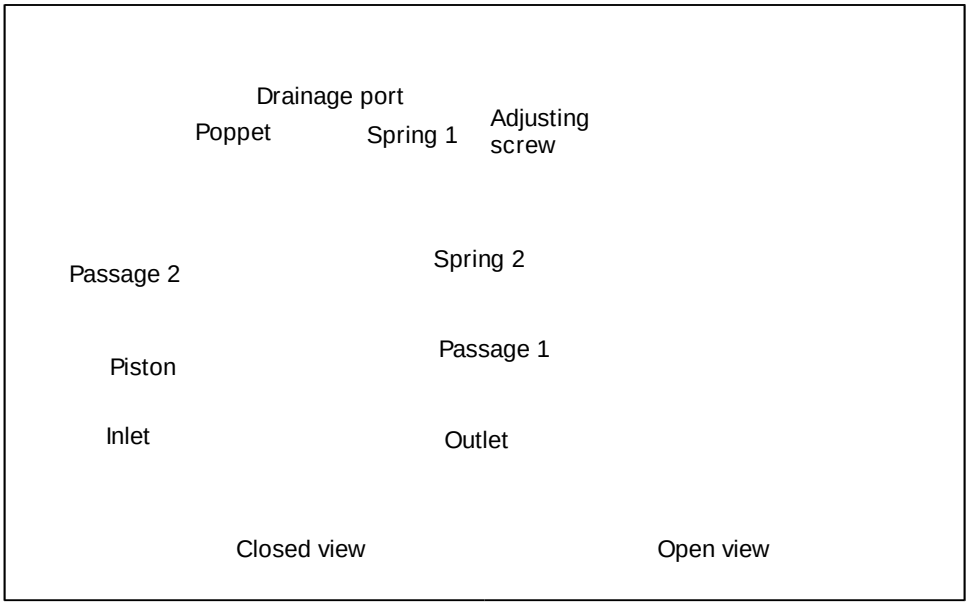


Figure 2-2. Compound pressure-relief valve

b. Pressure-relief valves that provide emergency overload protection must be periodically cleaned even if they are not operated often. To clean the valve, reduce the pressure adjustment and operate the valve under reduced pressure for a few minutes to clean out the accumulated sludge deposits. Adjust the pressure to the prescribed setting.

PART B: DIRECTIONAL-CONTROL VALVES

2-6. Complex Directional-Control Valves. Complex directional-control valves are used on engineer construction equipment, including the J. I. Case Scoop Loader Model MW24C. All complex directional-control valves control the direction of fluid flow, but they vary considerably in physical characteristics and operation. The valving element in these units is classified under one of the following types:

- Poppet—the piston or ball moves on and off a seat.
- Rotary—the spool rotates around its axis.
- Sliding spool—the spool slides axially within a bore.

2-7. Valve Classification.

a. Directional-control valves may be classified according to the method used to actuate the valving element. A poppet valve is usually hydraulically operated. A rotary spool valve may be operated manually (lever or piston action), mechanically (cam or trip action), or electrically (solenoid action). The sliding-spool valve may be operated manually, mechanically, electrically, hydraulically, or in combination.

b. Directional-control valves may also be classified according to the number of positions in the valving element or by the total number of flow paths provided in the extreme position. For example, a three-position, four-way valve has two extreme positions and a center (neutral) position. Each of the extreme positions has two flow paths.

2-8. Poppet Valve. The operation of a simple poppet valve is shown in Figure 2-3. The valve has a movable poppet that closes against a valve seat. Pressure from the inlet holds the valve tightly closed. A slight force applied to the poppet stem opens the valve. The poppet stem usually has an O-ring seal to prevent leakage. On some valves, poppets are held in the seated position by springs.

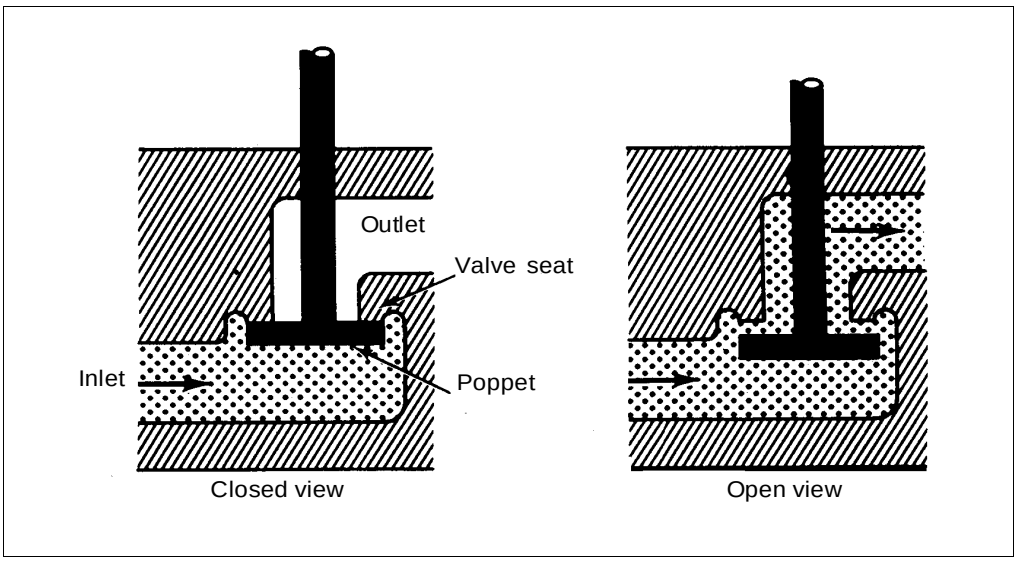


Figure 2-3. Simple poppet valve

2-9. Sliding-Spool Valve.

a. A sliding-spool valve is also known as a piston-type valve because it has a piston with two inner areas of equal size. Pressure from the inlet port acts equally on both inner areas regardless of the position of the spool. The ports are sealed by a machine fit between the spool and valve body or sleeve.

b. The spool in a sliding-spool valve is classified based on the flow conditions created when it is in the neutral (normal) position. For example, a closed-center spool blocks all valve ports when it is in the neutral position. An open-center spool opens all valve ports when it is in the neutral position. Closed-center and open-center valves are two of many designs used for sliding-spool, directional-control valves.

c. The sliding-spool valve is shown in Figure 2-4. During operation, the valve element slides back and forth to block or uncover ports in the housing.

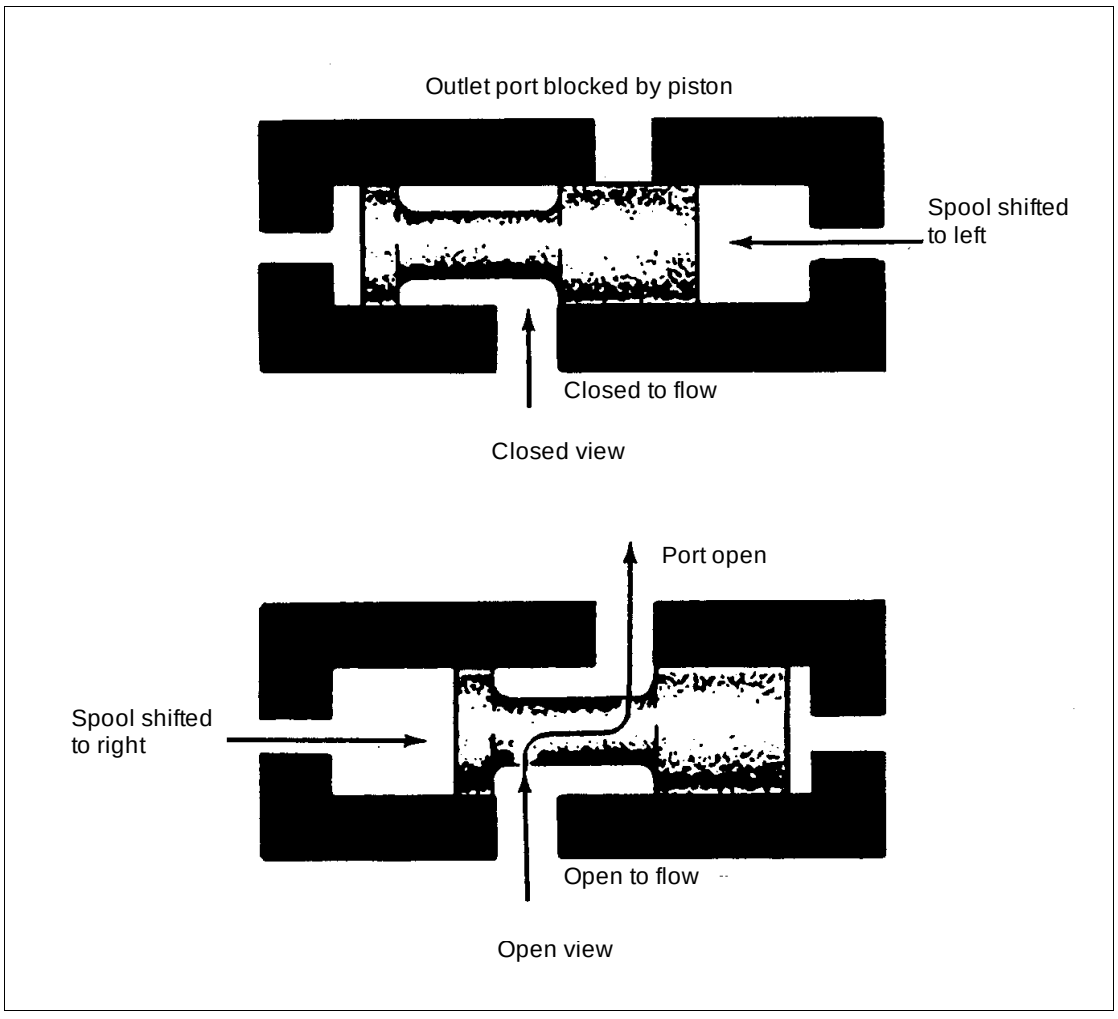


Figure 2-4. Sliding-spool valve

2-10. Two-Way Valves. Two-way valves are used to control the direction of fluid flow in a hydraulic circuit. These valves are usually the sliding-spool type. As the spool moves back and forth, it allows or prevents the flow of fluid through the valve.

2-11. Four-Way Valves. Four-way valves also control the direction of fluid flow in a hydraulic circuit. The fluid movement controls the direction of a work cylinder or the rotation of a fluid motor.

a. Four-way valves are usually the sliding-spool type. They have a rectangular cast body, a sliding spool, and a control lever for positioning the spool. The spool is precision fitted to a bore through the longitudinal axis of the valve's body. The lands of the spool divide the bore into a series of separate chambers. Ports in the valve's body lead into these chambers. The position of the spool determines which ports are open to each other and which are sealed. Ports that are sealed in one position may be interconnected in another position.

b. Four-way, directional-control valves have four ports—a pressure, a return (exhaust), and two working. The pressure port connects to the pressure line (inlet), the return port connects to the reservoir (outlet), and the two working ports connect to the actuating unit.

PART C: CONTROL-VALVE REPAIR

2-12. General. The control valve on a J. I. Case Scoop Loader Model MW24C enables the operator to direct the flow of hydraulic fluid to the cylinders that operate the loader. It serves a combination of purposes and functions as a pressure-relief, directional-control, and overload-check valve. The valve has three operating spools as shown in Figure 2-5.

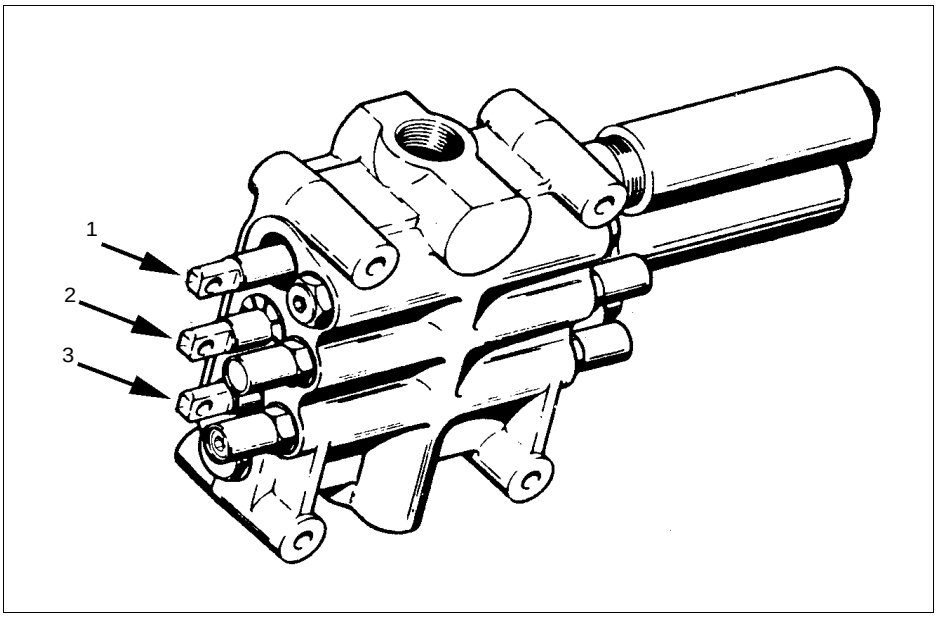
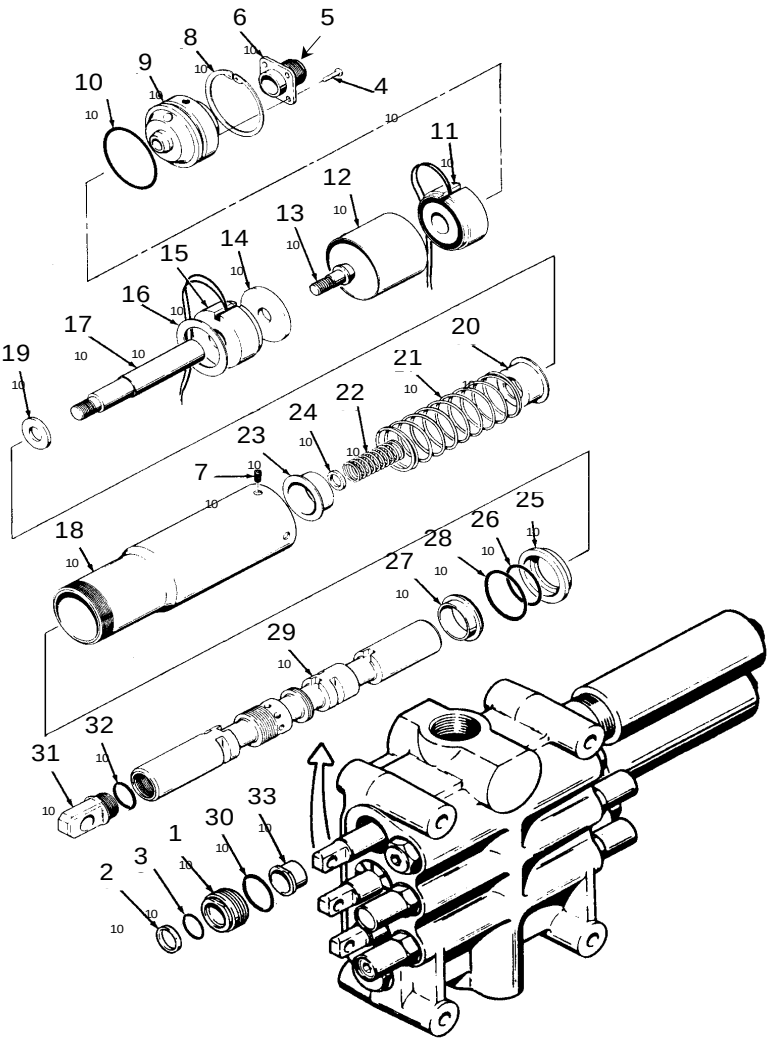


Figure 2-5. Control valve

a. The upper spool (1) controls the lift circuit, the center spool (2) controls the tilt circuit, and the lower spool (3) controls the clam circuit.

b. When the spools are in the neutral position, oil flow from the pump is directed through the valve to the outlet port and returned to the reservoir. When the spool is moved by the control linkage, the bypass is closed and oil flows through the spool-load check valve to the desired cylinder port. At the same time, a port at the opposite end of the cylinder is opened to allow oil to flow to the control valve's outlet port.

2-13. Disassembling the Control Valve. Refer to Figure 2-6, and complete the following steps to disassemble the control valve:



1. Seal assembly
2. Wiper
3. O-ring
4. Screws (4)
5. Contact wires
6. Connector
7. Setscrew
8. Retaining ring
9. Cap
10. O-ring
11. Coil
12. Spacer
13. Screw
14. Washer
15. Coil
16. Washer
17. Stud
18. Detent housing
19. Washer
20. Spring seat
21. Spring
22. Spring
23. Spring seat
24. Washer
25. Retainer
26. O-ring
27. Retainer
28. O-ring
29. Spool
30. O-ring
31. Spool eye
32. O-ring
33. Sleeve

Figure 2-6. Control valve

NOTE: Before beginning the disassembly process, clean the valve's exterior and ports with cleaning-compound solvent and dry them thoroughly.

a. Place the control-valve assembly on a clean workbench.

b. Use an open-end wrench to loosen and remove the seal assembly (1).

c. Use a screwdriver to remove the wiper (2) from the seal assembly (1). Discard the wiper (2).

d. Remove the O-ring (3) from the seal assembly (1). Discard the O-ring (3).

WARNING

Do not overtighten the vise as it will cause damage to the control-valve body.

e. Place the control valve assembly in a soft-jawed vise.

f. Loosen the detent housing (18).

g. Install a rod or small pry bar in the spool eye (31).

h. Loosen and remove the four screws (4).

i. Pull the connector (6) up from the cap (9) just enough to gain access to the wires soldered to the contacts. Tag and unsolder the wires from the connector (6) contacts. Remove the connector (6).

j. Remove the setscrew (7).

k. Use a screwdriver to remove the retaining ring (8). Remove the cap (9).

l. Remove and discard the O-ring (10) from the cap (9).

NOTE: On some units, tape may be used to hold the coils (11 and 15) and spacer (12) together, preventing their removal. If removal is not possible, disregard paragraph 2-13(m) and go to paragraph 2-13(n).

m. Remove the coil (11) and the spacer (12) from the detent housing (18).

WARNING

Hold the coil (11) against the spring (21) tension when loosening the screw. Failure to do so could result in serious injury from flying parts.

n. Loosen the screw (13) with the coil (11) against the spring (21) tension.

- If tape is around the coils (11 and 15), and the spacer (12) and the screw (13) have not been loosened from the stud (17), remove the coils (11 and 15), the spacer (12), the screw (13), the washers (14 and 16), the stud (17), the washer (19), the spring (22), and the washer (24) as an assembly and go to paragraph 2-13(q).

- If tape is around the coils (11 and 15), the spacer (12), the screw (13), and the washers (14 and 16) as an assembly, go to paragraph 2-13(o).

- If tape is not used, loosen and remove the screw (13), the washer (14), and the stud (17) as an assembly. If the screw (13) is loosened from the stud (17), remove only the screw (13) and the washer (14) and go to paragraph 2-13(s).

o. Remove and discard the tape securing the coils (11 and 15) and the spacer (12).

p. Tag and unsolder the coil (11 and 15) wires.

q. Separate the coils (11 and 15) and the spacer (12). If the screw (13) was not loosened from the stud (17), and the washer (24) and the spring (22) were removed with the stud (17), work the washer (24) from the stud (17) and remove the spring (22) and the washer (19). Remove the screw (13) and the washer (14) from the stud (17).

r. Remove the coils (11 and 15) and the spacer (12). If the screw (13) was loosened from the stud (17), the spring seat (20), the springs (21 and 22) and the washer (24); and if screw (13) was loosened from stud (17), and spring seat (23), go to paragraph 2-13(w).

s. Remove the coil (15), the washer (16), and the detent housing (18).

t. Remove the washer (19) and the spring seat (20) from the spring (21).

u. Remove the two springs (21 and 22), the spring seat (20), and the washer (24).

v. Unscrew and remove the stud (17) from the spool (29) if it is not already removed.

w. Remove the retainer (27) and the O-rings (26 and 28) from the spool (29) bore. Discard the O-rings (26 and 28).

x. Remove the retainer (27) and the O-ring (28) from the spool (29) bore. Discard the O-ring (28).

NOTE: Clean all metal parts in cleaning-compound solvent and let them air dry. Do not use compressed air.

2-14. Inspecting and Repairing the Control Valve. Refer to Figure 2-6, page 2-9, and complete the following steps to inspect and repair the control valve:

a. Inspect the control-valve body for cracks, breaks, or other damage. Inspect the spool bore for grooves, deep scratches, or other visible wear. If damage is discovered, replace the entire control-valve body.

b. Inspect the spool (29) for grooves, deep scratches, or other visible wear. Replace the spool if necessary.

c. The free length of the spring (22) should be 2.63 inches. Use a spring gauge and check that the force required to compress the spring (22) to 1.375 inches is 13.5 to 16.5 pounds. The force required to compress the spring (22) to 0.938 inch should be 18 to 22 pounds. Replace the spring (22) if the free length or the force required to compress it is not as specified.

d. The free length of the spring (21) should be 4.25 inches. Use a spring gauge and check that the force required to compress the spring (21) to 2.25 inches is 27 to 33 pounds. The force required to compress the spring (21) to 1.375 inches should be 38 to 48 pounds. Replace the spring (21) if the free length or the force required to compress it is not as specified.

e. Connect a multimeter across the coil (11) wires. The multimeter should indicate a 45 to 65 ohms resistance. Connect a multimeter across one wire of the coil (11) and its metal housing. The multimeter should indicate infinity (open circuit). Repeat the multimeter test on the second coil wire and its metal housing. Again, the reading should indicate infinity. Replace the coil if the multimeter reading is not as specified. Repeat paragraph 2-14(e) on the second coil (15).

f. Inspect the remaining parts for cracks, breaks, deformation, distortion, and damaged or stripped threads.

2-15. Reassembling the Control Valve. Refer to Figure 2-6, page 2-9, and complete the following steps to reassemble the control valve:

NOTE: Coat all valve parts and body bores with engine oil before beginning the reassembly process.

a. Place a rod through one hole in the spool (29). Place the spool (29) in a soft-jawed vise.

b. Install the sleeve (33) on the spool (29), sleeve shoulder up.

c. Place a small amount of retaining compound on the threads of the spool (29).

d. Install a new O-ring (32) on the spool eye (31). Install the spool eye in the spool (29) and tighten to 19 to 21 foot-pounds. Install a new O-ring (30) in the spool bore of the control-valve body.

e. Lubricate the spool (29) and its bore with clean lubricating oil. Install the spool (24) in its bore.

f. Install a rod or a pry bar in the spool eye (31).

g. Place the control-valve assembly in a soft-jawed vise.

h. Install a new O-ring (28) in the bore on the control-valve body. Install the retainer (27) in the bore.

i. Place a new O-ring (26) on the spool (29) and install the retainer (25).

j. Place the washer (24) and the spring seat (23) on the spool (29). Make sure that the washer (24) is in the spring-seat (23) hole.

k. Install the two springs (21 and 22) and the spring seat (20). Install the washer (19) in the spring seat (20).

l. Install the detent housing in the control-valve body. Tighten the detent housing to 30 to 32 foot-pounds.

m. Install the washer (16).

n. Install the coil (15) and fasten the lead ends together with tape.

o. Apply a small amount of retaining compound to the stud's internal threads if the screw (13) and stud (17) were separated. Install the washer (14), screw on the stud, and tighten to 10 to 12 foot-pounds.

p. Apply a small amount of retaining compound to the stud (17) threads. Install the stud (17) in the detent housing (18).

q. Push down and turn the screw (13) to install the stud (17) in the spool (29). Tighten to 19 to 21 foot-pounds.

r. Install the spacer (12) in the detent housing (18).

s. Install the coil (11).

t. Install a new O-ring (10) on the cap (9).

u. Feed the leads from the coils (11 and 15) through the cap (9) hole. Install the cap in the detent housing (18), aligning the setscrew (7) hole with the hole in the detent housing.

v. Install the retaining ring (8) and the setscrew (7). Tighten the setscrew (7).

w. Solder the coil (11 and 15) leads to the connector (6) using a rosin-core solder. Solder one lead from each coil (11 and 15) to contact B (5) in connector (6). Solder the second lead from the coil (15) to contact A (5) in connector (6). Solder the second lead from the coil (11) to contact C (5) in connector (6).

x. Position the connector (6) on the cap (9). Install and tighten the four screws (4).

y. Remove the rod or the pry bar from the spool eye (31).

z. Install a new O-ring (3) in the seal assembly (1).

aa. Place the seal assembly (1) in a hydraulic press, threaded end down. Place the wiper (2) on the seal assembly. Use a 1 3/4-inch diameter rod to press the wiper (2) into the seal assembly (1) until the wiper is flush with the top of the pump.

bb. Install and tighten the seal assembly (1).

cc. Install the control-valve assembly.

2-16. Testing and Adjusting the Control Valve. Test the control valve assembly by observing it during operation. With the oil at the recommended operating temperature and the engine running at a fast idle, check the time required to raise the empty bucket on the scoop loader from the ground to its highest raised position. This should take approximately 6 seconds. If it takes more than 6 seconds for the bucket to raise, ensure that the—

- Reservoir is filled to the proper oil level as stated in the appropriate TM.
- Oil is the type specified in the appropriate TM.

- Suction line is unrestricted and the strainer is clean.
- Scoop loader is operating at the correct fast-idle speed, as stated in the appropriate TM.
- Power-steering pump and the demand valve are operating properly.

NOTE: Repeat this test with a loaded bucket. If the lifting time is good (6 seconds) with an empty bucket but slow with a loaded bucket, check the cylinder packing, main pressure-relief valve, and hydraulic pump.

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 answer with the answer key that follows. If you answer any item incorrectly, study again that part which contains the portion involved.

1. Valves are rated by their _____, pressure capabilities, and pressure drop versus flow capabilities.

   A. Function
   B. Construction
   C. Capacity
   D. Size

2. _____ occurs when pressure on one side or end of a ball, poppet, or spool is opposed by a spring on the opposite end.

   A. Level operation
   B. Restricted operation
   C. Hydraulic balance
   D. Definite flow

3. What is the most common type of pressure-control valve?

   A. Relief
   B. Check
   C. Plunger
   D. Gate

4. The difference between full-flow pressure and cracking pressure is called _____.

   A. Override
   B. Spool valve
   C. Pressure drop
   D. Pilot stage

5. Which valve may be operated manually, mechanically, electrically, hydraulically, or in combination?

   A. Poppet

B. Rotary spool
C. Closed center
D. Sliding spool

6. The sliding-spool valve is also known as the _____ -type valve because it has a _____ with two inner areas of equal size.

A. Plunger
B. Piston
C. Sleeve
D. Poppet

7. How many spools are in the hydraulic control valve on a J. I. Case Model MW24C scoop loader?

A. Two
B. Three
C. Four
D. Five

8. When testing the control valve, how many seconds should it take a scoop loader to lift an empty bucket?

A. 4
B. 6
C. 8
D. 10

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LESSON 2

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	D. Size Valves are rated by . . . (page 2-2, Introduction)
2.	C. Hydraulic balance Hydraulic balance occurs when . . . (page 2-2, para 2-1b)
3.	A. Relief The relief valve is the most common . . . (page 2-3, para 2-3a)
4.	A. Override The difference between full-flow pressure . . . (page 2-3, para 2-2b)
5.	D. Sliding spool The sliding-spool valve . . . (page 2-6, para 2-7a)
6.	B. Piston The sliding-spool valve is . . . (page 2-6, para 2-9a)
7.	B. Three The valve has three . . . (page 2-8, para 2-12)
8.	B. 6 This should take approximately . . . (page 2-14, para 2-16)

APPENDIX A

LIST OF COMMON ACRONYMS

°C	degrees Celsius
°F	degrees Fahrenheit
ACCP	Army Correspondence Course Program
ACE	armored combat earthmover
AIPD	Army Institute for Professional Development
AMEDD	Army Medical Department
APO	Army Post Office
ATTN	attention
AUTOVON	automatic voice network
AV	automatic voice network
AWR	answer weight reference
coml	commercial
cont'd	continued
DED	diesel-engine driven
DETC	Distance Education and Training Council
dia	diameter
DINFOS	Defense Information School
DOD	Department of Defense

DSN	Defense Switched Network
EM	engineering manual
FM	field manual
ft	foot (feet)
GPM	gallon(s) per minute
HSTRU	Hydraulic System Test and Repair
ICE	Interservice Correspondence Exchange
in	inch(es)
IPD	Institute for Professional Development
JFK	John F. Kennedy
lb	pound(s)
lb-ft	pound(s) per foot
lb-in	pound(s) per inch
LO	lubrication order
MI	middle initial
mil	military
MOS	military occupational specialty
NSN	national stock number
para	paragraph
psi	pound(s) per square inch
RCOAC	Reserved Component Officer's Advanced Course
reg	regulation

RYE	retirement year ending
SGT	sergeant
SSN	social security number
SSN	specification serial number
STP	soldier training publication
TM	technical manual
TRADOC	United States Army Training and Doctrine Command
US	United States
VA	Virginia
vol	volume

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APPENDIX B

RECOMMENDED READING LIST

The following publications provide additional information about the material in this subcourse. You do not need this material to complete this subcourse.

FM 5-499. *Hydraulics*. 1 August 1997.

STP 5-62B1-SM. *Soldier's Manual, MOS 62B, Construction Equipment Repairer Skill Level 1.* 25 September 1990.

STP 5-62B24-SM-TG. Soldier's Manual and Trainer's Guide: MOS 62B, Construction *Equipment Repairer (Skill Level 2/3/4).* 15 October 1990.

TM 5-2350-262-20-1. *Unit Maintenance Manual Vol 1 of 2 for Armored Combat Earthmover (ACE), M9 (NSN 2350-00-808-7100*) *(This Item is Included on EM 0035).* 3 January 1997.

TM 5-2350-262-20-2. *Unit Maintenance Manual, Vol 2 of 2 for Armored Combat Earthmover (ACE), M9 (NSN 2350-00-808-7100) (This Item is Included on EM 0035).* 3 January 1997.

TM 5-2410-237-20. *Unit Maintenance Manual for Tractor, Full Tracked, Low Speed: DED, Medium Drawbar Pull, SSN M061, Tractor With Ripper, (NSN 2410-01-223-0350) Tractor With Winch, (2410-01-223-7261) Tractor With Ripper and Winterized Cab, (2410-01-253-2118) Tractor With Winch and Winterized Cab, (2410-01-253-2117) (This Item is Included on EM 0119).* 30 March 1993.

TM 5-2410-237-34. *Direct Support and General Support Maintenance Manual for Tractor, Full Tracked, Low Speed: DED, Medium Drawbar Pull, SSN M061 Tractor With Ripper, (NSN 2410-01-223-0350) Tractor With Winch, (2410-01-223-7621) Tractor With Ripper and Winterized Cab, (2410-01-253-2118) Tractor With Winch and Winterized Cab, (2410-01-253-2117) (This Item is Included on EM 0119).* 30 March 1993.

TM 5-3805-262-20. *Organizational Maintenance, Loader, Scoop Type, DED, 4 x 4, Articulated Frame Steer, 2-1/2 Cubic Yard (J. I. Case Model MW24C) (NSN 3805-01-150-4814) (This Item is Included on EM 0115).* 1 September 1987.

TM 5-3805-262-34. *Direct Support and General Support Maintenance Manual For Loader, Scoop Type, DED, 4 x 4, Articulated Frame Steer, 2-1/2 Cubic Yard (J. I. Case Model MW24C) (NSN 3805-01-150-4814) (This Item is Included on EM 0115).* 1 September 1987.

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APPENDIX C

METRIC CONVERSION CHART

This appendix complies with current Army directives which state that the metric system will be incorporated into all new publications. Table C-1 is a conversion chart.

Table C-1. Metric conversion chart

US Units	Multiplied By	Equals Metric Units
Length		
Inches	2.54	Centimeters
Inches	0.0254	Meters
Inches	25.4001	Millimeters
Area		
Square inches	6.4516	Square centimeters
Volume		
Cubic yards	0.7646	Cubic meters
Gallons	3.7854	Liters
Weight		
Ounces	28.349	Grams
Pounds	453.59	Grams
Pounds	0.45359	Kilograms
Metric Units	**Multiplied By**	**Equals US Units**
Length		
Centimeters	0.3937	Inches
Meters	39.37	Inches
Millimeters	0.03937	Inches
Area		
Square centimeters	0.155	Square inches
Volume		
Cubic meters	1.3079	Cubic yards
Liters	0.2642	Gallons
Weight		
Grams	0.03527	Ounces
Kilograms	2.2046	Pounds

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APPENDIX D – PUBLICATION EXTRACTS

TM 5-2410-237-34, 30 March 1993.

Use the above publication extracts to take this subcourse. At the time we wrote this subcourse, this was the current publication. In your own work situation, always refer to the latest official publications.

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(2) Do not pull bearings or bushings unless damaged. If you must get at parts behind them, pull out bearings or bushings carefully.

(3) Replace all gaskets, seals, and preformed packings.

2-11. CLEANING INSTRUCTIONS

a. General.

(1) The cleaning instructions will be the same for the majority of parts and components that make up the D7G tractor.

(2) The importance of cleaning must be thoroughly understood by maintenance personnel. Great care and effort are required in cleaning. Dirt and foreign material are a constant threat to satisfactory maintenance. The following should apply to all cleaning, inspection, repair and assembly operations.

(a) Clean all parts before inspection, after repair and before assembly.

(b) Hands should be kept free of any accumulation of grease, which can collect dust, dirt or grit.

(c) After cleaning, all parts should be covered or wrapped to protect them from dust and dirt. Parts that are subject to rust should be lightly oiled.

(3) Observe the following precautions during all cleaning operations:

WARNING

P-D-680 (Type II) is a flammable solvent that is potentially dangerous to personnel. Keep away from heat, sparks or open flame. Flashpoint of solvent is 138°F (59°C). Use only in a well ventilated area. Inhaling vapors over a period of time can cause headache and drowsiness. Use gloves to prevent irritation or inflammation of the skin. Solvent absorbed through the skin can result in internal disorders. If contact occurs, wash the affected area with water for 15 minutes. For eyes, flush with water and then seek immediate medical attention.

WARNING

Improper cleaning methods and use of unauthorized cleaning solvents may injure personnel and damage equipment. Refer to TM9-247 for correct information.

WARNING

Eye shields must be worn when cleaning with a wire brush. Flying rust and metal particles may cause injury to personnel.

WARNING

Particles blown by compressed air are hazardous. Make certain the air stream is directed away from user and other personnel in the area. To prevent injury, user must wear protective goggles or face shield when using compressed air.

b. External Engine Cleaning.

(1) Protect all electrical equipment that could be damaged by the steam or moisture before steam cleaning.

(2) Cover all openings before steam cleaning.

(3) After cleaning, dry and apply a light coat of oil to all parts subject to rust.

(4) Blow out all tapped (threaded) holes with compressed air to remove dirt and cleaning fluids.

c. Disassembled Parts Cleaning.

(1) Place all disassembled parts in wire baskets for cleaning.

(2) Dry and cover all cleaned parts.

(3) Place parts on or in "racks" and hold for inspection or repair.

(4) All parts subject to rusting must be lightly oiled and wrapped.

(5) Keep all related parts and components together. Do not mix parts.

d. Castings.

(1) Clean inner and outer surfaces of castings and all areas subject to grease and oil with cleaning solvents. Refer to TM9-247.

(2) Use a stiff brush to remove sludge and gum deposits.

(3) Blow out all tapped (threaded) holes with compressed air to remove dirt and cleaning fluids.

e. Oil Passages. Particular attention must be given to all oil passages in castings and machined parts. Oil passages must be clean and free of any obstructions.

(1) Clean passages with wire probes to break up any sludge or gum deposits.

(2) Wash passages by flushing with solvents. Refer to TM9-247.

(3) Dry passages with compressed air.

f. Oil Seals, Electrical Cables, and Flexible Hoses.

CAUTION

Washing oil seals, electrical cables and flexible hoses with dry cleaning solvents or mineral spirits will cause serious damage or destroy the material.

(1) Wash electrical cables and flexible hose with water and mild soap solution and wipe dry.

(2) Oil seals are generally damaged during removal, so cleaning will not be necessary since new seals will be used in assembly.

g. Bearings.

(1) Bearings require special cleaning. After removing surface oil and gum deposits, place bearings in hot oil (140°F (60°C)) to loosen congealed oil and grease. Wipe bearings dry. Do not use compressed air. After cleaning, coat bearings with oil, wrap in paper, and hold for inspection.

(2) Refer to TM9-214 for information and care of bearings.

h. Machine Tooled Parts.

(1) Clean machine tooled parts with dry cleaning solvent (P-D-680).

(2) Dry parts with compressed air.

i. Machined Surfaces.

(1) Clean machined surfaces with dry cleaning solvent (P-D-680).

(2) Dry surfaces with compressed air.

j. Mated Surfaces.

(1) Remove old gasket and/or sealing compound using wire brush and dry cleaning solvent (P-D-680).

(2) Lightly oil and wrap all parts subject to rust before storing.

k. Rusted Surfaces. Clean all rusted surfaces using wire brush and crocus cloth.

l. Oil Bathed Internal Parts. Wipe oil bathed internal parts clean with lint free cloth.

m. Air Actuated Internal Parts. Wipe air actuated internal parts clean with lint free cloth.

n. Externally Exposed Parts. Wash externally exposed parts with soap and water. Rinse thoroughly and air dry.

2-12. INSPECTION INSTRUCTIONS

a. General. All components and parts must be carefully checked to determine if they are serviceable for reuse, if they can be repaired, or if they must be scrapped.

b. Drilled and Tapped (Threaded) Holes.

(1) Inspect for wear, distortion (stretching), cracks or any other damage in or around holes.

(2) Inspect threaded areas for wear, distortion or evidence of cross-threading.

(3) Mark all damaged areas for repair or replacement.

c. Metal Lines, Flexible Lines (Hoses) and Fittings.

(1) Inspect lines for sharp kinks, cracks, bends or dents.

(2) Inspect flexible lines for fraying, evidence of leakage or loose fittings or connectors.

(3) Check all fittings and connectors for thread damage. Check for hex heads that are worn or rounded by poorly fitting wrenches.

(4) Mark all damaged material for repair or replacement.

d. Castings.

(1) Inspect all ferrous and nonferrous castings for cracks using a magnifying glass and strong light.

(2) Refer to MIL-I-6866, Inspection, Liquid Penetrant Methods, and MIL-I-6868, Inspection Process, Magnetic Particles.

(3) Particularly check areas around studs, pipe plugs, threaded inserts, and sharp corners. Replace all cracked castings.

(4) Inspect machined surfaces for nicks, burrs, or raised metal. Mark damaged areas for repair or replacement.

(5) Inspect all pipe plugs, pipe plug openings, screws, and screw openings for damaged or stripped threads.

13-4. HYDRAULIC PUMP - TEST/REPAIR

This task covers:
a. Disassembly
b. Cleaning
c. Inspection
d. Lubrication
e. Assembly
f. Test

INITIAL SETUP

Applicable Configurations
All

Common Tools
Shop Equipment, General Purpose
Repair, Semi-Trailer Mounted
NSN 4940-00-287-4894
Tool Outfit, Hydraulic System
Test and Repair (HSTRU)
NSN 4940-01-036-5784

Materials/Parts
Seal (8), (10), (12), (14), (18), (21), (24), (26), (28), (32), (34), (36), (37), (40), (44), (46), (52), (53)
Plug (54)
1" dia. X 8" long pipe
Lubricating Oil OE/HDO-10 (See LO5-2410-237-12)

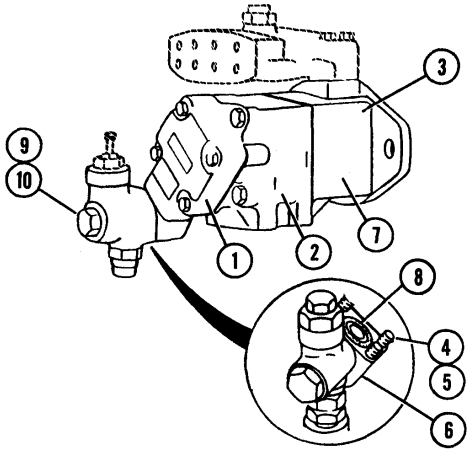
Equipment Condition
Hydraulic pump removed. See TM5-2410-237-20.

a. Disassembly

(1) Clean the outside of the pump body and cover. Put reference marks between the end cover (1) and center cover (2) and center cover and pump body (3) prior to pump disassembly. These marks will reference the correct port relation at assembly.

(2) Use a wrench to remove four capscrews (4), four washers (5) and elbow (6) from hydraulic pump (7). Remove and discard seal (8) from elbow (6).

(3) If necessary, use a wrench to remove plug (9) from elbow (6). Remove and discard seal (10) from plug.



13-7

13-4. HYDRAULIC PUMP - TEST/REPAIR (Cont'd)

(4) If necessary, use a wrench to remove plug (11) from elbow (6). Remove and discard seal (12) from plug.

(5) If necessary, use a wrench to remove adapter (13) from elbow (6). Remove and discard seal (14) from adapter (13).

(6) Use a wrench to remove four capscrews (15), four washers (16), and manifold (17) from hydraulic pump (7). Remove and discard seal (18) from manifold.

(7) If necessary, remove nipple assembly (19), dust cap (20) and seal (21) from adapter (22). Discard seal (21).

(8) If necessary, use a wrench to remove adapter (22) from manifold (17).

(9) Use a wrench to remove four capscrews (23) and end cover (1) from center cover (2).

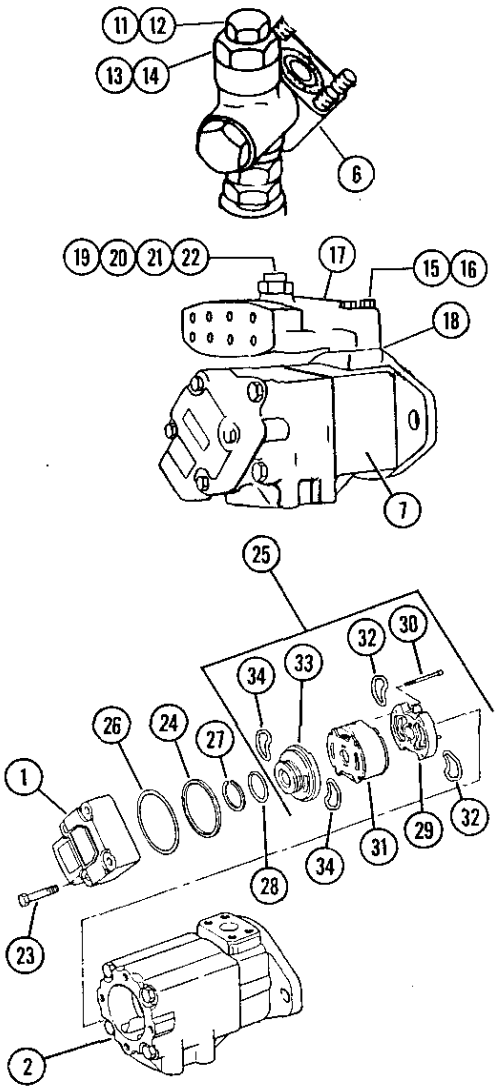
(10) Remove seal (24) and cartridge (25) from end cover (1). Discard seal (24).

(11) Remove and discard seal (26) from end cover (1).

(12) Remove backup ring (27) and seal (28) from cartridge (25). Discard seal (28).

NOTE

Put an alignment mark across the components of the cartridge to give reference for correct assembly.



13-4. HYDRAULIC PUMP - TEST/REPAIR (Cont'd)

NOTE

Make a note of the directions of the arrows on plate (29) and the location of capscrews (30) for correct assembly. The arrows show the rotation direction of the hydraulic pump. Capscrews are installed in the holes next to the arrows that show the direction of pump rotation.

(13) Remove four capscrews (30) that secure the cartridge (25) together.

(14) Remove plate (29) from the plate (31).

(15) Remove and discard two seals (32) from plate (29).

(16) Remove plate (33) from plate (31).

(17) Remove and discard two seals (34) from plate (33).

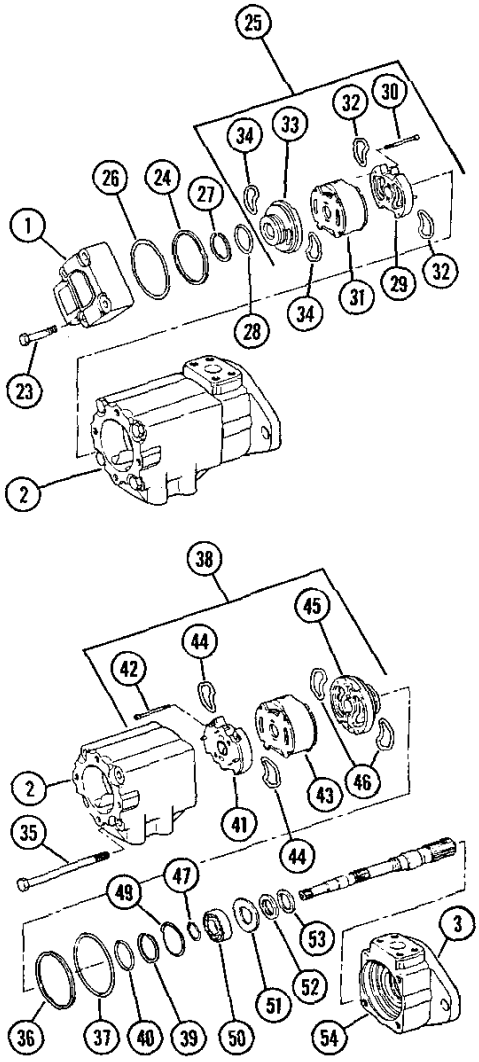
(18) Use a wrench to remove four capscrews (35) that hold center cover (2) in place. Remove cover and seal (36). Discard seal.

(19) Remove seal (37) and cartridge (38) from pump body (3). Discard seal.

(20) Remove backup ring (39) and seal (40) from cartridge (38). Discard seal.

NOTE

Put an alignment mark across the components of the cartridge to give reference for correct assembly.



13-9

13-4. HYDRAULIC PUMP - TEST/REPAIR (Cont'd)

NOTE

Make a note of the direction of the arrows on plate (41) and the location of capscrews (42) for correct assembly. The arrows show the rotation direction of the hydraulic pump. Capscrews are installed in the holes next to the arrows that show the direction of pump rotation.

(21) Remove four capscrews (42) that secure the cartridge (38) together.

(22) Remove plate (41) from plate (43).

(23) Remove and discard two seals (44) from plate (41).

(24) Remove plate (45) from plate (43).

(25) Remove and discard two seals (46) from plate (45).

(26) Use snap ring pliers to remove retaining ring (47) from the shaft (48).

(27) Use a press and tool to remove shaft (48) from pump body (3).

(28) Remove retaining ring (49) that holds the bearing (50) in place.

(29) Remove bearing (50) and washer (51) from the pump body (3).

(30) Remove and discard two lip type seals (52 and 53) from the pump body (3).

(31) If necessary, remove and discard plug (54) from pump body (3).

b. Cleaning

Thoroughly clean and dry all parts. Refer to page 2-29.

c. Inspection

Inspect all parts for wear or damage. Damage to any component of either cartridge group, except seals, will cause replacement of the complete cartridge group.

d. Lubrication

Put clean oil on all parts during assembly.

e. Assembly

(1) During assembly all components must be installed in the correct direction of pump rotation. Pump rotation as seen from the splined end of the shaft is counter-clockwise.

(2) If removal of the plug (54) was necessary, install a new plug in pump body (3).

(3) Use a driver tool to install new outer lip type seal (53) in pump body (3). Install the seal with the spring loaded lip toward the pump bearing.

(4) Turn pump body (3) over and use a driver tool to install new inner lip type seal (52) in pump body (3). Install the seal with the spring loaded lip toward the pump bearing.

(5) Install washer (51) and bearing (50) in pump body (3).

(6) Install retaining ring (49) that holds the bearing (50) and washer (51) in place.

13-4. HYDRAULIC PUMP - TEST/REPAIR (Cont'd)

(7) Put a piece of 1 in. diameter pipe that is 8 in. long in position against the inner race of bearing (50). Use a driver tool, pipe and a press to install shaft (48).

(8) Use pliers to install retaining ring (47) on the shaft (48).

(9) Install a new seal (37) in pump body (3).

(10) Seals (46) are a two piece seal. Ensure that preformed packing seal is in plastic seal before seals are installed. Install two new seals with the preformed packing in contact with end plate (45).

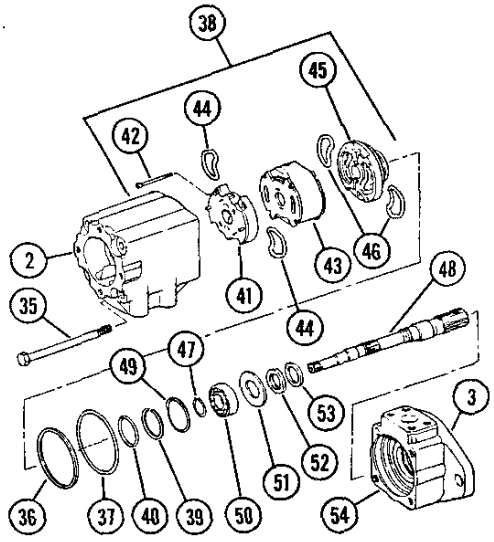
(11) Seals (44) are a two piece seal. Ensure that preformed packing is in plastic seal before seals are installed. Install two new seals with the preformed packing in contact with plate (41).

(12) Put plates (41 and 45) in position on the plate (43).

(13) Loosely install four capscrews (42) in the holes nearest the arrows that are in the same direction as the arrow on plate (41). These arrows show the direction of pump rotation and must be assembled with the arrows in the same direction.

(14) Install a new seal (40) and backup ring (39) on the cartridge (38). Install the seal toward the pressure source.

(15) Install cartridge (38) on pump body (3). Put the cartridge in position so pins in the plate are in alignment with mounting holes of pump body.



13-11

13-4. HYDRAULIC PUMP - TEST/REPAIR (Cont'd)

(16) Tighten four capscrews (42).

(17) Install a new seal (36).

(18) Ensure that pins in the plate of the cartridge (38) are in alignment with the holes in center cover (2). Install pump body (3) and cartridge in center cover according to markings made at disassembly. Use a wrench to install four capscrews (35) that secure the cover to the pump body. Tighten the capscrews to a torque of 70±10 lb. ft.

(19) Seals (32) are a two piece seal. Ensure that preformed packing is in plastic seal before seals are installed. Install two new seals with the preformed packing in contact with end plate (29).

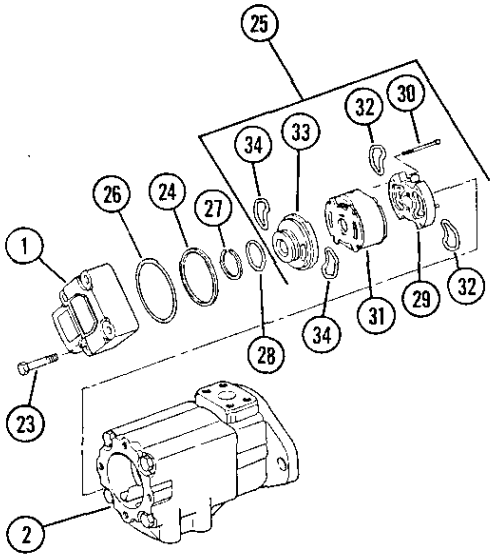
(20) Seals (34) are a two piece seal. Ensure that preformed packing is in plastic seal before seals are installed. Install two new seals with the preformed packing in contact with plate (33).

(21) Put plates (33 and 29) in position on the plate (31).

(22) Install four capscrews (30) in the holes nearest the arrows that are in the same direction as the arrow on plate (29). These arrows show the direction of pump rotation and must be assembled with the arrows in the same direction.

(23) Install a new seal (28) and backup ring (27) on the cartridge (25). Install the seal toward the pressure source.

(24) Install a new seal (26) in end cover (1).



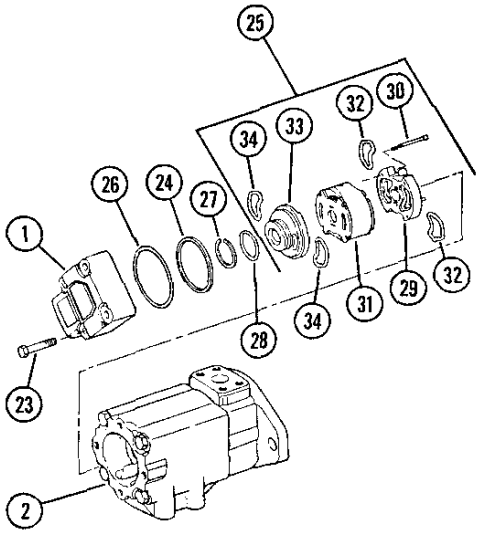
13-4. HYDRAULIC PUMP - TEST/REPAIR (Cont'd)

(25) Install cartridge (25) on end cover (1). Put the cartridge in position so pins in the plate are in alignment with mounting holes in the cover.

(26) Install a new seal (24) on end cover (1).

(27) Ensure that pins in the plate of the cartridge (25) are in alignment with the holes in end cover (1). Install cartridge in cover.

(28) Align the covers properly and use a wrench to install the four capscrews (23) that secure the covers together. Tighten the capscrews to a torque of 45±5 lb. ft.



NOTE

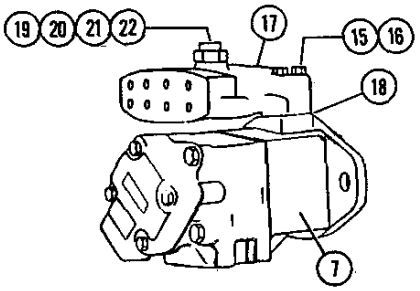
After assembly of the hydraulic pump, the pump shaft must turn by hand.

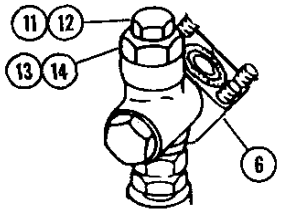
(29) If removal of the adapter (22) was necessary, use a wrench to install it in the manifold (17).

(30) If removal of the seal (21), dust cap (20) and nipple assembly (19) was necessary, install a new seal, dust cap and nipple assembly in manifold (17).

(31) Install a new seal (18) in manifold (17). Install manifold onto hydraulic pump (7) and secure with four capscrews (15) and four washers (16). Use a wrench to tighten capscrews.

(32) If removal of the seal (14) and adapter (13) was necessary, use a wrench to install adapter with a new seal in elbow (6).





13-13

13-4. HYDRAULIC PUMP - TEST/REPAIR (Cont'd)

(33) If removal of seal (12) and plug (11) was necessary, use a wrench to install plug with a new seal in elbow (6).

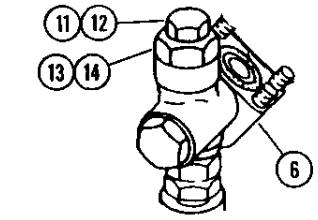
(34) If removal of seal (10) and plug (9) was necessary, use a wrench to install plug with a new seal in elbow (6).

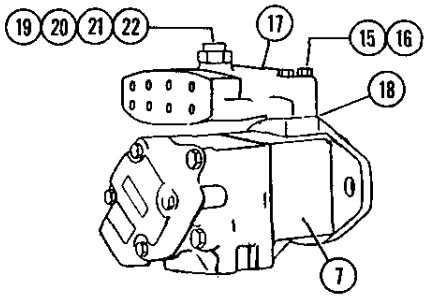
(35) Install a new seal (8) on elbow (6). Install elbow on hydraulic pump (7) and secure with four capscrews (4) and four washers (5). Use a wrench to tighten capscrews.

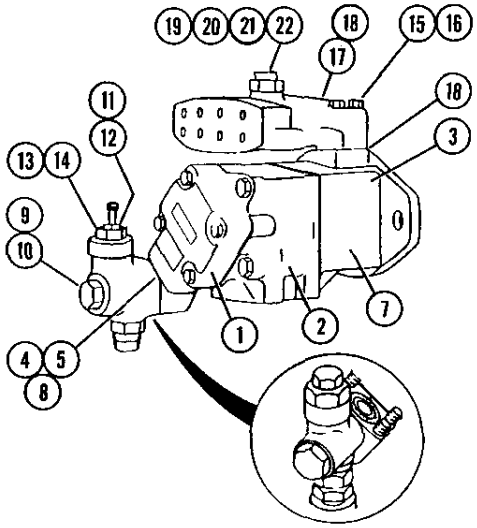
(36) Install the hydraulic pump. See TM5-2410-237-20.

f. Test

Before returning the machine to service, perform pump tests to make sure operation is correct. Pump tests are contained in the Hydraulic System Test, page 13-111. Do the Test Setup and proceed to Pump Tests. Be sure to follow all safety precautions.







13-18. HYDRAULIC SYSTEM - TEST (Cont'd)

e. Pump Tests

NOTE

These tests will determine the operating efficiency of the system hydraulic pump. The pump is isolated from the system during test.

(1) Preparation

WARNING

Personal injury and equipment damage can result when disconnecting lines to install flow blocking devices. The blade and ripper can move and pressure oil can be released.

NOTE

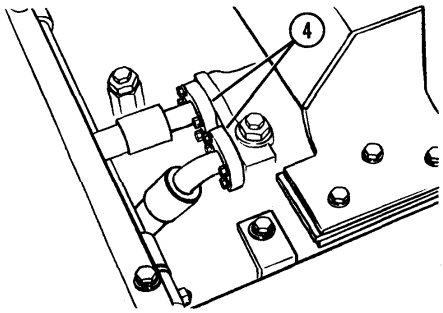
Do all tests for the large section then the small section. Record results as shown in Table 13-12 (large section) or 13-13 (small section).

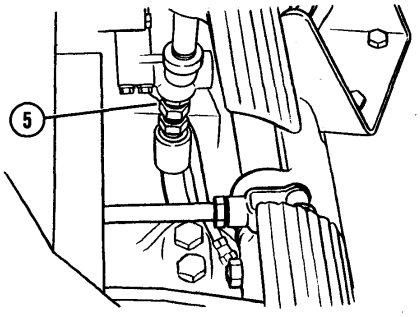
WARNING

The main relief valve is NOT in the pump test circuit. Injury to personnel or damage to the machine can result if excessive pressure is created. Fully open the manual load valve on the flow meter before starting the engine for these tests.

(a) For test of the large section pump, install blocking plates (4).

(b) For test of the small section pump, install blocking plate (5).





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13-18. HYDRAULIC SYSTEM - TEST (Cont'd)

(2) Test 14 (Full Speed Pump Flow - Low Pressure).

(a) Fully open the manual load valve.

(b) Slowly close the manual load valve to get 100 psi.

(c) Record the oil temperature and flow rate (gpm).

(3) Test 15 (Full Speed Pump Flow - High Pressure).

(a) With engine speed at full load rpm, slowly close the manual load valve to get 1000 psi.

(b) Record oil temperature and flow rate (gpm).

(4) Test 16 (Half Speed Pump Flow - Low Pressure).

(a) Decrease engine speed to 1/2 full load rpm.

(b) Set the manual load valve to get 100 psi.

(c) Record oil temperature and flow rate (gpm).

(5) Test 17 (Half Speed Pump Flow - High Pressure).

(a) With engine at 1/2 full load rpm, slowly close the manual load valve to get 100 psi.

(b) Record oil temperature and flow rate (gpm).

13-18. HYDRAULIC SYSTEM - TEST (Cont'd)

(6) Comparison of Data

(a) Compare your test data with the data in Tables 13-12 and 13-13. Data shown is the maximum allowable for the best performance. If your values are not acceptable, go to Table 13-14 to identify the problem.

(b) Remove blocking plate from the pump.

13-18. HYDRAULIC SYSTEM - TEST (Cont'd)

Table 13-12. Large Section Pump Test Data

Test Name	Full Speed Pump Flow		Half Speed Pump Flow	
	Low Pressure	High Pressure	Low Pressure	High Pressure
Test Number	14	15	16	17
Engine Speed	2000 RPM	2000 RPM	1000 RPM	1000 RPM
Pump Test Pressure	100 PSI	1000 PSI	100 PSI	1000 PSI
Oil Temperature	150 ±5°F	150 ±5°F	150 ±5°F	150 ±5°F
Test Data	35.0 GPM	31.5 GPM	17.5 GPM	14.0 GPM
Flow Differential		(14-15) 3.5 GPM		(16-17) 3.5 GPM
Percent Flow Loss		$\frac{(14-15)}{14} \times 100$ 10%		

Table 13-13. Small Section Pump Test Data

Test Name	Full Speed Pump Flow		Half Speed Pump Flow	
	Low Pressure	High Pressure	Low Pressure	High Pressure
Test Number	14	15	16	17
Engine Speed	2000 RPM	2000 RPM	1000 RPM	1000 RPM
Pump Test Pressure	100 PSI	1000 PSI	100 PSI	1000 PSI
Oil Temperature	150 ±5°F	150 ±5°F	150 ±5°F	150 ±5°F
Test Data	25.0 GPM	21.2 GPM	12.5 GPM	8.7 GPM
Flow Differential		(14-15) 3.8 GPM		(16-17) 3.8 GPM
Percent Flow Loss		$\frac{(14-15)}{14} \times 100$ 15%		

Table 13-14. Interpreting Pump Test Results

TEST RESULT	WHAT TO DO
1. Percent of flow loss for Test 15 is too high. Flow differential for Test 15 is 0 to 2 gpm greater than flow differential for Test 17.	Hydraulic pump is worn. Repair or replace pump (page 13-7).
2. Percent of flow loss for Test 15 is too high. Flow differential for Test 15 is at least 2 gpm higher than flow differential for Test 17.	a. Check for oil aeration caused by low oil level, wrong type of hydraulic oil, air leak in the pump suction line, or oil leaks in the tank. Correct as required. b. Check for pump cavitation which may be caused by a restriction in the pump suction line or wrong type of hydraulic oil. Correct the cause of cavitation and repair the pump (page 13-7) as required.