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AUTOMOTIVE DIESEL MAINTENANCE 1. UNIT XXIII, I--MAINTAINING THE FUEL SYSTEM, PART II--CATERPILLAR DIESEL ENGINE, II--UNDERSTANDING STEERING SYSTEMS.

HUMAN ENGINEERING INSTITUTE, CLEVELAND, OHIO

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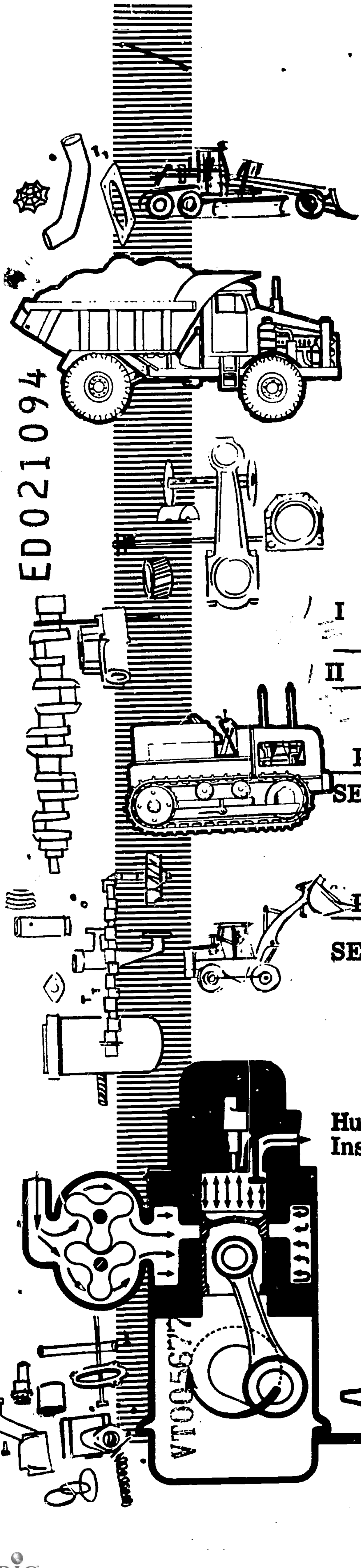
THIS MODULE OF A 30-MODULE COURSE IS DESIGNED TO DEVELOP AN UNDERSTANDING OF THE OPERATION AND MAINTENANCE OF THE DIESEL ENGINE FUEL INJECTION SYSTEM AND THE STEERING SYSTEM OF DIESEL POWERED VEHICLES. TOPICS ARE FUEL INJECTION SECTION, AND DESCRIPTION OF THE STEERING SYSTEM. THE MODULE CONSISTS OF A SELF-INSTRUCTIONAL BRANCH PROGRAMED TRAINING FILM "UNDERSTANDING THE CATERPILLAR FUEL SYSTEM" AND OTHER MATERIALS. SEE VT 005 655 FOR FURTHER INFORMATION. MODULES IN THIS SERIES ARE AVAILABLE AS VT 005 655 - VT 005 684. MODULES FOR "AUTOMOTIVE DIESEL MAINTENANCE 2" ARE AVAILABLE AS VT 005 685 - VT 005 709. THE 2-YEAR PROGRAM OUTLINE FOR "AUOTMOTIVE DIESEL MAINTENANCE 1 AND 1" IS AVAILABLE AS VT 006 006. THE TEXT MATERIAL, TRANSPARENCIES, PROGRAMED TRAINING FILM, AND THE ELECTRONIC TUTOR MAY BE RENTED (FOR $1.75 PER WEEK) OR PURCHASED FROM THE HUMAN ENGINEERING INSTITUTE, HEADQUARTERS AND DEVELOPMENT CENTER, 2341 CARNEGIE AVENUE, CLEVELAND, OHIO 44115. (HC)

STUDY AND READING MATERIALS



AUTOMOTIVE DIESEL 1 MAINTENANCE

I -- MAINTAINING THE FUEL SYSTEM
PART II -- CATERPILLAR DIESEL ENGINE

II -- UNDERSTANDING STEERING SYSTEMS

UNIT XXIII

PART I

SECTION A FUEL INJECTION SECTION

PART II

SECTION B DESCRIPTION OF THE STEERING SYSTEM

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This Unit is divided into two parts. The first part continues the discussion on the CAT diesel engine fuel system (pump and injection components). The second part explains the steering system, its function, and some front end geometry.

I -- MAINTAINING THE FUEL SYSTEM (PART II) CATERPILLAR DIESEL ENGINE

SECTION A -- FUEL INJECTION SECTION

In Unit AM 1-22, we traced the fuel to the filtered side of the filter housing. From here it flows to the manifold in the fuel injection pump housing. At this point the fuel leaves the supply section of the system and enters the injection section.

INJECTION SECTION COMPONENTS -- The fuel injection section of the fuel system consists of the injection pump housing, fuel manifold, injection pumps, lines, injection valves and precombustion chambers.

A vertical passage in the filter housing delivers fuel through a manifold in the injection pump housing to the individual fuel injection pumps. The fuel is delivered at about 15 pounds per square inch pressure to the injection pumps. On some CAT engines, a single air bleed vent is provided to bleed air from the fuel system. The vent is connected to the air bleed manifold on the injection pump housing and to the highest point in the fuel filter housing. On other CAT engines, air is bled from each fuel injection pump by a bleed screw located on top of each pump.

Each fuel injection pump consists of a separate body, barrel and plunger (one for each cylinder) manufacturered to limits measured in millionths of an inch. As a result of this precision, the pumps are interchangeable between cylinders and engines of the same model. However, the pump plungers are not interchangeable with other pump barrels. THEY FIT ONLY THE BARREL OF THE PUMP FROM WHICH THEY WERE REMOVED.

Two functions are performed by the fuel injection pumps: they meter the fuel to be injected into the respective cylinders and they build up pressure sufficient to deliver fuel through the injection valves.

The pump plunger has two motions within the pump barrel; a vertical motion builds up pressure to inject fuel and a rotary motion determines the amount of fuel to be injected. Vertical movement is caused by the fuel injection pump camshaft moving the pump filters. Since the camshaft lobes have a fixed shape, the length of the stroke of the plunger is constant.

A recess machined around the upper end of the pump plunger forms a helical relief, sometimes called a scroll. A vertical passage connects the recess to the space above the plunger. The plunger will pump only during the time the inlet part of the pump is covered.

When the plunger is at its lowest point in the barrel, the inlet port is uncovered. Fuel flows into the space above the plunger and through the vertical groove into the recess around the plunger. As the plunger rises in the barrel, the inlet port is covered and injection begins. Since the stroke of the plunger is always constant, the volume of fuel in the recess (not to be confused with what is injected) is always the same. As the plunger continues upward, fuel is forced out of the top of the pump, at about 1500 pounds per square inch, through the check valve.

Fuel injection continues, as the plunger rises, until the edge of the helix uncovers the inlet port. Then fuel in the recess, vertical groove and space above the plunger, which is under high pressure, will escape through the inlet port back to the fuel manifold. This happens because the fuel in the manifold is held to a relatively low pressure.

Remember, fuel is injected only during that part of the upward stroke when the inlet port is covered by the plunger. The distance the plunger travels while fuel is being injected is called the effective stroke.

Very small amounts of fuel tend to seep between the barrel and the plunger. A pressure relief groove on the lower part of the plunger and a return passage to the fuel inlet prevent leakage of the fuel down into the fuel pump housing.

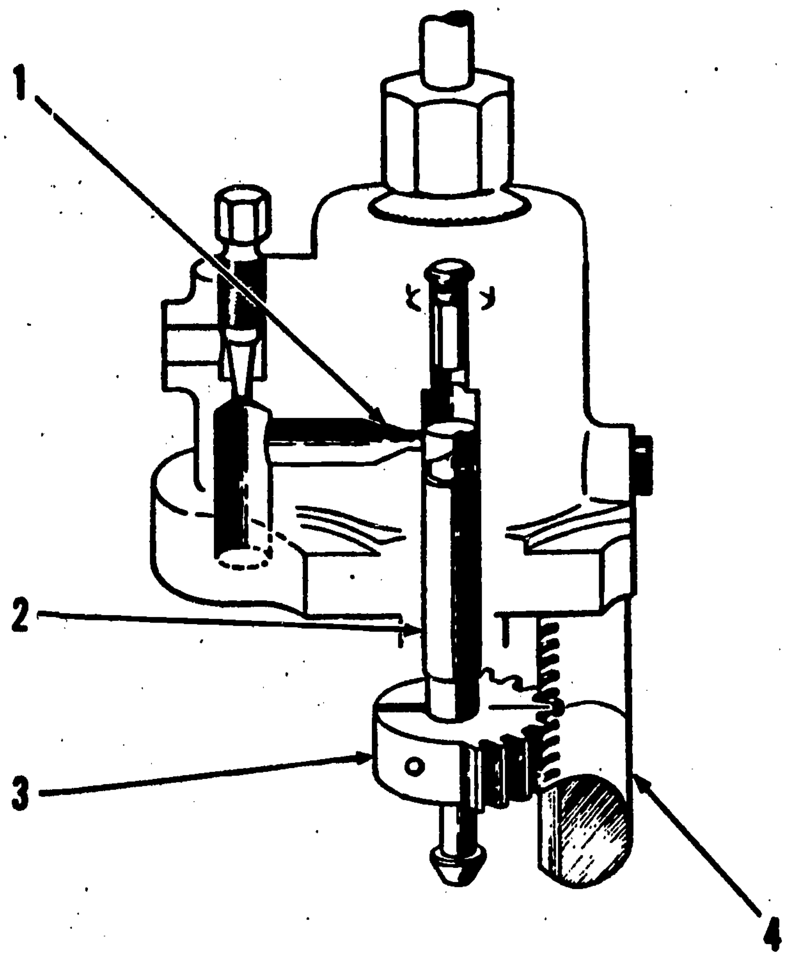
To meet changes in load, the volume of fuel injected is varied by the action of the rack which causes rotation of the pump plunger. This changes the position of the helical portion of the plunger in relation to the inlet port.

FUEL INJECTION PUMPS (Figures 1, 2 and 3). Each pump measures the amount of fuel to be injected into its respective cylinder and delivers it to the fuel injection valve. The injection pump plunger (2) is lifted by a cam and always makes a full stroke. The amount of fuel pumped per stroke can be varied by turning the plunger in the barrel. The plunger is turned by the action of the fuel rack (4) which meshes with the gear segment (3) on the bottom of the pump plunger.

Parts (a), (b), and (c) of Figure 2 illustrate the functioning of an injection pump as the plunger makes a stroke.

In Figure 2 (a) the plunger is down and the inlet port (1) is uncovered. Fuel flows into the space above the plunger through the slot and into the recess around the plunger.

In Figure 2 (b) the plunger has started up and the port is covered. The fuel is trapped, and will be forced through the check valve, fuel line, and injection valve as the plunger moves upward.



1-Inlet port. 2-Pump plunger. 3-Gear segment. 4-Rack.

Fig. 1 Fuel injection pump.

In Figure 2 (c) the plunger has risen until the port is uncovered by the recess in the plunger. The fuel can now escape back through the port into the fuel manifold, and injection will cease.

Figures D, E and F of Figure 3 illustrate how rotating the pump plunger affects the quantity (amount) of fuel injected.

In Figure 3 (d), the plunger has been rotated into the shut off position. The slot connecting the top of the plunger with the recess is in line with the port; therefore, no fule can be trapped and injected.

In Figure 3 (e), the plunger has been rotated into the idling position. The narrow part of the plunger formed by the helix will cover the port for

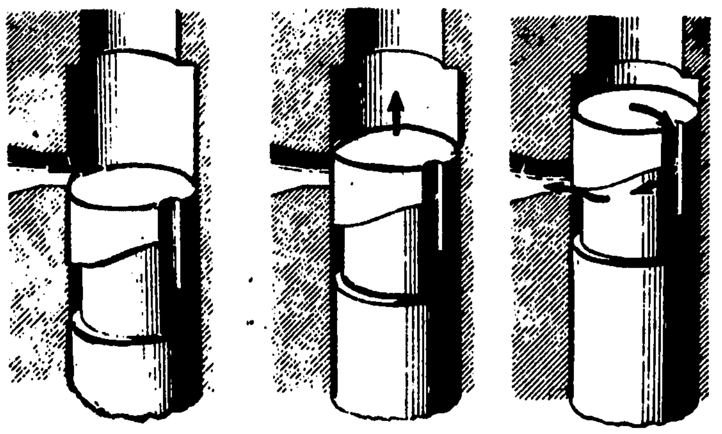


FIG. A
Port Uncovered
Fuel Enters Barrel

FIG. B
Port Covered
Injection Begins

FIG. C
Port Uncovered
Injection Ends

Fig. 2 Helix positions.

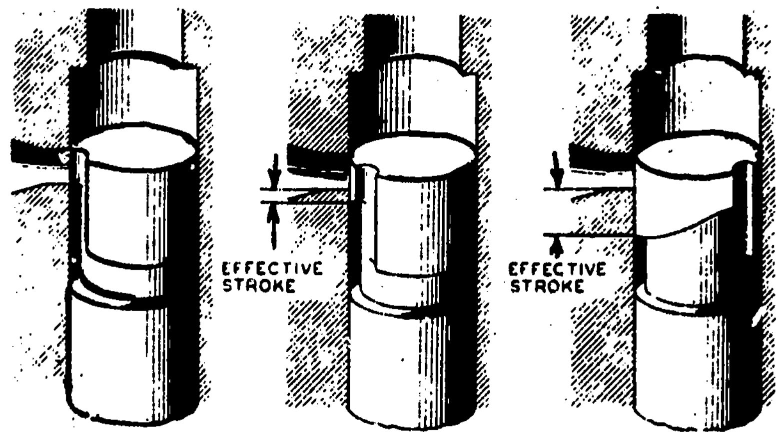


FIG. D
SHUT OFF

FIG. E
IDLING
POSITION

FIG. F
FULL LOAD
POSITION

Fig. 3 Helix positions.

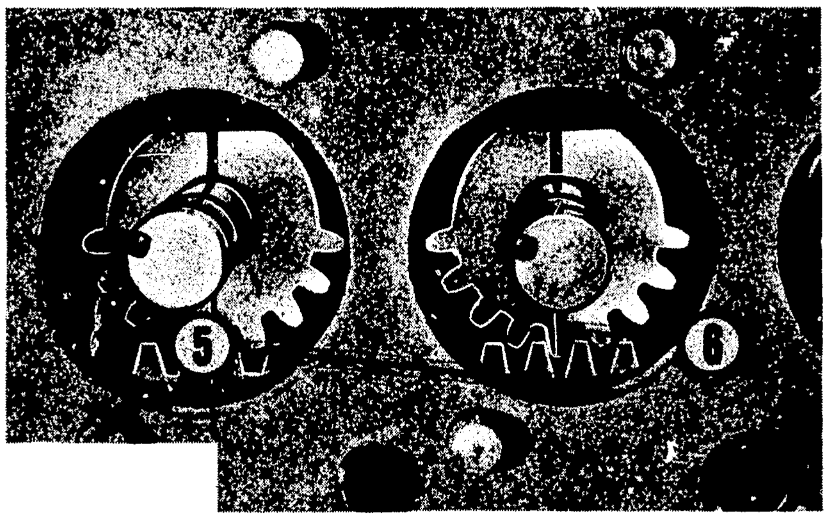
only a short part of the stroke. This permits only a small amount of fuel to be injected per stroke.

In Figure 3 (f) the plunger has been rotated into the full load position. The wide part of the plunger formed by the helix covers the port for a longer part of the stroke. This permits a larger amount of fuel to be injected per stroke.

Worn fuel injection pumps will result in loss of power and in hard starting.

Rotation of the plungers is accomplished by a gear segment, attached to the bottom of each plunger, which meshes with the fuel rack, see Figure 4. Fuel rack position, effective pump stroke and quantity of fuel injected are primarily controlled by the throttle. The governor maintains engine speed to meet throttle settings - except when the rack limiter, speed limiter and idle rack positions override the governor.

Several manufacturers use the "Pump and helix metering pump" principle shown in Figure 5. The parts shown are enclosed in a body casting and fuel oil is delivered under low pressure from the supply pump to the two



5-Mark on rack. 6-Marked gear tooth.

Fig. 4 Removing fuel injection pump.

ports in the barrel just above the plunger. The plunger forces fuel past the check valve at the top of the injection pump. The plunger body has a helical relief. This relief section is connected to the space above the plunger by the slot on the left front surface of the plunger.

The plunger is forced upward by a tappet and cam and is returned by a spring. As the plunger is moving downward, the intake, or suction, port is uncovered and the barrel is filled with fuel. On the upward stroke, fuel is forced back out the intake port until the top of the plunger covers the port. Fuel is then delivered past the check valve (delivery valve) to the injection nozzle and into the combustion chamber. Injection ends when the plunger helix uncovers the port on the right side of the barrel, allowing fuel oil to escape back to the fuel supply.

Action of the plunger in different positions can be seen in Figures 2 and 3. Rotation of the plunger varies its effective stroke and, therefore the quantity of fuel oil injected into the combustion chamber, or pre-combustion chamber. When the plunger is rotated until the slot registers with the port, as shown in the extreme right, no injection occurs.

Some manufacturers design the plunger helix for a constant beginning and variable ending of fuel injection; others design the plunger helix for variable beginning and constant ending; still others design injector plungers for variable beginning and variable ending. Can you determine what type fuel injection system Cat has, of the three mentioned? See Figure 6.

The fuel output and the operating characteristics of the injector are, to a great extent, determined by the type of plunger used. Three types of plungers are illustrated in Figure 6. The beginning of the injection period is controlled by the upper helix angle. The lower helix angle retard or advances the end of the injection period. Therefore, it is imperative that the correct plunger is installed whenever an injector is overhauled. If injectors with different type plungers (and spray tips) are mixed in an engine erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

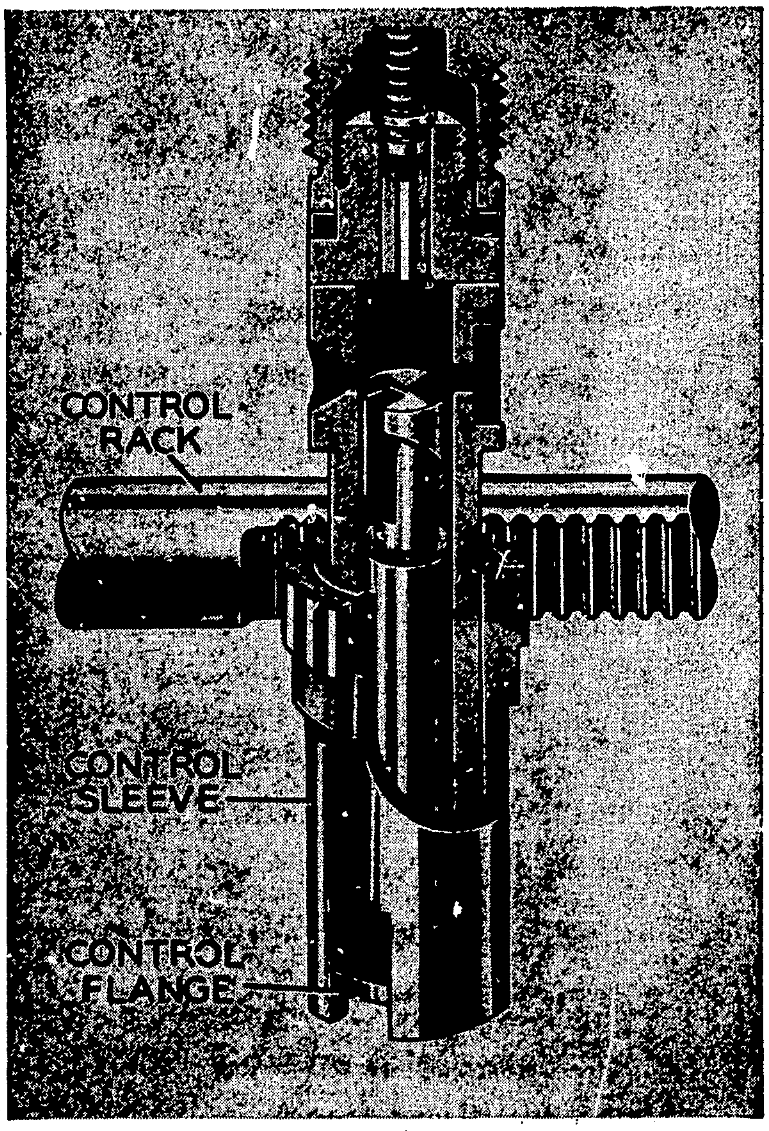


Fig. 5 Helical relief of the oscillating plunger.

As fuel leaves the pump, it opens a check valve located in the top of the pump body. This check valve (sometimes referred to as the delivery valve) keeps the fuel line between the pump and injector full of fuel at

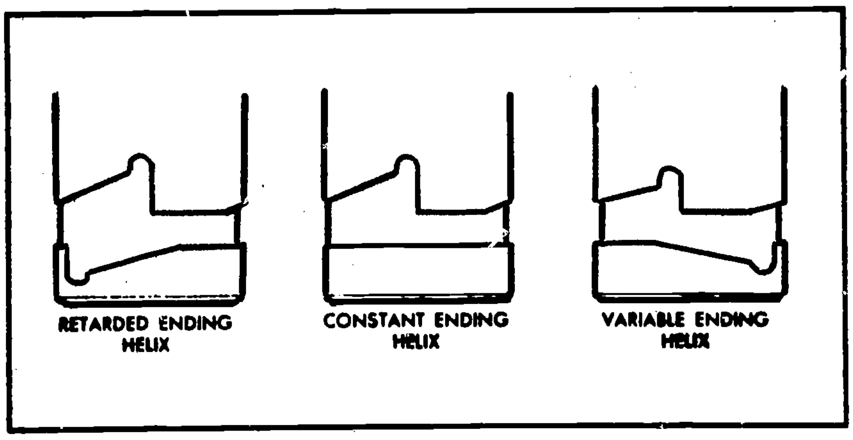


Fig. 6 Types of injector plungers.

all times so that the pump need not refill the line on each pumping stroke.

All the fuel lines from the injection pump to the injection valves are the same length even though the span between connections is quite different. Fuel lines of equal length insure flow of fuel to each cylinder at precisely the correct time.

The fuel injection valves are of the single orifice capsule type which atomize fuel and inject it into the precombustion chamber.

The injection valve assembly consists of a retainer nut, valve body and nozzle assembly in position.

The nozzle and body should be assembled only finger tight before installation in the precombustion chamber. Course threads of the valve body and nozzle assembly are designed to fit loosely. Clearance between the threads provides a passage for fuel to enter the nozzle assembly from the valve body.

The condition of a capsule type nozzle assembly can be tested out of the engine, on the CAT Diesel Fuel Injection Test Apparatus. The spray characteristics, valve unseating (popping pressure), and the rate of leakage of the nozzle assembly can be determined .

Don't tamper with the fuel injection system. Follow the practices recommended by the manufacturer and the results will be maximum service life from your Caterpillar Diesel Engine.

This completes Part II of the Caperpillar Fuel Injection System.

II -- UNDERSTANDING STEERING SYSTEMS

SECTION A -- DESCRIPTION OF THE STEERING SYSTEM

Figure 7 shows a typical steering system from a large vehicle.

This steering system incorporates a combination of mechanical linkage and hydraulic assists for greater efficiency and ease of steering. Standard steering linkage connects the steering wheel Figure 1 (8), to the front wheels, assuring positive steering control of the vehicle at all times. If any of the hydraulic assists fails to operate, the driver can steer manually without interference from non-operative hydraulic components.

In addition to the mechanical linkage, hydraulic powered steering boosters, Figure 7 (1 & 2), are connected to each front wheel. There are hydraulic piston and cylinder assists. More will be covered on these and other hydraulic components later on. These parts are provided to reduce the effort required from the driver in turning the front wheels.

MECHANICAL SECTION -- To steer the vehicle, the driver turns the steering wheel, Figure 7 (8), in the usual manner. The steering wheel and the column actuate the steering gear, Figure 7 (11). The turning of the steering gear worm transmits motion to the pitman arm, Figure 7 (12), which causes a push or pull action on the L. H. drag link, Figure 7 (4), and to the R. H. drag link, Figure 7 (4), through the tie rod. The drag links turn the steering arms, Figure 7 (6 & 13), and spindles, Figure 7 (5).

The tie rod, which is mounted to the spindles, Figure 7 (5), by means of the tie rod arms, is the means by which mechanical motion is transmitted simultaneously to both steering spindles, thus turning both of the front wheels together.

A-Suction Line
B-Pressure Line
C-Pressure Line, Relief Valve to Steering Valve
D-Booster Line
E-Booster Line
F-Return Line, Steering Valve to Relief Valve
G-Return Line, Relief Valve to Hydraulic Oil Tank

1-L.H. Steering Booster
2-R.H. Steering Booster
3-R.H. Pitman Arm
4-Drag Links
5-Spindles
6-R.H. Steering Arm
7-Pump
8-Steering Wheel
9-Relief Valve
10-Steering Valve
11-Steering Gear
12-L.H. Pitman Arm
13-L.H. Steering Arm

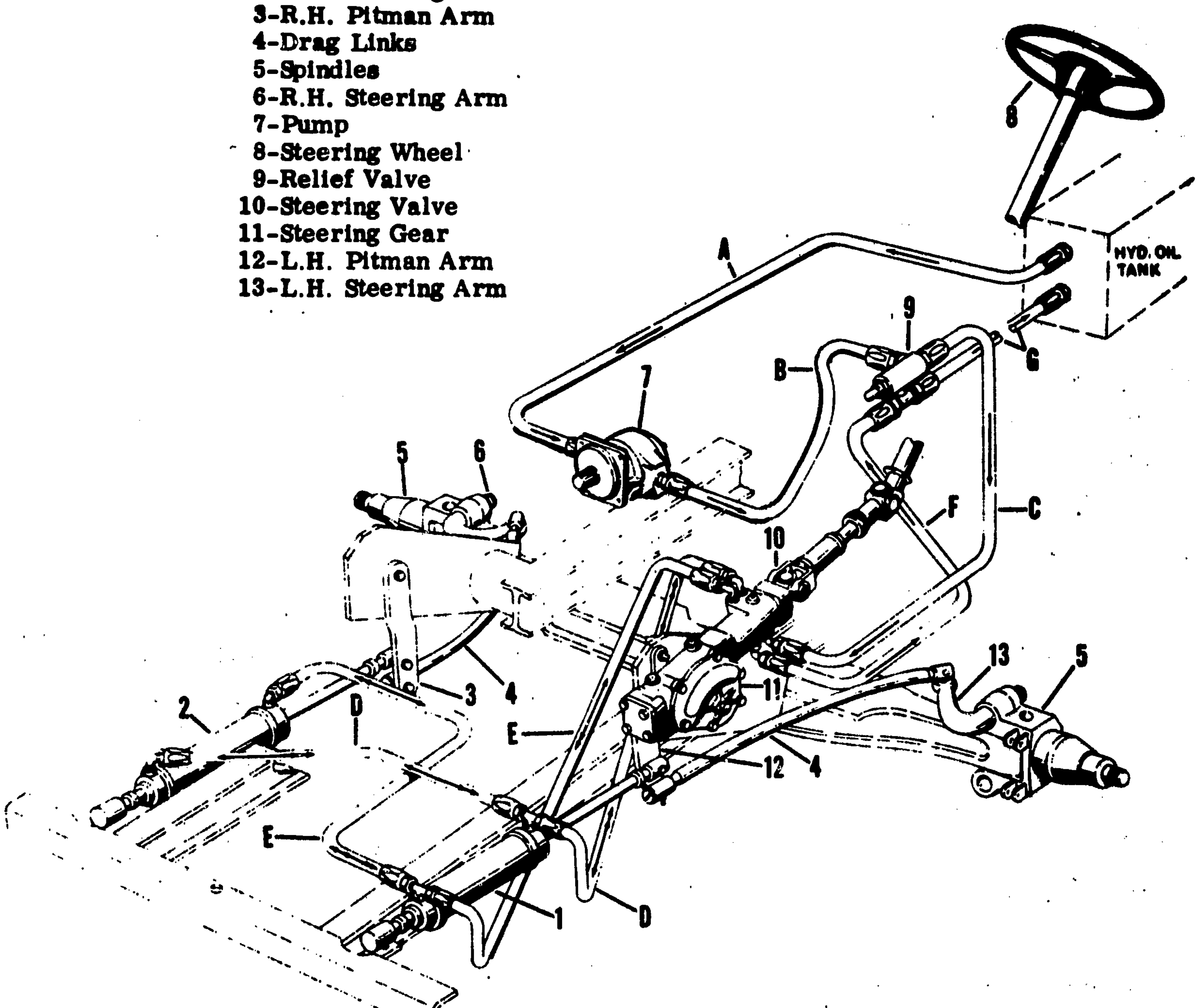


Fig. 7 Schematic view of steering system.

HYDRAULIC SECTION -- The hydraulic section consists of the steering boosters, Figure 7 (1 & 2), steering pump, Figure 7 (7), steering valve, Figure 7 (10) and the necessary lines and fittings. The primary function of the steering hydraulic system is to provide assistance to the mechanical force exerted by the linkage for ease of steering.

The steering boosters are anchored to the frame and the steering booster piston rods are mounted to the pitman arms, Figure 7 (3 & 12). The extension or retraction of the steering booster pistons in the booster cylinders causes the piston rods to react directly on the pitman rams.

RIGHT TURN -- NOTE: The steering valve, Figure 7 (10), is actuated in the opposite direction depending on steering wheel rotation.

Turning the steering wheel clockwise (right turn) actuates the steering valve, which directs pressurized oil, through booster line, Figure 7 (e) to the cylinder end of the steering booster, Figure 7 (1), and to the piston end of steering booster Figure 7 (2). This force causes the steering booster Figure 7 (1), to extend, and steering booster, Figure 7 (2) to contract. Displaced hydraulic oil from the steering boosters is then forced through booster line Figure 7 (d), return line Figure 7 (f), and line Figure 7 (g) to the tank.

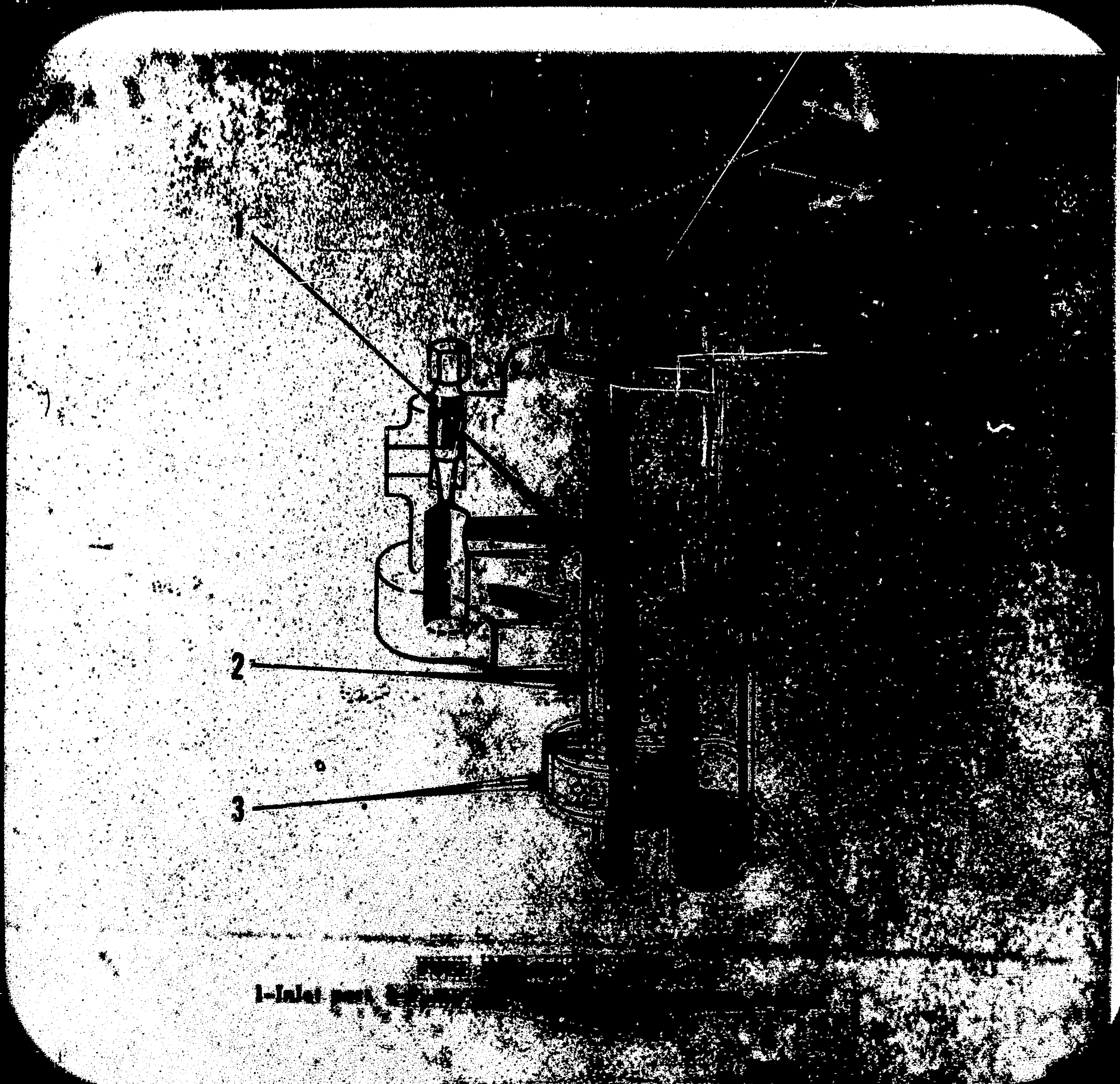
NEUTRAL POSITION -- In the neutral position, both ports leading from the steering valve to the steering boosters are closed, causing the boosters to hold their position. The oil flows through the steering valve and is directed back to the hydraulic tank through return lines, Figure 7 (f & g).

With the steering valve piston in this position, any oil in the steering boosters is trapped there by the closing of the steering valve ports. This produces a hydraulic lock, locking the boosters in place. They remain locked until the steering valve piston is actuated by the steering gear.

LEFT TURN -- Turning the steering wheel counterclockwise (left turn) again actuates the steering valve, which directs pressurized oil through booster line, Figure 7 (d), to the piston end of steering booster, Figure 7 (1), and to the cylinder end of steering booster, Figure 7 (2). This force causes the steering booster, Figure 7 (1), to contract and steering booster Figure 7 (2) to extend. Displaced hydraulic oil from the steering boosters is then forced through booster line, Figure 7 (e), back to the steering valve, through the return line, Figure 7 (f) and line, Figure 7 (g), to the tank.

OIL FLOW -- Oil flows from the tank, through line, Figure 7 (a), into the suction side of the pump. Pressurized oil leaves the pump and flows through line, Figure 7 (b), and relief valve, Figure 7 (9) and line, Figure 7 (c), to the steering valve. The relief valve is set for 1100 to 1150 psi at 500 engine rpm. Should the pressure exceed 1150 psi, the oil will flow back to the tank.

This has been a very brief description of how the steering gear operates on a large vehicle. More about the steering gear and its components will be covered in greater detail in later Units.


1
2
3
1-Inlet port,

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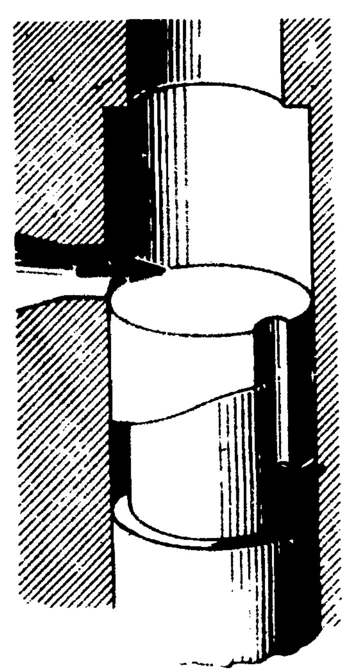

FIG. A
Port Uncovered
Fuel Enters Barrel

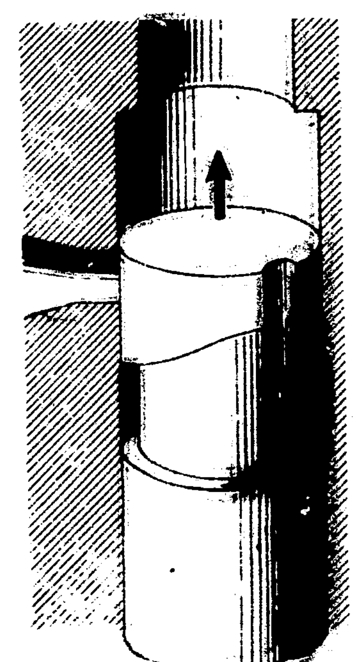

FIG. B
Port Covered
Injection Begins

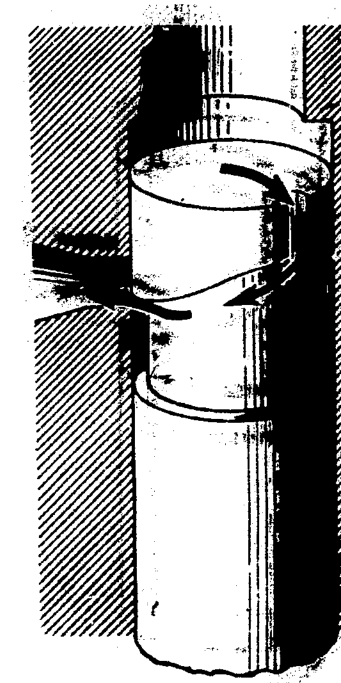

FIG. C
Port Uncovered
Injection Ends

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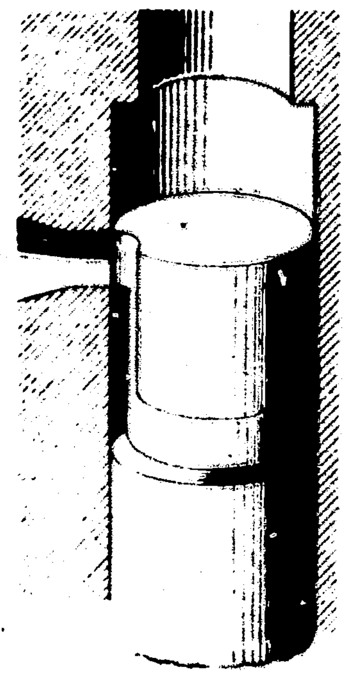


FIG. D
SHUT OFF

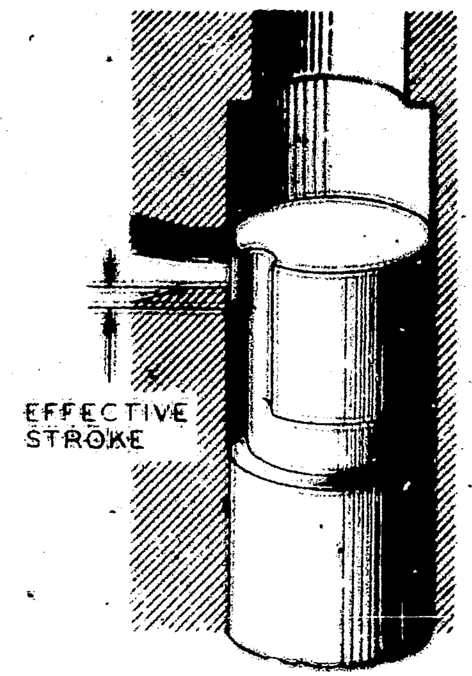


FIG. E
IDLING
POSITION

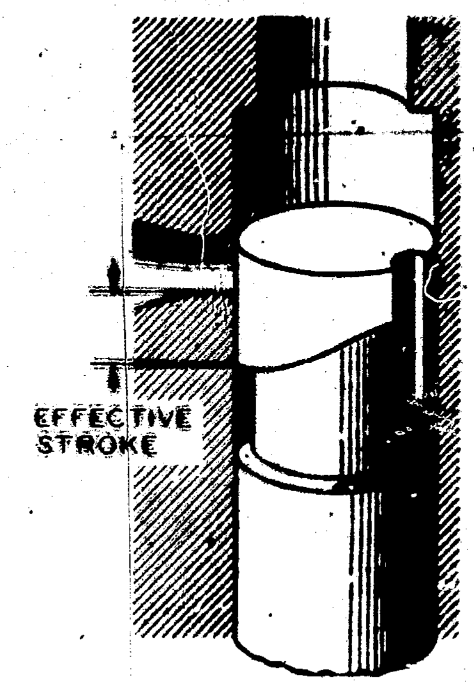
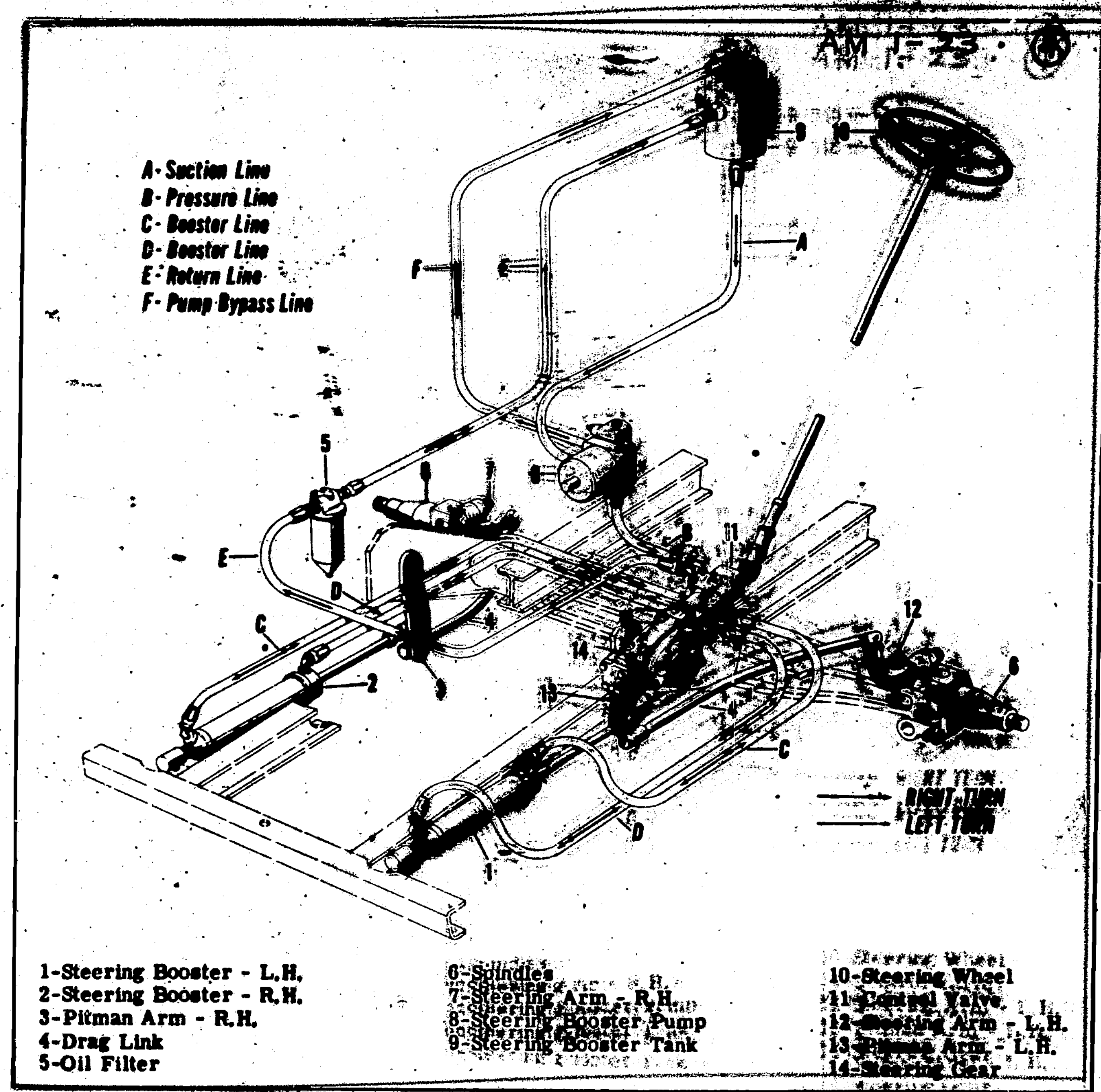


FIG. F
FULL LOAD
POSITION



Schematic View of Steering System

INSTRUCTOR'S GUIDE

Title: I -- MAINTAINING THE FUEL SYSTEM
PART II -- CATERPILLAR DIESEL ENGINE
II -- UNDERSTANDING STEERING SYSTEMS

AM 1-23
8/16/66

OBJECTIVES for this Unit:

1. To continue discussion of the CAT fuel system. PART I covers the supply section of the fuel system. PART II covers the pump, injectors and general injection section.

2. To give the student a brief look at a typical steering system of a large vehicle.

LEARNING AIDS suggested:

VUE CELLS:

AM 1-23 (1) (Fuel injection pump)
AM 1-23 (2) (Helix positions I)
AM 1-23 (3) (Helix positions II)
AM 1-23 (4) (Schematic view of steering system)

MODELS:

Any components of the CAT fuel system (injection section) that can be brought to class would be helpful. Check the nearest CAT distributor for any cut-aways he might loan out.

QUESTIONS FOR DISCUSSION AND GROUP PARTICIPATION:

1. What are the components that make up the fuel injection side of the CAT fuel system?

2. What is the amount of pressure that is delivered to the inlet side of of the pump?

3. What is the amount of pressure delivered to the nozzles from the pump?

4. What two motions does the pump plunger have? Which motion is variable?

5. Since the pump's speed is in direct relation to the engine speed, how is the fuel metered?

6. Is the CAT multi-cylinder fuel pump gear or belt driven? From where?

7. Which turns the fastest - the pump crankshaft, or the engine crankshaft?

8. What component of the steering system assures that both wheels turn the same number of degrees?