TRAINING
COURSE 7

DIESEL ENGINES AND FUEL SYSTEMS

VOLUME 2

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INTRODUCTION

The prime job of the diesel fuel system is to inject a precise amount of atomized and pressurized fuel into each engine cylinder at the proper time. Combustion in the diesel engine occurs when this charge of fuel is mixed with hot compressed air. No electrical spark is used (as in the gasoline engine).

The diesel fuel injection system must supply the correct quantity of fuel, time the fuel delivery, control the delivery rate, atomize the fuel, and distribute the fuel evenly through the cylinder. The fuel systems have the following components:

Fuel Tanks. There are many different types and shapes of fuel tanks. Each size and shape is designed for a definite requirement. It must be capable of storing enough fuel to operate the engine for a reasonable length of time. The tank must be closed to prevent dirt from entering. It must also be vented to allow air to enter, replacing the fuel used. Three other tank openings are required--one to fill, one to discharge, and one to drain.

Fuel Lines. There are three types of diesel fuel lines. Heavy weight lines for very high pressure between the injection pump and the nozzles, medium weight lines for light or medium fuel pressures between the tank and injection pump, and light weight lines where there is little or no pressure.

Fuel Filters. Diesel fuel must be filtered not once, but several times in most systems. A typical system might have three stages of progressive filters--a filter screen at the tank or transfer pump, a primary fuel filter, and a secondary fuel filter. In series filters, all the fuel goes through one filter and then through the other. In parallel filters part of the fuel goes through each filter.

Fuel Transfer Pumps. Simple fuel systems use gravity or air pressure to get fuel from the tank to the injection pump. On modern high speed diesel engines, a fuel transfer pump is normally used. This pump, driven by the engine, supplies fuel automatically to the diesel injection system. The pump often has a hand primer lever for bleeding air from the system. Modern injection pumps are almost all jerk pumps which use the plunger and cam method of fuel injection. The four major ways of injecting fuel are the individual pump and nozzle for each cylinder, pumps in a common housing with

nozzles for each cylinder, a combined pump and nozzle for each cylinder (unit injector type), and one pump serving nozzles for several cylinders (distributor type). The unit injector pump is common on larger engines, while the in-line and distributor types are used on off-the-road farm and industrial machines.

Injection Nozzles. The injection nozzle must atomize the fuel for better combustion and spread the fuel spray to fully mix it with air. In addition, all nozzles in multicylinder engines must inject fuel equally for smooth power. Nozzles are simple devices. They use a spring to oppose fuel pressure until the right instant for injecting fuel, when the nozzle valve opens. The injector nozzle is the bottom section of the fuel injector.

Diesel Fuels. The fuels used in modern high speed diesel engines are derived from the heavier residues of the crude oil that are left over after the more volatile fuels such as gasoline and kerosene are removed during the refining process. The Army uses No. 1 and No. 2 diesel fuel. In normal operations, No. 2 diesel fuel is used during the warm months with a change to No. 1 for winterization purposes. There are no adjustments necessary when changing from one fuel to another. Efficient operation demands that fuel system components be maintained in first class condition at all times. Servicing the components of the diesel fuel system is not a difficult task and may be performed by the average mechanic. However, due to close tolerances of various parts of the fuel system, extreme cleanliness and strict adherence to instructions is required. A high percentage of failures occurs in the diesel fuel system due to carelessness or faulty workmanship.

Lesson 1

MULTIPLE PUMP FUEL SYSTEMS

TASK

Describe the correct procedures for the adjustment, repair, or replacement of components of multiple pump fuel systems.

CONDITIONS

You will be given information describing the correct procedures for the adjustment, repair, and replacement of the multiple pump fuel system components.

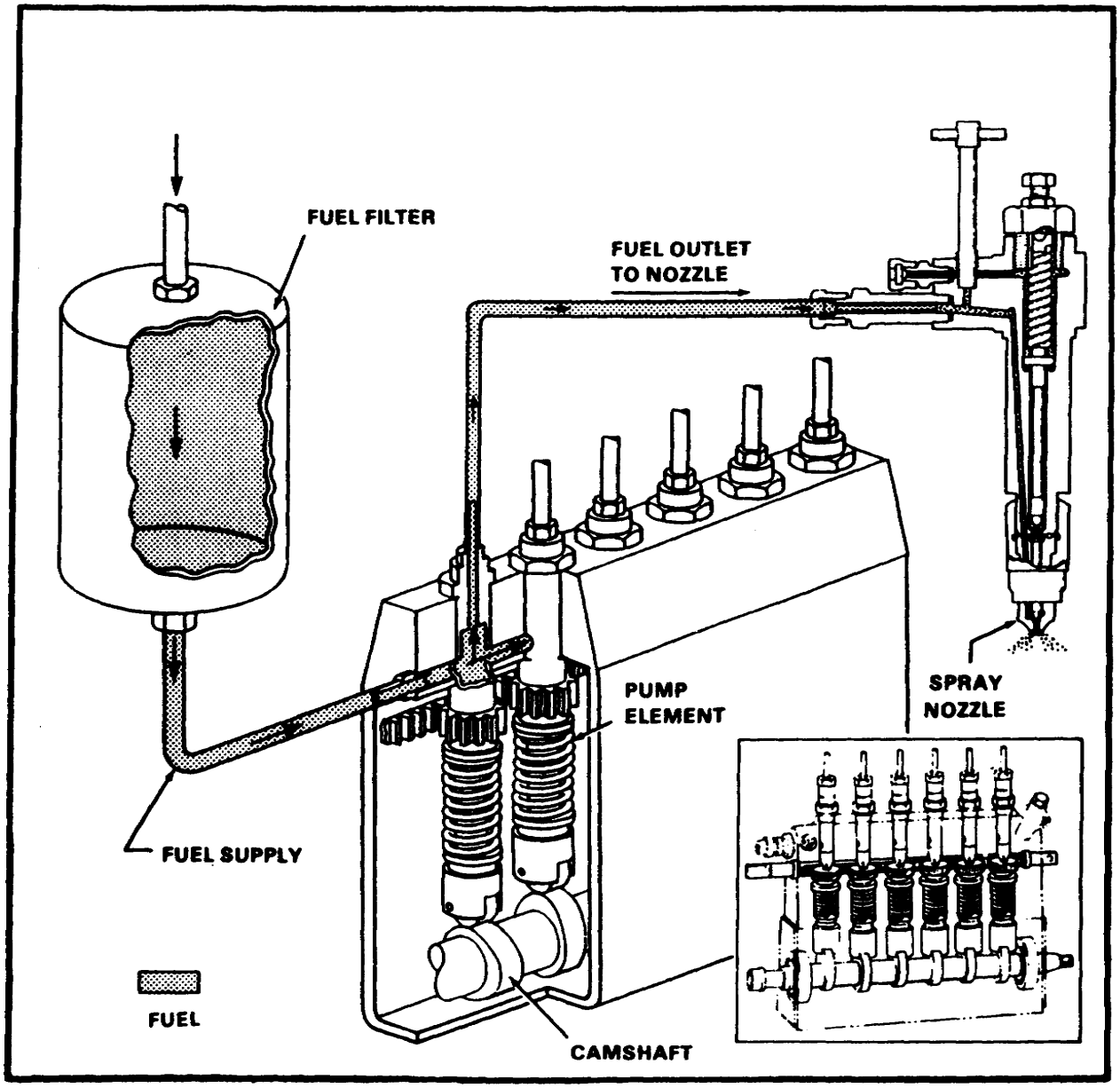
STANDARDS

You are expected to demonstrate competency of the task skills and knowledge by responding correctly to 70 percent of the examination questions pertaining to this lesson.

Learning Event 1
SYSTEM COMPONENTS AND OPERATION

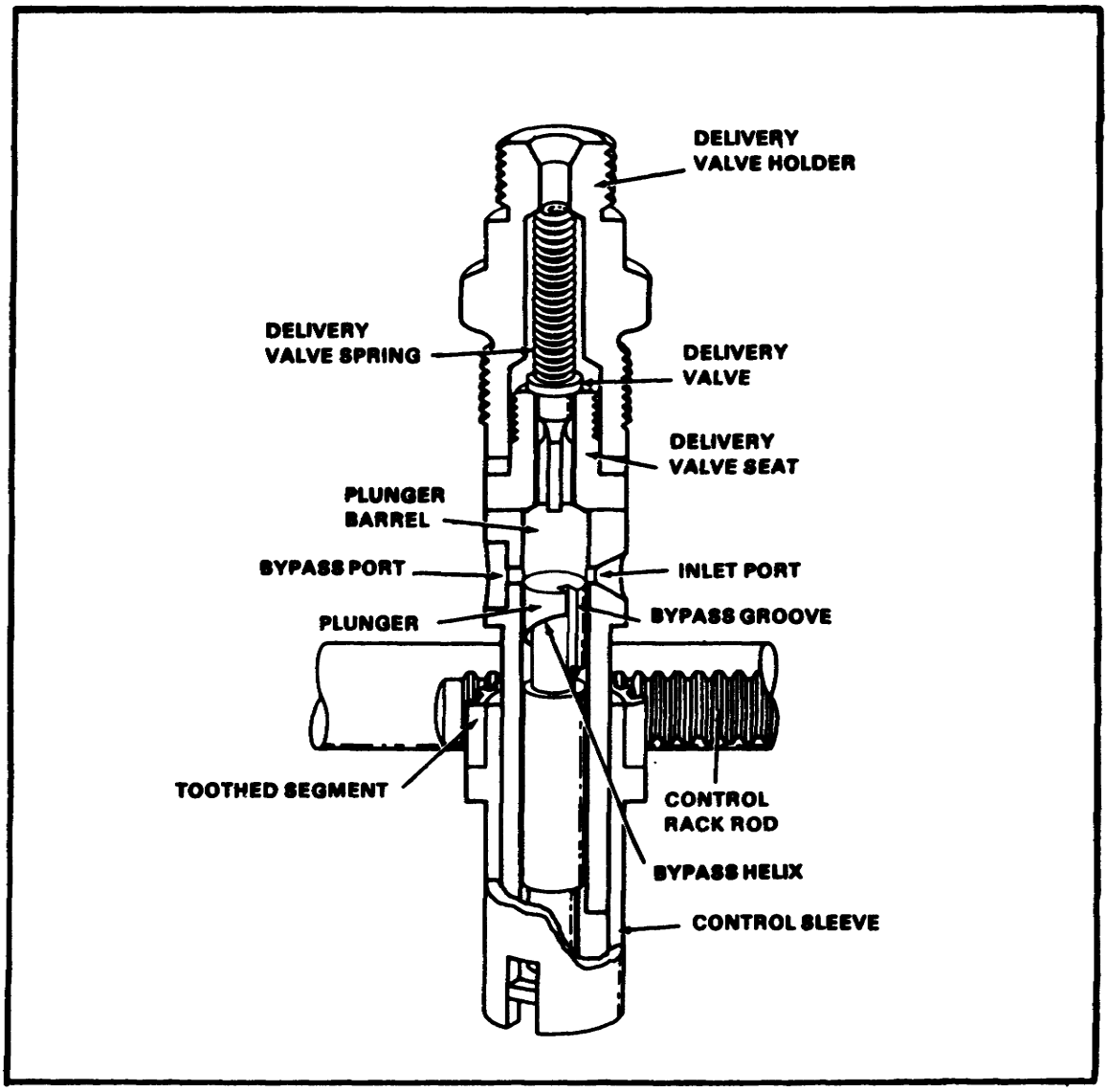
In the multiple pump fuel system, each cylinder has an individual injection pump which meters the fuel and delivers it under high pressure to the spray nozzles which lead into the combustion chambers. The pumps mounted in a common housing are operated by a common camshaft, and utilize the same control mechanism to ensure an equal amount of fuel in each cylinder at the proper time. The flow of fuel in a typical multiple pump fuel system is shown in Figure 1.

FIGURE 1. FUEL FLOW IN A MULTIPLE PUMP FUEL SYSTEM



Diesel fuel oil flows from the supply tank through a fuel filter to the fuel supply pump. The fuel supply pump forces the fuel through an additional filter to the injection pumps (Figure 2). The fuel injection pumps force a measured amount of fuel through high-pressure lines to the spray nozzles in the combustion chamber. Surplus fuel flows from the injector pumps through a check valve on the common housing and is returned to the fuel supply tank.

FIGURE 2. FUEL INJECTION PUMP AND CONTROL RACK



FUEL INJECTION PUMPS

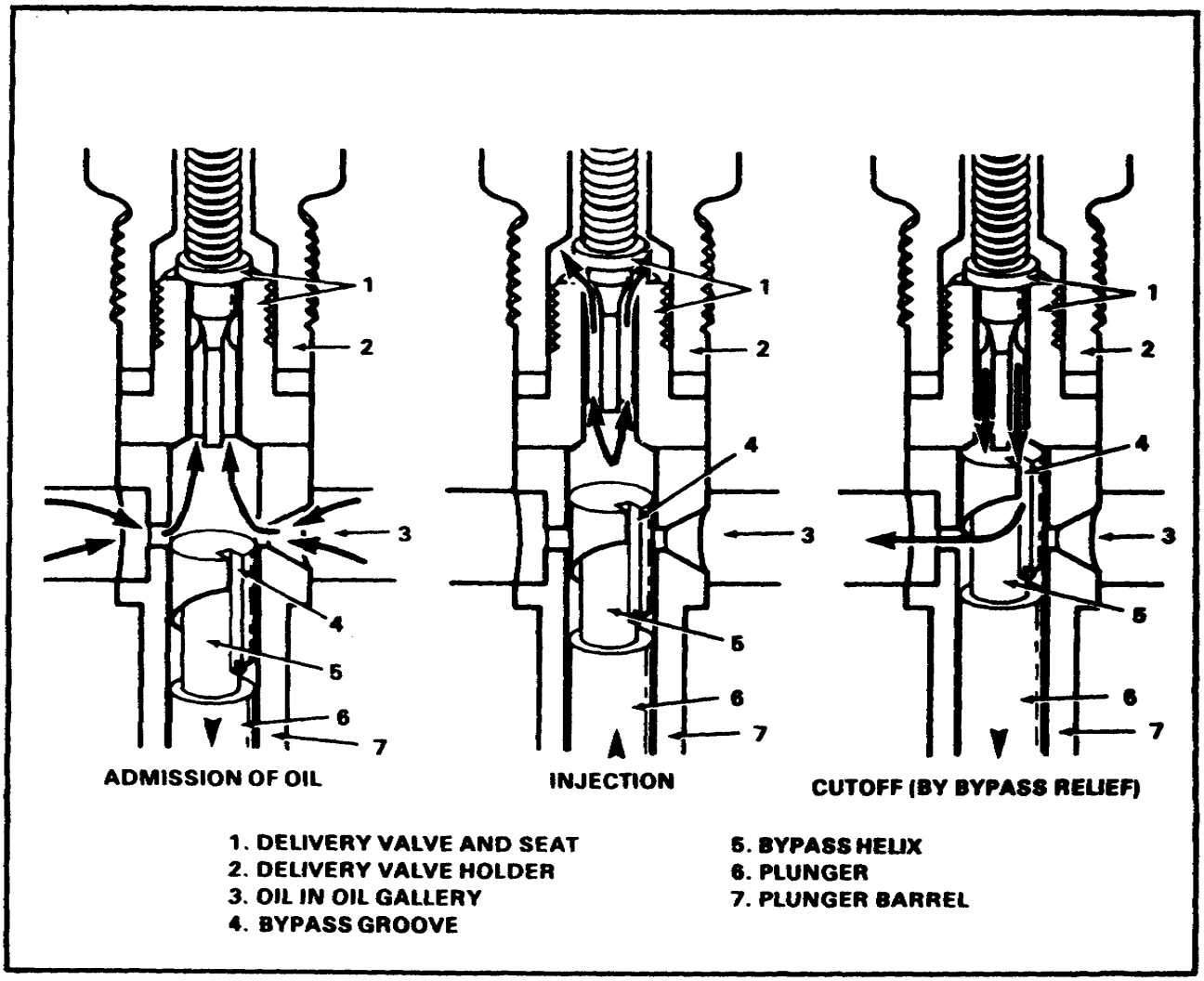
A phantom cross-sectional view of a typical multiple pump is shown in Figure 1. The unit is mounted on the engine in such a manner as to permit it to be driven by the engine.

The pump camshaft, near the bottom of the housing, is carried on ball bearings. The cam lobes cause the upward movement of the plungers and springs to produce the downward motion. The cams are arranged to activate the individual pumps in the same sequence as the firing order of the engine to eliminate the necessity for crossing lines leading from the pumps to the spray nozzles. On the four-stroke-cycle engine, the injection pump is driven at one half engine speed; on the two-stroke-cycle engine it is driven at engine speed.

The individual pumps are the lapped plunger, the constant stroke, the metering, and the bypass. The quantity of fuel delivered to the spray nozzles is regulated by the time the plunger covers the bypass port. The plunger stroke remains constant at all loads. The injection must be timed to occur as demanded by the requirements of the engine. Volumetric control is affected by rotating the plunger. Two ports lead to the plunger barrel as shown in Figure 2 on page 3 and Figure 3; one is the inlet port and the other is the bypass port. The plunger has a groove around its circumference, which has a circular lower edge and helical upper edge. The space formed is connected to the top face of the plunger through a vertical slot. Hence, any fuel above the plunger will flow down the vertical slot and fill the helical space. At the lower end of the plunger there are two lugs which fit in corresponding slots in the bottom of an outer sleeve fitted around the pump barrel. The upper portion of the sleeve is fastened to a gear segment which meshes with a horizontal toothed rack. Any movement of the rack rotates the outer sleeve and plunger relative to the bypass port in the stationary pump barrel.

Fuel from the sump rushes into the barrel as soon as the upper edge of the plunger opens the two opposite ports in the barrel. This action begins during the downward stroke of the plunger and the ports remain open until the plunger starts moving upward. After the plunger covers the ports on its upward stroke, the pressure exerted on the fuel causes the spring-loaded delivery valve to lift off its seat, thereby, permitting the fuel to discharge into the tubing which leads to the spray nozzle. The delivery of the fuel ceases as soon as the helix on the plunger uncovers the bypass port in the barrel. At this instant, the pressure chamber is connected to the sump through a vertical groove and the helix on the plunger which relieves the pressure in the barrel. The delivery valve is quickly returned to its seat by the combined action of its spring and the great difference in pressure that exists between the barrel and the high pressure line. In returning to its seat, the delivery valve performs a double function. It prevents

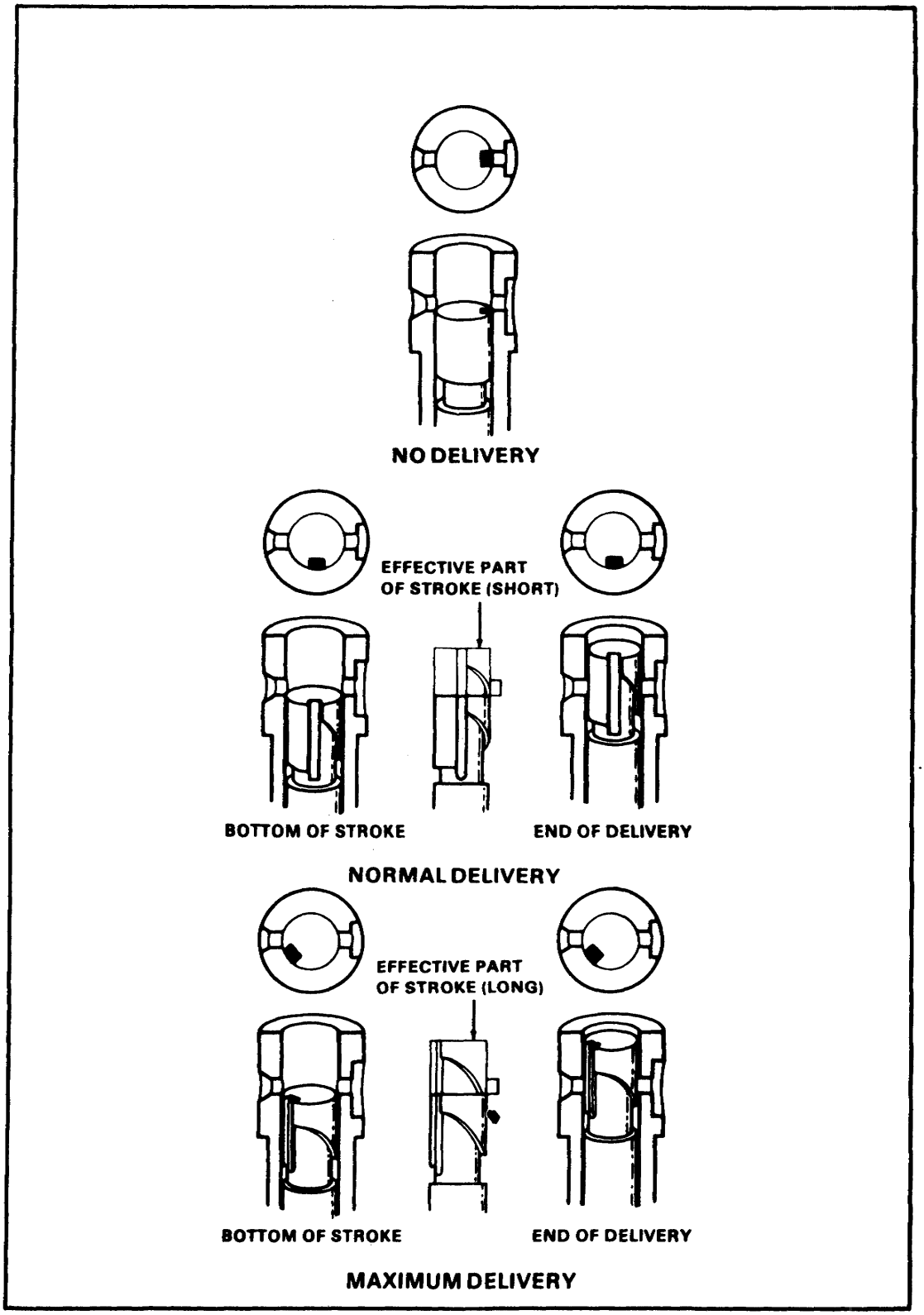
FIGURE 3. FUEL INJECTION PUMP PLUNGER



excessive draining of the fuel from the high pressure line and relieves the pressure in the high pressure line. This pressure relief is accomplished by an accurately lapped displacement piston on the delivery valve. Before the delivery valve actually reseats, it reduces the pressure in the high pressure line by increasing the volume by a quantity equal to the volume of the displacement piston.

The positions of the plunger from no fuel to maximum fuel delivery are shown in Figure 4 on page 6. For maximum delivery, the plunger is positioned in the barrel so that it will complete its stroke before the helix indexes with the bypass port. For zero delivery, the plunger is turned in its barrel until the vertical slot registers with the bypass port. In this position, the pressure chamber is connected with the sump during the entire stroke of the plunger. Any position between no fuel to maximum fuel delivery can be obtained by moving the control rack in or out, as the movement of the rack causes the plunger to rotate a proportionate amount. The same rack controls the position of all the plungers simultaneously, thereby ensuring the injection of equal amounts of fuel in each cylinder of the engine.

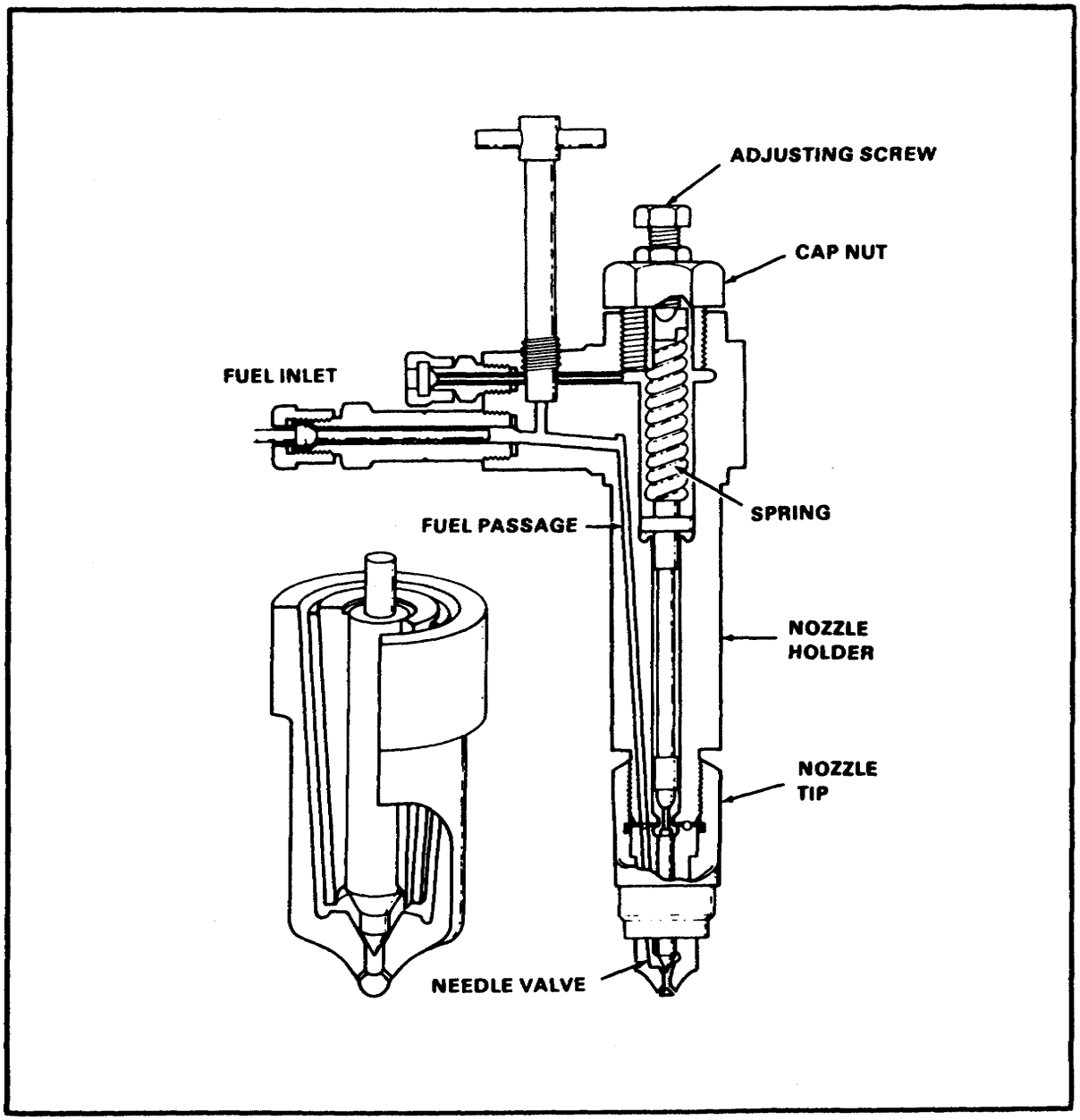
FIGURE 4. INJECTOR PUMP PLUNGER FOR VARYING AMOUNTS OF FUEL DELIVERY



SPRAY NOZZLES AND NOZZLE HOLDERS

For proper engine performance, the fuel oil must be injected into the combustion space in a definite spray form. This is accomplished by the spray nozzle, which is held in the correct position in the cylinder head by the nozzle holder. The type of unit most often used with the multiple pump system is shown in Figure 5. The fuel delivered by the

FIGURE 5. SPRAY NOZZLE FOR MULTIPLE PUMP SYSTEMS



injection pump flows through the high pressure line and enters the nozzle holder inlet stud. Then it passes through the edge filter, flows through the ducts in the holder and nozzle body and down into the pressure chamber of the spray nozzle above the valve seat. There, the pressure of the fuel oil acts on the differential area of the nozzle valve. At the moment when the pressure of the fuel exceeds the pressure exerted by the adjusting spring, the nozzle valve is lifted off its seat and the fuel is forced through the orifices and sprayed into the combustion chamber of the engine. The nozzle valve returns to its seat after the injection pump has ceased to deliver fuel. The hydraulic opening pressure of the spray nozzle may vary from 1,000 to 4,000 pounds per square inch (psi), depending on engine combustion-chamber requirements.

Spray Nozzles. Because of the requirements in the shapes of the fuel spray for various combustion chamber designs and the wide range in engine power demands, there is a wide variety of nozzles used with multiple pump injection systems. The two basic groups are the pintle nozzles and the hole nozzles (Figure 6). Pintle nozzles are generally used in engines having precombustion turbulence or divided chambers, whereas the hole nozzles are generally used with open combustion chamber designs.

In pintle nozzles (Figure 7), the nozzle valve carries an extension at its lower end in the form of a pin (pintle) which protrudes through the hole in the nozzle bottom. This requires the injected fuel to pass through an annular orifice, producing a hollow, cone-shaped spray, the nominal included angle of which may be from 0 to 60 degrees, depending on the combustion system requirement. The projection of the pintle through the nozzle orifice induces a self-cleaning effect, discouraging the accumulation of carbon at this point. A specific type of pintle nozzle mostly used in small bore high speed diesel engines is the throttling nozzle. It differs from the standard pintle nozzle in that the pintle projects from the nozzle body for a much greater distance and the orifice in the bottom of the nozzle body is much longer. These differences are readily apparent from the cross-sectional views shown in Figure 7. The outstanding feature of the throttling nozzle is its control of the rate at which fuel is injected into the combustion chambers. The pintle extends through the nozzle orifice when no fuel is being injected. Hydraulic pressure from the injection pump causes the pintle to rise for fuel delivery.

FIGURE 6. PINTLE AND HOLE FUEL NOZZLES

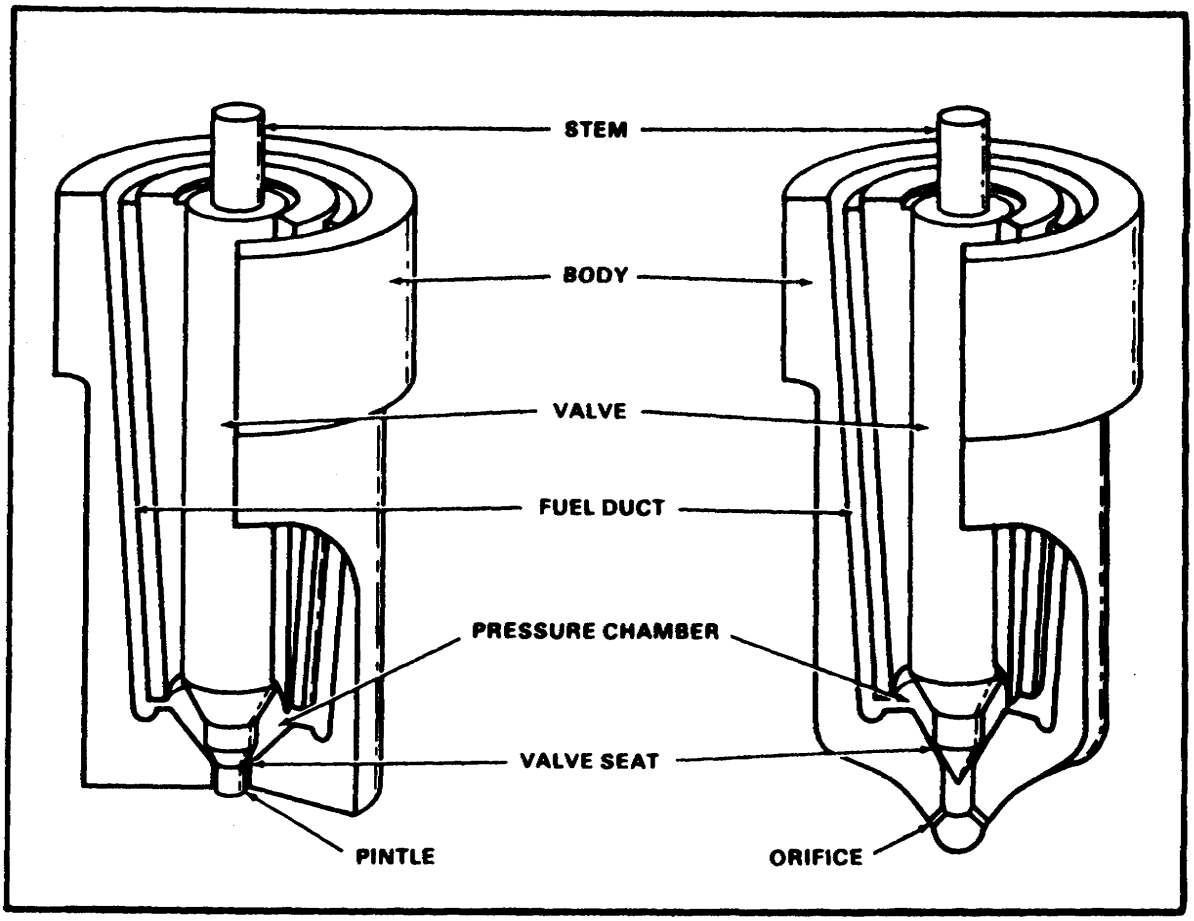
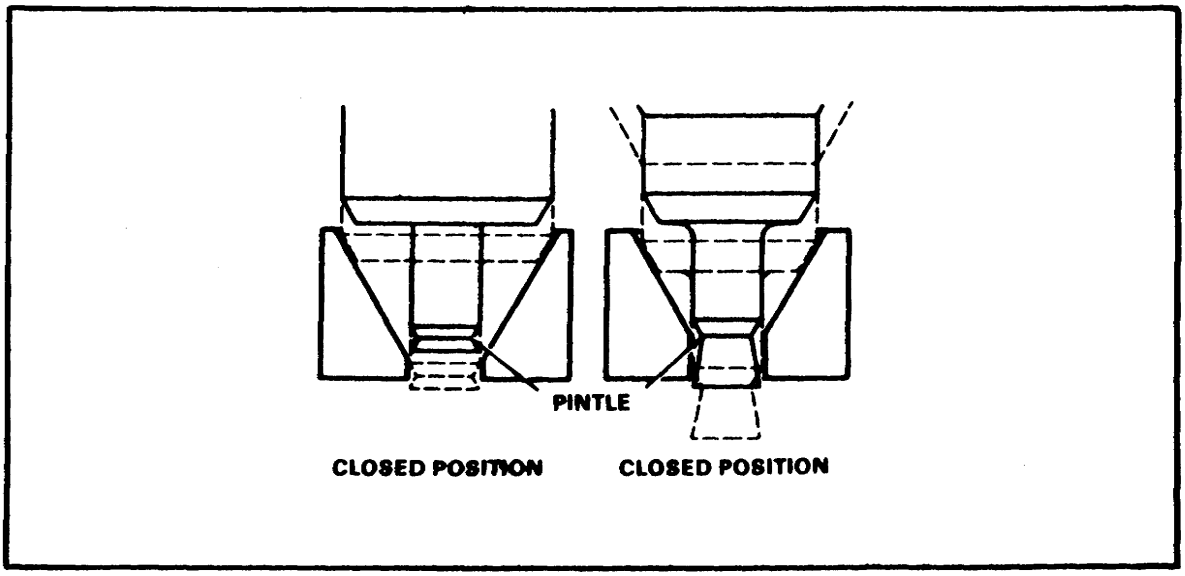


FIGURE 7. PINTLE (LEFT) AND THROTTLING PINTLE (RIGHT) NOZZLES



The hole nozzles have no pintles but are similar in construction to the pintle type. They have one or more spray orifices which are straight, round passages through the tip of the nozzle body beneath the valve seat (Figure 6). The spray from each orifice is relatively dense and compact and the general spray pattern is determined by the number and arrangement of the holes. As many as 18 spray holes are provided in the larger nozzles and the diameter of these drilled orifices may be as small as 0.006 inch. The spray pattern may or may not be symmetrical, depending on the engine combustion chamber design and fuel distribution requirements. The size of the hole determines the degree of atomization attained. The smaller the hole, the greater the atomization, but if the hole is too small, it will be impossible to get enough fuel into the chamber during the short time allowed for injection. If the hole is too large, there will be an over-rich mixture near the nozzle tip and a lean mixture at a distance from it. Multiple hole nozzles overcome this difficulty, because the holes can be drilled small enough to provide proper atomization and a sufficient number can be provided to allow the proper amount of fuel to enter during the injection period.

Nozzle Holders. The nozzle holder holds the spray nozzle in its correct position in the engine cylinder, provides a means of conducting fuel oil to the nozzle, and conducts heat away from the nozzle. The holder also contains the necessary spring and a means of pressure adjustment to provide proper action of the nozzle valve. The component parts of a typical nozzle holder are shown in Figure 5 on page 7. The body has drilled passages for conducting the fuel from the inlet connection to the nozzle. Its lower end is provided with an accurately ground and lapped surface which makes a leak proof and pressure tight seal with the corresponding lapped surface at the upper end of the nozzle. The nozzle is secured by means of the cap nut. At its upper end, the nozzle valve has an extension of reduced diameter (referred to as the stem) which makes contact with the lower end of the spring loaded spindle. Adjustment of the nozzle valve opening pressure is accomplished by means of the spring pressure adjusting screw. The adjustment in other types of holders is accomplished by means of spaces between the top of the spring and the upper spring seat.

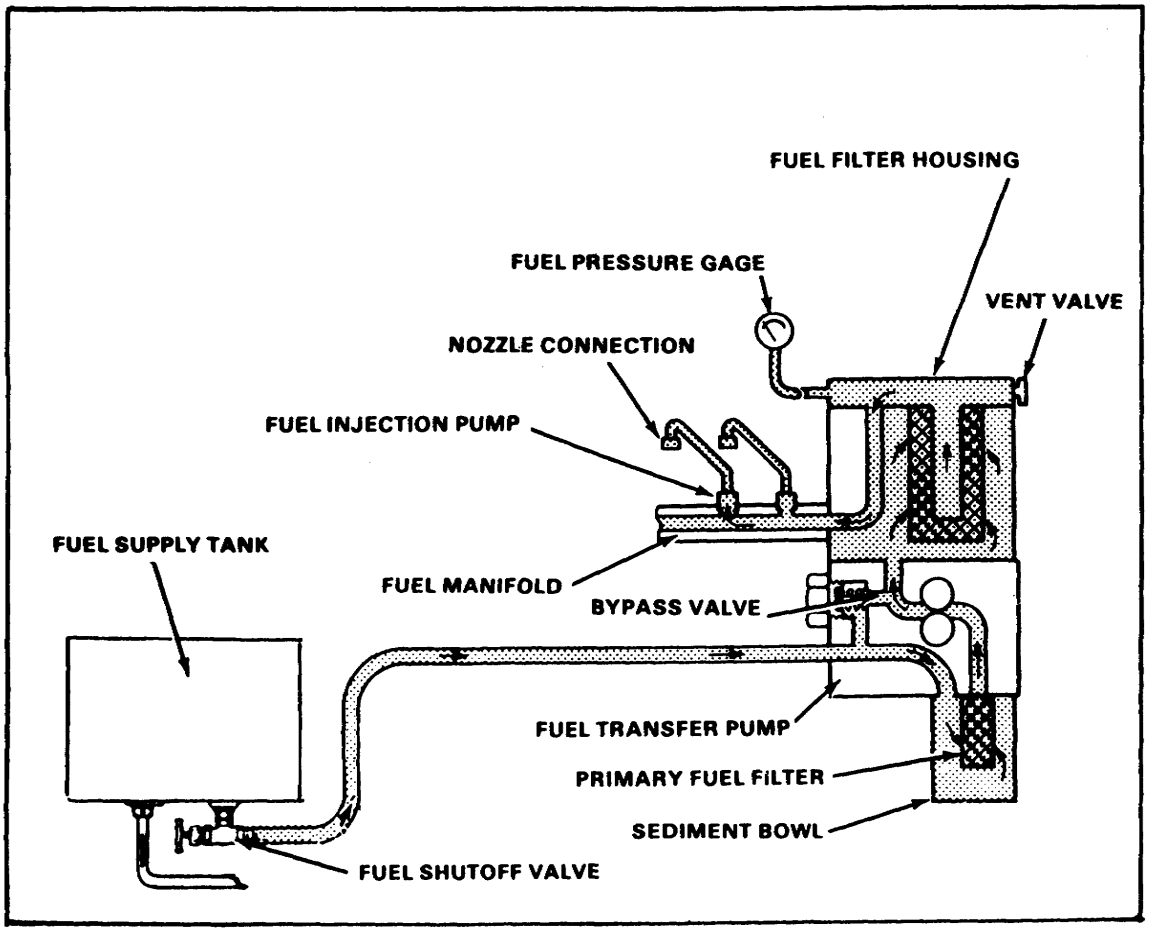
Learning Event 2
TROUBLESHOOTING THE MULTIPLE PUMP FUEL SYSTEM

The information covered in this learning event is applicable to any item of equipment that uses a diesel engine with a multiple pump fuel system. Component location may vary depending on the item of equipment used. Use the appropriate technical manual for the exact component location. The Caterpillar Model 12 road grader will be used throughout this learning event. The applicable manual is TM 5-3805-209-15.

We will begin this learning event by locating and identifying the components in the fuel system. In order to check the fuel system, you must first make sure that you can identify, locate, and state the function of each component in the fuel system.

The first component to locate is the fuel supply tank (Figure 8). The next item, the fuel shutoff valve, is located on the bottom of the fuel supply tank. The shutoff valve controls the flow of fuel from the tank to the rest of the fuel system.

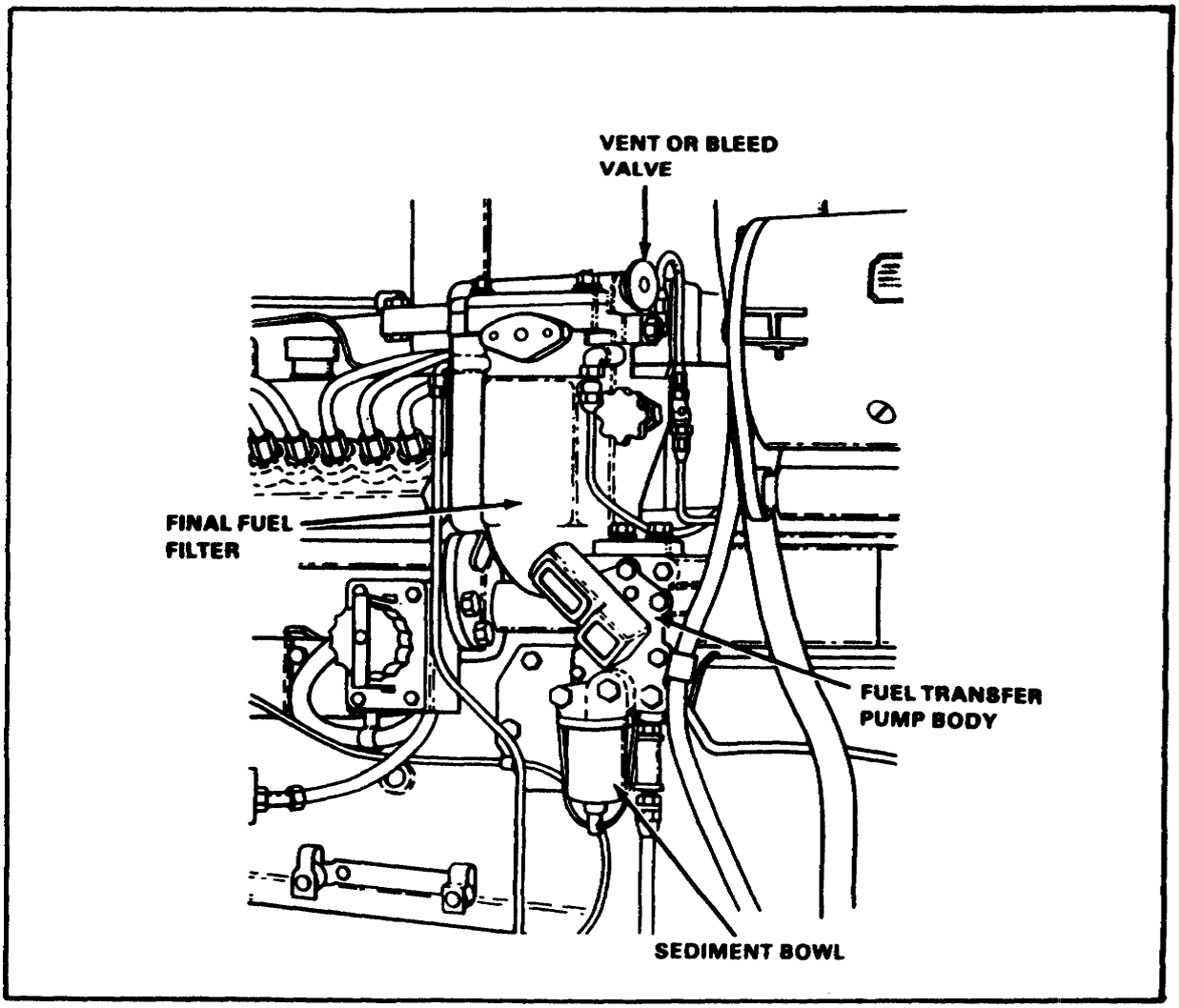
FIGURE 8. FUEL FLOW SCHEMATIC



Follow the fuel supply lines from the fuel supply tank to the primary fuel filter (Figure 8 on page 11). The primary fuel filter is mounted inside the sediment bowl (Figure 9) mounted on the fuel transfer pump housing Just below the final fuel filter. The primary fuel filter strains out foreign material from the fuel before it enters the fuel transfer pump.

From the primary fuel filter, the fuel flows to the fuel transfer pump (Figure 8). The transfer pump draws fuel from the supply tank through the primary filter and passes it to the secondary fuel filter.

FIGURE 9. FUEL SYSTEM COMPONENTS

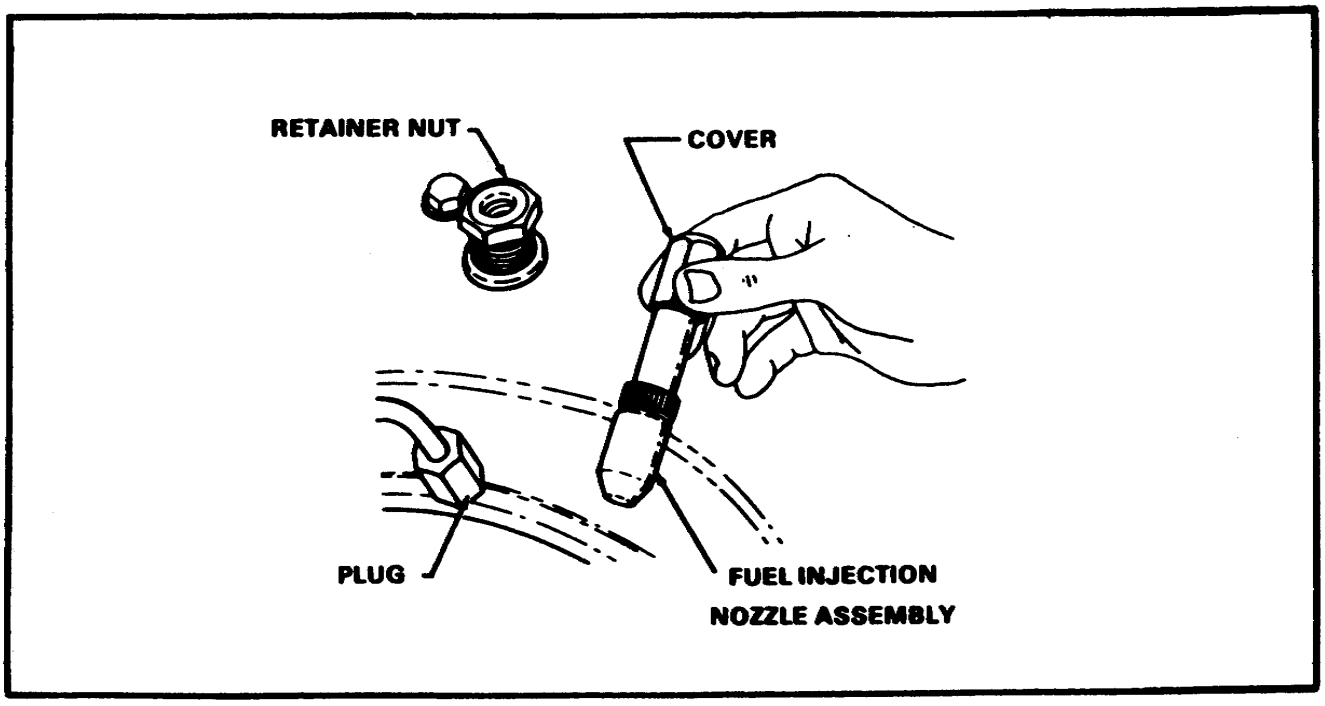


As the fuel flows to the secondary fuel filter, a bypass valve (Figure 8) is provided to control the fuel pressure. The fuel transfer pump supplies more fuel than is required for engine operation. The fuel bypass valve prevents excessive pressure within the system. The bypass valve is installed in the fuel transfer pump body. On this item of equipment you will not have a fuel return line to the fuel supply tank. The bypass line is built into the pump housing.

The next item to locate is the vent valve (or bleed valve) (Figure 9). This valve is used to vent or bleed air from the fuel system. From the vent valve, the fuel flows into the final fuel Filter (Figure 9). This filter cleans the fuel the second time before it flows into the fuel manifold. The fuel manifold (Figure 8) is located just to the rear of the fuel filter housing. It carries fuel to the individual injection pumps. From the fuel manifold, the fuel is picked up by the individual fuel injection pumps (Figure 8). Each fuel injection pump will have a high pressure fuel line connecting the injection pump assembly and the fuel injector.

The last item in the fuel system is the fuel injection valve (Figure 10). The fuel injection valve injects and atomizes the fuel into the combustion chamber.

FIGURE 10. FUEL INJECTION VALVE



Now that you are able to locate, identify, and state the function of each component, you are ready to move into the troubleshooting procedures. All troubleshooting will be done in accordance with the troubleshooting chart shown in Figure 11. Anytime you encounter a problem with the fuel system that cannot be pinpointed, start at the fuel supply tank and follow the system.

FIGURE 11. TROUBLESHOOTING CHART

DIESEL ENGINE WILL NOT START

Probable cause	Possible remedy
Lack of fuel in tank	Fill diesel engine fuel tank.
Fuel line shut off at tank	Open the valve under the diesel engine fuel tank.
Air lock in fuel system	Bleed the fuel system.
Clogged air cleaner	Service air cleaner.
Clogged or mashed fuel line	Clean, repair or replace main fuel line and bleed the fuel system.
Fuel transfer pump failure	Remove pump and clean the bypass valve. Replace the fuel transfer pump.
Faulty injection pump	Replace injection pump.

DIESEL ENGINE KNOCKS OR VIBRATES EXCESSIVELY

Probable cause	Possible remedy
Poor grade of fuel	Use an approved diesel fuel.
Clogged air cleaner	Service the air cleaner.
Excessive rocker arm clearance	Adjust the rocker arms and tappets.
Injection valve inoperative	Replace the injection valve.
Defective valve action	Recondition valves and seats.
Excessive coolant temperature	Replace coolant pump.
Loose, cracked, broken, or unbalanced flywheel	Tighten balance or replace flywheel.
Excessive flywheel runout	Check flywheel radial and face runout and correct as necessary.

DIESEL ENGINE LACKS POWER

Probable cause	Possible remedy
Poor grade of fuel	Use an approved diesel fuel.
Parking brake partially applied	Release parking brake.
Faulty injection pump	Replace the injection pump.
Improper adjustment or defective governor	Adjust, repair or replace the governor.
Defective valve action	Recondition valves and seats.
Low fuel pressure	Replace drive and idler gear.
Governor operation defective	Adjust fuel rack.

DIESEL ENGINE SMOKES EXCESSIVELY

Probable cause	Possible remedy
Clogged air cleaner	Service air cleaner.
Poor grade of fuel	Improve quality of fuel.
Altitude	None.
Faulty injection valves	Test and clean or replace the valves.
Defective valve action	Recondition valves and seats.

FIGURE 11. TROUBLESHOOTING CHART (CONTINUED)

DIESEL ENGINE MISFIRES OR OPERATES ERRATICALLY

Probable cause	Possible remedy
Air in fuel system	Bleed the fuel system.
Water in fuel	Drain and refill the fuel tank with clean fuel. Clean sediment bowl.
Clogged fuel filter, indicated by low fuel pressure gage reading	Replace the fuel filter element, flush the filter housing and bleed the fuel system.
Clogged vent in diesel fuel tank	Remove dirt from the hole in the filler cap.
Defective fuel transfer pump	Replace the fuel transfer pump.
Fuel transfer pump bypass valve clogged	Remove and clean the bypass valve.
Faulty injection valve	Inspect, test, or replace defective valve.
Defective inlet or exhaust valves	Adjust valves.
Defective valve action	Recondition valves and seats.
Low fuel pressure	Replace drive and idle gears.
Governor operation defective	Adjust fuel rack.

ENGINE STOPS UNEXPECTEDLY

Probable cause	Possible remedy
Water in fuel tank and lines	Drain and flush system and refill with an approved fuel.
Fuel tank empty	Fill fuel tank.

LOW OR NO COMPRESSION

Probable cause	Possible remedy
Cylinder head gasket blown	Replace gasket.
Warped or cracked cylinder head	Reface or replace head.
Defective compression release linkage	Adjust or replace.

LOSS OF FUEL

Probable cause	Possible remedy
Loose or cracked fuel transfer pump	Tighten, replace or repair pump.
Loose or cracked fuel filter housing	Tighten, replace or repair housing.
Loose or cracked fuel injection pump housing	Tighten, replace or repair housing.
Loose or cracked fuel injection pump	Tighten or replace pump.
Loose or cracked fuel injection lines	Tighten, replace, or repair lines.
Defective fuel tank	Repair or replace.

LOW OR NO FUEL PRESSURE

Probable cause	Possible remedy
Clogged fuel filter	Service fuel filter.
Open vent valve	Check the bleed valves, close the open valve.
Defective fuel transfer pump	Replace the fuel transfer pump.
Faulty bypass valve	Remove and clean the bypass valve.
Defective gage	Replace the gage.
Worn fuel transfer pump gears	Replace or repair pump.
Broken drive shaft or gear	Replace or repair pump.
Faulty gaskets	Replace gaskets.
Faulty seals	Replace worn or damaged seals.
Bypass valve stuck open	Replace valves.
Cracked fuel manifold in injection pump housing	Replace housing.
Cracked fuel filter housing	Replace housing.
Air in system	Bleed the fuel system.

Inspect the fuel supply tank first. Check the fuel level and drain some fuel to check for water in the fuel. Look for leaks. Ensure the tank is securely mounted.

The next item to inspect is the fuel shutoff valve. Inspect the valve for leaks or loose mountings.

Now inspect the fuel lines between the shutoff valve and the primary fuel filter. Inspect the lines for leaks, broken, crushed, or loose connections. Tighten or replace any faulty items.

The primary fuel filter is the next item to inspect. Inspect the condition of the fuel in the sediment bowl and the filter element. Clean the bowl, and replace the filter element as necessary. Inspect all parts for cracks, breaks, and other damage. Replace any defective parts.

The next item that may have caused the problem is a faulty fuel transfer pump. Inspect the pump housing for cracks, leaks, or other damage.

Don't forget the fuel bypass valve. A broken spring or a piece of dirt under the valve may cause low or no fuel pressure. Remove and replace faulty components.

Another problem with the fuel system is a low pressure indication while the engine is operating. Any leaks in the line between the transfer pump and the line between the transfer pump and the tank will result in air being drawn into the system. Check and repair any loose or crushed lines or a leaking fuel filter gasket.

The operator of the equipment may also report good fuel pressure at the start of the day but two hours later the equipment stopped from low fuel pressure. Check first for a loose fuel line. Then you should check the fuel filters.

A sudden drop in fuel pressure is another common problem. Again, you must look at the items between the tank and the pump. First check the fuel tank and be sure there is plenty of fuel. Next, inspect for a broken or loose fuel line between the tank and the transfer pump. Also a faulty bypass valve or a broken spring may be the problem. The last item to inspect is a defective fuel transfer pump. If the fuel transfer pump is faulty, refer to Learning Event 3 of this lesson.

Now, let's talk about the diesel engine that misfires under load and at low speed. First, be sure the engine is at the correct operating temperature. Inspect all the items shown on the troubleshooting chart (Figure 11 on page 14) under the heading "diesel engine misfires or operates erratically." If this does not solve the problem, check for correct engine speed.

Learning Event 3
COMPONENT ADJUSTMENT, REPAIR, OR REPLACEMENT

During this learning event, you will be shown how to adjust, repair, or replace components of the multiple pump fuel system. All work described will be in accordance with the maintenance allocation chart shown in Figure 12.

FIGURE 12. MAINTENANCE ALLOCATION CHART

Functional Group	Components and Related Operation	Echelons of Maintenance					Remarks
		1	2	3	4	5	
03	FUEL SYSTEM						
0301	FUEL INJECTOR						
	Injector, Fuel						
	Replace		X				
	Repair		X				
0302	FUEL PUMPS						
	Pump, Fuel Transfer						
	Replace		X				
	Repair			X			
	Pump, Diesel Injection						
	Service	X					
	Test		X				
	Replace			X			
	Repair				X		
	Plunger Assembly						
	Replace		X				
0304	AIR CLEANER						
	Cleaner, Air						
	Service	X					
	Replace		X				
0306	TANKS, LINES, FITTINGS						
	Tank						
	Service	X					
	Inspect	X					
	Lines						
	Replace		X				
	Repair		X				
	Cap; Fittings						
	Replace		X				
	Filter, Strainer						
	Service	X					
	Replace		X				
0308	ENGINE SPEED GOVERNOR						
	Governor						
	Replace			X			
	Repair					X	
	Linkage; Rod; Lever						
	Replace		X				

FIGURE 12. MAINTENANCE ALLOCATION CHART (CONTINUED)

Functional Group	Components and Related Operation	Echelons of Maintenance 1	2	3	4	5	Remarks
0309	FUEL FILTERS						
	Filter, Fuel						
	Service	X					
	Replace		X				
0310	ENGINE STARTING AIDS						
	Glow Plugs						
	Service		X				
	Replace		X				
	Pump, Priming						
	Replace		X				
	Wiring						
	Repair		X				
0312	ACCELERATOR						
	Pedal; Linkage						
	Replace		X				
04	EXHAUST SYSTEM						
0401	MUFFLER AND PIPES						
	Muffler; Pipes; Clamps; Cap						
	Replace		X				
05	COOLING SYSTEM						
0501	RADIATOR						
	Radiator						
	Service	X					
	Inspect	X					
	Core; Tanks						
	Replace			X			
	Cap						
	Replace	X					
	Grille						
	Replace		X				
0502	SHROUD						
	Covers; Shroud						
	Replace		X				

FUEL INJECTION VALVES

Testing Valves. Whenever an engine performs in such a manner that a fuel injection valve is suspected of causing trouble, test all the fuel injection valves. To test the injection valves, loosen the fuel injection line nuts at the fuel injection pumps one at a time while the engine is running. When a nut is loosened and the exhaust smoking is completely or partially eliminated and the irregularity in running is not affected, this identifies the defective valve and a new one should be installed in that cylinder.

Removal.

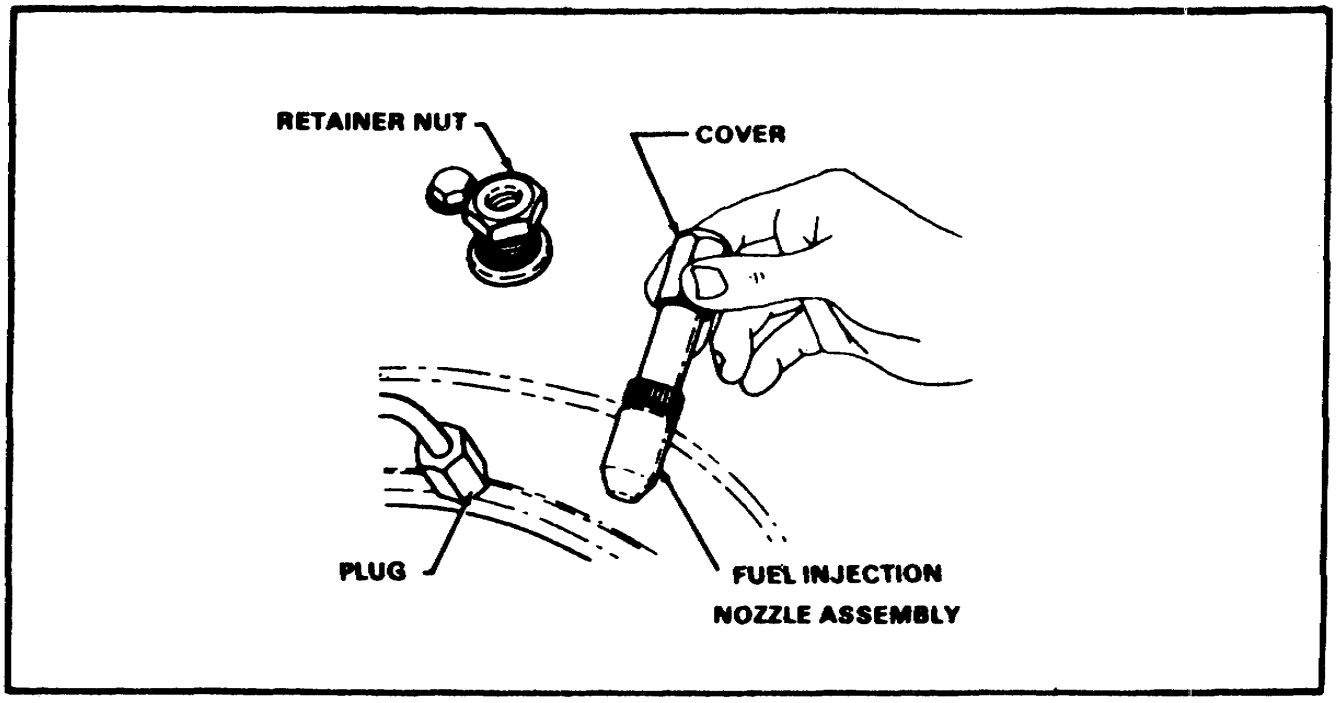
1. Before removing a valve, clean the dirt from around the valve and connections.

2. Remove the glow plugs so they will not be damaged.

3. Loosen the fuel injection line at the pump and disconnect it from the fuel injection valve. Install a plug in the end of the line and a cover on the fuel injection valve (Figure 13).

4. Remove the valve retainer nut and lift out the fuel injection nozzle assembly and body as a unit (Figure 13).

FIGURE 13. FUEL INJECTION VALVE REMOVAL



Cleaning and Inspection.

1. Clean all parts with an approved cleaning solvent and dry thoroughly.

2. Inspect all parts for damage and replace any defective parts.

3. If the orifice in the nozzle becomes partially filled with carbon, remove the nozzle assembly from the body and clean the fuel discharge hole, using the drill and chuck supplied in the 5B1401 Cleaning Tool Group. If the valve does not operate properly after cleaning, the nozzle should be checked for leakage.

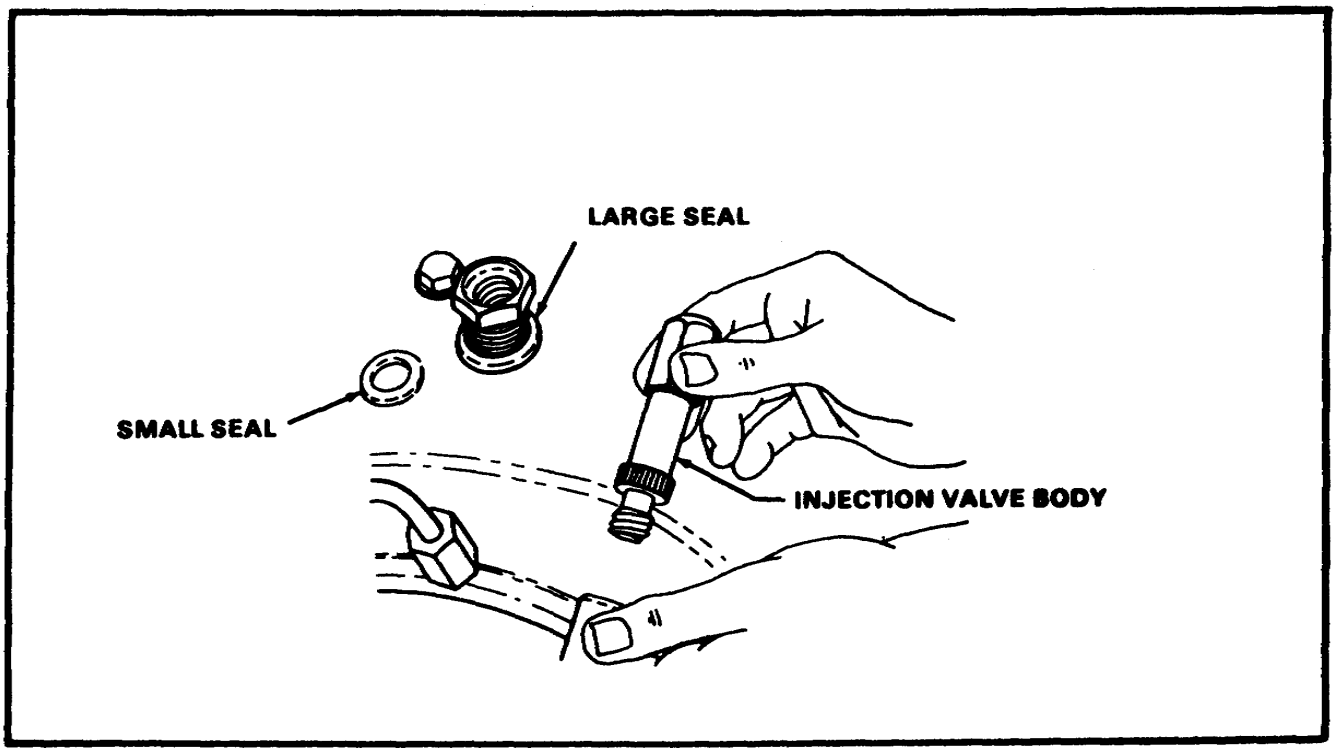
Installation. Refer to Figures 13 and 14.

1. Screw the injection valve body into the fuel injection nozzle assembly only finger tight.

2. Insert the nozzle assembly and valve body as a unit into the precombustion chamber opening. Turning the body in a clockwise direction, and at the same time pressing down will assure alignment of the serrations.

3. Install a new large seal on the retainer nut. A light coating of lubricant on the seal will permit it to seal properly.

FIGURE 14. FUEL INJECTION VALVE INSTALLATION



4. Tighten the retainer nut tight to prevent leaks between the nozzle assembly and the nozzle assembly seats. A torque of 100 to 110 foot-pounds is adequate to tighten the retainer nuts.

5. Remove the cover from the injection valve body and place a new small seal over the threads on the top of the valve body and on the retainer nut.

6. Remove the plug from the end of the injection line and connect it to the fuel injection valve and tighten. Remember to tighten the line connection at the pump.

PRIMARY FUEL FILTER

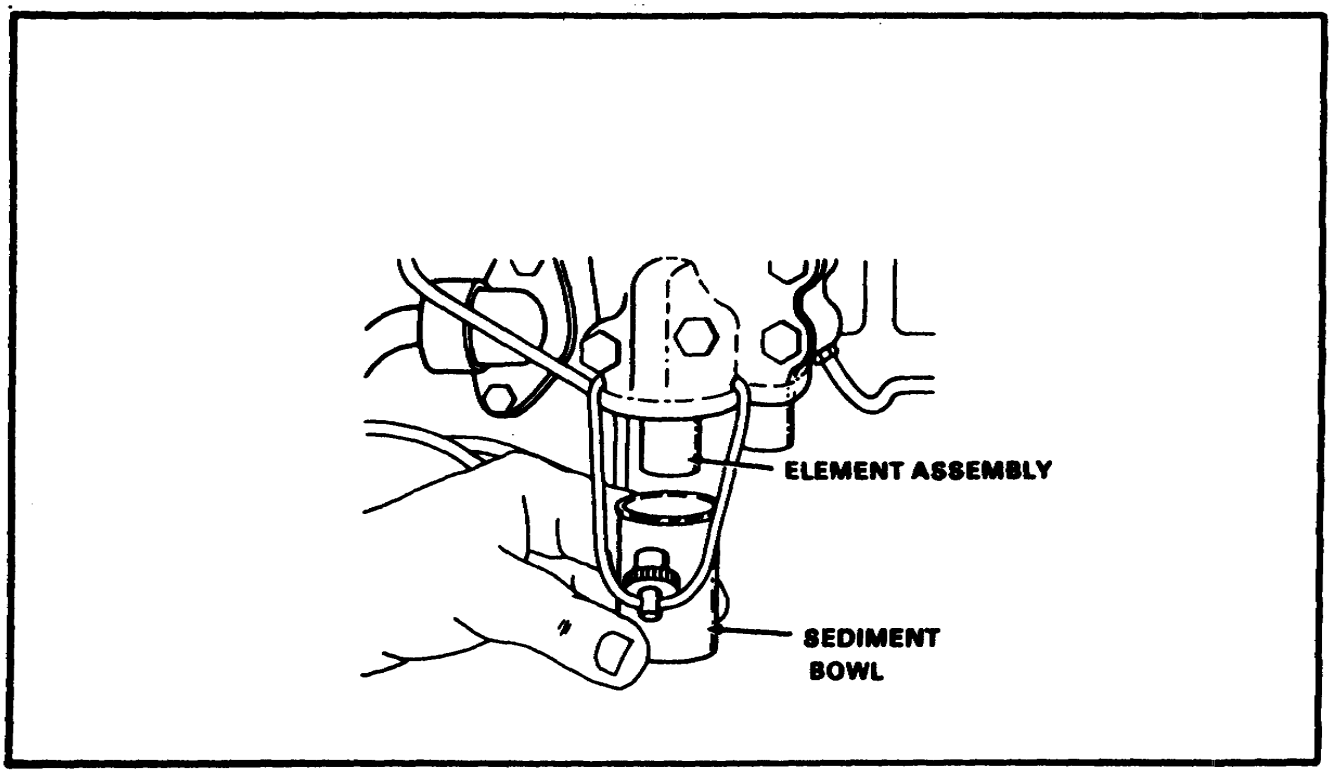
Removal.

1. Shut off the fuel valve on the fuel supply tank.

2. Remove the nut on the bail and remove the sediment bowl. The primary fuel filter is mounted inside the sediment bowl (Figure 9 on page 12).

3. Remove the element assembly (Figure 15) from the cover on the fuel transfer pump.

FIGURE 15. PRIMARY FUEL FILTER



Cleaning and Inspection.

1. Clean all parts with an approved cleaning solvent and dry thoroughly.
2. Inspect all parts for cracks, breaks, and other damage.
3. Replace the defective parts.
4. Inspect the gasket between the sediment bowl and the fuel transfer pump.
5. Replace the gasket if it is damaged.

Installation.

1. Install the element assembly by screwing it into the cover on the fuel transfer pump.
2. Place the sediment bowl in position and center the bail under the sediment bowl.
3. Screw the nut on the bail to fasten the sediment bowl in position (Figure 15).

FINAL FUEL FILTER

Removal. Refer to Figure 16.

1. Close the fuel shutoff valve on the bottom of the fuel supply tank.
2. Drain the fuel filter housing by removing the drain plug.
3. . Disconnect the fuel pressure gage line.
4. Disconnect the drain line.
5. Remove fuel filter housing retaining bolts.
6. Remove the fuel filter housing by sliding it toward the front of the engine to clear the adapter.

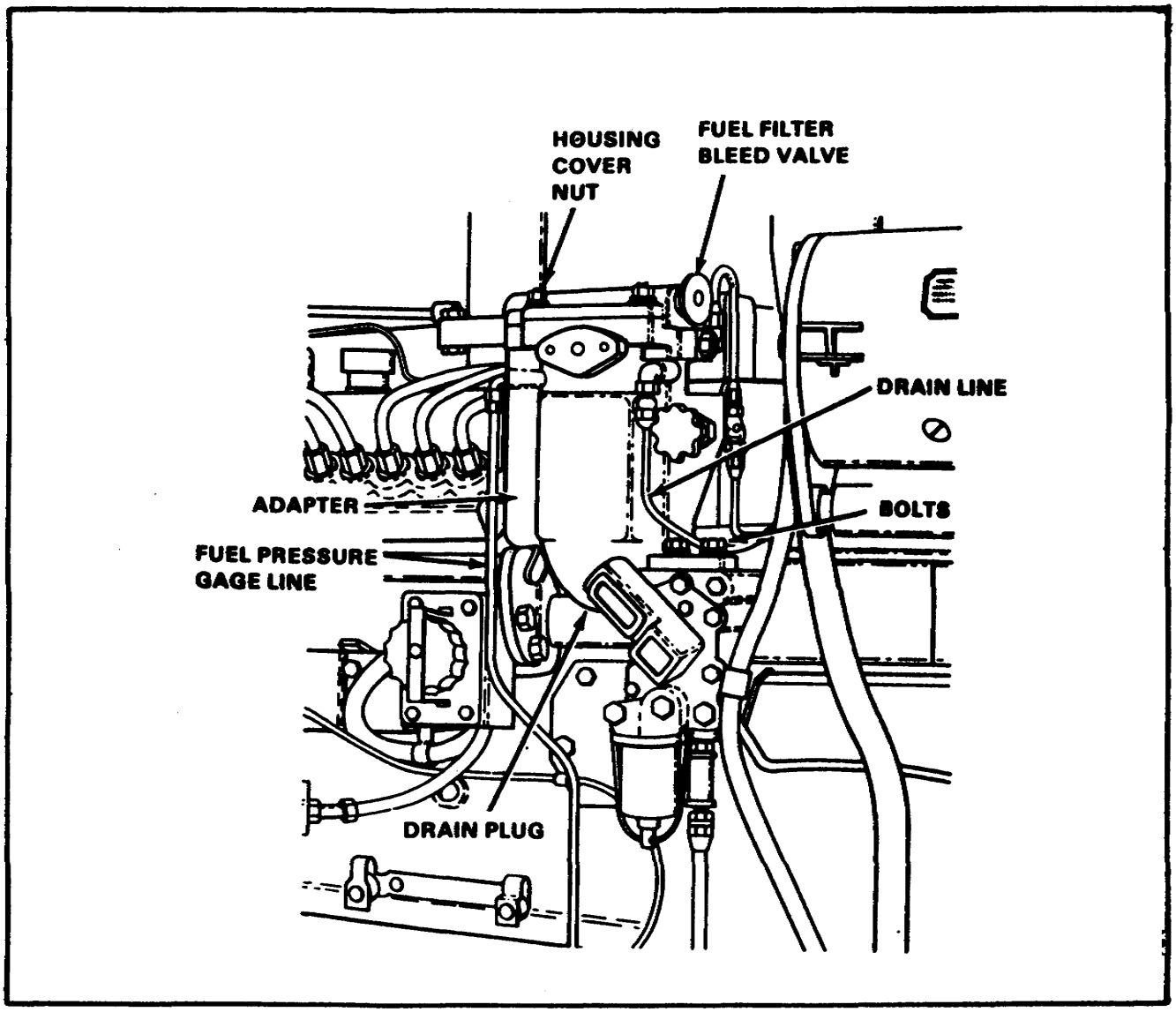
Installation. Refer to Figure 16.

1. Place the fuel filter housing in position and install the retaining bolts.
2. Connect the drain line.
3. Connect the fuel pressure gage line.
4. Install the drain plug.
5. Open the fuel shutoff valve.
6. Prime the fuel system.

Removing Used Filter Element. Refer to Figure 16.

1. Close the fuel shutoff valve.
2. Remove the filter housing drain plug.
3. Open the fuel filter bleed valve.
4. Thoroughly clean the top of the cover and around the edges of the gasket joint and cover to prevent dirt from dropping into the filter housing when the cover is removed.
5. Remove the housing cover nuts.
6. Remove the housing cover.

FIGURE 16. FINAL FUEL FILTER REMOVAL



7. Lift the filter element, rod, and spring from the housing (Figure 17).

Cleaning and Inspection.

1. Clean all parts with an approved cleaning solvent and dry thoroughly.

2. Clean the inside of the housing and dry thoroughly.

3. Inspect all parts for cracks, breaks, and other damage. Replace any defective parts.

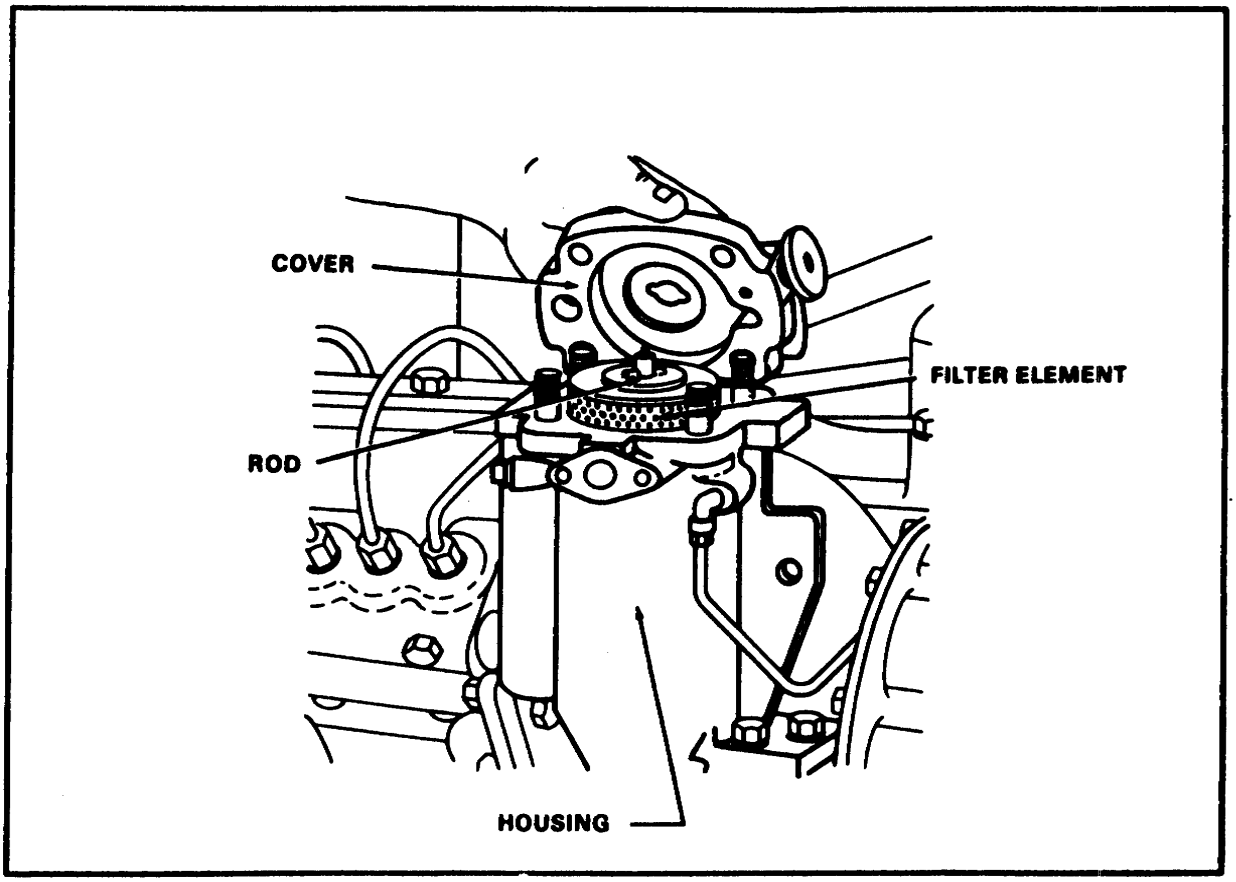
Installing New Filter Element. Refer to Figure 17.

1. Replace the spring and the rod in the housing. Make certain that the rod enters the drilled hole in the bottom of the housing and that the spring is piloted on the bosses of the housing and rod.

2. Place a new filter element over the rod.

3. Place a new gasket on the filter housing.

FIGURE 17. FUEL FILTER ELEMENT REMOVAL AND INSTALLATION



4. Replace the cover.

5. Fasten the nuts.

FUEL TRANSFER PUMP

Removal. Refer to Figure 18.

1. Close the fuel shutoff valve.

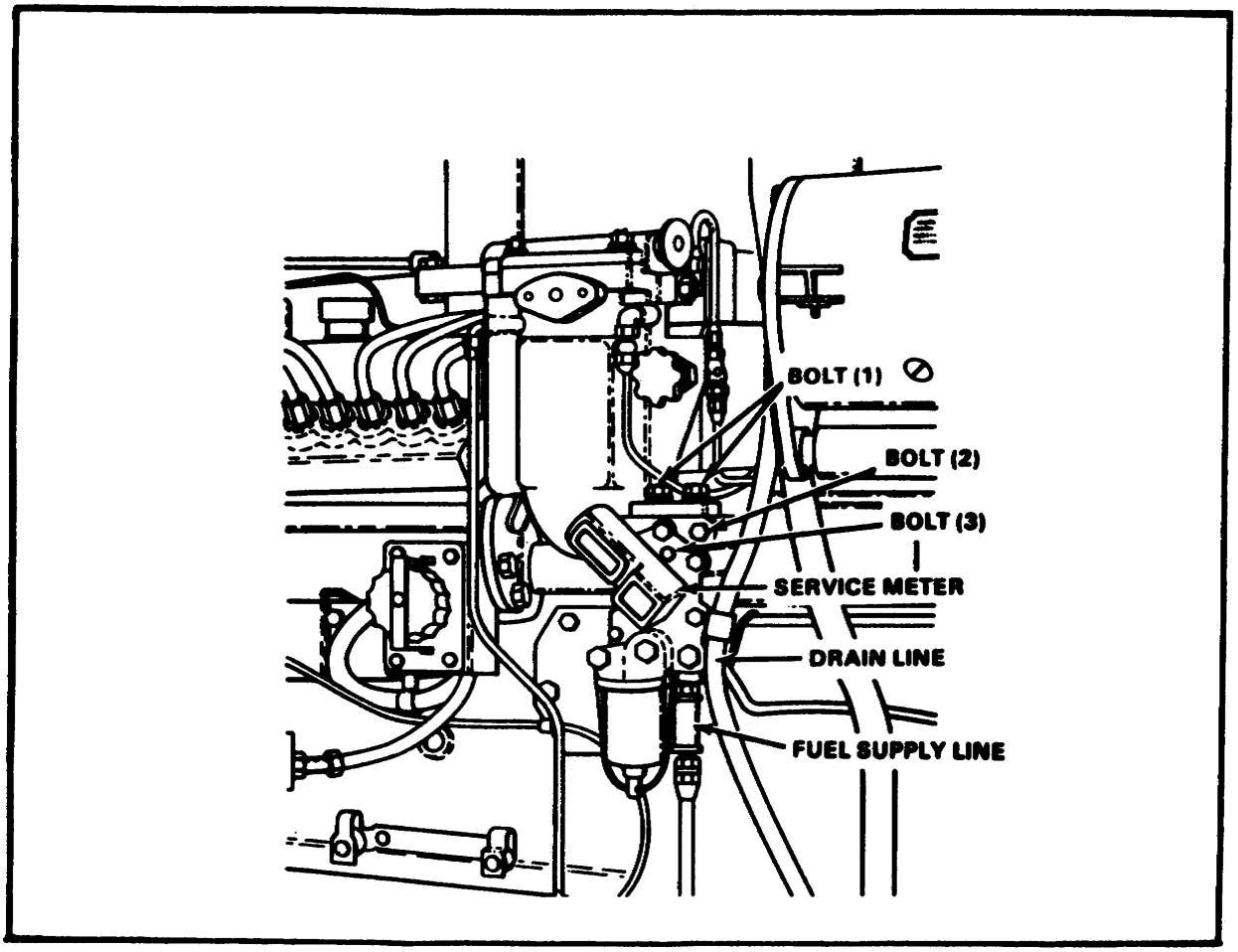
2. Remove the two bolts (3) and the service meter.

3. Disconnect the drain line and fuel supply line.

4. Remove the two bolts (1) and then remove the seven bolts (2).

5. Pull the fuel transfer pump outward from the accessory drive housing.

FIGURE 18. FUEL TRANSFER PUMP REMOVAL AND INSTALLATION



Cleaning and Inspection.

1. Clean the pump and hardware in an approved cleaning solvent and dry thoroughly.

2. Inspect the mating surfaces of the pump and filter housings for nicks, burrs, and scratches. Replace a defective pump.

3. Inspect the pump housing for cracks, leaks, or other damages. Replace a defective pump.

4. Inspect the gasket and replace if it is damaged.

5. Inspect all hardware for damaged threads. Replace all damaged hardware.

Installation. Refer to Figure 18.

1. Place the fuel transfer pump in position and install the bolts (1) and (2).

2. Connect the drain line and fuel supply line.

3. Place the service meter in position and install the bolts (3).

4. Open the fuel shutoff valve.

BYPASS VALVE

Removal and Installation. Refer to Figure 19 to remove and install the plunger and the bolts on the bypass valve.

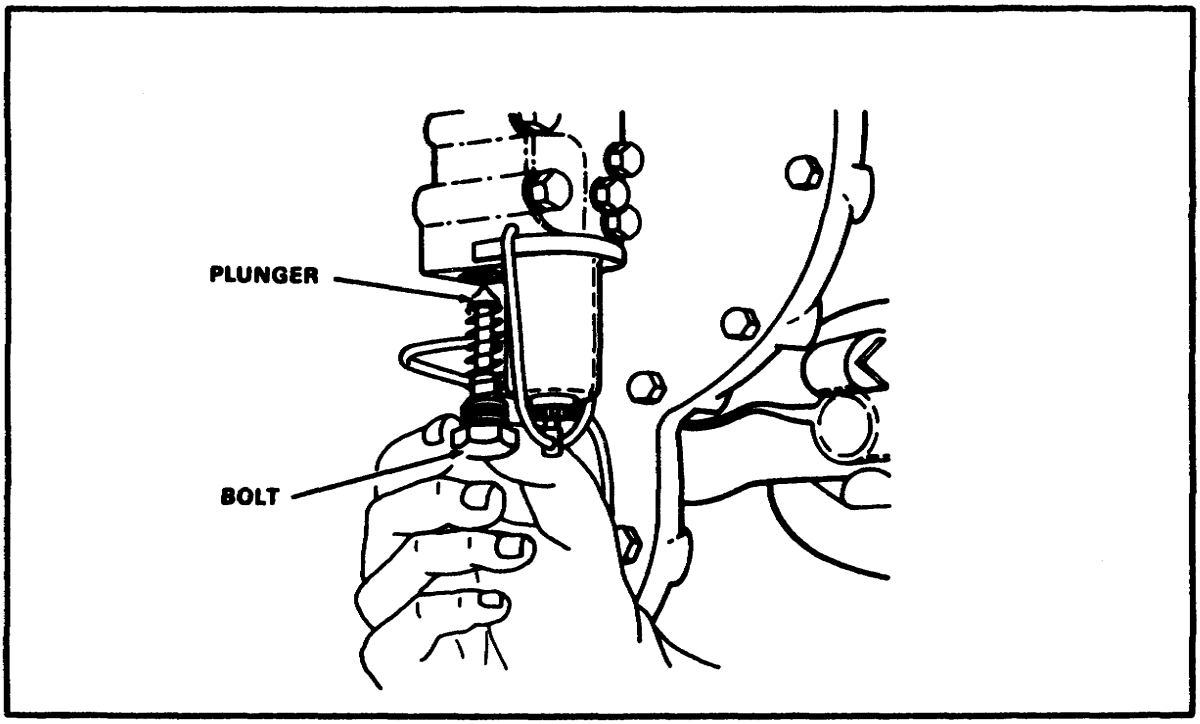
Cleaning and Inspection.

1. Clean all parts in an approved cleaning solvent and dry thoroughly;

2. Inspect all parts for damage and replace any defective parts.

3. Ensure that the seat is smooth and flat, and that the sealing surface of the plunger is in good condition. Replace any defective parts.

FIGURE 19. BYPASS VALVE



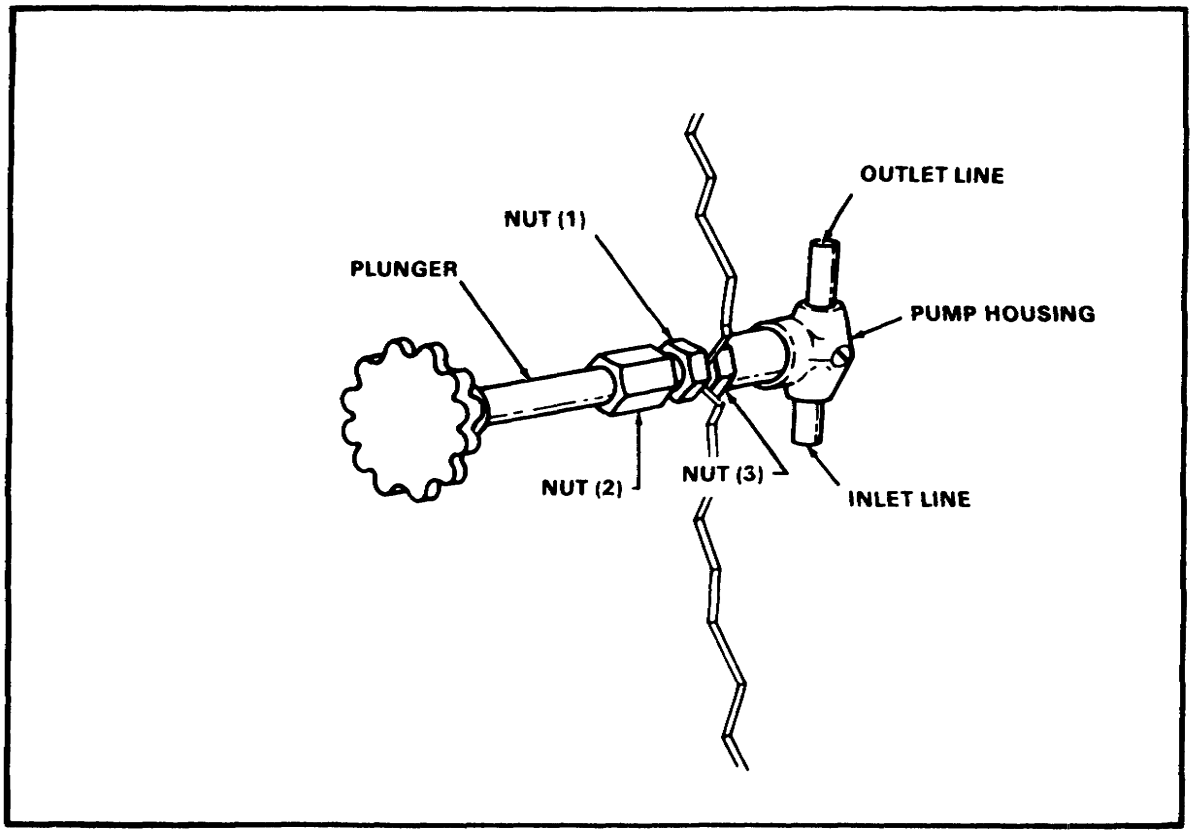
FUEL PRIMING PUMP

Removal and Installation. Refer to Figure 20 to remove and install the plunger, nut (1), outlet line pump housing, nut (2), nut (3), and inlet line on the fuel priming pump.

Disassembly.

1. Disassemble the fuel priming pump as shown in Figure 20.

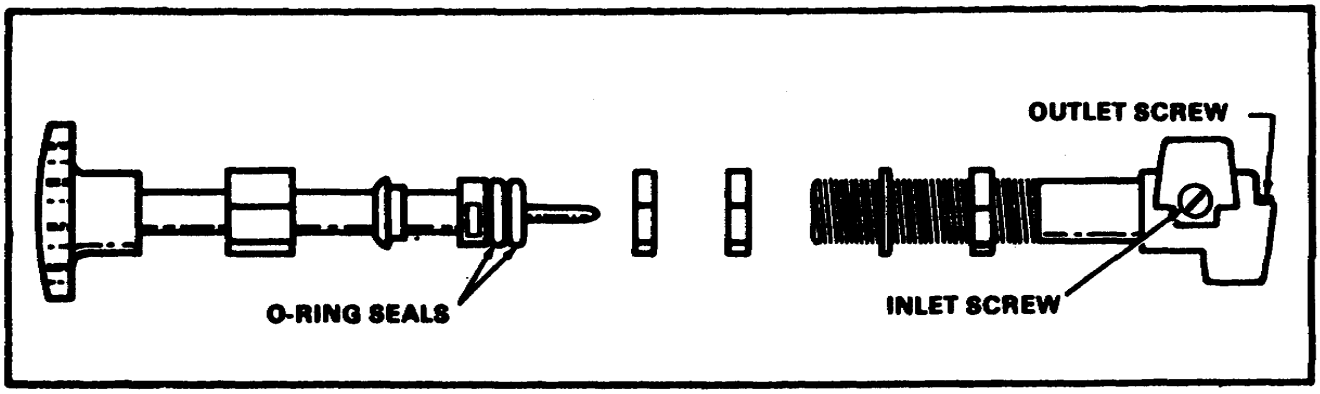
FIGURE 20. FUEL PRIMING PUMP REMOVAL AND INSTALLATION



2. The outlet check valve may be removed by removing the outlet screw (Figure 21).

3. The inlet check valve may be removed by removing the inlet screw (Figure 21).

FIGURE 21. FUEL PRIMING PUMP



Cleaning and Inspection.

1. Clean all parts with an approved cleaning solvent and dry thoroughly.
2. Inspect all parts for damage and replace any defective parts.
3. Inspect the 0-rings and check valves and replace if necessary.

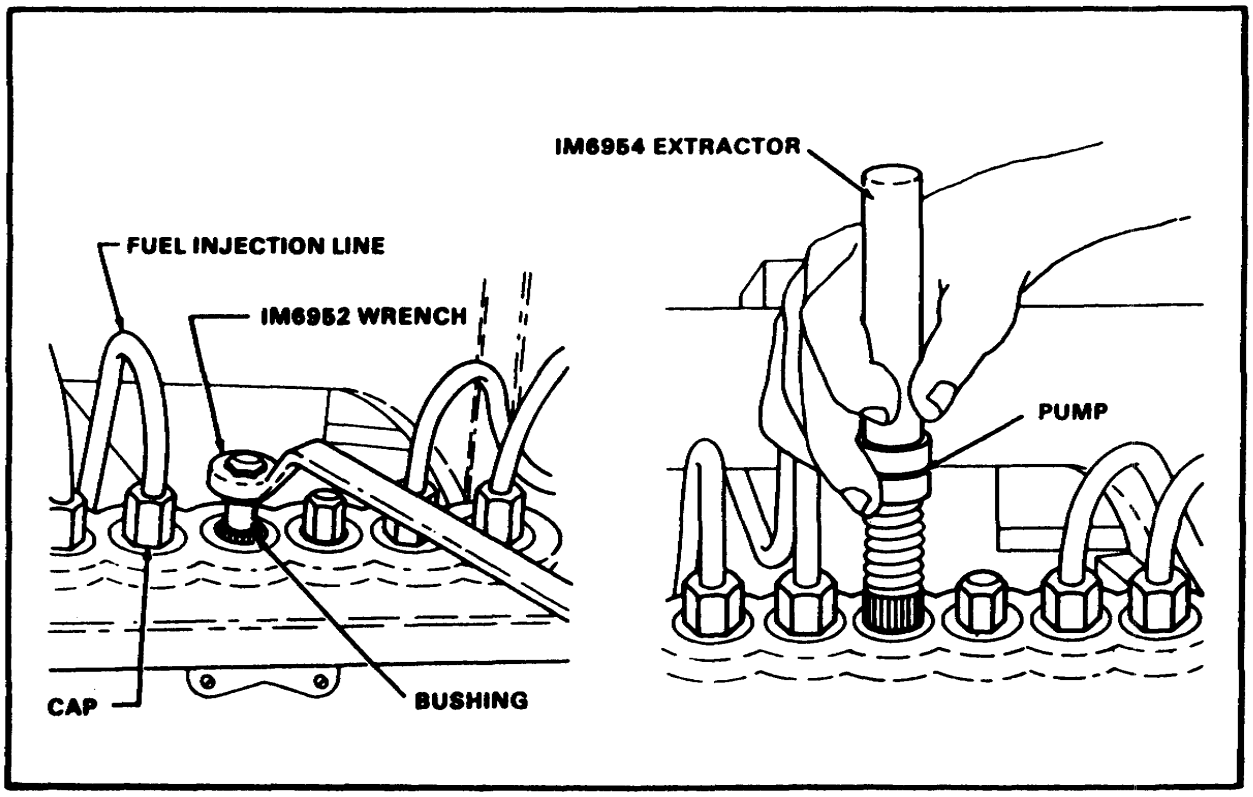
Reassembly. Refer to Figure 20 to reassemble the fuel priming pump.

FUEL INJECTION PUMP PLUNGERS

Removal. Refer to Figure 22.

1. Remove the fuel injection line from the fuel injection pump.
2. Remove the cap and felt washer under the cap.
3. Use a 1M6952 wrench to remove the fuel injection pump retaining bushing from the fuel injection pump housing.
4. Use a 1M6954 extractor to remove the fuel injection pump from the housing.

FIGURE 22. FUEL INJECTION PUMP REMOVAL AND INSTALLATION



Disassembly and Assembly. Refer to Figure 23.

1. Remove the seal.

CAUTION
All disassembly and assembly should be done with clean hands and a clean lint-free cloth.

2. Remove the retaining ring and separate the bonnet and barrel assembly.

NOTE: Considerable care should be taken not to drop and lose the check valve and spring retained in the bonnet,

3. Separate the spring, washer, and plunger from the barrel.

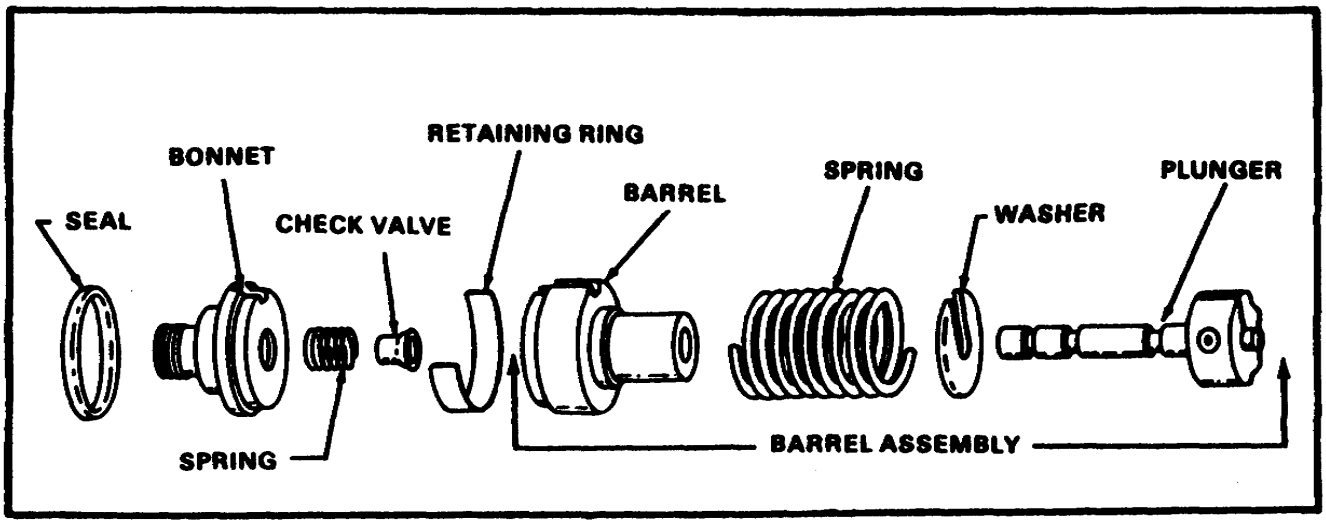
4. Remove the washer and spring from the plunger.

CAUTION
Considerable care should be taken when removing the spring and washer to prevent damage to the plunger surfaces.

5. Clean all parts with clean diesel fuel and assemble, replacing any worn or damaged parts.

CAUTION
The barrel and the plunger assembly are matched and the individual parts are not interchangeable with other barrels or plunger assemblies. Use extreme care in inserting the plunger into the bore of the barrel.

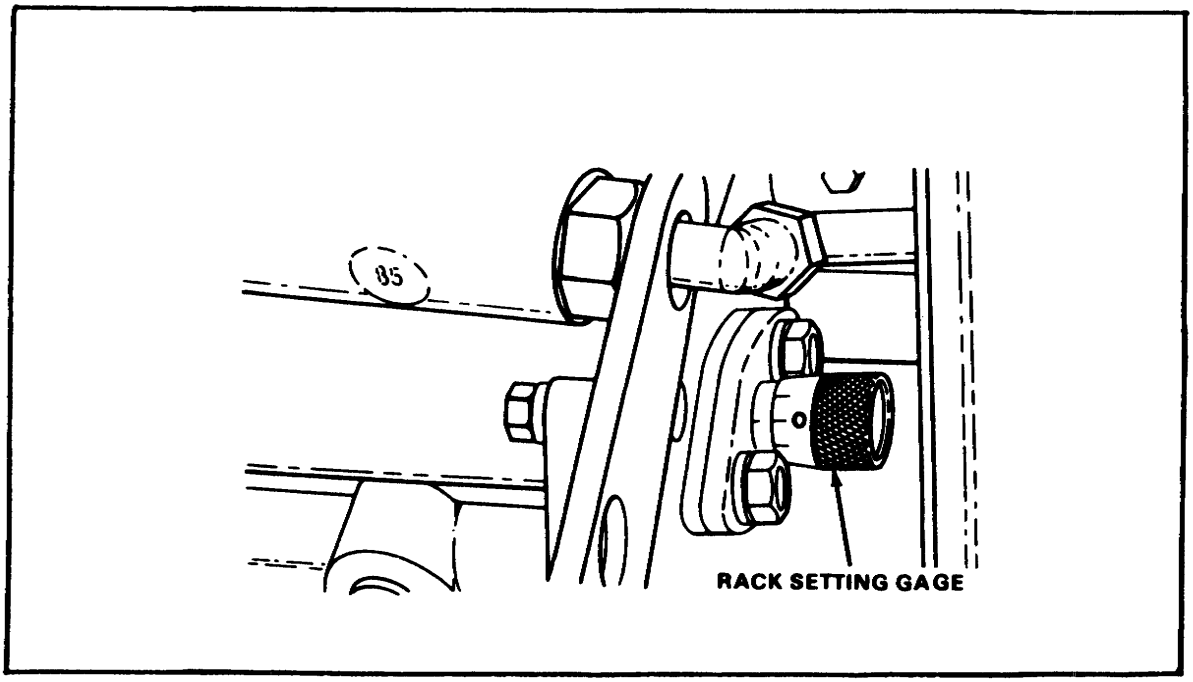
FIGURE 23. FUEL INJECTION PUMP DISASSEMBLED



Installation.

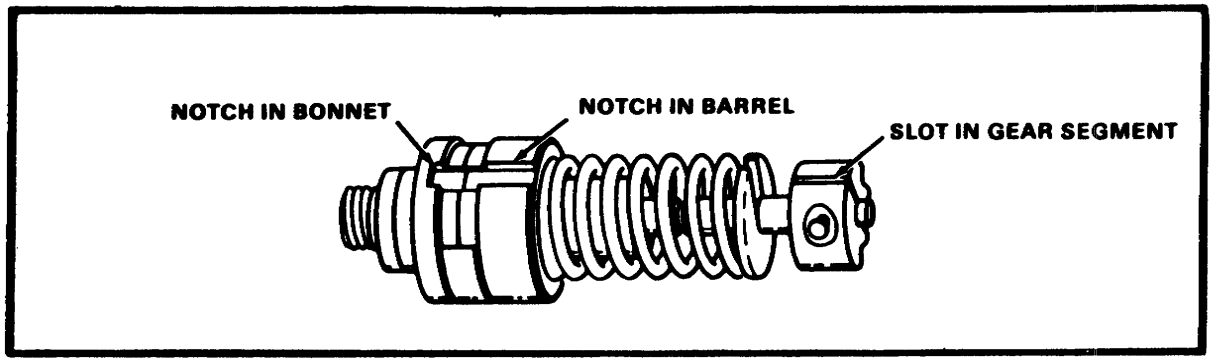
1. Remove the cover on the end of the accessory drive housing and position the fuel rack by using the 8M530 rack setting gage (Figure 24). When the rack is properly positioned, the reading on the gage should be .000.

FIGURE 24. POSITIONING RACK



2. Align the notches on the bonnet and on the barrel with the slot in the gear segment (Figure 25).

FIGURE 25. ALIGNING THE INJECTION PUMP



3. Insert the assembly into the bore of the housing with the extractor. The notches in the bonnet and the barrel must engage with the two locating dowels in the bore of the pump housing. These dowels align the pump barrel fuel inlet port with the fuel manifold outlet port.

4. After each new plunger and barrel assembly is installed, place a new rubber seal over the bonnet and start the retainer bushing into the housing. Push the plunger and barrel assembly into the housing until the dowel is engaged with the bonnet and screw the retainer bushing finger tight.

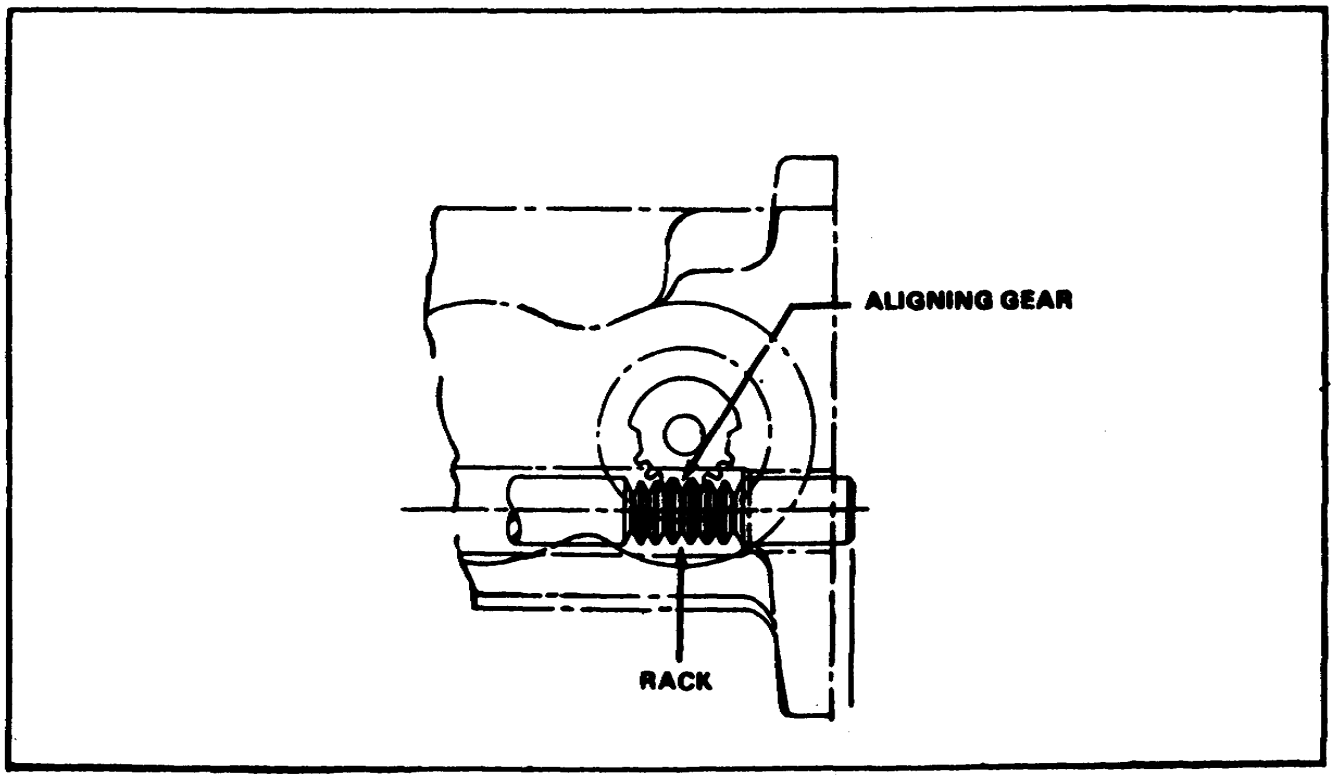
5. Tighten the bushing to the torque specified.

NOTE: Prior to installation of the plunger and barrel assembly, make certain the lifter for the assembly to be installed is at the bottom of its stroke.

CAUTION
With a torque less than that listed in the specifications, the pump will leak. If the torque value is greater, the housing can be damaged.

The procedure thus far has aligned the center notch on the rack for each pump with the center tooth of the gear segment on the injection pump plunger (Figure 26).

FIGURE 26. ALIGNING THE GEAR AND RACK



6. The rack travel must be measured to make certain that the plunger gear segment is properly meshed with the fuel rack. The gear segment and rack are so constructed that the maximum travel of the rack in either direction can be obtained only when the fourth tooth of the gear segment is meshed with the fourth notch on the rack. If the gear segment is misplaced in either direction, the rack travel will be reduced in both directions. It is, therefore, necessary to measure the rack travel in only one direction to make certain that the gear segment is properly meshed with the fuel rack. The rack is moved to its extreme fuel-on position. A micrometer reading of .688 inch or less indicates that the gear segment is properly positioned with the rack. The rack collar must be removed in order to obtain this much rack travel.

7. If this measurement is not obtained, the gears are improperly positioned and the procedure must be repeated.

8. Install the felt washer and connect the fuel injection line.

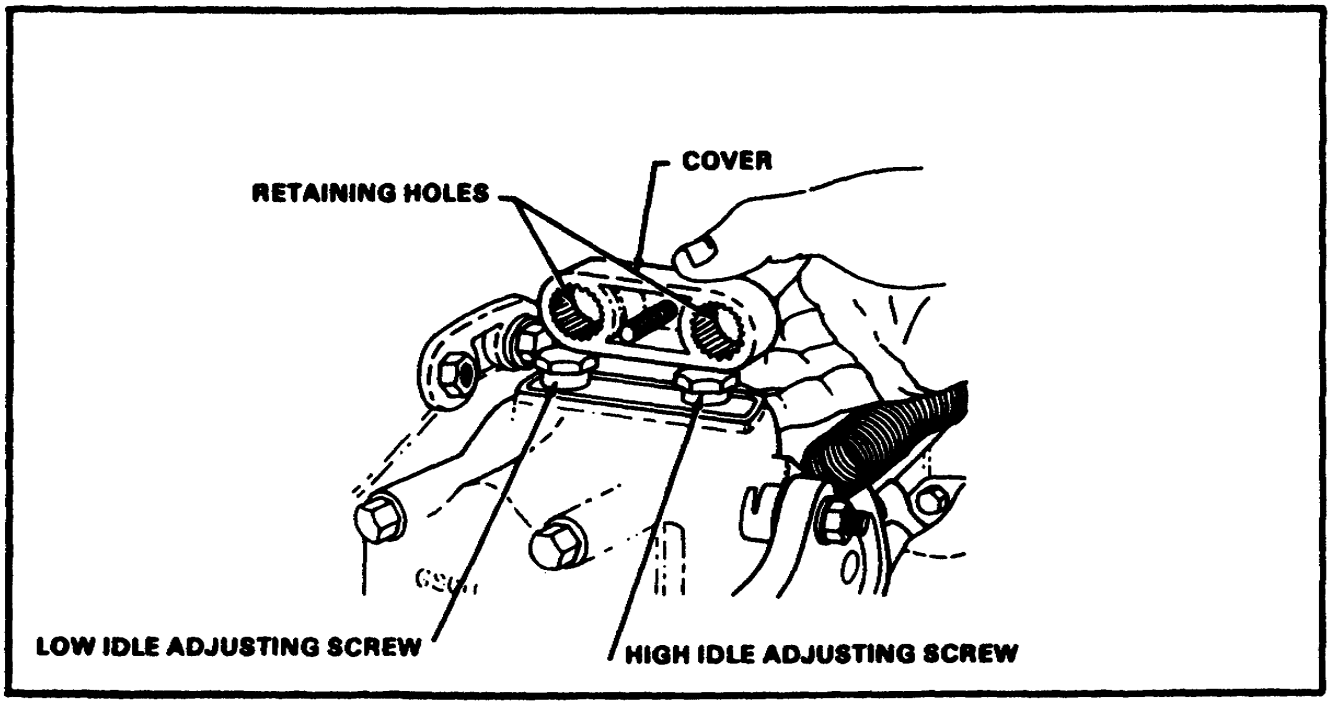
GOVERNOR ADJUSTMENTS

High and Low Idle Speeds.

1. The low and high idle speeds can be adjusted by removing the cover on top of the governor housing and adjusting the low idle adjusting screw or high idle adjusting screw. Turning either screw in a clockwise direction will decrease idle speed. The holes in the cover are shaped to act as retainers to prevent the screws from turning after the adjustment has been made (Figure 27).

2. After setting the idling speed, move the governor control lever to change the engine speed. Return it to the desired idle position and recheck the idle speed. Repeat this procedure until the desired idle speed is obtained.

FIGURE 27. GOVERNOR ADJUSTMENT



LESSON 1

REVIEW EXERCISE

Check your understanding of Lesson 1 by completing this review exercise. Try to complete it without looking back at the lesson. When you have completed the exercise, turn to the solutions at the end of the lesson and check your responses. If you do not understand a solution, go back and restudy the section in the lesson where the information is given.

Match the components in Column A with their function in Column B.

Column A	Column B
____1. Fuel transfer pump.	A. Stores fuel.
____2. Fuel manifold.	B. Pressurizes, meters, and times fuel.
____3. Fuel supply line.	C. Bleeds air from fuel system.
____4. Injector nozzles.	D. Prevents excessive pressure in system.
____5. High pressure fuel line.	E. Cleans fuel for second time.
____6. Tank.	F. Shuts off fuel supply.
____7. Bypass valve.	G. Lets fuel pass from tank to system.
____8. Vent valve.	H. Sends fuel under high pressure to injectors.
____9. Primary fuel filter.	I. Injects and atomizes fuel.
____10. Fuel shutoff valve.	J. Cleans fuel before it enters the transfer pump.
____11. Injection pump.	K. Pumps fuel from tank to system.
____12. Final fuel filter.	L. Distributes fuel to injection pumps.

13. There are _____ types of diesel fuel lines.

    A. Two

    B. Three

    C. Four

    D. Five

14. In a multiple pump fuel system each cylinder has a/an _____ injector pump.

    A. Rotary

    B. Centrifugal

    C. Individual

    D. Composite

15. On the four-stroke-cycle engine the injection pump is driven at _____ engine speed.

    A. One-fourth

    B. One-half

    C. Three-fourths

    D. Two times

16. A _____ type spray nozzle is generally used in engines having a precombustion chamber.

    A. Throttling pintle

    B. Pintle

    C. Hole

    D. Orifice

17. All parts should be cleaned using _____.

    A. Kerosene

    B. Gasoline

    C. Diesel fuel

    D. Cleaning solvent

18. When the fuel rack is properly positioned the 8M530 rack setting gage should read _____.

    A. .000

    B. .100

    C. .200

    D. .500

19. The low and high idle speed adjusting screws are located on top of the _____.

    A. Fuel transfer pump

    B. Engine starter

    C. Governor housing

    D. Fuel rack

LESSON 1

REVIEW EXERCISE SOLUTIONS

1. K (Introduction)
2. L (page 13)
3. G (page 12)
4. I (Introduction)
5. H (page 7)
6. A (Introduction)
7. D (page 13)
8. C (page 13)
9. J (page 12)
10. F (page 11)
11. B (page 2)
12. E (page 13)
13. B (Introduction)
14. C (page 2)
15. B (page 4)
16. B (page 8)
17. D (page 26)
18. A (page 34)
19. C (page 36)

Lesson 2

UNIT INJECTOR FUEL SYSTEMS

TASK

Describe the correct procedures for the adjustment, repair, or replacement of components of unit injector fuel systems.

CONDITIONS

You will be given information describing the correct procedures for the adjustment, repair, or replacement of unit injector fuel system components.

STANDARDS

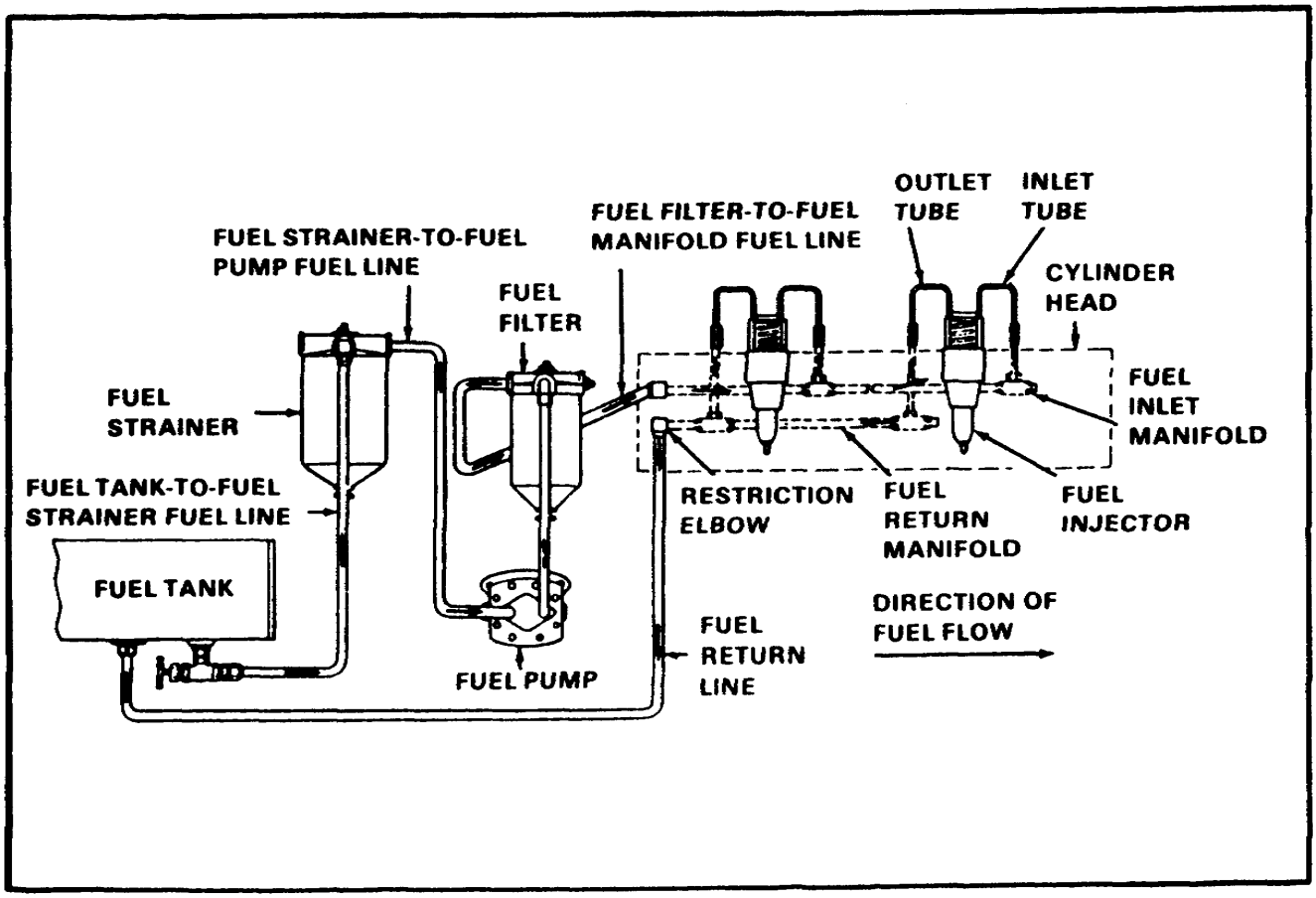
You are expected to demonstrate competency of the task skills and knowledge by responding correctly to 70 percent of the examination questions pertaining to this lesson.

Learning Event 1
SYSTEM COMPONENTS AND OPERATION

In the unit injection system, fuel is drawn from the fuel tank (Figure 28) through the strainer by the fuel pump. From the fuel pump, the fuel is forced under pressure through the fuel filter. From the fuel filter, the fuel is forced into the inlet manifold and to the inlet side of the injectors. Excess fuel or fuel not used in engine operation is returned through the outlet manifold to the fuel tank through the fuel return line. The fuel manifolds are cast as an integral part of the cylinder head. The elbow or fitting from the outlet fuel manifold has a restricted opening to maintain the proper pressure within the fuel system. The injectors are located in the cylinder head and are protected by the valve rocker cover. Fuel connectors in the cylinder head connect the injectors to the fuel manifolds with fuel inlet and outlet pipes delivering fuel to and from the injectors.

NOTE: Fuel manifolds are an integral part of the cylinder head.

FIGURE 28. FUEL SYSTEM SCHEMATIC DIAGRAM



Injector Mounting. Unit injectors (Figure 29) combine the injection pump, the fuel valves, and the nozzle in a single housing to eliminate the high pressure lines. These units provide a complete and independent injection system for each cylinder and are mounted in the cylinder head with their spray tips slightly below the top of the inside surface of the combustion chambers. A clamp, bolted to the cylinder head and fitted into a machined recess in each side of the injector body, holds the injector in place in a water cooled copper tube which passes through the cylinder head. The tapered lower end of the injector seats in the copper tube, forming a tight seal to withstand the high pressures inside the cylinders.

FIGURE 29. UNIT INJECTION SYSTEM

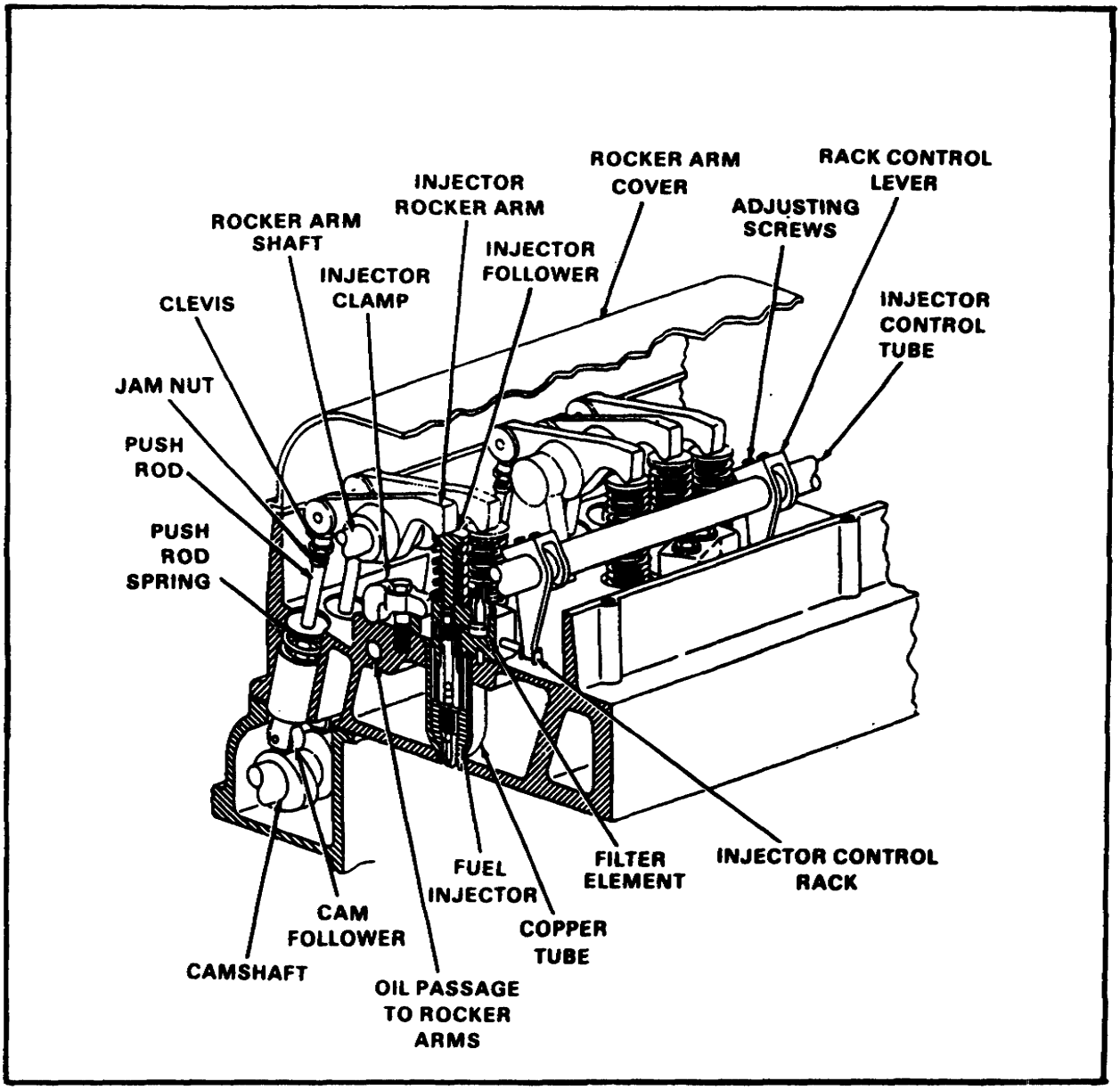
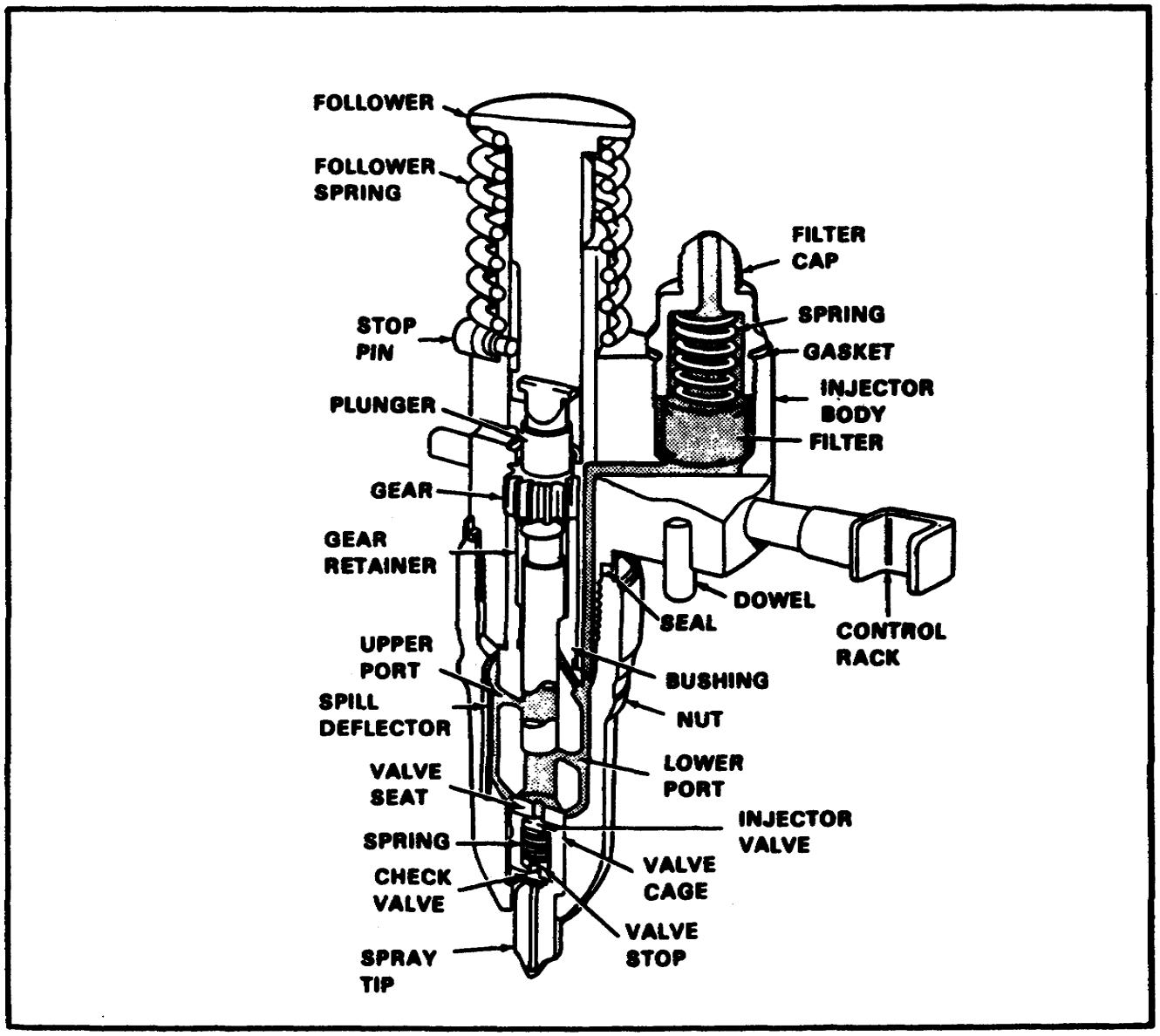


FIGURE 29. UNIT INJECTION SYSTEM (CONTINUED)



Injector Operation. The cross section of a typical unit injector (Figure 29) shows the various parts. Fuel oil is supplied to the injector at a pressure of about 20 psi and enters the body at the top through the filter cap. After passing through the fine-grained filter element in the inlet passage, the fuel oil fills the ring shaped supply chamber between the bushing and the spill deflector. The plunger operates up and down in this bushing, the bore of which is connected to the fuel supply in the ring shaped chamber by two funnel-shaped ports, one on each side at different heights.

The injector rocker arms (Figure 29) are actuated through push rods from the engine camshaft. The motion of the injector rocker arm is transmitted to the plunger by the follower, which bears against the return spring. In addition to this reciprocating motion, the plunger can be

rotated in operation around its axis by the gear, which is in mesh with the control rack. Each injector control rack is connected by an easily detachable joint to a lever on a common control tube which, in turn, is linked to the governor and throttle. For metering purposes, a recess with an upper helix and a lower helix or a straight cutoff is machined into the lower end of the plunger. The relation of this upper helix and lower cutoff to the two ports changes with the rotation of the plunger. As the plunger moves downward, the fuel oil in the high pressure cylinder or bushing is first displaced through the ports back into the supply chamber until the lower edge of the plunger closes the lower port. The remaining oil is then forced upward through the center passage in the plunger into the recess between the upper helix and the lower cutoff, from which it can flow back into the supply chamber until the helix closes the upper port. The rotation of the plunger, by changing the position of the helix, retards or advances the closing of the ports and the beginning and ending of the injection period. At the same time, it is increasing or decreasing the desired amount of fuel which remains under the plunger for injection into the cylinder.

Figure 30 shows the various plunger positions from no-injection to full-load injection. With the control rack pulled out completely (no-injection), the upper port is not closed by the helix until after the lower port is uncovered. With the control rack in this position, all the fuel charge is forced back into the supply chamber and no injection of fuel takes place.

With the control rack pushed in completely (full-load), the upper port is closed shortly after the lower port has been covered, thus producing a full effective stroke and maximum injection. From the no-injection position to full-load position (full rack movement), the contour of the helix advances the closing of the ports and the beginning of injection.

Figure 31 shows various positions for downward travel of the plunger with the rack in a fixed position. On the downward travel of the plunger, the metered amount of fuel is forced through the center passage of the valve assembly, through the check valve, and against the spray tip valve. When sufficient fuel pressure is built up, the spray tip valve is forced off its seat and fuel is sprayed through several small orifices (or holes) in the spray tip and atomized in the combustion chamber. The check valve prevents air leakage from the combustion chamber into the fuel system if the spray tip valve is accidentally held open by a small particle of dirt, allowing the injector to operate until the

FIGURE 30. PLUNGER POSITIONS FROM NO INJECTION TO FULL-LOAD INJECTION

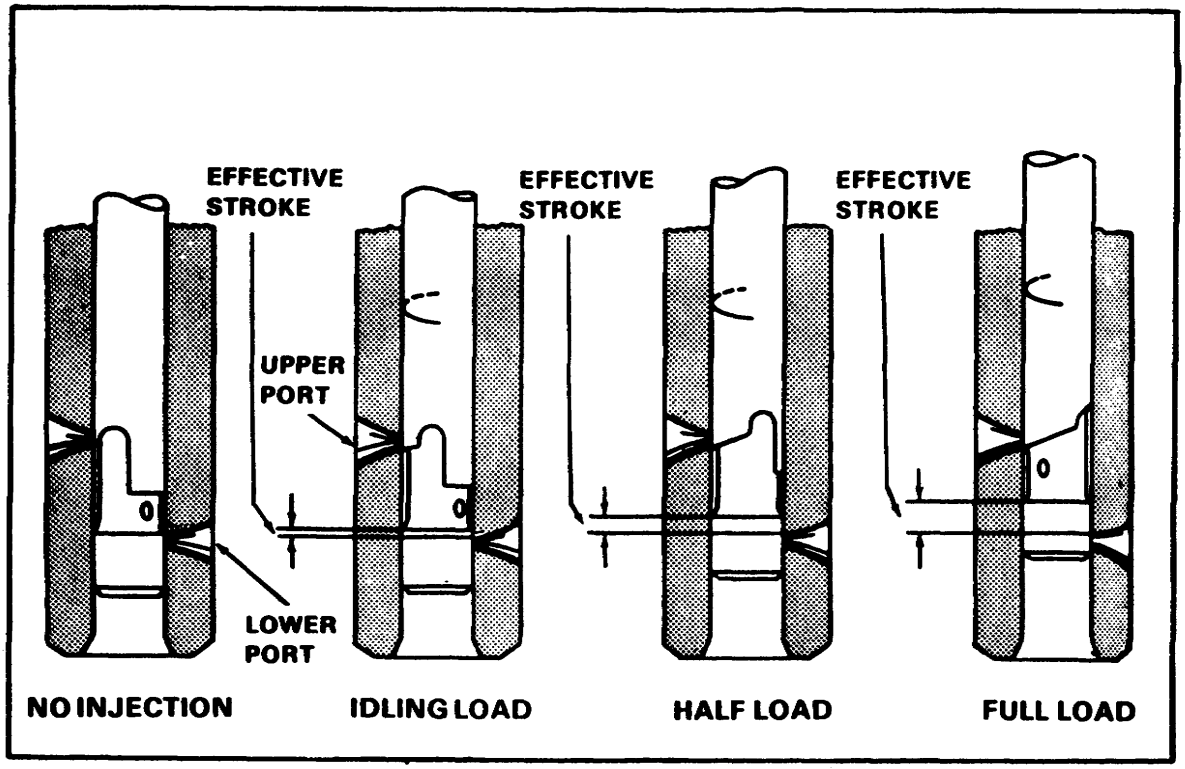
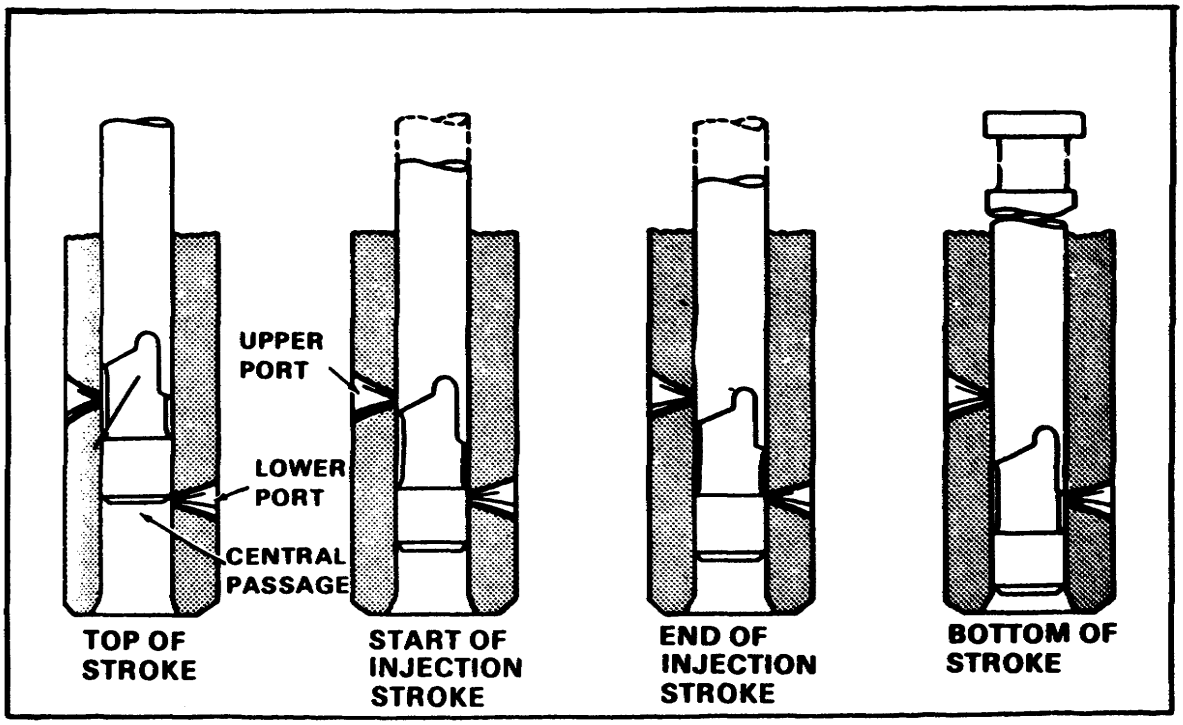


FIGURE 31. FOUR POSITIONS OF THE INJECTOR DURING DOWNWARD TRAVEL



particle works through the valve. On the return upward movement of the plunger, the high pressure cylinder is again filled with oil through the ports. The constant circulation of fresh cool fuel through the injector which renews the surplus fuel supply in the chamber, helps to maintain even operating temperature of the injectors. It also effectively removes all traces of air which might otherwise accumulate in the system.

The amount of fuel circulated through the injector is in excess of maximum needs, thus ensuring sufficient fuel for all conditions.

Learning Event 2
TROUBLESHOOTING THE UNIT INJECTOR FUEL SYSTEM

The information covered in this learning event is applicable to any item of equipment that uses a diesel engine with a unit injector fuel system. Component location may vary depending on the item of equipment used. Use the appropriate technical manual for the exact component location. The LeTourneau-Westinghouse model 440HA road grader will be used throughout this learning event. The applicable manual is TM 5-3805-237-12.

We will begin this learning event by locating the components of the fuel system.

In order to check the fuel system, you must first make sure the fuel tank is filled with fuel. Inspect the fuel tank cap and screen. If the fuel shows signs of water or other contamination, drain the fuel tank and refill with clean fuel. Inspect the fuel tank mountings and fuel lines for any signs of fuel leaks. Tighten mountings and fuel lines as necessary.

Check the fuel shut off valve and make sure its in the open position.

The next items that should be inspected are the lines from the fuel tank to the check valve. All lines must be in good condition with no leaks. Tighten or replace defective fuel lines. On equipment where the fuel tank is above or higher than the engine, there will be no check valve.

Misfiring or a faulty injector tip may cause a loss of engine power.

To check for a faulty injector in a unit injector fuel system, you should hold down each injector's follower, noting when there is no change in the engine's performance.

A loss of compression will result if one or more of the valves are adjusted incorrectly.

If the flared end of a fuel jumper line begins to leak, there will probably be a dilution of the lubrication oil.

A dirty air cleaner will cause the engine to run rough and lose power.

A leak in the fuel strainer gasket will cause air to enter the fuel supply.

To check for air in the fuel system, hold the fuel return line in a container of fuel and watch closely for air bubbles.

The fuel strainer and fuel filter should be inspected next. Inspect the strainer and filter for leaks or signs of loose lines and mountings. Drain water and sediment from the fuel filter and strainer by opening the drain cocks on the bottom of the filters.

Next inspect the fuel pump. Check the fuel lines for leaks or damage. Check the fuel pump for loose mounting and damage. Observe any fuel leaks on the pump assembly. A defective fuel pump must be replaced.

The fuel manifolds are the next item in the fuel system to inspect. On this item of equipment, the manifolds are a part of the cylinder head. Inspect the fuel line connections to the fuel manifold. Tighten or replace any defective parts. The fuel manifolds are held in place by the fuel connectors.

Next inspect the fuel connectors, fuel jumper lines, and injectors. The fuel travels from the fuel connectors to the injectors through the fuel jumper lines. Inspect the fuel lines and connectors for fuel leaks.

As the fuel leaves the injector, it passes through the return lines to the outlet manifold and to the restricted elbow. Notice that the elbow has the letter R stamped on its front or side. This elbow is responsible for maintaining the fuel pressure in the system. Without this fitting, you will not maintain the correct fuel pressure. From the restricted elbow, the fuel flows through the return line to the fuel tank.

Learning Event 3
COMPONENT ADJUSTMENT, REPAIR, OR REPLACEMENT

During this learning event, you will be shown how to adjust, repair, or replace components of the unit injector fuel system. All work described will be in accordance with the maintenance allocation chart shown in Figure 32.

FIGURE 32. MAINTENANCE ALLOCATION CHART

Functional Group Number	FOR: Component Assembly Nomenclature	Essentiality	Maintenance Operations: A Service	B Adjust	C Align	D Calibrate	E Inspect	F Test	G Replace	H Repair	I Overhaul	J Rebuild	Note Ref: K T&TE Rqmt	L Remarks
02	CLUTCH													
0200	Clutch Assembly:													
	Clutch assembly			F							H			
	Disks, plates								F	F				
0202	Clutch Release Mechanism:													
	Bearings, shaft, yoke		O							F				
	Pedal, linkage			O					O					
0206	Clutch Brake:													
	Hub, plate									F				
03	FUEL SYSTEM													
0301	Fuel Injector:													
	Injector, fuel								F	H				
0302	Fuel Pumps:													
	Plunger assembly								O					
	Pump, diesel injector		O/C					O	F	H				D
	Pump, fuel transfer								O	F				
0304	Air Cleaner													
	Cleaner, air, cartridge		O/C						O					
0306	Tanks, Lines, Fittings:													
	Cap, fittings								O					
	Lines								O	O				
	Tank		O/C				O/C							
0308	Engine Speed Governor & Controls:													
	Governor								F	D				
	Linkage, rod, lever								O					
0309	Fuel Filters:													
	Filter, fuel		O/C						O					
0312	Accelerator, Throttle:													
	Linkage, pedal								O					

KEY

O/C - Operator or Crew
O - Organizational Maintenance
F - Direct Support Maintenance
H - General Support Maintenance
D - Depot Maintenance

FUEL PUMP

Inspection. Check the fuel pump for secure mounting. Tighten the mounting bolts if necessary. Check the fuel tubes for leaks and tighten or replace tubes as necessary.

Testing. Test the fuel flow as follows:

1. Disconnect the fuel return tube from the hose to fuel tank. Connect a hose to the fuel return tube and hold the hose in a convenient receptacle.

2. . Start the engine and run it at 1,200 revolutions per minute.

3. Measure the fuel flow from the tube for one minute.

4. A minimum of one-half gallon of fuel should flow in one minute.

5. If the fuel flow is less than one-half gallon per minute, check the fuel filters and service as necessary.

6. Check the fuel flow again (3 and 4 above). If the flow is still below minimum, replace the pump using the replacement procedures.

Replacement. Refer to Figure 33.

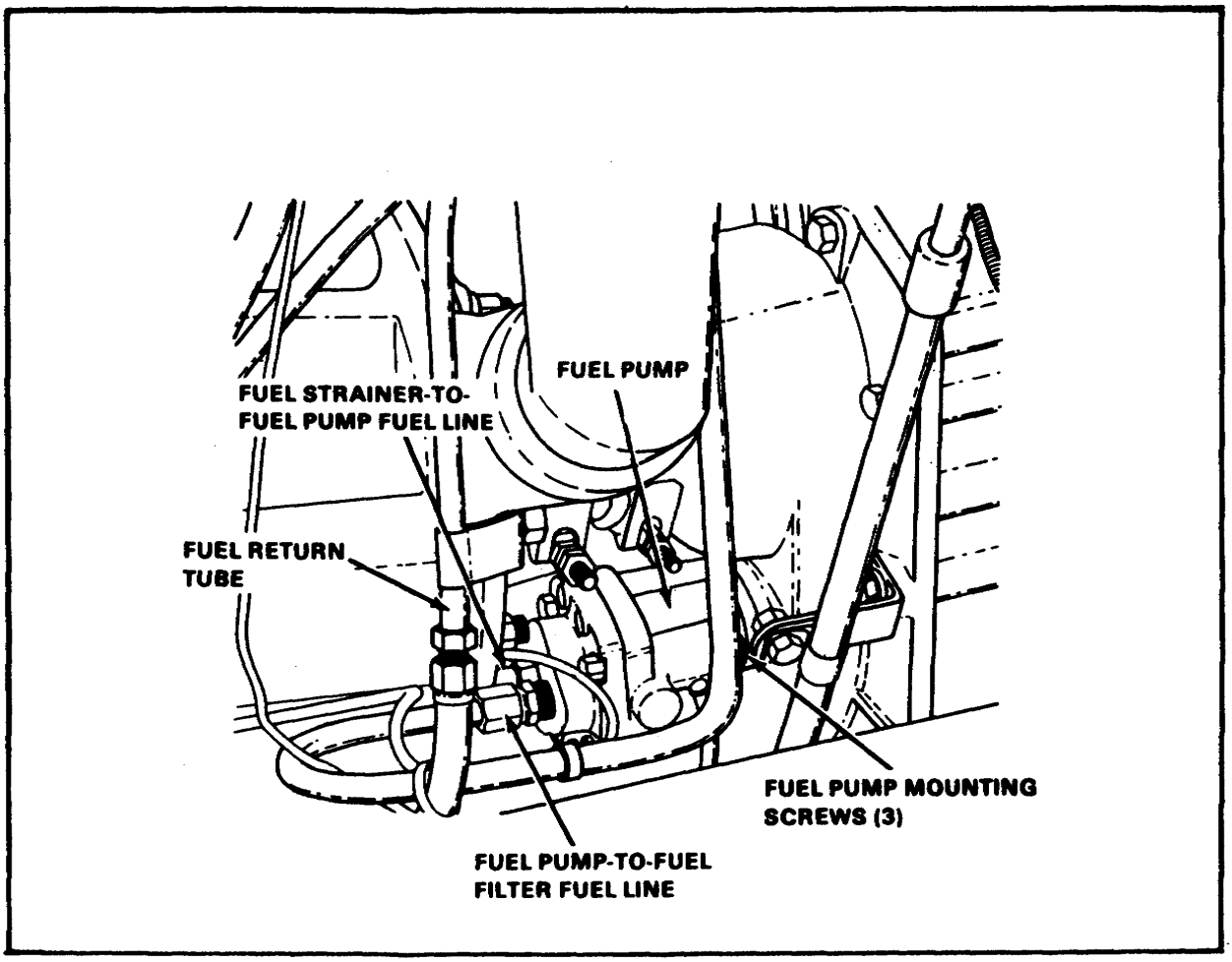
1. Disconnect the fuel pump-to-fuel filter fuel line from the fuel pump.

2. Disconnect the fuel strainer-to-fuel filter fuel line from the fuel pump.

3. Remove the three fuel pump mounting screws with the seal washers.

4. Remove the fuel pump from the blower.

FIGURE 33. FUEL PUMP REMOVAL AND INSTALLATION



FUEL TANK

Inspection. Refer to Figure 34.

1. Remove the cap and check the gasket.
2. Check the overflow tube for damage.
3. Inspect the fuel tank for leaks and damage.

COLD WEATHER STARTING AID

Inspection. Check the fuel primer for damage. Operate the priming knob in the operator's compartment and check the primer for correct operation.

Removal and Installation.

1. Disconnect the cable from the priming pump.
2. Disconnect the fluid tube to the engine from the priming pump.
3. Remove the four mounting screws securing the starting aid to the engine compartment and remove the starting aid.
4. Install the new starting aid in reverse order if removal.

FUEL FILTER AND FUEL STRAINER

General. The fuel strainer and fuel filter are mounted on the right side of the engine forward of the blower. The fuel strainer has a cloth or sock-type element and is connected between the fuel tank and the fuel pump. The fuel filter is connected between the fuel pump and the fuel manifold.

Element Replacement. Refer to Figure 35.

NOTE: Drain the water and sediment from the filter and strainer daily.

1. Drain the filter or strainer.
2. Remove the cover screw.
3. Remove the shell from the filter cover. Remove the gasket from the cover.
4. Remove the filter or strainer element from the shell.

FIGURE 34. FUEL TANK SERVICE

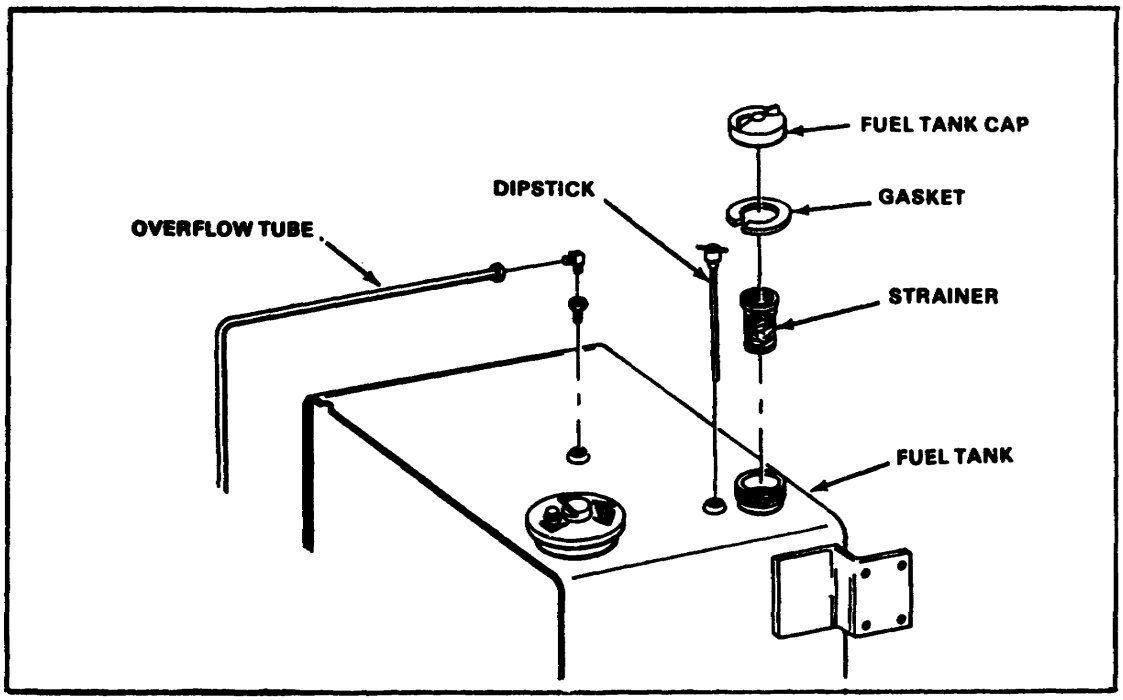
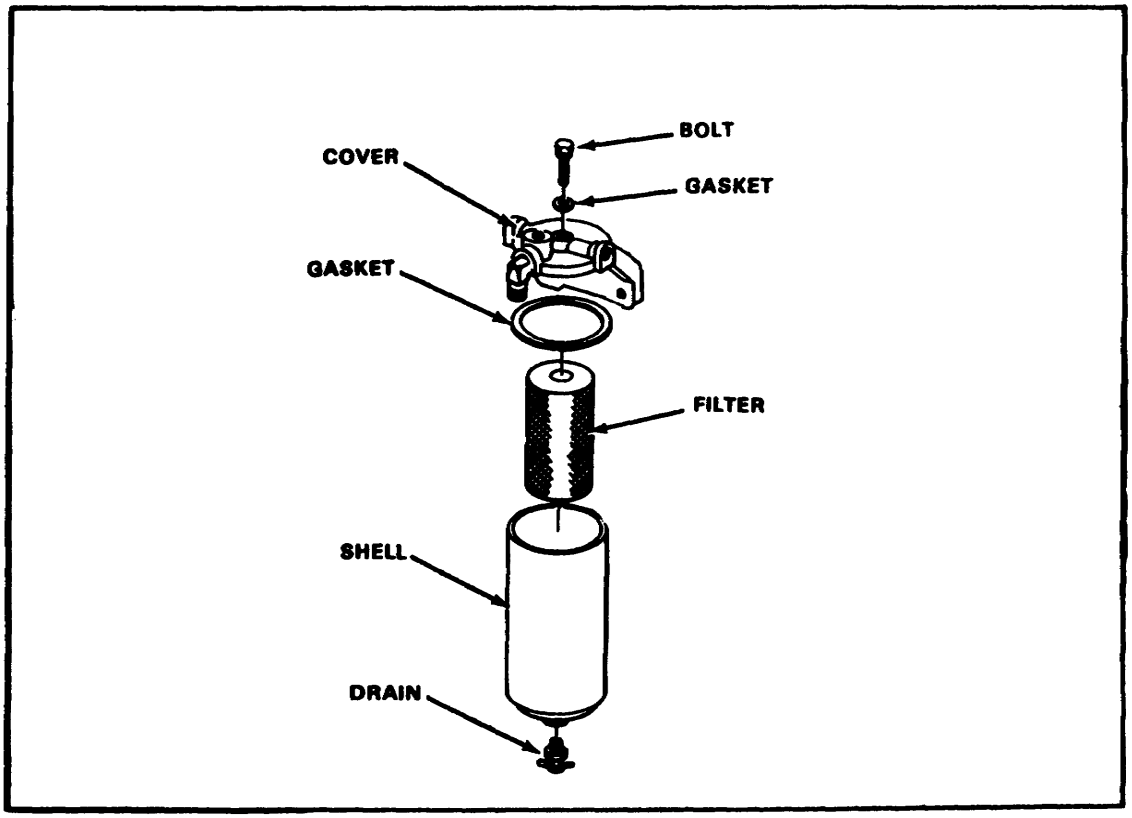


FIGURE 35. FUEL FILTER AND STRAINER ELEMENT REPLACEMENT



5. Clean the shell with an approved cleaning solvent and a clean cloth.

6. After installation of new elements, prime the filter and strainer by filling the shell with clean fuel.

7. Install the shell and cover gasket in the cover and secure with the cover screw.

NOTE: Change the filter and strainer elements every 300 hours of operation.

Filter and Strainer Replacement. Refer to Figure 36.

1. Open the drain cocks, and drain the filter and strainer.

2. Disconnect the fuel tank-to-strainer fuel line from the strainer.

3. Remove the screw and washer and remove the clamp.

4. Disconnect the fuel strainer-to-fuel pump fuel line from the strainer and the fuel pump.

5. Remove the two screws, lock washers, and nuts and remove the fuel strainer from the bracket.

6. Remove the two screws and lock washers and remove the fuel strainer mounting bracket.

7. Disconnect the fuel pump-to-fuel filter fuel line from the fuel filter and fuel pump. Remove the nylon ties and remove the fuel line.

8. Disconnect the fuel filter-to-fuel manifold fuel line from the fuel filter.

9. Remove the two screws, lock washers, and flat washers and remove the fuel filter.

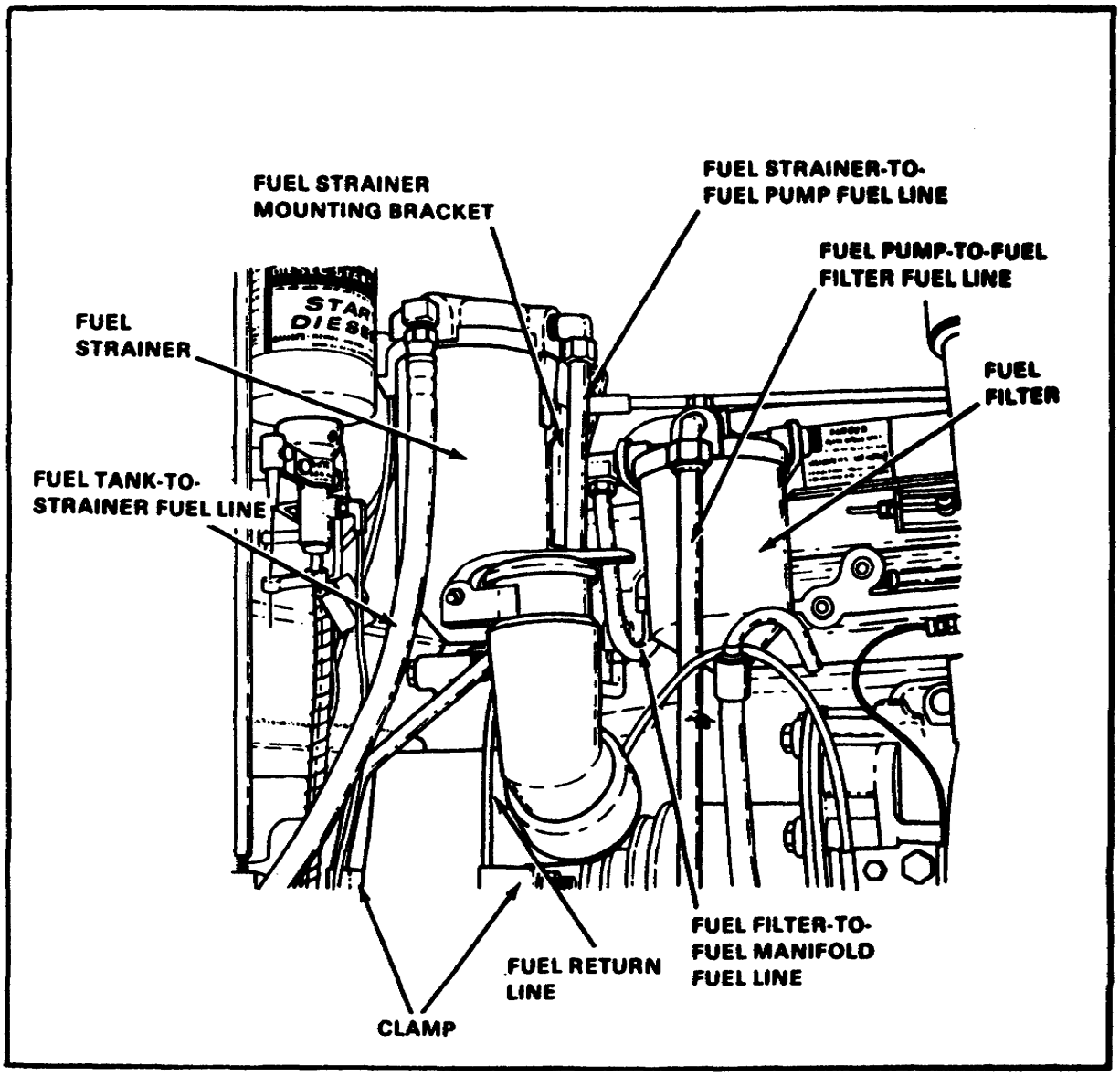
10. Disconnect the fuel filter-to-fuel manifold fuel line from the elbow in the manifold. Remove the elbow from the manifold.

11. Disconnect the fuel return line from the elbow in the fuel manifold and fuel tank return line. Remove the elbow from the manifold.

12. Remove the nut and lock washer and remove the clamp and fuel return line.

NOTE: After installing, fill the filter and strainer with clean diesel fuel to prime the fuel system.

FIGURE 36. FUEL FILTER AND STRAINER REPLACEMENT



GOVERNOR LINKAGE

Inspection. Check the governor lever (Figure 37) and shutoff rod for damage and smooth operation. Pull the ball in the operator's compartment to check the lever and rod operation. The lever must move enough to completely close the governor to stop the engine. If the lever or rod is damaged, replace the defective parts.

Removal and Installation. Refer to Figure 37.

1. Remove the ball from the shutoff rod in the operator's compartment. Remove the retaining ring and insulating bushing.

2. Remove the cotter pin and washer and remove the shutoff rod from the lever.

3. Remove the shoulder bolt, lock washer, and nut securing the lever to the bracket.

4. Disconnect the lever from the ball Joint and remove the lever.

5. Remove the ball Joint from the governor rod and the rod from the governor lever.

6. Install the new governor rod in the governor lever and connect the ball Joint to the rod.

7. Install the lever on the bracket and secure with the shoulder bolt, lock washer, and nut.

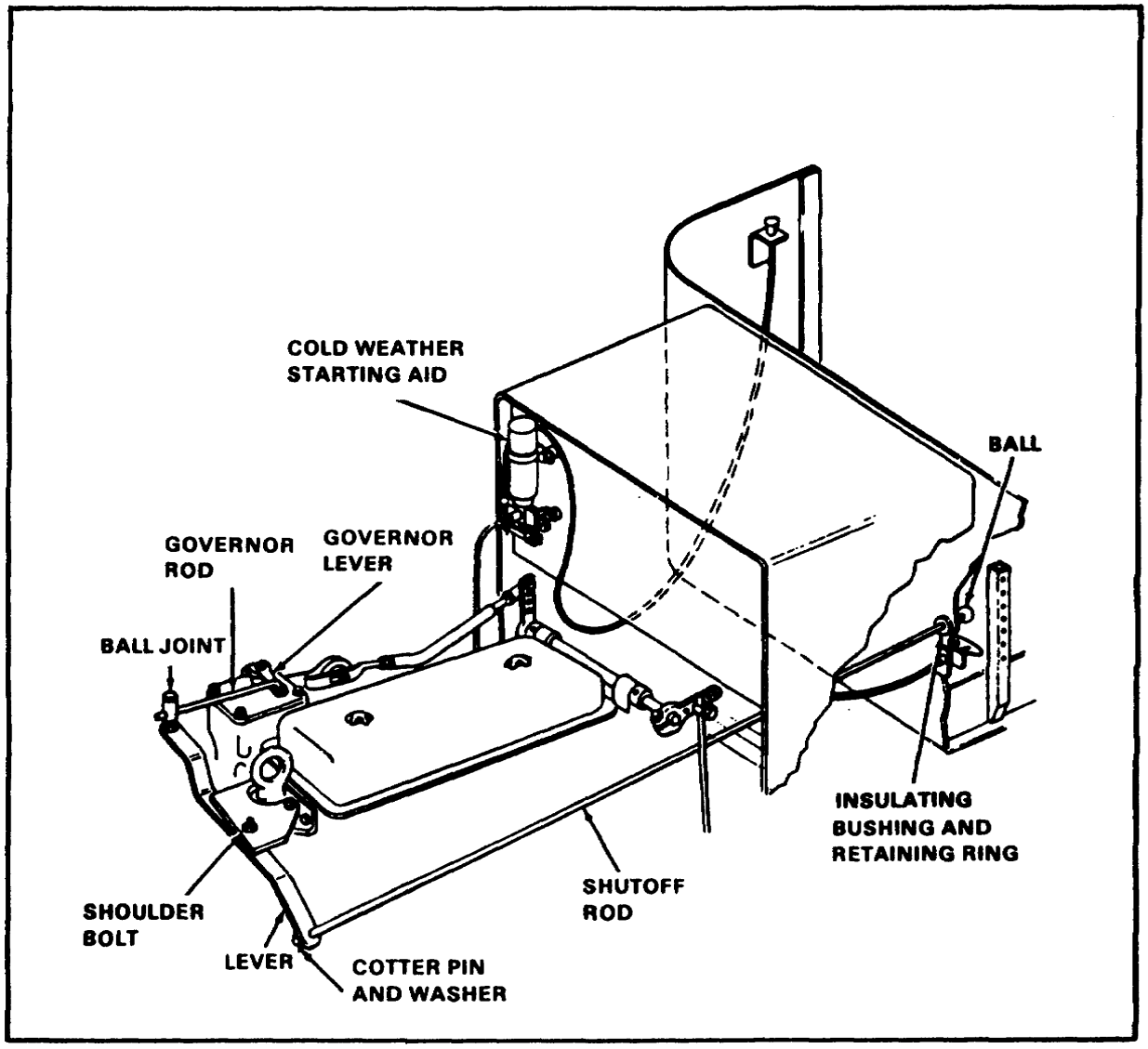
8. Connect the ball joint to the lever.

9. Slide the new shutoff rod into the operator's compartment through the insulating bushing and secure with the retaining ring. Install the ball on the rod.

10. Install the shutoff rod through the hole in the lever and secure with the cotter pin and washer.

11. Operate the rod from the operator's compartment to check operation.

FIGURE 37. GOVERNOR LEVER AND LINKAGE



THROTTLE LINKAGE

Inspection. Check the operation of the throttle linkage by depressing both foot pedals and moving the governor control lever through complete travel. The linkage should operate smoothly and completely control the governor. The governor control lever should stop and hold in any position, due to friction bearings in the shaft. Check the rods for bent condition or damage. Replace the damaged parts in the linkage.

Removal. Refer to Figure 38.

1. Remove the cotter pin and straight pin.
2. Remove the two cotter pins, washer, and straight pin.
3. Remove the accelerator-decelerator.
4. Remove the ball joint and rod from the lever.
5. Remove the cotter pin and washer.
6. Remove the cotter pin and straight pin and remove the rod and clevis.

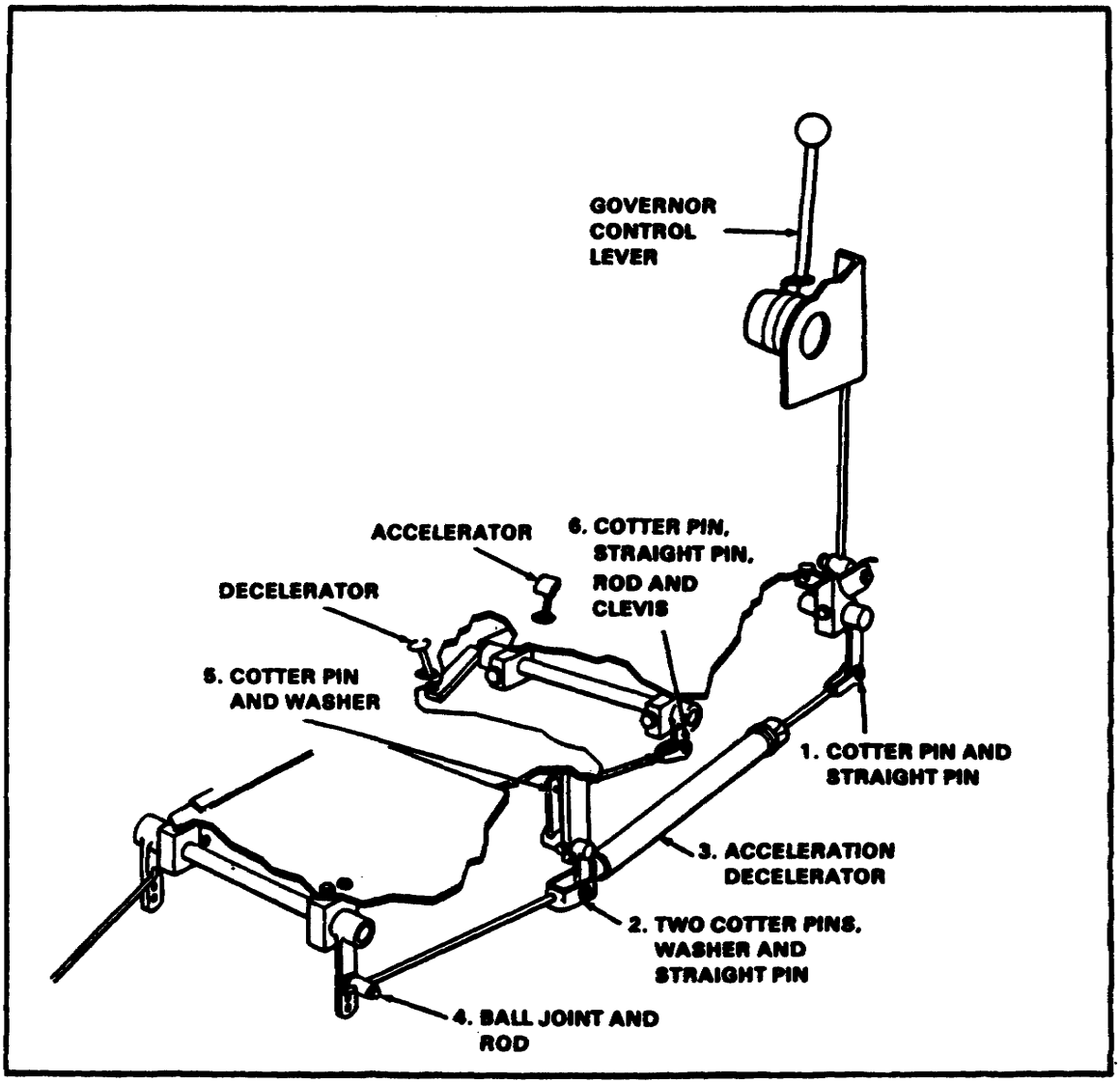
Adjustment. Refer to Figure 38.

1. With the engine off, place the governor control lever against the full speed stop (all the way back). Adjust the rod, attached to the lever through the floor plate, until the accelerator-decelerator rod is pulled out of its housing 3/16 to 1/4 inch. When the governor control lever is against the low speed stop, the rod should be pushed into the housing the same distance.
2. After making the above adjustments, adjust the length of the rod from the pedal support to the accelerator-decelerator to prevent either pedal from striking the floor plate.
3. After making all the adjustments, hook a spring scale to the governor control lever as close to the ball as possible. A pull of 8 to 25 pounds should be required to move the lever through the full range of travel.

EXHAUST VALVE CLEARANCE

General. Exhaust valve clearance at normal engine operating temperature is important to smooth, efficient operation of the engine. Whenever the cylinder head is overhauled, the exhaust valves are reconditioned or replaced, or the valve operating mechanism is replaced or disturbed, the valve clearance must be adjusted to the cold setting to allow for normal expansion as the engine warms up.

FIGURE 38. THROTTLE LINKAGE REMOVAL AND INSTALLATION



Adjustment.

1. Loosen the two bolts and remove the valve rocker cover and gasket from the engine (Figure 39).

2. Remove the two pins from the bolts and remove the two bolts and washers from the cover.

3. Remove the two studs from the cylinder head.

4. Place the governor speed control lever in the no-fuel position.

5. Rotate the crankshaft until the injector follower on number 1 cylinder is fully depressed.

6. Loosen the push rod locknut (Figure 40).

7. Place a 0.013-inch feeler gage (Figure 40) between the valve stem and the rocker arm.

8. Adjust the push rod to obtain a smooth pull on the feeler gage. Remove the feeler gage.

9. Hold the push rod with a 5/16-inch wrench and tighten the locknut with a 1/2-inch wrench.

10. Check the clearance again. If the clearance is correct a 0.011-inch feeler gage will pass freely between the valve stem and the rocker arm, but a 0.013-inch feeler gage will not.

11. Set the remaining seven exhaust valve clearances in the same manner in firing order (1-3-4-2) sequence.

12. Stop and operate the engine until it reaches operating temperature (160°F to 185°F). Stop the engine.

13. With the engine at operating temperature, rotate the crankshaft until the injector follower on number 1 cylinder is fully depressed.

14. Check the valve clearance as described above and as shown in Figure 40. If the valve clearance is correct, a 0.008-inch feeler gage will pass freely between the rocker arm and the valve stem but a 0.010-inch gage will not pass through. Adjust the push rod, if necessary, to obtain this clearance.

FIGURE 39. VALVE ROCKER COVER

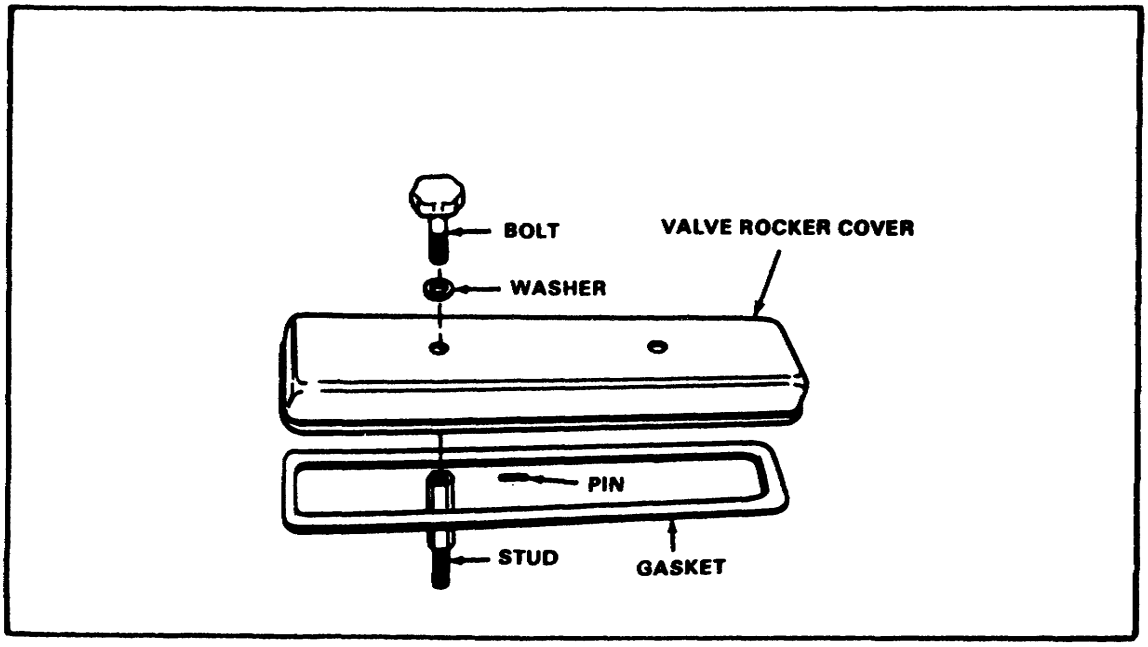
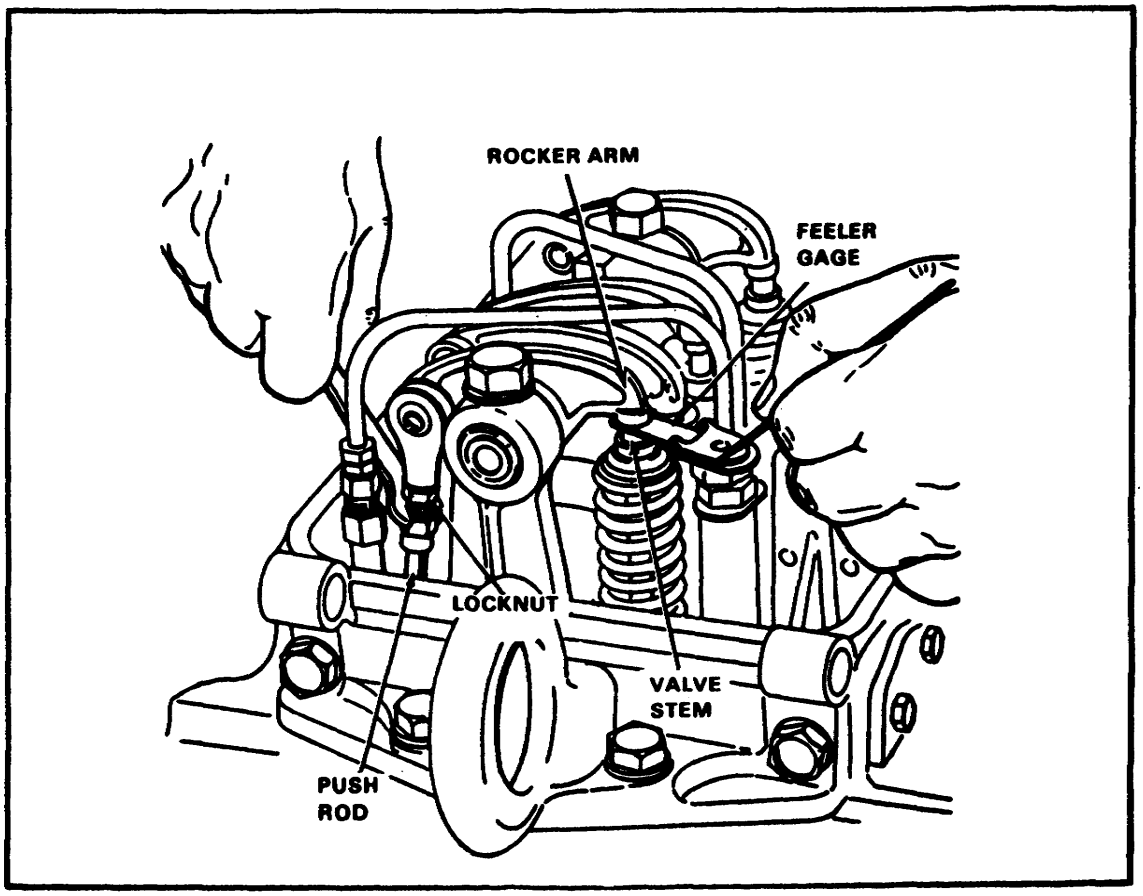


FIGURE 40. ADJUSTING VALVE CLEARANCE



NOTE: If the engine cools off before adjustments are completed, bring the engine to operating temperature before continuing with the adjustments.

15. Check all valves in the same manner it firing order (1-3-4-2) sequence.

16. Refer to items 1 through 3 and install the valve rocker cover. Install the valve rocker cover in reverse order of removal.

INJECTOR TIMING

General. The injectors are timed properly when the injector follower is adjusted to a definite height in relation to the injector body. This height varies with the type of injectors incorporated in the engine. All of the injectors should be timed in firing order sequence.

Adjustment.

1. Refer to Figure 39 on page 63 and remove the valve rocker cover.

2. Place the governor speed control lever in the no-fuel position.

3. Rotate the crankshaft until the exhaust valve on number 1 cylinder is fully depressed.

4. Place the small end of an injector timing gage in the hole provided in top of the injector body with the flat of the gage toward the injector body as shown in Figure 41.

NOTE: The injector timing gage has a timing dimension of 1.460 inches as shown in Figure 41. The gage number is 72582-J1853 and is available from General Motors Corporation, Detroit Diesel Engine Division, 13400 West Outer Drive, Detroit, Michigan 48239.

5. Loosen the injector rod locknut (Figure 41). Turn the push rod and adjust the injector rocker arm until the extended part of the follower will Just pass over the top of the injector follower.

6. Hold the push rod and tighten locknut. Check the adjustment and, if necessary, readjust the push rod.

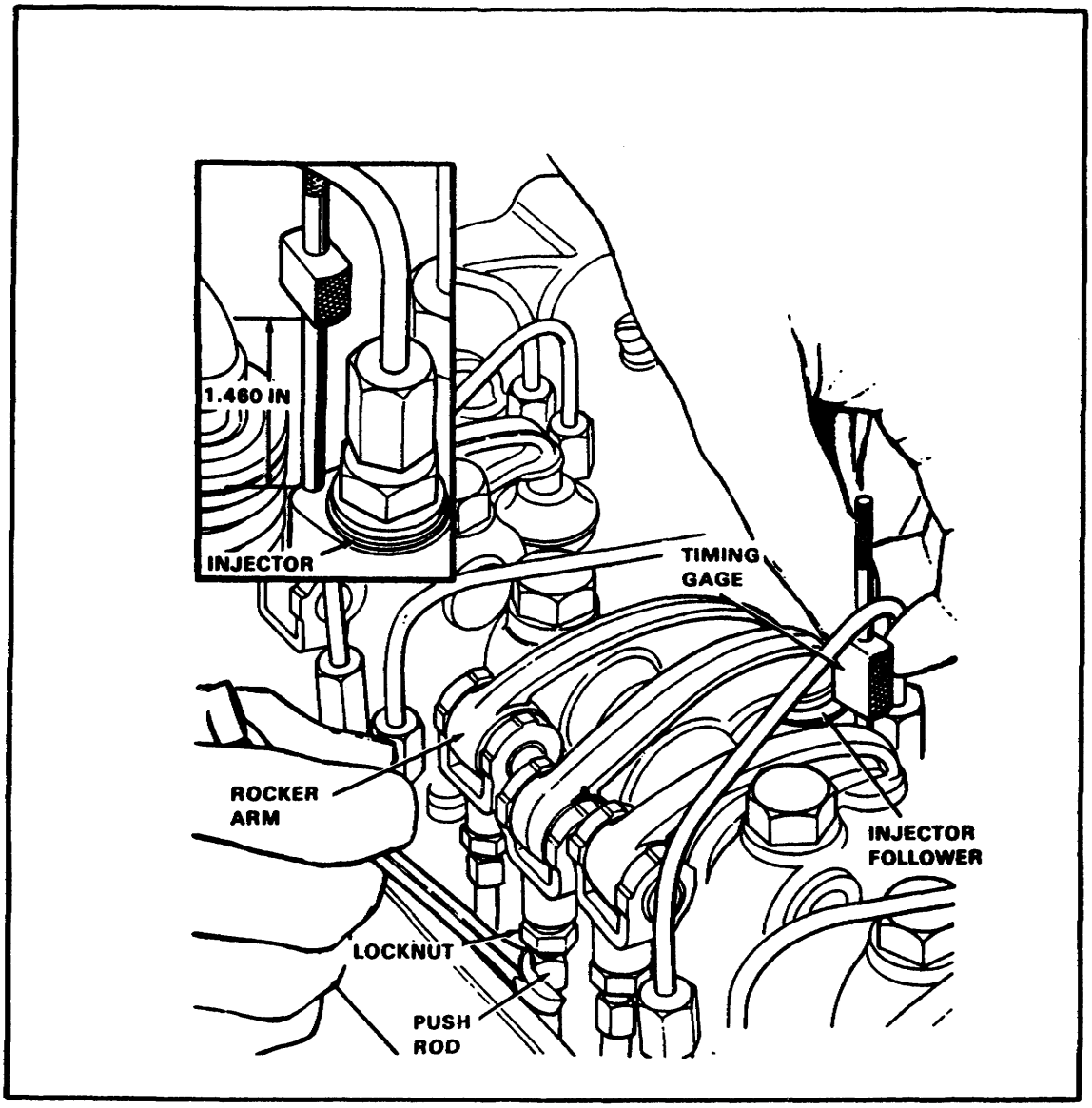
7. Adjust the timing of the remaining injectors in the same manner.

8. Refer to Figure 39 on page 63 and replace the rocker valve cover.

GOVERNOR GAP

General. When the governor speed control lever is at full-fuel position, a gap must be maintained between the spacing plunger and the plunger guide in the governor control housing.

FIGURE 41. TIMING FUEL INJECTORS



Adjustment. Refer to Figure 42.

1. Remove the governor cover.
2. Set the governor speed control lever in the full-fuel position (all the way back).
3. Insert a 0.006-inch feeler gage between the spacing plunger and the plunger guide. Check the pressure on the feeler gage.
4. If necessary, loosen the locknut and turn the adjusting screw in or out until a slight drag is felt on the feeler gage.
5. Hold the adjusting screw and tighten the locknut to secure adjustment. Check the gap, after tightening the nut, to be sure the gap is correct. Readjust if necessary.
6. Install the governor cover.

INJECTOR RACK CONTROL

General. Properly positioned injector rack control levers determine the amount of fuel injected into each cylinder and equalizes distribution of the load. The control levers must be positioned with the governor at the full-load setting.

Adjustment.

1. Adjust the governor gap.
2. Remove the valve rocker cover.
3. Disconnect the throttle linkage from the governor stop lever.
4. Loosen the locknut and back out the buffer screw (Figure 43) approximately 5/8 inch.
5. Loosen all eight inner and outer control lever adjusting screws (Figure 44 on page 69).
6. Move the governor speed control lever (Figure 43) to the maximum speed position (all the way back).

FIGURE 42. ADJUSTING GOVERNOR GAP

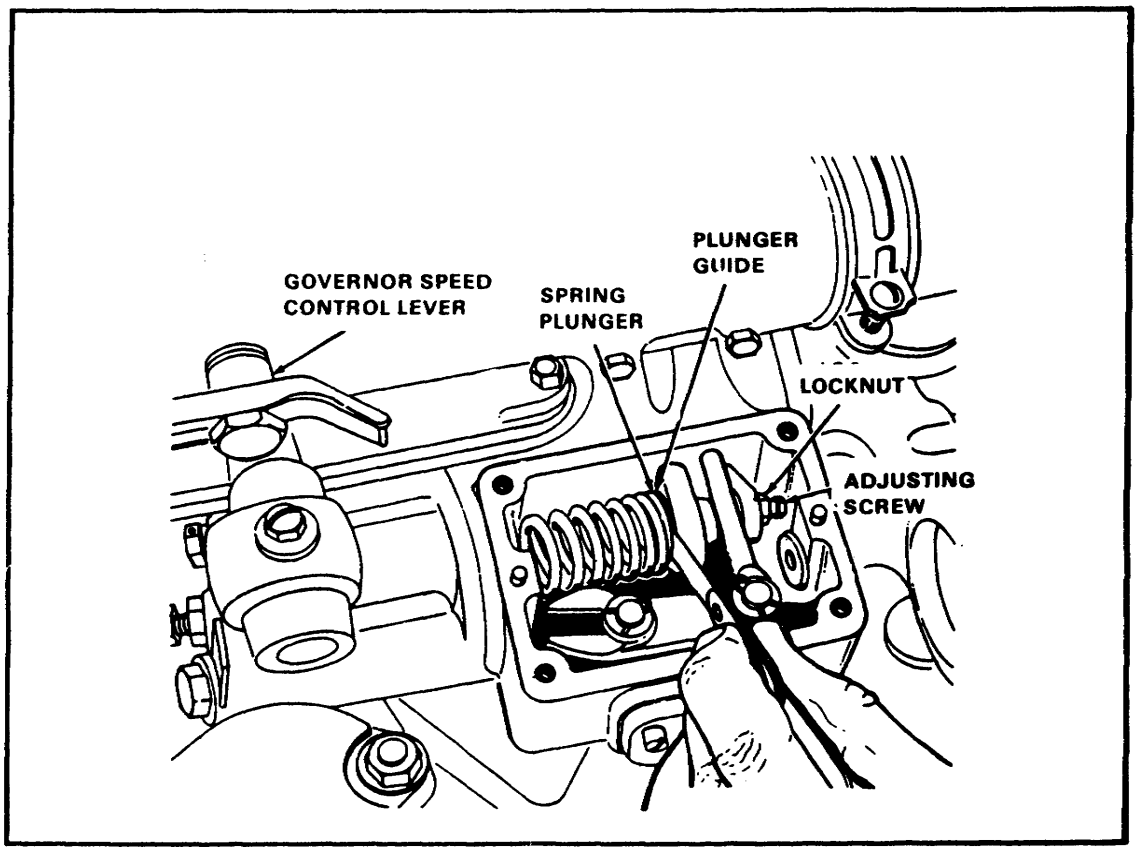
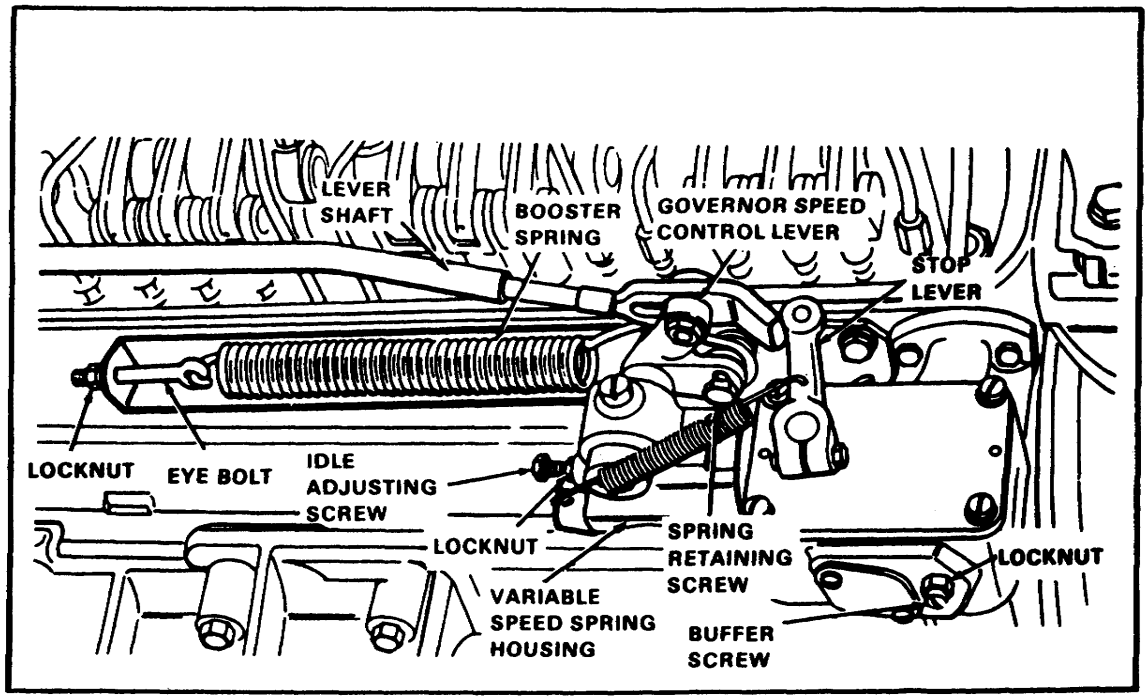


FIGURE 43. GOVERNOR ADJUSTING POINTS



7. Move the stop lever (Figure 44) to the run position (forward). Hold the lever in run the position with light finger pressure.

8. Turn the inner adjusting screw (Figure 44) on No. 1 injector rack control lever down until a step up in effort to hold the stop lever in run position is noted. This places the No. 1 injector rack control lever in the full-fuel position.

9. Turn down the outer adjusting screw (Figure 44) until it bottoms lightly on the injector control tube.

10. Alternately tighten the inner and outer adjusting screws to hold adjustment.

NOTE: The above step should result in placing the governor linkage and the control tube in the same positions they will attain while running at full load.

11. Check adjustment as follows: Refer to Figure 44.

    a. Hold the stop lever in the run position.

    b. Press down on the injector rack control lever with a screwdriver or fingertip, causing the injector control tube to rotate. When the control lever is released, the injector rack should return to its original position. If the rack does not return to its original position, the setting is too loose. To correct, back off outer adjusting screw slightly and tighten inner adjusting screw slightly.

    c. Setting is too tight if, when moving the stop lever from the stop to the run position, the injector rack becomes tight before the stop lever reaches the end of its travel. If this occurs, back off the inner adjusting screw slightly and tighten outer adjusting screws slightly.

    d. Continue the adjustments above until the injector control rack operates smoothly through its complete length of travel.

    e. Completion of these adjustments should establish No. 1 injector rack control lever in the full-fuel position.

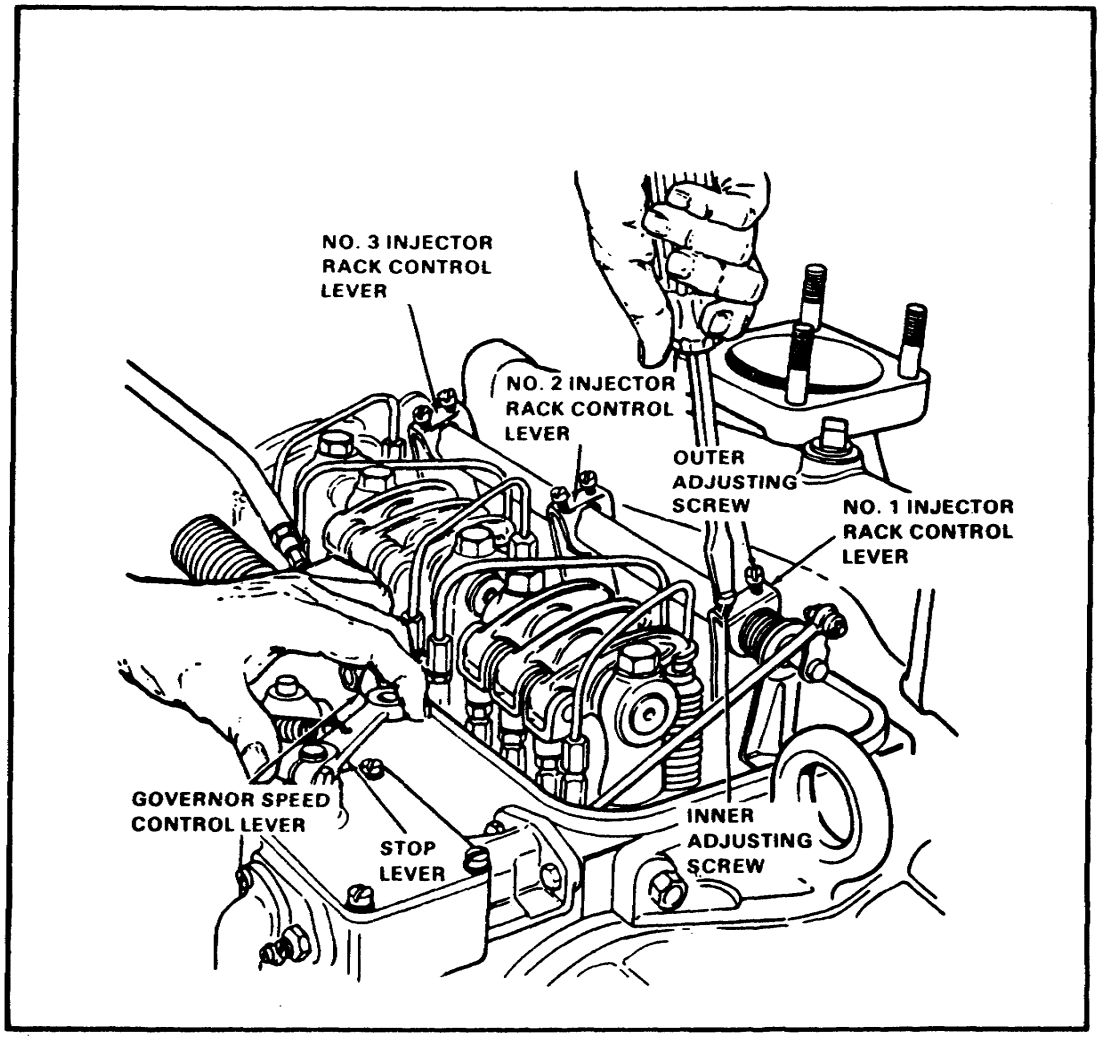
12. With No. 1 cylinder fuel injector adjusted as above, adjust the remaining injectors as follows:

    a. Manually hold No. 1 injector rack in the full-fuel position (all the way in).

    b. Turn the inner adjusting screw on No. 2 control down until No. 2 injector rack control lever has moved into the full-fuel position and the adjusting screw is bottoming on the injector control tube.

    c. Turn the outer adjusting screw down until it bottoms lightly on the control tube. Alternately tighten both inner and outer adjusting screws until tight.

FIGURE 44. ADJUSTING THE INJECTOR GOVERNOR LEVER



d. Recheck No. 1 injector rack control lever to be sure it has remained snug on the ball end of the control lever while positioning No. 2 rack. If the rack on No. I has become loose, back off the inner adjusting screw on No. 2 injector rack control lever slightly and tighten outer adjusting screw slightly.

e. Continue the adjustments until No. 2 injector rack functions in accordance with No. 1 injector rack.

13. Adjust remaining injectors in the same manner.

14. Install the valve rocker cover.

15. Connect the linkage to the stop lever.

LESSON 2

REVIEW EXERCISE

Check your understanding of Lesson 2 by completing this review exercise. Try to complete it without looking back at the lesson. When you have completed the exercise, turn to the solutions and check your responses. If you do not understand a solution, go back and restudy the section of the lesson where the information is given.

1. In the unit injector fuel system, the section between the fuel pump and the injectors is under _____ psi.

   A. 10

   B. 20

   C. 30

   D. 40

2. The drain at the bottom of the full tank is used to _____.

   A. Add rust inhibitors

   B. Remove sediment from the fuel system

   C. Control pressure in the fuel tank by automatically opening at a certain pressure

   D. Add fuel at special bottom fill supply depots

3. The fuel manifolds are held in place by _____.

   A. Restricted elbows

   B. Welds

   C. The fuel connectors

   D. The inlet and return manifolds

4. The fuel travels from the fuel connectors to the injectors through _____.

   A. Jumper lines

   B. Distribution tubes

   C. Fuel ports

   D. Check valves

5. In the unit injector fuel system, the fuel is metered at _____.

   A. The fuel strainer

   B. The jumper lines

   C. The injectors

   D. The fuel transfer pump

6. After passing through the check valve, the fuel enters the _____.

   A. Injectors

   B. Inlet manifold

   C. Fuel tank

   D. Spray tip valve

7. Fuel which is unused by the injectors is returned to the _____.

   A. Fuel tank

   B. Inlet manifold

   C. Injectors through jumper lines

   D. Fuel transfer pump

8. A misfiring or faulty injector tip may cause _____.

   A. Loss of power

   B. Good mileage

   C. Sediment in the fuel tank

   D. Break in the fuel line

9. When checking for a faulty injector in a unit injector fuel system you would _____.

   A. Replace the injectors one at a time until you have found the faulty injector

   B. Put your ear to each injector, checking for smooth operation

   C. Switch the injectors around, paying attention to the changes in engine performance

   D. Hold down each injector's follower, noting when there was no change in the engine's performance

10. A dirty air cleaner will cause the engine to _____.

   A. Overheat

   B. Overwork its fuel transfer pump

   C. Run rough and lose power

   D. Clog its injector fuel strainers

11. When performing a fuel flow test, the correct rate is _____.

   A. One quart per minute

   B. One half gallon per minute

   C. Two gallons per minute

   D. Four gallon per minute

12. The correct way to check for air in the fuel system is to _____.

   A. Attach an oxygen check gage to the fuel strainer

   B. Check for white exhaust

   C. Hold the fuel return line in a container of fuel and watch closely for air bubbles

   D. Listen closely to each jumper line for a popping sound

13. A leak in the fuel strainer gasket will cause _____.

    A. Air to enter the fuel supply

    B. Fuel to spill all over the engine

    C. The fuel pump to become overworked

    D. The engine to have a sudden burst of power

14. Pressure is maintained in the outlet manifold through the use of a _____.

    A. Fuel connector

    B. Restricted elbow

    C. Tapered L-clamp

    D. Secondary fuel pump

LESSON 2

REVIEW EXERCISE SOLUTIONS

1. B (page 45)
2. B (page 50)
3. C (page 50)
4. A (page 50)
5. C (page 43)
6. D (page 46)
7. A (page 43)
8. A (page 49)
9. D (page 49)
10. C (page 49)
11. B (page 52)
12. C (page 50)
13. A (page 49)
14. B (page 50)

Lesson 3

ROOSA MASTER DISTRIBUTOR FUEL SYSTEMS

TASK

Describe the correct procedures for the adjustment, repair, or replacement of components of the Roosa Master distributor fuel system.

CONDITIONS

Given information describing the correct procedures for the adjustment, repair, or replacement of Roosa Master Distributor Fuel System components, an ACCP Examination Response Sheet, and a No. 2 pencil.

STANDARDS

You are expected to demonstrate competency of the task skills and knowledge by responding correctly to 75 percent of the examination questions pertaining to this lesson.

Learning Event 1
SYSTEM COMPONENTS AND OPERATION

General. The Roosa Master pump is of the single cylinder, opposed plunger, inlet metering, distributor type. Simplicity is the prime advantage of this design. It contributes to the ease of manufacture and servicing, lower maintenance costs, greater dependability, and ability to operate at greater speeds than conventional types. Since the basic Roosa Master model has eighty parts and only three main rotating members, there is less chance of part failure. With the development of smaller diesel engines with greater engine speeds, a simplified injection system is needed. The problem is solved with the distributor type fuel pump. There are no spring loaded lapped surfaces, no ball bearings or gears, and most accessories are built in. Self-lubricated by the filtered fuel, the unit operates in any position and has the same number of parts regardless of the number of cylinders served.

A mechanical-centrifugal governor is an integral part of the pump. The governor controls fuel delivery and therefore engine speed. Drive for the governor is supplied by the pump drive shaft.

A transfer pump, mounted on the front of the pump, draws fuel from the tank and delivers it to the injection pump. The transfer pump is of the positive displacement, vane type. Lubrication for the pump is supplied by the fuel oil. No other lubrication is required.

A switch, mounted on top of the pump, controls fuel flow out of the pump. The switch activates a solenoid, which when energized, opens the metering valve and allows fuel to flow from the pump to the engine. When the master switch on the instrument panel is placed in the off position, the solenoid closes the valve, ending fuel delivery and stopping the engine.

Charging Cycle. As the rotor revolves, the charging passage in the rotor registers with one of the charging ports in the charging ring. Fuel, at transfer pump pressure, then passes into the pumping cylinder, forcing the plungers apart a distance proportionate to the amount of fuel required for injection on the following stroke. Only at full load will the plungers move to the most outward position, controlled by the leaf spring setting (maximum fuel adjustment).

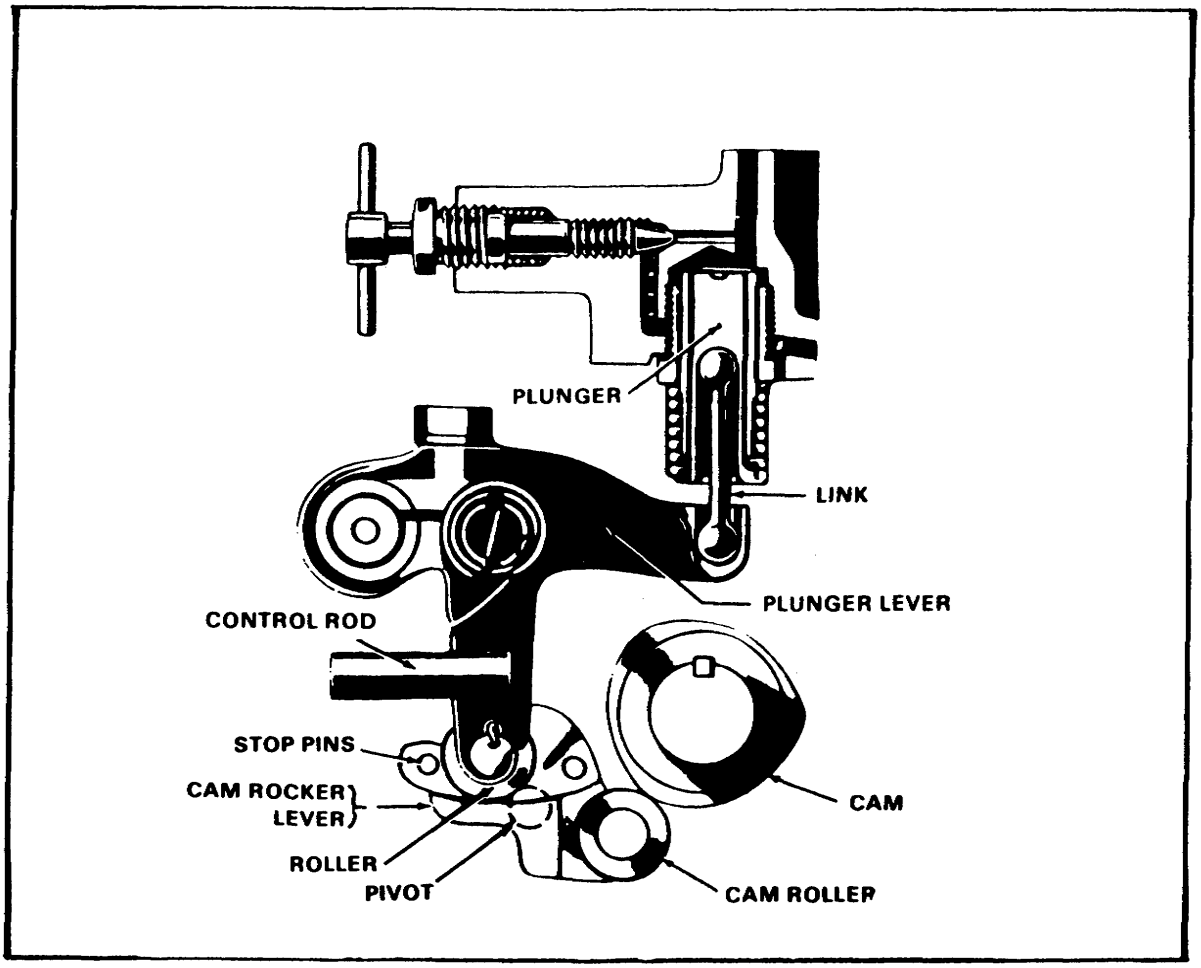
While the charging passage in the rotor is in register with one of the charging ports in the hydraulic head, the discharge passage is out of register with the head outlet poet. The rollers are between the cam lobes.

Discharging Cycle. As the rotor continues to revolve, the charging passage passes out of register with the charging port. For a brief interval the fuel is trapped until the rotor discharge passage registers with one of the head outlet ports. As this registration takes place, both rollers contact the rise of the cam lobes and are forced together. This is the discharge or injection stroke. The fuel trapped between the plungers is forced through the axial passage and out one of the head outlet ports to an injection nozzle.

Metering Units. The metering pump is a closely fitted reciprocating pump, obtaining its motion through a link from the plunger lever. The plunger lever (Figure 45) is operated by a vertical lever controlled in turn by an eccentric rocker lever running directly off a cam on the fuel pump main shaft. The position of the vertical lever in the eccentric of the rocker lever determines the travel of the plunger lever and, consequently, the travel of the metering plunger. As the metering plunger starts upward on its controlled stroke, it pushes fuel to the injector through passages formed by the rotating distributor disk. The stroke of the metering plunger, which determines the amount of fuel going to each injector, is varied by changing the position of the vertical lever between the stop pins in the cam rocker lever. When the roller is against the inside stop pin, there is no travel on the vertical lever or on the metering plunger, therefore, no fuel is going to the engine. If the vertical lever is moved over to the outside pin, the stroke of the metering plunger is sufficient to deliver enough fuel to the engine for full speed and load.

Injector. The injector consists of a forged body with a properly fitted plunger (Figure 46 on page 80). This plunger is forced down against spring action by a rocker arm activated by push rods from the engine camshaft. Mounted on the end of the body is the cup which contains the nozzle tip. On the intake stroke of the engine, the fuel metering pump forces a charge of fuel of the exact amount necessary to meet the load and speed of the engine into this cup.

FIGURE 45. METERING UNIT



Operation. The operation of the metering pump requires that the fuel line and passage leading to the cup be filled with fuel (1, Figure 47 on page 80). It naturally follows that any fuel added at the fuel metering pump end will push the same amount of fuel into the injector cup. The fuel lies in the cup during the compression stroke of the engine and the compressed air is forced through the small spray holes in the cup. The fuel oil in the tip of the cup is exposed to the intense heat and blasting of the compression and is thus preheated and broken up (2, Figure 47). A few degrees before top center, the plunger Ls forced down and the preheated fuel charge is driven out into the cylinder (3, Figure 47) and the plunger ends its stroke (4, Figure 47). A small check valve is located in the lower end of the fuel passage in the injector body. This check valve prevents the compression pressures from blowing the fuel back and filling the lines with air.

FIGURE 46. INJECTOR

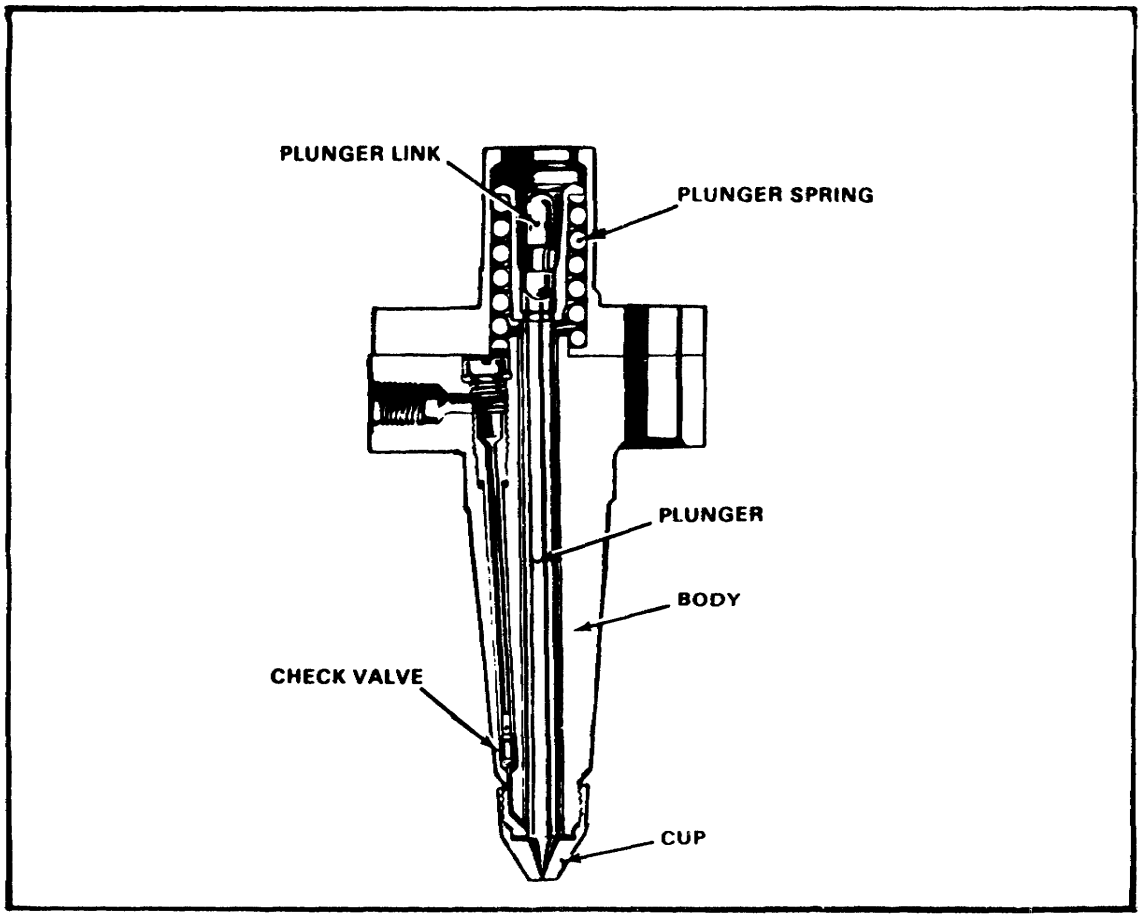
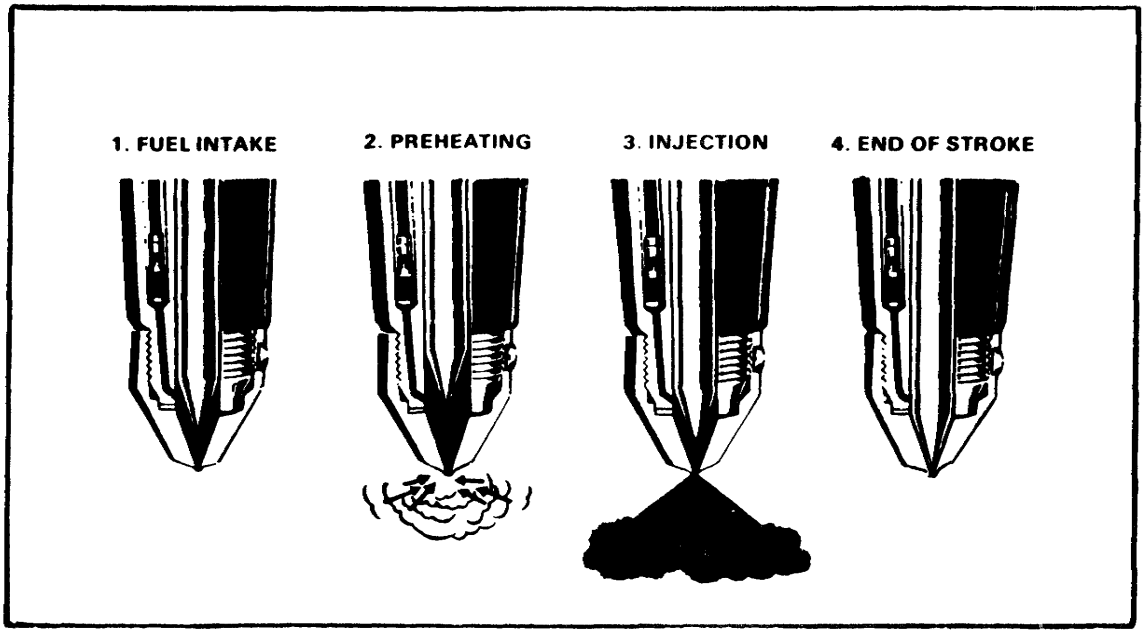


FIGURE 47. FUEL INJECTION STAGES



Learning Event 2
TROUBLESHOOTING THE ROOSA MASTER FUEL SYSTEM

The information covered in this learning event is applicable to any item of equipment that uses a Roosa Master fuel system on the engine. Component location may vary depending on equipment used. Use the appropriate technical manual for the exact component location. The Allis-Chalmers Model 645M scoop loader will be used throughout the remainder of this lesson. The applicable manual is TM 5-3805-239-12.

We will begin this learning event by locating and identifying the components of the fuel system. In order to troubleshoot the fuel system, you must make sure that you can identify, locate, and state the function of each component.

The main components of the fuel system include the fuel tank, fuel sediment bowl, hand primer pump, fuel filters, transfer pump, fuel injection pump, fuel injection nozzles, and the fuel lines. Two systems comprise the overall fuel system for the engine. A low pressure system brings the fuel from the tank through the sediment bowl, primer pump, and fuel filters, to the transfer pump, and the return lines to the tank. The high pressure system includes the fuel injection pump, fuel lines to the injectors, and the injectors. Figure 48 on page 82 shows the fuel system in order of flow.

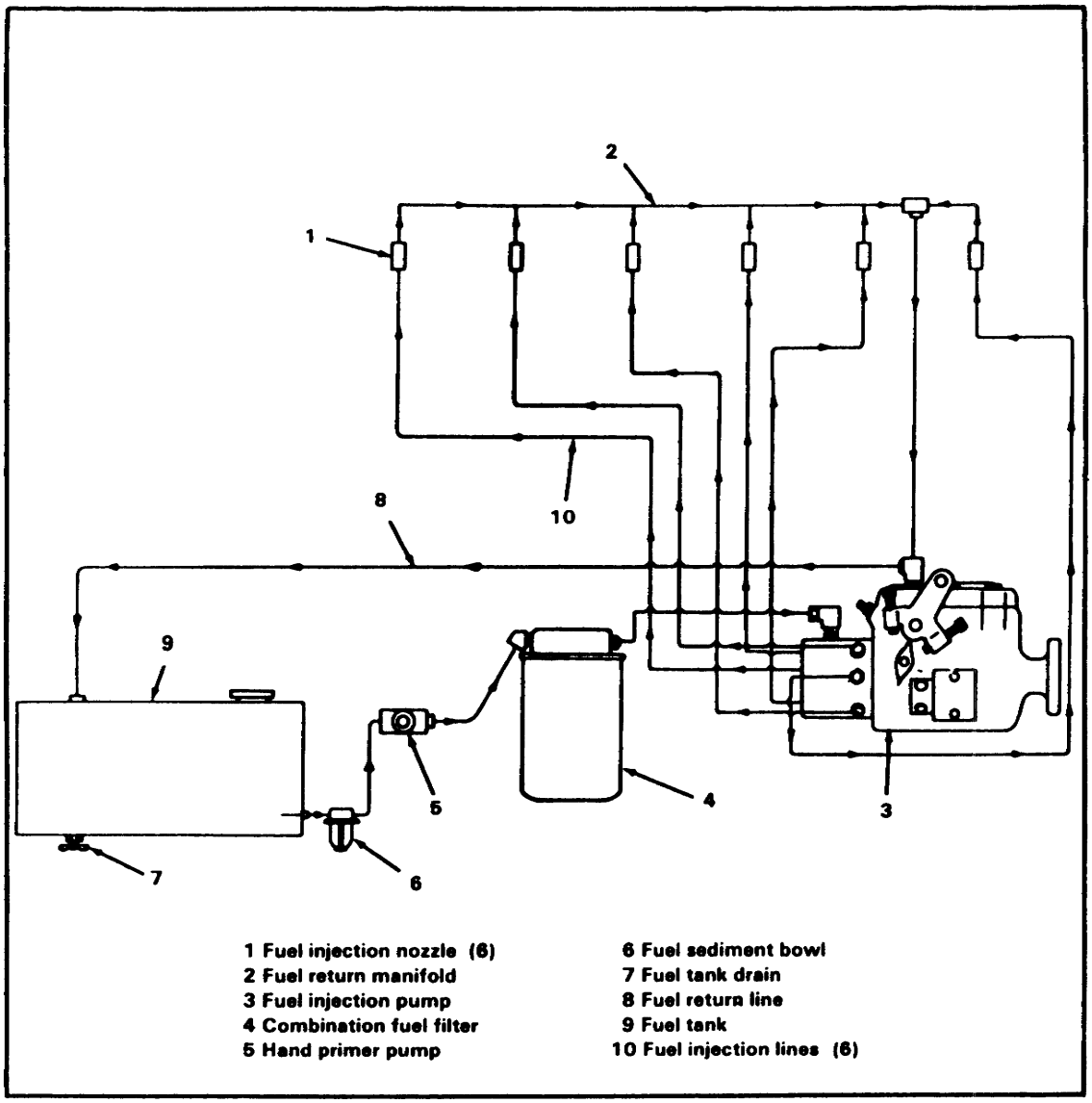
Fuel Tank. The fuel tank is mounted at the rear of the loader beneath the radiator. The filler pipe extends through the radiator grill for access in filling the tank. A fuel tank drain is located on the bottom of the tank for draining purposes.

Fuel Sediment Bowl. Follow the fuel supply line from the fuel tank to the fuel sediment bowl. It is mounted on a bracket along the frame on the left side of the engine near the fuel injection pump. This component acts as a primary fuel filter.

Hand Primer Pump. The hand primer pump is mounted on the same bracket as the sediment bowl. It is used to prime the system after replacement of the fuel filter or cleaning of the fuel sediment bowl.

Secondary Fuel Filter. Sometimes called a combination fuel filter is located on the left side of the engine. The secondary filter provides additional cleaning of the fuel before it enters the fuel pump.

FIGURE 48. FUEL SYSTEM SCHEMATIC DIAGRAM



Fuel Injection Pump. The Roosa Master fuel pump is mounted at the front of the engine on the left side. The function of the fuel pump is to draw fuel from the tank and send fuel to the injectors under high pressure.

Fuel Injection Lines. From the fuel pump, the pressurized fuel flows through individual lines to each injector. Remember, these lines carry high pressure fuel to each injector.

Fuel Injection Nozzle. Each cylinder is supplied with fuel through an injection nozzle. The high pressure fuel enters through the nozzle ports and is atomized instantly within the cylinder to combine with the air to provide the explosive mixture.

Fuel Return Line. The fuel return line carries unused fuel from the injectors back to the tank.

You are troubleshooting the scoop loader fuel system and determine that there is a loss of fuel to the fuel pump. Now you must check the following components in the low pressure tank system to correct the problem. The first components that should be inspected are the fuel tank and shutoff valve.

Check the tank and shutoff valve for leakage. Make sure the valve is in the open position and that the tank has been filled with fuel. Check all fuel lines from the tank to the Roosa Master pump for leakage or damage that could cause the loss of fuel. Check the primary filter for a cracked or leaking sediment bowl, damaged gaskets, or leaks at the fuel Line fittings.

Check the hand primer for external leaks and make sure the pump is pushed into the pump body and locked in place by the pump bail. Check the secondary filter for leaks or a loose bleed screw. And finally, check the pump for leaking lines.

The next troubleshooting problem is a rough or erratic running engine. Leaking fuel lines or air in the fuel lines will cause a rough running engine. Because you have already checked the low pressure side of the system, this inspection will cover the fuel flow from the Roosa Master pump to the injectors. Check the pump and high pressure fuel outlet fittings for leaks or damage. Check each injector for signs of leakage. Start the engine to check each injector for proper operation. Loosen each injector inlet connector one at a time in sequence and wrap a rag around the fitting to prevent fuel spray. If the engine runs worse with number one injector line loose, that is not the faulty injector. Continue checking until you find the injector that <u>does not</u> cause a change in engine operation with the inlet line loose. Check the fuel injectors.

If the scoop loader engine fails to start and you have checked the fuel tank for proper servicing, you should check the electrical solenoid connections on the Roosa Master pump. If the solenoid does not open, the fuel will not flow into the pump. Check the solenoid wire for proper installation, cleanliness, and security.

Another problem you my have with the scoop loader is that the engine stops frequently. This is an idle speed problem. See Learning Event 3 of this lesson for low and high idle speed adjustment.

Learning Event 3
COMPONENT ADJUSTMENT, REPAIR, OR REPLACEMENT

During this learning event, you will be shown how to adjust, repair, or replace components of the Roosa Master fuel system. All work described will be in accordance with the maintenance allocation chart shown in Figure 49.

FIGURE 49. MAINTENANCE ALLOCATION CHART

(1)	(2)	(3) Maintenance Functions											(4)	(5)
		A	B	C	D	E	F	G	H	I	J	K		
Group No.	Functional Group	Inspect	Test	Service	Adjust	Align	Calibrate	Install	Replace	Repair	Overhaul	Rebuild	Tools and Equipment	Remarks
03	FUEL SYSTEM:													
0301	Fuel Injector:		F		O				O					
	Injector, fuel									F		D	1	
0302	Fuel Pumps:													
	Pump, fuel								F			D		
0304	Air Cleaner:													
	Cleaner, Air			O					O	O				
0305	Turbocharger:													
	Turbocharger								O			H		
	Hose & Clamps	O							O					
0306	Tanks, Lines, Fittings:								O					
	Tank, fuel	O		O					F	F				
0309	Fuel Filters													
	Filters, fuel			O					O					
0311	Engine Starting Aids:													
	Aids, starting			O					O					
0312	Accelerator, Throttle Controls:													
	Control, accelerator throttle				O				O					

Key

C - Operator or Crew
O - Organizational Maintenance
F - Direct Support Maintenance
H - General Support Maintenance
D - Depot Maintenance

FUEL FILTER ELEMENT

Replacement and Installation. Refer to Figure 50.

1. Remove the vent plug.
2. Remove the screw and gasket.
3. Inspect the gasket and replace if necessary.
4. Remove the retaining ring.
5. Remove and discard the element.
6. Remove the body. Check the rubber seat and spring. Clean the body with a clean cloth and cleaning solvent.
7. Remove the drain plug and drain the fuel filter before servicing.

NOTE: After installing the new fuel filter element, vent the system by loosening the vent plug and pumping the fuel primer until the flow of fuel around the vent plug is free of air bubbles. Tighten the vent plug.

NOTE: Service the fuel filter every 500 hours.

FUEL SEDIMENT BOWL

Replacement and Installation. Refer to Figure 51.

1. Loosen the bowl nut and move the bail to one side.
2. Remove and empty the fuel sediment bowl.
3. Clean the bowl with a clean cloth.
4. Check the bowl gasket and replace if necessary.
5. Install the fuel sediment bowl and secure with the bail and screw.
6. Vent the fuel system.

FIGURE 50. FUEL FILTER SERVICE

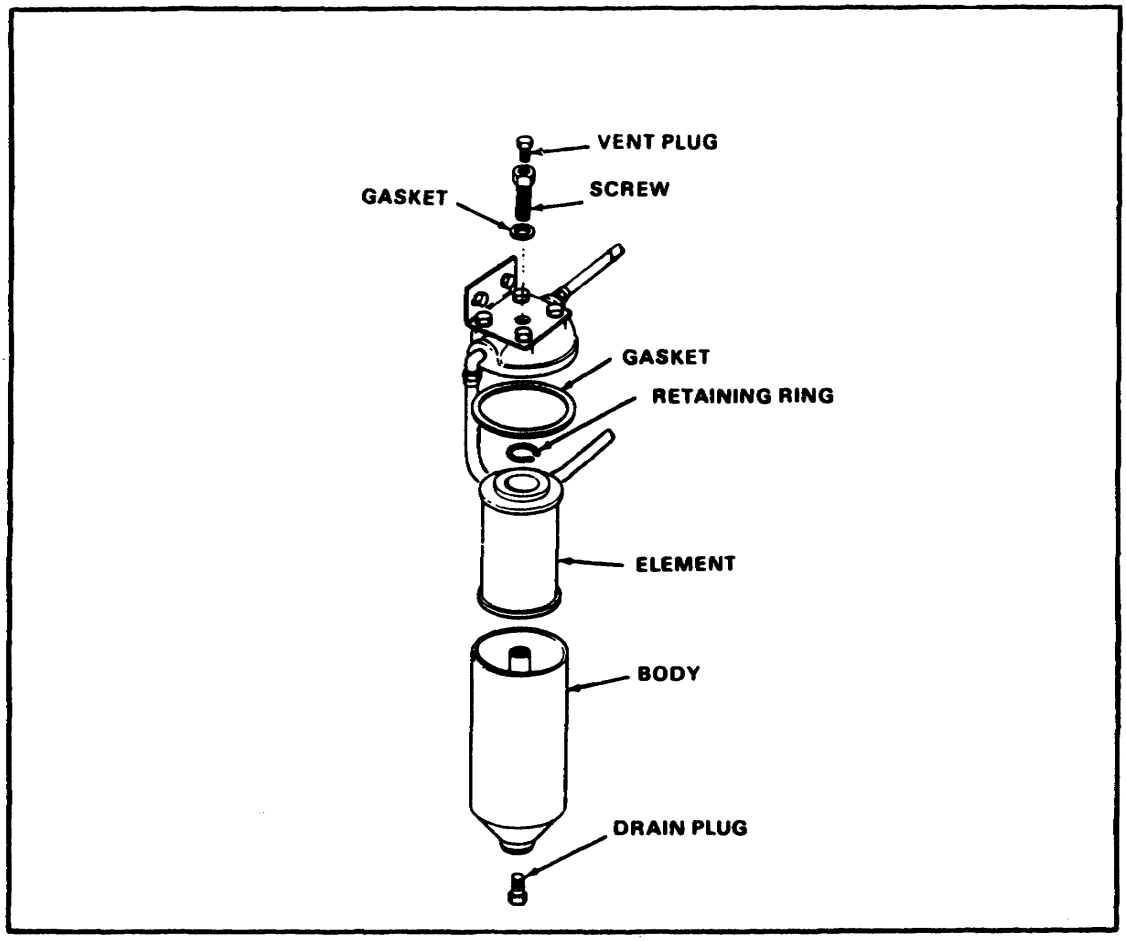
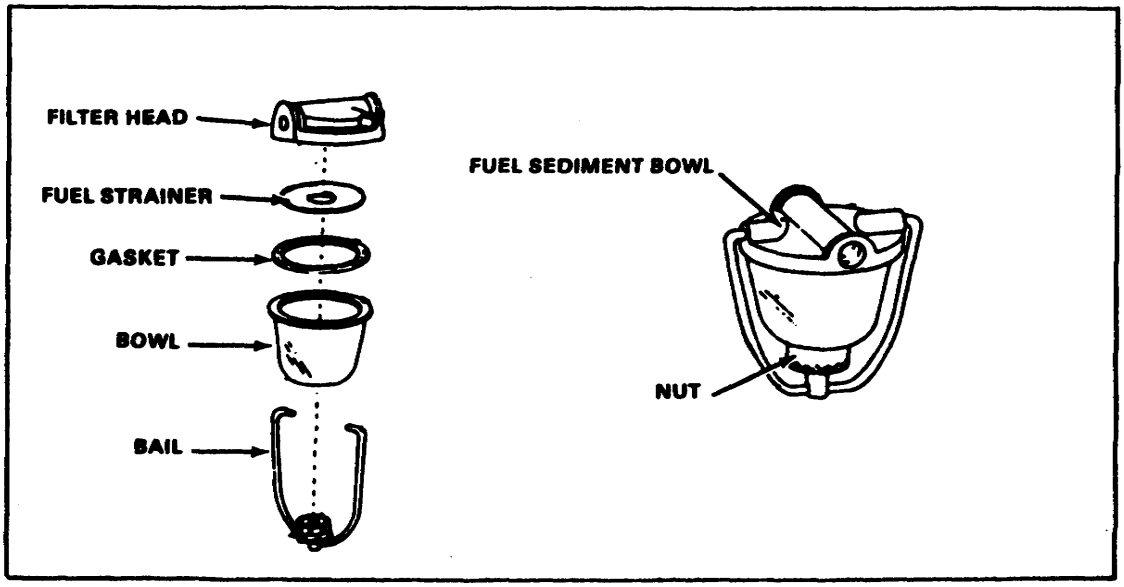


FIGURE 51. FUEL SEDIMENT BOWL



LOW PRESSURE FUEL SYSTEM

Venting and Priming. After replacement of the fuel filter or cleaning the sediment bowl, vent and prime the fuel system as follows:

1. Loosen the vent plug in the top of the fuel filter.
2. Remove the screw and move the bail on the fuel primer pump to one side.
3. Move the primer pump plunger back and forth in a pumping motion to pump the fuel through the fuel filter.
4. Continue pumping until the fuel filter has been filled with fuel and the flow of fuel around the vent plug is free of air bubbles.
5. Tighten the vent plug securely into the top of the fuel filter.
6. Install the bail an the primer pump and secure with the locking screw.

HIGH PRESSURE FUEL SYSTEM

Venting and Priming. If fuel lines have been removed, the engine has run out of fuel, or if the loader has not been operated for sometime, it may be necessary to vent the high pressure system to facilitate starting the engine. The correct venting procedures are as follows:

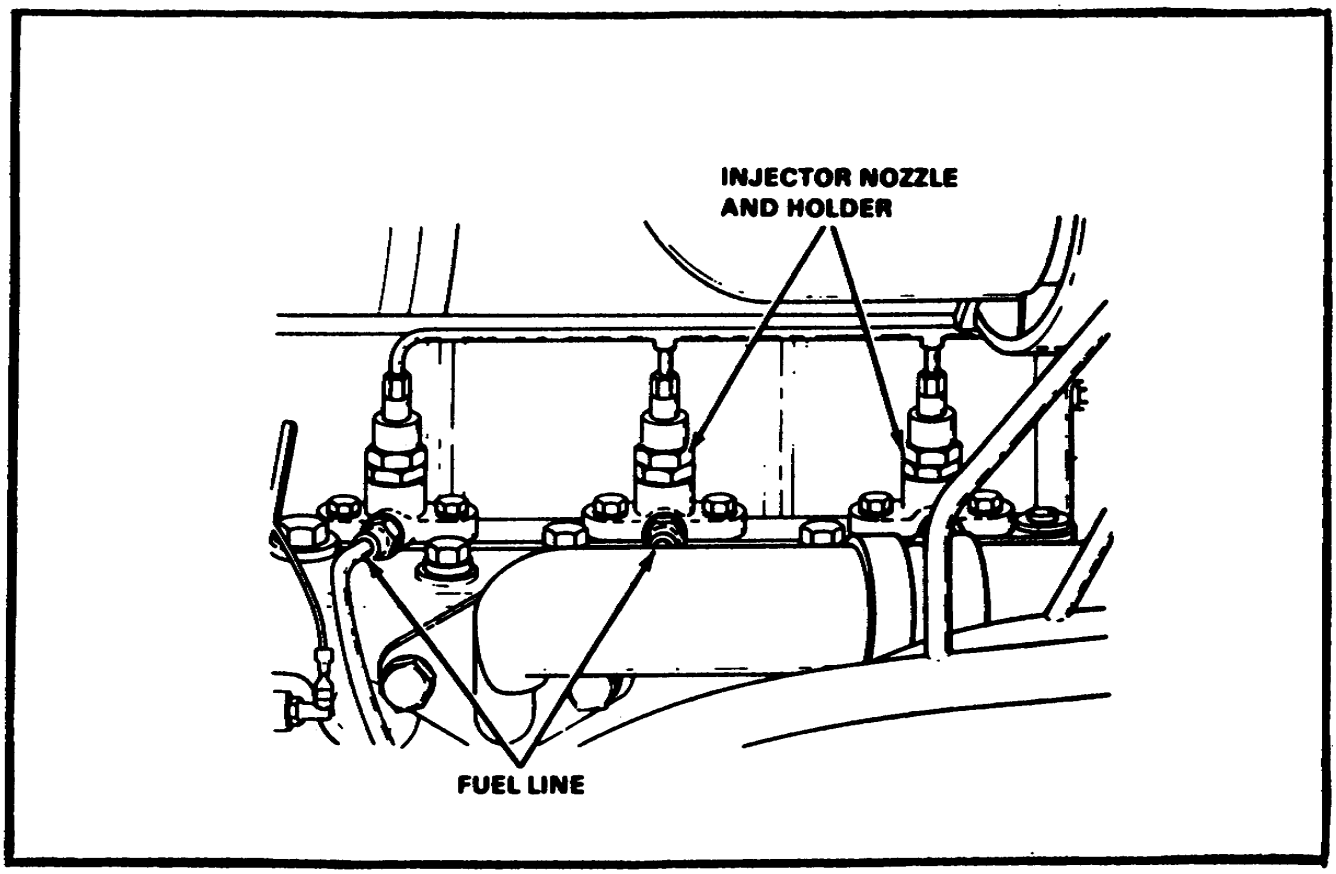
1. Disconnect the fuel lines at all six nozzles and holders (Figure 52).
2. Depress the accelerator and crank the engine.
3. Observe the fuel lines and check to see that the fuel flows from each line with no air bubbles present. Discontinue cranking.
4. Connect the lines to the nozzle holders and tighten securely.

HAND PRIMER PUMP AND SEDIMENT BOWL

Removal and Installation.

1. Disconnect the fuel lines from the sediment bowl and primer pump.

FIGURE 52. FUEL SYSTEM VENTING AND PRIMING



2. Remove the two screws, nuts, and lock washers securing the hand primer pump to the bracket.

3. Remove the hand primer pump and sediment bowl from the bracket.

4. Remove the sediment bowl from the fitting in the hand primer pump.

5. To install the hand primer pump and sediment bowl reverse the procedures above.

THROTTLE LINKAGE

Removal and Installation. Refer to Figure 53.

1. Disconnect the two ball joints, and remove the clamp and rear rod.
2. Disconnect the two ball joints, and remove the front cod.
3. Remove the four Jam nuts and lock washers, two lever bearings, and cross over lever.
4. Remove the two cotter pins, the pivot pin, and the accelerator.
5. Remove the pedal spring and limit control rod.
6. Install the throttle linkage in reverse order of removal.

Adjustment.

1. With the rear rod disconnected from the speed control lever, start the engine, rotate the low speed adjustment screw in or out to set the low idle speed. Rotate the high speed adjustment screw to set the high idle speed.
2. Connect the rear rod to the speed control lever. Adjust the length of the rod to have the low speed adjustment screw against the lever stop when the accelerator is fully released.

COLD WEATHER STARTING AID

Removal. Refer to Figure 54.

1. Remove the two screws and disconnect the control cable. Remove the clamp from the top of the hydraulic tank and control knob and remove the cable.

FIGURE 53. THROTTLE LINKAGE REMOVAL AND INSTALLATION

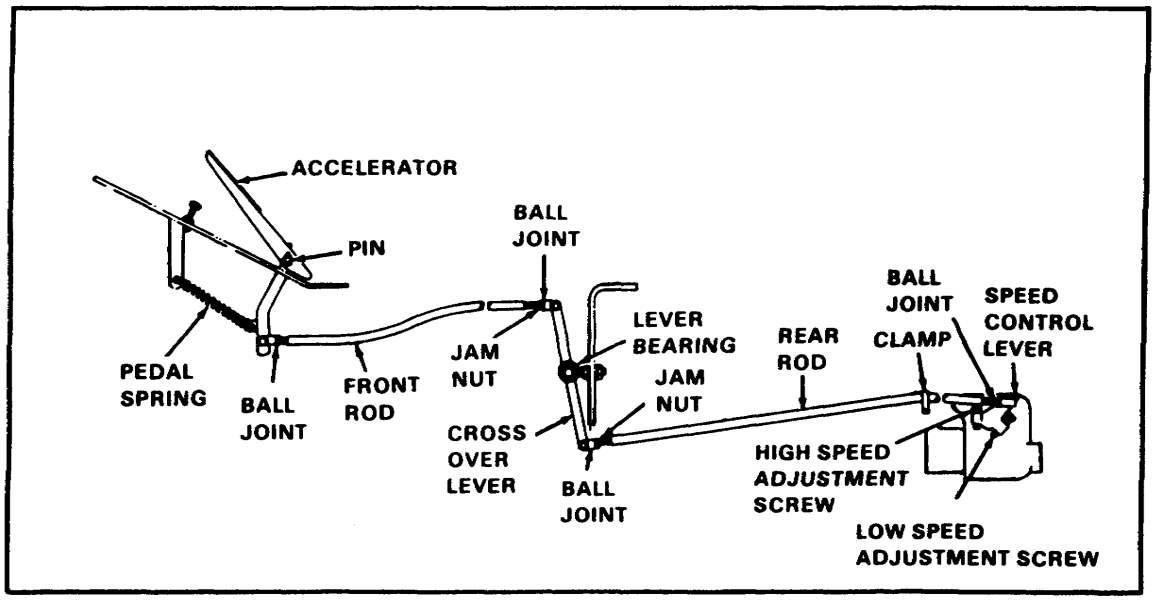
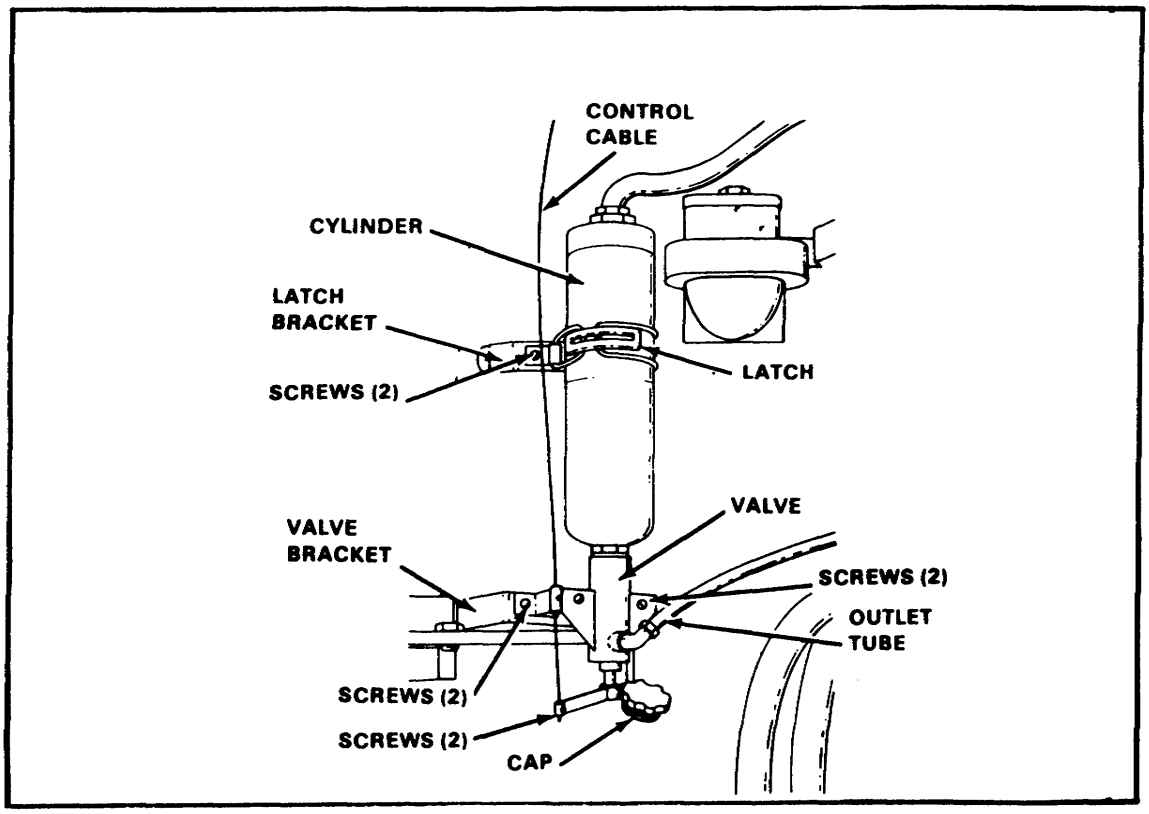


FIGURE 54. COLD WEATHER STARTING AID



2. Disconnect the latch and unscrew the cylinder from the valve. Install the cap on the valve.

3. Disconnect the outlet tube from the valve and disconnect the injector from the manifold. Install the plug in the manifold after removing the injector.

4. Remove the two screws and nuts and valve from the valve bracket.

5. Remove the two screws and nuts and valve bracket.

6. Remove the two screws and nuts and latch bracket.

FUEL FILTER

Removal and Installation. Refer to Figure 55.

1. Disconnect the fuel lines from the fuel filter.

2. Remove the four screws and lock washers securing the fuel filter to the bracket.

3. Remove the fuel filter from beneath the bracket.

FUEL TRANSFER STRAINER

Removal and Installation. Refer to Figure 56.

1. Disconnect the filter to the pump inlet line, and remove the elbow.

2. Remove the end plate sleeve and strainer.

3. Clean strainer, and install the strainer and end plate sleeve in the pump.

4. Install the elbow and connect the filter to the pump inlet line.

5. Prime and vent the fuel system if necessary.

FIGURE 55. FUEL FILTER REMOVAL AND INSTALLATION

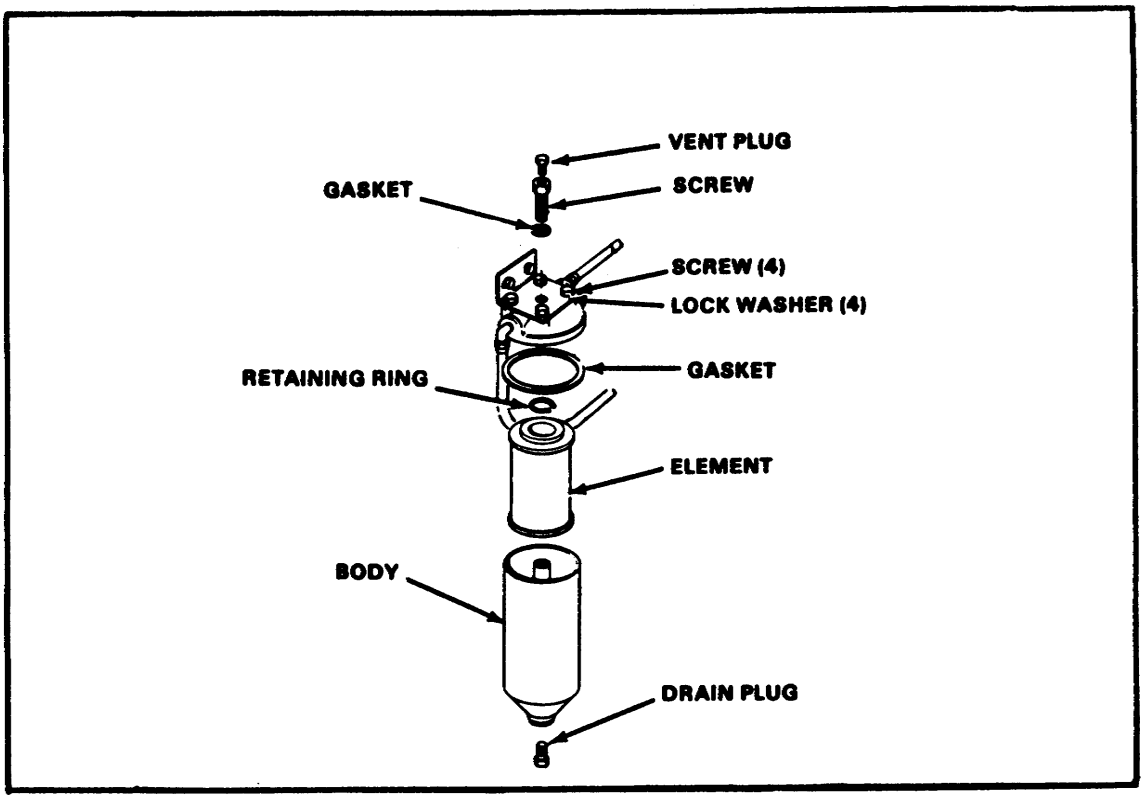
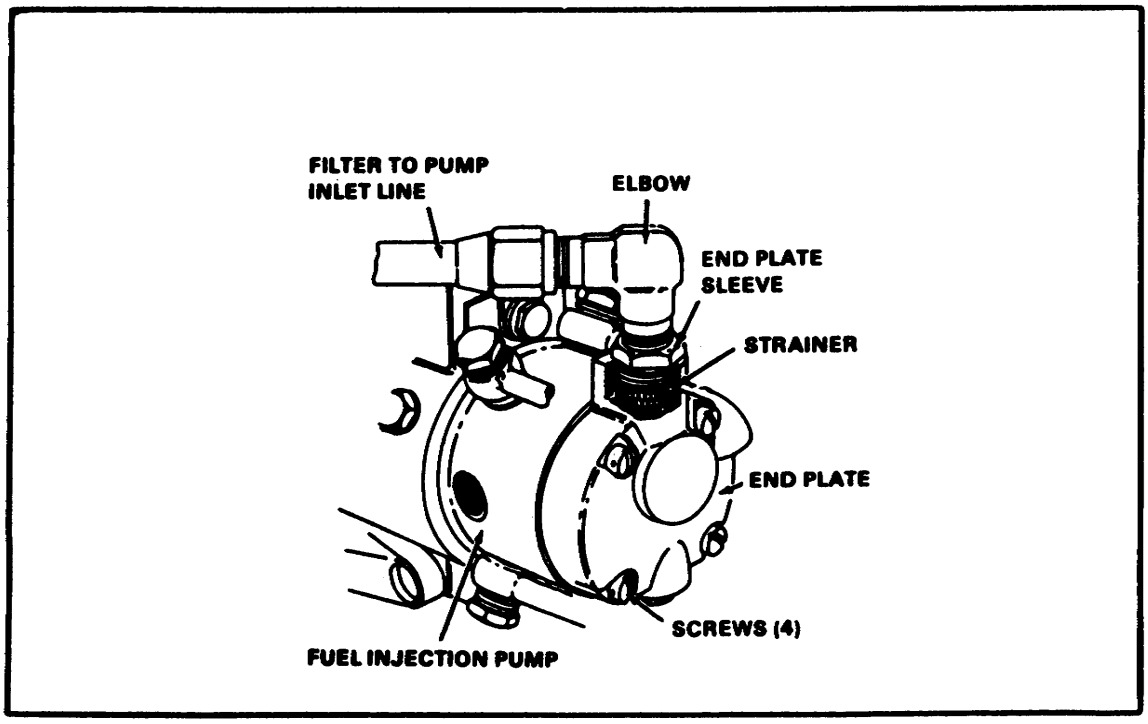


FIGURE 56. FUEL TRANSFER PUMP



LESSON 3

REVIEW EXERCISE

Check your understanding of Lesson 3 by completing this review exercise. Try to complete it without looking back at the lesson. When you have completed the exercise, turn to the solutions and check your responses. If you do not understand a solution, go back and restudy the section in the lesson where the information is given.

1. The basic Roosa Master fuel pump has _____ main rotating members.

   A. Three

   B. Four

   C. Five

   D. Six

2. The distributor injection system is classed as a _____ pressure system.

   A. Low

   B. High

   C. Intermediate

   D. High/low

3. A _____ valve in the lower end of the injector body prevents compression pressure from blowing fuel back and filling the lines with air.

   A. Check

   B. Drain

   C. Pressure release

   D. Bypass

4. _____ fuel systems comprise the overall fuel system for the engine.

   A. Two

   B. Three

   C. Four

   D. Five

5. The _____ provides high pressure fuel for injection.

   A. Fuel transfer pump

   B. Fuel injection pump

   C. Hand primer pump

   D. Injector nozzle

6. The _____ draws fuel from the tank through the filters to the injection pump.

   A. Hand primer

   B. Fuel transfer pump

   C. Fuel injection pump

   D. Turbocharger

7. The fuel injection pump, fuel lines to the injectors, and the injectors comprise the _____ pressure fuel system.

   A. High/low

   B. High

   C. Low

   D. Intermediate

8. The tank, sediment bowl, primer pump, fuel filters, transfer pump, and the fuel return line comprise the _____ pressure fuel system.

   A. High/low

   B. High

   C. Low

   D. Intermediate

9. If the scoop loader fails to start, the most likely cause is _____.

   A. Bad connection to the solenoid

   B. Idle speed too low

   C. Air in the fuel system

   D. Improperly timed fuel injection pump

10. If the engine on a scoop loader stops frequently, _____ is the most likely cause.

   A. No fuel

   B. Low idle speed

   C. Cylinder cutting out

   D. Loss of compression

LESSON 3

REVIEW EXERCISE SOLUTIONS

1. A (page 77)
2. D (page 81)
3. A (page 79)
4. A (page 81)
5. B (page 82)
6. B (page 77)
7. B (page 81)
8. C (page 81)
9. A (page 83)
10. B (page 84)

Lesson 4

PRESSURE-TIMED FUEL SYSTEMS

TASK

Describe the correct procedures for the adjustment, repair, or replacement of components of the pressure time fuel systems.

CONDITIONS

Given information describing the correct procedures for the maintenance of pressure time fuel systems, an ACCP Examination Response Sheet, and a No. 2 pencil.

STANDARDS

You are expected to demonstrate competency of the task skills and knowledge by responding correctly to 75 percent of the examination questions pertaining to this lesson.

Learning Event 1
SYSTEM COMPONENTS AND OPERATION

The pressure-timed injection system (Figure 57) has a metering system that is based on the principle that the volume of liquid flow is proportional to the fluid pressure, the time allowed to flow, and the size of the passage the liquid flows through. The operation of the system is as follows:

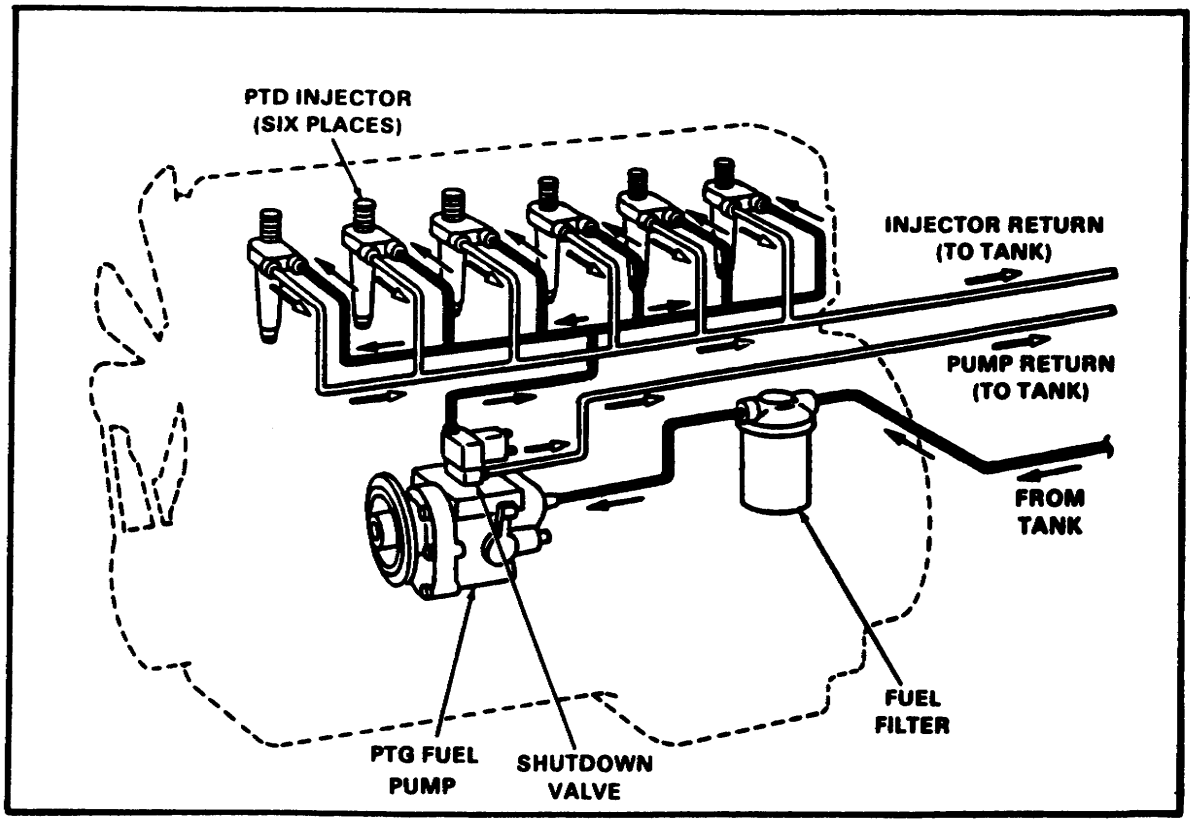
1. A fuel tank with a vented filler cap stores the fuel supply.

2. Fuel is supplied from the tank to the pressure-timed gear (PTG) pump through the delivery line. An inline filter is placed in series in the line to trap foreign matter and moisture.

3. A return line from the PTG pump to the fuel tank is provided to bleed off excess fuel so that operating pressures can be regulated.

4. The PTG pump delivers controlled amounts of fuel to the pressure-timed delivery (PTD) injectors.

FIGURE 57. PRESSURE-TIMED INJECTION SYSTEM



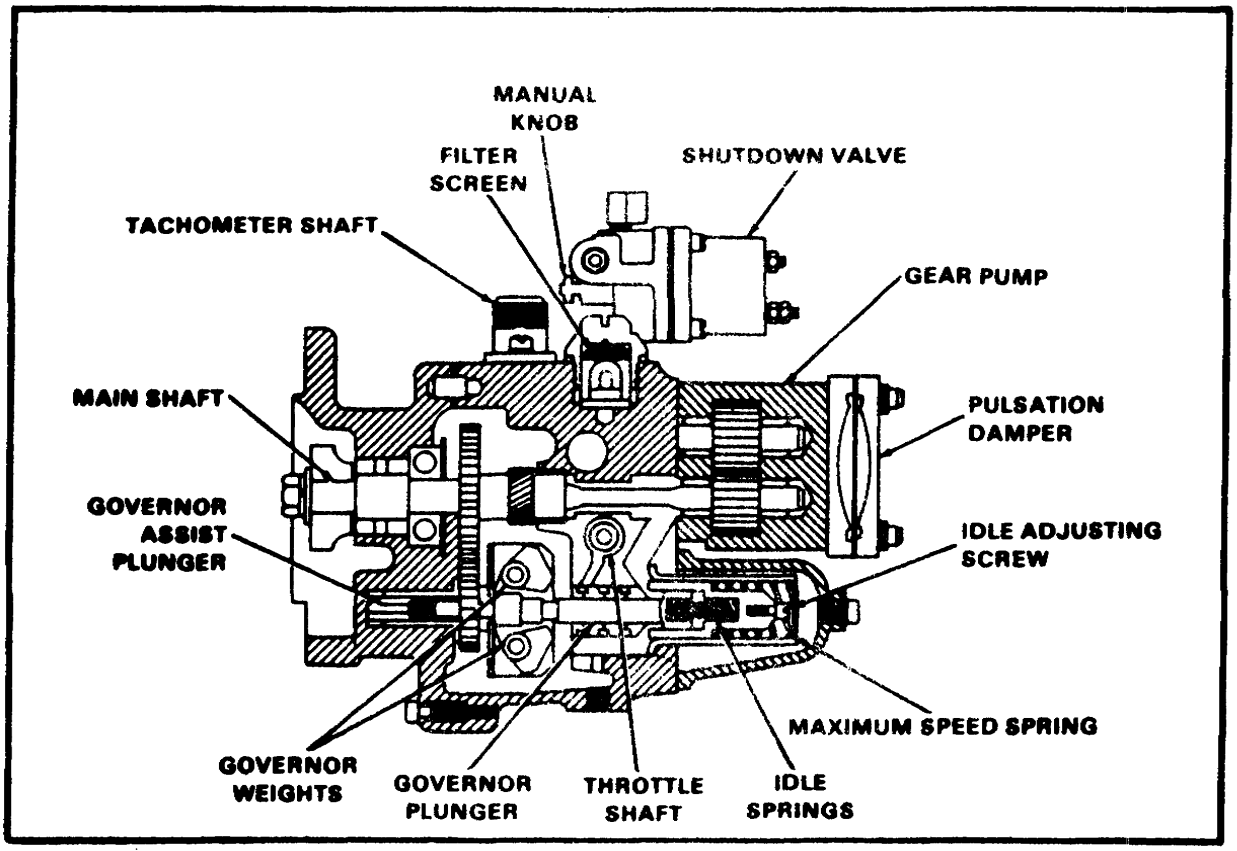
5. Delivery of fuel to the PTD injectors is through a common rail type delivery line.

6. A common rail type return line connects the PTD injectors to the fuel tank so that excess fuel may be delivered back to the fuel tank.

PTG Injection Pump (Figure 58). The PTG pump is driven by the engine at a one-to-one speed ratio. The pump contains four main components. These four components and their respective operations are as follows:

1. The gear type pump draws fuel from the supply tank and forces it through the pump filter screen to the governor. It is driven by the pump main shaft and picks up and delivers fuel throughout the fuel system. A pulsation damper mounted to the gear pump contains a steel diaphragm that absorbs pulsations and smoothes fuel flow through the fuel system. From the gear pump, fuel flows through the filter screen to the governor screen. The PTG pumps are equipped with a bleed line that is attached to the engine injector return line or to the tank. This prevents excessive fuel temperature within the fuel pump by using the surplus fuel as a coolant. The bleed line functions primarily when the pump throttle is set at

FIGURE 68. PRESSURE-TIMED GEAR INJECTION PUMP



idle speed, but gear pump output is high due to engine operating speed, as occurs during downhill operation. A special check valve and/or fitting is used in the gear pump to accomplish the bleed action.

2. The governor controls the flow of the fuel from the gear pump, as well as the maximum and idle speeds. The mechanical governor is actuated by a system of springs and weights and has two functions. First, the governor maintains sufficient fuel for idling with the throttle control in idle position; second, it will restrict fuel to the injectors above maximum rated revolutions per minute (rpm). The idle springs (in the governor spring pack) position the governor plunger so the idle fuel port is opened enough to permit passage of fuel to maintain engine idle speed. During operation between idle and maximum speeds, fuel flows through the governor to the injector in accordance with the engine requirements, as controlled by the throttle and limited by the size of the idle spring plunger counterbore on the PTG fuel pumps. When the engine reaches governed speed, the governor weights move the governor plunger, and fuel flow to the injectors is restricted. At the same time, another passage opens and dumps the fuel back into the main pump body. In this manner, engine speed is controlled and limited by the governor, regardless of throttle position. Fuel leaving the pump flows through the shutdown valve, inlet supply lines, and into the injectors.

3. The throttle provides a means for the operator to manually control engine speed above idle as required by varying operating conditions of speed and load. In the PTG pump, fuel flows through the governor to the throttle shaft. At idle speed, fuel flows through the idle port in the governor barrel, past the throttle shaft. To operate above idle speed, fuel flows through the main governor barrel port to the throttling hole in the shaft.

4. The fuel shutdown valve is located on top of the fuel pump. It shuts off fuel to the injectors. With the master switch on, the solenoid opens the valve. With the switch off, the spring-loaded valve returns to the off position. In case of an electrical failure, rotation of the manual knob clockwise will permit fuel to flow through the valve. The knob is located on the front of the valve.

PTD Injectors (Figure 59). A PTD injector is provided at each engine cylinder to spray the fuel into the combustion chambers. The PTD injectors are of the unit type, operated by an engine-based camshaft. Fuel flows from a connection at the top of the fuel pump shutdown valve through a supply line into the lower drilled passage in the cylinder head at the front of the engine. A second drilling in the head is aligned with the upper injector radial groove to drain away excess fuel. A fuel drain at the flywheel end of the engine allows return of the unused fuel to the fuel tank. There are four phases of injector operation.

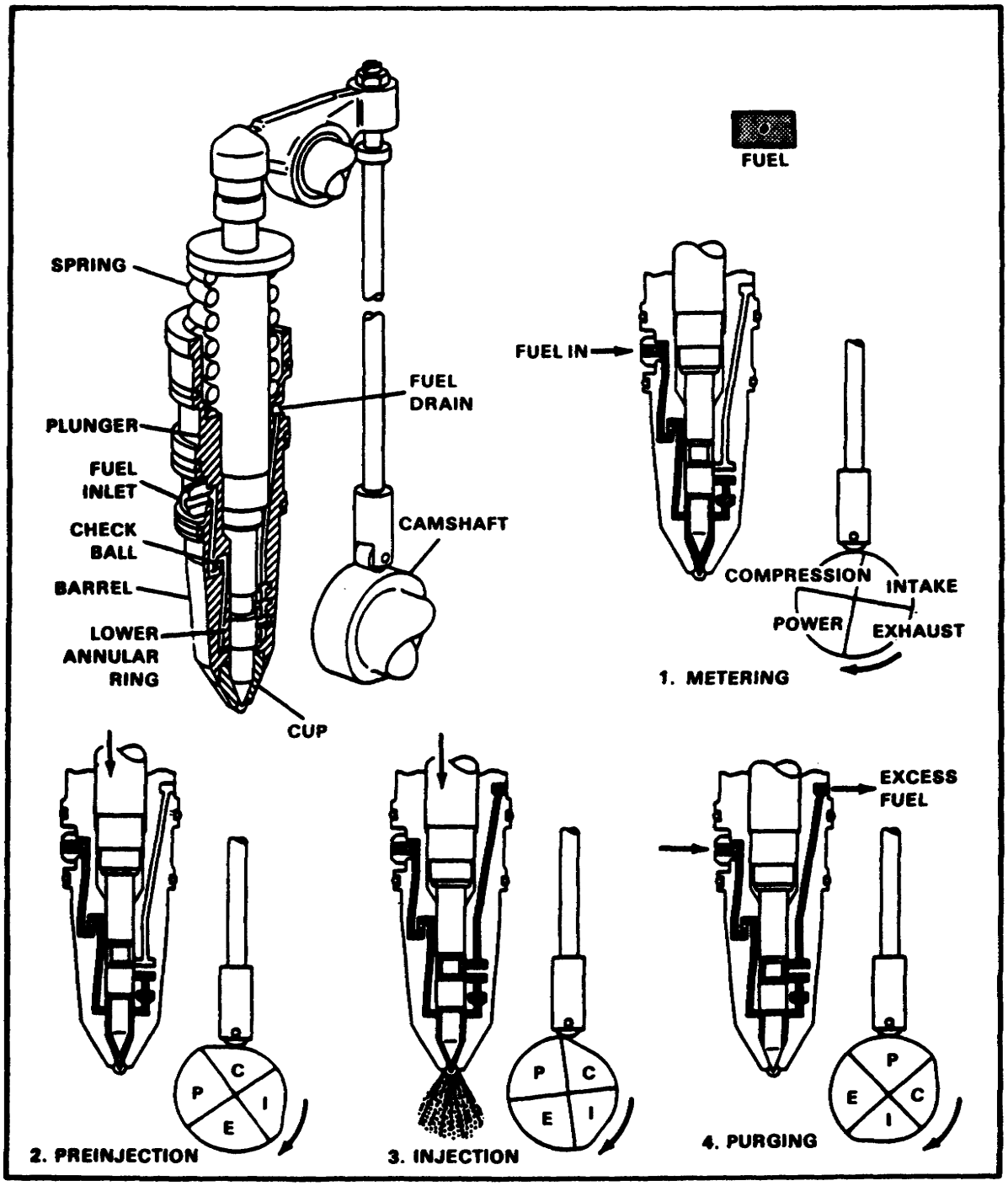
1. Metering (1, Figure 59). This phase begins with the plunger Just beginning to move downward and the engine is on the beginning of the compress ton stroke. The fuel is trapped in the cup, the check ball stops the fuel from flowing backwards, and the fuel begins to be pressurized. The excess fuel flows around the lower annular ring, up the barrel, and is trapped there.

2. Preinjection (2, Figure 59). The plunger is almost all the way down, the engine is almost at the end of the compression stroke and the fuel is being pressurized by the plunger.

3. Injection (3, Figure 59). The plunger is almost all the way down, the fuel is injected out the eight orifices, and the engine is on the very end of the compression stroke.

4. Purging (4, Figure 59). The plunger is ail the way down, injection is finished, and the fuel is flowing into the injector, around the lower annular groove, up a drilled passageway in the barrel around the upper annular groove, and out through the fuel drain. The cylinder is on the power stroke. During the exhaust stroke, the plunger moves up and waits to begin the cycle all over again.

FIGURE 59. PRESSURE-TIMED DELIVERY INJECTOR OPERATION



Learning Event 2
TROUBLESHOOTING THE PRESSURE-TIMED FUEL SYSTEM

The information covered in this learning event is applicable to any item of equipment that uses a pressure time fuel system. Component location may vary depending on equipment used. Use the appropriate technical manual for the exact component location. The Bucyrus-Erie Model 22BM crawler crane shovel will be used throughout the remainder of the lesson. The applicable manual is TM 5-3810-289-12.

We will begin this learning event by locating and identifying the components in the fuel system.

The first item to locate and inspect is the fuel tank and fuel cap strainer. The fuel tank is located at the back of the cab and directly below the engine. Inspect the tank for leaks and loose mounting bolts or fuel line connections. Tighten as necessary. Check the tank cap strainer for cleanliness and be sure the cap vent is open. Have the operator service the fuel tank and fuel cap strainer as required.

Follow the fuel supply lines from the fuel tank to the primary fuel filter. Check for leaks and crushed or damaged places on the fuel lines. All leaking or damaged lines must be replaced.

Next locate the primary and secondary fuel filters. They are located on the left side of the engine. The fuel flows into the primary filter first. The primary and secondary filters have a common filter head and a drain valve in each filter body to drain any water or dirt which has been filtered from the fuel.

After the fuel leaves the secondary filters, it continues through a flexible line to the fuel transfer pump which is mounted on the left side of the engine just forward of the filters. The transfer pump has a filter screen which should be checked for signs of leakage and will require normal servicing.

From the transfer pump, the pressurized fuel flows into the fuel inlet manifold which is mounted on the left side of the engine.

The manifold distributes fuel to each injector. Check the manifold lines for any damage or loose fittings.

From the inlet manifold the fuel flows through an inlet connector to the injector. The inlet tube connector contains a very small screen which acts as a final filter for the fuel entering the injector. The inlet connectors and injectors are located on the left side of the engine. Each injector and inlet connector fitting should be checked for security and leakage.

The fuel pump will always supply more fuel to the injector metering valve than will be used for engine operation. The drain or return manifold will return this excess fuel to the tank through a return line. The drain manifold is similar in appearance to the inlet manifold. The drain manifold should be checked for secure mounting and leakage.

Now that you are able to locate and state the function of each component in the fuel system, you are ready to move into troubleshooting procedures. We will start with some of the simple problems and continue to the more complex areas that you would encounter to keep equipment in good operating condition.

You are assigned to troubleshoot a piece of equipment that has a loss of engine power during operation. If the fuel line between the tank and the pump develops a leak, air will be drawn into the system. This will cause the engine to run rough and lose power.

You also notice that the engine misfires or surges, gaining or losing speed. These are also symptoms of an air leak in a fuel line. The corrective action for this problem is to check all fuel lines for any loose connections or cracks. Any loose lines should be tightened and cracked lines or fittings replaced.

A loss of engine power can be caused by fuel contamination. It is a good practice to drain a small amount of fuel from the tank and filters daily to remove any water or dirt particles which will contaminate the fuel system. Encourage your operators to drain these items daily.

A dirty filter will also restrict the flow of fuel causing a loss of power. If you think the fuel filters are clogged, this problem can be checked with the help of a vacuum gage. The gage should be connected between the outlet port of the filters and inlet port of the fuel pump with a tee fitting. Refer to the TM for a fuel flow problem for the particular engine you are working on.

Remember, the filter screens in the inlet connector screens must be cleaned and the filter elements replaced.

The next problem is an engine which is smoking excessively while idling or under a load. Excessive black smoke means that there is not enough air to burn all the fuel reaching the cylinders.

The component to check is the air cleaner. Rave the operator open the air cleaner and clean or replace it.

Learning Event 3
COMPONENT ADJUSTMENT, REPAIR, OR REPLACEMENT

During this learning event you will be shown how to adjust, repair, or replace components of a pressure time fuel system. All work described will be in accordance with the maintenance allocation chart shown in Figure 60.

FIGURE 60. MAINTENANCE ALLOCATION CHART

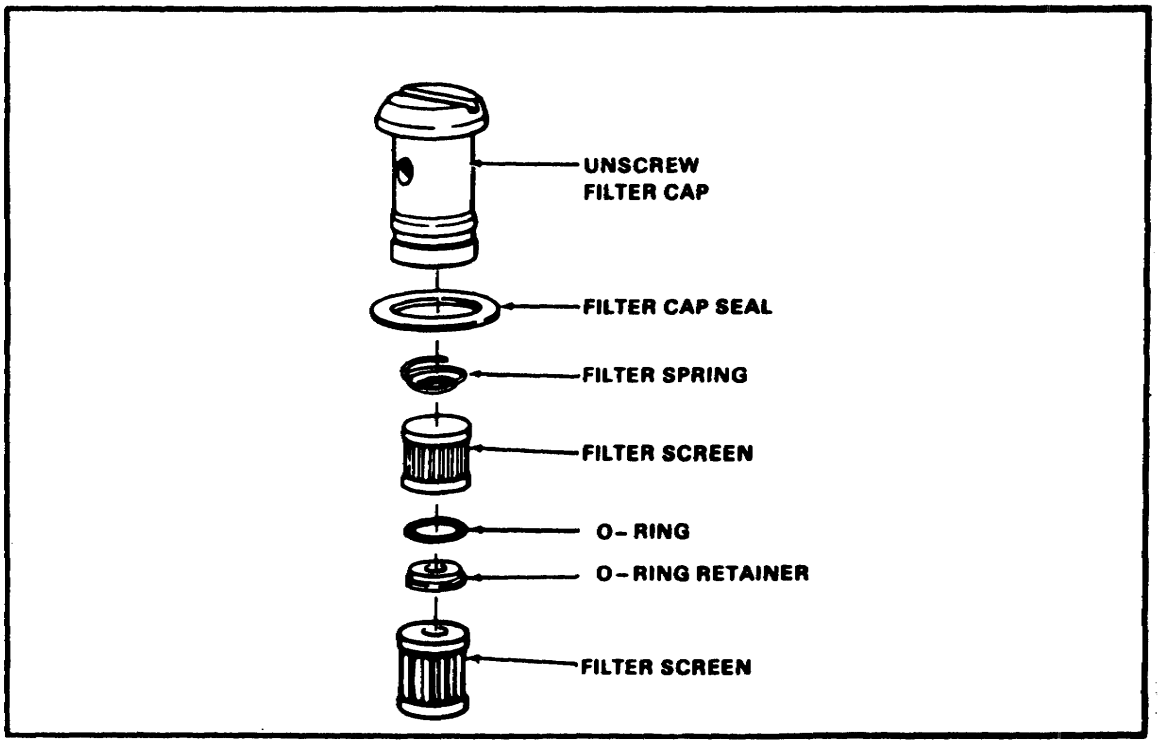
(1) Group No.	(2) Functional Group	(3) Maintenance Functions A Inspect	B Test	C Service	D Adjust	E Align	F Calibrate	G Install	H Replace	I Repair	J Overhaul	K Rebuild	(4) Tools and Equipment	(5) Remarks
03	FUEL SYSTEM													
0301	Fuel Injector		F		F				F	F				
0302	Fuel Pump		H	O	F				F	F	H	D		C
0304	Air Cleaner			C					O					
0306	Tanks, Lines, Fittings:													
	Lines, fittings, valve, shutoff	O							O					
	Strainer, cap, tank			C					O					
	Tank, fuel	C							O	F				
0308	Engine Speed Governor		O		O				O	F	H			
0309	Fuel Filters			O					O					D
0311	Engine Starting Aids:													
	Primer unit, lines, fittings								O	F				
0312	Throttle Control		O						O					
04	EXHAUST SYSTEM													
0401	Muffler and Pipes	O							O					

Key
C - Operator or Crew
O - Organizational Maintenance
F - Direct Support Maintenance
H - General Support Maintenance
D - Depot Maintenance

Fuel Pump Service. Refer to Figure 61.

1. Remove the filter screen cover on top of the main housing.
2. Lift the cap, spring, and filter screen assembly from the main housing.
3. Discard the fiber filter screens.
4. Clean the metal filter screens with approved solvent and blow dry with compressed air.

FIGURE 61. FUEL PUMP FILTER SCREEN SERVICE

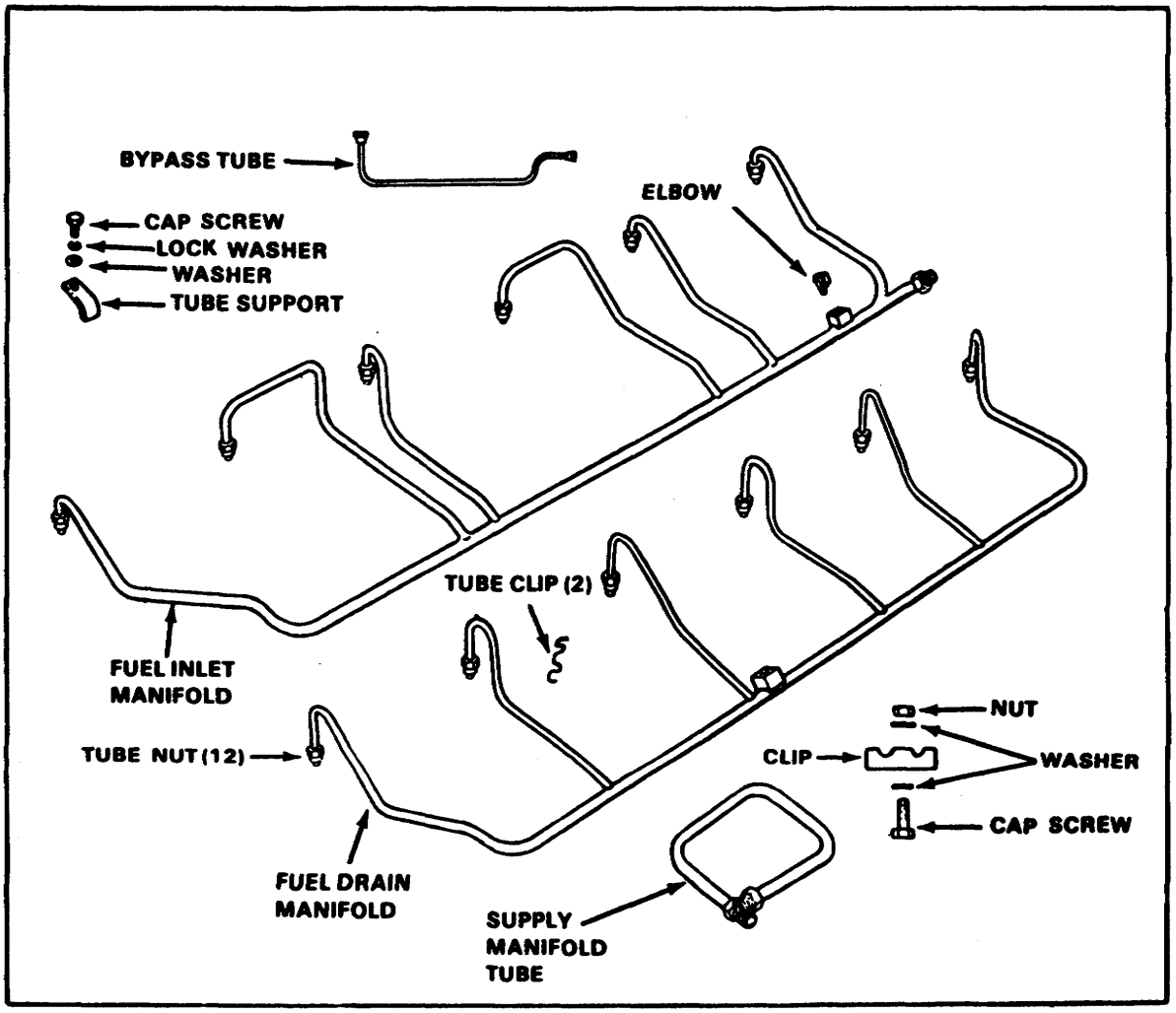


Fuel Lines and Fittings Replacement. Refer to Figure 62.

1. Remove the fuel inlet manifold by loosening the tube and nut at each injector. Remove the cap screw holding the tube support to the engine.

2. Remove the fuel drain manifold by loosening the tube nut at each injector. Remove the cap screw and clip holding the manifold to the engine.

FIGURE 62. FUEL LINES AND FITTINGS



Shutdown Valve Replacement. Disconnect the shutdown valve from the fuel pump by removing the cap screw, two lock washers, and two flat washers. Discard the used preformed packing. Install the shutdown valve, using new preformed packing. Reassemble in reverse order.

Air Cleaner Replacement.

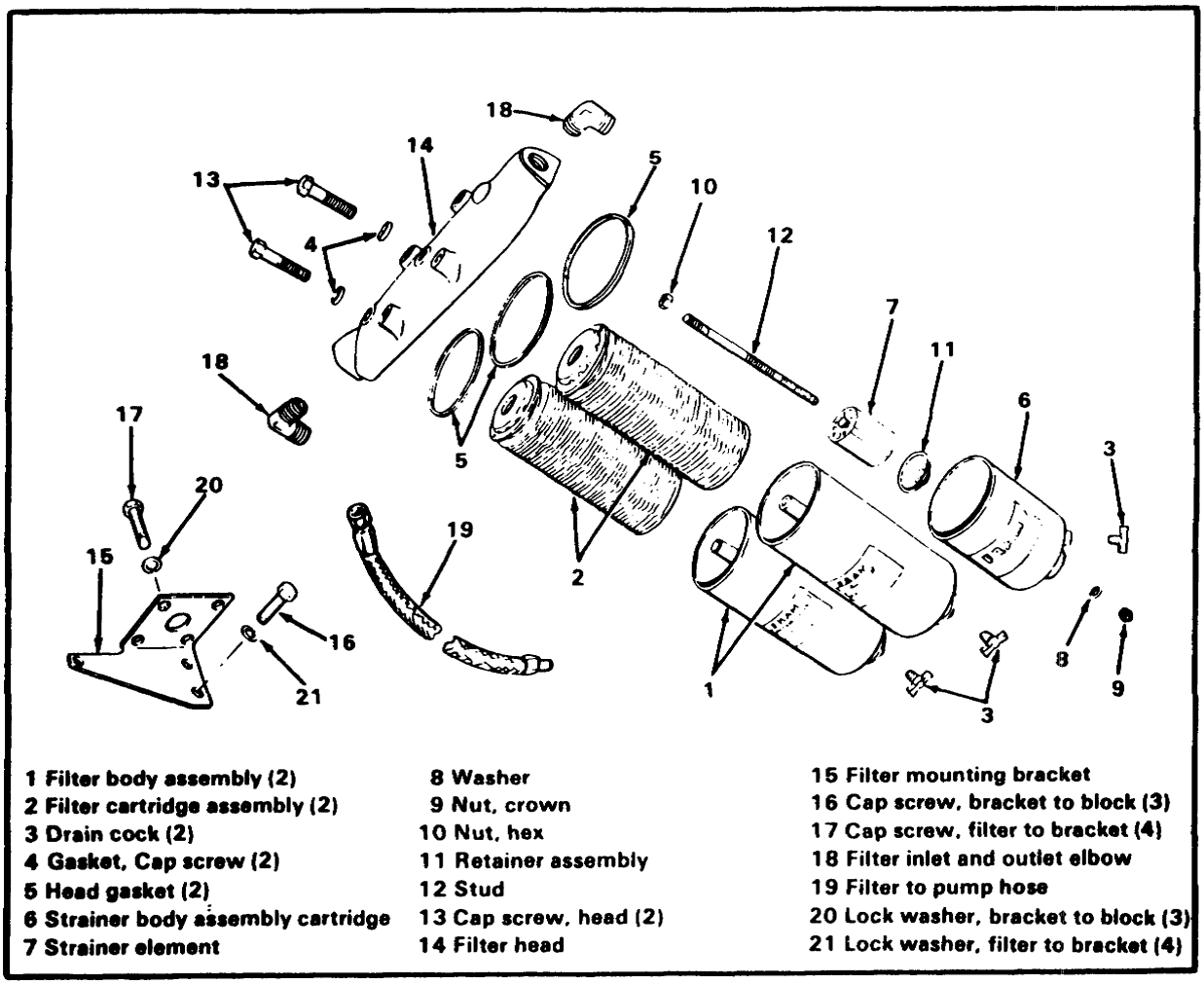
1. Remove the screw from each mounting ring.

2. Remove the screw from the outlet clamp.

3. Remove the air cleaner assembly.

Fuel Filter Replacement. Refer to Figure 63 and disassemble, replace, or clean the fuel filters. Discard the filter cartridge assemblies. Wash the strainer element and filter bodies in an approved cleaning solvent; blow dry with compressed air.

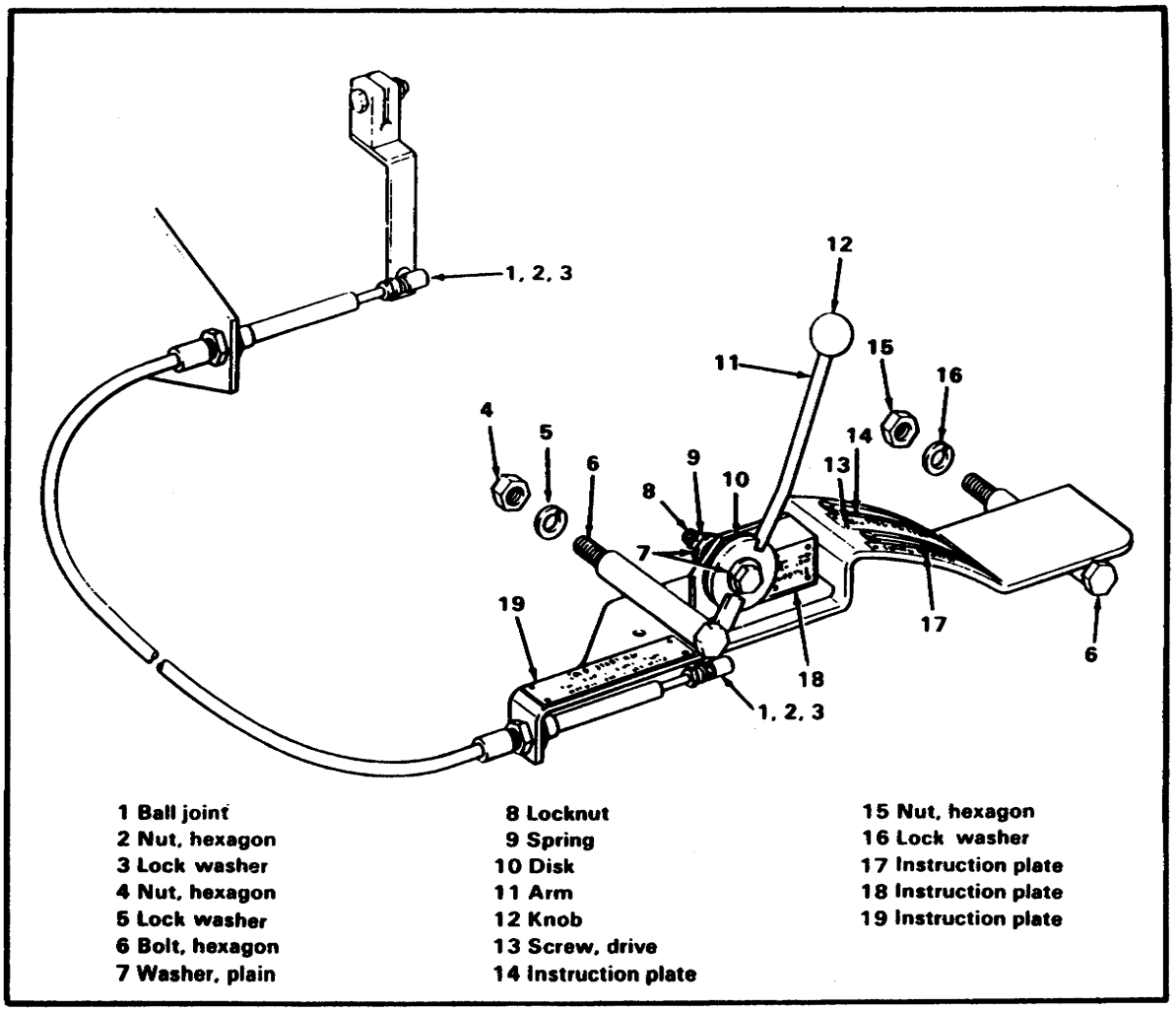
FIGURE 63. FUEL FILTER REPLACEMENT



Primer Assembly Replacement. Replace the primer unit (cold weather starting aid "quick start") by loosening the holding clamp and removing the canister. Discard properly, and install new unit in reverse order.

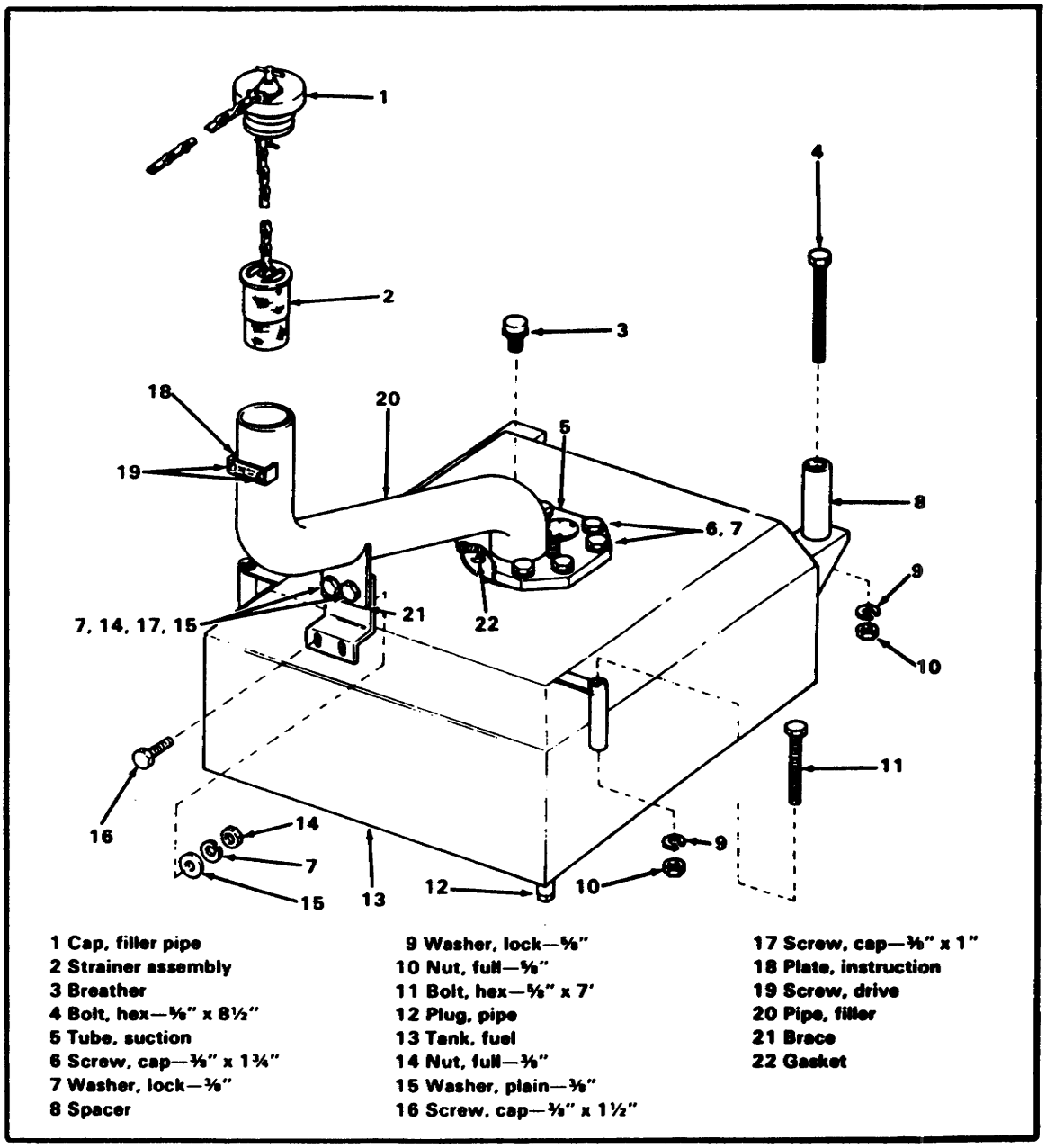
Throttle Control Replacement. Refer to the exploded view of the throttle control assembly (Figure 64) to replace the throttle control.

FIGURE 64. THROTTLE CONTROL REPLACEMENT



Fuel Tank Replacement. Refer to the exploded view of the fuel tank (Figure 65) to replace the fuel tank.

FIGURE 65. FUEL TANK REPLACEMENT



LESSON 4

REVIEW EXERCISE

Check your understanding of Lesson 4 by completing this review exercise. Try to complete it without looking back at the lesson. When you have completed the exercise, turn to the solutions and check your responses. If you do not understand a solution, go back and restudy the section in the lesson where the information is given.

1. The pressure-timed gear (PTG) pump contains _____ main components.

   A. Two

   B. Three

   C. Four

   D. Five

2. In the pressure-timed system, any fuel which is unused by the injectors enters the drain manifold and is returned to the _____.

   A. Fuel tank

   B. Fuel filters

   C. Injectors

   D. Inlet manifold

3. The engine speed in a pressure-timed diesel engine is controlled by the _____.

   A. Fuel mixture

   B. Spark advance

   C. Governor

   D. Injector intake openings

4. What are the phases of injector operation in the pressure-timed fuel system?

   A. Times, pressurizes, and meters

   B. Meters, preinjects, injects, and purges

   C. Pressurizes and injects

   D. Times and meters

5. A pressure-timed diesel engine that idles roughly usually has _____.

   A. A clogged inlet manifold

   B. Too little fuel in the fuel tank

   C. An air leak in the fuel line between the fuel tank and the pump

   D. A maladjusted governor

6. What is the second cause of restricted fuel flow?

   A. A clogged fuel filter

   B. A strainer missing from the inlet connector

   C. An open drain manifold

   D. A disconnected fuel filter

7. How can fuel restriction be detected?

   A. By holding a finger over the inlet for the fuel supply line

   B. By attaching a sight gage to the system and checking how quickly the fuel supply is moving

   C. By attaching a vacuum gage to the system

   D. By opening and closing the throttle while carefully timing the acceleration of the engine

8. What causes a pressure-timed diesel engine to smoke excessively?

   A. A disconnected shutdown valve

   B. Water in the fuel

   C. A pinched fuel line

   D. A dirty air cleaner

9. When an engine surges, what is the problem?

   A. An air leak in the fuel intake line

   B. A defective valve train

   C. Fuel contamination

   D. A faulty shutdown valve

LESSON 4

REVIEW EXERCISE SOLUTIONS

1. C (page 100)
2. A (page 100)
3. C (page 101)
4. B (page 102)
5. C (page 105)
6. A (page 105)
7. C (page 105)
8. D (page 106)
9. A (page 105)

Lesson 5

FUEL SUPPLY UNITS

TASK

Describe the correct procedures for the adjustment, repair, or replacement of fuel supply units.

CONDITIONS

Given information describing the correct procedures for the adjustment, repair, or replacement of fuel supply pumps, governors, and fuel filters; an ACCP Examination Response Sheet, and a No. 2 pencil.

STANDARDS

You are expected to demonstrate competency of the task skills and knowledge by responding correctly to 75 percent of the examination questions pertaining to this lesson.

Learning Event 1
FUEL SUPPLY PUMPS

General. Fuel injection pumps must be supplied with fuel oil under pressure because they have insufficient suction ability. Therefore, all injection systems require supply pumps to transfer fuel from the supply tanks to the injector pumps. Pumps used for this purpose have a positive suction lift and their performance is largely independent of any reasonable variations in viscosity, pressure, or temperature of the fuel. The pumps in use today are of the vane, plunger, or gear types.

Vane Type. The fuel oil pump shown in Figures 66 and 67 is a vane type. An integral steel rotor and shaft, one end supported in the pump flange and the other end in the cover, revolves in the body, the bore of which is eccentric to the rotor. Two sliding vanes are placed 180 degrees apart in slots in the rotor and are pressed against the body bore by springs in the slots. Two oil seals on the pump shaft prevent leakage of fuel or lubricating oil. A drain hole between the two seals leads to the atmosphere. When the shaft is rotated, the vanes pick up fuel at the inlet port and carry it around the body to the outlet side, where the fuel is discharged. Pressure is produced by the wedging action of the fuel as it is forced toward the outlet port by the vane. A spring-loaded horizontal relief valve is provided in the cover of the pump, connecting the inlet and outlet ports, and opens at a pressure of approximately 55 psi. This valve does not normally open since its purpose is to relieve excessive pump pressure if any of the fuel lines or filters become plugged and build up an extremely high pressure in the pump. When the relief valve opens, fuel passes from the discharge side (pressure side) to the suction side of the pump.

FIGURE 66. VANE TYPE FUEL SUPPLY PUMP

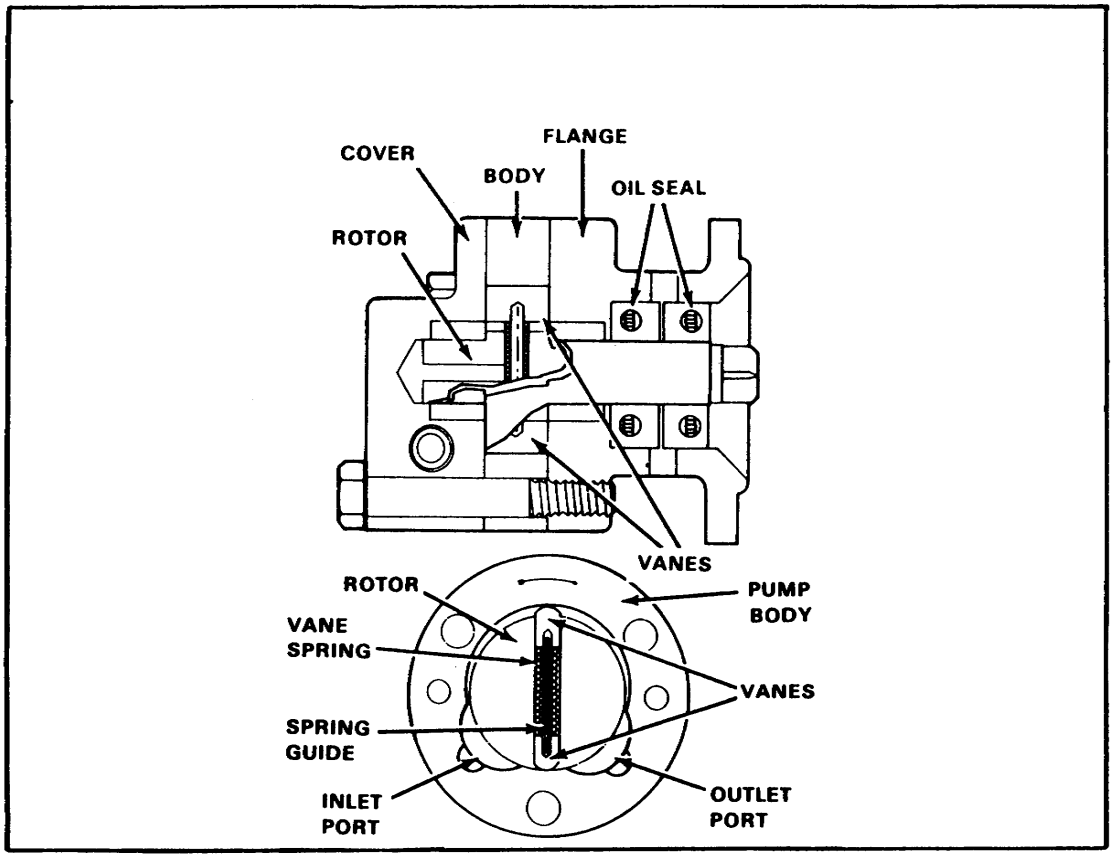
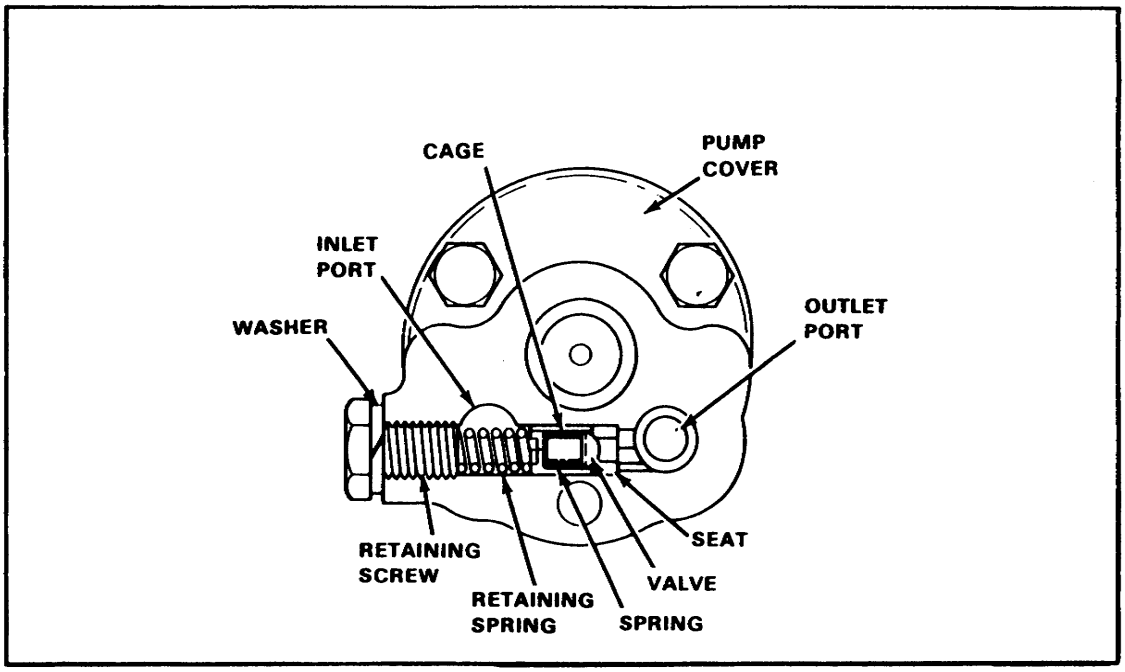
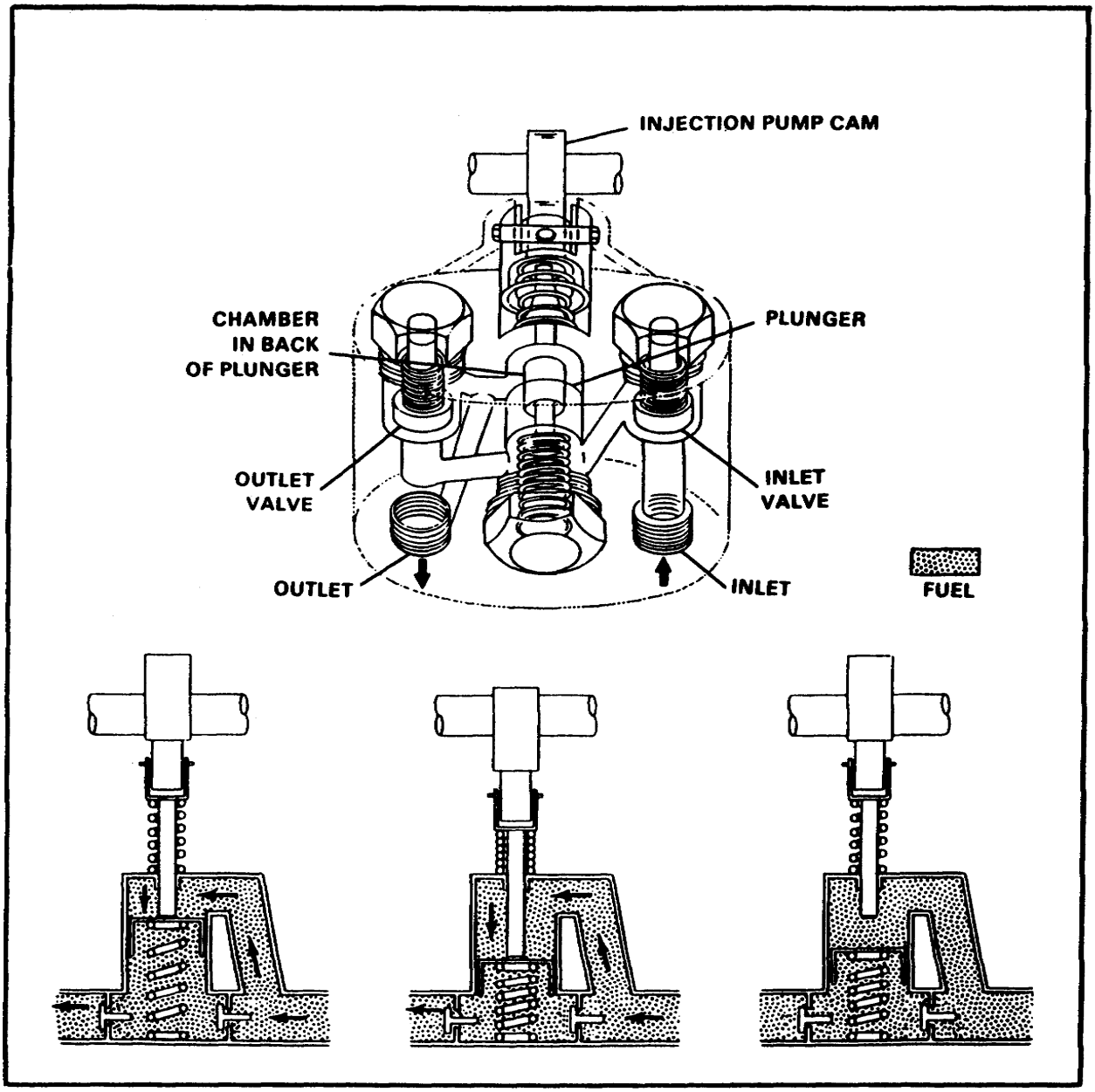


FIGURE 67. FUEL SUPPLY PUMP RELIEF VALVE



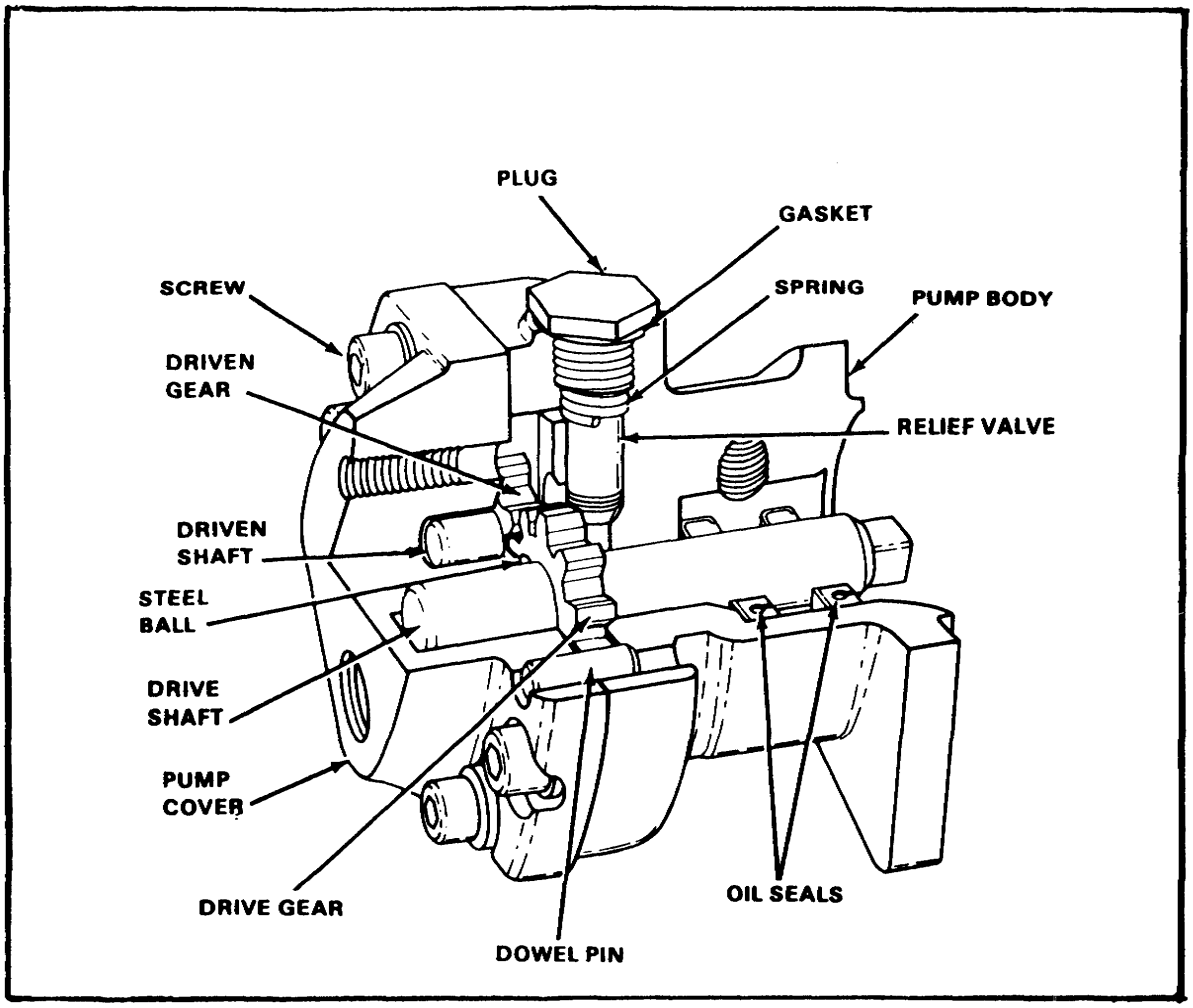
Plunger Type. The plunger-type pump shown in Figure 68 is usually mounted directly on the housing of the injection pump and is driven by the injection pump camshaft. It is a variable-stroke, self-regulating, plunger-type pump that will build pressure up to a predetermined point. As the injection pump cam allows the plunger to be forced by its spring toward the camshaft, the suction effect created opens the inlet valve and permits the fuel to enter the plunger spring chamber. As the cam lobe drives the plunger against its spring, the fuel is forced by the plunger through the outlet valve and around into the chamber created in back of the plunger by its forward movement. As the injection pump cam continues to rotate, it allows the plunger spring (which is now under compression) to press the plunger backward again, forcing the fuel oil behind the plunger out into the fuel line leading to the filters and injection pump. At the same time, the plunger is again creating a suction effect, which allows additional fuel to flow through the inlet valve into the spring chamber. This pumping action continues as long as the fuel is being used by the injection pump fast enough to keep the supply pressure from rising to the point where it equals the force exerted by the spring on the plunger. The pressure between the supply pump and the injection pump holds the plunger stationary against the spring and away from the rod. This prevents further pumping action until the pressure drops enough to permit the plunger to resume operation. This entire cycle is automatic and continues as long as the engine is running.

FIGURE 68. PLUNGER TYPE FUEL SUPPLY PUMP



Gear Type. The fuel pump shown in Figure 69 is a positive displacement gear type pump. Drive for the fuel pump is supplied from the blower. The shaft rotates in two oil seals to prevent leakage. The pump cover and body are set on two dowel pins to assure correct shaft alignment. The cover and body mating surfaces are perfectly flat and require no gasket. Two gears provide the pumping action. A relief valve in the pump body will bypass fuel to prevent excessive discharge pressures.

FIGURE 69. GEAR TYPE FUEL PUMP



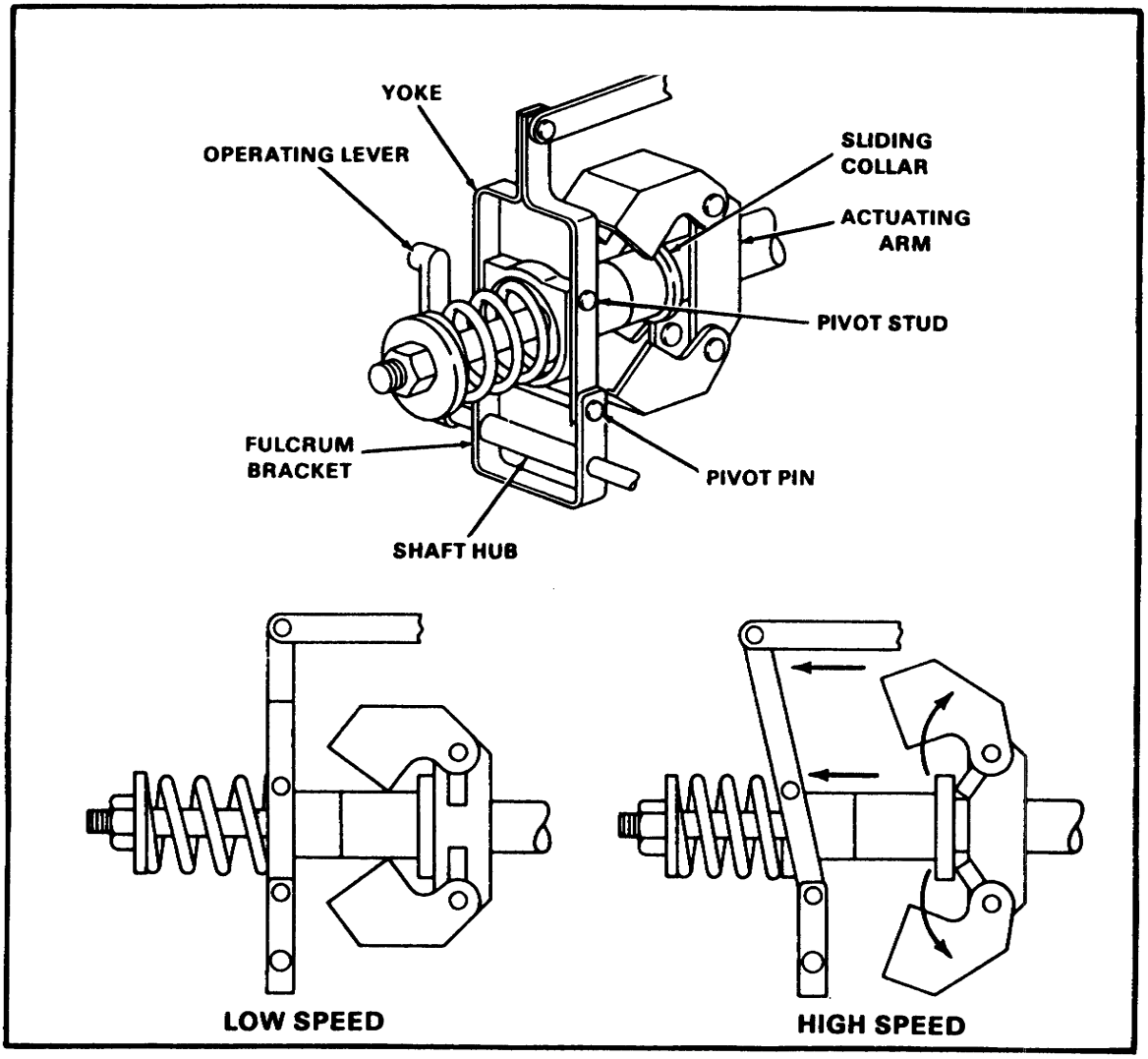
Learning Event 2
GOVERNORS

General. All diesel engines require governors to prevent overspeeding of the engines under light loads. Automotive diesel engines also demand control of the idling speed. Any of the installations provide a variable speed control which, in addition to controlling minimum and maximum speeds, will maintain any intermediate speed desired by the operator. Engine speed in a diesel engine is controlled by the amount of fuel injected. The injection system is designed to supply the maximum amount of fuel which will enable the engine to operate at full load and reach a predetermined maximum speed. However, if the maximum fuel charge was supplied to the cylinder with the engine operating under "partial load" or "no load," the engine speed would increase beyond the critical range and soon cause failure. The governor must control the amount of fuel injected in order to control the engine speed.

Actuation. Governors may be actuated through the movement of centrifugal flyweights or by the air-pressure differential produced by a governor valve and venture assembly. The centrifugal flyweight type may incorporate a mechanical linkage system to control the injection pump or it may include a hydraulic system to transmit the action of the weights to the pump. Where the rate of acceleration must be high, the governor-controlling weights must be small to obtain the required rapidity of response from the governor. These small weights may not exert sufficient force to control the injection equipment; instead, the injection pump will be controlled by a servo piston utilizing the pressure from a pump within the governor. The centrifugal weights actuate a valve which controls the amount of oil going to the servo piston.

Mechanical (Centrifugal). The operation of the mechanical governor is based on the centrifugal force of rotating weights counterbalanced by springs. When the speed of the engine increases, the weights fly outward, pulling with them suitable linkage to change the setting of the injection pump control rod. The governor linkage is connected to the injection pump in such a manner that the spring moves the control mechanism toward the full-fuel position, and the action of the flyweights reduces the amount of fuel delivered. A typical variable speed governor is shown schematically in Figure 70 on page 124.

FIGURE 70. MECHANICAL (CENTRIFUGAL) GOVERNOR



With this type of governor, the operator varies the governor spring tension to control the quantity of fuel and does not at any time move the injector control rack directly. The control rack of the injection pump is connected to the yoke of the governor in such a manner that any movement of the yoke will directly affect the quantity of the fuel injected. The spring tension is controlled by the operating lever, the movement of which is determined by the position of the foot throttle. The travel of the operating lever is limited by the idle and maximum speed screws. With the weights fully collapsed (engine stopped), the spring moves the sliding sleeve and yoke so the fuel injection pump is in the full-fuel position. When the weights are fully extended, the sliding sleeve and yoke move to the right and decrease the amount of fuel delivered.

If the load on the engine is decreased, the engine tends to accelerate. However, when the engine accelerates, the governor flyweights move outward as a result of increased centrifugal force. Since the flyweights are in contact with the sliding sleeve assembly, this movement causes a longitudinal movement of the sleeve to the right. This movement continues until an equilibrium is established between the governor spring force and the centrifugal exerted by the flyweights. This occurs when the engine returns to the original speed as determined by the position of the foot throttle and its effect on the governor spring.

If the load on the engine increases, the engine tends to slow down, thereby causing an inward movement of the flyweights. As the weights move inward, the compressed governor spring shifts the sleeve to the left until the spring force and the centrifugal force exerted by the flyweights are again balanced. In this way, the yoke, following the movement of a sliding sleeve, moves the control rack of the fuel injection pump toward the more-fuel position and thereby returns the engine to the preset speed.

To accelerate the vehicle, the foot throttle is depressed, which, in turn increases the spring tension. This causes the yoke to pivot to the left, thereby increasing the supply of fuel. The flyweights move outward as a result of increased engine speed and prevent the control rack from reaching the full-fuel position unless the foot throttle is depressed. Deceleration is accomplished in the reverse manner. Spring pressure is decreased, the engine slows down, the flyweights move inward, and a balanced condition between the flyweights and the spring is obtained at a lower engine speed.

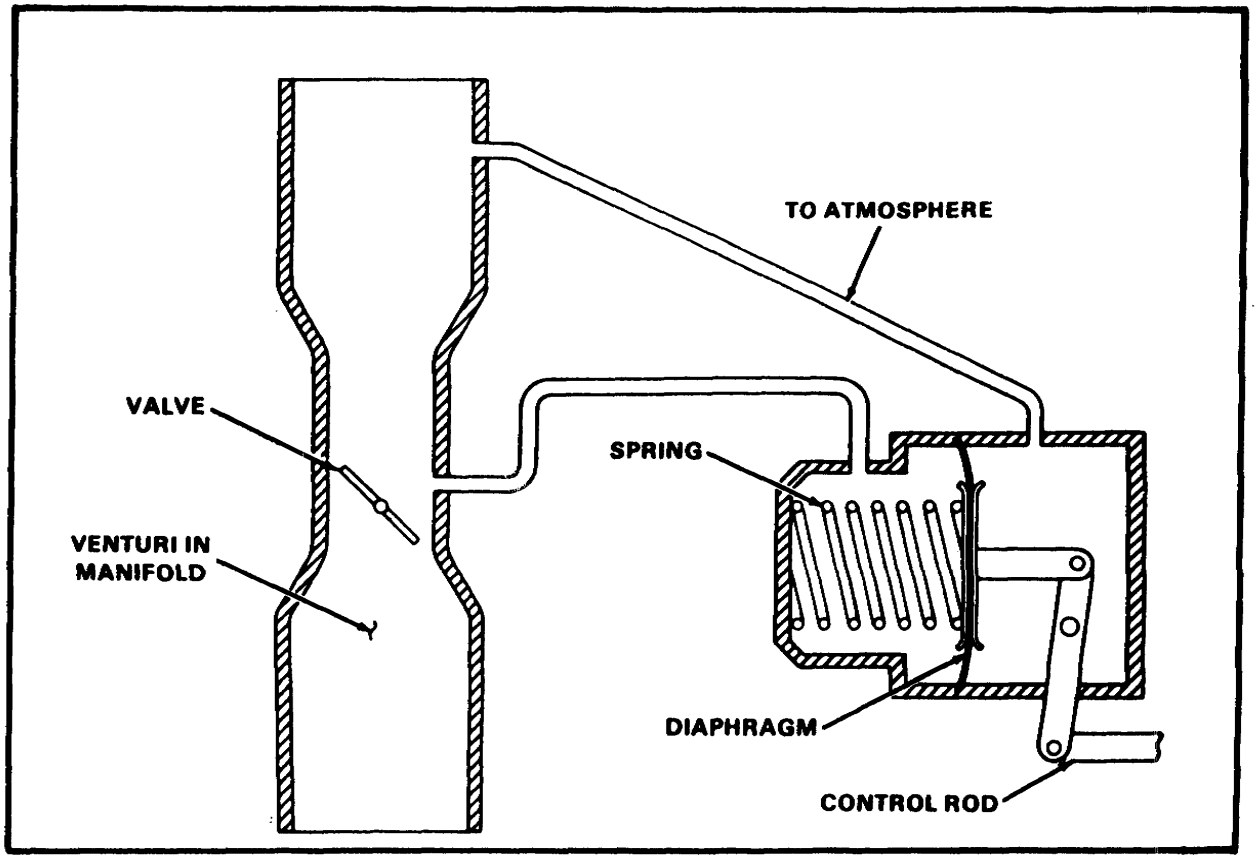
The adjustable bumper spring prevents rapid oscillations of the control rack at low no-load engine speeds. The spring contacts the yoke at idling speed and ensures steady operation of the governor. The bumper spring also assists in preventing stalling of the engine on sudden deceleration to idle speed, as it prevents the control rack of the injection pump from moving into the full-stop position when this speed change occurs.

Pneumatic (Vacuum Controlled). The actuating force for the pneumatic or vacuum-controlled governor (Figure 71) is the pressure drop caused by the velocity of air passing through a venturi located in the air intake manifold. The governor consists essentially of an atmospheric-suspended diaphragm connected by linkage to the control rack of the fuel injection pump. The chamber on one side of the diaphragm is open to the atmosphere and the chamber on the other side is sealed and connected to the venturi in the manifold. In addition, there is a spring acting on the sealed side of the chamber, which moves the diaphragm and control rack to the full-fuel position when the engine is not operating and both sides of the diaphragm are at atmospheric pressure.

When the engine is running, however, the pressure in the sealed chamber is reduced below the atmospheric pressure existing in the other chamber. The amount of pressure reduction depends on the position of the governor valve and the speed of the engine. It is this pressure differential that positions the diaphragm and, consequently, the control rack. The governor valve is controlled by a lever which is connected by linkage to the foot throttle.

There is no actual connection between the foot throttle and the governor or fuel injection pump.

FIGURE 71. PNEUMATIC (VACUUM CONTROLLED) GOVERNOR



If the engine is operating under load and the speed is below governed speed, the velocity of air passing through the venturi is comparatively low and only a slight pressure differential is present. The spring moves the diaphragm and control rack toward the full-fuel position and the engine speed approaches that of governed speed. The same principle prevents the engine from overspeeding at light loads. As the engine speeds up, the velocity of air through the venturi increases with the result that the pressure differential at the diaphragm is increased. This differential is sufficient to overcome the spring force and to cause the diaphragm and control rack to move toward the stop position. When the engine is operating at governed speed with the valve wide open, the pressure differential is just slightly below that of the spring force and the diaphragm remains in the full-delivery position.

For any position of the governor valve between idling and full load of the engine, the diaphragm finds its relative position. Since any movement of the diaphragm is also transmitted to the control rack, the amount of fuel delivery is definitely controlled at all engine speeds. As the pressure drop between the chambers is increased, the diaphragm is moved in the direction of less fuel delivery.

As the pressure drop is decreased, the spring can move the control rack in the direction of greater fuel delivery. Therefore, in order to increase the speed of the engine, the governor valve is opened; to decrease the engine speed, the valve is closed.

Learning Event 3
FUEL FILTERS

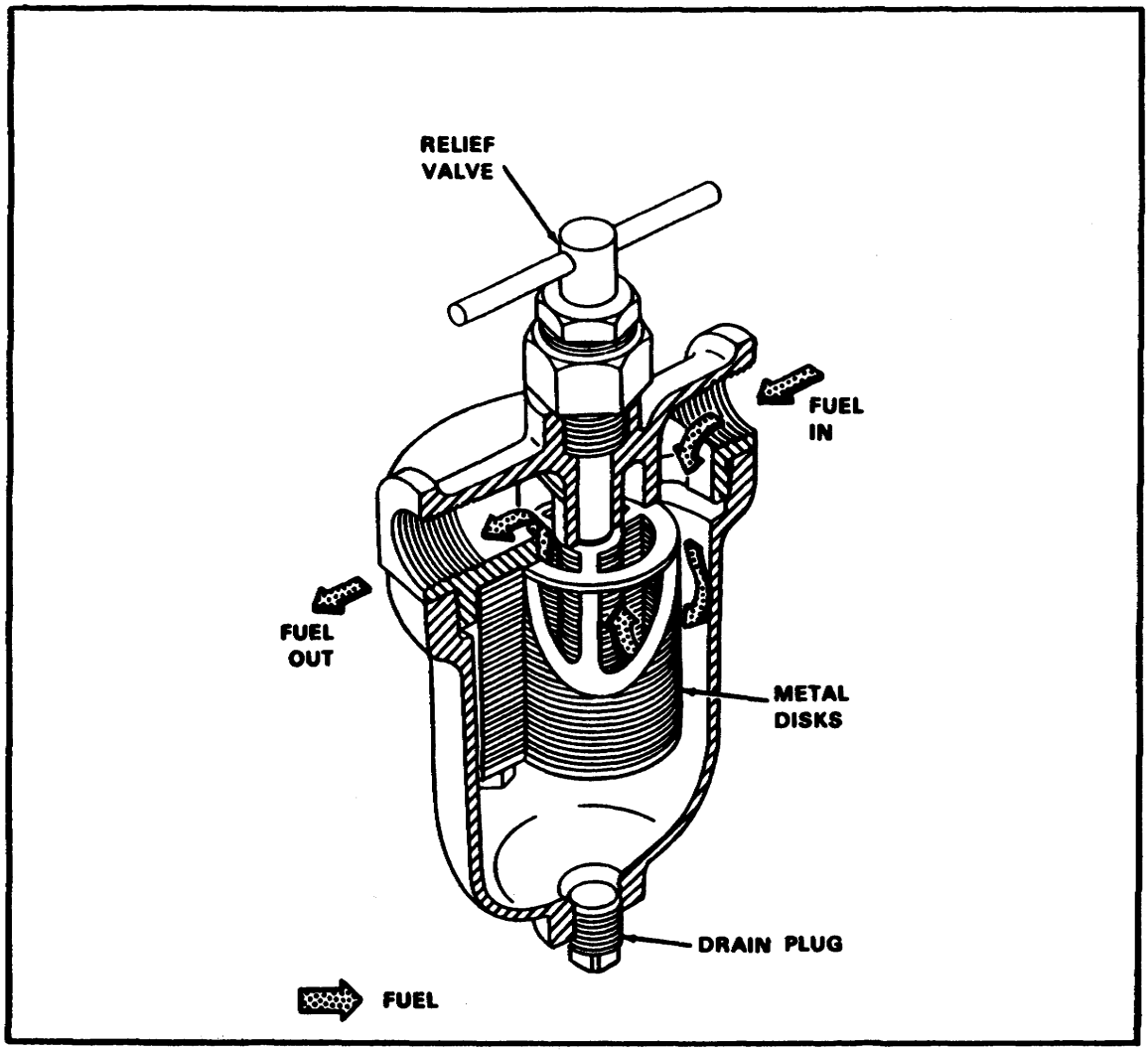
General. Thorough and careful filtration is necessary to keep diesel engines efficient. Diesel fuels are more viscous than gasoline and contain more gums and abrasive particles that may cause premature wear of injection equipment. The abrasives may consist of material that is difficult to eliminate during refining or they may enter the tank during careless refueling. Regardless of the source abrasives must be removed from the fuel.

Configuration. Most diesel engine designs include at least two filters in the fuel supply systems to protect the closely fitted parts in the pumps and nozzles. The primary filter usually is located between the fuel tank and the fuel supply pump. The primary filter contains a coarse filter medium that removes the larger foreign matter. The secondary filter usually is located between the fuel supply pump and the fuel injection pump. The secondary filter contains a fine filter medium that removes even the most minute traces of foreign matter from the fuel. Additional filtering elements frequently are installed between the injection pump and the nozzle.

Types. Diesel fuel oil filters are referred to as full-flow filters, because all the fuel must pass through them before reaching the injection pumps. A diesel fuel filter usually incorporates an air valve to release any air that might accumulate in the filter during operation.

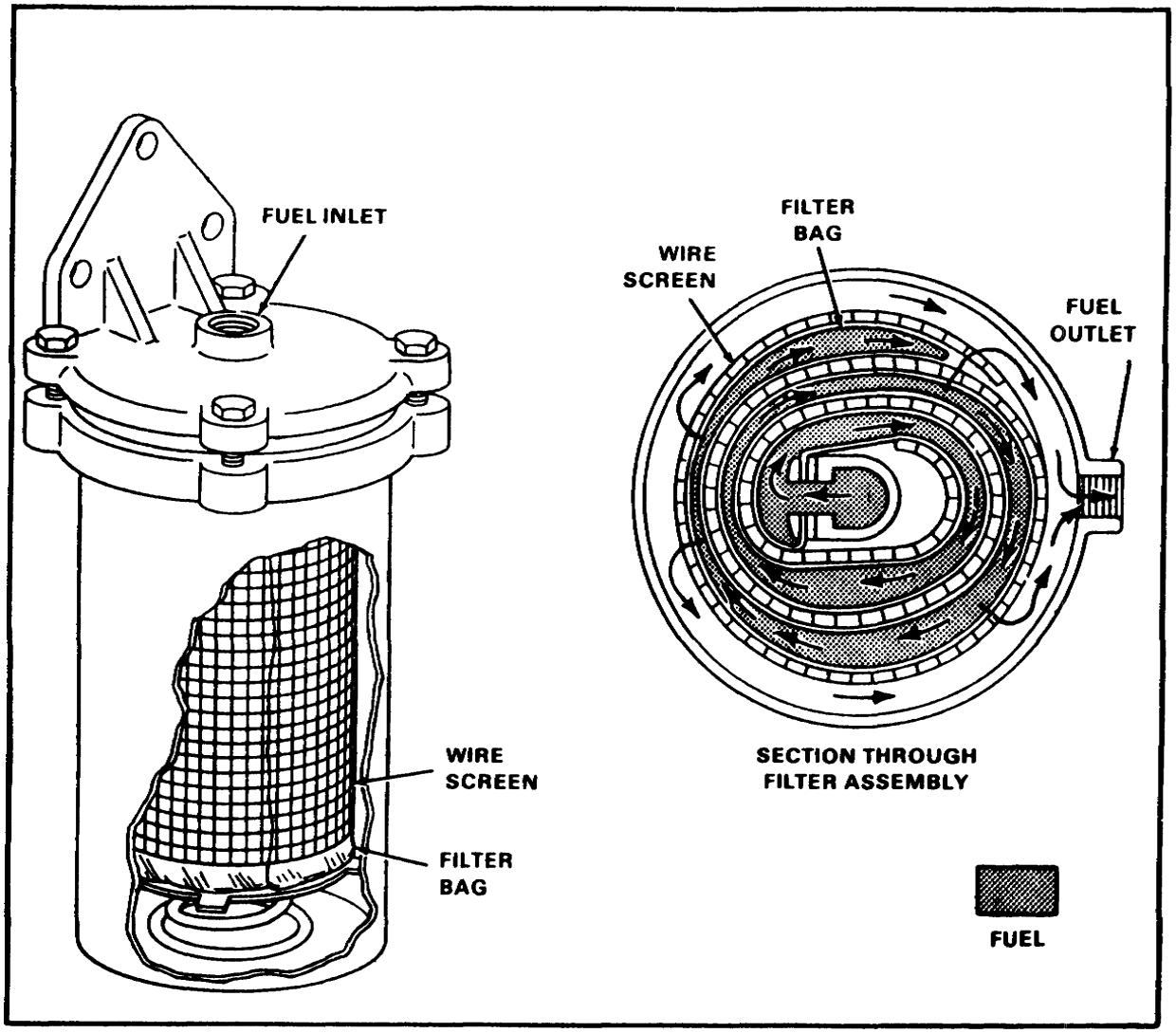
Primary Filters (Figure 72). Metal filters are used as primary filters because the fine particles that will pass through them are not harmful to the supply pump. Solids larger than 0.005 inch remain outside the metal disks, while the larger foreign matter and the majority of the water settles to the bottom of the bowl. From here, the foreign matter can be removed through a drain plug. A relief valve in the filter cover enables the oil to bypass the filter element if the disks become clogged.

FIGURE 72. PRIMARY FUEL FILTER



Secondary Filters (Figure 73). Fabric filters, because of their greater filtering qualities, are used primarily as main filters for protecting the fuel injection pump. The filter medium is a large bag of close, evenly woven, lintless, acid-resisting textile material. Maximum benefit is derived from the bag's large area by keeping the sides of the bag separated by a wire-screen mat. The screen is the same size as the bag and the two are fastened detachably to a central feeding spool and wound around it. The fuel to be filtered flows from the filter inlet at the top, through the spool, and out of the ports to the inside of its bag. The dirt, solids, abrasives, and carbon are caught in the bag and the clean fuel passes outward and to the fuel outlet. The bag may be removed, cleaned, and reinstalled.

FIGURE 73. SECONDARY FUEL FILTER

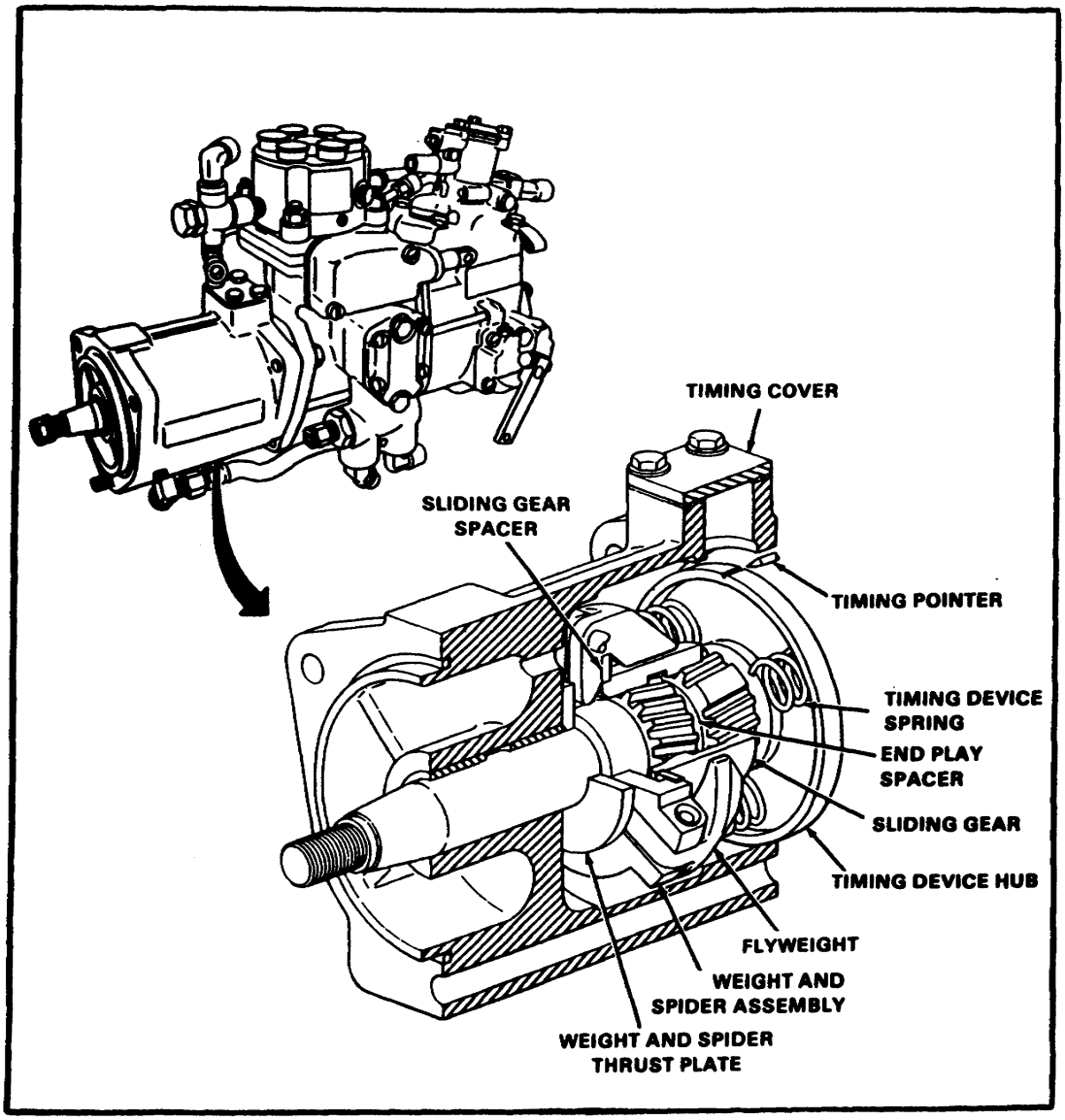


Learning Event 4
TIMING DEVICES

General. A large percentage of fuel injection pumps have timing devices incorporated in them. Varying the time when fuel injection begins will improve diesel engine performance and fuel economy for the same reasons that varying spark timing will improve the performance of a gasoline engine.

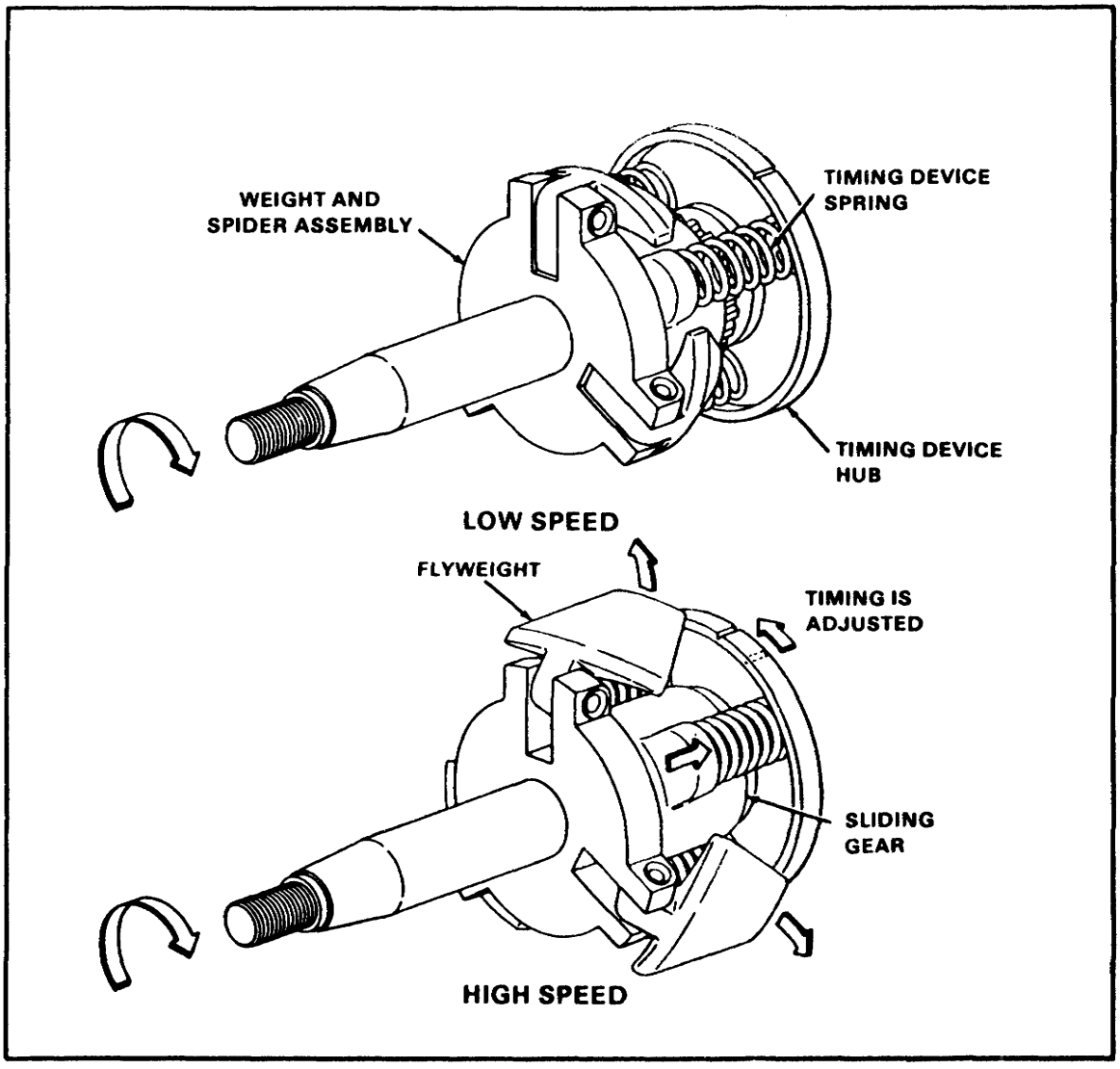
Description (Figure 74). The timing device usually consists of an aluminum casting with mounting flanges at both ends. A bore in the housing guides and supports the spider assembly. A timing opening with cover is located in the top of the housing. It is used to observe the position of the timing pointer in relation to the timing mark on the timing device hub during injection pump timing procedures.

FIGURE 74. TIMING DEVICE



Operation (Figure 75). As the engine rotates the weight and spider assembly, centrifugal force opens the flyweights from their collapsed position against the force of the three timing device springs. As the flyweights swing out, the sliding gear is forced toward the timing device hub. The longitudinal movement of the sliding gear on its helical spline causes a slight change in the rotational relationship in the injection pump to the engine, causing injection to begin slightly earlier in the power stroke.

FIGURE 75. TIMING DEVICE OPERATION



Learning Event 5
COLD WEATHER STARTING AIDS

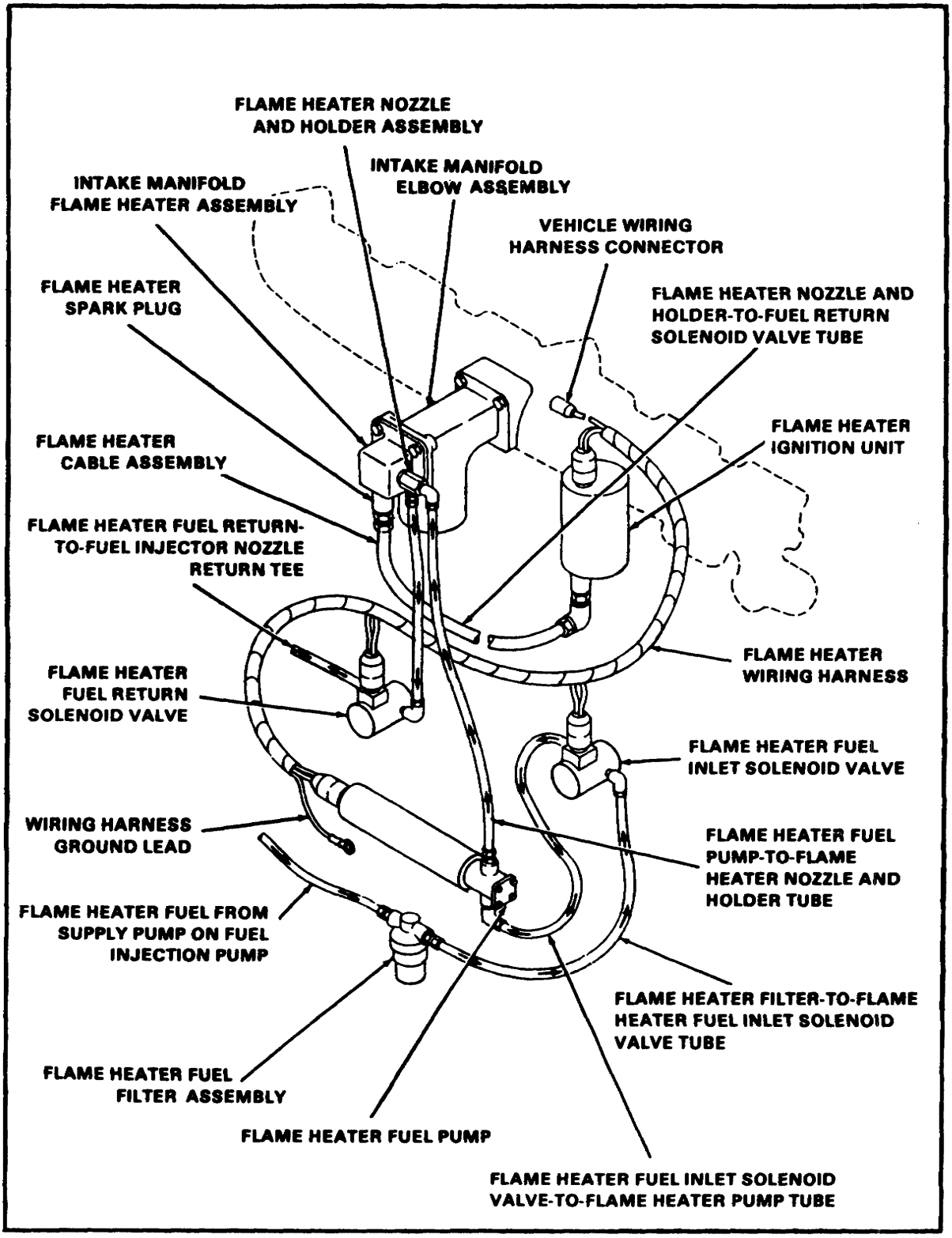
General. Diesel engines are very difficult to start in cold weather. This is due mainly to the low volatility of the fuel. The two most popular methods of assisting a diesel engine in starting are preheating the induction air in the intake manifold so that adequate vaporization will take place for combustion and injecting a fuel into the engine that remains volatile enough in cold weather to initiate combustion.

Intake Manifold Flame Heater System (Figure 76 on page 134). Engines are equipped with a flame-type manifold heater for heating the induction air during cold weather starting and warm up operations.

Operation. The flame heater assembly is composed of a housing, spark plug, flow control nozzle, and two solenoid control valves. The spark plug is energized by the flame heater ignition unit. The nozzle sprays fuel under pressure into the intake manifold elbow assembly. The fuel vapor is ignited by the spark plug and burns in the intake manifold, heating the air before it enters the combustion chambers. The flame fuel pump assembly is a rotary type, driven by an enclosed electric motor. The fuel pump receives fuel from the vehicle fuel tank through the vehicle's supply pump and delivers it to the spray nozzle. The pump is energized by an ON-OFF switch located on the instrument panel. Two fuel solenoids are used in the flame heater system.

The valves are energized whenever the system is activated. The valves ensure that fuel is delivered only when the system is operating. They stop fuel flow the instant the engine or heater system is shut down.

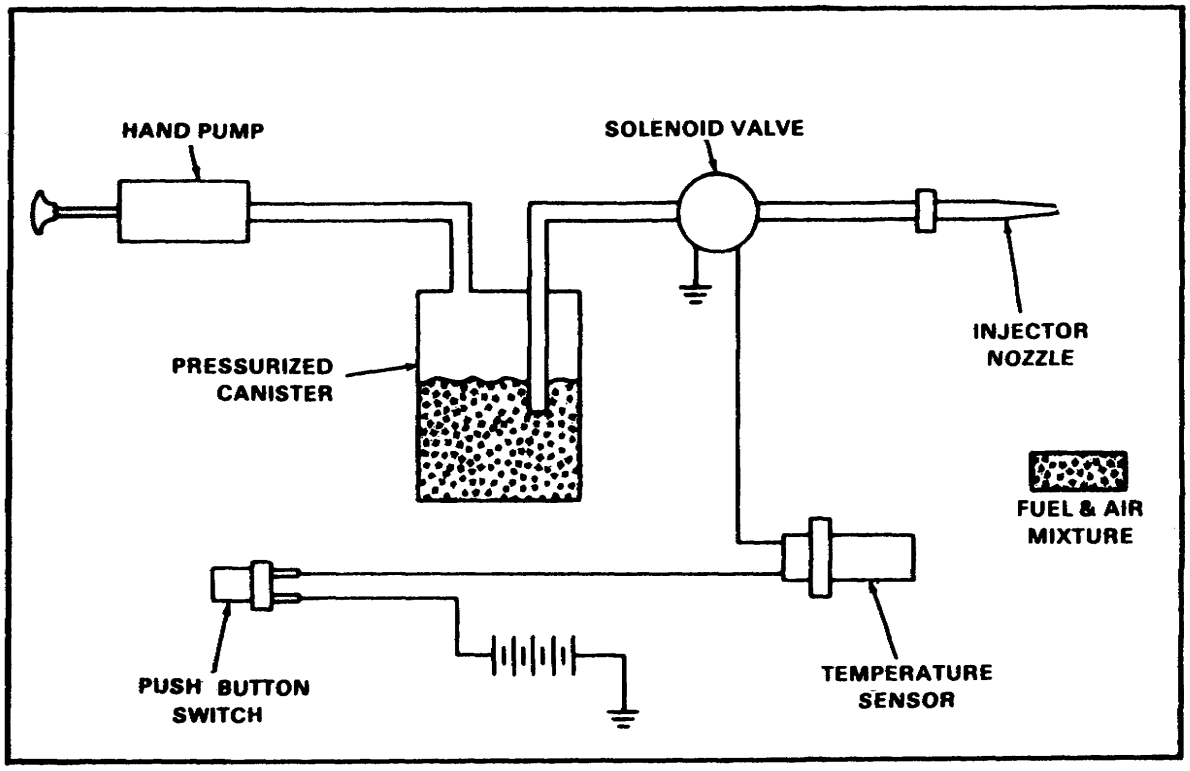
FIGURE 76. MANIFOLD FLAME HEATER SYSTEM



Ether Injection System (Figure 77). The ether injection system assists in the cold weather starting of a diesel engine by injecting ether into the intake manifold. Ether, which is very volatile, will vaporize readily in cold weather, initiating combustion.

Operation. A pressurized canister containing ether is fitted to the engine. The flow of ether from the canister to the spray nozzle is controlled by a solenoid valve that closes when it is deenergized. The solenoid is controlled by a push button switch on the instrument. When the switch is pushed, the solenoid is energized. This opens the ether canister. Pressure from the canister pushes ether through a connecting tube to the nozzle, where it discharges into the intake manifold.

FIGURE 77. ETHER INJECTION SYSTEM



LESSON 5

REVIEW EXERCISE

Check your understanding of Lesson 5 by completing this review exercise. Try to complete it without looking back at the lesson. When you have completed the exercise, turn to the solutions and check your responses. If you do not understand a solution, go back and restudy the section in the lesson where the information is given.

1. There are three major types of fuel supply pumps. These are vane, gear, and _____.

   A. Centrifugal

   B. Rotary

   C. Diaphragm

   D. Plunger

2. A _____ prevents overspeeding of an engine under light loads.

   A. Servo-meter

   B. Governor

   C. Load controller

   D. Differential

3. Diesel fuel oil filters are referred to as _____ filters.

   A. Full flow

   B. Half flow

   C. Intermittent flow

   D. Interrupted flow

4. The primary fuel filter contains a _____ filter medium.

   A. Fine

   B. Coarse

   C. Granulated

   D. Pulverized

5. Fabric filters are used primarily as _____ filters.

   A. Spiral

   B. Helical

   C. Primary

   D. Secondary

6. There are two major types of cold weather starting systems. One of these is the intake manifold flame heater system and the other is the _____ system.

   A. Forced air

   B. Hot air

   C. Ether injection

   D. Oxygen injection

7. The secondary fuel filter contains a _____ filter medium.

   A. Fine

   B. Coarse

   C. Granulated

   D. Pulverized

8. The plunger type fuel supply pump is driven by the _____ camshaft.

   A. Engine

   B. Injector

   C. Injection pump

   D. Governor

9. Regardless of type, all fuel supply pumps use a _____ valve to prevent excessive discharge pressure.

   A. Vent

   B. Relief

   C. Bypass

   D. Diaphragm

10. Governors may be actuated by air-pressure differential or _____ flyweights.

   A. Plunger

   B. Diaphragm

   C. Vacuum

   D. Centrifugal

Lesson 5/Review Exercise Solutions

1. D (page 118)
2. B (page 123)
3. A (page 128)
4. B (page 128)
5. D (page 130)
6. C (page 135)
7. A (page 128)
8. C (page 120)
9. B (page' 122)
10. D (page 123)