ENGINEERING-PDH.com
ONLINE CONTINUING EDUCATION

ENGINE FUEL SYSTEMS

Main Category:	Mechanical Engineering
Sub Category:	-
Course #:	MEC-156
Course Content:	38 pgs
PDH/CE Hours:	2

OFFICIAL COURSE/EXAM

(SEE INSTRUCTIONS ON NEXT PAGE)

WWW.ENGINEERING-PDH.COM
TOLL FREE (US & CA): 1-833-ENGR-PDH (1-833-364-7734)
SUPPORT@ENGINEERING-PDH.COM

MEC-156 EXAM PREVIEW

- TAKE EXAM! -

Instructions:

- At your convenience and own pace, review the course material below. When ready, click "Take Exam!" above to complete the live graded exam. (Note it may take a few seconds for the link to pull up the exam.) You will be able to re-take the exam as many times as needed to pass.
- Upon a satisfactory completion of the course exam, which is a score of 70% or better, you will be provided with your course completion certificate. Be sure to download and print your certificates to keep for your records.

Exam Preview:

1. According to the reference material, never clean the injection valves with a wire brush. The use of a wire brush to remove carbon from the injection valves might damage the orifice and reduce power output.
    a. True
    b. False
2. According to the reference material, compressed air used for cleaning purposes should not exceed __ psi. Wear goggles and other appropriate protective equipment when using compressed air.
    a. 15
    b. 30
    c. 45
    d. 60
3. There are three basic configurations of gasoline fuel injection: timed, continuous, and throttle body. Which of the following matches the description: one or two injectors delivering gasoline to the engine from one central point in the intake manifold?
    a. Timed
    b. Continuous
    c. Throttle body
    d. N/A
4. According to the reference material, the governor on the compact fuel system is vacuum operated. Governor action controls the amount of fuel injected by turning the plunger in the barrel through a gear segment on the bottom of the plunger.
    a. True
    b. False

5. According to the reference material, valve opening pressure ranges from 400 to 800 psi, as registered on the test gauge. If the injection valve fails to reach a minimum of 400 psi, observe the gauge to note any drop in pressure. If the pressure falls more than ___ psi in 30 seconds, discard the injection valve nozzle.
   a. 25
   b. 50
   c. 75
   d. 100
6. According to the reference material, a diesel engine may be equipped with a supercharger. The supercharger is a belt-driven air pump that uses rotors to force air into the engine cylinders when a requirement for more power exists.
   a. True
   b. False
7. According to the reference material, the specified valve opening pressure for the crown or high valve injector is 450 to 850 psi. For the needle valve injector, the specified opening pressure is 2,000 to ____ psi.
   a. 2,500
   b. 2,800
   c. 3,200
   d. 3,500
8. The holding pressure test is used to determine whether the various lapped surfaces in the injector are sealing properly. If the injector pressure drops from 450 psi to 250 psi in less than __ seconds, dry the injector thoroughly and make the following checks as outlined in the reference material.
   a. 30
   b. 40
   c. 50
   d. 60
9. Superchargers and turbochargers increase the power output of specific engines by forcing air into the combustion chambers so that an engine can burn more fuel and develop more horsepower than if it were naturally aspirated.
   a. True
   b. False
10. Turbochargers can be mounted on the engine in many different positions. Always locate the oil outlet at least __ degrees below the turbocharger horizontal center line when the unit is in the operating position.
   a. 15
   b. 90
   c. 45
   d. 120

FUEL SYSTEM OVERHAUL

As described in the *Construction Mechanic 3 & 2* it is the job of the fuel system to send the correct quantity of fuel or fuel-air mixture to the engine at all times. To do this, the fuel system components must be clean and correctly adjusted or they will not function properly. After troubleshooting, when the problem has been identified and isolated, it will be your job to see that components of the fuel system are overhauled correctly.

CARBURETOR OVERHAUL

The carburetor has been designed and manufactured in literally thousands of makes and models. Therefore, it is not practical to discuss even a few of them in this training manual (TRAMAN). The basic principles of all carburetors are the same and may be found in the *Construction Mechanic 3 & 2,* NAVEDTRA 10644-G1, or U.S. Army publication *Principles of Automotive Vehicles,* TM-9-8000. The purpose of this section of this chapter is not to make you an expert in carburetor overhaul, but, to familiarize you with carburetor overhaul procedures in general.

CLEANING AND IDENTIFICATION

Before starting any carburetor rebuild, first you should know and make absolutely sure the carburetor is the problem. Good troubleshooting can save you a lot of time and work. Why overhaul when you could have done the job with a simple adjustment. Second, find out the make and model of the carburetor you are about to rebuild and make sure the rebuild kit for the unit that you are going to overhaul is on hand. There is nothing more frustrating for a person than to disassemble an automotive part like a carburetor only to find out that the rebuild kit is unavailable. Third, locate the technical manual and have it on hand for the job. Only now will you be ready to start by removing the carburetor from the engine.

The first thing you should do after removing the carburetor from the vehicle is the initial cleaning, which will remove deposits of dirt and grime and allow the identification tags or numbers to be read. These ID numbers are stamped into the base of the largest part of the carburetor, or they may be found on a small metal tag screwed or riveted to the carburetor. (Remember, when you complete the overhaul job, reattach any identification tags to their proper place.) Before you dip the carburetor into the cleaning solution, remove items that may be affected by the cleaning solution. (These items could be electric solenoids, plastic parts, vacuum pulldowns, etc. They should be removed and set aside for individual cleaning and testing.) Dip the carburetor into the solvent and brush away any deposits of dirt or grease. Remove the unit from the cleaning solution, let it drip-dry, or blow-dry it using low pressure air.

CAUTION

Compressed air used for cleaning purposes should not exceed 30 psi. Wear goggles and other appropriate protective equipment when using compressed air.

MANUFACTURER'S INSTRUCTIONS AND TOOLS

As you know, modern carburetors are complicated assemblies. They cannot just be taken apart, cleaned out, and put back together again. Each overhaul kit has assembly instructions, an exploded view for parts identification purposes, and a specification sheet with it. If this paper work is not in the overhaul kit, find the manufacturer's repair manual which is available in your technical library. Without this information and the proper tools, you may irreversibly damage the carburetor. If you adjust the carburetor improperly, poor engine performance may result.

DISASSEMBLY AND CLEANING

Carburetor disassembly and cleaning is basically a matter of logic and good judgment. Use common sense and work slowly. Some tips to follow are shown below.

- Have the instructions handy. Read them first to find out any special disassembly techniques.
- Make sure your work space is clean and well ventilated.
- Use a small tray or container to put the reusable parts in that must be cleaned. This will help prevent the search for that lost or missing screw,

check valve, jet, and so forth, a search which is usually held on the floor.

- Have a sufficient quantity of carburetor cleaner on hand.

CAUTION

Wear rubber gloves and eye protection when you use this highly caustic cleaning solution.

Use a small wire basket for dipping the smaller parts into the cleaner.

When you dip larger parts, use a short piece of wire, such as an old coat hanger, to hang the parts into the cleaning solution. Submerge the parts for at least 30 minutes.

During any disassembly operation, be careful not to lose or damage any parts. Keep unauthorized people away from your work area so your parts do not get lost, misplaced, or walk away. Thoroughly rinse the carburetor parts with clean water or solvent and blow-dry them with low-pressure air. Before reassembly, inspect all parts for wear or damage.

CAUTION

Disassemble the carburetor only as far as you have to. Normally, it is not necessary to remove the throttle shaft and its plates or the choke shaft and its plate.

REPAIR AND REPLACEMENT

Very little actual repair work is performed on modern carburetors because it is less expensive to replace the unit than repair it. Most repairs you do on carburetors will be in the form of parts replacement.

REASSEMBLY AND ADJUSTMENT

When you have finished your final cleaning and made the necessary repairs, you are ready to reassemble the carburetor. You do this in reverse sequence; that is, the last item taken out is the first put back. Look at the specification sheet for any special instructions, such as setting the float level and float drop, initial choke setting, initial idle adjustments, and any linkage adjustments.

CAUTION

Use care in the assembly process. Carburetor bodies may be made of aluminum, bronze, iron, or even plastic. Overtorquing may damage or warp the parts and lead to expensive repairs or deadlined equipment.

TESTING

When you reinstall the carburetor on the engine, check all connections for proper attachment. Some manufacturer's mark, with numbers or letters, individual connections; others color-code the vacuum lines. Remember, the incorrect hookup of emissions control vacuum lines will lead to decreased fuel economy, increased exhaust emissions, or both.

WARNING

Unauthorized alteration, disconnection, or any tampering with emission control devices in any way is in direct violation with state and federal law. CESE being shipped to overseas locations may be modified according to the manufacturer's specifications to meet operational requirements as directed by CBC, Port Hueneme, CA, Code 15, COMCBPAC Equipment Office or COMCBLANT Detachment, Gulf Port, MS.

To test and adjust today's carburetor properly, an exhaust gas analyzer is a requirement. Without this machine, it is impossible to know if you are exceeding the allowable ppm (parts per million) emissions of the HC, CO, and CO_2. There are many different makes of this machine. The information listed here is only to give you a basic understanding of the unit.

CAUTION

Follow the directions for the hookup of the unit exactly. These instructions may come from the manufacturer's operating instructions, or even special instructions from the under the hood data plate. Failure to obtain proper hookup may result in testing equipment or vehicle damage.

If the analyzer does not respond, check to see if one of the following conditions exists:

- The vehicle is not at operating temperature. (Warm up the engine by normal running.)

- The probe is not inserted far enough into the tailpipe of the vehicle. (Remove and reinsert the probe.)

- Check the vehicle for an exhaust leak. (Repair the exhaust system.)

- Check the mode switch of the unit you are testing with reset switches.

- The analyzer sampling system leaks. (Check for tight connections at both of the IR hoses. Check the O-rings in the filter bowl of the analyzer. Perform a leak check.)

- Run the analyzer through the test calibration series only after the engine has been brought to operating temperature.

Adjust the cold- and hot-idle speed of the engine. Assuming all other parts of the engine and its controls are working properly, use the specifications provided by the manufacturer's repair manual to adjust the carburetor to meet the minimum ppm of HC, CO, and CO_2 emissions. Return the vehicle to the shop supervisor for final inspection and return it to service.

GASOLINE FUEL INJECTION SYSTEMS

Fuel injection systems are an increasing y popular alternative to the carburetor for providing an air-fuel mixture. They inject, under pressure, a measured amount of fuel into the intake air usually at a point near the intake valve. Fuel injection systems provide the following advantages:

- Fuel delivery can be measured with extreme accuracy, giving the potential for improved fuel economy and performance.

- Because the fuel is injected at the intake port of each cylinder, fuel distribution will be much better and fuel condensing in the manifold will not be a problem.

- There is no venturi as in a carburetor to restrict the air intake, making it easier to keep volumetric efficiency high.

- The fuel injector, working under pressure, can atomize the fuel much finer than the carburetor, resulting in improved fuel vaporization.

There are three basic configurations of gasoline fuel injection: timed, continuous, and throttle body.

TIMED FUEL INJECTION SYSTEMS

In gasoline engines, the timed fuel injection system injects a measured amount of fuel in timed bursts synchronized to the intake strokes of the engine. Timed injection is the most precise form of fuel injection; it is also the most complex. There are two basic forms of timed fuel injection: mechanical and electronic. The operation of the two are very different and will be covered separately in the following two paragraphs.

Mechanical-Timed Fuel Injection

The mechanical-timed injection system (fig. 5-1) has a high-pressure pump that draws fuel from the gas tank and delivers it to the metering unit. A pressure relief valve is installed between the fuel pump and the metering unit to regulate fuel line pressure by bleeding off excess fuel back to the gas tank. The metering unit is a pump that is driven by the engine camshaft. It is always in the same rotational relationship with the camshaft so that it can be timed to feed the fuel at just the right moment to the injectors. There is one injector for each cylinder. Each injector contains a spring-loaded valve that is opened by fuel pressure injecting fuel into the intake at a point just before the intake valve. The throttle valve regulates engine speed and power output by regulating manifold vacuum, which, in turn, regulates the amount of fuel supplied to the injectors by the metering unit.

Electronic-Timed Fuel Injection

In an electronic system (fig. 5-2), all of the fuel injectors are connected in parallel to a common fuel line that is fed by a high-pressure pump from the gas tank. A fuel pressure regulator is installed in line with the injectors to keep fuel pressure constant by diverting excess fuel back to the gas tank, Each injector contains a solenoid valve and is normally in the closed position. With a pressurized supply of fuel behind it, each injector operates individually whenever an electric current is applied to its solenoid valve. By sending electric current impulses to the injectors in a sequence timed to coincide with the needs of the engine, the system will supply gasoline to the engine as it should.

For this function and that of providing the proper amount of fuel to the engine, the system is fitted with an electronic computer to time the impulses. The computer receives a signal from the ignition distributor to

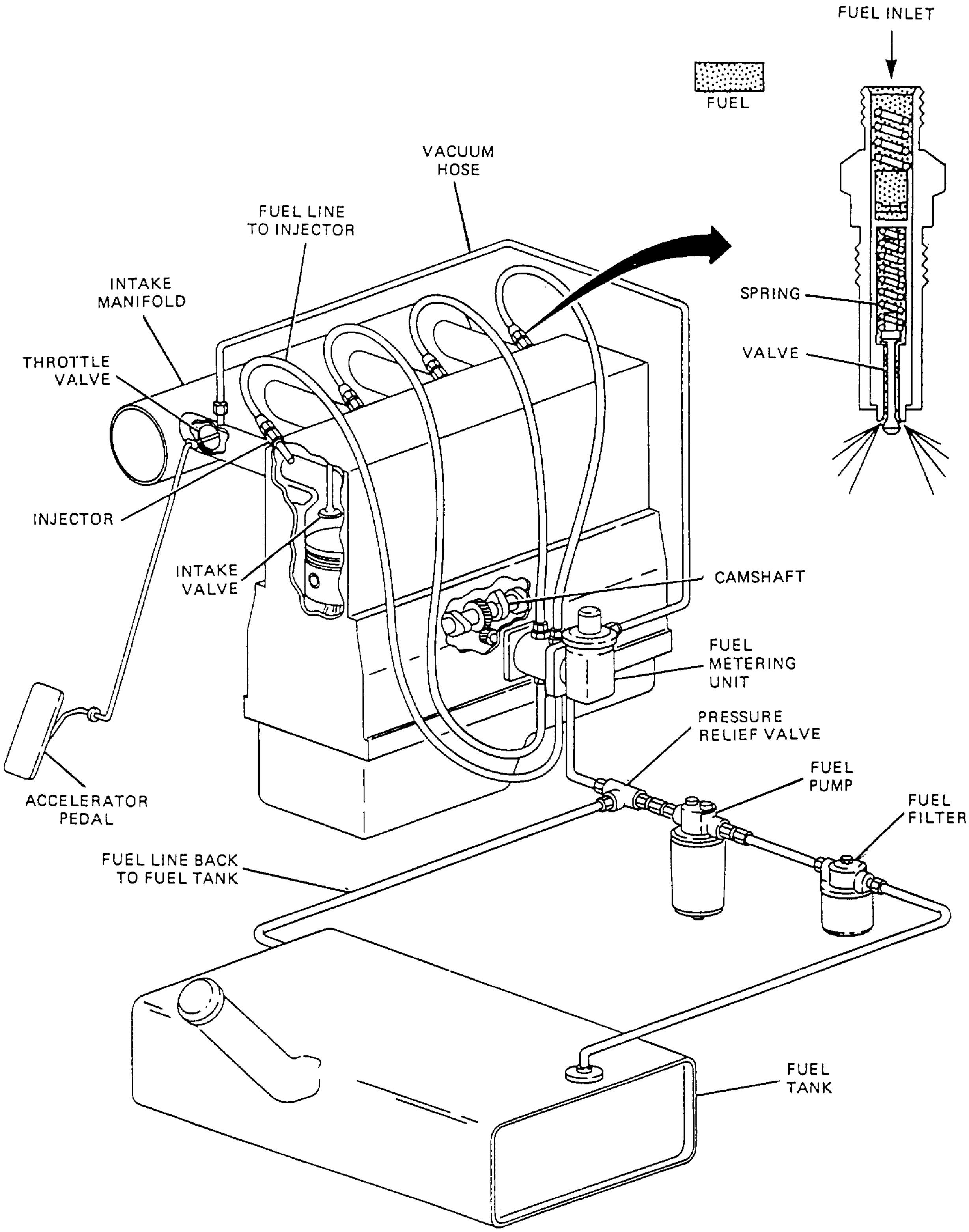


Figure 5-1.-Mechanical-timed injection.

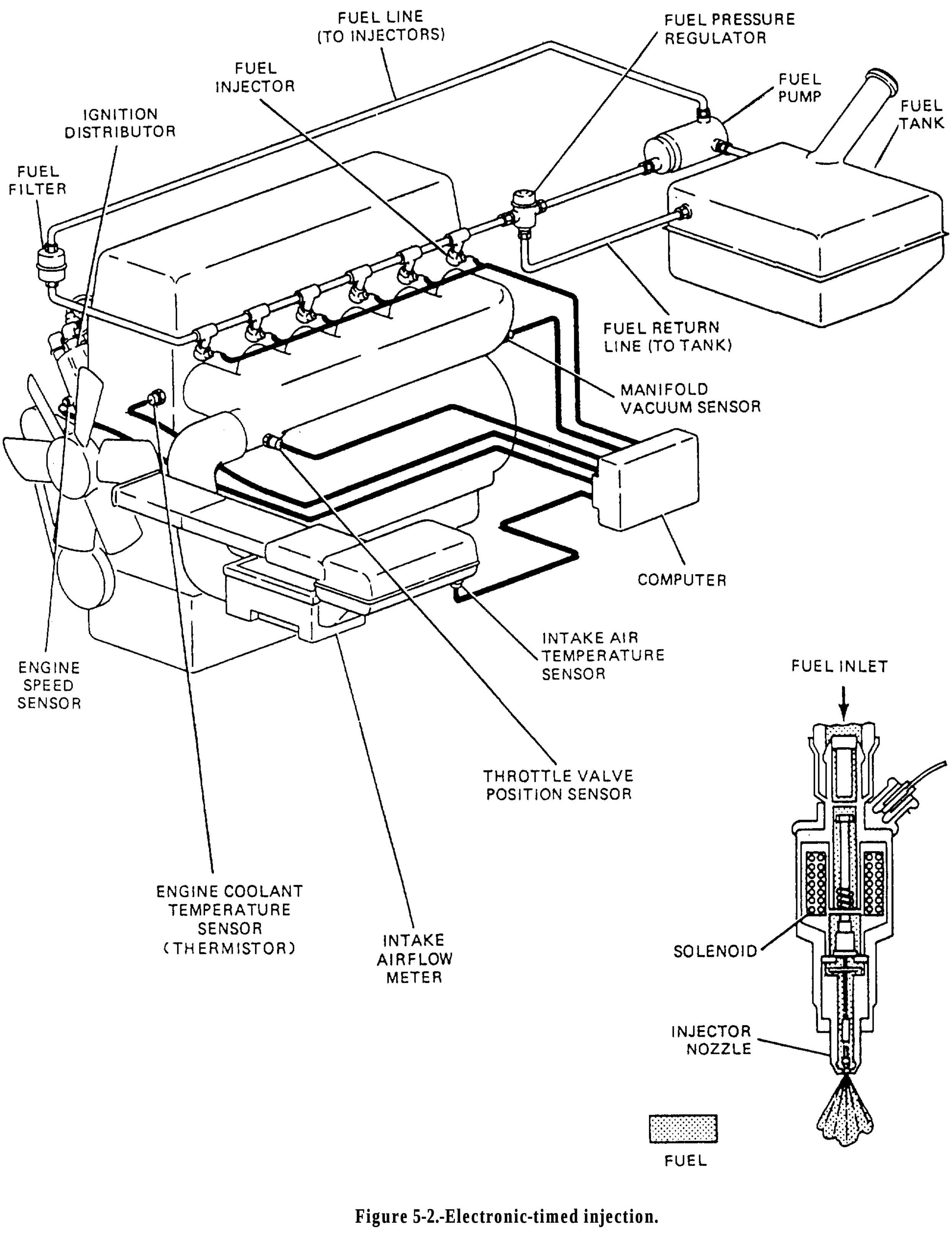


Figure 5-2.-Electronic-timed injection.

establish the timing sequence. The engine is fitted with a variety of sensors and switches to gather the following information:

- Intake air temperature
- Engine speed
- Manifold vacuum
- Engine coolant temperature
- Throttle valve position
- Intake manifold airflow

The computer receives this information and uses it to calculate the amount of fuel delivered at each injection cycle. The computer is capable of changing the rate of fuel delivery to the engine hundreds of times a second, making the system extremely accurate. The computer regulates the amount of fuel delivered by varying the duration of injector operation.

CONTINUOUS FUEL INJECTION SYSTEMS

Continuous fuel injection systems (fig. 5-3) provide a continuous spray of fuel from each injector at a point before the intake valve. Because the entrance of the fuel into the cylinder is controlled by the intake valve, the continuous system will fulfill the requirements of a gasoline engine. Timed injection systems, though a necessity on diesel engines, cost more than continuous systems. They are used on gasoline engines only when more precise fuel metering is desired.

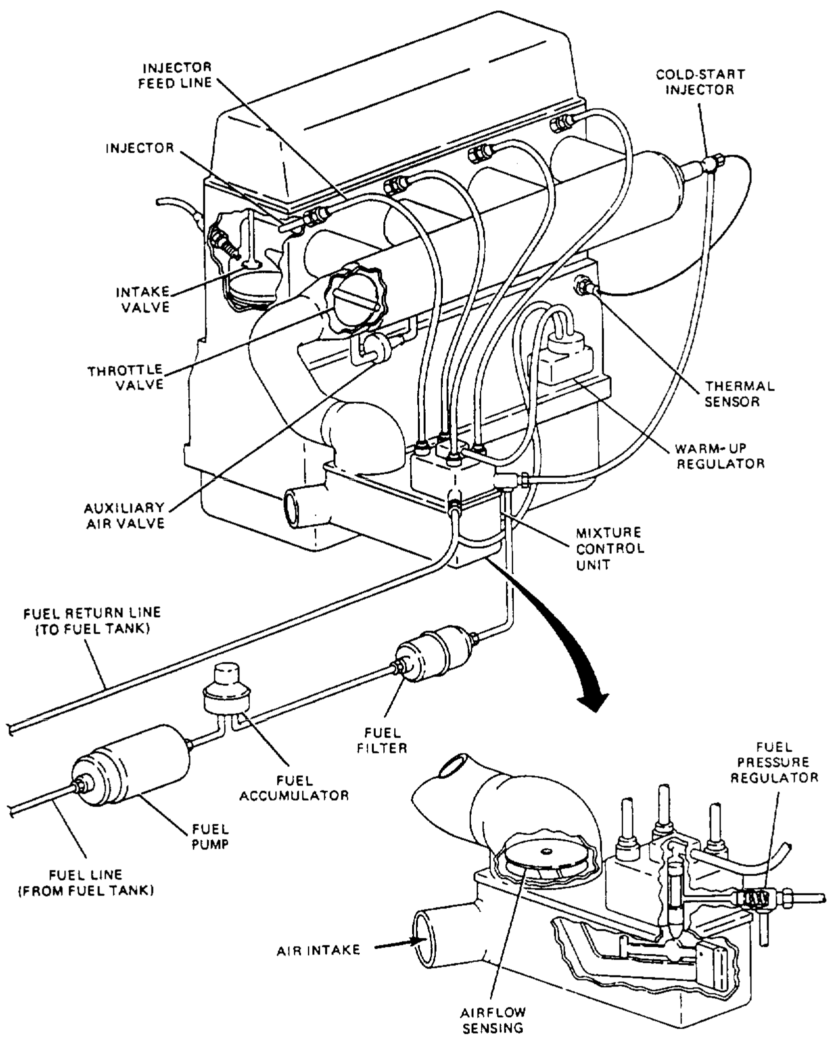


Figure 5-3.-Continuous injection.

In the continuous system, fuel is delivered to the mixture control unit by the fuel pump. The fuel pressure regulator maintains fuel line pressure by sending excess fuel back to the gas tank.

The mixture control unit regulates the amount of fuel that is sent to the injectors, based on the amount of airflow through the intake and the engine temperature. The mixture control unit on mechanical systems is operated by the airflow sensing plate and the warm-up regulator. This information on an electronic system is fed into a computer that regulates the fuel injection rate.

The accelerator pedal regulates the rate of airflow through the intake by opening and closing the throttle valve. A cold-start injector is installed in the intake to provide a richer mixture during engine start-up and warm-up. It is actuated by electric current from the thermal sensor whenever the temperature of the coolant is below a certain level. The cold-start injector works in conjunction with the auxiliary air valve. Its function is to speed up the engine idle during warm-up. It is also actuated by the thermal sensor.

THROTTLE BODY INJECTION SYSTEMS

Throttle body injection (fig. 5-4) is a form of continuous injection-one or two injectors delivering gasoline to the engine from one central point in the intake manifold. Though throttle body injection does not provide the precise fuel distribution of the direct port injection, it is cheaper to produce and to provide a degree of precision fuel metering. The throttle body injection unit is usually an integral one and contains all of the major system components. The unit mounts on the intake manifold in the same manner as a carburetor. Airflow sensors and electronic computers usually are mounted in the air cleaner body.

SERVICING AND PRECAUTIONS

When a vehicle equipped with a gasoline type of fuel injection system has a problem, check all other systems first, such as ignition, air intake, charging, exhaust systems, and so forth-before you work on the fuel injection system. The fuel injection system is usually the last (least problematic) system to cause trouble. There are servicing precautions you should observe before you work on gasoline fuel injection systems.

1. Do not jump the battery to start the vehicle.

2. Do not disconnect the battery cables from the battery with the engine running.

3. When charging a battery in the vehicle, disconnect the negative (grounded) terminal.

4. Do not remove or attach the wiring harness plug to the electronic control unit (computer) with the ignition on.

5. Before performing a compression test, check the manufacturer's repair manual for special instructions.

6. Always make sure all other systems are in good working order before you adjust or troubleshoot the gasoline fuel injection system.

These precautions are general and apply to most systems. Nevertheless, use good judgment, and always

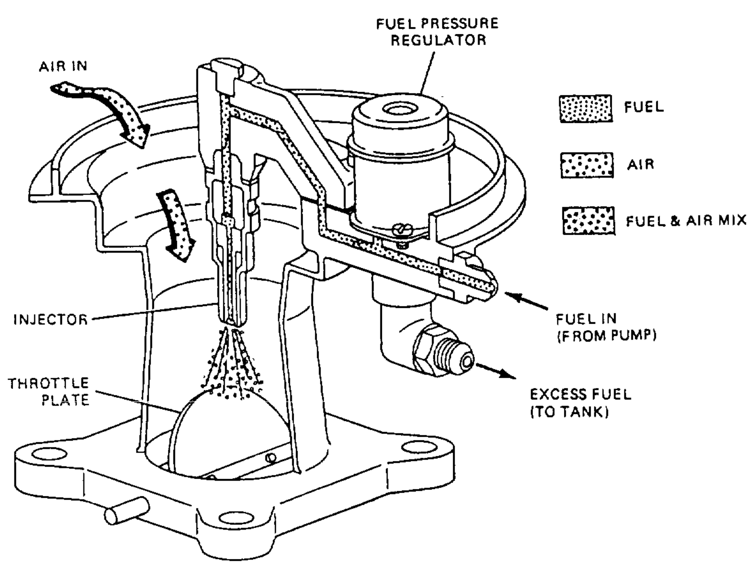


Figure 5-4.-Throttle body injection.

check your manufacturer's repair manual for proper specifications and procedures.

Preventive maintenance is the most frequent type of servicing you will perform on a gasoline fuel injection system. Preventive maintenance consists of periodic visual checks and scheduled fuel filter service. Fuel filters are of the cartridge type, in line type, and disposable type.

All fuel injection system control sensors, such as temperature, oxygen, manifold absolute pressure, and so forth, (these are fully described in chapter 4 of this TRAMAN) are electrically connected to the electric control module (ECM). Some of these sensors, such as the oxygen sensor, have a regular maintenance cycle. Check your manufacturer's repair manual for special instructions pertaining to these sensors.

Be sure the air intake system is sealed properly. Early detection will save fuel and prevent engine damage. Air leaks are a problem to gasoline fuel injection systems. If the air leak is after the air filter, dirt will be ingested into the engine causing internal damage to the engine. Air leaks that bypass temperature sensors can cause false readings to be delivered to the ECM, changing injection quantity. Unmetered air leaks in the intake manifold can cause a lean fuel-air mixture to be delivered to the combustion chambers.

During regular maintenance and always after reassembly, you should check for fuel leaks. Gasoline leaks, however small, arc extremely dangerous. They must be dealt with immediately. Clean around all areas to be disassembled. Heavy layers of dirt and grime may make some leaks hard to find. Install new seals on leaking connections and replace cracked or leaking hoses.

CAUTION

Gasoline fuel injection systems operate with fuel pressures up to five times greater than that of standard gasoline fuel systems. Any replacement fuel lines used should be approved for higher pressures. Failure to do so will result in an unsafe fuel system on the vehicle with the danger of possible explosion and fire.

Clean around all areas before reassembly. When you tighten injector line nuts (injector head), use new seals and proper torque specifications. When you tighten fuel lines, use flare nut type of wrenches because regular open-end wrenches may damage these fuel line fittings.

Gasoline fuel injection systems have up to eight different manufacturers and over 21 different models. The 1990 edition of *Electronic Fuel Injection (Domestic) Diagnosis and Testing Manual* by Mitchell is an excellent source for additional study on this subject.

DIESEL FUEL INJECTION SYSTEMS

When you studied the *Construction Mechanic 3 & 2*, you learned about general maintenance, removal, and replacement of diesel fuel; injection pumps, injectors, blowers, and turbochargers, as well as timing, minor adjustments, and repairs to the Caterpillar, International Harvester, General Motors, and Cummins diesel fuel systems. In this section, you will learn about the processes used to overhaul and troubleshoot diesel fuel and air induction systems.

CATERPILLAR FUEL INJECTION SYSTEMS

There are three types of Caterpillar fuel injection systems: the forged body, the compact, and the sleeve metering systems. While these systems serve the same purpose and you use common general troubleshooting procedures, each has an individual design. These systems have a capsule type of injector with a precombustion chamber that conditions the injected fuel for more effective combustion.

Forged Body Fuel System

The two main parts of the Caterpillar fuel injection system are the fuel injection pump (fig. 5-5), which times, meters, and creates the pressure needed for fuel

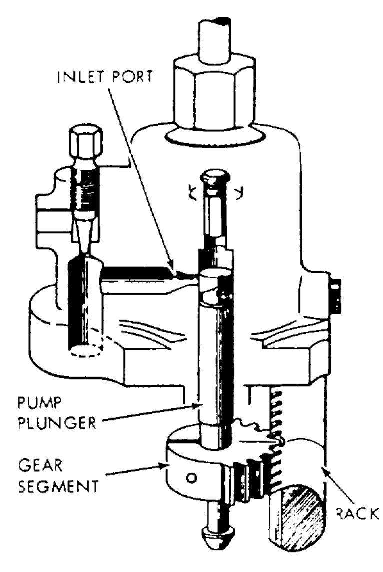


Figure 5-5.-Fuel injection pump.

delivery and the capsule type injector valve (fig, 5-6), which injects and atomizes the fuel.

The most likely causes of faulty fuel injection performance are (1) air in the fuel, (2) low fuel supply, (3) water in the fuel, (4) dirty fuel filters, and (5) low transfer pump pressure. If, after you have checked and corrected these conditions, the engine still does not perform properly, check the fuel injection components. Some of the guidelines for troubleshooting and general test procedures used to test pumps and valves are discussed below.

TROUBLESHOOTING.— Before you remove either the injector pump or injector valve from an erratically running engine, make a simple test. Run the engine at a speed that makes the defect most pronounced. Momentarily, loosen the fuel line nut on the injector pump far enough so that the cylinder misfires or cuts out. Check each cylinder in the same manner. If you find one that has no effect on the irregular operation of the engine or black smoke stops puffing from the exhaust, you have located the misfiring cylinder. You will probably only have to remove the pump and valve for that cylinder for additional testing.

TESTING.— The Caterpillar fuel injection tester provides a means for determining the condition of the fuel injection pumps and valves. Before you perform any test, be sure to study and follow the instructions in the manual for the type of testing equipment you are using.

Injection Pump.— Clean the fuel pump thoroughly before installing it on the tester. If any abrasive material enters the pump, it may be carried into the discharge collector of the tester and impair the discharge measurement accuracy. Close the fuel pump openings with the covers provided, holding the plunger in place. Clean the pump thoroughly with cleaning solvent or fuel oil.

Pumps are tested at or near (within .025 inch) the full-load setting of the engine. If the fuel delivery from the pump is within the limits of the full-load setting, the pump will perform properly throughout the full range of rack travel. The governor will compensate for pump wear at any rack setting less than the full-load setting.

Caterpillar fuel injection pumps have no adjustments or replacement parts for rebuilding. If the tester reveals that the pump is no longer serviceable, discard the pump.

To test the injector pump, determine the plunger diameter by inserting the portion of the plunger under the gear into the gauge supplied with the tester. Insert the portion of the pump plunger and gear segment into the gauge setting of the housing of the tester, as shown in figure 5-7. Determine the proper full-load rack setting by referring to the rack setting charts for the engine from which the pump was removed. After you have made the full-rack setting (usually to the nearest .025 inch), you also will be able to determine the number of discharge strokes required from the pump test chart. Now you are ready to attach the collector assembly and jar to the fuel

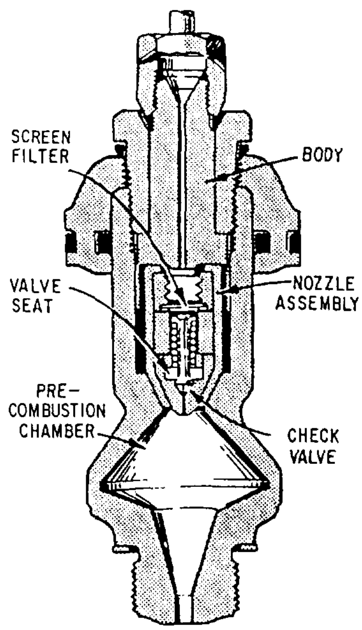


Figure 5-6.-Capsule type of fuel injection valve assembly.

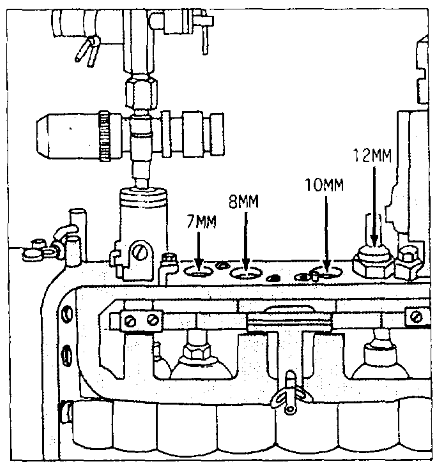


Figure 5-7.-Test location of various size pumps.

pump, as shown in figure 5-8. Remember, bleed the air from the pump and the collector assembly during the priming. After the priming, remove the collector jar and drain. Reset the counter to zero and attach the collector jar to the collector assembly. Operate the pump the prescribed number of discharge strokes. Remove the collector jar and place it on a level surface. The fuel level in the jar is to read from the bottom, as shown in figure 5-9.

The condition of the pump is indicated directly by the calibrations on the collector jar. If the fuel level is within or above the GOOD range, the pump is equivalent to a new one. A fuel level within or below the POOR range shows that the pump plunger and barrel have worn so much that the engine will be hard to start and may have less power. Such pumps should be replaced.

Capsule Type Injector Valve.— Capsule type fuel injection valves can be tested on the fuel injection tester for spray characteristics valve opening pressure, and leakage rate. Before testing the valve, inspect the screen filter. (See fig. 5-2.) If the screen is broken or clogged with the dirt particles, discard the valve.

When cleaning thc deposited carbon from the injection valve nozzle (fig. 5-10), use a drill from the cleaning tool group kit, furnished by Caterpillar, that corresponds to the orifice size of thc nozzle. The orifice size is usually stamped on thc side of the valve.

NOTE

NEVER clean the injection valves with a wire brush. The use of a wire brush to remove carbon from the injection valves might damage the orifice and reduce power output.

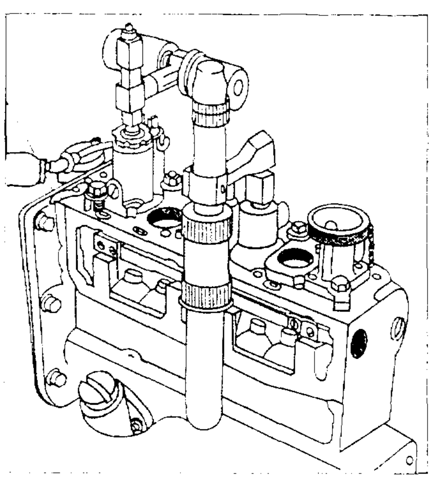


Figure 5-8.-Collector assembly and jar.

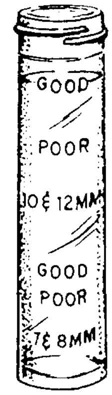


Figure 5-9.-Correct level in collector jar.

After inspecting the valve screen filter and cleaning the injector valve nozzle, test the valve for spray characteristics. A solid stream of fuel with little or no atomization is caused either by a gummy carbon accumulation or a particle of foreign material.

If the fuel emitted is properly atomized and the cutoff is sharp with no dribble, the spray characteristics of the valve are satisfactory.

Next, test the valve for opening pressure and leakage. Valve opening pressure ranges from 400 to 800 psi, as registered on the test gauge. If the injection valve fails to reach a minimum of 400 psi, observe the gauge to note any drop in pressure. If the pressure falls more than 100 psi in 30 seconds, discard the injection valve nozzle.

Compact Fuel System

The pressure type of compact fuel system has a separate injection pump and injection valve for each cylinder. Fuel is injected into a precombustion chamber (fig. 5-11). A transfer pump delivers filtered fuel to the manifold from which the injection pumps get their fuel. The transfer pump supplies more fuel than is required

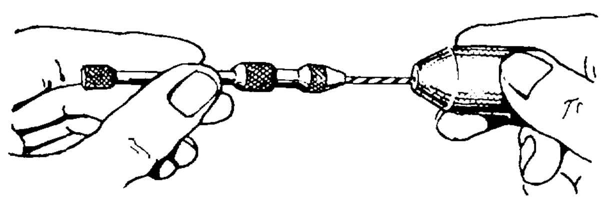


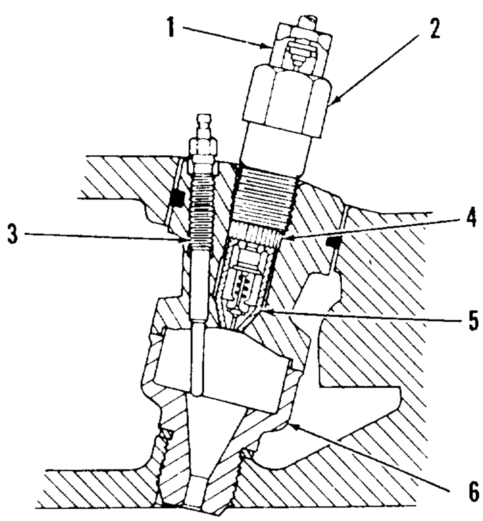
Figure 5-10.-Cleaning capsule type of nozzle.

for injection. A bypass pressure relief valve limits the maximum pressure.

OPERATIONS.— The injection pump (fig. 5-12) forces fuel under high pressure to the injection valves. Injection pump plungers and lifters are actuated by lobes on the pump camshaft and always make a full stroke. The lifters are held against the pump camshaft by spring pressure, applied to the plungers.

GOVERNOR.— The governor on the compact fuel system is hydraulically operated. Governor action controls the amount of fuel injected by turning the plunger (fig. 5-1) in the barrel through a gear segment on the bottom of the plunger. Pressurized lubrication oil enters the passage in the governor cylinder. The oil encircles the sleeve within the cylinder and is directed through a passage to operate the piston.

When the engine is started, the speed limiter plunger restricts the governor control linkage. Operating oil pressure has to react on the speed limiter before the governor control can be moved to the high-idle position. At low idle, a spring-loaded plunger bears against the shoulder of the low-idle adjusting screw. This action forces the plunger past the shoulder on the adjusting screw, and stops the engine.



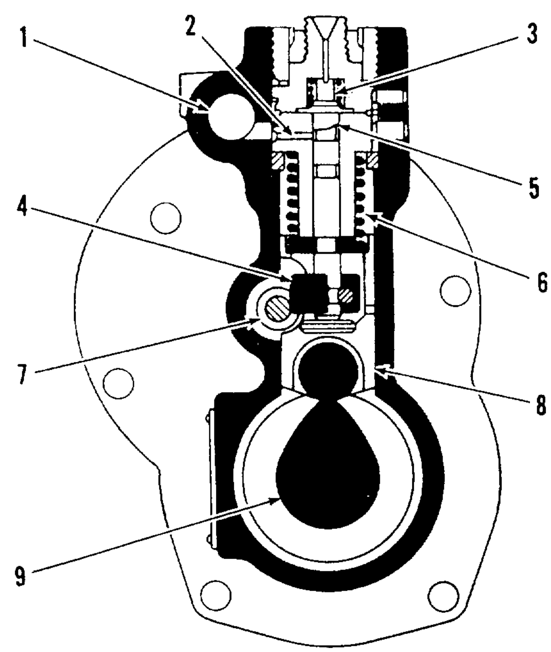
1. Fuel injection line
2. Nut
3. Glow plug
4. Body
5. Nozzle assembly
6. Precombustion chamber

Figure 5-11.-Precombustion chamber and fuel injection valve.

Lubrication oil from the governor drains into the fuel injection pump housing.

TROUBLESHOOTING.— Many times the fuel system is blamed when the fault lies elsewhere, especially when smokey exhaust is the problem. Smokey exhaust can be caused by lack of air for complete combustion, overloading, oil burning, lack of compression, as well as faulty injection valves or pumps.

The two troubles in the compact system are lack of fuel and too much fuel for proper combustion. If the time dimension is too small, injection will begin early; and if too great, injection will be late. When checking plunger wear, check the lifter washer for wear to avoid rapid wear of the plunger. If the plunger length is not within limits, discard the plunger.



1. Fuel manifold
2. Inlet port
3. Check valve
4. Gear segment
5. Pump plunger
6. Spring
7. Fuel rack
8. Lifter
9. Camshaft

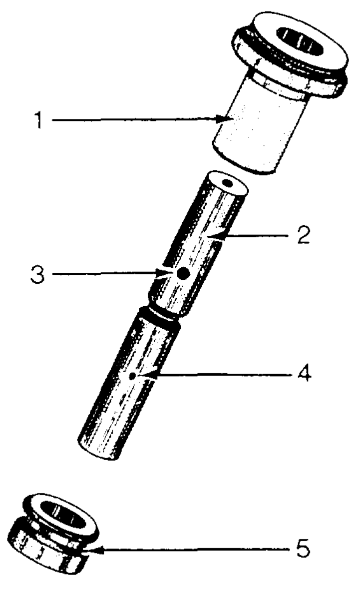
Figure 5-12.-Compact fuel injection pump.

Sleeve Metering Fuel System

The sleeve metering fuel system on some models of the Caterpillar engine gets its name from the method of controlling the amount of fuel injected into the cylinder. This system has an injection pump and an injection valve for each cylinder. Most injection valves are located in the precombustion chamber, while the injection pumps are located in a common housing.

As with other diesel injection systems, proper operation depends on the quality and cleanliness of the fuel. Certain applications of the sleeve metering system have a water separator to remove up to 95 percent of the water in the fuel.

COMPONENTS.— Thc three main components of the sleeve metering fuel system are designed and operated differently from earlier Caterpillar fuel injection systems. These components arc the plunger, barrel, and sleeve, which arc mated sets (fig. 5-13) and must be kept together. The plunger moves up and down inside the barrel and sleeve. The barrel is stationary while the sleeve is moved up and down in the plunger. Sleeve position is controlled by the action of the governor through varied loads to regulate the amount of fuel injected. Located in the inlet side of the system is a priming pump. When you open the bleed valve and operate the priming pump, air is removed from the injection pump housing filters and suction lines.



1. Barrel
2. Plunger
3. Fill port
4. Spill port
5. Metering sleeve

Figure 5-13.-Sleeve metering barrel and plunger assembly.

OPERATIONS.— The lifter and plunger are lifted through a full stroke with each revolution of the pump camshaft. Spring force on the plunger, through the retainer, holds the lifter against the camshaft through the full-stroke cycle. The fuel in the housing supplies the injection pumps and lubricates the moving parts in the housing. Before the engine will start, the housing must be charged, as shown in figure 5-14, Position 1. The sleeve must be high enough on the plunger to close the fuel outlet (spill port) during part of the stroke. The chamber fills with fuel through the fuel inlet (fill port), which is below the level of thc fuel in the housing.

Injection begins when the rotation of the camshaft lifts the plunger far enough into the barrel to close the fuel inlet (fig. 5-14, Position 2). Both the fuel inlet and outlet are now closed. Continued rotation of the camshaft (fig. 5-14, Position 3) lifts the plunger farther into the chamber of the barrel and increases the pressure on the trapped fuel. This pressure is felt by both the reverse flow check valve in the pump (fig. 5-15, No. 1) and the injector valve located in the nozzle assembly (fig. 5-11, No. 5). When the pressure is high enough to open the capsule, injection occurs.

Injection ends when the camshaft rotation causes the plunger to open the fuel outlet, as shown in figure 5-14, Position 4. The open fuel outlet reduces the

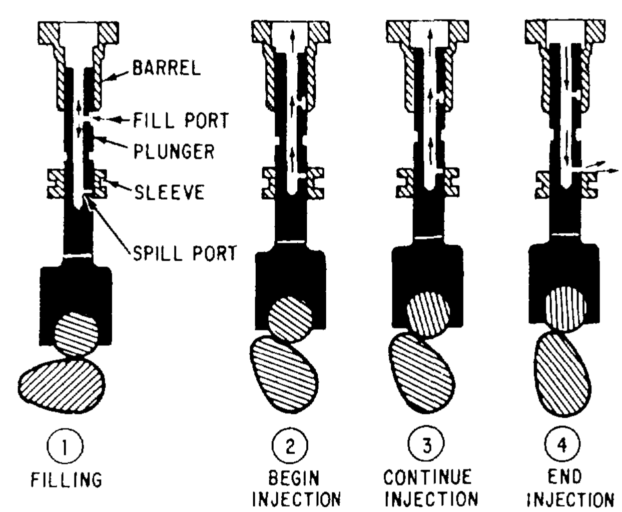
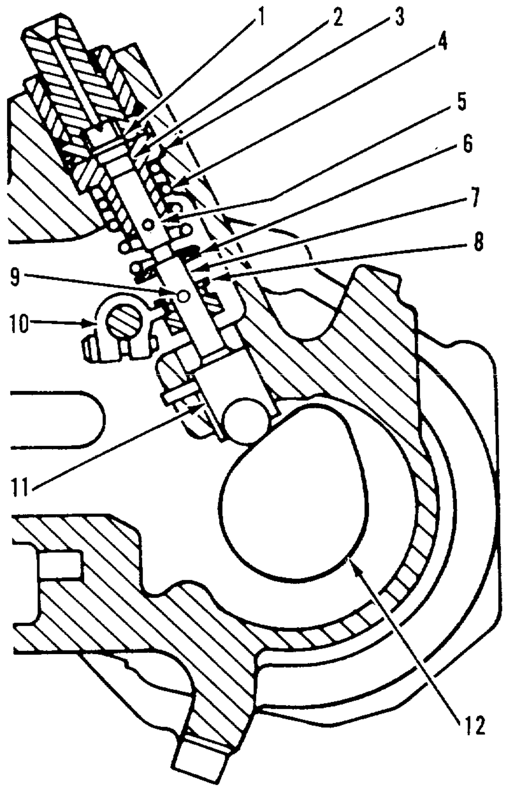


Figure 5-14.-Injection pump operating cycle.

pressure on the fuel within the pumping chamber. Residual pressure in the fuel lines closes the reverse flow check valve in the pump and prevents surges on the fuel lines. No fuel flowing permits the injection valve to close and complete injection.

The camshaft continues to lift the plunger to the top of the stroke. The fuel in the housing fills the space in the pumping chamber through the fuel outlet until the sleeve closes the outlet on the downward stroke. Spring pressure pushes the plunger farther down as the camshaft rotates, allowing the fuel inlet to fill the rest of the chamber and restarting the cycle.



1. Reverse flow check valve
2. Chamber
3. Barrel
4. Spring
5. Fuel inlet
6. Retainer
7. Plunger
8. Sleeve
9. Fuel outlet
10. Sleeve control lever
11. Lifter
12. Camshaft

Figure 5-15.-Sleeve metering fuel pump.

GOVERNOR.— The mechanical type governor shaft of the governor for the sleeve metering fuel system controls the position of the sleeve on the plunger, which regulates the amount of fuel injected. The volume of fuel injected is equal to the displacement of the plunger lift into the barrel between the start and end of injection. The start-up control sets the fuel injection pumps at full stroke to aid in starting, regardless of the throttle position. Normal governor operation takes over at low-idle speed, approximately 500 rpm.

TROUBLESHOOTING AND ADJUSTMENTS.— Most problems in this system can be traced to lack of fuel, low fuel pressure, dirty fuel filters, poor quality fuel, or a broken or damaged fuel line. Air enters the fuel system when there are loose connections of the suction side of the pump.

Individual fuel injection pumps for each cylinder with built-in calibration means little or no balancing or adjustment. Before you calibrate any sleeve metering fuel system, be sure the proper tools and manuals are available.

ROOSA MASTER FUEL INJECTION PUMP

The *Construction Mechanic 3 & 2* covers the general construction and operation of the Roosa Master DB and DC fuel injection pumps.

In this TRAM AN, you will learn about troubleshooting, disassembly, inspection, reassembly, and testing of the basic DC fuel pump of the Roosa Master system. Before you perform any work on an injection pump, refer to the manufacturer's maintenance and service manuals.

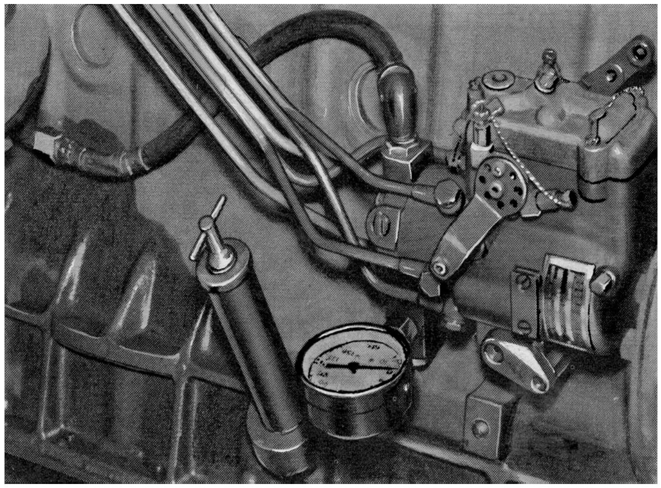
The troubleshooting chart (table 5-1) lists some of the problems and their possible causes that you might encounter in the Roosa Master fuel system.

Troubleshooting

A field test (Kiene) on an engine is an efficient way to pinpoint the cause of poor engine performance. This test will eliminate unnecessary fuel injection pump removal. Since this field test permits some analysis of engine condition, as well as the fuel system, you will quickly see the extent of the difficulty and the required remedies.

Table 5-1.-Troubleshooting Chart for Roosa Master Fuel System

CAUSE OF PROBLEM (Numbers in "Problem" Check Chart indicate order in which to check possible "Causes" of Problem.)	A. Fuel not reaching pump.	B. Fuel delivered from transfer pump but not to nozzles.	C. Fuel reaching nozzles but engine won't start.	D. Engine starts hard.	E. Engine starts and stops.	F. Erratic engine operation–surge, misfiring, poor governor regulation.	G. Engine idles imperfectly.	H. Engine does not develop full power or speed.	I. Engine smokes black.	J. Engine smokes blue or white.	CORRECTIVE MEASURES
Hand primer installed backwards.	3										Re-install properly.
One or more connector screws obstructed.		3		2					9		Replace.
Seizure of distributor rotor.	2										Check for cause of seizure. Replace hydraulic head and distributor rotor assembly.
Failure of electrical shutoff.		2			7						Remove, inspect, and adjust parts. Replace parts as necessary.
Fuel supply lines clogged, restricted, wrong size, or poorly located.	6	7	5	3	1	2	8	4			Blow out all fuel lines with filtered air. Replace if damaged. Remove and inspect all flexible lines.
Air leaks on suction side of system.	7			4	6	7	3	5			Troubleshooting the system for air leaks.
Automatic advance faulty or not operating.			8	9		9	8	11	4	2	Remove, inspect, correct, and reassemble.
Water in fuel.			3	6	2	5	1	13			Drain fuel system and pump housing, provide new fuel, prime system.
Return oil line or fittings restricted.				11	4	13	11	8			Remove line, blow clean with filtered air, and reassemble. Replace if damaged.
Air intake restricted.					3			14	1		Check manual.
Pump housing not full of fuel.						6	2				Operate engine for approximately 5 minutes until pump fills with fuel.
Fuel lines incorrect, leaking, or connected to wrong cylinders.			4			1		15			Relocate pipes for correct engine firing sequence.
Shutoff device interfering with governor linkage.			6	8				2			Check and adjust governor linkage dimension.
Governor high-idle adjustment incorrect.								3			Adjust to pump specifications.
Throttle arm travel not sufficient.			2					1			Check installation and adjust throttle linkage.
Transfer pump blades worn or broken.	5			7	9	12	5	12			Replace.
Shutoff device at "stop" position.		1									Move to "run" position.
Metering valve sticking or closed.		4		8	8	10	6	10			Check for governor linkage binding, foreign matter, burrs, etc.
Governor spring worn or broken.		5				11	9				Remove and replace.
Governor linkage broken.		6					10				Remove, replace, and readjust per specifications.
Tank valve closed.	1										Open valve.
Nozzles faulty or sticking.			7	10		8	7		3		Replace or correct nozzles.
Pump timed incorrectly to engine.			1	1		4	4	7	2	1	Correct timing.
Filters or Inlet strainer clogged.	4			5	5	3		6			Remove and replace clogged elements. Clean strainer.



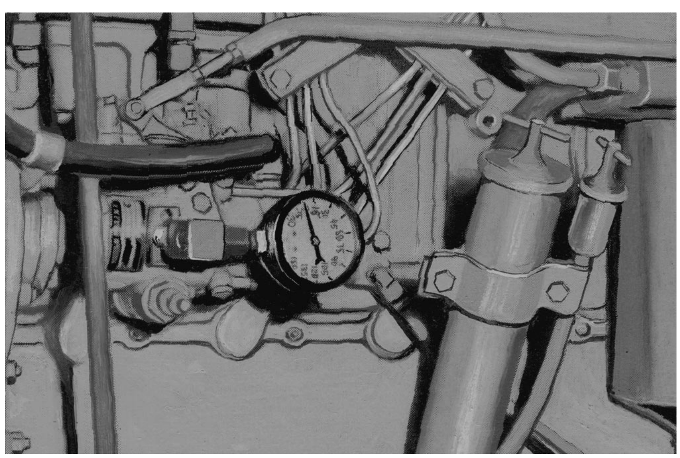
2.492

Figure 5-16.-Gauge installed for checking transfer pump pressure.

Since most tests are more conveniently made under no load conditions, all possible readings are determined at high idle. If the supply pressure is lower than normal, an engine can still operate smoothly at approximately the correct high-idle speed. The governor opens the metering valve further to make up for the lower pressure; therefore, you can take successful readings at high idle.

First, disconnect the throttle linkage. Then, with the engine running, hold the throttle lever all the way to the rear. Adjust the high-idle stop screw until the specified high-idle speed is obtained to test the fuel pressure at high idle. Install the gauge assembly in the pressure trap of the transfer pump, as shown in figure 5-16. If this reading does not fall within the prescribed range, the pump will not deliver sufficient fuel to obtain full power under load. The most common causes of low pressure are restricted fuel supply, air leaks on the suction side of the pump, worn transfer pump blades, or a malfunctioning regulator valve.

To test for excessive pressure (fig. 5-17), remove the injection fuel pump timing plate. Be sure you make a small hole in the timing plate gasket as you install the gauge on the pump. This hole allows pump pressure to reach the gauge as you operate the engine at both low



2.493

Figure 5-17.-Testing pump housing pressure.

and high idle. If the pressure is excessive, a restricted fuel return line is the probable cause.

To test for restricted fuel supply on the suction side of the pump, operate the engine at high idle and read the vacuum developed. If the vacuum reading exceeds 10 inches mercury (Hg), check the fuel supply system for dirty filters, pinched or collapsed hoses, or a plugged vent.

Removal

If, after field testing, you find you must remove the injection fuel pump from the engine, be sure to remove all external grease and dirt. Remember, dirt, dust, and other foreign matter are the greatest enemies of the injection fuel pump. As a precaution, keep all openings plugged during removal and disassembly.

Disassembly

The workbench, surrounding area, and tools must be clean. You should have a clean pan available to put parts into as you disassemble the pump, You also need a pan of clean diesel fuel oil in which the parts can be washed and cleaned.

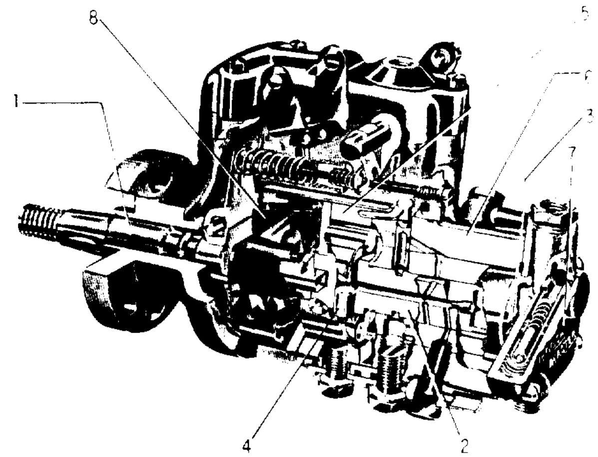
After mounting the pump in a holding fixture, clamp the fixture in a vise. Now you are ready to disassemble the pump. Follow the step-by-step procedure in the manual for the model pump on which you are working. Figure 5-18 shows the main internal working parts of the Roosa Master fuel injection pump.

Cleaning, Inspecting, and Reassembly

Now that you have disassembled the pump, and inspected all the parts carefully, replace all O rings, seals, and gaskets, and inspect all springs for wear, or distortion. Clean and carefully check all bores, grooves, and seal seats for damage of any kind. Replace damaged parts as necessary.

Also, inspect each part of the injection pump for excessive wear, rust, nicks, chipping, scratches, cracks, or distortion. Replace any defective parts.

When you have finished cleaning and inspecting the pump, reassemble it. Follow the steps specified by the manufacture's maintenance and repair manual.



1. Drive shaft
2. Distributor rotor
3. Transfer pump
4. Pumping plungers
5. Internal cam ring
6. Hydraulic head
7. End plate
8. Governor

Figure 5-18.-Roosa Master fuel injection pump.

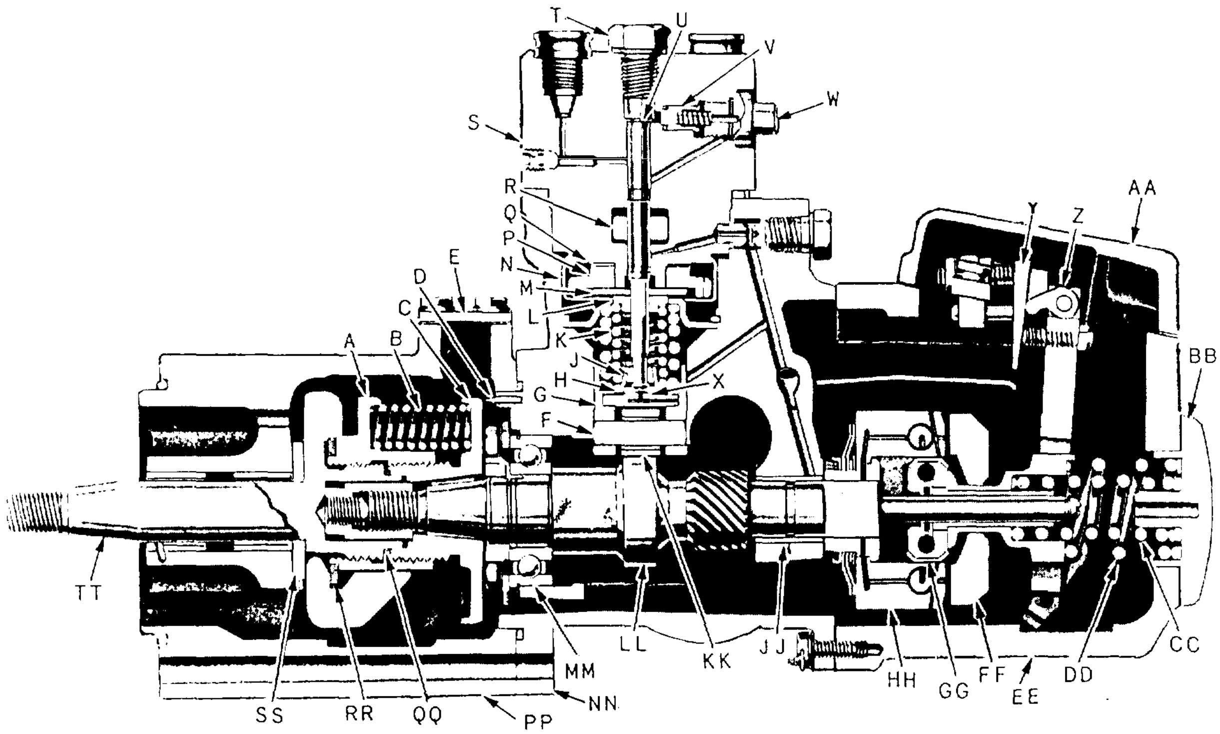
AMERICAN BOSCH FUEL INJECTION PUMP

The American Bosh fuel injection pump is used on multifuel engines. This pump meters and distributes fuel. It is a constant-stroke, distributing-plunger, sleeve-control type of pump. As with other fuel systems, only clean fuel should be used. Good maintenance of the filtering system and reasonable care in fuel handling will give trouble-free operation. Fuels used in the multifuel engine must contain sufficient lubrication to lubricate the fuel pump and injectors. Because of close tolerances, extreme cleanliness and strict adherence to service instructions are required when it is time to service this pump.

In this section, you will learn about the operation and troubleshooting of the American Bosch, Model PSB, pump and the Bosch nozzles that are used with the International Harvester engines.

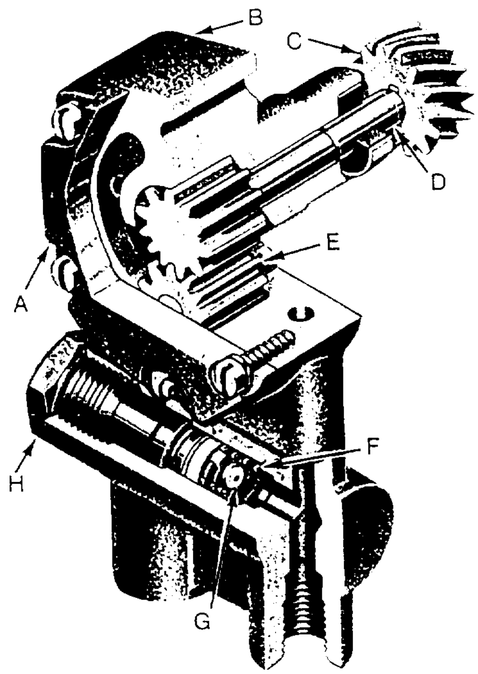
Operation

The purpose of the fuel pump (fig. 5-19) is to delivcr measured quantities of fuel, accurately, under high pressure to the spray nozzle for injection. The positive



A – **Sliding gear**
B – **Advance unit spring**
C – **Advance unit hub**
D – **Timing pointer**
E – **Timing cover**
F – **Tappet roller pin**
G – **Tappet guide**
H – **Spring lower seat**
J – **Plunger lock**
K – **Plunger inner spring**
L – **Spring upper seat**
M – **Plunger guide**
N – **Drive gear retainer**
P – **Plunger drive gear**
Q – **Gear thrust washer**
R – **Plunger sleeve**
S – **Hydraulic head**
T – **Plunger bore screw**
U – **Fuel plunger**
V – **Fuel delivery valve**
W – **Delivery valve screw**
X – **Plunger button**
Y – **Stop plate**
Z – **Smoke limit cam**
AA – **Governor cover**
BB – **Governor end cap**
CC – **Governor inner spring**
DD – **Governor outer spring**
EE – **Governor housing**
FF – **Governor weight**
GG – **Sliding sleeve**
HH – **Friction drive spider**
JJ – **Camshaft bushing type bearing**
KK – **Tappet roller**
LL – **Camshaft**
MM – **Camshaft ball bearing**
NN – **Injection pump housing**
PP – **Advance unit housing**
QQ – **End play spacer**
RR – **Sliding gear spacer**
SS – **Spider thrust plate**
TT – **Spider assembly**

Figure 5-19.-Metering and distributing fuel pump assembly–left sectional view.



A – Housing cover
B – Supply pump housing
C – Camshaft driven gear
D – Drive shaft
E – Idler gear
F – Check valve spring
G – Check valve
H – Valve screw

Figure 5-20.-Fuel supply pump assembly-sectional view.

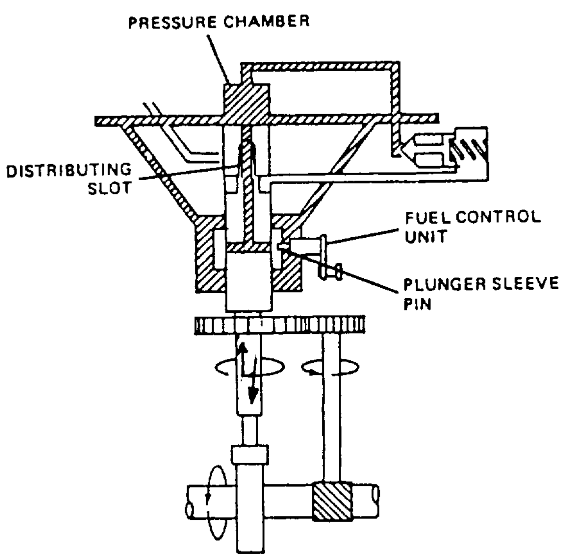


Figure 5-21.-Fuel intake flow diagram.

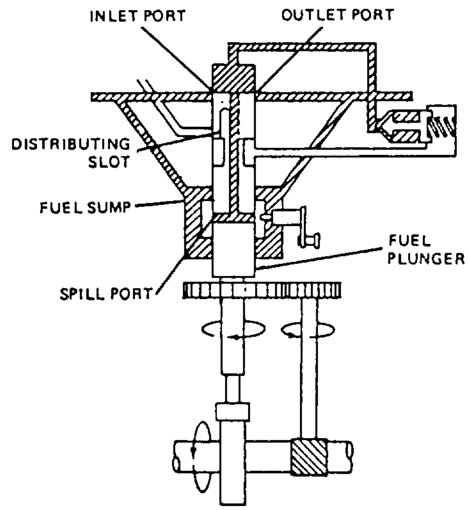


Figure 5-22.–Beginning of fuel delivery flow diagram.

displacement fuel supply pump (fig. 5-20) is gear driven by the pump camshaft through an engine camshaft gear and provides fuel to the hydraulic head for injection and cooling.

Figure 5-21 shows fuel intake at the hydraulic head. Injection (fig. 5-22) begins when fuel flows around the fuel plunger annulus (fig. 5-23) through the open distributing slot to the injection nozzle. A continued upward movement of the fuel plunger causes the spill passage to pass through the plunger sleeve (fig. 5-24). This reduces pressure, allowing the fuel delivery valve to close, ending injection. This is accomplished through a single plunger, multioutlet hydraulic head assembly (fig. 5-19).

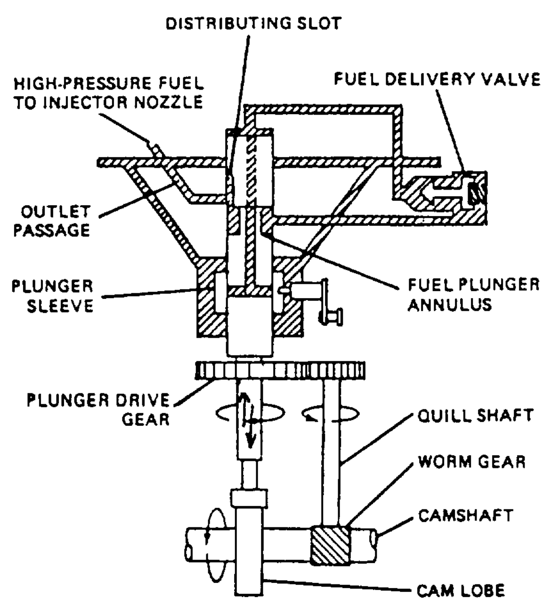


Figure 5-23.-Fuel delivery flow diagram.

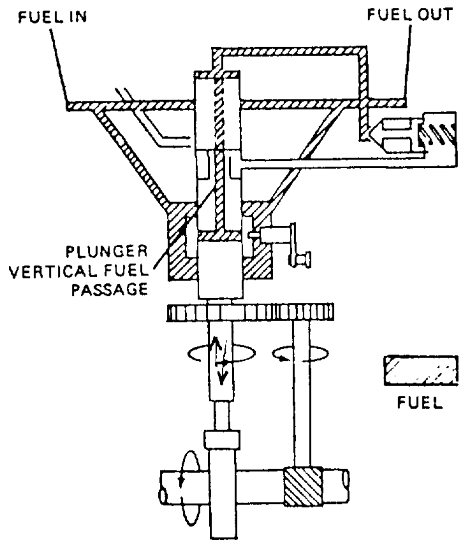


Figure 5-24.-End of fuel delivery flow diagram.

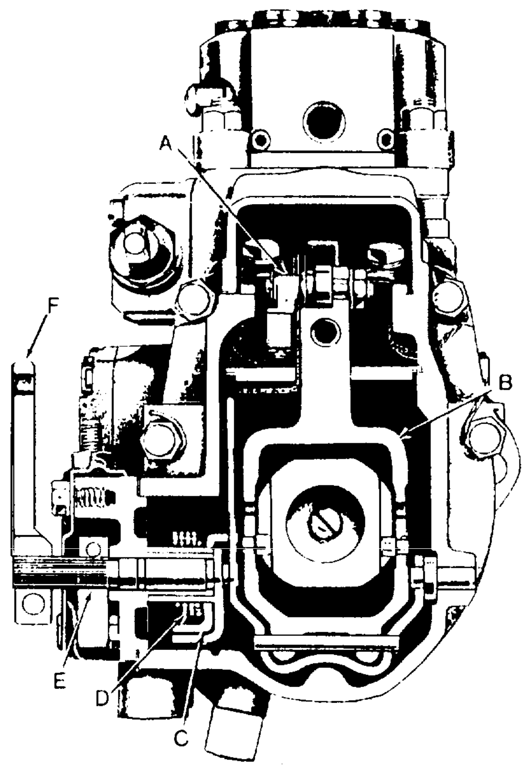
The plunger is designed to operate at crankshaft speed on four-cycle engines. It is actuated by a camshaft and tappet arrangement. The pump camshaft, which also includes the gearing for fuel distribution, is supported on the governor end by a bushing-type bearing and by a ball roller bearing on the driven end. An integral mechanical centrifugal governor (fig. 5-25) driven directly from the pump camshaft without gearing controls fuel delivery in relation to engine speed. This pump has a smoke limit cam within the governor housing to help control the exhaust smoke of various fuels. The mechanical centrifugal advance unit of this pump provides up to 9-degrees advance timing and is driven clockwise at crankshaft speed.

Troubleshooting

Table 5-2 lists the most common malfunctions and the probable causes. Further tests, adjustments, and specifications are available through the manufacturer's manual which you should use for repairs or adjustments.

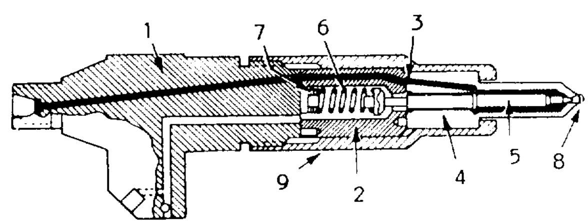
Types of Nozzles

Bosch nozzles are inward opening with a multiple orifice and a hydraulically operated nozzle valve. The two models of this nozzle in use are the American Bosch and the Robert Bosch. They may be easily identified by either the length of the nozzle tip holding nut or the nozzle drilling code on the smaller diameter of the nozzle valve body. The American Bosch nozzle nut is 3 inches long, and the nozzle tip has a hand-printed drilling code. The Robert Bosch nozzle nut is 2 inches long, and the nozzle tip has a machine-etched drilling code. Figure 5-26 shows a view of the nozzle and identifies the various component parts. Component parts, although similar, are not interchangeable between the two nozzles.



A – Fuel control rod
B – Fulcrum lever
C – Shaft spring plate
D – Operating shaft spring
E – Operating shaft
F – Operating lever

Figure 5-25.-Governor–sectional view.



1. **Nozzle body**
2. **Spring retainer**
3. **Annular groove**
4. **Nozzle valve body**
5. **Nozzle valve**
6. **Nozzle spring**
7. **Shims**
8. **Orifice holes**
9. **Nozzle holding nut**

Figure 5-26.-Bosch nozzle nomenclature.

Table 5-2.-Troubleshooting Bosch System

MALFUNCTION	PROBABLE CAUSE
1. No fuel output.	a. Operating shaft frozen in operating shaft bearing. b. Operating shaft spring plate broken or not engaged with fulcrum lever or operating shaft. c. Fuel control rod bent or broken. d. Sheared plunger guide in hydraulic head assembly.
2. Fuel output cannot be controlled.	a. Incorrect idle and full speed adjustments. b. Operating shaft spring not engaged with fulcrum lever or operating shaft. c. Fuel control rod bent or broken.
3. Fuel leakage into oil lubrication system.	a. Hydrualic head lower ring gasket damaged. b. Worn fuel plunger. c. Worn supply pump housing oil seal.
4. Fuel leakage around the fuel control unit.	a. Control unit packing damaged. b. Fuel control unit assembly worn.
5. Fuel leakage around the hydraulic head assembly.	a. Head upper ring gasket damaged.
6. Uneven fuel distribution.	a. Inner plunger spring broken. b. Worn fuel plunger. c. Fuel plunger sticking.
7. Excessive vibration.	a. Excessive camshaft runout. b. Governor weight and spider worn or damaged. c. Camshaft ball bearing worn or damaged. d. Camshaft bushing type of bearings worn or damaged. e. Advance unit housing bushing type of bearings worn or damaged. f. Advance unit weight and spider worn or damaged.

NOZZLE OPERATION.— The pressurized fuel from the injection pump enters the top of the nozzle body and flows through a passage in the body and nozzle spring retainer. An annular groove in the top face of the nozzle valve body tills with fuel, and two passages in the nozzle valve body direct fuel around the nozzle valve. When the fuel in the pressure chamber reaches a predetermined pressure, the spring force (adjusted by shims) is overcome and injection occurs. Atomized fuel sprays from the orifice holes in the nozzle tip as the nozzle valve is opened inward by pressurized fuel. When injection ends, spring pressure snaps the valve in its seat. During each injection, a small quantity of high pressured fuel passes between the nozzle valve stem and the nozzle valve body to lubricate and to cool the nozzle valve. A manifold that connects to all of the nozzles returns this fuel to the tank.

NOZZLE TROUBLESHOOTING.— You can check the condition of a nozzle before it is disassembled by using the field test (Kiene). Remove the nozzle from the engine, and using the test pump shown in figure 5-27, check for nozzle spray angle and pattern. There are four orifices in the nozzle tip, and the spray angle should be uniform from all four. Also, check the spray valve opining pressure. A pressure reading that is more than 50 psi below the specified opening pressure of the valve indicates a need to adjust the pressure by adding shims. Next, test the leakage past the seat and stem. If this leakage is excessive due to wear, install a new nozzle valve.

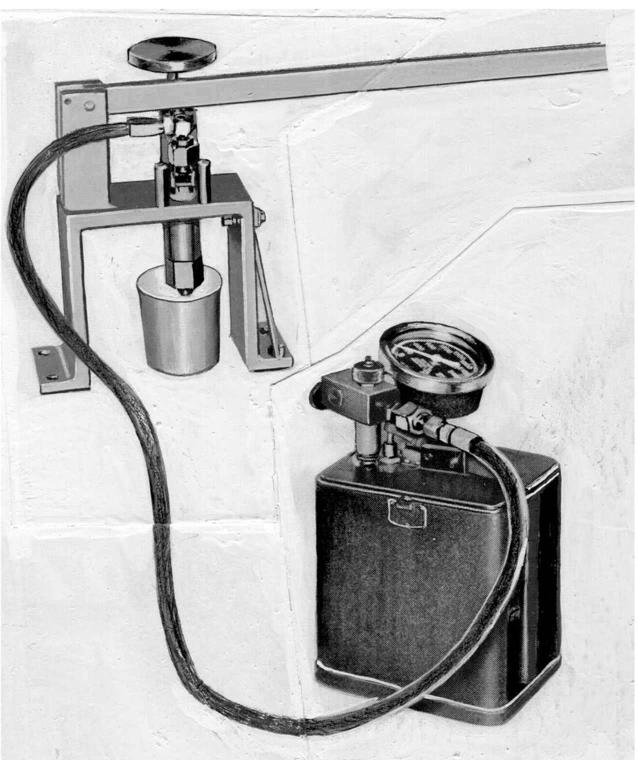


Figure 5-27.-Test pump.

Proceed with nozzle disassembly only after you have performed these and other tests prescribed in the test manual. While testing, record the results of the tests for each nozzle. They can help you determine the nature and extent of necessary repairs.

NOZZLE DISASSEMBLY/REASSEMBLY.-— Before you disassemble the nozzle, clean the external area with cleaning fluid or clean diesel fuel oil, using a brush with long, soft bristles. Keep the disassembled nozzles separated to prevent mixing the various components. During inspection, refer to the test results which are used as a guide to determine the extent of reconditioning necessary.

After you have disassembled the nozzle, make sure each disassembled nozzle has been placed in a separate pan containing a cleaning solvent or clean diesel fuel oil. Soak the tips in a good carbon removal compound for the length of time prescribed by the manufacturer.

NOTE

As a word of caution, remember NOT to mix the tips together. Each tip must be reassembled with its own group parts.

Be careful when you clean the spray holes of the nozzle tip so that you do not enlarge or damage them. Use a magnifying glass during your inspection for signs of scratches, corrosion, or erosion on the spring retainer, the nozzle body holder, and the valve body face. Also, check the stem and the body of the valve, making sure they do not bind.

Reassemble the nozzle in the manner prescribed and specified by the manufacturer's maintenance and repair manual.

Before you install the nozzle in the engine, retest it for spray angle and pattern, valve opening pressure, and leakage past the seat and stem. When test results are good, install the nozzle in the engine.

GENERAL MOTORS FUEL INJECTION SYSTEM

The General Motors fuel injection system includes fuel injectors, fuel pipes, fuel manifolds, fuel pump, fuel strainer, fuel filter, and fuel lines connecting the fuel tank. The operation of this system depends on the injection of the correct amount of fuel at exactly the right time directly into the combustion chamber.

Efficient engine operation demands that the fuel system be maintained in first-class condition at all times. Use only clean water-free fuel. Good maintenance of the fuel filtering system and reasonable care in handling the fuel are the key to a trouble-free fuel system.

Servicing the fuel system is not a difficult task. However, because of the close tolerances of the various fuel system components, mechanics should practice cleanliness and strictly adhere to service instructions.

In this section, troubleshooting, testing, disassembly, cleaning out, inspection, and reassembly of the fuel pump and fuel injector are discussed. Before you work on these components, refer to the manufacturer's maintenance and service manuals.

Troubleshooting

When a piece of equipment is brought into the shop for maintenance and service, the hard card or Equipment Repair Order (ERO) may show a fuel system problem. You can pinpoint the problem by troubleshooting the fuel system until you find the trouble.

Check the fuel lines for improper or faulty connections. If any leaks occur, tighten the connection only enough to stop the leak. Also, check the filter cover bolt for tightness. If the fuel pump fails to function satisfactorily, first check the level of the fuel tank; then make sure the fuel supply valve is open. Check for a broken pump drive shaft or drive coupling by inserting the end of a wire through one of the pump flange drain holes; then crank the engine and note if the wire vibrates. Vibration will be felt if the pump shaft is turning.

The result of most fuel pump failures is that either no fuel or an insufficient amount of fuel is delivered to the fuel injectors. This lack of fuel will show up if the engine runs unevenly, vibrates too much, stalls at idling speeds, or loses power.

The most common failure of a fuel pump is a sticking relief valve. The relief valve, due to its close fit in the valve bore, may stick in a full-open position because a small amount of grit or foreign material lodges between the relief valve and its bore or seat. The fuel oil circulates within the pump rather than being forced through the fuel system. If the fuel pump is not functioning properly, remove the fuel pump from the engine. hen remove the relief valve plug, spring, and pin, and check the movement of the valve within the valve bore. If the valve sticks, recondition it by using fine emery cloth to remove any scuff marks. Clean the valve bore and the valve components. Then lubricate the valve and check it for free movement throughout the entire length of its travel. If its operation is satisfactory, reassemble the valve in the pump. If not, replace it.

After the relief valve has been checked and the fuel pump reinstalled on the engine, start the engine and check the fuel flow at some point between the restricted fitting in the fuel return manifold and the fuel tank.

If, after making the above checks, there is still a lack of power, uneven running, excessive vibration, or stalling at idle, you should suspect a faulty injector in one or more cylinders. Start the engine and run it at part load until it reaches normal operating temperature. Remove the valve rocker cover(s) and let the engine run at idle speed. Hold the injector follower down with a screwdriver, which prevents operation of the injector. If the cylinder has been misfiring, there will be no noticeable difference in the sound or operation of the engine. If the cylinder has been firing properly, there will be a noticeable difference in the sound and operation when the follower is held down. If that cylinder is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.

At this point you can remove the fuel injector for additional testing, provided that the injector operating mechanism of the faulty cylinder is functioning satisfactorily.

TESTING

The General Motors injector tester gives you a means to determine the condition of the injector to avoid unnecessary overhauling. An injector that passes all of the tests outlined below may be considered to be satisfactory for service without disassembly (except for the visual check of the plunger). If an injector fails to pass one or more of the tests, it is unsatisfactory. Be sure to identify each injector and record the pressure drops and fuel output during the tests. Also remember, all tests must be performed **before** the injector is disassembled.

INJECTOR CONTROL RACK AND PLUNGER MOVEMENT TEST.— To perform this test, lock the injector in a test stand.

CAUTION

Keep your hands away from the tip of the injector while depressing the plunger. High-pressure fuel spray that penetrates the skin will cause blood poisoning.

Depress the plunger to the bottom of its travel while working the control rack back and forth. If the rack sticks, binds, or fails to move at all, it indicates that the internal parts of the injector are either dirty or damaged.

VALVE OPENING/PRESSURE TEST.— The purpose of this testis to determine the pressure at which the valve opens and injection begins. Place the injector in the tester (fig. 5-28). Operate the pump handle until all air is purged from the injector tester and the injector. Then close the outlet clamp. If you are testing an injector that has just been removed from the engine, the flow of fuel through the injector on the tester should be the same as it was on the engine. If required, reverse the fuel connections on the tester to obtain the proper fuel flow.

With the injector rack in the full-fuel position, pump the handle of the injector tester with smooth, even strokes (fig. 5-29), and record the injector valve opening pressure. The specified valve opening pressure for the crown or high valve injector is 450 to 850 psi. For the needle valve injector, the specified opening pressure is 2,000 to 3,200 psi. If the pressure is not within limits, check the manufacturer's maintenance manuals for probable causes and corrections.

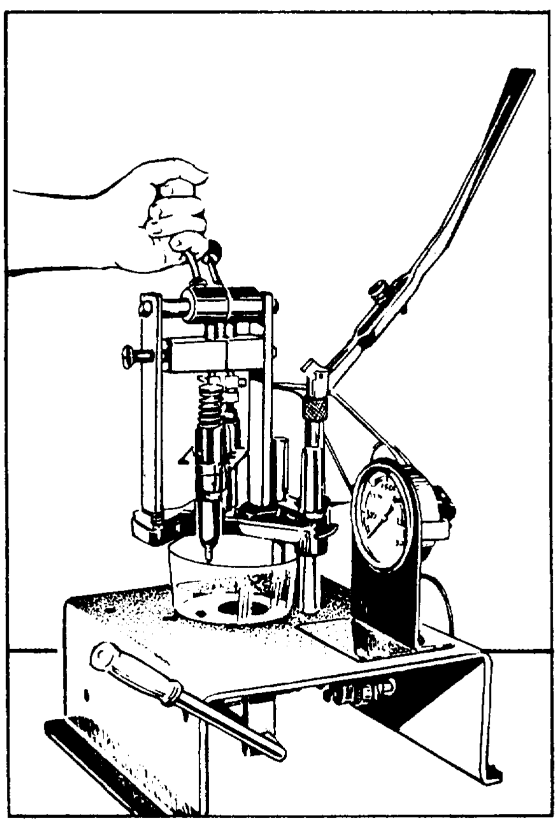


Figure 5-28.-Injector installed in tests.

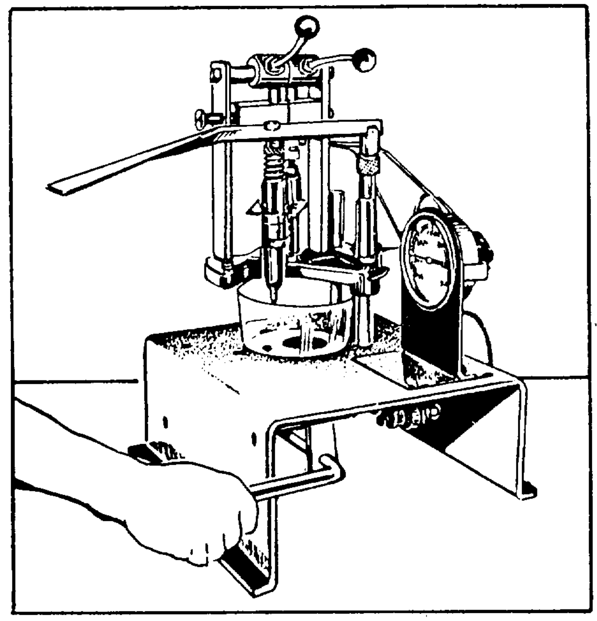


Figure 5-29.-Checking injector valve opening pressure.

HOLDING PRESSURE TEST.— This test is used to determine whether the various lapped surfaces in the injector are sealing properly.

To conduct this test, bring the pressure up to a point just below the valve opening pressure (450 psi for crown, needle, and high valve injectors). Then close off the fuel shutoff valve. These actions cause the pressure to drop. The time for the pressure to drop from 450 psi to 250 psi must **NOT** be less than 40 seconds. If the injector pressure drops from 450 psi to 250 psi in less than 40 seconds, dry the injector thoroughly and make the following checks:

1. Open the injector tester fuel valve and operate the pump to maintain the test pressure.

2. Check for a leak at the injector rack opening. A leak indicates a poor bushing-to-body fit.

3. Check for leaks around the spray tip or seal ring. Leaks in these areas are usually caused by a loose injector nut, a damaged seal ring, or a burned surface on the injector nut or spray tip.

4. Check for leaks at the filter cap, which would indicate a loose filter cap gasket.

5. If you find a dribble at the spray tip orifices, it indicates a leaking valve assembly due to either a damaged surface or dirt. Leakage at the tip will cause preignition in the engine.

NOTE

A drop or two of fuel at the spray tip is only an indication of the fuel trapped in the spray tip at the beginning of the test. It is not detrimental as long as the pressure drop specified is not less than 40 seconds.

HIGH-PRESSURE TEST.— This testis performed to discover arty fuel leaks at the injector filter cap gaskets, body plugs, and nut seal ring which did not appear during the valve holding pressure test. The high-pressure test also indicates whether the injector plunger and bushing clearance are satisfactory. To perform the test, place the injector rack in the **FULL-FUEL** position. Operate the pump handle (fig. 5-30) to build up and maintain a pressure of 1,600 to 2,000 psi. Then inspect the injector filter cap gaskets, body plugs, and injector nut seal ring for leaks.

Next, you should use the adjusting screw in the injector tester handle to depress the injector plunger just far enough to close both ports in the injector bushing. Both ports are closed if the injector spray decreases and the pressure rises. Now, you can determine the condition of the plunger and bushing. If there is excessive clearance between the plunger and bushing, it means that pressure will not rise beyond the normal valve-opening pressure. Next, you should replace the plunger and bushing.

SPRAY PATTERN TEST.— This test is performed after you have completed the valve holding pressure test. After placing the injector in the tester, open the fuel shutoff valve; then place the injector rack in the **FULL-FUEL** position. Operate the injector several times in succession by pumping the tester handle (fig. 5-31) at approximately 40 strokes per minute. Observe the spray pattern to see whether all of the spray tip orifices are open and injecting evenly. The beginning and ending of injection should be sharp, and the fuel injected should be finely atomized. If all the spray tip orifices are not open and injecting evenly, clean the orifices in the spray tip during injector overhaul.

CAUTION

To prevent damage to the pressure gauge, do not exceed 250 psi during this test.

You should visually inspect the injector plunger even if the injector passes all of the previous tests. The plunger is visually checked under a magnifying glass for excessive wear or a possible chip on the bottom helix. There is a small area on the bottom helix and the lower portion of the upper helix, that, if chipped, will not be indicated in any of the tests.

FUEL OUTPUT TEST.— This test is performed to check injector fuel output. To test the injector, place it

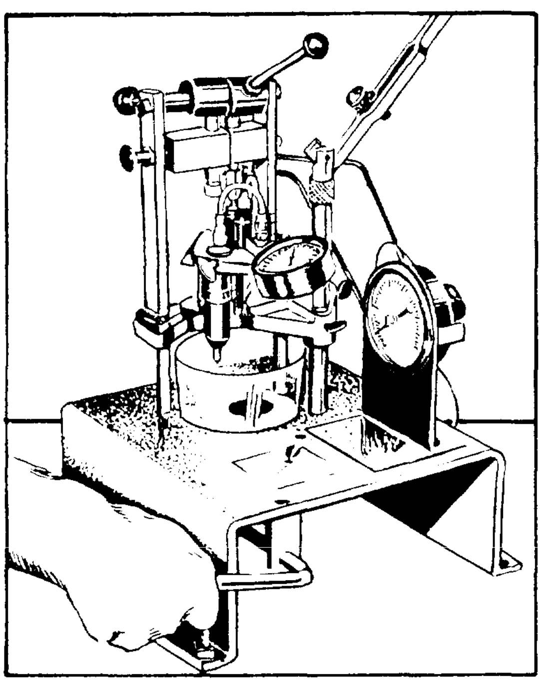


Figure 5-30.-Injector high-pressure test.

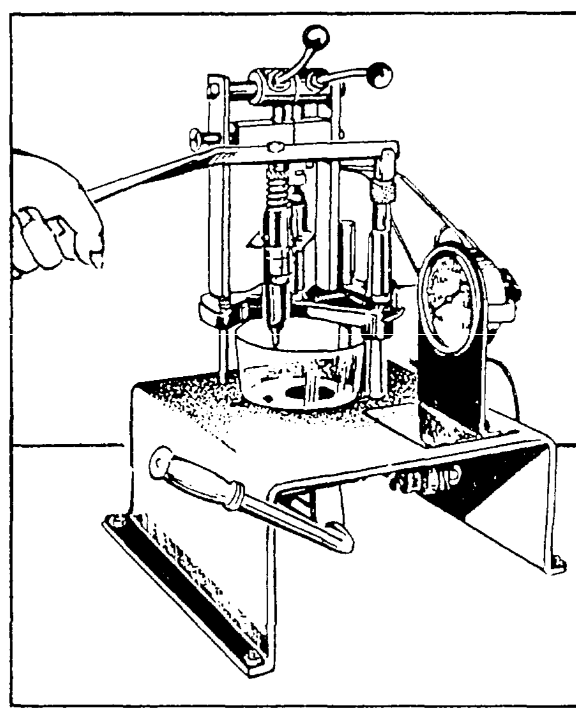


Figure 5-31.-Spray pattern test.

in the comparator (fig. 5-32), and seal the injector firmly by tightening the handwheel. Pull the injector rack out to the **NO-FUEL** position and start the comparator. After the comparator has started, push the injector rack to the **FULL-FUEL** position. Let the injector run for approximate y 30 seconds to purge air in the system. After 30 seconds, press the fuel flow start button to start the flow of fuel into the vial. The comparator will automatically stop the flow of fuel after a thousand strokes. After the fuel has stopped flowing into the vial, pull the injector rack out to the **NO-FUEL** position. Turn the comparator off, reset the counter, and observe the reading on the vial. Refer to the chart on the comparator and see if the injector fuel output falls within its specified limits. If the quantity of fuel in the vial does not fall within the specified limits, refer to the manufacturer's manual for the cause and remedy. Any injector that has been disassembled and rebuilt must be tested again before being placed in service.

Injector Disassembly, Cleaning and Inspecting, and Reassembly

To disassemble an injector, you should place it in an injector assembly fixture. Now, you are ready to remove the falter caps, springs, filter elements, and gaskets. Discard the falter elements and gaskets and replace them with new components during reassembly. Follow the manufacturer's repair and maintenance manual when disassembling injectors.

While you disassemble an injector, put the injector and its parts together in a separate receptacle containing a cleaning solvent or clean diesel fuel oil.

Wash all the parts and dry them. Do not use rags for cleaning. Clean out all passages, drilled holes, and slots in all of the injector parts.

You should soak injector spray tips in a suitable solvent for approximately 15 minutes. This loosens the

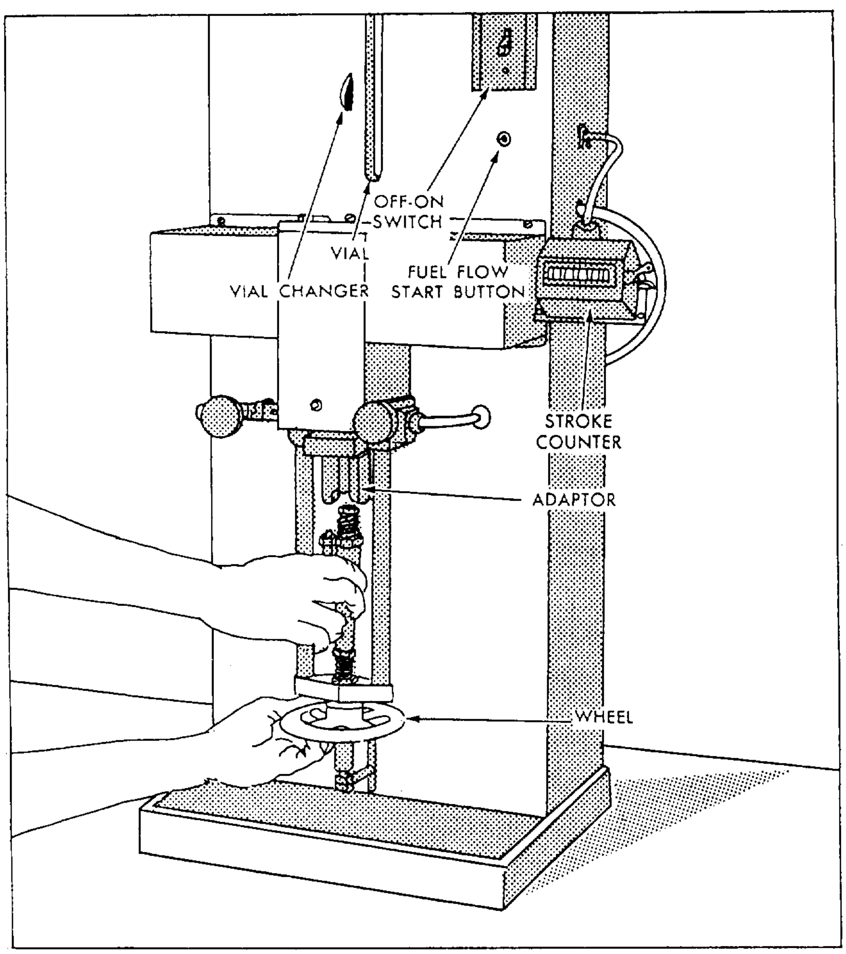


Figure 5-32.-Comparator used to check injector fuel output.

carbon on the inside of the tip. Then they can be cleaned out by using the proper size spray tip cleaning wire.

Inspect injector parts for excessive wear, damage, defects, burrs, scratches, scoring, erosion, or chipping. Replace the damaged or excessively worn parts.

Lap all of the sealing surfaces, such as the bottom of the injector body, the injector bushing, the valve seat, the valve cage, the check valve, and the spray tip, before you reinstall used valve parts in an injector.

Now you are ready to reassemble the injectors. Follow the steps prescribed by the manufacturer's maintenance and repair manuals. The injector is satisfactory if it passes these tests. Failure to pass any one of the tests indicates that defective or dirty parts have been assembled. In this case, disassemble, clean, inspect, reassemble, and test the injector again.

CUMMINS PRESSURE TIME FUEL INJECTION SYSTEM

The Cummins Pressure Time (PT) Fuel Injection System (fig. 5-33) consists of the fuel pump (with governor), the supply lines, drain lines, fuel filters, fuel injectors, and shutdown valve. An aneroid valve is installed on the fuel system of turbocharged engines only.

As in previous sections of this chapter, we will cover troubleshooting, disassembly, inspection, reassembly, and testing of components. Remember, before performing any service on the PT injector or pump, refer to the manufacturer's maintenance and repair manuals.

Troubleshooting

Troubleshooting is an organized study of a problem and a planned method or procedure to investigate and correct the difficulty.

Most troubles are simple and easy to correct; for example, excessive fuel oil consumption is caused by leaking gaskets or connections. A complaint of a sticking injector plunger is usually corrected by repairing or replacing the faulty injector; however, something caused the plunger to stick. The cause maybe improper injector adjustment, or, more often, water in the fuel.

In general, the complaint of low pwer is hard to correct because it can have many causes. There are many variables in environmental operation and installations, and it is difficult to measure power in the field correctly. With the PT fuel system, you can often eliminate the pump as a source of trouble. Simply check to see that the manifold pressure is within specified limits. The fuel rate of the pump must not be increased to compensate

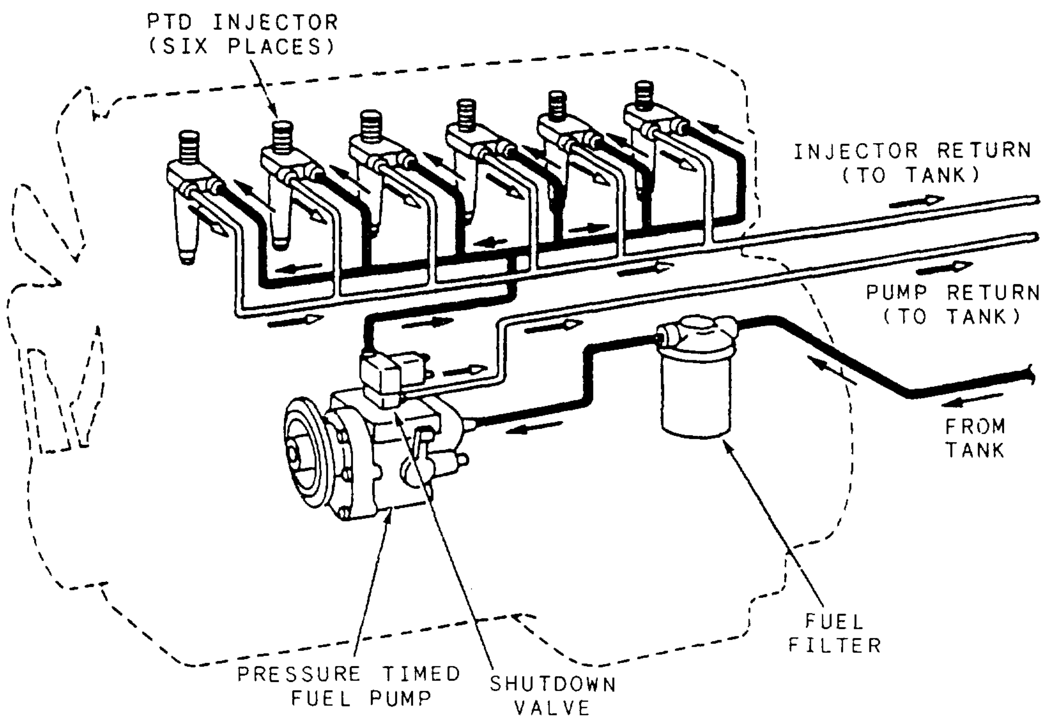


Figure 5-33.-Pressure-timed injection system.

for a fault in other parts of the engine; damage to the engine will result.

When you check the fuel pump on the engine, remove the pipe plug from the pump shutoff valve and connect the pressure gauge. At the governed speed (just before the governor cuts in), maximum manifold pressure should be obtained. If the manifold pressure is **NOT** within specified limits, adjust for maximum manifold pressure by adding or removing shims from under the nylon fuel adjusting plunger in the bypass valve plunger. Be careful you do not lose the small lock washer that fits between the fuel adjusting plunger and the plunger cap.

To check the suction side of the pump, connect the suction gauge to the inlet side of the gear pump. The valve in the pump, if properly adjusted, should read 8 inches on the gauge. When the inlet restrictions reaches 8.5 to 9 inches, change the fuel filter element and remove any other sources of restriction. The engine will lose power when the restriction is greater than 10 to 11 inches.

Always make the above checks on a warm engine. Also, operate the engine for a minimum of 5 minutes between checks to clear the system of air.

If the pump manifold and suction pressures are within specified limits and there is still a loss of power, you should check the injectors.

Carbon in the PT injector metering orifices restricts the fuel flow to the injector cups, which results in engine power loss. Remove the carbon from the metering orifices by reverse flushing; it should be performed on a warm engine. To remove carbon, perform the following steps:

1. Loosen all injector adjusting screws one turn from the bottom or one and one-eighth turns from the set position. Lock with the jam nut after completing the required turns.

2. Start the engine and accelerate with maximum throttle from idling to high-10 to 15 times.

3. Readjust the injectors to their standard setting.

The engine will be difficult to start with the loose injector setting; it will smoke badly and will be sluggish. If the injector adjusting screws are loosened, the meter orifice will not be closed during injection. Extremely high injection pressure will force some of the fuel to backflow through the orifice and should remove carbon deposits. If this method is not effective, remove the injectors for cleaning.

When working on the PT fuel system of a turbocharged Cummins engine, you may find an aneroid control device. This device creates a lag in the fuel system so that its response is equivalent to that of the turbocharger, thus controlling the engine exhaust emissions (smoke level).

WARNING

The aneroid is an emissions control device. Removing it or tampering with it is in direct violation of state and federal vehicle exhaust emissions laws.

During troubleshooting of the fuel system, you should check the aneroid according to the manufacturer's specifications.

Pump Disassembly

If you determine that the fuel pump (fig. 5-34) must be removed from the engine, take the following precautions:

- Make sure the shop area is clean.
- Use clean tools.

Good cleaning practices are essential to good quality fuel pump repair. Take special care when the PT fuel pump, which is made of a lightweight aluminum alloy, is disassembled. Use proper tools to prevent damage to machined aluminum surfaces, which are more easily damaged than parts made of cast iron.

Before disassembling the unit, try to determine what parts need replacement.

After you place the fuel pump on the holding device, place the device in a vise and disassemble the pump. Follow the procedures given in the manufacturer's maintenance and repair manuals.

Pump Cleaning and Inspection

Now that the pump has been disassembled, you should clean and inspect all parts. Do not discard parts until they are worn beyond reasonable replacement limits. The PT fuel pump parts will continue to function long after they show some wear. Parts that are worn beyond reasonable replacement limits must not be reused. From experience you know reasonable replacement limits. Reuse all those parts that will give another complete period of service without danger of failure.

NOTE

Take special care when you clean aluminum alloy parts. Some cleaning solvents will attack and corrode aluminum. Mineral spirits is a good neutralizer after using cleaning solvents.

Pump Reassembly

After you complete] y clean and inspect the pump and the parts of it, reassemble the pump as prescribed by the manufacturer's manual. In all assembly operations, be careful to remove burrs and use a good pressure lubricant on the mating surfaces during all pressing operations. A good pressure lubricant aids in pressing and prevents scoring and galling. Use flat steel washers. They go next to the aluminum to prevent goring by the spring steel lock washers.

Pump Testing

The PT fuel pump is mounted on a test stand, as shown in figure 5-35. In the test, the pressure from the PT pump is measured and adjusted before the pump is placed on the engine. To test this pump, let pressure develop across the special orifices in the orifice block assembly. The pressure is measured on the gauges

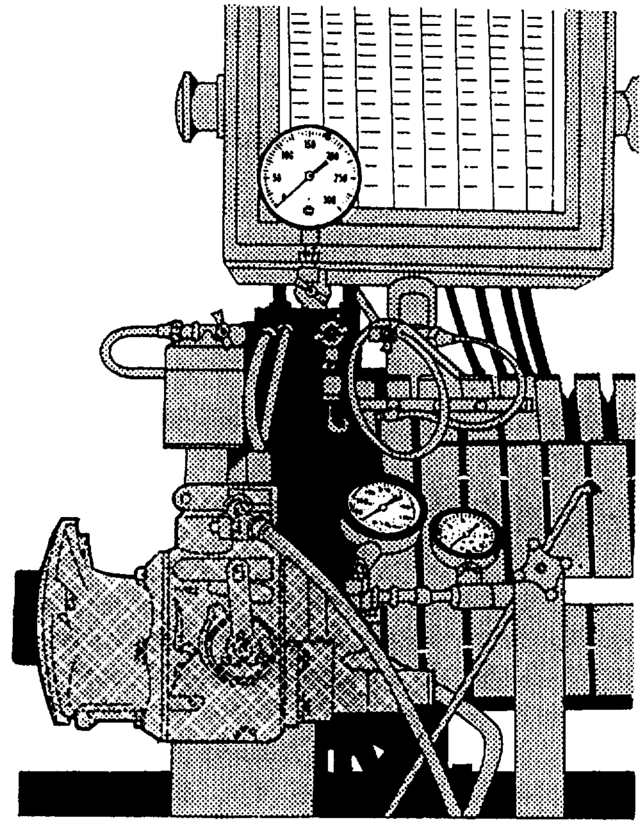


Figure 5-35.-PT pump mounted on test stand.

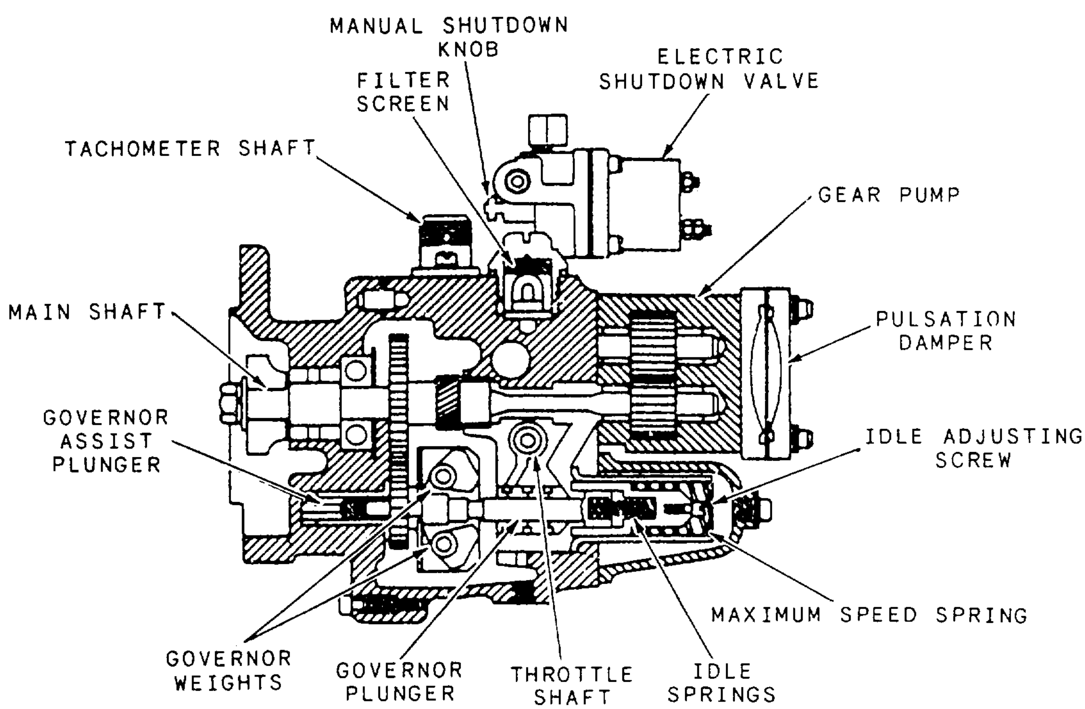


Figure 5-34.-Cummins PT fuel pump.

provided. All pump tests should be made with the testing fuel oil temperature between 90°F and 100°F. Now you are ready to conduct the test.

Open the fuel shutoff valve and manifold orifice valve. Open the stand throttle, start and run the pump at 500 rpm until the manifold pressure gauge shows the recommended pressure. If the pump does not pickup the specified pressure, check for closed valves in the suction line or an air leak.

If the pump is newly re-built, run it at 1500 rpm for 5 minutes to flush the pump and allow the bearings to seat. Continue to run the pump at 1500 rpm and turn the rear throttle stop screw in or out to find the maximum manifold pressure at full throttle.

NOTE

With a standard governed pump, the throttle screws will be readjusted later. If the pump has a variable speed governor, the throttle shaft is locked in full-throttle position; do not readjust. On a dual or torque converter governor pump, the throttle must be locked in the shutoff position and the converter-driven governor idle-adjusting screw turned in until the spring is compressed. The converter-driven governor must be set on the engine.

The pump idle speed is set by closing the bypass and manifold orifice valves and opening the idle orifice valve. Set the pump throttle to idle and run at 500 rpm. To decrease or raise the idle pressure, add or remove shims from under the idle spring. Remember not to set the idle screw until you have adjusted the throttle screws.

Once the tests and adjustments have been completed according to the specifications recommended by the manufacturer, remove the pump from the test stand. Make sure the suction fitting is not removed or disturbed. Next, loosen the spring pack cover and drain the pump body. Cover all openings and bind fittings with tape until you are ready to install the pump.

Injector Maintenance and Testing

In the PT fuel system, fuel is metered by fuel pressure against the metering orifice of the injector. Any change in fuel pressure, metering orifice, or timing will affect the amount of fuel delivered to the combustion chamber. The following two things will interfere with the normal functions of injector orifices:

1. Dirt or carbon in the orifices or in the passages to and from the orifices; and

2. A change in the size or shape of the orifices, particularly caused by improper cleaning of the orifices

After soaking dirty injectors in a cleaning solvent to remove the carbon, be sure to dip the injectors in a neutral rinse, such as mineral spirits, and then dry them.

NOTE

Never use cleaning wires on PT fuel injector orifices.

Be sure to use a magnifying glass to inspect the injector orifices for damage. When the injector orifices are damaged, they cannot be made to function properly and must be replaced.

Check the injector for a worn plunger or injector body. Worn injectors may cause engine oil dilution from excessive plunger to body clearances. Dilution may also result from a cracked injector body or cup or a damaged O ring. To check the injector for leakage, assemble it. Remember to plug off the injector inlet and drain connection holes; then mount the injector on the injector test stand.

Test the injector at a maximum of 1000 psi with the fuel flowing upward through the cup spray holes. If the counterbore at the top of the injector body falls with fuel in less than 15 seconds, the plunger clearance is excessive and may cause engine oil dilution. During this check inspect the injector for leaks around the injector cup, body, and plugs. If the injector does not pass the test and checks, remove the damaged parts and replace them with new parts.

Any time you remove an injector plunger, use the lubricant recommended by the manufacturer when you replace the plunger in the injector body.

If the injector plunger does not seat in the injector cup, change the cup rather than trying to lap the plunger and cup together. Lapping changes the relationship between the plunger groove and metering orifice and disturbs fuel metering. Always use a new injector cup gasket when you assemble the cup to the injector body to avoid distortion of the cup. When the cup is tightened to the injector body, the gasket compresses everywhere, except under the milled slot on the end of the injector body. Then, if the gasket is reused, the uncompressed areas may cause the injector cup to cock and prevent the injector plunger from seating properly.

AIR INDUCTION SYSTEM

The purpose of an air intake system is to supply the air needed for combustion of the fuel. In addition, the air intake system of a diesel engine will have to clean the intake air, silence the intake noise, furnish air for supercharging, and supply scavenged air in two-stroke engines.

The three major components of the air induction systems that increase internal combustion engine efficiency are blowers, superchargers, and turbochargers. They may be of the centrifugal or rotary type, gear driven directly from the engine, or driven by the flow of exhaust gases from the engine.

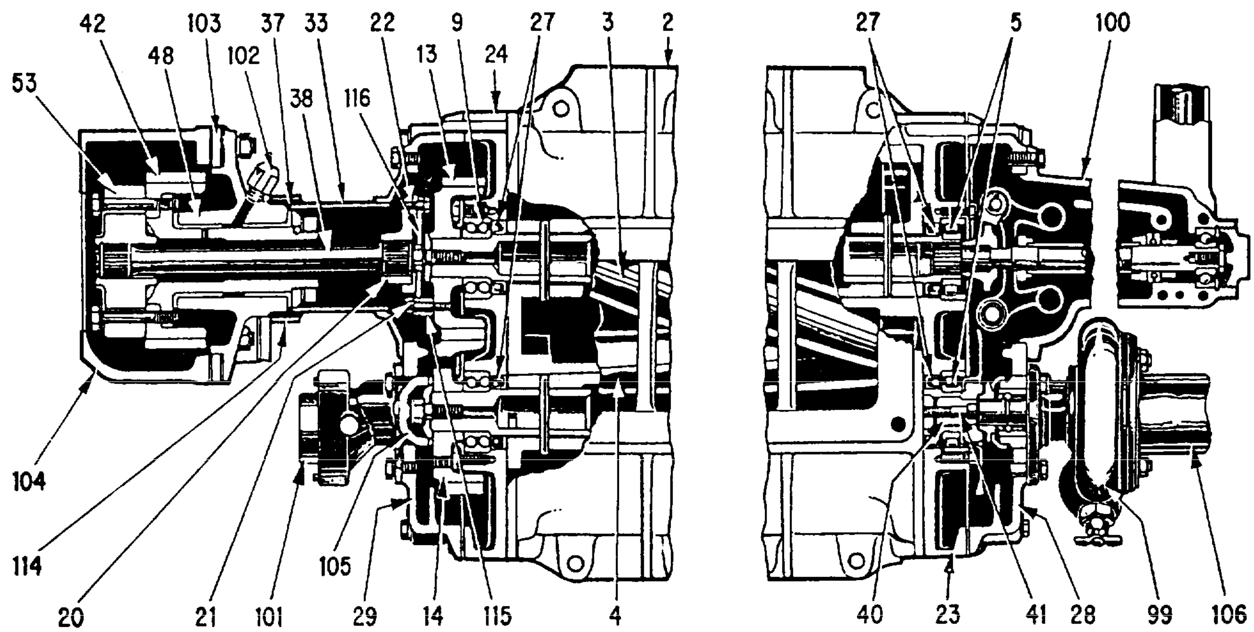
In the following sections, certain abnormal conditions of air induction system components which sometimes interfere with satisfactory engine operation are covered. Also, methods of determining causes of such conditions will be covered. Before performing any work on these components, make sure you follow the recommendations given in the manufacturer's service manual.

BLOWERS

Scavenging blowers are used to clear the cylinders of exhaust gases to introduce a new charge of fresh air. Superchargers and turbochargers increase the power output of specific engines by forcing air into the combustion chambers so that an engine can burn more fuel and develop more horsepower than if it were naturally aspirated.

Blower Inspection

The blower (fig. 5-36) may be inspected for any of the following conditions without being removed from



2. Housing
3. Rotor, blower, upper
4. Rotor, blower, lower
5. Bearing, front
9. Bearing, rear
13. Gear, rotor, upper
14. Gear, lower, rotor
20. Hub, rotor drive
21. Bolt
22. Bolt
23. End plate, front
24. End plate, rear
27. Seal, oil, rear
28. Cover, end plate, front
104. Housing, flywheel
106. Cover, water pump inlet
115. Plate, blower rotor drive hub
29. Cover end plate rear
33. Cover, blower drive shaft
37. Seal, drive shaft cover
38. Shaft, blower drive
40. Shaft coupling
41. Bolt
42. Gear blower drive
48. Support
53. Coupling assembly
99. Pump fresh water
100. Housing, governor weight
101. Pump, fuel
102. Elbow
103. End plate
105. Fork
114. Clamp, drive cover seal
116. Spacer, plate to gear

Figure 5-36.-Blower and drive assembly and accessories.

the engine. However, the air silencer or air inlet housing must be removed.

CAUTION

> When a blower on an engine is being inspected with the engine running, keep your fingers and clothing away from moving parts of the blower. RUN THE ENGINE AT LOW SPEED ONLY.

Dirt or chips, drawn through the blower, will make deep scratches in the rotors and housing and throw up burrs around these abrasions. If the burrs cause interference between rotors or between rotors and blower housing, remove the blower from the engine and dress down the parts to eliminate this interference. Replace the rotors if they are too badly scored.

Oil on the blower rotors or on the inside surfaces of the blower housing indicate rotor shaft oil seal leaks. To confirm your finding, run the engine at a low speed while shining a light into the rotor compartment. A film of oil radiating away from the rotor shafts shows the oil seal leakage.

A worn blower drive results in a rattling noise inside the blower. You can detect this condition by grasping the top rotor firmly and attempting to rotate it. The rotor may move from three-eighths to five-eighths inch, measured at the lobe crown. When released, the rotor should move back at least one-fourth inch. If the rotor cannot be moved this distance or if the rotor moves too freely, the flexible blower drive coupling should be inspected and if necessary, replaced.

If a check shows the drive coupling to be worn, remove the blower drive assembly from the cylinder block end plate. After the blower has been removed from the engine, remove the drive gear hub bearing support-to-cylinder block end plate bolts.

Loose rotor shafts or damaged bearings will cause rubbing and scoring between the following components: the crowns of the rotor lobes and the mating rotor roots, the rotors and the end plates, or the rotors and the blower housing. Generally, a combination of these conditions exists.

Excessive backlash in the blower timing gears usually results in rotor lobes rubbing throughout their length.

To correct any of the above conditions, remove the blower from the engine and either repair it or replace it.

The blower inlet screen should be inspected periodical y for dirt accumulation. After prolonged operation, dirt accumulation affects the airflow. Wash the screen thoroughly in clean fuel oil and clean it with a stiff brush until no dirt remains.

The air box drains should always be open. Check them regularly and make sure the passages are clean. If the liquid collects on the air box floor, a drain tube may be plugged. Remove the cylinder block handhole covers. Wipe the dirt out with rags or blow it out with faltered compressed air. Then remove the drain tubes and connectors from the cylinder block and clean them thoroughly.

Blower Removal and Disassembly

After you inspect the blower and determine what you need to do to recondition it, remove and disassemble the blower. Follow the instructions in the manufacturer's maintenance and repair manual.

After you remove the assembly, disassemble it and be careful not to damage any parts. Use the proper tools and follow the recommended disassembly procedures, particular y when the blower drive, driven gears, and timing gears from the rotor shafts are removed. Pull them from the rotor shaft at the same time or you will damage the rotors.

Cleaning, Inspecting, and Reassembly

After the blower has been disassembled, wash all the parts in cleaning solvent or clean fuel oil. Then blow-dry them, using filtered compressed air. Inspect the parts before reassembly.

Wash the bearings by rotating them by hand in either cleaning solvent or fuel oil until they are free from grease and foreign matter. Clean the balls (or rollers) and races by directing air through the bearings, at the same time, rotating them by hand. Do not spin the bearing with air pressure.

After thoroughly cleaning the bearings, rotate them again by hand and inspect it for rough spots. The bearings should run free. They should not show indications of roughness. The double-row bearings are preloaded and have no end play. A new double-row bearing will seem to have considerable resistance to motion when revolved by hand.

Check oil seals in the end plates. If necessary, replace them, when the blower is being reconditioned which is the recommended time to install new seals.

Inspect blower rotor lobes for smoothness. Inspect rotor shaft serrations and bearing surfaces for wear or burrs.

Check the finished faces of the end plates to see that they are smooth and flat.

Check the finished ends of the blower housing, which receive the end plates, to see that they are flat and free from burrs. The end plates must set flat against the blower housing.

Check blower timing gears for wear or damage. If either timing gear is worn or damaged sufficiently to require replacement both gears must be replaced as a set

Inspect the inside of the housing to see that the surfaces are smooth. The blower drive shaft should be straight and true. Shaft serrations should be clean and straight. You should replace all worn or excessively damaged blower parts.

After you have cleaned and inspected all the blower parts, reassemble the blower as prescribed in the manufacturer's maintenance and service manuals.

SUPERCHARGERS

A diesel engine may be equipped with a supercharger (fig. 5-37). The supercharger is a gear-driven air pump that uses rotors to force air into the engine cylinders when a requirement for more power exists. The supercharger must be maintained periodicaly.

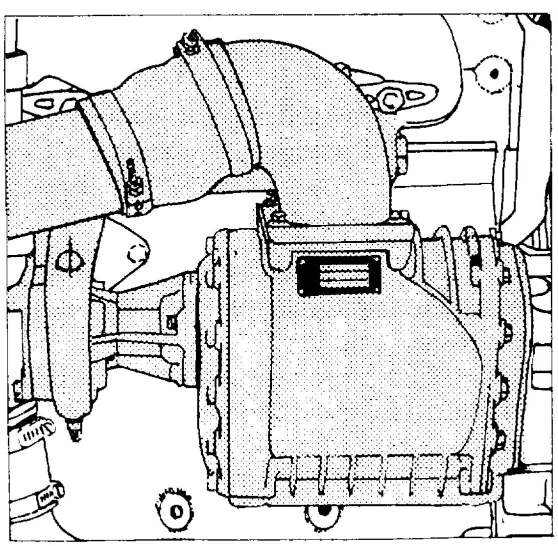


Figure 5-37.-Supercharger.

Remove the outlet connection of the suprcharger and visually check the ends of the rotors and case for evidence of oil leaking from the supercharger seals. Rotors will always show some oil from the vapor tube, which is connected to a rocker housing cover. However, only the appearance of wet oil at tie ends of the rotors would be cause for changing the seals of the supercharger. Be sure to check the lubricating oil lines and connections for any leaks. Correct these conditions if needed.

Removal

When the supercharger has to be removed from the engine, follow the procedures given in the manufacturer's service manual.

Disassembly

If you have to disassemble the supercharger, be careful when you remove the intake and discharge connections. Be sure to cover both openings. To prevent damage to its finished surfaces, usually made from aluminum, wash the outside of the supercharger with mineral spirits. Use the correct service tools and follow recommended disassembly procedures in the manufacturer's maintenance and repair manuals.

Cleaning and Inspecting

As the supercharger parts are disassembled, you should clean and dry them thoroughly with filtered compressed air. Discard all used gaskets, oil seals, recessed washers, roller bearings, and ball bearings. Replace these parts with new ones.

Inspect the rotors, housing, and end plates for cracks, abrasions, wear spots, and buildup of foreign material. With a fine emery cloth, smooth all worn spots found. Discard cracked, broken, or damaged parts. Remember, rotors and shafts we not separable. They must be replaced as a matched set or unit.

Inspect the drive coupling for worn pins, distorted or displaced rubber bushings, and damaged or worn internal splines. Examine the hub surface under the oil seal and replace the coupling if its surface is grooved or worn.

Check the gear fit on the rotor shafts and the gear teeth for evidence of chatter and wear. Replace the rotors and gears if they are not within the required tolerances.

Inspect all dowels, oil plungers, piston ring seals, and gasket surfaces. Replace them as necessary.

Reassembly

After you have inspected, cleaned, and replaced worn or damaged parts, put the supercharger back together as prescribed in the manufacturer's maintenance and service manuals. Upon complete reassembly and after the supercharger is installed on the engine, add the proper quantity of recommended engine lubricating oil to the gear end plate through the pipe plughold.

TURBOCHARGERS

The turbocharger (fig. 5-38) is a unit that is driven by exhaust gas to force (charge) air into the diesel engine cylinders for more complete burning of fuel and to increase engine power. As with any air induction component, the turbocharger is subject to environmental situations that could result in a turbocharger failure.

The real problem lies not in fixing the failure but in determining the cause. Replacing a failed turbocharger without first determining why it failed will often result in a repeated failure.

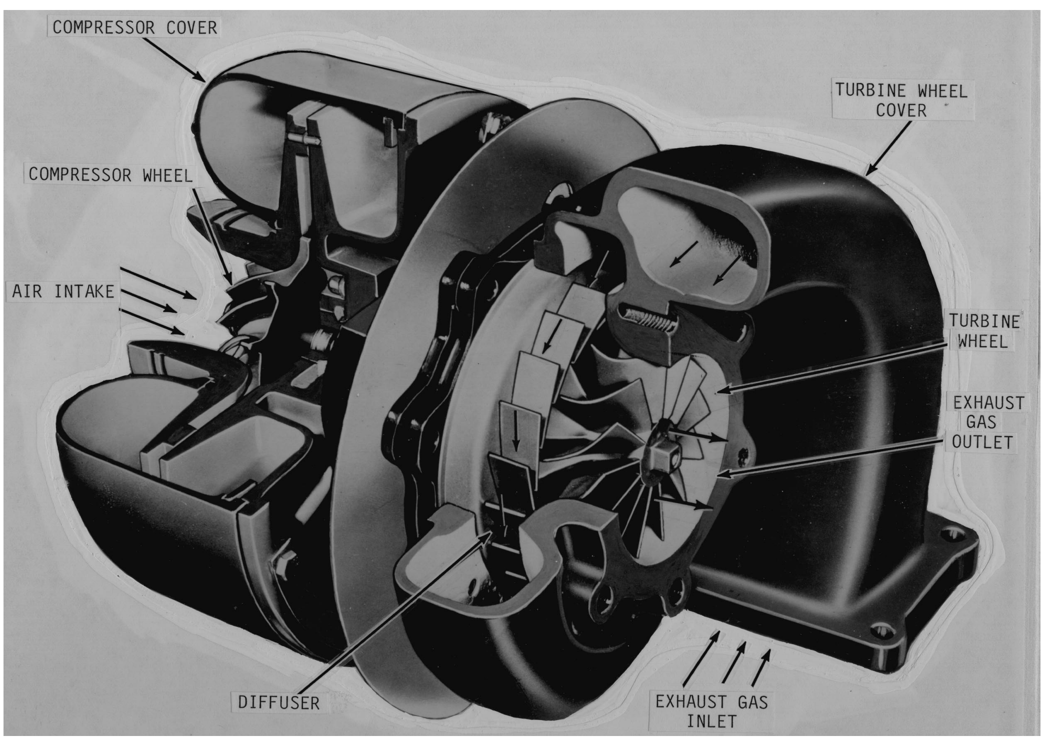
There are many causes of turbocharger failure, but they can be grouped into the following categories:

- Lack of lubricating oil
- Foreign material or dirt in the lubricating system
- Foreign material in either the exhaust or air induction system
- Material or workmanship

A failure can occur if the lubricating oil being supplied to the turbocharger is not sufficient to lubricate the thrust and journal bearings, stabilize the journal bearings and shaft, and cool the bearing and journal surfaces, even for periods as short as 5 seconds.

Operating the engine with contaminated oil under the assumption that the oil filter will remove the contaminants before they reach the bearings of the turbocharger can be quite costly. Actually, there are certain conditions under which the oil filter is bypassed and, if the oil is contaminated, turbocharger damage can result. Some examples of instances where the filter will be bypassed areas follows:

- The turbocharger lubrication valve is open as it is in starting.



81.367

Figure 5-38.-Turbocharger (cutaway view).

- The oil filter is clogged and the bypass valve is open.
- A lubrication valve or filter bypass valve malfunctions as a result of worn or binding components.

If enough contaminated oil enters the turbocharger bearings, the bearings will wear out or large particles may plug the internal oil passages and starve the turbocharger of oil.

Because of the extremely high top speeds of the turbine and compressor wheels (up to 100 mph), any large particles that enter through the inlet or exhaust systems can mechanical y damage the rotating parts of the turbocharger. Therefore, proper maintenance of the air cleaner is extremely important. Also, thorough cleaning of the inlet and exhaust systems is essential if there has been a previous turbocharger failure, valve failure, or other failure that could leave foreign particles in the engine.

Removal, Disassembly, and Cleaning

The removal of the turbocharger from the engine is not a complicated task when you follow the procedures in the manufacturer's instructions.

After removing the turbocharger from the engine, you should make sure the exterior of the turbocharger is cleaned of all loose dirt before disassembly to prevent unneccessary scoring of the rotor shaft. Disassemble it according to the manufacturer's maintenance and repair manuals.

The turbocharger parts accumulate hard-glazed carbon deposits, which are difficult to remove with ordinary solvents. This is especially true if the turbine wheel and shaft, diffuser plate, and the nozzle ring and inner heat shield are affected. The cleaner must remove these stubborn deposits without attacking the metal. All parts should be cleaned as follows:

1. Place all parts in a divided wire basket so parts will not be damaged through contact with each other. Do not pile them in the basket. Avoid mutilating precision ground surfaces.

2. Immerse the parts in mineral spirits or similar solvents.

CAUTION

Never use a caustic solution or any type solvent that may attack aluminum or nonferrous alloys.

3. Allow the parts to soak as needed to remove the carbon. A soft bristle brush maybe used, if necessary, to remove heavy deposits. Never use wire or other brushes with stiff bristles.

4. With the oil orifice removed, flush out the oil passages in the main casing from the bearing end to remove dirt loosened by the soaking.

5. Remove the parts from the tank. Drain and steam clean thoroughly to remove all carbon and grease. Apply steam liberally to the oil passages in the main casing.

6. Blow off excess water and dry all parts with filtered compressed air.

7. Carefully place parts in a clean basket to avoid damaging them before inspection and reassembly.

Parts Inspection

Inspect all turbocharger parts carefully before you rinse them. All parts within manufacturer's recommended specifications can be used safely for another service period. Damage to the floating bearing may require replacement of the turbocharger main casing with a new part or an exchange main casing.

Inspect the turbine casing. If you find cracks which are too wide for welding, replace the casing.

Do not use the exhaust casing if it is warped or heavily damaged on the inside surface caused by contact with the turbine wheel or a foreign object, or if it is cracked in any way.

Usually, oil seal plates do not wear excessively during service and can be reused if they have not been scored by a seizure of the piston ring.

As you inspect the diffuser plates, look for contact scoring by the rotor assembly on the back of the diffuser plate or broken vanes. This scoring will make the plate unacceptable for reuse.

Inspect the inner heat shield. If it is distorted, replace it.

Dents found on the outer heat shield can usually be removed, allowing its reuse. However, if this shield is cut or split in the bolt circle area, replace it.

Inspect the nozzle rings closely for cracks. If the nozzle rings are cracked or if the vanes are bent, damaged, or burnt thin, replace them.

If you see signs of wear or distortion during the inspection of the piston ring seals, discard and replace them with new ring seals.

Inspect the turbocharger main casing for cracks in the oil passages, cap screw bosses, and so forth. Also, check the casing for bearing bore wear. If it exceeds the limits allowed by the manufacturer, the bearing bore may be reworked to permit oversize, outer diameter bearings.

Check the oil orifices plug for stripped or distorted threads. Install a new plug if necessary.

The rotor assembly, which consists of a turbine wheel, thrust washer, and locknut, is an accurately balanced assembly. Therefore, if any one of the above parts is replaced as a result of your inspection, the assembly must be rebalanced according to the manufacturer's specifications.

When inspecting the semifloating bearing, measure both the outside and inside diameters of the bearing. If either diameter is worn beyond limits allowed by the manufacturer, replace the bearing.

The front covers that are deeply scored from contact with the compressor wheel cannot be reused. Slight scratches or nicks only can be smoothed out with a fine emery cloth and the covers reused. Cracked covers, however, cannot be reused and must be replaced with new ones.

All cap screws, lock washers, and plain washers should be cleaned and reused unless they are damaged.

Reassembly and Installation

After inspection of the turbocharger component parts and replacement of damaged or worn parts, reassemble the turbocharger as prescribed by the manufacturer's maintenance and repair manuals.

Close off all openings in the turbocharger immediately after reassembly to keep out abrasive material before you mount it on the engine.

Turbochargers can be mounted on the engine in many different positions. Always locate the oil outlet at least 45 degrees below the turbocharger horizontal center line when the unit is in the operating position.

COLD STARTING DEVICES

Gasoline and diesel fuel engines are difficult to start in cold weather. They are difficult to start because of the low volatility of the fuel. In this section, the most common cold starting devices for gasoline and diesel fuel injection systems are discussed.

GASOLINE FUEL INJECTION COLD STARTING DEVICES

Gasoline fuel injection systems may have a cold-start injector (fig. 5-39) screwed directly into the air intake manifold. This fuel injector will introduce additional fuel into the intake manifold for cold starts and initial cold engine operation. Other gasoline fuel injection systems have a coolant sensor called a thermistor (fig. 5-2). This sensor changes the electrical resistance with the changes in the coolant temperature. The lower the coolant temperature, the higher the resistance. The electronic control module (ECM) provides a low voltage signal to the thermistor and monitors the return voltage value. A lower value means a warm engine, a higher value means a cold engine. The ECM then knows when the engine is cold and when to provide a richer fuel mixture for cold starts and initial cold operation.

DIESEL ENGINE INJECTION COLD STARTING DEVICES

The most common cold starting system for diesel engines is the glow plug system. This is an electrically operated system used to heat the combustion chamber

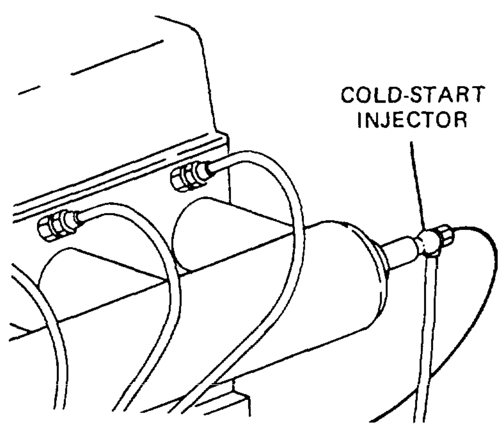


Figure 5-39.-Typical cold-start injector mounted on the intake manifold.

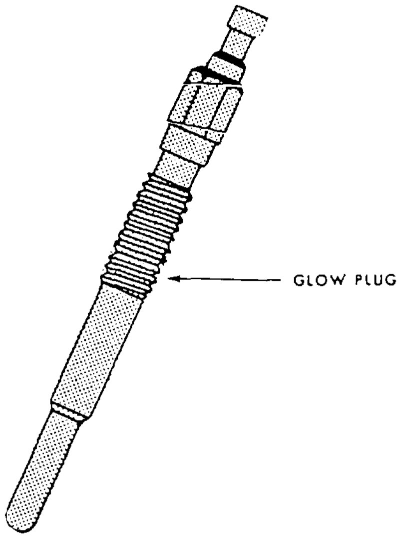


Figure 5-40.-Typical diesel engine glow plug.

before normal initial starting. The glow plug (fig. 5-40) resembles the spark plug of a normal gasoline engine. The system is operated manually by depressing a switch or button; or, it may be turned on with the ignition switch and turned off by a timed relay. During colder weather, the system, with the relay, may have to be run through more than one glow plug cycle to start the engine.

Glow plugs are not complicated and are easy to test. Disconnect the wire going to the glow plug and use a multimeter to read the ohms resistance of the glow plug. Specifications for different glow plugs vary according to the manufacturer. Be sure and check the manufacturer's repair manual for the correct ohms resistance value.

The manifold flame heater system (fig. 5-41) is another type of cold starting system found on diesel

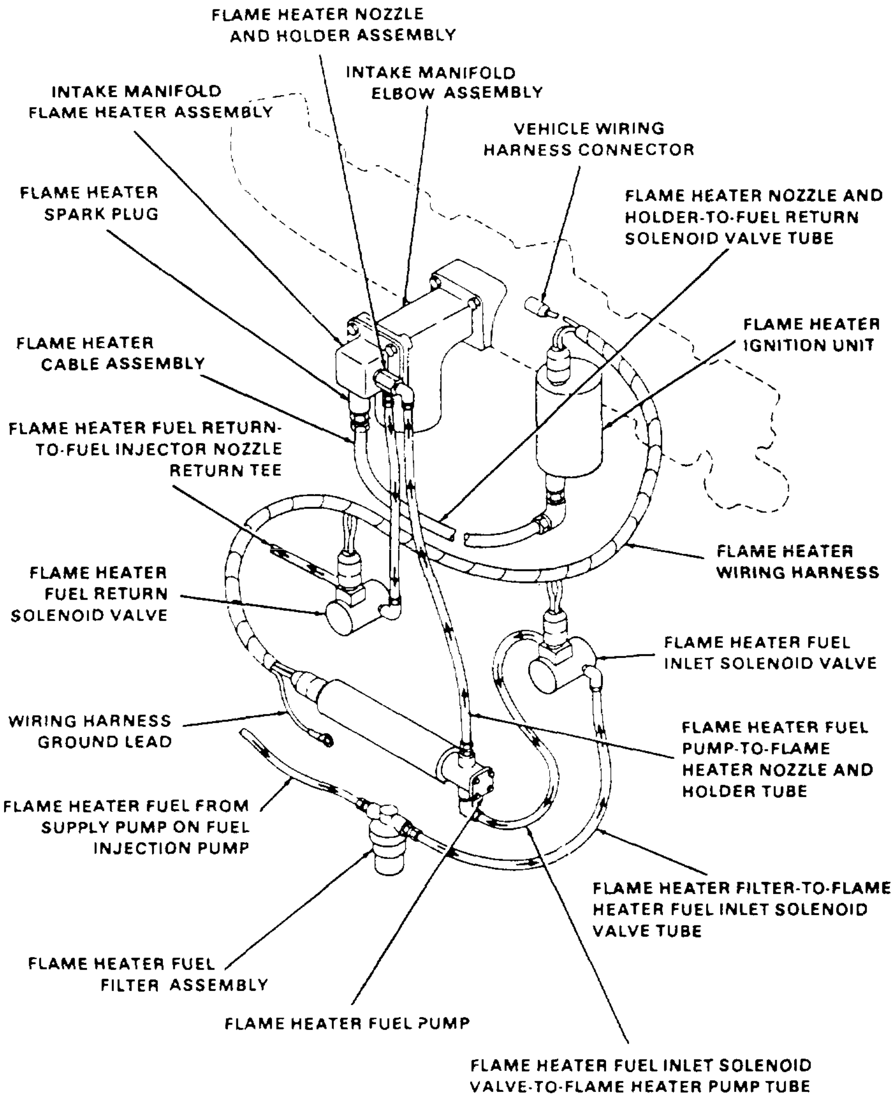


Figure 5-41.-Manifold flame heater system.

engines. This system is composed of a housing, spark plug, flow control nozzle, and two solenoid control valves. This system is operated as follows:

1. The spark plug is energized by the flame heater ignition unit.

2. The nozzle sprays fuel under pressure into the intake manifold assembly.

3. The fuel vapor is ignited by the spark plug and bums in the intake manifold heating the air before it enters the combustion chamber.

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 supply pump of the vehicle and delivers it to the spray nozzle. The pump is energized by the on/off switch located on the instrument panel.

The intake manifold flame heater system has a filter to remove impurities from the fuel before it reaches the nozzle.

The two fuel solenoid valves are energized (open) whenever the flame heater system is activated. The valves ensure that fuel is delivered only when the system is operating. These valves stop the flow of fuel the instant that the engine or the heater is shut down.

When troubleshooting or repairing these units, consult the manufacturer's repair manual.

ETHER

Cold starting aids, such as ether, should be used only in extreme emergencies. Too much ether may detonate in the cylinders too far before top dead center on the compression stroke. This could cause serious damage, such as broken rings, ring lands, pistons, or even cracked cylinder heads. If you must use ether, the engine has to be turning over before you spray it into the air intake.

CAUTION

ETHER IS TO BE USED ONLY IN EXTREME EMERGENCIES.