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AUTOMOTIVE DIESEL MAINTENANCE 1. UNIT III, MAINTAINING THE FUEL SYSTEM--DETROIT DIESEL ENGINE.

HUMAN ENGINEERING INSTITUTE, CLEVELAND, OHIO

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THIS MODULE OF A 30-MODULE COURSE IS DESIGNED TO DEVELOP AN UNDERSTANDING OF THE OPERATION AND MAINTENANCE OF THE DIESEL ENGINE FUEL SYSTEM. TOPICS ARE (1) PURPOSE OF THE FUEL SYSTEM, (2) TRACING THE FUEL FLOW, (3) MINOR COMPONENTS OF THE FUEL SYSTEM, (4) MAINTENANCE TIPS, (5) CONSTRUCTION AND FUNCTION OF THE FUEL INJECTORS, AND (6) TROUBLESHOOTING TIPS. THE MODULE CONSISTS OF A SELF-INSTRUCTIONAL BRANCH PROGRAMED TRAINING FILM "MAINTAINING THE FUEL SYSTEM--DETROIT DIESEL" AND OTHER MATERIALS. SEE VT 005 655 FOR FURTHER INFORMATION. MODULES IN THIS SERIES ARE AVAILABLE AS VT 005 655 - VT 005 684. MODULES FOR "AUTOMOTIVE DIESEL MAINTENANCE 2" ARE AVAILABLE AS VT 005 685 - VT 005 709. THE 2-YEAR PROGRAM OUTLINE FOR "AUTOMOTIVE DIESEL MAINTENANCE 1 AND 2" IS AVAILABLE AS VT 006 006. THE TEXT MATERIAL, TRANSPARENCIES, PROGRAMED TRAINING FILM, AND THE ELECTRONIC TUTOR MAY BE RENTED (FOR $1.75 PER WEEK) OR PURCHASED FROM THE HUMAN ENGINEERING INSTITUTE, HEADQUARTERS AND DEVELOPMENT CENTER, 2341 CARNEGIE AVENUE, CLEVELAND, OHIO 44115. (HC)

STUDY AND READING MATERIALS

AUTOMOTIVE DIESEL MAINTENANCE

MAINTAINING THE FUEL SYSTEM -- DETROIT DIESEL ENGINE

UNIT III

TABLE OF CONTENTS

PTAM 1-3
9/29/65

HUMAN ENGINEERING INSTITUTE

SECTION A - PURPOSE OF THE FUEL SYSTEM

The fuel system in any GM diesel engine:

1. Supplies fuel to the injectors.
2. Maintains its own pressure (45 to 65 psi).
3. Cools the injectors.
4. Lubricates the injectors.
5. Bleeds air and vapor from the system.

SECTION B - TRACING THE FUEL FLOW

Let's trace the flow of fuel through the system. Follow along in Figure 1 as you read. Fuel goes from the supply tank, through the primary filter, and into the fuel pump. The fuel travels from the pump, through the secondary filter, and into the upper fuel manifold. From the upper fuel manifold, the fuel travels through the fuel pipes to the inlet side of the injectors. Surplus fuel returns from the outlet side of the injectors, goes into the outlet fuel pipes to the return manifold. From the return manifold, the fuel passes through a restricted fitting, and back into the tank.

Notice the check valve between the tank and the fuel pump. This valve prevents fuel from draining back to the tank when the engine isn't running.

Now we'll cover some maintenance steps, starting with the first component in the system: the fuel tank.

The fuel in the supply tank must be kept free from water and sediment. This insures clean fuel for the engine. During servicing, sediment and water can be drained from the tank by means of the plug on the bottom of the tank. When clear fuel oil comes out of the drain, you know that the tank is clean. Remember to check the filler cap; a loose cap can let dirt enter the tank.

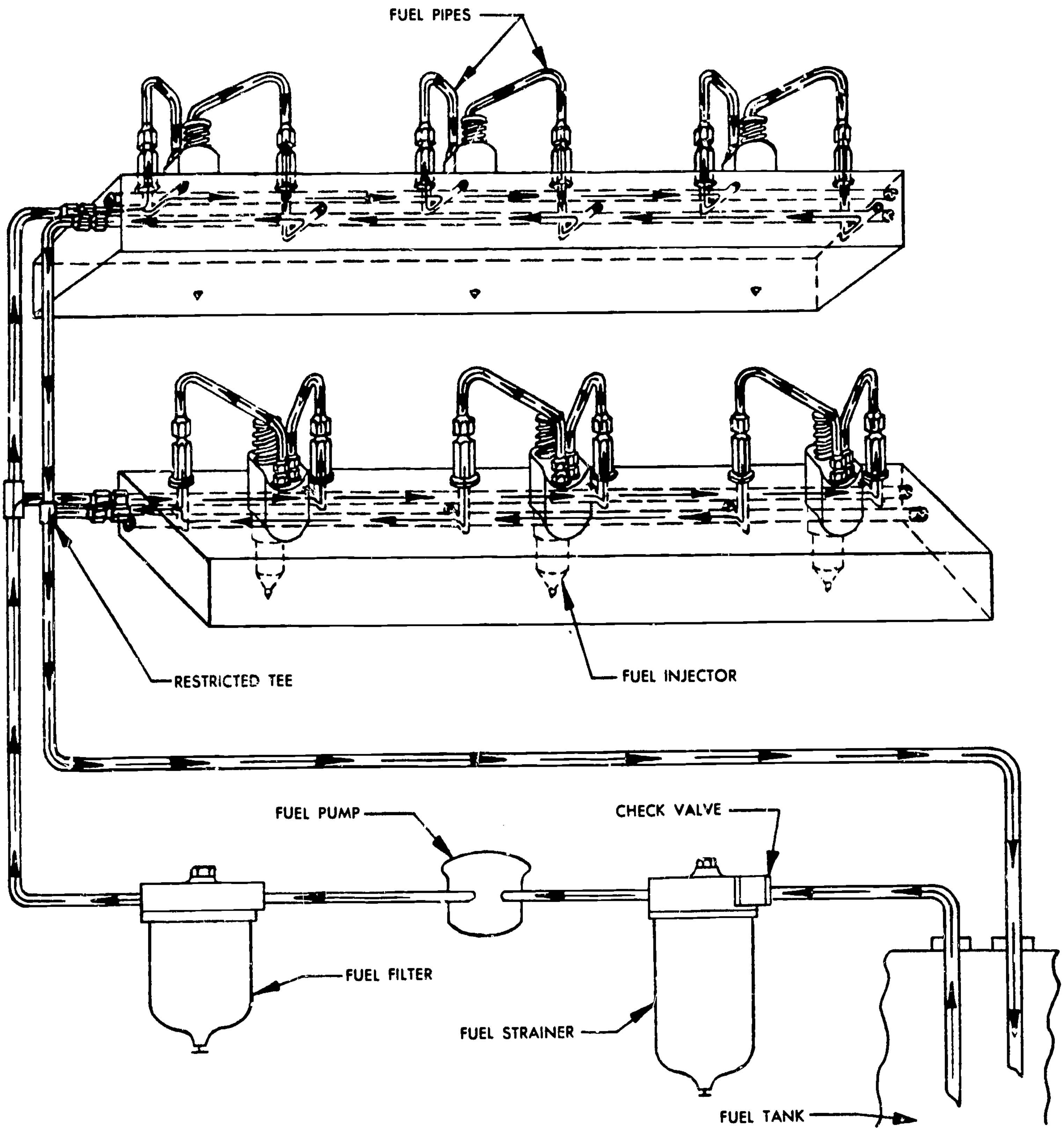

Fig. 1 The fuel system.

SECTION C - COMPONENTS OF THE FUEL SYSTEM

FILTERS (See Figure 2) - Fuel filters are used to remove any impurities which may have gotten into the fuel and could damage parts of the engine. The primary filter removes large impurities, while the secondary filter catches the finer impurities in the fuel. These filters are similar in construction and operation.

The primary filter is located between the supply tank and the fuel pump. Fuel is drawn trhough the primary filter while fuel is forced through the secondary filter by pressure. The secondary filter is found between the fuel pump and the fuel inlet manifold.

Fuel goes into the inlet passage in the cover of the filter and fills the shell surrounding the filter element. Pressure or suction created by the pump pulls the fuel through the filter element, removing the dirt. Cleaned fuel moves to the inside of the filter element, up through the central passage in the cover, and into the outlet passage.

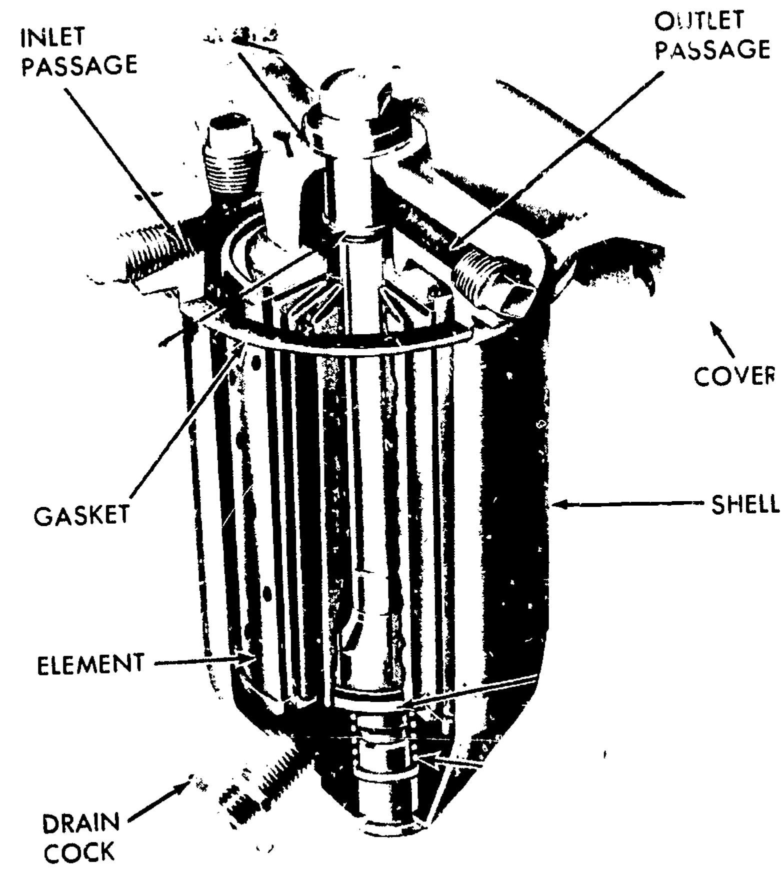

Fig. 2 Typical fuel filter.

About one quarter of a pint of fuel should be drained from the fuel filter shells during servicing. As with the fuel tank, this move assures us that dirt and water impurities are removed from the fuel.

Filter elements should be replaced at about 500 hours, depending on conditions -- such as excessive dust, etc. Remember that as the filter elements get dirty, the pressure in the system drops. So, a good way of checking the filters is to check the pressure at the fuel inlet manifold. If the reading is below normal, (45 to 65 psi), it's time for a change.

THE FUEL PUMP (See Figure 3) - A positive displacement gear type fuel pump is used to transfer fuel from the supply tank to the fuel injectors. The pump actually circulates an excess supply of fuel through the injectors. This excess fuel purges the air from the system and also cools the injectors. It is then returned to the fuel tank via the fuel return manifold and line.

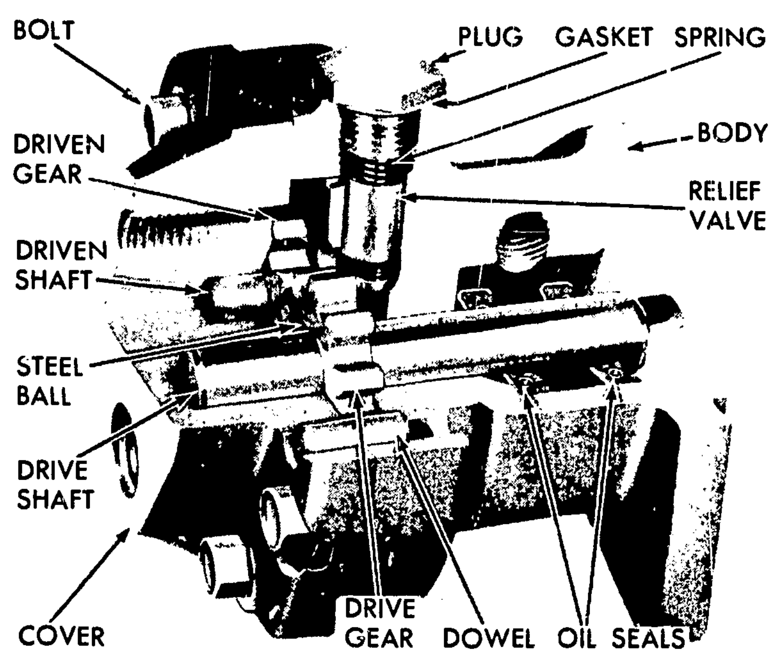

Fig. 3 Fuel pump.

A left hand rotating fuel pump is used on all V-71 engines, regardless of engine rotation. In-line 71 engines, however, use either right or left hand rotating fuel pumps, depending on the rotation of the engine. Note, that these in-line pumps are not interchangeable.

Two dowels help to maintain gear shaft alignment, while holding the fuel pump body and cover together. The mating surfaces of the pump body and cover are ground perfectly flat, and no gasket is used between them. A thin coat of sealant protects against any irregularities in the mating surfaces.

If the fuel supply tank is mounted at a higher level than the fuel pump, the inner seal of the pump is installed with its lip toward the gear pocket. See Figure 4. This is done to prevent seepage of fuel along the pump shaft and out the drain holes in the pump body. (Two holes in the underside of the pump body furnish a means of draining off leakage.)

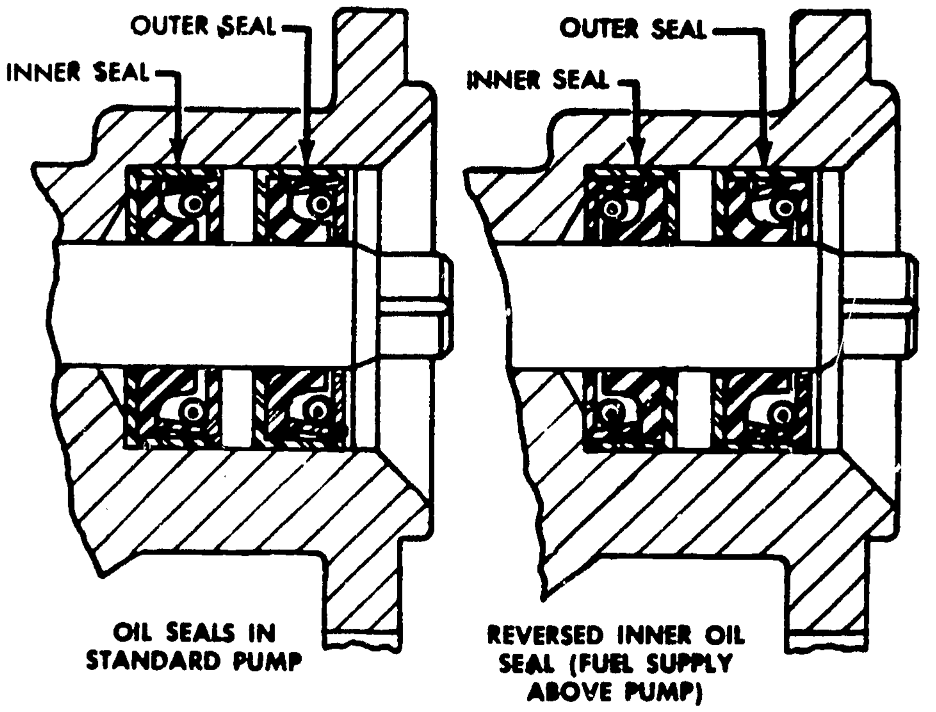

Fig. 4 Pump seal arrangements.

SECTION D - MAINTENANCE TIPS

AIR LEAKS - Air drawn into the fuel system can result in uneven running of the engine, stalling, and loss of power. This is most noticeable at lower running speeds.

If you suspect that an air leak is the cause of poor engine performance, check for loose connections. Look for improper connections as well, such as the fuel pump suction line connected to the short fuel return tube in the fuel tank. This would cause the pump to draw air. Another indication of air leaks comes by watching the fuel filter contents after the filter is bled and the engine is run for 15 to 20 minutes at a fairly high speed. If you find that the filter shell is only partially full after this operation, air leak is indicated.

FUEL LINES - When replacing the restricted fitting, be sure that you are installing one of proper size. (The restricted fitting connects the fuel return line to the fuel return manifold and maintains pressure in the head.) Do not use restricted fittings anywhere else in the fuel system.

When installing fuel lines, tighten connections just enough to prevent leakage of fuel; this way, the flared ends of the fuel lines will not become twisted or fractured because of over-tightening. When all the fuel lines are in place, the engine should be run long enough to check out all the connections and make sure they are tight. Check the filter cover bolts as well. If any leaks are found at the connections, tighten them only as far as needed to stop the leak.

TROUBLESHOOTING - By using clean, water-free fuel and maintaining the fuel filters in good condition, the fuel pump will provide long, satisfactory service and require very little maintenance.

If the fuel pump should fail to work right, check the level of fuel in the supply tank and then make sure that the fuel supply valve is open. Next, check for external fuel leaks at the fuel line connections, filter gaskets, and air heater lines.

If you don't find any leaks, check for a broken drive shaft or drive coupling on the pump. Stick the end of a wire through one of the pump flange drive holes, then crank the engine for a moment and see if the wire vibrates. If it <u>does</u> vibrate, the pump shaft is rotating.

Fuel pump failure results in insufficient fuel sent to the fuel injectors. This is indicated by uneven running of the engine, excessive vibration, stalling at idling speeds, and loss of power.

A sticking relief valve is the most common cause of fuel pump failure. Due to its close fit in the valve bore, the relief valve may become stuck in an open position. Sticking usually is due to a small amount of grit or foreign matter lodging between the relief valve and bore or seat. If the valve is stuck in an open position, fuel oil circulates within the pump rather than getting forced through the fuel system. To check out the valve, remove it, along with the pin and spring from the pump. If the valve gives any sign of sticking, it should either be replaced by a new valve or be reconditioned by using fine emery cloth to remove any score or scuff marks. Check the tension of the valve spring at the same time. When finished, the valve, spring, and bore should be cleaned, the valve lightly oiled, and the parts re-installed. Make sure that the valve is free during the entire length of its travel.

With the pump re-installed, the fuel flow should be checked at a point between the restricted fitting and the fuel supply tank. To check the fuel flow:

1. Disconnect the fuel return tube from the fitting at the fuel tank and hold the open end of the tube in a convenient receptacle.

2. Start and run the engine at 1200 rpm; measure the fuel flow return from the manifold for a period of one minute. Approximately 0. 8 gallon of fuel oil should flow from the return tube per minute (with a fuel line restriction fitting having an . 080" spill orifice).

3. Put the end of the fuel tube into the fuel in the container, (See Figure 5). Air bubbles rising to the surface of the fuel will indicate air being drawn into the fuel system on the suction side of the pump. If air is present, tighten all fuel line connections between the fuel supply tank and the fuel pump.

Fig. 5 Checking the fuel flow.

If the fuel flow is insufficient for good engine performance, then put a new element in the primary filter and recheck the flow. If flow is still poor, replace the element in the secondary filter and recheck the flow. If that didn't help, substitute the fuel pump with one that is known to be in good working order. When changing the fuel pump, clean all the lines with compressed air and be sure that all the connections are tight. Check out the fuel lines for restrictions caused by bends or other damage. If engine performance is not improved after all this, one or more of the fuel injectors may be at fault.

Fuel injectors may be checked as follows:

1. Run the engine at idling speed and cut out each injector, in turn, by holding the injector follower down with a screw driver. If any cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine when that particular injector has been cut out.
2. Stop the engine and remove the fuel pipe between the fuel return manifold and the injector.
3. Hold a finger over the injector fuel outlet and crank the engine with the starter. A gush of fuel while turning the engine indicates an ample fuel supply; otherwise, the injector filters are clogged and the injector should be removed for service.

FUEL MANIFOLD MAINTENANCE - Fuel injectors are supplied with fuel oil by short pipes connected to a fuel manifold (found on the side of the cylinder heads). A different manifold takes the excess fuel from the injectors and sends it to the supply tank via tubes.

The fuel inlet and outlet manifolds are cast into the cylinder heads. Fuel passages are identified by the words IN and OUT cast in several places on the side of the cylinder head.

Fuel manifold connectors are attached to the integral fuel manifold cylinder head with a special sealing washer made of steel. The connectors are tightened to 30/35 ft-lb. torque.

The restricted fitting mentioned before is used in the fuel outlet manifold. It maintains the proper pressure within the system.

SERVICING THE FUEL MANIFOLDS - When replacing an old cylinder head equipped with external fuel manifolds by a current cylinder head, discard the old fuel manifolds and connectors.

The new and old fuel connectors are NOT interchangeable. The new cylinder head includes the new shorter fuel connectors and the steel sealing washers. A length of flexible hose and two hose fittings are also provided. Since the fuel inlet can be located at any one of the inlet passages in the side of the head, the flexible hose can be cut to the required length for connecting the fuel filter to the fuel inlet manifold.

The direction of flow of the fuel will, in most cases, be reversed when replacing an old type head with a new type head. Replace the filters before the injectors are put into the replacement head. Otherwise, damage to the injectors will result, due to foreign particles entering the injector.

INSPECTING FUEL CONNECTORS - Since the manifolds are positioned and locked in place by the fuel connectors, be sure the tapered seats in the manifold tee connectors and the tapered ends of the fuel connectors are clean and free of score marks. If scored surfaces cannot be cleaned up, replace the parts.

SECTION E - CONSTRUCTION AND FUNCTION OF THE FUEL INJECTORS

The GM unit fuel injector performs four functions;

1. It creates the high fuel pressure necessary for efficinet injection.
2. It meters and injects the amount of fuel needed to handle the load.
3. It atomizes the fuel, which is then mixed with air in the combustion chamber.
4. It permits continuous fuel flow.

Each injector control rack (Figures 6 and 7) is controlled by a lever found on the injector control tube. This lever is connected to the governor by a fuel rod. Adjusting the levers independently on the control tube permits an even setting of all injector racks.

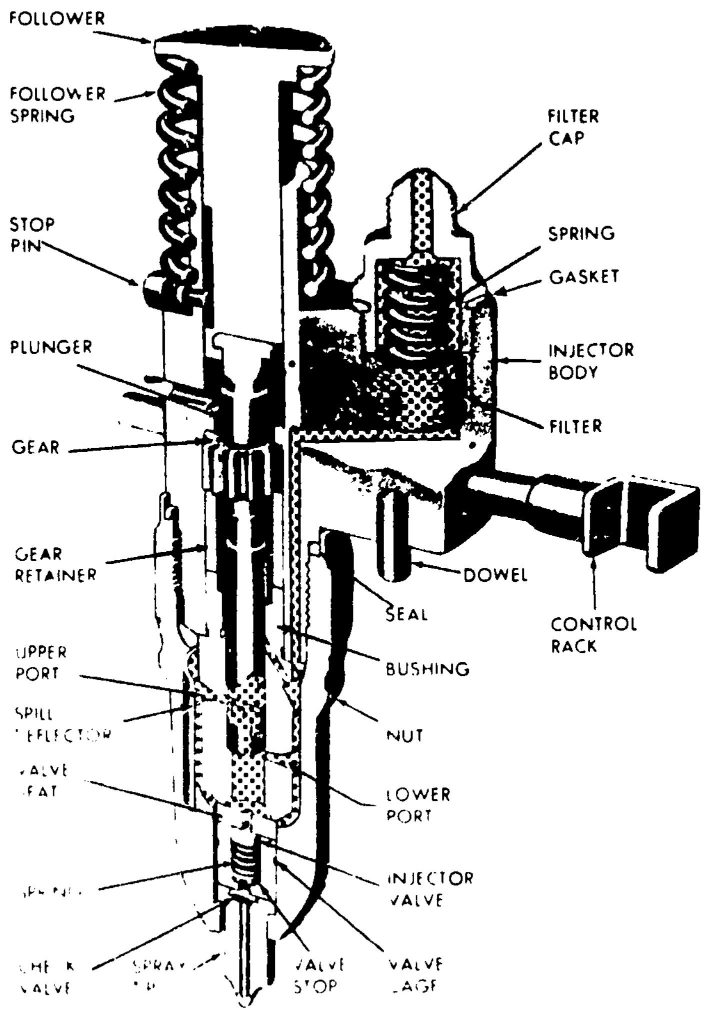

Fig. 6 Crown valve injector.

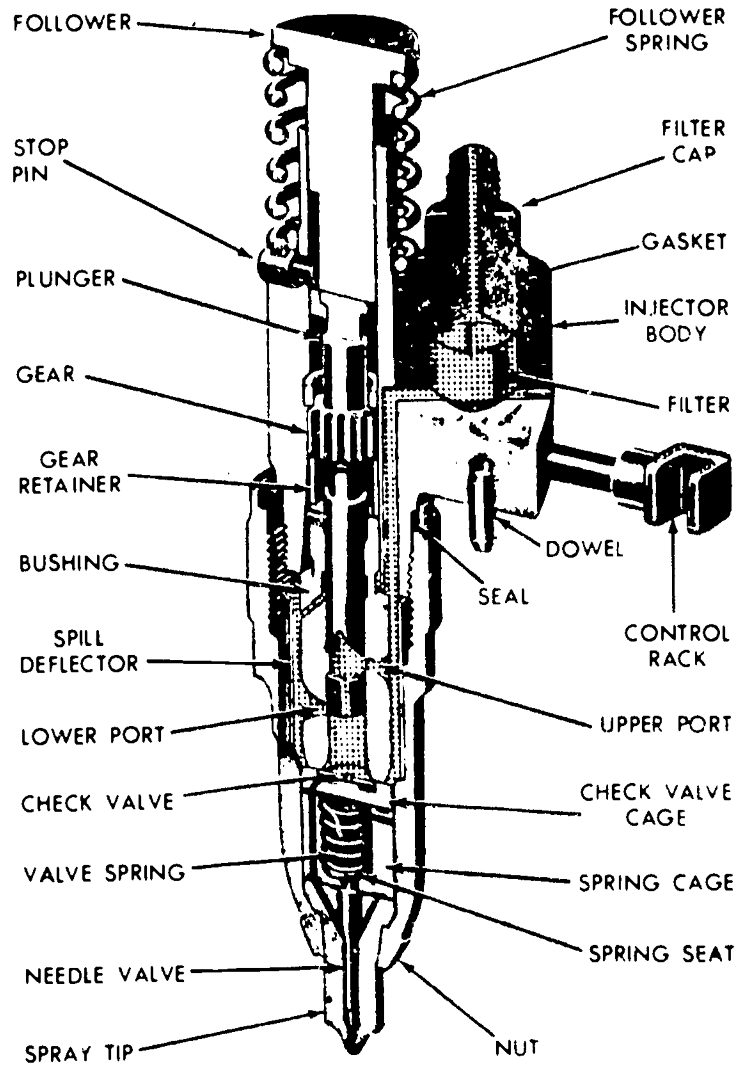

Fig. 7 Needle valve injector.

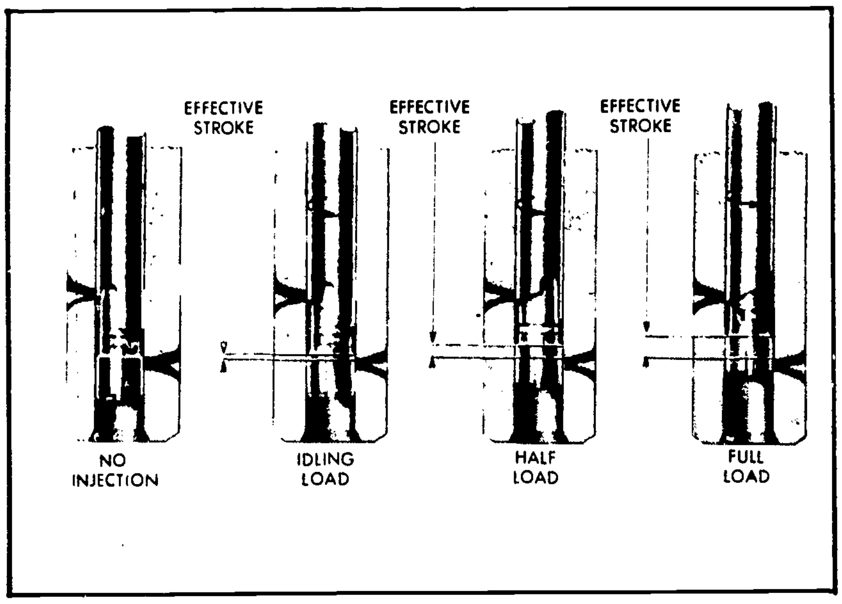

Fig. 8 Fuel metering.

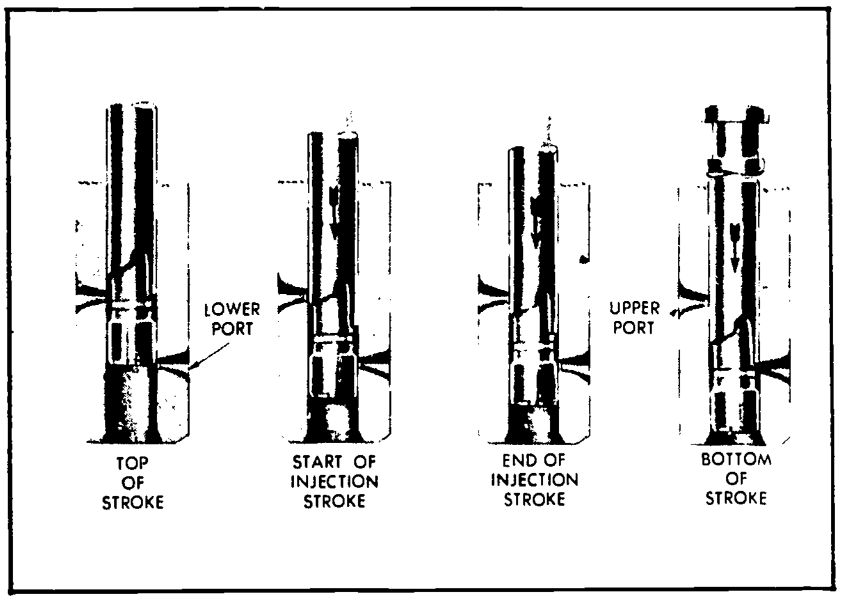

Fig. 9 Injector operation.

METERING is done by a machined angle (helix) in the lower end of the injector plunger. Figure 8 shows how fuel is metered by the rotation of the plunger in the bushing.

Figure 9 shows the phases of injector operations by the vertical travel of the injector plunger.

To vary the required power output, injectors having different fuel output capacities are used. This fuel output is controlled by the helix angle of the plunger and the choice of spray tip. The fuel output sepcifications can be found in the maintenance manual for each engine. Since the helix angle of the plunger determines the output and operating characteristics of a particular type of injector, the correct injectors MUST be used for each application. If injectors of different types are mixed, erratic operation will result - causing serious damage to the engine.

There is an identification tag on each injector which indicates what its output is. All injectors in one engine should have similar tags.

OPERATION OF THE FUEL INJECTOR - Follow Figures 6 and 7 as the operation of the injector is described.

Fuel, under pressure, enters the injector at the inlet side through a filter cap and element. The fuel travels through a drilled passage into the supply chamber (that area between the plunger bushing and the spill deflector -- including the area under the injector plunger located within the bushing). The plunger operates up and down in the bushing. The bore of the bushing is open to the fuel supply in the annular chamber through two funnel-shaped ports in the plunger bushing.

The follower transfers the movement of the injector rocker arm to the plunger. (See Figure 10). Besides reciprocating motion, the plunger can be rotated during operation. This is done by the gear which meshes with the rack. In order to meter the fuel, the upper and lower helixes are machined in the lower part of the plunger. As the plunger rotates, the relation of the helixes to the two ports changes.

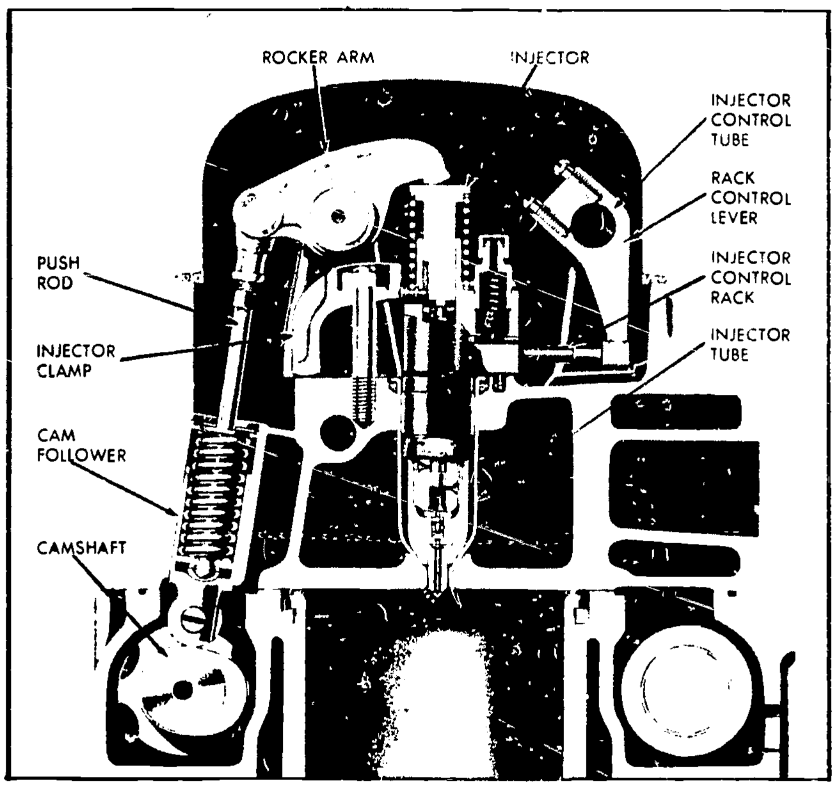

Fig. 10 Fuel injector mounting.

As the plunger moves down under pressure of the injector rocker arm, some of the fuel trapped under the plunger is displaced into the supply chamber. It goes through the lower port until the port is closed off by the lower end of the plunger. Some of the fuel trapped below the plunger is then forced up through the central passage of the plunger into the supply chamber. It goes through the upper port until that port is closed off by the upper helix of the plunger. With the upper and lower ports both closed off, the fuel left under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

When this pressure is built up, it opens a flat, non-return, check valve. The fuel -- in the check valve cage, spring cage passages, tip passages and tip fuel cavity -- is compressed until the pressure acting upward on the needle valve is sufficient to open the valve (against the downward force of the valve spring). As soon as the needle valve lifts off its seat, the fuel is forced through the small orifices in the spray tip. It goes into the combustion chamber atomized.

When the lower land of the plunger uncovers the lower port in the bushing, it relieves the fuel pressure from below the plunger. The valve spring then closes the needle valve -- ending injection. The pressure relief passage seen in the spring cage permits the bleed-off of fuel leaking past the needle pilot.

A check valve below the bushing prevents leakage into the fuel injector from the combustion chamber (in case the valve is accidentally held open by dirt). The injector plunger returns to its original position. Figure 9 shows the various phases of injector operation by the vertical travel of the injector plunger. On the return upward movement of the plunger, the high pressure cylinder within the bushing is again filled with fuel.

The excess fuel goes to the fuel return passage by going through the injector outlet opening. This opening is near the inlet opening and contains the same kind of filter element.

Changing the position of the helixes, by rotating the plunger, varies the closing of the ports and the beginning and end of the injection period. At the same time, it changes the amount of fuel injected into the cylinder. Figure 9 shows the various plunger positions from NO LOAD to FULL LOAD. With the control rack pulled out all the way (no injection), the upper port is not closed by the helix until after the lower port is uncovered. With the rack in this position, all of the fuel is forced back into the supply chamber and no injection of fuel takes place. With the control rack pushed in (full injection), the upper port is closed shortly after the lower port has been covered, thus producing a maximum effective stroke and maximum injection position (full rack movement). The contour of the upper helix advances the closing of the ports and the beginning of the injection.

CARE MAINTENANCE & INJECTOR SERVICING - The unit fuel injector is one of the most important and precisely built parts of the engine. On this unit depends the injection of the correct amount of fuel at exactly the right time into the combustion chamber. Because the injector operates against high compression in the combustion chamber, efficient operation demands that injector assemblies be maintained in first-class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and clean water-free fuel are the keys to trouble-free operation of the injectors.

When servicing injectors, the following instructions should be carefully followed:

1. Whenever fuel pipes are removed from an injector, cover the filter caps with caps to keep dirt out of the injector. Also, protect the fuel pipes and fuel connectors from entry of dirt or other foreign material.

2. After the injectors have been operated in an engine, the filter caps or filters should not be removed while the injectors are in the engine. Filter elements should be replaced only at the time of complete disassembly and assembly of an injector.

3. Whenever an injector has been removed and re-installed, or a new injector has been installed in an engine, the following adjustments must be made:

   a. Time the injector.
   b. Position the injector control rack(s).

4. When a reconditioned injector is to be placed in stock, it should be filled with a quality grade of rust preventative. Install shipping caps on both filter caps immediately after filling. Do not fill the injector with fuel oil.

NOTE: Make sure that new filters have been installed in a reconditioned injector which is to be placed in stock. This precaution will prevent dirt particles from entering the injector due to a possible reversal of fuel flow when installing the injector in an engine other than the original unit.

TIMING THE INJECTOR - To time an injector properly, the injector follower must be adjusted to a definite height in relation to the injector body.

All of the injectors can be timed, in firing order sequence, during one full revolution of the crankshaft. Refer to the general specifications in the GM maintenance manual for the engine firing order.

TIMING STEPS

1. Place the governor control lever in the NO-FUEL position.

2. Rotate the crankshaft until the exhaust valves are fully depressed on the particular cylinder to be timed.
   CAUTION: When using a wrench on the crankshaft bolt at the front of the engine, do NOT turn the crankshaft in a left-hand direction of rotation as this will loosen the bolt.

3. Place the small end of the injector timing gage in the hole provided in the top of the injector body, with the flat of the gage toward the injector follower (See Figure 11).

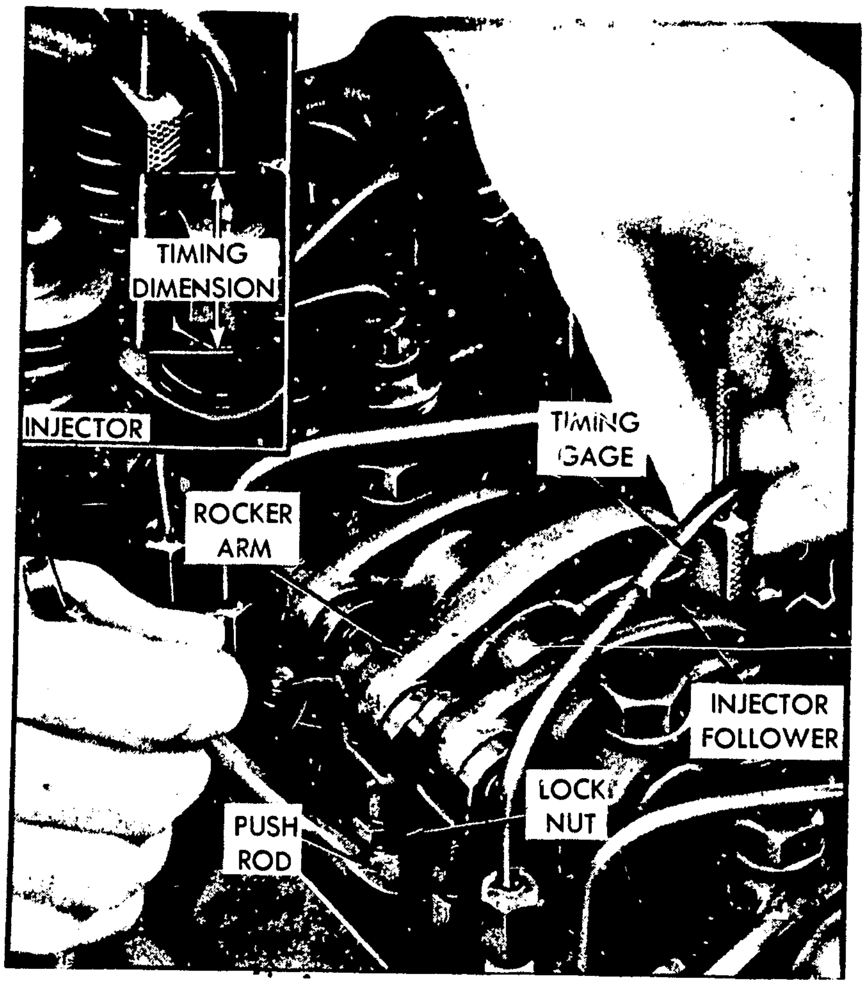

Fig. 11 Timing fuel injectors.

4. Loosen the push rod lock nut.

5. Turn the push rod and adjust the injector rocker arm until the extended part of the gage will just pass over the top of injector follower.

6. Hold the push rod and tighten the lock nut. Check the adjustment and readjust the push rod if necessary.

7. Time the remaining injectors in the same manner as outlined in items 1 through 6.

TESTING THE INJECTOR ASSEMBLY - After removing an injector, clean the exterior. Then inspect the injector. If inspection does not reveal any external damage, a series of tests should be made to determine the condition of the injector (to avoid unnecessary overhauling).

An injector that passes ALL of the tests outlined below may be satisfactory for service, other than the visual check of the plunger.

Identify each injector and record its pop pressure and fuel output as indicated by the following tests:

1. CHECKING THE INJECTOR RACK AND PLUNGER MOVEMENT
See if plunger works freely in its bushing and whether the control rack moves back and forth freely.

   Free movement of a plunger may be checked by placing the injector against a bench, and depressing the follower to the bottom of its stroke while moving the rack back and forth. Failure to produce a free rack indicates that the internal parts of the injector are damaged or dirty.

   CAUTION: The injector must always be held in such a way as to prevent any fuel spray from penetrating one's skin. Fuel oil which enters the blood stream may cause a serious infection.

2. CHECKING "POP PRESSURE" - VALVE OPENING TEST
The purpose of the pop pressure test is to determine the pressure at which the valve opens and injection begins.

   The pop pressure test is performed with the injector placed in testing and popping fixture J7509-01.

   Place the injector in testing and popping fixture (See Figure 12) with the dowel on the underside of the injector located in the proper slot of the adaptor plate J8538-10. Position the injector support plate and the popping handle support to the proper height.

   CAUTION: The injector must always be in the proper position in relation to the spray deflector before it is tested, in order to prevent the fuel spray from penetrating the skin.

   Close the clamp with the inlet tube on the injector. Operate the pump handle until all the air is purged from the test fixture and injector. Then close the outlet clamp, see Figure 12

   With the injector rack in FULL FUEL position, pump the handle of the test fixture with smooth even strokes (see Figure 13.) and record the injector valve opening (pop) pressure as indicated when the injector sprays fuel. Consult your maintenance manual to obtain the specific pop pressure rating of the injector you are working on.

3. TESTING THE HOLDING PRESSURE OF THE VALVE
The holding pressure test will determine if the various lapped surfaces in the injector are sealing properly.

   Each type of injector has a specific holding pressure rating. Consult your maintenance manual for the holding pressure rating of the injector on which you are working.

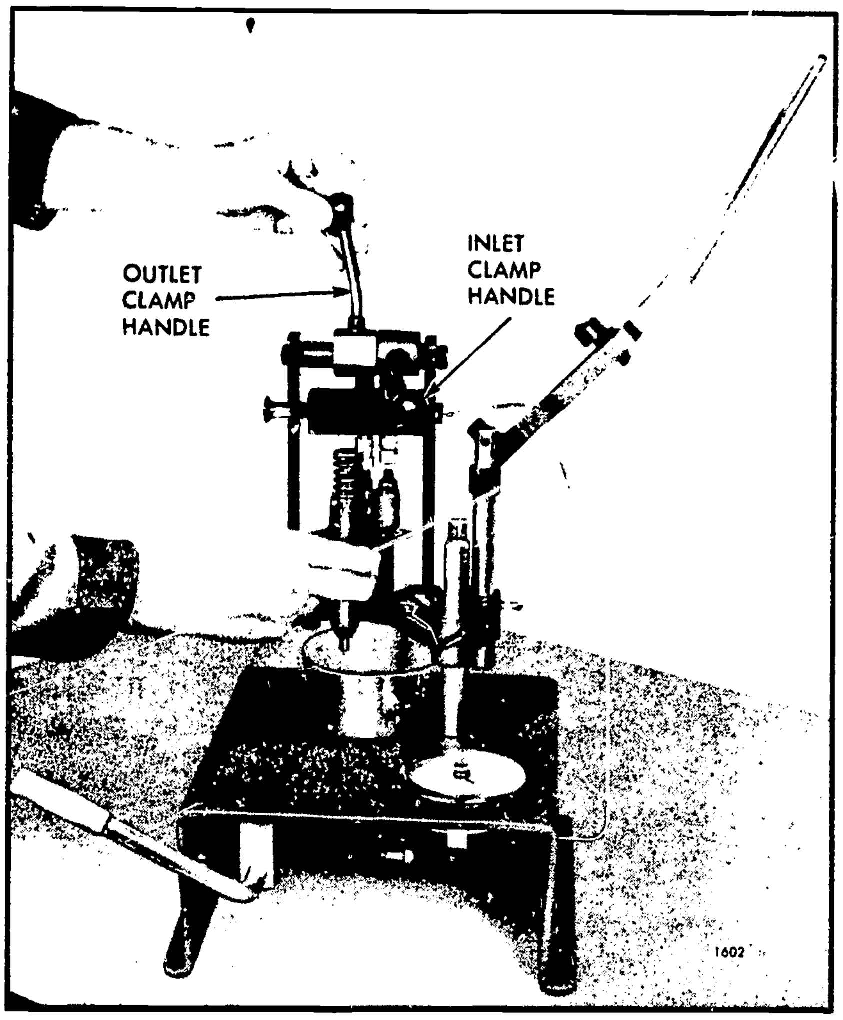

Fig. 12 Injector testing.

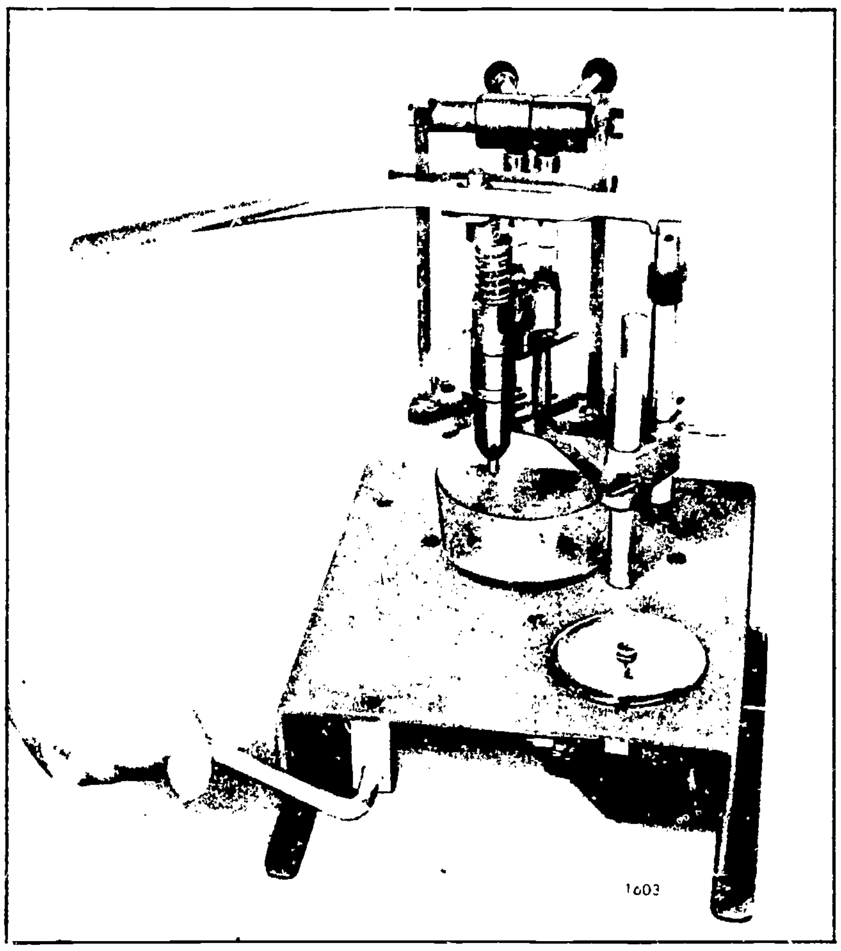

Fig. 13 Pop pressure check.

For an example, we'll run through this testing procedure using the needle valve injector and its specifications.

Operate the pump handle to bring the pressure up to a point just below the injector pop pressure.

Then close the fuel shut-off valve and note the pressure drop. The time for a pressure drop from 500 psi to 1000 psi should not be less than 20 seconds.

If the injector pressure drops from 1500 psi to 1000 psi in less than 20 seconds, the injector should be checked as follows:

a. Thoroughly dry the injector with compressed air.

b. Open test fixture fuel valve and operate the pump handle to to maintain the testing pressure.

c. Look for a leak at the injector rack opening. If this occurs, a poor bushing-to-body fit is indicated.

d. A leak around the spray tip or seal ring usually is caused by a loose injector nut, a damaged seal ring, or a brinelled surface on the injector nut or spray tip.

e. A leak at the filter cap indicates a loose cap or damaged filter cap gasket.

f. A "dribble" at the spray tip orifices indicates a leaking valve assembly due to a damaged surface or dirt. Leakage at the tip will cause pre-ignition in the engine.

4. THE HIGH PRESSURE TEST
This test is performed to discover any fuel leaks at the injector filter caps, body plugs, nut seal ring or internal lapped surfaces which did not appear during the valve holding pressure test. The high pressure test also indicates whether or not the plunger and bushing clearances are satisfactory.

a. Thoroughly dry the injector with compressed air.

b. Check the fuel connections for leaks and tighten if necessary. If leaks have occured, dry injector again.

c. With the injector rake in FULL FUEL position and the popping handle locked in position (see Figure 14) operate the pump handle to build up and maintain pressure.

Use the adjusting screw in the popping handle to depress the injector plunger just far enough to close both ports in the injector bushing. The point at which both ports are closed is found when the injector spray decreases considerably and a rise in pressure occurs.

Now the condition of the plunger and bushing may be established. If there is an excessive clearance between the plunger and bushing,

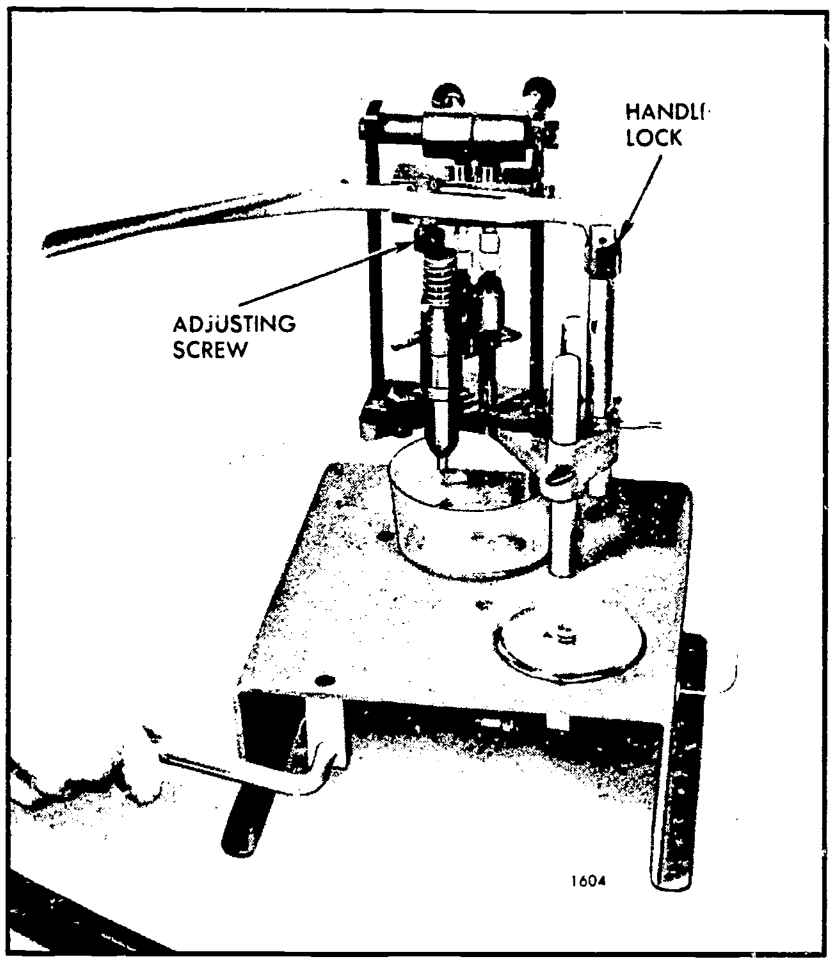

Fig. 14 High pressure test.

you will be unable to pump the pressure up beyond normal valve opening (pop) pressure. Replacement of the plunger and bushing assembly is required when this happens.

Pump up the test fixture and maintain a pressure of 1600 to 2000 psi. Inspect for leaks at the injector filter cap gaskets, body plugs, injector nut seal ring area, and injector rack hole.

> CAUTION: Do not permist the pressure in the test fixture to equal or exceed the capacity of the pressure gage.

5. TESTING THE SPRAY PATTERN

With the injector rack in FULL FUEL position, operate the pump handle to maintain a fuel pressure just below the valve opening (pop) pressure. Pop the injector several times with the popping handle and observe the spray pattern emitted from the spray tip orifices. Fuel should be discharged from each orifice and the spray should produce a uniform pattern.

If the spray tip does not produce a uniform pattern, clean the orifices in the spray tip during injector overhaul.

INJECTOR INSTALLATION - Before installing a new or reconditioned injector in an engine, the carbon deposits must be removed from the beveled seal of the injector hole tube in the cylinder head. If this carbon is not removed, the injector may be cocked during installation -- resulting in undue stresses being exerted against the spray tip. This could finally result in a fractured spray tip.

An injector tube bevel seat reamer should be used to clean the carbon out of the tube before installing the injector. Care must be exercised to remove ONLY the carbon so that the proper clearance between the injector body and cylinder head is maintained. The flutes of the reamer should be packed with heavy grease to hold the carbon removed from the tube.

As a safety measure against scoring the injector parts due to lack of lubrication, any trapped air should be bled from the injector before tightening the connections on the fuel outlet side of the injector. This may be done by cranking the engine briefly with the injector rack in the NO FUEL position and then tightening the fuel pipe connection.

When installing the injector fuel lines, connections should be tightened to 12 to 15 ft-lb torque. Over tightening may result in the flared end of the fuel line being twisted or fractured. When all injector fuel lines are installed, the engine should be run long enough (during tune-up procedure) to check for leaks.

Following the installation of the injectors in the engine, a complete engine tune-up should be performed. However, if only one injector has been removed and replaced, and the other injectors and the governor adjustment have not been disturbed, you only have to adjust the clearance of the valves, time the one injector, and position the control racks.

SECTION F - TROUBLESHOOTING TIPS

If there is any suspicion that a fuel injector is "out of time," the injector rack-to-gear timing may be checked without disassembling the injector.

A hole located in the injector body, on the side opposite the identification tag, may be used to visually determine if the injector rack and gear are correctly timed. When the rack is all the way in the FULL FUEL position, the flat side of the plunger will be visible in the hole. This indicates that the injector is "in time." If the flat side of the plunger does not come into full view, (see Figure 15) and appears in the "advanced" or "retarded" position, the injector should be disassembled and the rack-to-gear timing corrected.

NOTE: Remember that rebuilt injectors are classified as to their flow volumes. These often are color coded as follows:

Red - High flow.
Yellow - Medium flow.
Blue - Low flow.

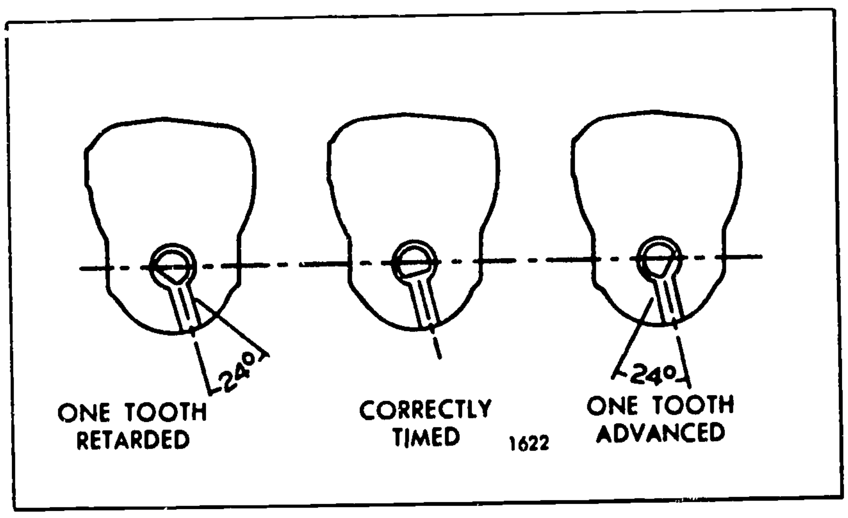

Fig. 15 Rack to gear timing.

ACTOR **FILM NO.** PTAM 1-3D

0

MAINTAINING THE FUEL SYSTEM --
DETROIT DIESEL ENGINES

PTAM 1-3D

Human Engineering Institute

9/65

Press A — 1

1

1

Although the selection and purchasing of diesel fuel is not part of the maintenance man's job, it is essential that he understands some basic concepts about fuel. In this unit we will cover such things as: (1) fuel ratings, (i. e. cetane, viscosity, distillation, and sulfur content); (2) abnormal engine performance due to fuel; (3) importance of cleanliness; and (4) general properties of diesel fuel.

Press A — 2

1

2

Complete this statement by picking the correct choice below.

The three most important properties of any Diesel fuel oil are ______________.

A. whether the fuel will burn, make the engine run smoothly, and leave a minimum of exhaust smoke. — 3
B. whether the fuel is refined, since refined oil gives more heat. — 4
C. the distillation range, the cetane rating, and the sulfur content of the fuel. — 5

1

3

No. Most fuels will burn in a diesel; but after a period of time, if the fuel is not of the right type, carbon will form from misfiring and the engine may stop.

Press A — 5

1

4

No. Refining is required to manufacture the fuel, but it actually lowers the Btu content or heat value of the fuel. Btu's and other properties of fuel will be discussed in more detail later in this unit.

Press A — 5

1

5

You are right. Let's talk about these terms.

DISTILLATION measures volatility. Volatility determines whether or not the fuel vaporizes, or turns into a gas. It is important that the fuel oil can be vaporized. If the fuel oil is not vaporized it will not burn completely.

If all the Diesel oil isn't burned in the cylinder, it will collect and form sludge and other harmful deposits in the engine.

These deposits adhere to and destroy vital engine parts.

Press A — 6

1

6

The DISTILLATION RANGE is given as the temperature at which 90% of the fuel is vaporized as compared to the temperature at which all of the fuel oil is vaporized.

For example a distillation range of 550 F to 575 F means that 90% of the fuel is vaporized at 550 and that all of the oil is vaporized at 575 F.

It is vital that the fuel be completely vaporized so the fuel ______________.

A. will not be wasted. — 7
B. will not collect and form sludge and other harmful deposits. — 8
C. tank will not have to be refilled. — 7

1

7

You are wrong. Unburned fuel is harmful to engines. When fuel is not vaporized it won't burn completely. The unburned fuel will accumulate as sludge and harmful engine deposits.

Valve and ring deposits are not good for an engine, right?

Press A — 8

1

8

You are right. The kind of oil that you use will depend on the normal operating temperature of your engine. An engine that operates under load or at a high speed will have a higher operating temperature and use a diesel oil that has a higher distillation range.

The opposite of this statement is also true. An engine that idles a great deal and operates under light load will have ___(1)___ operating temperature. It should use a fuel that has ___(2)___ distillation range.

A. (1) a higher (2) a higher — 9
B. (1) about the same (2) about the same — 9
C. (1) a lower (2) a lower — 10

1

9

You are wrong. A diesel engine that usually idles and operates under light load will develop lower engine temperatures. Because of its lower engine temperatures, the engine would be better off burning a fuel oil with a lower distillation range.

Engines with high temperatures use fuels with high distillation ranges, and engines with low temperatures use fuel with low distillation ranges, right?

Press A —10

1

10

You are right. A high distillation oil vaporizes at temperatures of about 700 F or more, sometimes even higher than 800 F.

A low distillation fuel vaporizes at temperatures of about 600 F or less.

High diesel engine temperatures are created by compression. Fresh air enters the cylinder through a valve or a port and is compressed by a stroke of the piston. A spray of fuel is shot into the cylinder, where the heat ignites it, giving the engine its power.

A cold engine will start better with an oil with a ________ distillation range.

A. low — 12
B. high — 11
C. The distillation range doesn't matter. —11

1

11

You are wrong. A cold engine will start with an oil that has a low distillation range. As a matter of fact, if the temperature around the engine is extremely cold the engine won't start unless it is heated or a fuel with a low distillation range is used.

An engine that normally idles or operates under light load will operate better with a fuel oil with a low distillation range, isn't that right?

Press A — 12

1

12

You are right. The idea of using cetane ratings to judge fuel is similar to the use of distillation ranges to judge fuel.

The CETANE RATING OF A FUEL OIL is the time that it takes for the fuel to ignite after it enters the cylinder.

A HIGH cetane rating means that a fuel ignites quickly.

A LOW cetane rating means that a fuel ignites slowly.

In cold weather, when engines are difficult to start, you would use a fuel with a ________ cetane rating.

A. low —13
B. high — 14
C. the cetane rating doesn't matter. — 13

1

13

You are wrong. The cetane rating is important to a cold engine. A fuel oil with a high cetane rating will help a cold engine to ignite more quickly.

Of course there are other ways to help start a cold engine. But here we want you to understand that a fuel with a high cetane rating (a fuel that ignites quickly) will help a cold engine to start.

Press A — 14

1

14

You are right if you said that a high cetane rating means that a fuel will start quickly. A fuel that ignites quickly helps start a cold engine.

Another important area in choosing the right fuel for your use is the area of contaminants or impurities in diesel oil. One of the worst impurities in fuel oil is sulfur.

The greater the amount of sulfur in fuel, the greater will be the amount of corrosion, wear, and deposit formation in the engine.

The corrosive power of sulfur is extremely dangerous. Generally speaking, in smaller engines where the temperatures are not high, combustion is less complete. Sulfurous acid results from incomplete combustion.

1

Press A —15

15

Sulfur is a natural enemy of the diesel engine. The acids formed by the incomplete combustion of sulfur and the formation of water can ruin an engine. The worst effects of sulfur occur on pistons, rings, and cylinder liners.

Many engine designers and manufacturers state that it is desirable to use fuels with a sulfur content of less than .5%. However, some fuels commonly have a sulfur content of about 1%.

In order to maintain engines with a minimum of wear and corrosion due to acid formation ________________.

A. fuel should be used which has no sulfur content at all. —16
B. the engine should always be run "hot" to burn up the sulfur. —16
C. fuel should be used which has a relatively low sulfur content. — 17

1

15

You are wrong. Fuel which has no sulfur content at all would be too expensive. As for running the engine "hot" in order to burn up the sulfur (1) you might also burn up the engine (2) it isn't always practical to run an engine under a heavy load all the time.

We stated that common diesel fuel has 1% or more sulfur in it, didn't we?

Press A — 17

1

17

You are right.

Sulfur is just one of the contaminants that can harm an engine. Here are the major categories of contaminants: free water, minerals, and grit or sand.

Free water is dangerous to the engine because it lowers the heat value of the fuel. Lower heat value in fuel is dangerous because it allows all of the troubles that we have been discussing to build up. (Water is a natural product of the combustion of oil. However, by FREE WATER we mean water that is present in the fuel before it is burned.)

Why is sulfur dangerous to an engine?

A. Because it lowers the heat in the engine cylinders. —18
B. Because it doesn't burn in the cylinders. —18
C. Because it helps form deposits on and corrode rings, pistons, and cylinders. —19

1

18

You are incorrect. Sulfur harms an engine by causing formation of deposits which damage vital engine parts. Also, sulfur forms acids which corrode important parts of an engine.

We said that sulfur was the most dangerous engine contaminant.

Didn't we also say that the other important impurities fell under the headings of free water, minerals, and grit and sand?

Press A — 19

1

19

Very good. You are right.

Now, minerals, grit and sand are dangerous to the engine because they can get into the lubrication system and grind away moving parts.

Minerals can get into fuel in any of two ways (1) They can be in the fuel from the time it is pumped out of storage, or (2) they can be added to the fuel to give the fuel certain desirable properties.

In either case the ash from these minerals can become mixed with the lubricating oil and cause dangerous wear if the engine heat is not high enough to vent the ash.

Press A —20

1

20

So far we have talked about (1) DISTILLATION RANGE, (2) CETANE RATING, (3) SULFUR and (4) other impurities namely WATER, MINERALS, GRIT and SAND.

Fill in the following sentences from the choices given below. (Pick the set of three words which will complete all three statements correctly.)

A __(1)__ distillation range means that the fuel oil vaporizes faster and that combustion is more complete.

A __(2)__ cetane rating or number means that fuel ignites fast.

A __(3)__ amount of sulfur in Diesel fuel is not desirable.

A. (1) high (2) low (3) low — 21
B. (1) low (2) high (3) high — 22

× C → 46

2

21

You are wrong.

A low distillation range means that the fuel oil is more volatile and that combustion is more complete.

A high cetane rating or number means that the fuel ignites faster.

You want the amount of sulfur in Diesel fuel to be as low as possible.

You also want the amount of water and sand to be as low as possible, don't you?

Press A —22

2

22

You are right.

While cetane number, distillation range and sulfur content are the most important properties of fuel oil, there are still other properties and contaminants which should be mentioned. The first property that we will talk about is VISCOSITY.

VISCOSITY measures a fuel oil's internal resistance to flow -- that is, how slowly the oil will flow or whether it will flow at all.

Fuel should be able to flow at the lowest temperature expected. Multiple fuel pump systems require a closer tolerance in viscosity to prevent fuel leakage and loss of power.

Press A —23

2

23

OK. The POUR POINT is the temperature at which fuel stops flowing. For cold weather operation the pour point specified should be 10 degrees F below the temperature where the engine will be operated. Some cold weather problems with the POUR POINT can be overcome with heaters.

Complete this sentence:

A fuel's internal resistance to flow (whether or not the oil will flow) is called ______________.

A. volatility — 24
B. viscosity — 25
C. variation — 24

2

24

You are incorrect.

How fast a fuel or any liquid will flow is called VISCOSITY. Another way of describing viscosity is: VISCOSITY measures a fuel's (or liquid's) internal resistance to flow.

One thing you want to remember about the flow of fuel is the pour point. The POUR POINT is the temperature at which fuel stops flowing.

Pick another answer.

Press A — 25

2

25

Very good; you are right.

Most diesel fuels contain dissolved wax. The CLOUD POINT is the temperature at which the wax starts to separate from the fuel. The CLOUD POINT should be below the lowest temperatures where the fuel will be used. As long as the temperature is above the CLOUD POINT the wax in the oil will not clog the fuel filters.

Complete these sentences:

Viscosity measures a fuel's ability to __(1)__. The __(2)__ is the temperature at which a fuel stops flowing.

A. (1) ignite (2) cloud point — 26
B. (1) vaporize (2) zero — 26
C. (1) flow (2) pour point — 27

2

26

You are wrong.

The ability of a fuel to flow is called its viscosity. The temperature at which a fuel stops flowing is called the pour point.

VISCOSITY and POUR POINT tell whether and under what conditions fuel will flow.

Isn't the temperature at which wax separates from fuel oil called the cloud point? Go back and make another choice.

Press A - 25

2

27

You are correct. You have just learned some terms which tell whether fuel will flow or not.

The ability of a fuel to flow is called viscosity. The temperature at which a fuel stops flowing is called the pour point.

What is the temperature called where the wax in diesel fuel can separate from the fuel and clog the filters?

A. Second pour point. — 28
B. Cloud point. — 29
C. Viscosity point. — 28

2

28

You made a mistake. The temperature where the wax in diesel fuel separates from the fuel oil is the cloud point. The wax in the fuel can begin to clog the filters at the cloud point.

The viscosity measures a fuel's internal resistance to flow.

The temperature at which fuel stops flowing is called the pour point, isn't it? Try again.

Press A — 27

2

29

Right! The ability of a fuel (or liquid) to flow is called the viscosity. The greater the viscosity, the slower a liquid will flow. A viscous fluid will flow slower than a fuel that is not viscous.

The pour point is the temperature at which fuel will not flow.

The cloud point is the temperature at which the wax separates from the fuel and starts to clog the fuel filters.

Which is more viscous, crankcase oil or diesel fuel oil?

A. Crankcase oil. — 31
B. Diesel fuel oil. — 30
C. Neither; they have the same viscosity. — 30

2

30

Wrong. The greater the viscosity, the slower a liquid (fluid) will flow -- so crankcase oil is more viscous than fuel oil.

Remember, the pour point is the temperature at which fuel will not flow.

Isn't the cloud point the temperature at which wax starts to separate from the diesel oil (and starts to clog the fuel filters)?

Press A — 29

2

31

Right. The greater the viscosity the slower a liquid (fluid) will flow -- so, crankcase oil is more viscous than fuel oil.

The pour point is the temperature at which fuel will not flow.

The cloud point is the temperature at which wax starts to separate from the diesel oil (and starts to clog the fuel filters).

You have already been told that water is harmful to the engine fuel system. It lowers the heat value of the fuel, mixes with the fuel to form acids, and causes rust. The rust formed by water may also begin to wear out the engine.

Press A — 32

2

32

Another fuel property which is harmful to engines is CARBON RESIDUE. Fuel which does not burn clean may leave a coat of carbon residue on cylinder walls, piston heads and rings, valves and ports. These deposits can lead to engine failure.

However the permissible amount of carbon residue depends largely on engine size and speed. Large, slow-speed engines can use fuels which contain large amounts of carbon residue. Small high-speed engines must use fuels which contain small amounts of carbon residue.

Now, complete this sentence:

Water ________ the heat value of diesel fuel.

A. maintains — 33
B. lowers — 34
C. raises — 33

2

33

You made a mistake. Water lowers the heat value of a fuel. Also it mixes with fuel products such as sulfur to form acids. These acids can ruin an engine.

Water will cause the steel parts of an engine to rust. This rust can wear away and destroy parts of the engine, can't it?

Press A — 34

2

34

You are right. Now back to carbon residue. CARBON RESIDUE should be low enough to minimize the tendency for carbon to collect on fuel injector tips. Carbon deposits at this point affect fuel spray characteristics which, in turn, affect combustion efficiency. Now complete these sentences by picking the correct choice below:

(1) can burn the cheaper fuels which contain larger amounts of carbon residue because they create the high pressures and temperatures which eliminate the carbon from the engine parts.

(2) must use fuels which contain smaller amounts of carbon residue.

A. (1) Small high-speed engines (2) Large slow-speed engines. — 35
B. (1) Large slow-speed engines (2) Small high-speed engines. — 36
C. The size and speed of the engine doesn't matter: all engines must use low carbon fuel oils. — 35

2

35

You are wrong. The permissible amount of carbon residue depends on engine size and speed. Large slow-speed engines can use fuels which contain large amounts of carbon residue.

Small high-speed engines must use fuels which contain less carbon residue.

Carbon residue should be low enough to minimize the tendency for carbon to collect on fuel injector tips, shouldn't it?

Press A — 36

2

36

You are right.

High carbon residue (much above 0.25%) also indicates that the fuel has not been completely distilled. Such fuels contain water and sediment such as sand or metallic particles. Fuels that have not been completely distilled do not burn as cleanly as the higher distillates. They are often more economical in the long run (than distilled fuel) because their cost is generally less. However maintenance costs may be higher, and engine performance may be less satisfactory.

________ has a tendency to coat the injector tips, valves, liner ports, rings, piston heads and cylinder walls with hard black carbon.

A. Sulfur ash — 37
B. Paraffin
C. Carbon residue — 38

2

37

You are wrong. When a fuel that contains a higher amount of carbon residue than the engine can burn or vent (exhaust), the carbon residue may collect on injector tips, valves, liner ports, rings, piston heads and cylinder walls.

Does the viscosity and pour point increase the fluidity of a fuel (whether or not the fuel will flow)?

Try again.

Press A — 36

2

38

Correct.

Viscosity and pour point measure the fluidity of a fuel. VISCOSITY is the tendency of a fuel NOT to flow (or of internal resistance to flow).

The POUR POINT of a fuel is the temperature at which the fuel STOPS flowing.

Choose the best pair of answers for these two questions:

(1) Fuels with high carbon residue are more economical because ________.
(2) What is the drawback for fuels with high carbon residue?

A. (1) They burn cleaner. (2) They usually cost more. — 39
B. (1) They are usually cheaper. (2) They may increase maintenance cost and decrease engine efficiency. — 40
C. (1) They increase engine efficiency. (2) They need high carbon residue to be really efficient. — 39

2

39

You are incorrect.

Diesel fuels which have more carbon residue are generally more economical for some operations because they are cheaper to buy.

The drawback with these fuels is that sometimes they create maintenance problems and give less satisfactory engine performance. For example, fumes and the coating of engine parts.

Isn't the pour point of a diesel fuel the temperature at which a fuel will not flow?

Press A — 40

2

40

Right.

Viscosity and pour point can create several maintenance problems. If viscosity is too high, the fuel simply will not flow and ignite or sustain combustion. Also a high viscosity does not allow the fuel to break up or atomize properly; it also causes smoking.

Larger engines can handle more viscous fuel.

Complete this sentence by picking the correct answer below:

Viscosity is the tendency of fuel not to ___________.

A. flow — 42
B. burn
C. freeze } 41

2

41

Incorrect. Viscosity is the tendency of a fuel not to flow or to resist flow. High viscosity can cause a fuel not to flow. It may also prevent a fuel from breaking up or atomizing properly in the cylinder.

Press A — 42

2

42

OK.

Now, this is what happens when the fuel is not viscous enough. The fuel spray will not atomize and cover the combustion chamber properly. The fuel will not break up and mix well with the air, causing power loss. Also, if the viscosity is too low, dribbling and leakage will occur around the injector valves and around fuel pump connections.

In general, which size engine handles fuel with higher viscosity better -- large engines or small engines?

A. Small engines. — 43
B. Large engines. — 44
C. Both are the same. — 43

2

43

You are mistaken.

Large engines can burn more efficiently than small engines. Large engines can also burn fuels containing impurities without damaging themselves better than small engines.

Press A — 44

2

44

You are right, very good.

The cetane number is an indication of how fast a diesel oil will ignite. A higher cetane number may be required as the temperature of compression is reduced by such factors as:

1. Low atmospheric temperature (cold weather).
2. Low jacket water temperature.
3. Low compression.
4. Light load operation.

There are other conditions that may make an engine need a fuel with a higher cetane number.

Press A — 75

X C — 45

2

45

OK. Very good.

Large engines can handle fuel with higher viscosity better than small engines. The reason large engines are more efficient handling this problem and other problems (such as high sulfur or carbon content) is because large engines develop high temperatures. High engine temperatures burn off fuel impurities.

The material which you have covered is important. Therefore, we will review to be sure that you understand.

Press A → 1 (repeat)

2

46

The cetane number helps to tell how fast a fuel will ignite. You were told some things which made an engine need a fuel with a higher cetane number. They were:

1. Low atmospheric temperature (cold weather).
2. Low water jacket temperature.
3. Low compression.
4. ____________________.

A. Light load operation. — 48
B. Engine too warm. — 47 (Choose one for line #4).
C. Leakage in fuel pump. — 47

3

47

You are wrong. The things which you were told might cause an engine to need a fuel with a higher cetane number were:

1. Cold weather (low atmospheric temperature).
2. Low water jacket temperature.
3. Low compression pressure.
4. Light load operation.

Try again.

Press A — 46

3

48

You are right. Let's rearrange the factors and see if you remember which two were left out.

1. Light load operation.
2. Cold weather.
3. ________.
4. ________.

A. (3) Low atmospheric temperature. (4) Leaky oil seal. > 49
B. (3) Low atmospheric temperature. (4) Leaky water seal.
C. (3) Low water jacket temperature. (4) Low compression. — 50

3

49

You are wrong. Low atmospheric temperature means the same as cold weather. Cold weather was already mentioned.

Leaky water and oil seals have nothing to do with cetane number.

The engine would not function properly with an incorrect cetane number even if the seal were in good condition.

Pick another answer.

3

Press A — 48

50

You are right. Fuel with a higher cetane number would be used under these conditions:

1. Cold weather.
2. Low water jacket temperature.
3. Low compression pressure.
4. Light load operation.

What does "higher cetane number" mean?

A. The fuel has more acetate in it. — 51
B. The fuel has better self-starting quality. — 52
C. The fuel will ignite only when brought into contact with a flame or spark. — 51

3

51

You are wrong. Cetane number has nothing to do with acetate.

Diesel fuels must be self igniting because there are no spark plugs in a diesel engine. Therefore diesel fuels are made self igniting. The higher the cetane number is, the better a fuel will ignite or start itself.

Pick another answer.

3

Press A 50

52

Correct.

Cetane numbers can fall between 0 and 100 for diesel fuels. The higher the cetane number the better a fuel will start itself.

Therefore an oil with a cetane number of __(1)__ will start better than an oil with a cetane number of __(2)__.

A. (1) 45 (2) 30 — 54
B. (1) 0 (2) 100 > 53
C. (1) 25 (2) 45

3

53

Wrong. The cetane number measures the ability of a fuel to start itself. Therefore, the higher the cetane number is, the better it will start itself -- right?

Try again.

Press A — 52

3

54

Very good. You are right.

Now, the lower a cetane number is the more difficult it is for a fuel to start itself.

Therefore an oil with a cetane number of __(1)__ would have poorer ignition qualities than an oil with a cetane number of __(2)__.

A. (1) 30 (2) 40 — 56
B. (1) 100 (2) 0 > 55
C. (1) 35 (2) 20

3

55

Wrong. The lower a cetane number is, the more difficult it will be for a fuel to start or ignite itself.

Read carefully and try again.

Press A — 54

3

56

Right. On a cold day when the water jacket is cold, a fuel oil with a cetane number of __(1)__ would start better than a fuel oil with a cetane number of __(2)__.

A. (1) 25 (2) 40 } 57
B. (1) 30 (2) 31 }
C. (1) 45 (2) 30 — 58

3

57

You are wrong.

Fuel with a higher cetane number would be used under these conditions:

1. Low atmospheric temperature.
2. Low water jacket temperature.
3. Low compression pressure.
4. Light load operation.

Right? Pick another answer.

Press A — 56

3

58

Right. A high cetane number means that a fuel will ignite itself easily. A low cetane number means that a fuel will have difficulty igniting.

Now, what is the range of cetane numbers?

A. From 0 F to 212 F. } 59
B. From 32 F to 212 F. }
C. From 0 to 100. — 60

3

59

You are wrong.

Cetane numbers can fall between 0 and 100 for diesel fuels. The higher the better a fuel will start itself -- right?

Try again.

Press A — 58

3

60

You are right.

Now, what is the rating which tells how fast a diesel will start?

A. Distillation range. — 61
B. Cetane number. — 62
C. Flash flame. — 61

3

61

You are wrong. The cetane number tells how fast a fuel will start or ignite itself. A cetane number may fall anywhere between 0 and 100.

The higher the cetane number is, the faster it will ignite itself -- right?

Try again.

Press A — 62

3

62

You are right.

When we start an engine, the injected fuel will ignite and the engine will run if the temperature of the air in the engine cylinder is above the ignition temperature of the fuel. The temperature in the engine cylinder depends on the temperature of the outside air. The cooler the outside air is, the lower its temperature will be after compression.

Therefore a diesel engine will start in colder weather with an oil having a higher __(1)__, because the oil will __(2)__ at the lower temperature of the cylinder.

A. (1) pressure point (2) react to a spark } 63
B. (1) fuel range (2) congeal }
C. (1) cetane number (2) self-ignite — 64

3

63

You have made a mistake.

A high cetane number means that a fuel will ignite easily. Wouldn't a fuel with a higher cetane number help start a cold engine in the winter?

Try again.

Press A — 62

3

64

You are correct.

If the ignition temperature of the fuel is not low enough, part of the fuel will fail to burn completely, and the resulting soot (unburned carbon) will appear as smoke in the exhaust gases. The smoking will be bad at light loads when the engine temperatures are low.

The smoke problem may be corrected by changing to a fuel with a ________ cetane number.

A. lower — 65
B. higher — 66
C. more pressurized — 65

3

65

You are wrong.

A combustion chamber must be hot (about 1000 F) for diesel fuel to burn properly. However, the combustion chamber may be much cooler than that during cold weather and at light loads. Therefore the fuel is not burned properly, or completely, and smoke results.

A fuel with a higher cetane number ignites more easily. Wouldn't an oil with a high cetane number operate better in this situation? Try again.

Press A — 64

3

66

Very good. You are right.

Fuel knock is caused by too great an increase in pressure when the fuel oil ignites. It happens when too much fuel accumulates as the combustion chamber is being charged with fuel.

When fuel ignites quickly, the oil doesn't accumulate and the fuel knock (combustion knock) doesn't occur.

If there were no combustion knock, it would be safe -- and probably cheaper -- to use a fuel with a __(1)__ cetane number. However if the engine had a combustion knock, it would be best to change to a fuel with a __(2)__ cetane number although the fuel might be more expensive.

A. (1) better (2) better
B. (1) higher (2) lower } 67
C. (1) lower (2) higher — 68

3

67

You are mistaken.

Usually fuel oil with higher cetane numbers is more expensive to buy and use. However, this expense may be offset by better engine wear and lower maintenance costs. For example, if the fuel oil being used causes a combustion knock, a change to a fuel with a higher cetane number might be desirable -- right? Try again.

Press A — 66

3

68

Correct.

All of these combustion problems may be helped by a change in fuel:

Combustion or fuel knock.

Difficulty or delay in starting in cold weather.

Exhaust smoke.

If some one decided to remedy these situations by changing diesel oil, he would be better off to change to a _______________.

A. higher cetane number. — 70
B. high octane like gasoline (instead of diesel fuel). — 69
C. lower cetane number. — 69

3

69

You are wrong.

If the fuel being used is causing engine problems because the cetane number (self-ignition quality) is too low, changing to a fuel with a higher cetane number (better ignition quality) will probably end the difficulty.

Gasoline is a poor diesel fuel because it has poor self-ignition, and because it is more expensive than diesel oil.

Isn't fuel knock caused by the ignition delay of fuels with low cetane numbers? Pick another answer.

Press A — 68

3

70

You are right.

An engine gets its power from the heat released during the burning or explosion of fuel. The fuel which releases the most heat while burning will give the engine more power.

These two characteristics of heavy oil -- greater heating power and economy -- tend to make heavy oil __________ for engines if the engines can be made to burn heavy oil efficiently.

A. undesirable — 71
B. desirable — 72
C. more viscous — 71

3

71

You are wrong. Greater heating power and economy are two very desirable qualities of heavy fuel oil. It is desirable to use a fuel that is cheap and gives more power.

Read the question carefully [illegible] another answer.

Press A — 70

3

72

You are right.

Some engines are designed to use heavier oils. Fuel heating and air injection mechanisms are examples of designs which accomodate heavier fuel oils.

These mechanisms usually make an engine more expensive-- but they limit or minimize the problems caused by heavy oil, such as poor spray or injection characteristics, fuel knock, exhaust smoke, and gumming and coating of engine parts with carbon and other combustion residues.

When the heavier diesel fuels are used instead of the lighter ones, it is usually because ______________.

A. heavier fuels cost less and develop more power. - 72½
B. heavier fuels are purer and cause fewer maintenance problems. — 74

X C → 73

72½

You have done very well. Thank you for working so hard. We have completed this section.

The material that you have learned will be helpful to you in spotting and repairing conditions caused by variations in types, grades and quality of diesel fuels.

Press Rewind.

73

You are right. Heavy oil has greater heating power and economy. It is a very desirable fuel for an engine that can burn it efficiently.

Some engines are designed to use heavier oils. Fuel heating and air injection mechanisms are examples of designs which accomodate heavier fuel oils.

The material which we have covered is important; so let's go back and review to be sure that we know it thoroughly.

Press A → 23 (review)

74

You are wrong. Heavier fuel oils are usually cheaper and often develop more heat than lighter fuels.

A problem with heavier fuels is that they usually have higher distillation ranges than the lighter fuels. Also, heavier fuel oils usually are not as pure as the lighter oils.

Heavy oil is usually cheap, isn't it?

Press A — 72

75

You are right. You have learned that heavy oils have more high-heat (Btu's) value per gallon. Heavy oils are heavier than lighter oils because they contain more carbon. The heavier an oil is, the more heat value it will have by volume.

However, lighter oils have more heat value per pound or per ton. Light oils have more high-heat value (Btu's) per pound because they contain more hydrogen than heavy oils. Hydrogen has more high-heat value than carbon.

By weight, light oils have more high-heat value than heavy oils, but by volume (gallon, barrel, etc.) ______________.

A. the high-heat value (Btu's) of the various weights is the same. — 76
B. heavy oils have more high-heat value (Btu's) than light oils. — 77
C. light oils have more high-heat value (Btu's) than heavy oils. — 76

76

You are wrong.

Generally, the heavier an oil is the more high-heat value it will have by volume (gallon, barrel, etc.).

Read carefully and try again.

Press A → 75

77

You are correct.

Probably the most important property of a fuel is cleanliness. The fuel should not contain more than a trace of foreign substances. Impurities in fuel can cause difficulties in the fuel pump, the injector, valves and cylinder walls.

Water is a common impurity in fuel. It is undesirable because it may lead to ___(1)___ of the engine and ___(2)___ of components of the system.

A. (1) abnormal operation (2) corrosion — 79
B. (1) overheating (2) cooling } 78
C. (1) heat in the cylinder (2) overheating

78

You are wrong. Water is an objectionable impurity in fuel oil because it causes abnormal operation of the engine and corrosion in the fuel system.

Water will also cause the formation of rust, won't it?

Press A — 77

75

You have done extremely well. You are correct.

Water is an undesirable impurity in fuel oil because it may lead to abnormal operation of the engine and corrosion of the fuel handling system.

This is the end of the material on the CHARACTERISTICS AND REQUIREMENTS OF DIESEL FUEL.

If you want to review the last portion of this lesson again -- PRESS A —76

If you feel sure you know it well enough -- PRESS the REWIND button.

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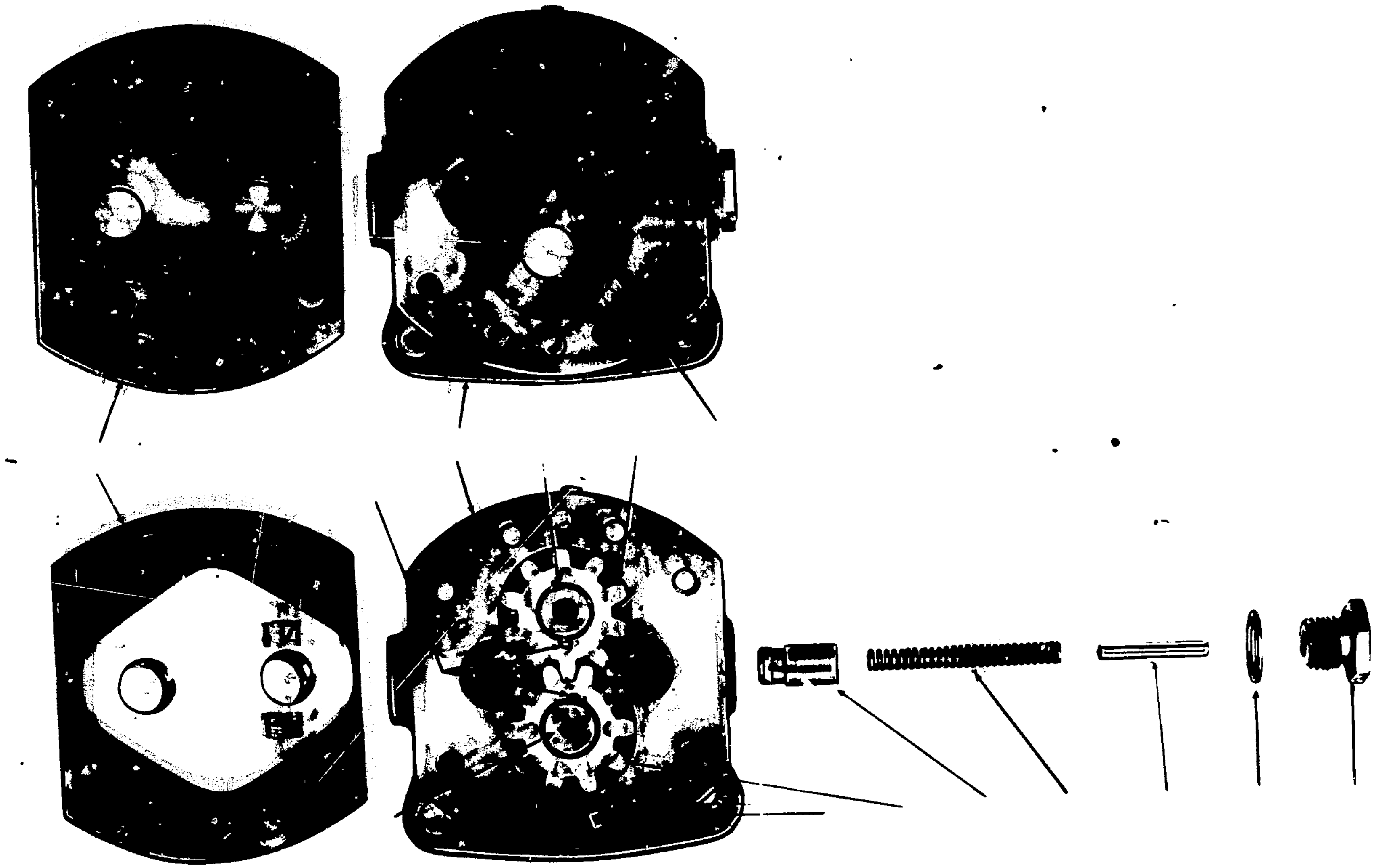

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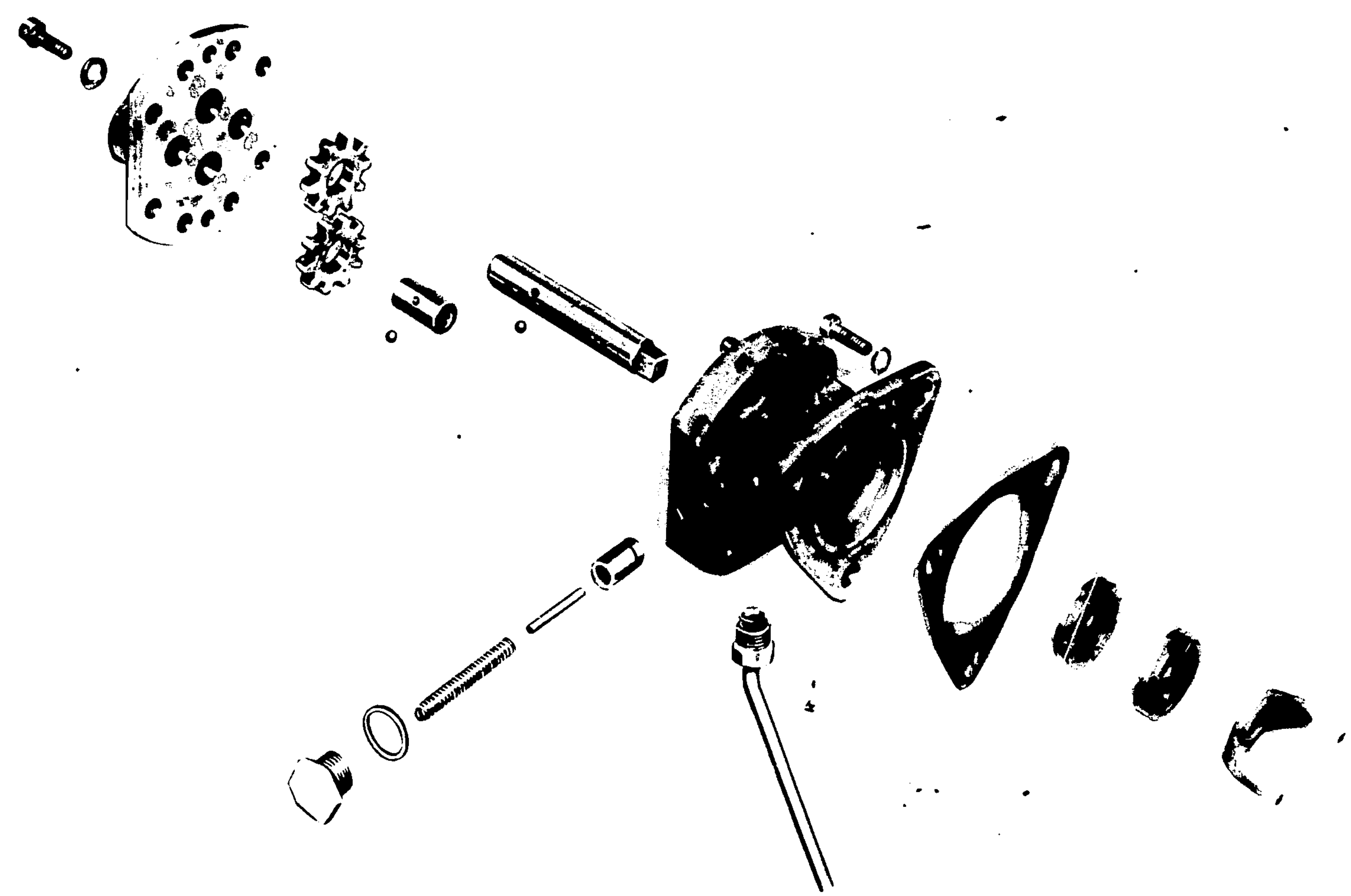

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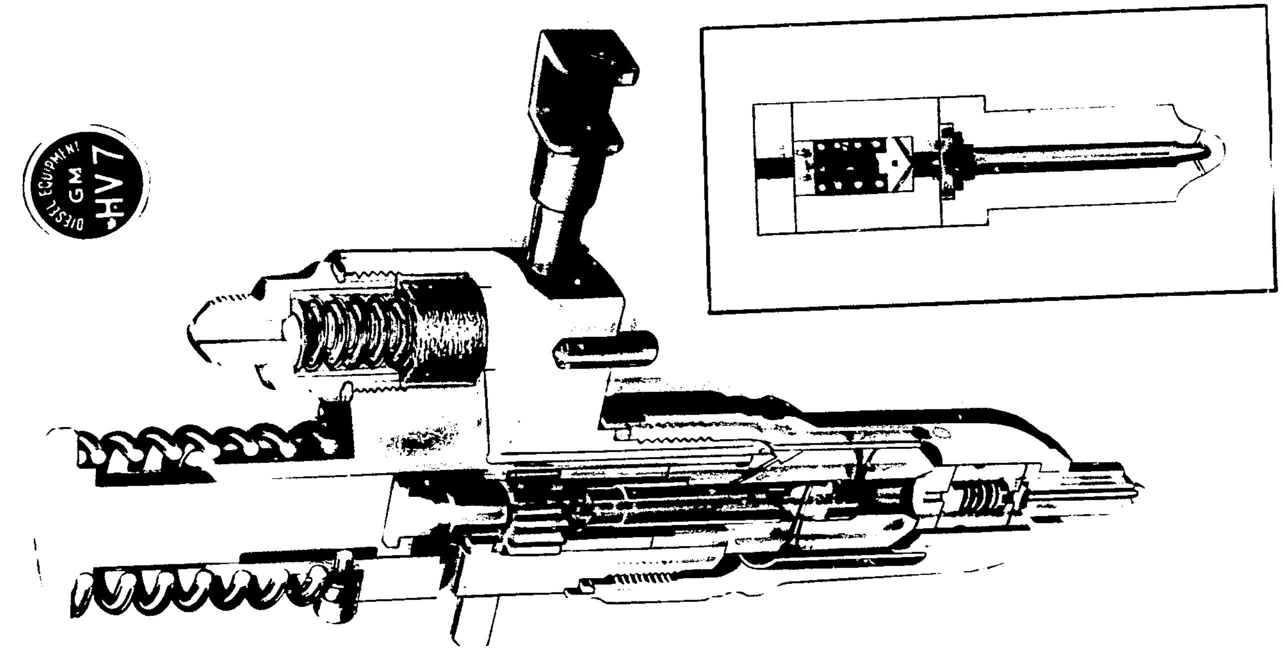
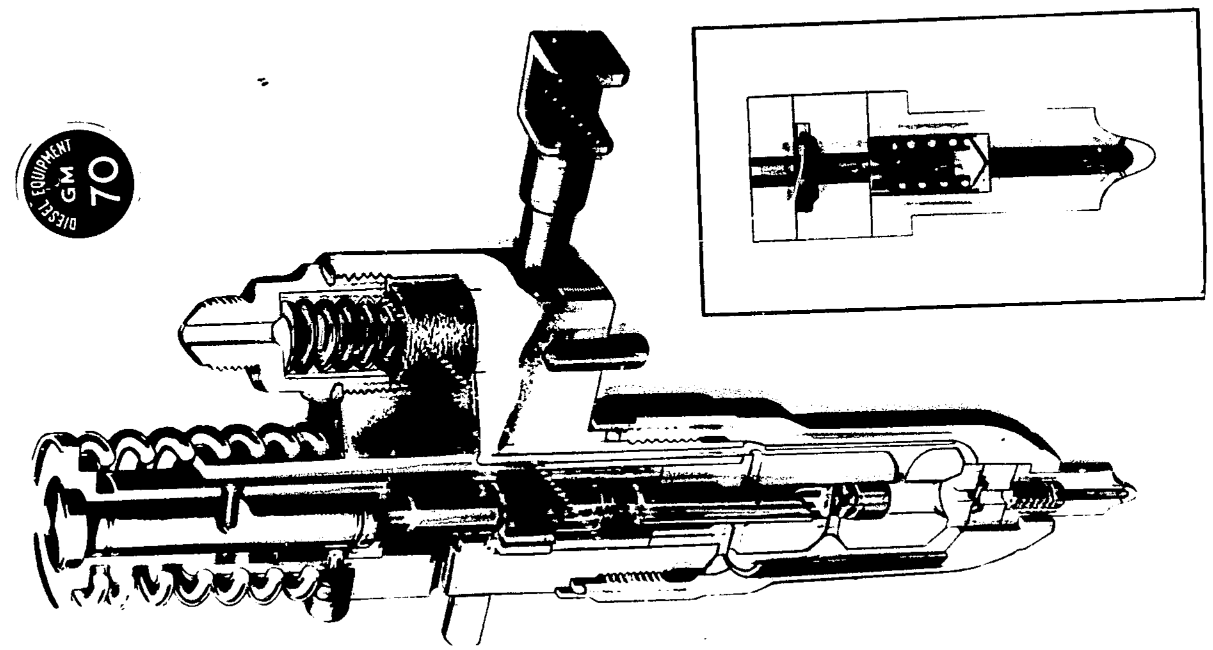
PTAM 1-3 ⑥





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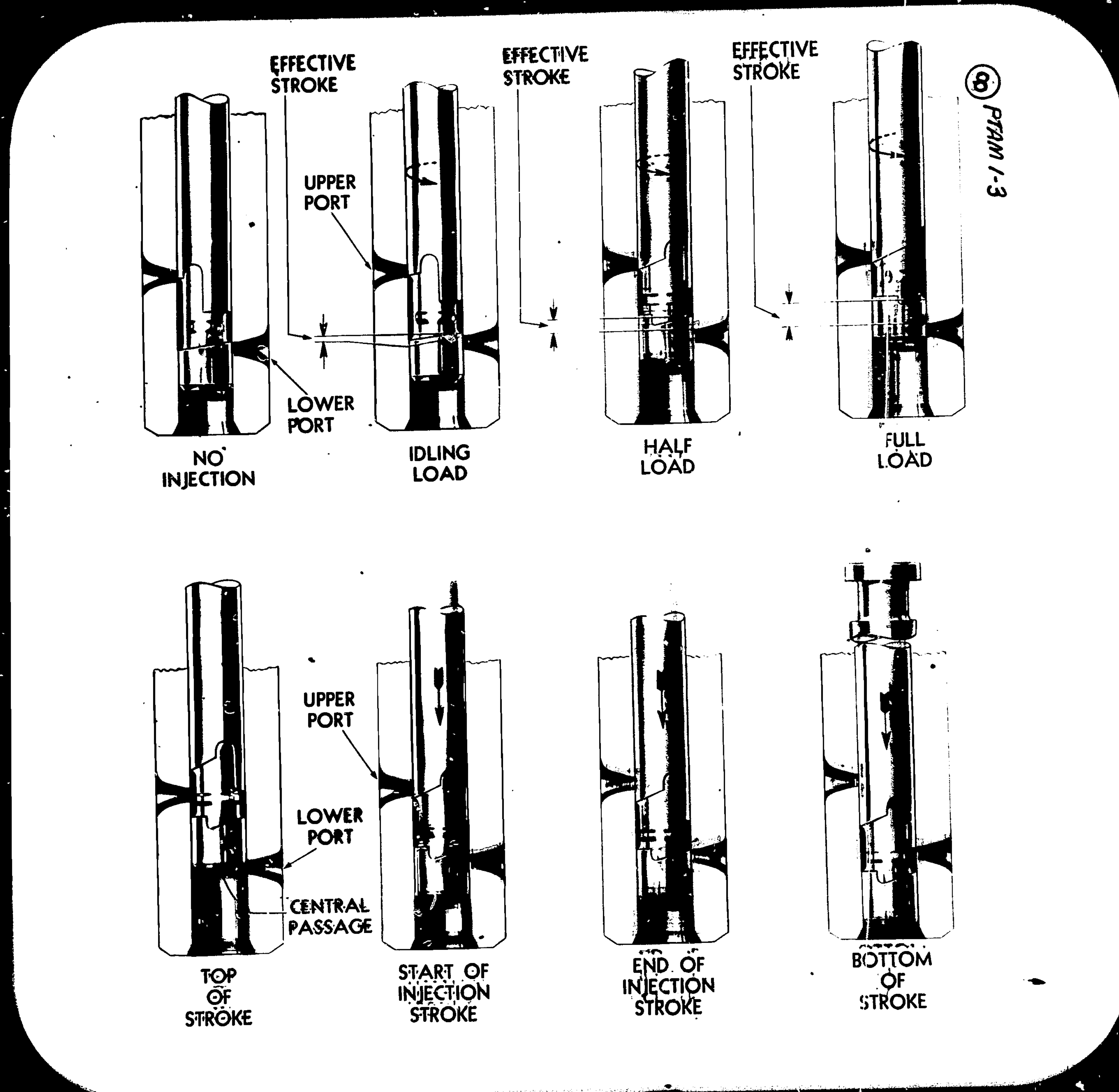

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INSTRUCTOR'S GUIDE

Title of Unit: Maintaining The Fuel System -- Detroit Diesel Engine

Code: PTAM 1-3

9/29/65

FIRST -- Be sure each student's questions on the previous tape have been answered.

OBJECTIVES -- By the end of class each student should understand:

The flow of fuel through the system.

The main components of the system and their function.

How an injector works and how it must be maintained and serviced.

How injectors are tested.

Various troubleshooting tips on the injection system.

How to inspect and maintain the fuel pump.

How to troubleshoot the fuel system.

How to care for the fuel strainers and filters.

How to inspect and maintain the fuel manifold.

TRAINING AIDS:

Charts -- Detroit Diesel - TA 301 (Show only fuel system)
TA 302

Visual aids - injectors, pumps, filters, etc., to be used to clarify verbal instruction. Testing apparatus to run tests on an injector in class.

Manuals - Both operators and maintenance for I-71 and V-71.

Vue Cells -
PTAM 1-1 (7) (Function of the fuel system)
PTAM 1-1 (8) (Fuel flow diagram)
PTAM 1-3 (1) (Primary fuel filter)
PTAM 1-3 (2) (Secondary fuel filter)
PTAM 1-3 (3) (Fuel Pump - Cutaway)
PTAM 1-3 (4) (Fuel Pump - End View)
PTAM 1-3 (5) (Fuel Pump assembly)
PTAM 1-3 (6) (Crown Value and High Value Injector)
PTAM 1-3 (7) (Valve assembly and Injector tip)
PTAM 1-3 (8) (Fuel metering)

QUESTIONS:

1. How is fuel drawn through the system?
2. What are the major components?
3. How do fuel injectors work?
4. How do we maintain fuel injectors?

Questions cont'd.

5. How do we time fuel injectors?
6. How do we check the injector rack and plunger movement? Why?
7. How do we check "POP PRESSURE"? Why?
8. How do we check holding pressure of the valve? Why?
9. How do we test the spray pattern? Why?
10. How do we check fuel output? Why?
11. How do we inspect:

    Injector timing?
    Injector spray tips?
    Injector plungers?

12. Where is the Fuel Pump located on the I-71 Series?
13. Where is the fuel pump located on the V-71 Series?
14. How does the fuel pump work?
15. What do you look for during inspection?
16. How do you check the fuel flow?
17. How do you locate air leaks in fuel lines?
18. How do fuel strainers and filters operate?
19. What goes wrong with them?
20. How does the fuel manifold operate?
21. How is it serviced?
22. What do you inspect the fuel connectors for?
23. Do you understand the working of the fuel system?