SECTION 11

FUEL SYSTEM

FUEL SYSTEM

DESCRIPTION

The engine fuel system, Fig. 11-1, consists of the fuel injector, the engine mounted fuel filter, and fuel supply and return manifolds.

Components external to the engine such as the motor driven fuel pump, fuel tank, fuel suction strainer, and connecting lines complete the fuel system.
In operation, fuel from the fuel tank is drawn up by the fuel pump through a suction strainer and is delivered to the engine mounted filter. It then passes through the filter elements to the fuel manifold supply line and injector inlet filter at each cylinder into the injector. A small portion of this fuel supplied to each injector is pumped into the cylinder, at a very high pressure, through the needle valve and spray tip of the injector.

The quantity of fuel injected depends upon the rotative position of the plunger as set by the injector rack and governor. The excess fuel not used by the injector, flows through the injector, serving to lubricate and cool the working parts.

The fuel leaves the injector through the return fuel filter. This filter protects the injector in the event of a backward flow of fuel into the injector from the return fuel line. From the return fuel filter in the injector, the excess fuel passes through the fuel return line in the manifold to the relief valve inlet of the "return fuel" sight glass on the engine mounted fuel filter. This valve restricts the return fuel, maintaining a back pressure on the injectors. The fuel continues into the "return fuel" sight glass, filling the glass, down through the standpipe under the glass and through the return line to the fuel supply tank

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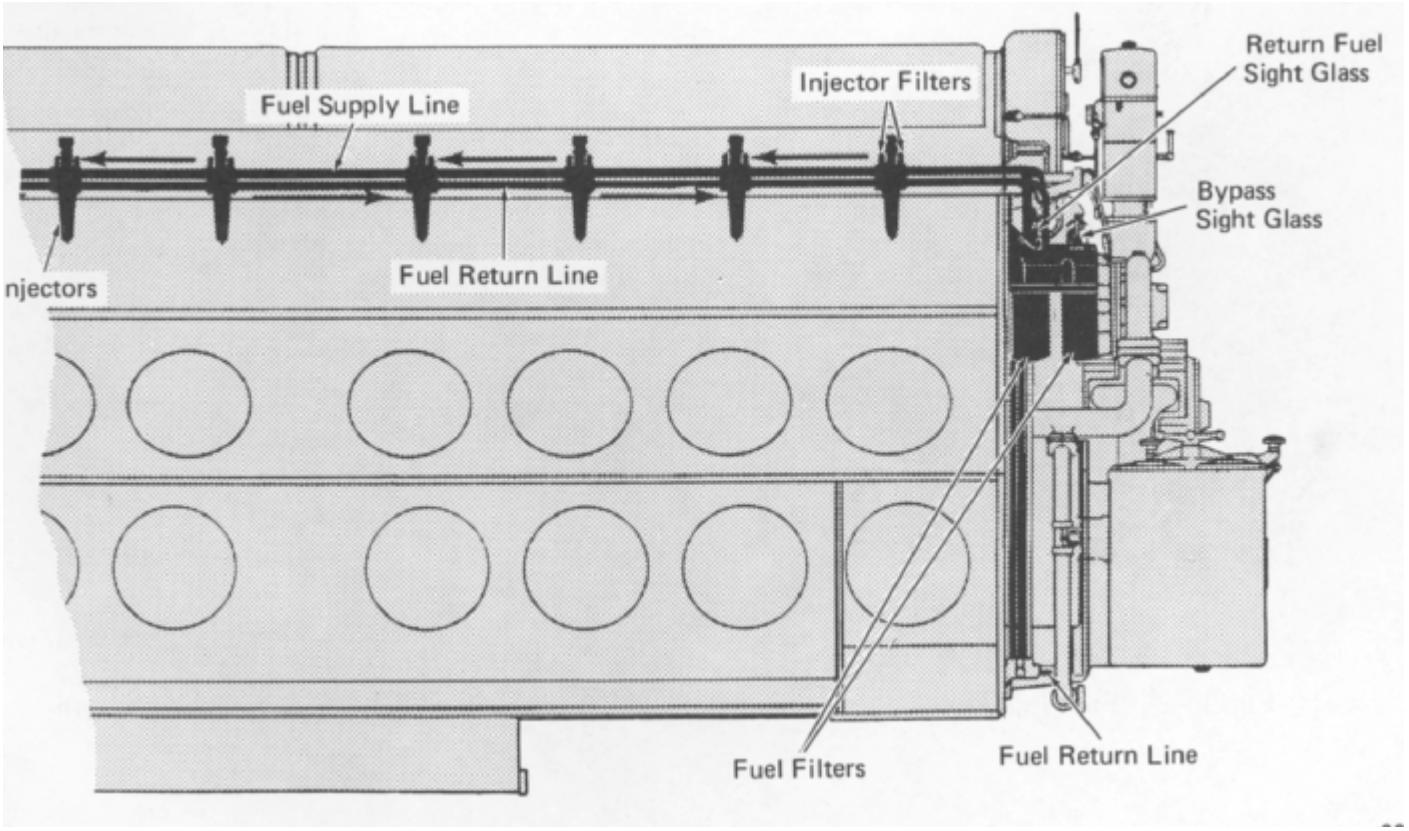

Fig. 11-1 - Typical Fuel System

FUEL INJECTORS

DESCRIPTION

An injector, Fig. 11-2, is located and seated in a tapered hole in the center of each cylinder head, with the spray tip protruding slightly below the bottom of the head. It is positioned in the head by a dowel and held in place by an injector crab and nut.

The external working parts of the injector are lubricated by oil from the end of the injector rocker arm adjusting screw. The internal working parts are lubricated and cooled by the flow of fuel oil through the injector.

A cross-section of the unit injector and names of the various parts are shown in Fig. 11-3.

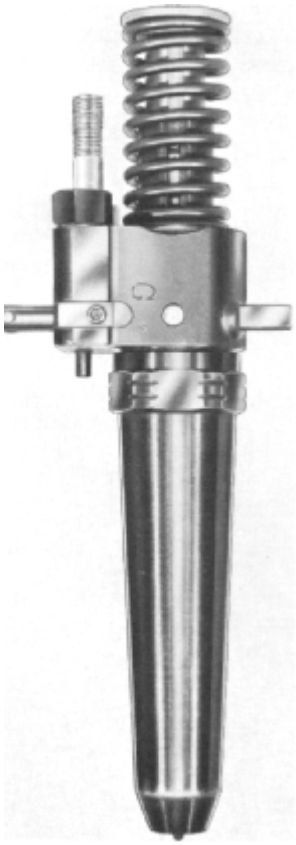

Fig. 11-2 - Fuel Injector

The plunger is given a constant stroke reciprocating motion by the injector cam acting through the rocker arm and plunger follower. The timing of the injection period during the plunger stroke is set by an adjusting screw at the end of the rocker arm. Fig. 11-4 shows flow of fuel through the injector during one downward stroke. Rotation of the plunger, by means of the rack and gear, controls the quantity of fuel injected into the cylinder during each stroke. Rack position is controlled by the governor through the injector control lever and linkage. The gear is keyed to and is a sliding fit on the plunger to allow plunger vertical movement.

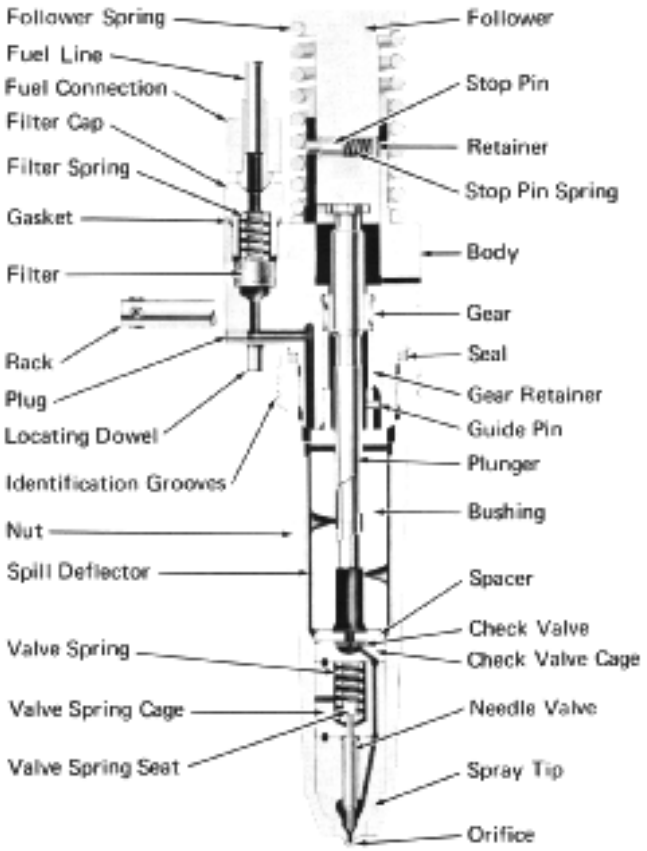

Fig. 11-3 - Fuel Injector, Cross-Section

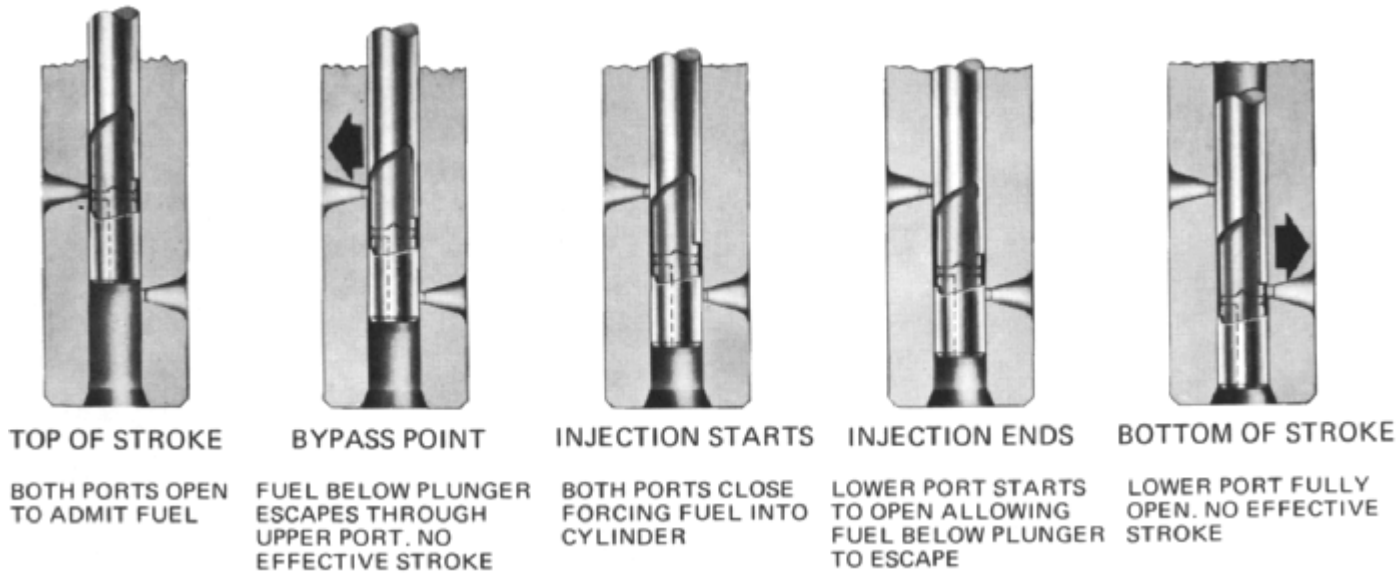

Fig. 11-4 -- Injector Fuel Flow

The helices near the bottom of the plunger control the opening and closing of both fuel ports of the plunger bushing. Rotation of the plunger regulates the time that both ports are closed during the downward stroke, thus controlling the quantity of fuel injected into the cylinder, as shown in Fig. 11-5. As the plunger is rotated from idling position to full load position, the pumping part of the stroke is lengthened, injection is started earlier, and more fuel is injected.
Proper atomization of the fuel is accomplished by the high pressure created during the downward stroke of the plunger, which forces fuel past the needle valve and out through the spray holes in the tip of the injector.

The injectors have an adjustable calibrating slide mounted on the side of the injector body, adjacent to the rack. This slide is incorporated solely as a means of adjusting injector output on the calibrating stand.

Filters at the fuel inlet and outlet connections protect the working parts of the injector.

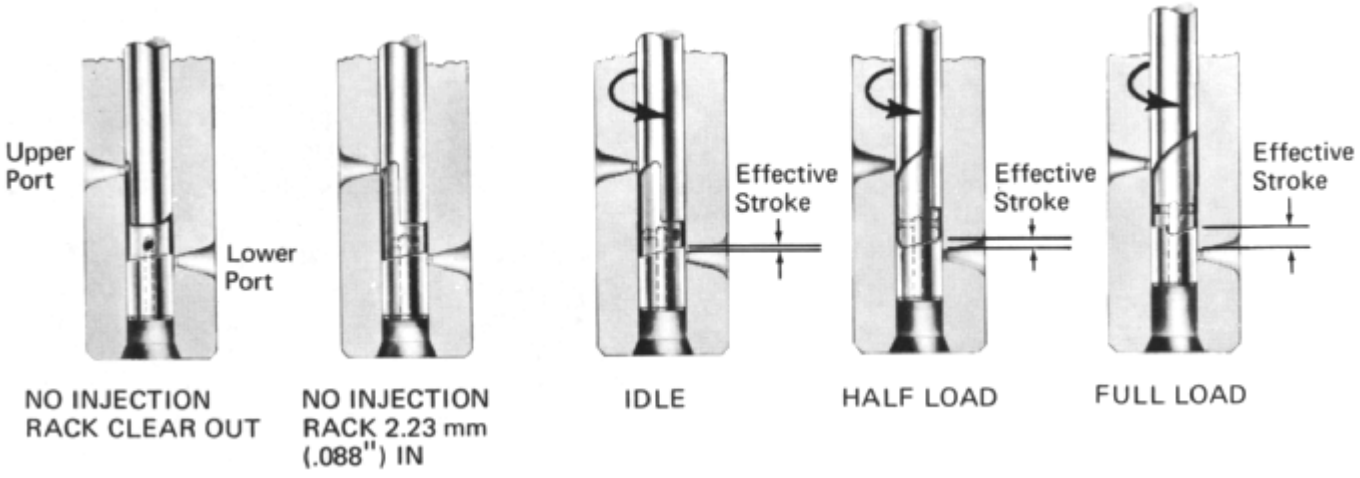

Fig. 11-5 -Plunger Fuel Control

MAINTENANCE

INSTALLATION

1. When installing an injector in an engine, make sure it is the correct injector for the engine in which it is to be applied.

2. See that injector body and tapered hole in cylinder head are clean.

3. Install injector and apply injector crab, spherical washer, and nut. Torque nut to 68 N·m (50 ft-lbs).

4. Connect injector rack to lever assembly.

5. Install and tighten fuel supply and return lines to injector and engine fuel manifold.

6. Install rocker arm shaft and rocker arms. Loosen injector rocker arm locknut and back off on adjusting screw before tightening rocker arm shaft nuts. Injector is now ready for timing.

TIMING THE INJECTOR

With the injector installed, make timing adjustment as follows:

NOTE: Injector cannot be timed if the overspeed has been tripped. It must first be reset and the engine crankshaft barred over at least one revolution.

1. Set the flywheel at 0° top dead center of the cylinder being timed.

2. Insert injector timing gauge into the hole provided for it in the injector body, Fig. 11-6.

3. Loosen locknut and turn the rocker arm adjusting screw until the shoulder of the gauge just passes over the injector follower guide.

4. Tighten adjusting screw locknut while holding adjusting screw in position with screwdriver.

5. Recheck setting.

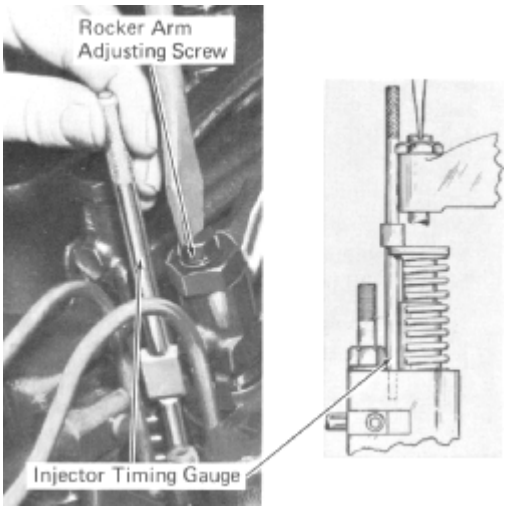

Fig. 11-6-Timing Injector

STICKING INJECTORS

Engines may encounter sticking injectors due to fuel, lube oil, or filter maintenance conditions. Since these conditions very often are momentary, injector removal may be minimized by utilizing alcohol to free up injectors while installed. This is done by applying. ordinary commercial methanol to the injectors through a hole opposite the timing tool hole, and "popping" the injectors or motoring the engine. This sticking condition usually occurs on injectors which are held with the plungers down when the engine is stopped. Should injector racks show signs of sticking, they should be checked for gum or varnish deposits. If present, the rack should be cleaned with alcohol and rechecked. If sticking persists, the injectors should be removed and replaced with operational injectors. In no case should injectors be it crutched out" or cut out and the engine operated. If injectors operating unsatisfactorily cannot be remedied or replaced, the engine should be shut down until corrective action has been taken.

SERVICING INJECTORS

When servicing injectors, clean working conditions must be maintained. Dust or dirt in any form is a frequent cause of injector failure. When an injector is in an engine it is protected against dirt, dust, and other foreign materials by the various filters employed. When an injector is in storage, it is protected against harmful material by the filters sealing the body openings, which are in turn protected by shipping blocks.

However, an entirely different set of conditions is encountered when it becomes necessary to disassemble an injector for repair or overhaul. These conditions necessitate special shops, equipment. and trained personnel. It is recommended that non-operational injectors be returned to Electro-Motive for rebuild or unit exchange.

INJECTOR TEST STAND

In order to ensure efficient engine performance, injectors should be tested whenever removed from an engine, regardless of the reason for removal. It is advisable to test the complete engine set during each annual inspection. It is recommended that injectors be tested with the same oil used for protection against rust as given under "Storing Injectors."

It is important that the individual doing the testing understands the basic principles of injector operation and testing procedures in order to prevent acceptance of defective injectors and rejection of good ones. Instructions in the use of the injector test stand and an outline of each separate test procedure along with a basic explanation of operation follows:

These instructions cover the testing of all needle valve injectors using the test stand shown in Fig. 11-7. The procedures are not applicable to other types of testing

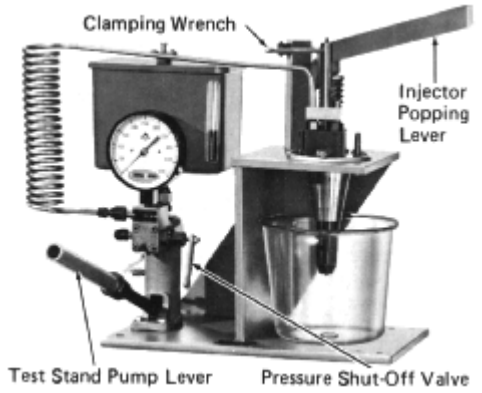

Fig. 11-7 - Injector Test Stand

equipment, since injector leak-off rates vary greatly in proportion to the volume of fuel contained in the high pressure portion of the test stand.

SETTING UP TEST STAND

Basically, the stand consists of a fuel reservoir, filter, high pressure pump, pressure gauge, and necessary connecting lines and fittings to supply fuel to the injector under test. The test stand should be set up as instructed by the manufacturer. Inspect carefully for dirt or foreign material in the tank and lines. Fill the tank with clean fuel and operate the pump to purge all free air from the system.

Investigation has shown that the viscosity of the fuel oil used in the test stand has a marked effect on the test results obtained. Regular fuel oil may be used provided the viscosity is not less than 32 S.S.U. at 38° C (100° F). Do not reuse fuel oil which has been pumped through the injectors into the plastic bowl.

CHECKING TEST STAND

Install the test block in place of an injector in the stand and pump up pressure to 13 790 kPa (2000 psi), as indicated by the gauge. After five minutes, the pressure should not have dropped below 13 618 kPa (1975 psi). Release the block and recheck at 3448 kPa (500 psi) and 6895 kPa (1000 psi). These pressures should hold one minute with no apparent gauge drop. Make these tests with the pressure shutoff valve, Fig. 11-7, open all the way. If the tests are satisfactory, all injector tests may be made without using the shutoff valve. If the preceding tests indicate leakage in the stand, repeat the tests, closing the shutoff valve before timing the leakoff rates. If the tests are satisfactory with the shutoff valve closed, it will be necessary to use the shutoff valve when making the injector holding pressure test.

When placing a new test stand in operation, or after removing and replacing the gauge, fuel tank, filter, or pump, for any reason, the test block should be installed and pressure raised to 17 237 kPa (2500 psi) and vented at least six times before making an operational check.

TEST STAND OPERATION

The operator must consider the test stand as an instrument, rather than a tool. Every effort should be made to make the manual operation of repeated tests the same. The following general information is provided to help in obtaining uniform operation:

GENERAL INFORMATION

1. When operating the pump, use a rate of 40 strokes per minute. This provides a fuel rate to operate the check valve smoothly and to circulate fuel within the injector.

2. When using the popping lever, do not use such force as to damage either the injector or the lever. Do not permit the lever to fly up freely.

3. In making holding tests, do not pump the stand above 17 238 kPa (2500 psi).

4. Test stands regularly in use should be checked daily for leaks, using the test blocks.

5. Fuel oil used for testing should not be reused.

INJECTOR TESTS

PREPARATION

1. Install the injector in the test stand.

2. Fill the injector with fuel oil, but do not connect the fuel line from pump to injector at this time.

3. Set the injector rack at maximum fuel output position (minimum rack length).

4. "Pop" the injector with the popping lever, Fig. 11-7, using approximately 40 smooth even strokes per minute. A finely atomized spray should show at each of the holes in the tip. Rapid closing of the needle valve should produce a sharp "chatter."

   If the valve opens without producing a finely atomized spray or the valve seats without producing a sharp "chatter," make several rapid strokes with the lever to dislodge any foreign material on the valve seat. If the needle valve still fails to function properly, a stuck needle, dirt on the valve seat, or a defective valve seat may be the cause.

HOLDING PRESSURE AND LEAK TEST

1. All injectors lose pressure due to leakage at any of several points, but this leakage must be controlled during injector manufacture to prevent engine lube oil dilution. The holding pressure test will qualify injectors having specified leakoff rates, providing this leakage is at the proper point and is satisfactorily controlled.

2. Manually hold the test stand fuel line block on the injector. Pump until fuel is discharged from filter cap on opposite side, to remove air. Apply 12 411 kPa (1800 psi) to 13 790 kPa (2000 psi) pressure to the injector. No leakage is permitted at the nut to body seal, filter cap gasket, body plugs, or between spray tip and injector nut.

3. Injectors should be qualified on the pressure holding test by timing the interval for a drop in pressure from 13 790 kPa (2000 psi) to 10 342 kPa (1500 psi). If this interval is less than 20 seconds (used) or 30 seconds (new or reconditioned), repeat the test, but close the pressure shutoff valve on the test stand immediately after establishing the 13 790 kPa (2000 psi) pressure. This is to ensure that the leakdown time is not being affected by the possible leakage in the test stand itself. If the timed interval for the pressure drop from 13 790 kPa (2000 psi) to 10 342 kPa (1500 psi) is still less than 20 seconds (used) or 30 seconds (new or reconditioned), the injector should be rejected. To relieve the pressure before removing the injector from the test stand, wrap a cloth around the injector fuel line connections and back off on the clamping wrench, Fig. 11-7.

RACK FREENESS TEST

1. The rack engages with a small pinion on the injector plunger and serves to rotate the plunger with respect to two ports in the injector bushing, which regulates the amount of fuel injected with each stroke of the plunger. Binding of the rack is generally caused by damaged gear teeth, scored plunger and bushing, or galling of rack itself. A binding rack may cause sluggish or erratic speed changes and overspeed trip action.

2. To be considered satisfactory, the rack must fall in and out through full travel by its own weight when injector is held horizontally and rotated about its axis.

BINDING PLUNGER TEST

1. Failure of the injector plunger to move up and down freely indicates scoring of the plunger and bushing or

weak or broken spring. A binding plunger will cause erratic cylinder firing and, in extreme cases, overspeed trip action.

2. Place injector in test stand but do not attach the fuel line. Place rack in the full fuel position and pump all the fuel out of the injector with injector popping lever, Fig. 11-7. When all of the fuel has been removed, depress the injector plunger to full extent of its travel. Slowly release popping lever and simultaneously move injector rack repeatedly in and out through its full travel.

REPLACING INJECTOR FILTERS

Injector filters should not be disturbed or removed except during injector reconditioning (when all parts are completely washed), or in the event of fuel stoppage to the injector.

STORING INJECTORS

When injectors are not to be used for a considerable length of time, they should be protected against rust by using a stable, noncorrosive straight-run petroleum distillate in the kerosene volatility range. It is also recommended that injectors be tested using this oil. If this is done, treatment will be taken care of at time of injector test.

After treatment, the injectors should be stored in a protective container until needed. This container should accommodate an injector holding rack similar to that shown in Fig. 11-8.

Fig. 11-8 - Injector Holding Rack

INJECTOR LINKAGE

DESCRIPTION

The injector linkage, Fig. 11-9, consists of the mechanical arrangement between the governor and the injector permitting all injector rack positions to be changed simultaneously when the governor terminal shaft is rotated. Two injector control rods connect the lever on the governor terminal shaft to the injector control shafts. The injector control shafts, one for each bank, extend the length of the cylinder banks under the cylinder head cover frames. At each cylinder location, a lever is pinned to the control shaft. An adjusting link connects the control shaft lever to an injector control lever mounted on the cylinder head, one end of which straddles the ball at the end of the injector rack.

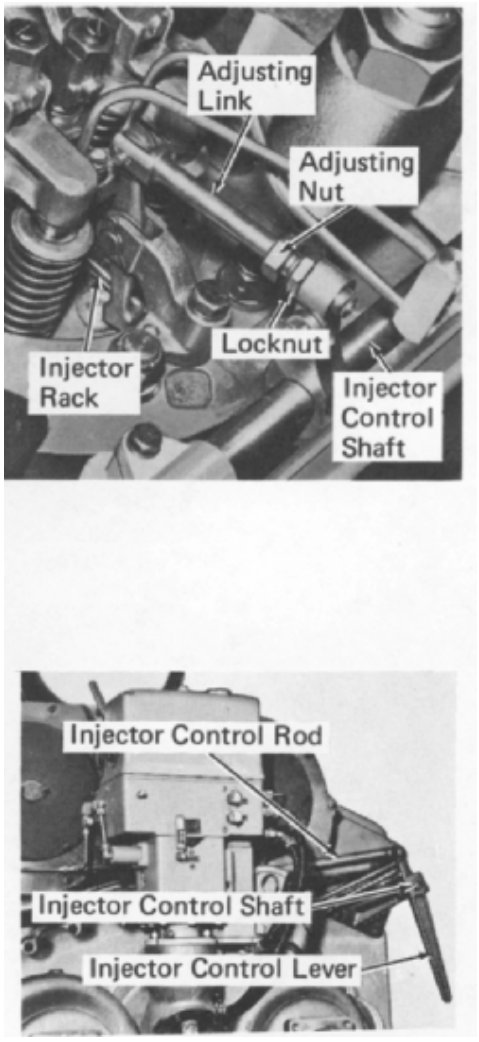

Fig. 11-9 - Injector Linkage

MAINTENANCE

Before attempting to set injector racks, all racks and linkage should be checked for binding, sticking, or wear which would affect operation.

SETTING INJECTOR RACKS

Injector racks should be set with the engine at operating temperature. If racks are set when engine

is not at operating temperature, the settings should be rechecked when operating temperature is reached. As engine temperature increases, the right bank rack length shortens and the left bank rack length increases. The change on the left bank is insignificant, but the change on right bank may shorten the racks beyond the minus 0.40 mm (1/64") tolerance.

NOTE: Every time a governor is installed on an engine the injector rack setting should be checked. Due to manufacturing tolerances in governor mounting bolt holes, the position of the governor in relation to the injector linkage can change the rack setting.

Set the injector rack on the engine as follows:

1. Install the injector linkage setting jack, Fig. 11-10.

Fig. 1 I-10 - Injector Rack Positioning

2. Adjust the setting jack until the pointer on the governor aligns with governor terminal shaft scale at the 1.00" mark.

3. Use the injector rack gauge, Fig. 11-11, to set the racks within the setting range marks on the gauge.

   The rack setting gauge is an 8 to 1 multiplying gauge which indicates the 0.40 mm (1/64") tolerance by marks 3.18 mm (1/8") each side of the center mark on the gauge scale.

   It is important that the proper rack gauge be used, as previous model rack gauges will measure the rack length from the body of the injector instead of from the face of the calibrating slide. The correct gauge for setting injectors with calibrating slides can be readily identified by a single locating button on the front face of the gauge. This gauge can be used for all injectors.

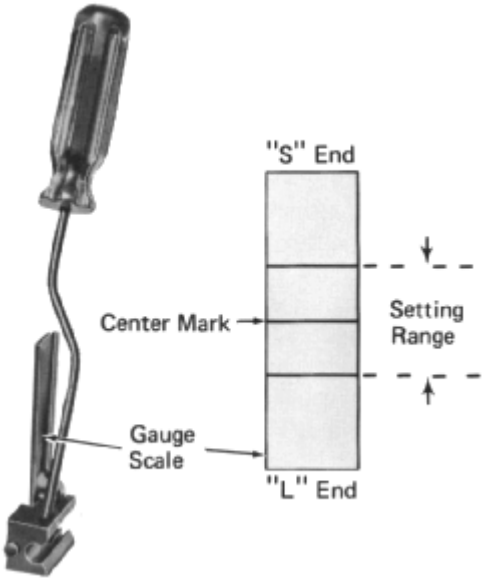

Fig. 11-11 - Injector Rack Gauge

4. Place the gauge over the injector rack and hold the gauge firmly against the face of calibrating slide on the injector, Fig. 11-12, and check the gauge pointer. If the pointer is at the short ("S") end of gauge scale, outside of the setting range, the rack is not extending out far enough from the injector. Loosen the locknut on the adjusting link, Fig. 11-9, and turn adjusting nut on link until pointer is at the long ("L") end of the scale; then reverse pointer travel until it is within the scale setting range. Hold the adjusting nut and tighten locknut. The reason for exceeding the setting range when making adjustment is so that, in setting all the racks, the backlash will be taken up in the same direction.

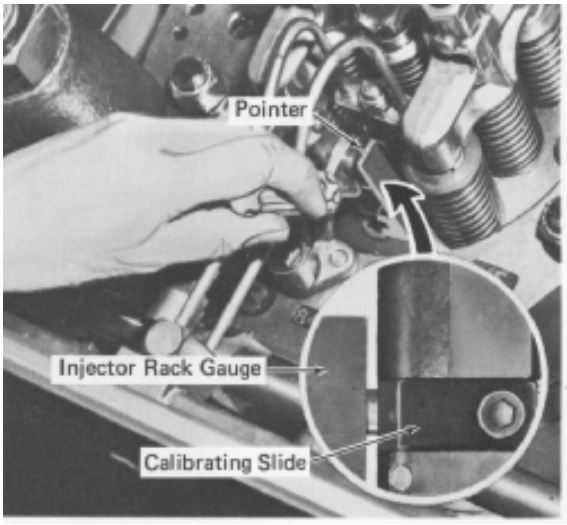

Fig. 11-12 - Injector Rack Gauge Application

5. When pointer is at the long ("L") end of scale, set pointer within the setting range. The accuracy of the injector rack gauge can be checked by inserting the master block in the gauge body. Pointer should align with center mark on scale.

FUEL FILTER

DESCRIPTION

The engine mounted fuel filter, Fig. 11-13, is located at the right front of the engine. Two sight glasses are provided on top of the filter housing to provide a visual indication of the condition of the fuel system. The flow diagram, Fig. 11-14, indicates fuel flow through the filter.

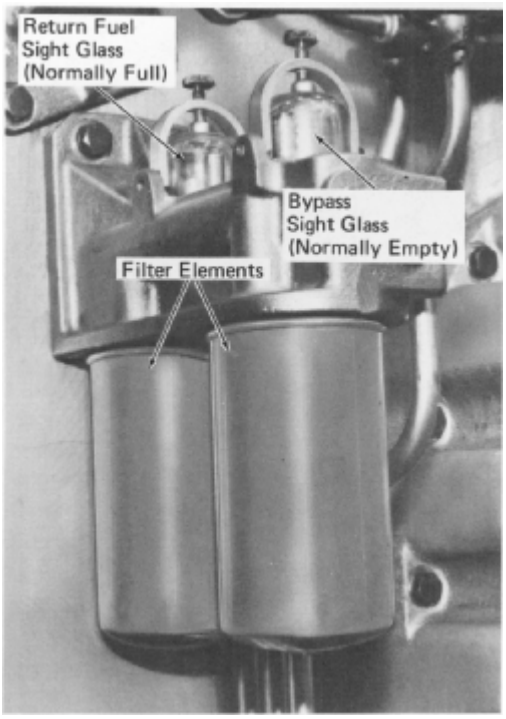

Fig. 11-13 - Fuel Filter

Fuel returning from the injectors passes through the "return fuel" sight glass nearer the engine and returns to the fuel tank. Under normal operation this glass is full of fuel. A 69 kPa (10 psi) relief valve at the inlet to the "return fuel" sight glass establishes a fuel back pressure at the injectors for improved operation.

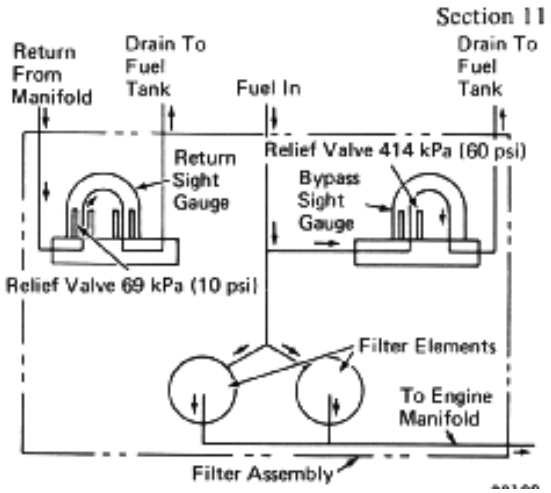

Fig. 1 1-14 - Fuel Flow Through Filter

Air or gas in the fuel system will appear in the 'return fuel" sight glass as bubbles. Air entering the fuel at any place in the suction line may cause the engine to misfire or stop. Bubbles in the "return fuel" sight glass with the fuel pump running and the engine stopped, indicates air entering the suction side of the fuel pump. If bubbles appear only when the engine is running, it indicates leaky valves in the fuel injectors, allowing combustion gases to get into the fuel. Little or no fuel in the "return fuel" sight glass, with the "bypass" sight glass empty, indicates insufficient fuel supply to the engine.

Under normal operation the "bypass" sight glass farther from the engine should be empty of fuel. As the elements of the filter become dirty, the fuel pressure in the filter will increase. When fuel pressure in the element housing is approximately 414 kPa (60 psi), the relief valve under the glass will open, fuel will enter and fill the "bypass" sight glass, and then return to the fuel tank, starving the engine.

The disposable filter elements are mounted directly to the filter body. The element consists of pleated paper around a perforated metal tube. The case is an enameled steel shell capable of withstanding internal pressures in excess of 1 034 kPa (150 psi). A neoprene gasket attached to the top of each element ensures sealing.

MAINTENANCE

The filter elements should be removed and new ones installed at intervals specified in the Scheduled Maintenance Program.

At the time of element replacement, the filter body and sight glasses should be cleaned.

1. Shut down the engine and the engine fuel supply.

2. Unscrew the elements, using a strap wrench if necessary, and discard them.

3. Apply a firm of oil to the gasket of a new element and apply element to filter body.

4. Hand tighten until the gasket contacts the filter body, then tighten 1/2 turn.

5. Check the condition of the sight glasses, and clean.

6. Check for leaks when the engine is started.

SERVICE DATA
FUEL SYSTEM

EQUIPMENT LIST

	Part No.
Injector timing gauge	8034638
Injector prybar	8041183
Plastic spray cup (extra - used with Injector Test Stand)	8171780
Oil (injector test, storage, and rust prevention - 50 gal. drum)	8203258
Injector rack gauge	8339610
Injector holding rack	8431626
Injector linkage setting jack	8432485
Injector test stand (complete)	8478027