SECTION X

FUEL SYSTEM

A. GENERAL DESCRIPTION

The most important part of the fuel system is the unit injector, which is a high pressure fuel metering pump and spray valve combined in one housing. The injectors (one per cylinder) are supplied with a continuous flow of low pressure fuel delivered by a separate pump. A fuel supply tank, strainers, filters, fuel manifold, supply and return fuel lines complete the system.

B. DESCRIPTION

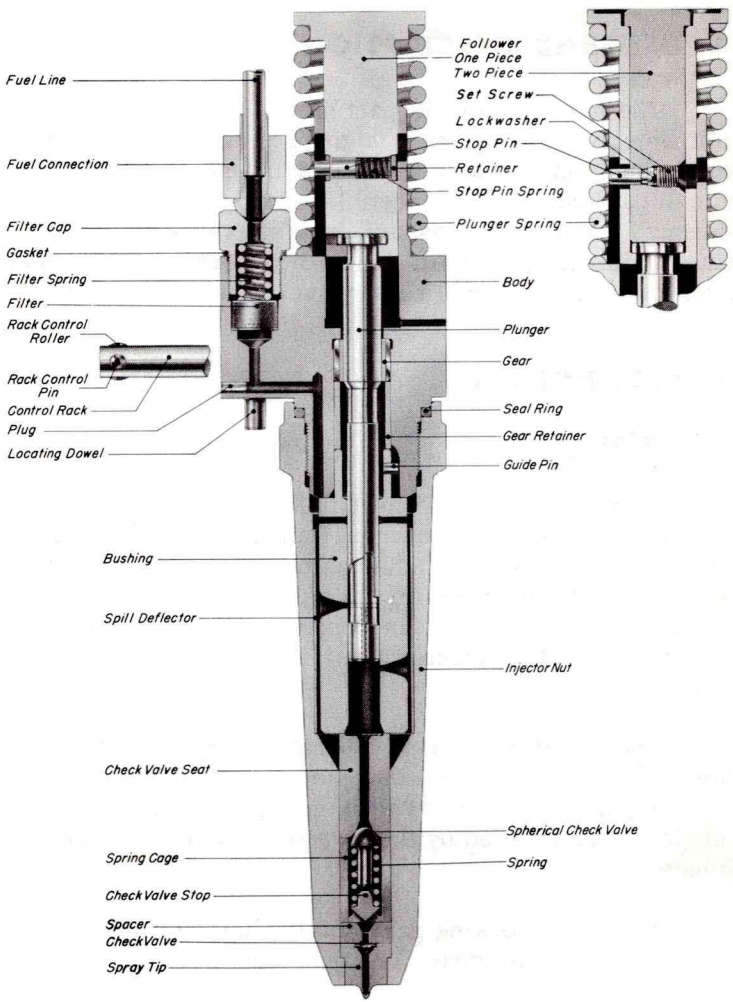
1. Injectors

A cross-section of the unit injector and names of the various parts is shown in Fig. 10-1. It is located and seated in a tapered hole in the center of the 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 hold down 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.

The main working parts of the injector are: rack, gear, plunger, follower, spring and spherical check valve.

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



Cross-Section of Unit Injector
Fig. 10-1

injection period during the plunger stroke is set by an adjusting screw at the end of rocker arm. Fig. 10-2 shows flow of fuel through injector during one downward stroke.

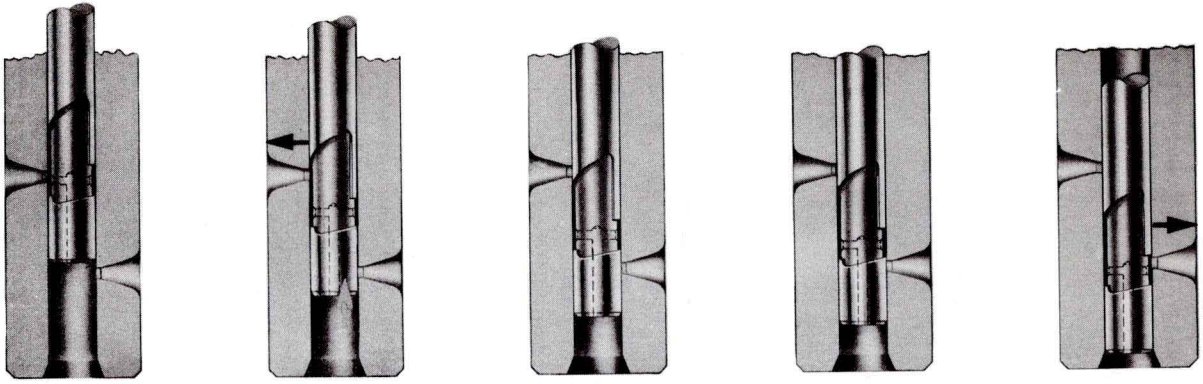
Rotation of the plunger by means of the rack and gear controls the quantity of fuel injected into the cylinder during each stroke. Rack position is controlled by the governor through the injector layshaft and linkage. The gear is keyed with a sliding fit to the plunger to allow plunger vertical movement. Injector rack setting adjustments are given in Section XII of this manual.

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. 10-3. 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 maintained by the high pressure created by the downward stroke of the plunger, which forces fuel past the spherical valve and out through the six spray holes in the tip of the injector. The spherical valve prevents fuel leakage out the tip. The flat check valve under the lower spacer excludes combustion gases from the injector.

The injector has filters at the fuel inlet and outlet connections to protect the working parts.

Two designs of fuel injectors are used in 567C engines, a high output injector 5228230 and a standard injector 5227852. The application of these injectors is given in Table B, Section XI, according to engine horsepower and full load injector rack length.



TOP OF STROKE
BOTH PORTS OPEN TO ADMIT FUEL

BY-PASS POINT
FUEL BELOW PLUNGER ESCAPES THROUGH UPPER PORT. NO EFFECTIVE STROKE

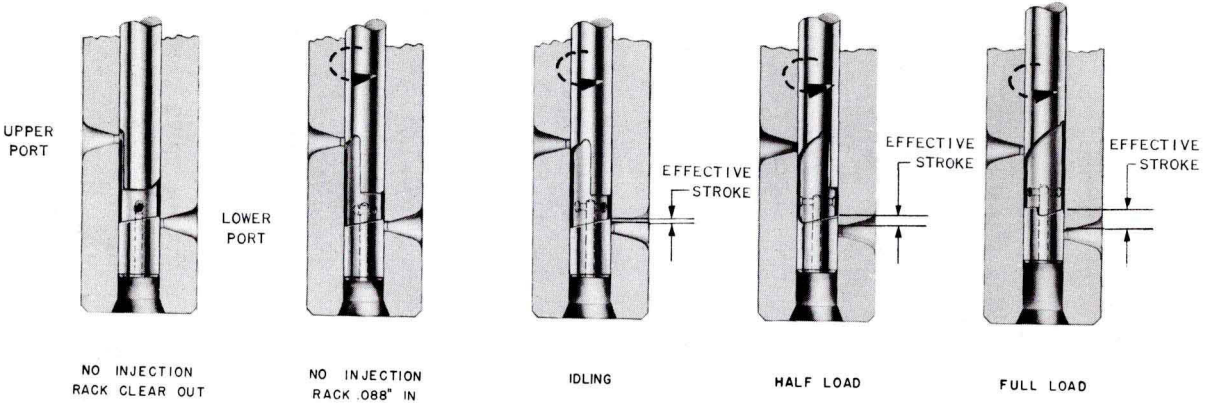
INJECTION STARTS
BOTH PORTS CLOSE FORCING FUEL INTO CYLINDER

INJECTION ENDS
LOWER PORT STARTS TO OPEN ALLOWING FUEL BELOW PLUNGER TO ESCAPE

BOTTOM OF STROKE
LOWER PORT FULLY OPEN. NO EFFECTIVE STROKE

ONE COMPLETE DOWN STROKE OF PLUNGER AT "HALF LOAD" POSITION

Pumping Action Of Injector Plunger
Fig. 10-2



Quanity of Fuel Injected Is Controlled by Rotating Plunger with Control Rack

Fuel Control By Plunger Rotation
Fig. 10-3

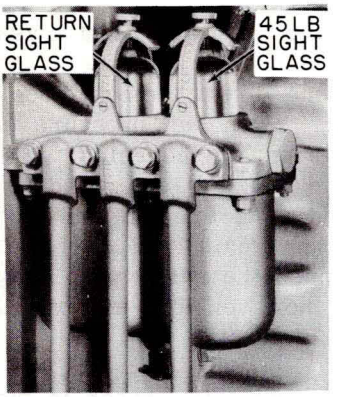
Injector 5228230 is similar to the .421" diameter plunger injector 5227852, but plunger helices are changed to give a greater effective fuel injection stroke. Externally the high output injector can be identified, in addition to its part number, by a vertical groove in the body, opposite the injector rack. Also, the locating dowels, used when installing the injectors in the cylinder head, differ in position. The locating dowel of injector 5227852 is on the body centerline, to line up with a corresponding hole in the cylinder head, but the locating dowel in injector 5228230 is positioned further out and to the left of the centerline to correspond with its locating hole in the cylinder head. Internally, the plunger bushing has a larger upper dowel to prevent installation in a 5227852 injector body, and its plunger can be identified by the number "7" stamped on it.

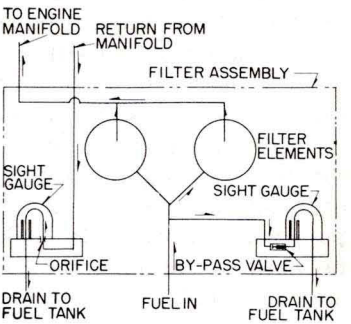
2. Filters

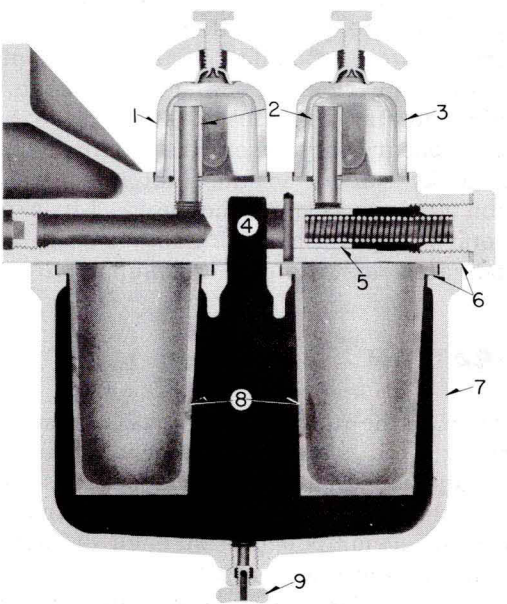
The only fuel filter mounted on the engine is the sintered bronze filter, shown in Fig. 10-4. However, other filters, not a part of the engine, are used in the fuel system, which vary in design, depending on the engine installation. See the Service Publications Index for the maintenance instruction of the particular filter used.

The engine mounted fuel filter is located at the right front of the engine. Sight glasses are provided on top of the filter housing to allow a visual indication of the condition of the fuel system.

Fuel returning from the injectors passes through the "return fuel" sight glass nearest the engine and returns to the fuel tank. Under normal operation this glass is full of fuel. An orifice inlet to the return sight glass causes a fuel back pressure on the injectors of about 5 pounds per square inch, to improve operation. An additional orifice is used in the return sight glass standpipe of this filter used on 8 and 12 cylinder engines.







1. Return sight glass-5 lb.
2. Stand pipe
3. By-pass sight glass
4. Fuel inlet passage
5. Relief valve
6. Gaskets
7. Case
8. Elements
9. Drain

Sintered Bronze Fuel Filter
Fig. 10-4

Under normal operation the "by-pass" sight glass furthest 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 exceeds 45 p.s.i., the relief valve in the filter will be opened and fuel will enter and fill the by-pass sight glass, returning to the fuel tank and starving the engine of fuel. A small trickle of fuel purposely allowed to leak around the relief valve may be noticed entering the glass, however, this is normal and does not indicate clogged elements.

Air or gas in the fuel system will appear in the "return" sight glass as bubbles. Air entering the fuel at any place in the suction line may cause the engine to mis-fire or stop. Bubbles in the return 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 sight glass with the by-pass sight glass empty indicates insufficient fuel supply to the engine.

C. OPERATION

Fuel from the fuel tank sump is drawn by the fuel pump through the suction strainer and discharges the fuel to the discharge filters. It then passes through the elements to the fuel manifold supply line from where it flows through a jumper line at each cylinder into the injector through the injector inlet filter. A small portion of this supply fuel to each injector is pumped into the cylinder, at a very high pressure, through the spherical check valve and spray tip of the injector. The quantity of fuel depends upon the rotative position of the plunger as set by the 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 then leaves the injector through the return fuel filter. This filter is to protect 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 returns through the fuel return line in the manifold to the orifice inlet of the return sight glass. This orifice restricts the return fuel to the extent of maintaining a back pressure of approximately 5 pounds. The fuel continues into the return sight glass filling the glass and down through the standpipe under the glass through return line to the fuel supply tank.

D. MAINTENANCE

1. Injectors

a. Installation

When installing an injector in an engine, make sure it is the correct one for the specific application, per identification given under "Description" in this section.

Install as follows:

(1) See that injector body and tapered hole in cylinder head are clean.

(2) Install injector and apply injector hold down crab, spherical washer and nut. Torque nut to 40-50 foot-pounds.

(3) Connect injector rack to adjusting micro-linkage.

(4) Install and tighten fuel supply and return lines to injector and engine fuel manifold.

(5) Install rocker arm shaft and rocker arms. Loosen injector rocker arm lock nut and back off on adjusting screw before tightening rocker arm shaft nuts. Injector is now ready for timing.

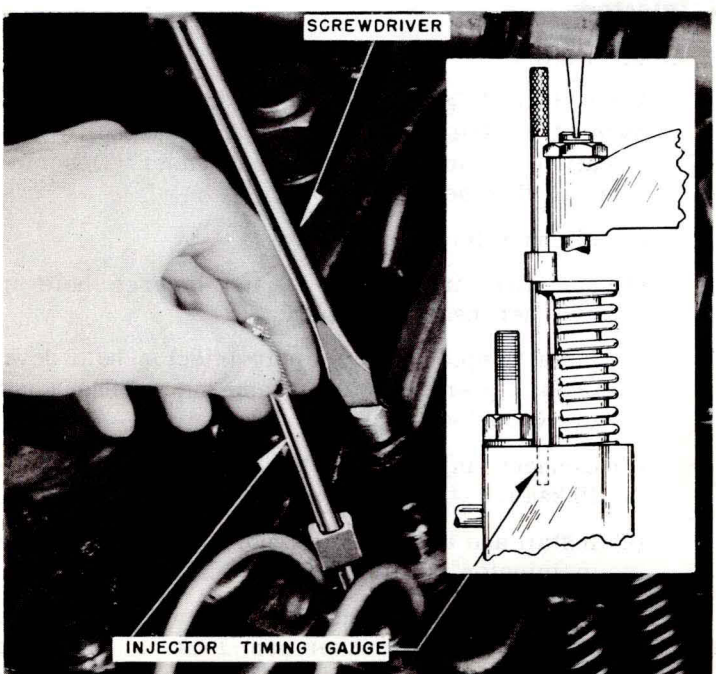
b. Timing

With the injector installed, make timing adjustment as follows:

(1) Set the flywheel at 4° before top dead center of the cylinder being timed. (See Section VI for firing order.)

(2) Insert gauge 8034638 into the hole provided for it in the injector body, Fig. 10-5.

(3) Turn the rocker arm adjusting screw until the shoulder of the gauge just passes over the injector follower guide.



Timing Injector
Fig. 10-5

NOTE: Injector rocker arms must be released by rotating the crankshaft at least one revolution after re-setting the overspeed trip, in the event it has tripped, before timing the injectors.

(4) Tighten adjusting screw locknut, holding adjusting screw in position with a screwdriver.

(5) Recheck setting.

c. Injector Sticking

Engines may encounter injector sticking difficulties 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 in place. Ordinary commercial methanol can be applied to the injectors through a hole opposite the timing tool hole, and "popping" the injector 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 they are present, the rack should be cleaned with alcohol and rechecked. If after these remedies, sticking persists, the injectors should be removed and replaced with injectors in proper working order. In no case should injectors be 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 measures to overcome the trouble have been carried out.

d. Servicing Injectors

When servicing the injectors, clean conditions must be maintained. Dust or dirt in any form is the most common 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 which seal the body openings, these in turn are 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 provision of special shops, equipment and trained personnel. These items are expensive, and in most cases the customer would not be warranted in the expense. Electro-Motive maintains this service for our customers and recommends the injector be returned to the nearest factory branch for rebuild or unit exchange. For particulars on this service see Factory Rebuild Bulletin No. 302.

2. Use of Injector Test Stand

In order to insure satisfactory engine performance, injectors should be tested whenever removed from an engine regardless of the reason for removal. In addition, it would be well to set up a program for testing all injectors in an engine during each annual inspection in order to insure qualifications of injectors in complete engine sets. It is recommended that injectors be tested with the same oil as used for their rust prevention, given under "Storing Injectors."

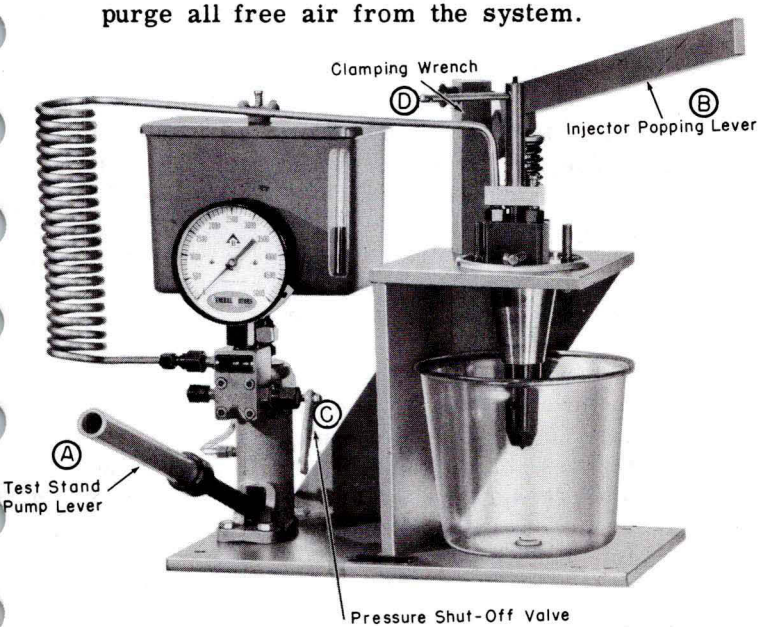
It is important that the individual doing the testing understands the basic principals of injector operation and testing procedures in order to prevent qualification of defective injectors and condemning of good ones. Instructions in the use of the injector test stand and an outline of each separate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

These instructions cover the testing of all 567 injectors through use of test stand part 8202944, Fig.

10-6, or revised test stand 8171779, but are not applicable to other types of testing 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.

a. Testing of Injector 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. On placing the test stand in operation, it 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 fuel and operate the pump to purge all free air from the system.



A. Test Stand Pump Lever C. Pressure Shut-Off Valve
B. Injector Popping Lever D. Clamping Wrench

Injector Testing Stand
Fig. 10-6

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 100° F. Do not re-use fuel oil pumped through injectors into the plastic bowl.

(1) Test the stand for leaks

Install the test block in place of an injector on the stand and pump the pressure to 2000 pounds, as indicated by the stand gauge. This pressure should not drop below 1975 pounds in 5 minutes. Release the block and recheck at 500 and 1000 p.s.i. These pressures should hold 1 minute with no apparent gauge drop. These tests are to be made with the pressure shut-off valve (Fig. 10-6, Item C) open all the way. If the tests are satisfactory, all injector tests may be made without using the shut-off valve. If the preceding tests indicate leakage in the stand, repeat the tests, closing the shut-off valve before timing the leakoff rates. If the tests are satisfactory with the shut-off valve closed, it will be necessary to use the shut-off 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 as outlined and pressure raised to 2500 p.s.i. and vented at least six times before testing the stand for leaks.)

b. Operation of Injector Test Stand

In using the test stand, the operator must consider it as an instrument, rather than a tool. Effort should be made to make the manual oper-

ation of repeated tests the same. The following general procedures are listed to help in obtaining uniform operation:

(1) When operating the pump, use a rate of 60 strokes per minute. This gives enough fuel rate to operate the check valve smoothly and 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 2500 p.s.i.

(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 re-used.

3. Injector Testing

a. Rack Freeness Test

(1) Explanation

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, thus regulating the amount of fuel injected per stroke of the plunger. Binding of the rack is generally caused by damaged gear teeth, scored plunger and bushing, or galling of rack itself. In an engine, a binding rack may cause sluggish or erratic speed changes and overspeed trip action.

(2) Test

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.

b. Binding Plunger Test

(1) Explanation

Failure of the injector plunger to move up and down freely indicates scoring of the plunger and bushing or weak or broken spring. In an engine, a binding plunger will cause erratic cylinder firing and, in extreme cases, overspeed trip action.

(2) Test

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. 10-6, Item B. When all of the fuel has been exhausted, depress the injector plunger to the extent of its full travel and release popping lever. Plunger should return to the top of its stroke with a definite snap action. Repeat this test with the rack in the half fuel and no fuel positions. Care should be used in the test to prevent the plunger from snapping back so violently that the plunger stop pin becomes broken.

c. Spray Tip Orifice Test

(1) Explanation

The six small holes in the injector spray tip serve to control injection pressure, fuel penetration and fuel atomization. Plugging of one or more of the holes may change injection characteristics enough to cause a smoky exhaust and in extreme cases, the pressure buildup in the injector body might lead to broken spray tips and injector rocker arms.

(2) Test

Attach the test stand fuel line to the injector, being careful to bleed all air from the system. This is best accomplished by holding the fuel line on the left-hand injector filter cap or oil inlet hole and slowly pumping the test stand pump lever, Fig. 10-6, Item A, until clear fuel flows from the outlet side of the injector. Slip the clamp bar over the injector stud and tighten the clamping wrench, Item D. Operate the test stand pump lever at the rate of sixty full strokes per minute and observe the spray at injector tip. Fuel should discharge from each orifice. Distribution and angle of the spray should be uniform.

CAUTION: Do not put hands near spray tip as the high pressure fuel is capable of penetrating the skin and entering into the blood stream, causing severe injury.

d. Valve Opening Pressure Test

(1) Explanation

The spherical check valve in the injector tip serves only to prevent the flow of fuel into the cylinder during the time when injection is not taking place. It does not control injection characteristics. In a new injector, this valve will open at a pressure of from 1000 to 1400 pounds per square inch. The nature of the valve spring, however, is such that it takes a slight "set" in the first several hundred hours of operation causing the opening pressure to drop 100 to 150 p.s.i. below the reading taken when new, prior to use in an engine. Any additional drop in pressure is the result of normal wear of the working parts of the valve.

When the valve opening pressure drops to a point below 600 p.s.i., valve action is likely to become erratic due to cocking of the valve stem through lack of spring pressure and excessive wear. The valve is then prone to leak which can result in smoky exhaust and possibly a scored liner and piston.

(2) Test

Test is to be made with the injector installed in the test stand as outlined in the preceding test. Place injector rack in the full fuel position. Operate pump lever at least twenty full strokes to insure that any observed leakage is not due to dirt or a cocked valve. Give pump lever one additional full stroke and immediately note pressure at which test stand gauge settles out. This is valve closing pressure but since there is very little differential between valve opening and valve closing pressures, the two can be considered as identical for the purpose of this test. If this pressure is less than 600 p.s.i., the injector should be rejected.

e. Body Pressure Test

(1) Explanation

No external fuel leakage at the injector body seal, body plugs, or filter cap gaskets is permitted. Such leakage would cause fuel dilution of the engine lube oil which, if not caught in time, could result in serious engine damage.

(2) Test

With injector installed in test stand, as outlined in preceeding tests, depress popping lever and, at same time, slowly operate test stand

pump lever. When the injector plunger has been depressed to a point where the ports in the bushing are covered, the pressure within the injector body will rise above the valve opening pressure. Hold popping lever in this position and operate pump lever until the body pressure builds up to about 2000 p.s.i. Injector should be rejected if leakage is observed at the body nut seal, body plugs or filter cap gaskets. Leakage at the rack should be disregarded for the purpose of this test, as this is covered in the following section.

During this test, observe the tops of the filter caps for any sign of leakage between the ball seats on the fuel supply line and the filter caps. If such leakage is suspected, blow the fuel oil accumulation off with compressed air and repeat the test. If leakage is evident, loosen the fuel line from the injector, retighten, and test again before changing filter cap or rejecting injector.

f. Holding Pressure Test

(1) Explanation

All injectors lose pressure due to leakage at one of several points, but this leakage must be controlled to a satisfactory degree during injector manufacture in order to prevent excessive engine lube oil dilution and, at the same time, achieve dependable injector operation. The Holding Pressure Test will qualify injectors having specified leak-off rates providing this leakage is at the proper point and is satisfactorily controlled as outlined below:

(a) No leakage is permitted at the nut to body seal, filter gaskets, or body plugs, as outlined in Body Pressure Test "e."

(b) Leakage at the injector tip is of no consequence providing the injector passes the following "hold" pressure test. (If leakage at the tip is observed, the injector should be "popped" hard several times to insure that leakage is not due to a "cocked" valve.)

(c) Leakage occuring other than as indicated in (a) and (b) above will show as fuel at the injector rack. This will be due to leakage past the ground joint between the injector body and the injector bushing, or leakage at top of plunger and bushing lapped fit.

The leakage at the injector rack is controlled by timing the interval required for the pressure in the injector body to leak off from 1000 p.s.i., or valve opening pressure (if less than 1000 p.s.i.) to 400 p.s.i. A fast leak-off rate usually indicates excessive wear between the plunger and the bushing since the ground joint between the injector body and the bushing seldom leaks unless disturbed. The amount of fuel leakage noted at the rack during this test is not indicative of the amount which will leak into the oil when the injector is operating in an engine at normal pressure of 20 to 40 p.s.i.

(2) Test

With injector installed in test stand as in preceding tests, pop injector smartly with the test stand pump lever 15 to 20 strokes. With a suitable stop watch, time the interval required for the pressure to drop from 1000 p.s.i. (or valve opening pressure, whichever is lower) to 400 p.s.i. If this interval is less than 35 seconds, repeat the test, but close the pressure shut-off valve, Fig. 10-6, Item C,

immediately after popping the injector. If the interval is still less than 35 seconds, the injector should be rejected.

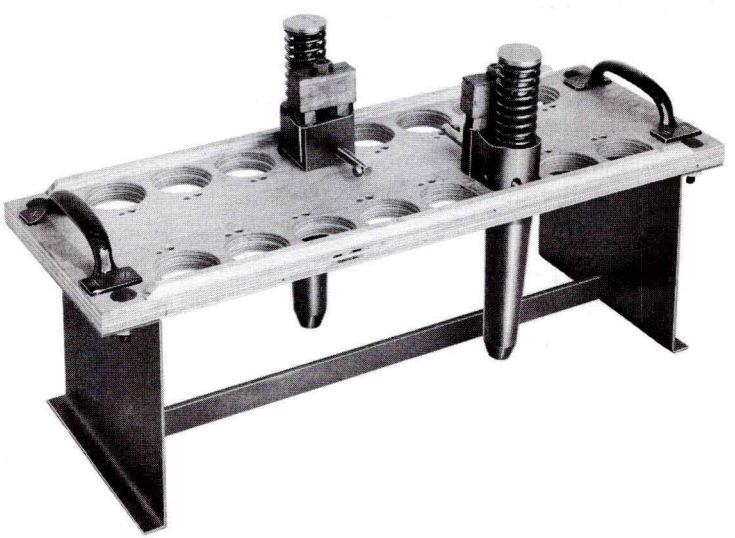
Any injector failing to pass any one of the tests outlined above should be returned to one of the Electro-Motive Factory Branches for remanufacturing.

4. 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.

5. Storing Injectors

When injectors are not to be used for a considerable length of time, they should be protected against



Injector Holding Rack
Fig. 10-7

rust by using oil 8203258 (50 gal.). This is a stable, non-corrosive 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. A drawing, file 207, giving details of construction of an injector storage box, may be obtained on request. This box will accommodate an injector holding rack 8159228 (holding 16 injectors) similar to that shown in Fig. 10-7.

6. Diesel Fuel Recommendations

For information on fuel oil specifications, see Maintenance Instruction 1750 for Railroad 567 engines, or 1751 for Industrial 567 series engines.

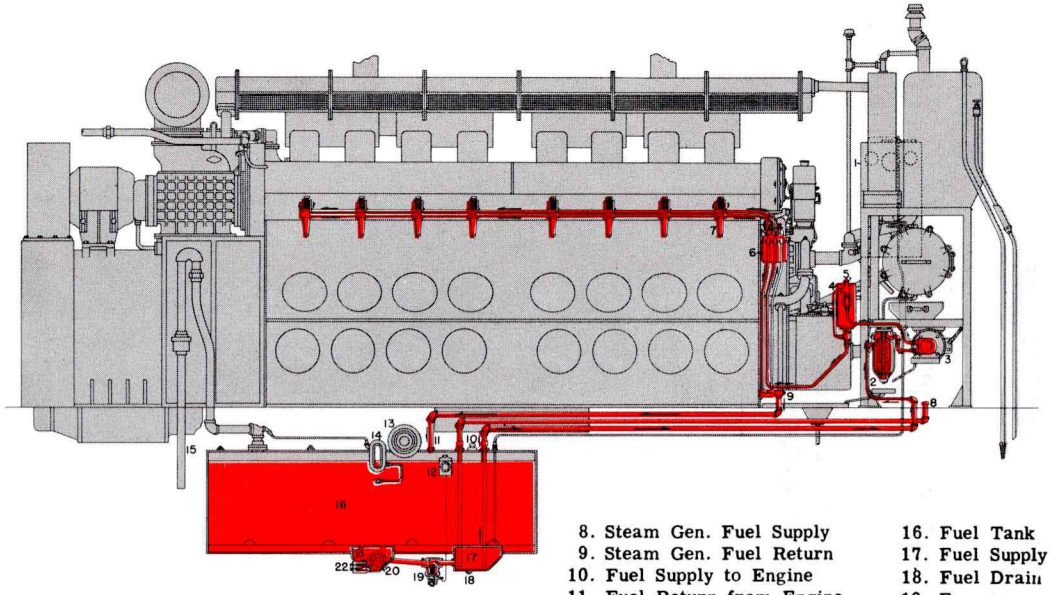
7. Fuel System Components

Varying types and designs of fuel system components are used on different engine installations which are more adequately covered by separate maintenance instructions. These instructions are listed in the Service Publications Index.

E. EQUIPMENT LIST

Name	Part No.
Injector holding rack (16 injectors)	8159228
Injector Prybar	8041183
Injector Timing Gauge	8034638
Injector test stand (complete)	8202944
Plastic spray cup (extra - used with 8202944	8171780

Injector storage box (drawing)	File 207
Fuel system - pre-test (including water and oil system piping, for checking systems)	Drwg. 294
Remote fuel gauge test kit (consists of "U" gauges and valves for test system construction)	8186329
Oil (injector test, storage, and rust prevention - 50-gallon drum)	8203258



1. Engine Control and Instrument Panel
2. Suction Filter
3. Fuel Pump and Motor
4. Fulflo Filter
5. Filter By-Pass Relief Valve
6. Sintered Bronze Filter and Sight Glass Assembly
7. Injector
8. Steam Gen. Fuel Supply
9. Steam Gen. Fuel Return
10. Fuel Supply to Engine
11. Fuel Return from Engine
12. Emergency Fuel Cutoff Pull Ring
13. Fuel Filler
14. Sight Gauge
15. Vent and Flame Arrestor
16. Fuel Tank
17. Fuel Supply Sump
18. Fuel Drain Plug
19. Emergency Fuel Cutoff Valve
20. Fuel Drain Plug
21. Fuel Tank Sump
22. Fuel Tank Water Drain Plug

Fig. 10-8 — Schematic of Fuel Oil System