SEULE0102-0

UNIT INSTRUCTION MANUAL

PT FUEL SYSTEM

for Cummins Diesel Engines

In Komatsu Machinary

KOMATSU

CONTENTS

1. FUEL SYSTEM IN CUMMINS ENGINE

Diesel engines are operated by the combustion of fuel oil injected into the cylinders. The principal purpose of the fuel system is to inject the fuel into the cylinders. In addition, the system should meter the amount of fuel to be injected as required.

For examples,

- When an engine is liable to run at a higher speed than required, the fuel amount should be decreased to lower the increasing speed.
- When letting the engine run at a low idling speed, the fuel amount should be controlled to the extent that the engine will not stall or stop running.
- When the load imposed on the engine is increasing, the fuel amount should be increased to raise torque. When the load on the engine is decreasing, the fuel amount should be decreased.
- When letting the engine stop, the fuel supply should be stopped.

Every type of diesel engine has the same functions as described above. The systemic composition, however, varies depending on the engine type.

Now, let us consider how the functions are accomplished in a CUMMINS engine.

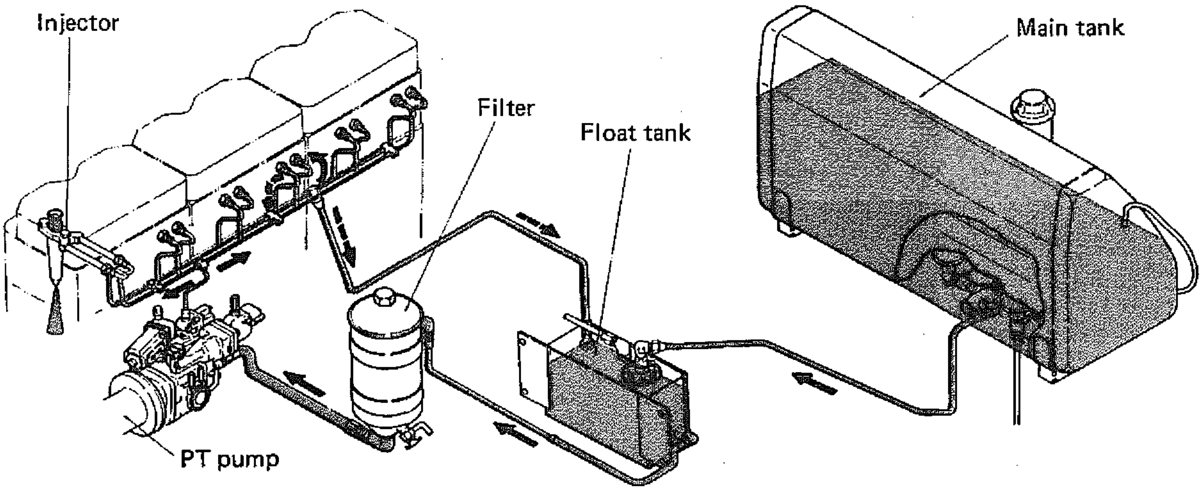


Fig. 1 — 1

Many engine components given in the illustration accomplish the functions in cooperation with each other. They work as follows:

MAIN TANK

The main tank serves to hold fuel in preparation for fuel supply to the fuel injection system.

FLOAT TANK

The float tank serves to hold the fuel flowing out of the main tank and supply to the PT pump. The fuel not being injected into the cylinder also flows back into the float tank. This tank is located in a low position, thereby preventing the fuel from flowing into the cylinders when the engine is at rest.

FUEL FILTER

This filter is installed in the fuel line between the float tank and the PT pump and serves to remove foreign particles from the fuel, thereby preventing troubles from taking place in the PT pump or in injectors.

PT PUMP

The PT pump serves to pressurize the fuel pumped up from the float tank and supply the pressurized fuel to the injectors. The amount of fuel being injected into each cylinder is controlled by changing the pressure of fuel delivered from the PT pump.

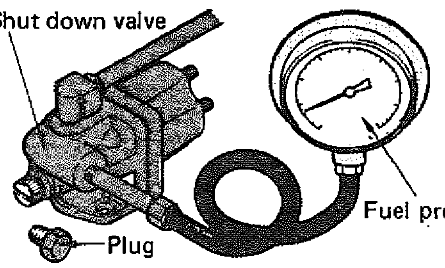
INJECTORS

Depending on the fuel pressure delivered from the PT pump, each injector meters the quantity of fuel and injects fuel into the cylinder. The fuel does not be delivered to the cylinders flows from the injectors to the float tank through the return passage.

FEATURES OF CUMMINS ENGINE as compared with other diesel engines

1. The fuel flows from the float tank to the injectors through the PT pump, and approximately 20% of the fuel being supplied to the injectors is actually injected into the cylinders. The remaining 80% of fuel serves for cooling and lubrication of the injectors and then flows back to the float tank.

   In other engines: The whole amount of fuel delivered from the injection pump is consumed in the cylinders. Very small amount of fuel leaking out of the needle valve clearances in each injection nozzle flows back to the fuel tank.



2. Fuel delivery pressure of the PT pump is as low as 10kg/cm^2 (145 psi) or less. This pressure varies depending on the engine speed so as to adjust the amount of fuel injection. That is, the amount of fuel is metered by each injector according to the fuel delivery pressure. If the fuel pressure from the PT pump should not vary as desired, the engine operation would be out of order. In such a case, check the pressure with a fuel pressure gauge jointed to the shut down valve as shown in the illustration.

   In other engines: The fuel injection pump meters the necessary amount of fuel to be injected and delivers the fuel under high pressure to the injection nozzles.

3. Injection timing is dependent on the time when each injection plunger lowers.

   In other engines: The injection pump determines the injection timing.

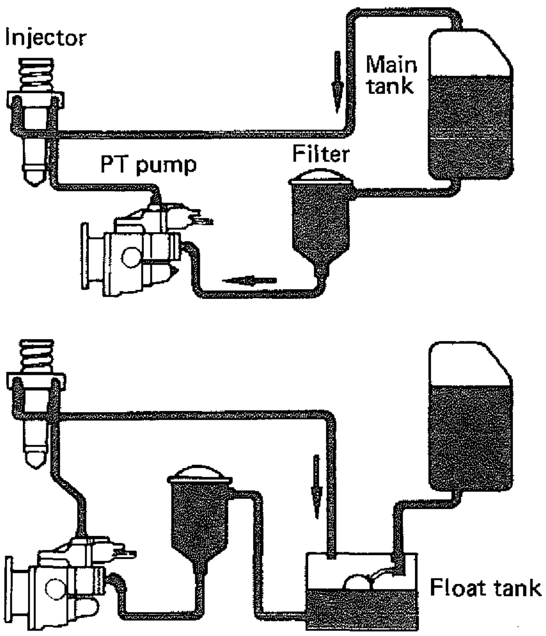
4. To stop the engine, the shut down valve should be closed to stop the flow of fuel.

   In other engines: The injection pump should be brought into the non-injection condition.

NOTE: For detailed description of the injector and the PT pump, refer to their respective Training Aids.

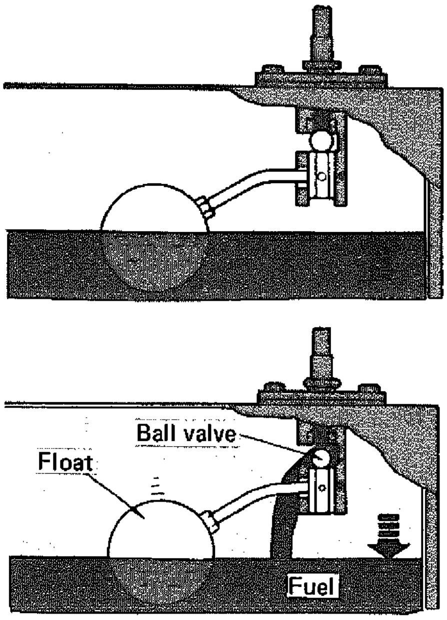
As the PT pump and injectors are accurately machined and finished to assure their respective significant functions, the foreign substances entrapped in the fuel deteriorate their functions. Such foreign substances are dust, water and air.

1. Dust
   Dust in the fuel will cause wear and seizure of the PT pump and injectors. Although the fuel filter is prepaired to clean the fuel passing through it, very fine particles of dust may pass through the filter. Therefore, it is imperative to take care not to allow the dust to enter the fuel.
2. Water
   Water contaminated in the fuel will cause the seizure or rusting of PT pump plunger, gear pump, injectors, etc. For this reason, be sure to open the drain cocks on the main fuel tank and fuel filter every morning, before daily operation, in order to drain the entrapped water or dust from the tank.
3. Air
   The entrapped air will cause the fuel injection quantity to be unstable, which will in turn make the engine difficult in starting. Even though the engine starts, it will vary the engine rpm, resulting in stoppage of the engine. The air may enter through the clearances which may accidentally be created at the following portions: PT pump; fuel supply line; filter gaskets; and priming pump and its piping.



Assume the engine has not been provided with the float tank. As the main fuel tank is located in a high position, the fuel filled up in a tank has a tendency to flow out during the engine is kept at rest. The fuel directed in the line passing through the PT pump may flow into the injectors through the clearances in the shut down valve. On the otherhand, the fuel may also flow directry into the injectors through the return pipe. The fuel accumulated in the injectors will drop from the injector nozzles into the cylinders and then into the oil pan, thereby diluting the oil with fuel.

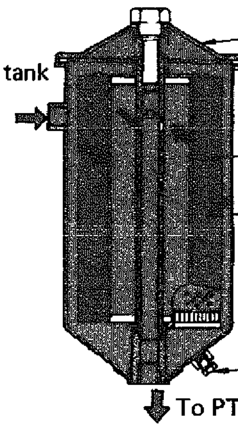
To prevent such a trouble, the float tank is installed in a position below the injectors.



The float provided inside the float tank prevents the overflowing of the fuel out of a tank. When the fuel flows into the float tank from the main fuel tank to fill the float tank full with fuel, the float will rise up to close the valve, thereby stopping the fuel flow from the main tank.

On the contrary, if the fuel in the float tank is reduced, the float will be lowered, thereby opening the valve. It will, then, allow the fuel to flow into the tank. Thus, the quantity of fuel in the float tank is kept in constant.

Fuel filter



The fuel filter contains a paper element by which fuel is screened to remove dust. As the element becomes dirty with the dust accumulated on its surface, it is necessary to renew the element every 500 service hours. To do so, uncover the filter case and replace the element. After replacement, fill the filter case full with fuel and cover the case. If the filter should be covered without filling of fuel, the engine will stop soon after starting up because of lack of fuel circulating in the fuel line. Also, the cover gasket should be renewed to prevent air leakage around the cover.

2. INJECTORS

2.1 General

Torque available from a diesel engine varies with the rate of fuel injection. Metering action is performed by a metering device of one type or another included in the fuel control system. In KOMATSU engines, the metering device is incorporated in the fuel injection pump, in CUMMINS engines, it is in the fuel injector.

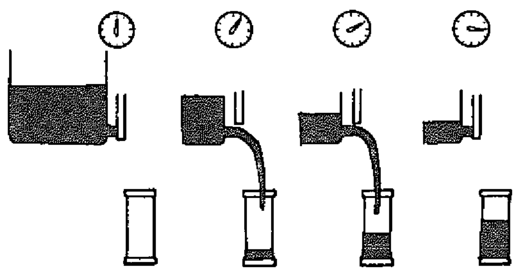


Fig. 2 – 1

Principle of pressure-time metering

Open the tapping valve to let the fuel oil out and collect it in the jar. Since the rate of oil flow is practically constant, clocking the duration of flow is equivalent to measuring the amount of oil let out: FLOW RATE x TIME = TOTAL AMOUNT.

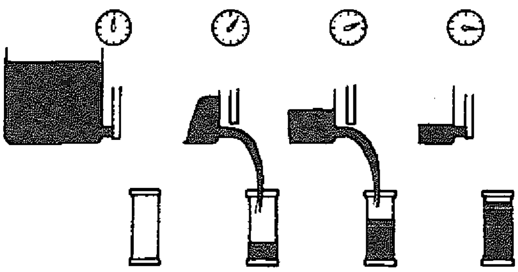


Fig. 2 – 2

Raising the oil surface in the tank increases the flow rate, because of the pressure due to the head (the column of oil) in the tank. For the same duration as above, a greater amount of fuel oil will be let out of the tank.

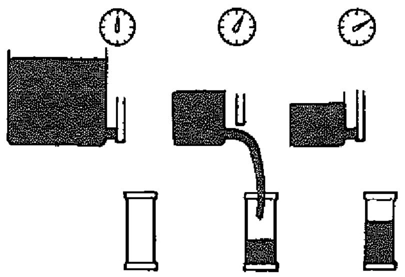


Fig. 2 – 3

To obtain the same amount of fuel oil as in 1) above from the tank, in a shorter duration, the oil surface must be raised still higher to increase the pressure at the tapping valve.

The hydraulic principle involved in the foregoing illustrations can be summarized as follows:

(1) If oil is pumped into an open system, the amount of oil delivered to this system will vary with pressure at the delivery point.

(2) The total amount delivered will vary with time.

2.2 Metering Action by Flange Type Injector

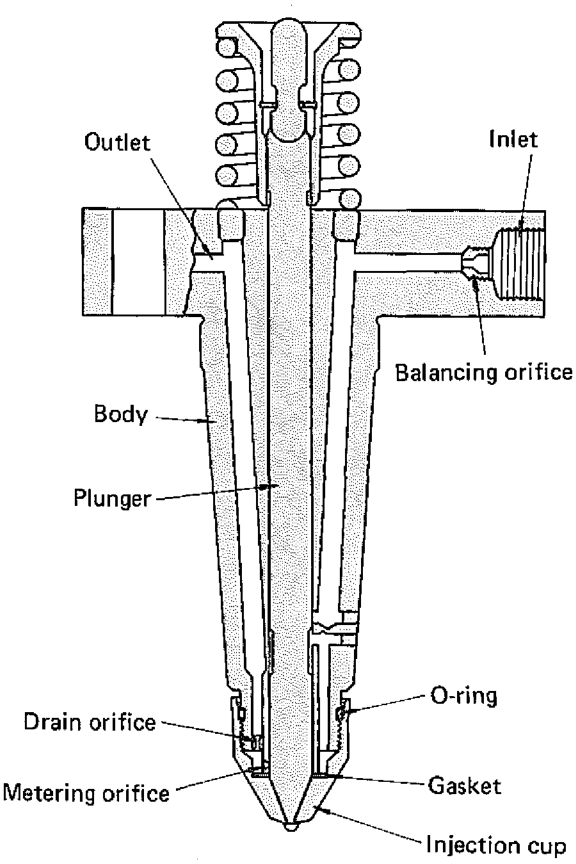


Fig. 2 – 4

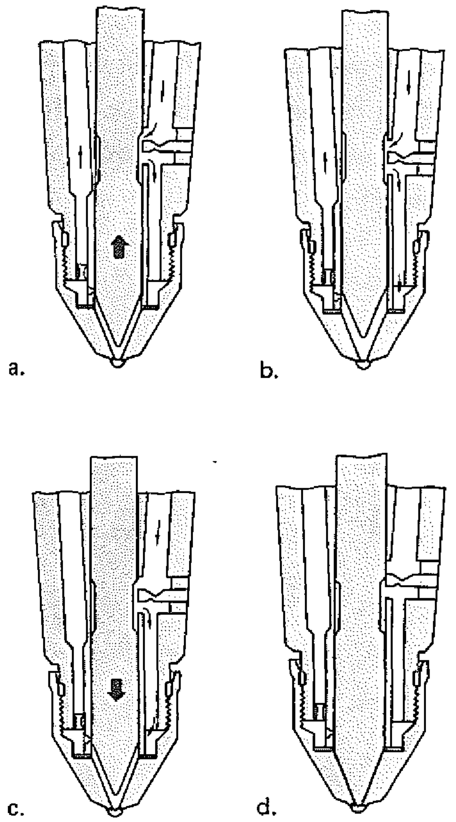


Fig. 2 – 5

The PRESSURE-TIME hydraulic principle just explained applies to the injector. The injector is supplied with fuel oil at a variable pressure. The fuel is then admitted into the small cavity within the cup through the metering orifice.

The amount of fuel oil admitted into the cup in an injection quantity for one cycle of diesel operation and is determined by 1) the supply pressure, and 2) the duration for which the metering orifice remains open.

One cycle of injector operation will be sequentially described by referring to the illustrations above:

a. The plunger is down, keeping the metering orifice closed.
b. The plunger rises to open the metering orifice. Fuel flows into the cup.
c. The plunger goes down, closing the metering orifice again and thereby trapping a certain amount of fuel in the injector cup, and plunges down with full force to force the trapped oil into the combustion chamber.
d. The tip of the injector reaches the bottom to complete one cycle.

The vertical stroke (or distance of travel between the limits) of the injector is constant. However, there are two variable associated with injector operation. One is the duration, stated above, which is determined by the speed with which the plunger completes one cycle of its reciprocating motion. The other is the supply pressure at the metering orifice, which is varied by the PT pump.

It follows therefore that, to increase the output torque when the engine is running at a constant speed, the supply pressure must be increased. To increase the speed at a constant output torque, the supply pressure must be raised. It will be seen from these relationships that the only variable that can be controlled at one's will is PRESSURE. The TIME variable is governed by engine speed or, in a larger measure, by the duty operation of the machine as a whole.

Two oil connection pipes, extending from the common supply line and return line outside the cylinder head, are tied into the injector. In the ferruled connection of the supply pipe with the external pipe, a strainer is provided as the final defense against foreign particles.

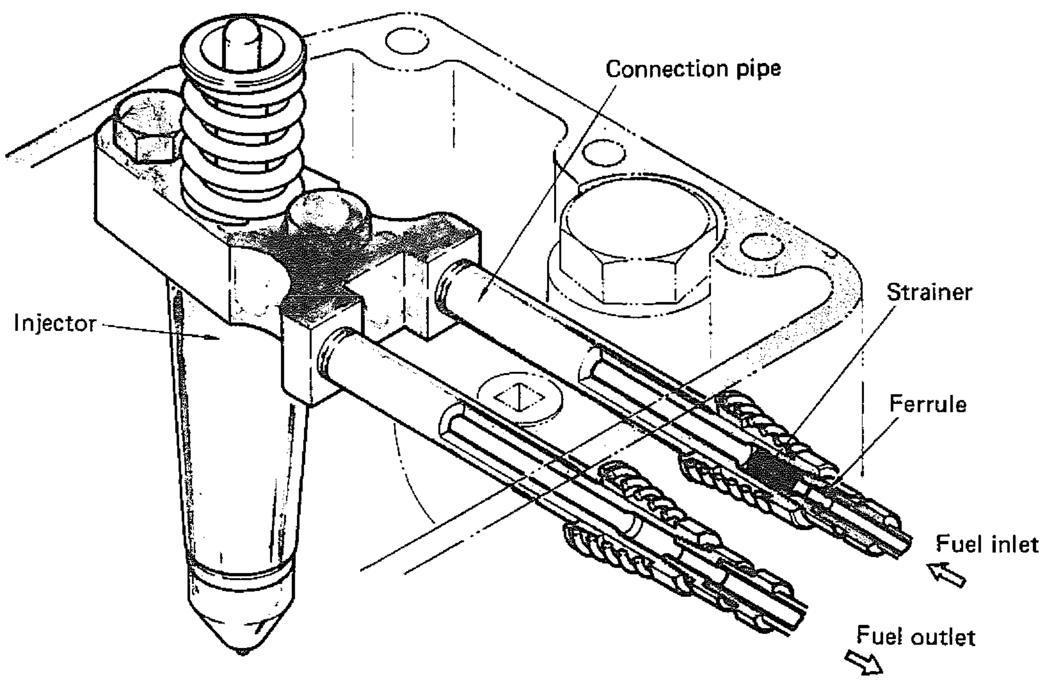


Fig. 2 – 6

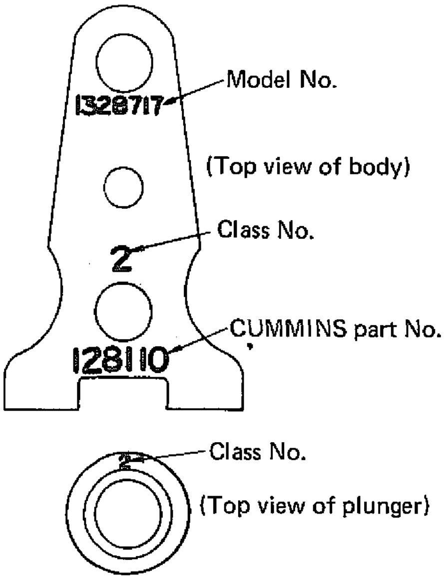


Fig. 2 — 7

Each injector body is marked with numerals, as shown on the left. The Model No. marking among these carries the following meanings:

Example:

FLOW RATE	NUMBER OF INJECTING ORIFICES	SIDE OF INJECTING ORIFICE	FUEL SPRAY ANGLE
132 (132cc for 1000 strokes)	8	7 (0.007")	17 (17°)

Metering orifice

An obstruction in the path of fluid flow introduces an increased pressure difference across the obstruction, that is, between its upstream and downstream sides. In hydrodynamics, a metering orifice is such an obstruction.

It is a plate inserted in a pipe and provided with a hole (orifice) for passing the fluid. Its position and design are so selected as to create a pressure difference that is large enough for detection. The differential pressure is a function of the flow rate. This relationship is utilized to measure the rate of flow or to control the rate of flow by varying the pressure on the upstream or downstream side.

In the injector, the metering orifice is used for the latter purpose.

2.3 Fuel Flow Through Injector

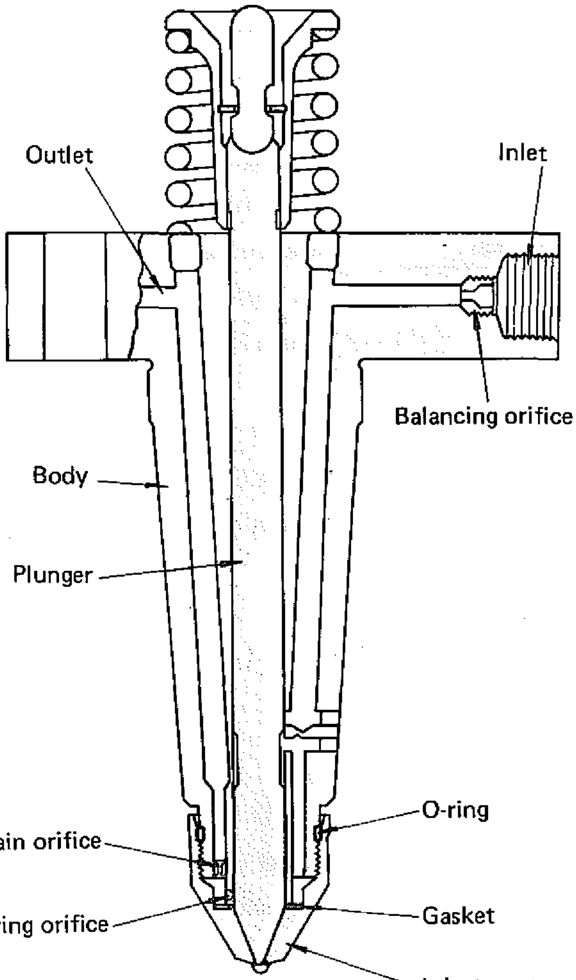


Fig. 2 – 8

The fuel oil supplied from the PT pump enters the injector through its balancing orifce (inlet orifice). Only when the plunger is up, even partially, the fuel circulates through the injector and comes out of the drain oilway into the return line. By circulating through the oil passages and oilways in the injector, the fuel keeps the plunger lubricated and cools the cup portion, which is the hottest portion of the plunger.

The reason why the fuel is circulated intermittently is that a high flow rate would have to be maintained for constant circulation and that such a high flow rate calls for a larger size of PT pump.

The metering orifice is located between the balancing orifice and the drain orifice, and opens out into the cup. If the fuel pressure at the orifice changes, the amount of fuel the metering orifice lets out into the cup in a unit time changes. Thus, as was pointed out earlier, the injection quantity is controlled by controlling the fuel pressure.

The mechanism of the metering action will be explained graphically for a clearer understanding of it.

Fuel pressure distribution and oil path are represented by these graphs.

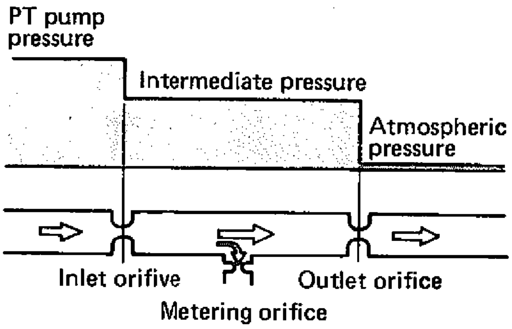


Fig. 2 – 9

With the metering orifice open, the amount of fuel being discharged by this orifice is determined according to the PT principle explained previously. The line up to the inlet orifice is at supply pressure.

This pressure is reduced by the inlet orifice to the intermediate pressure. The remaining fuel leaving through the outlet orifice loses its pressure and flows into the return line practically at atmospheric pressure.

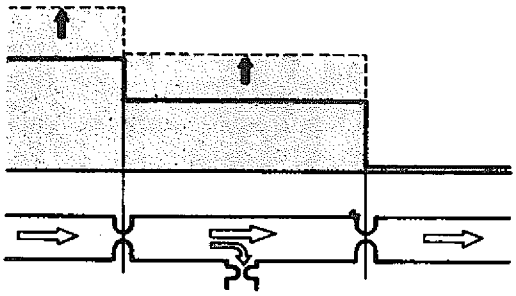


Fig. 2 – 10

If the PT pump supplies fuel oil at a higher pressure, the intermediate pressure rises to result in a greater injection quantity.

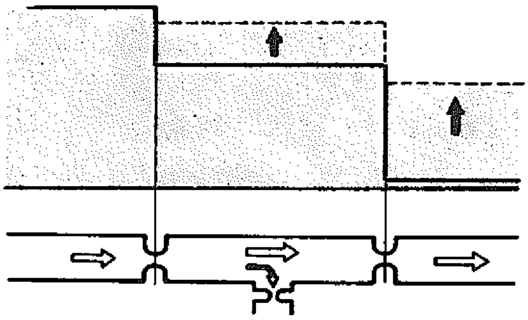


Fig. 2 – 11

If the return line happens to become clogged or closed inadvertently, the intermediate pressure rises to a level close to the raised supply pressure. This causes the metering orifice to let out a much greater amount of fuel.

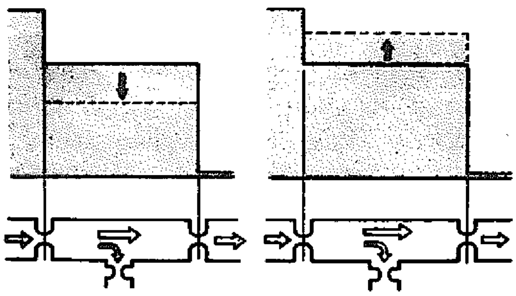
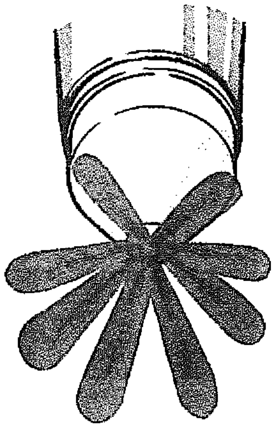


Fig. 2 – 12

Both inlet and outlet orifices are obstructions to fuel flow. For a given level of supply pressure, an outlet orifice with less resistance decreases the intermediate pressure and, by the same token, an inlet orifice with less resistance raises the intermediate pressure.

The inlet orifice is of screw-in replaceable type. A properly sized orifice is to be used for this orifice to secure the desired injection quantity.

2.4 Care of the Injector



A total of 8 spray orifices are provided in the injector cup. Each orifice is about 0.2mm (0.008 in.) in diameter. Satisfactory fuel injection may be expected of the injector even when one or two of these orifices are clogged with carbon. However, three or more clogged orifices will result in defective fuel injection. Use a carbon cleaner to clear clogged orifices.

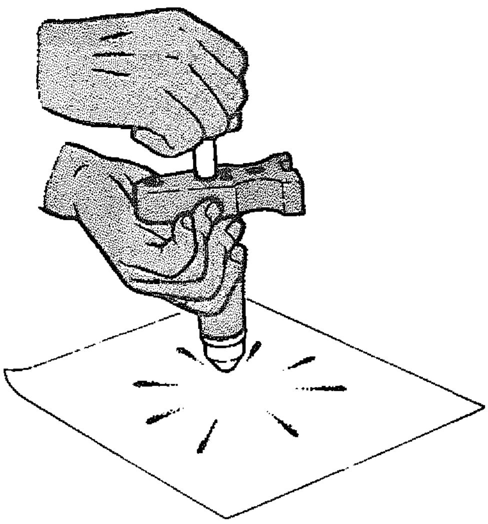


Fig. 2 – 13

To check a removed injector to see if any spray orifices are clogged or not, remove the spring from the injector and, with some fuel oil remaining within the injector cup, jog the plunger in, as shown on the left, to force oil out onto a sheet of paper. This will make an 8-dot smear pattern on the paper if the orifices are all clear.

Do not try to clear plugged orifices by poking with a wire or any hard or sharp-pointed tool. Even a minutest scratch on the orifice can alter its injection characteristic to affect the injection quantity.

CAUTION:

Never spray fuel oil against your palm or any part of the body, particularly when the injector is being operated for injection pattern in test equipment. The oil being ejected has tremendous momentum and can penetrate through the skin to cause a serious blood disease.

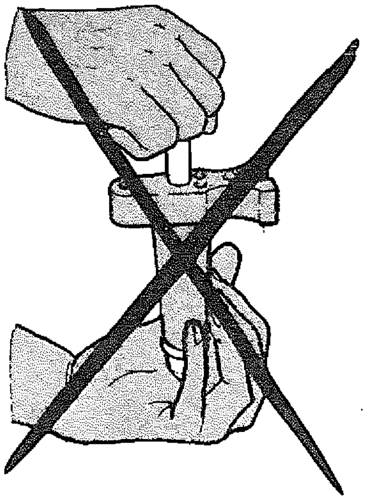


Fig. 2 – 14

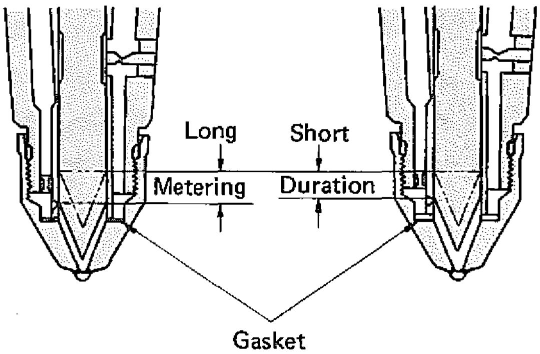


Fig. 2 – 15

The gasket used in the cup has a specified thickness. When replacing this gasket, make sure the replacement gasket meets the thickness specification. Changing the thickness of this gasket changes the metering duration. The illustration on the left shows the effect of a change in the thickness.

Removing the cup from the injector body will expose the "O" ring, which seals the screw-on connection of the cup with the injector body. Before putting the cup back, be sure to replace the existing "O" ring by a new one. Never re-use old "O" ring.

The gaskets used in the connection pipes are not re-usable. Whenever a connection pipe has been removed, be sure to discard its gasket and fit a new one before screwing the connection pipe back into the injector body.

The strainer in the inlet connection pipe is to be cleaned every 2000 hours. Upon taking out the strainer, be sure to search for metal particles caught in the strainer. Presence of such particles means that the PT pump is abnormally worn and needs overhauling.

2.5 Plunger Movement

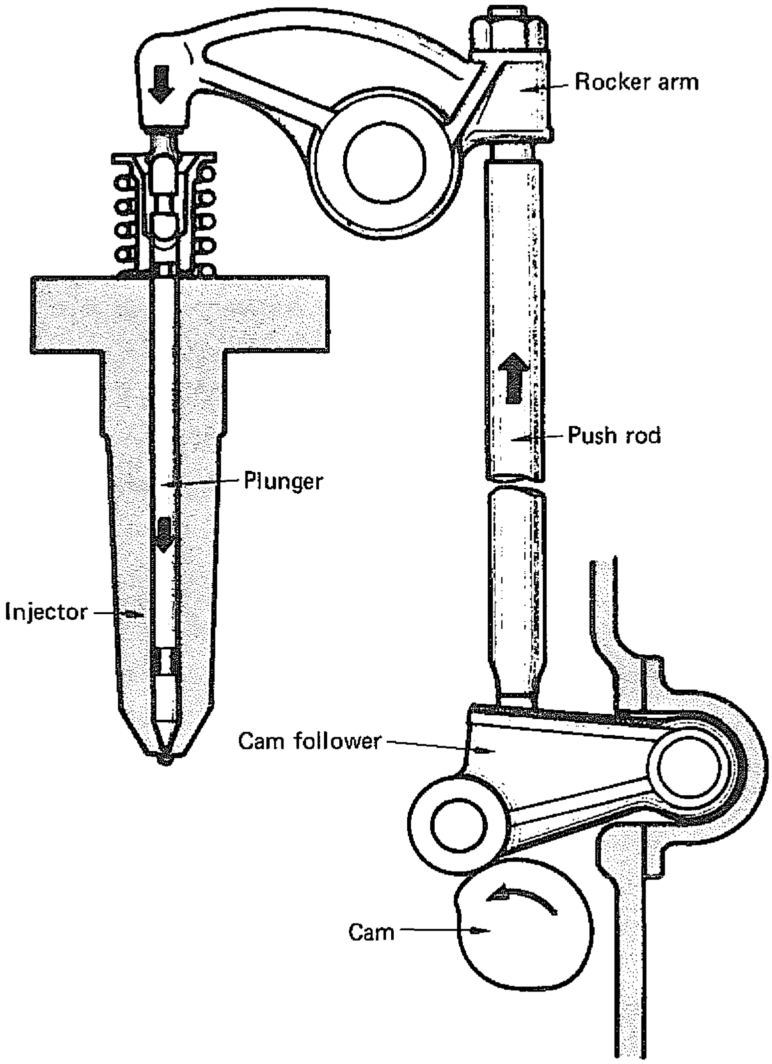


Fig. 2 — 16

The plunger is urged upward by the spring.
Force for pushing the plunger down is transmitted through the cam follower, push rod and rocker arm from the cam, just as in the valve mechanism for opening and closing the intake and exhaust valves.

A characteristic difference between the injector drive mechanism and the valve mechanism is that there is no clearance or gap in any part of the train of the force transmitting parts in the former, whereas, in the latter, a proper clearance (valve clearance) is necessary between valve stem and rocker arm.

With the plunger pushed all the way down, its tip cone is in perfect contact with the conical bore of the cup. If there happens to be some space due to insufficient contact, the fuel oil remaining in this space might become carbonized to clog up the spray orifices or foul up the injector as a whole. The corret injection quantity is ensured by the perfect contact, among other factors.
The rocker arm is provided with an adjusting screw arrangement for taking up and play and for pushing the plunger down without delivering a hammering blow to the cup.

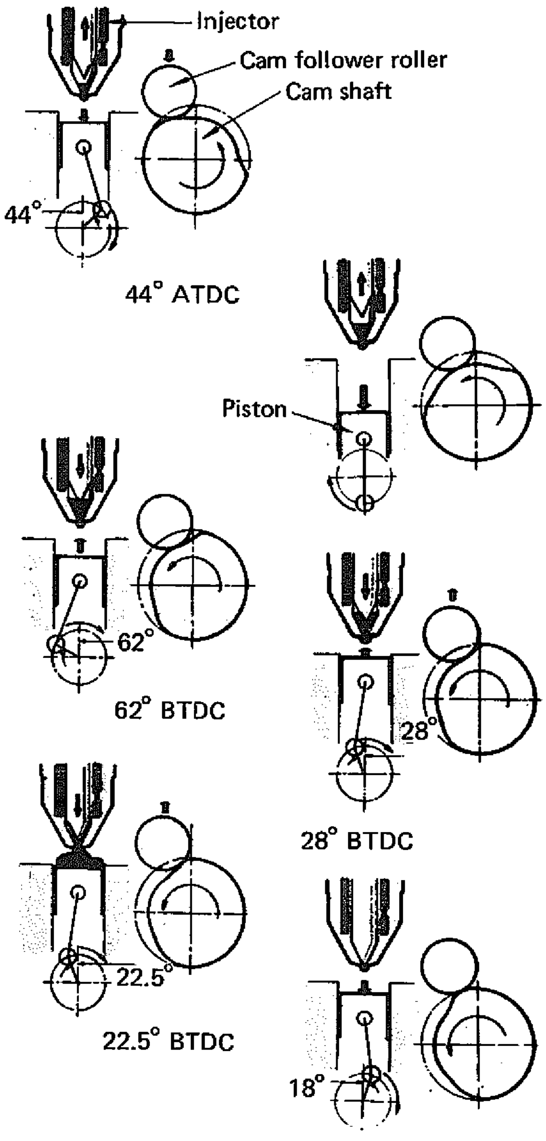


Fig. 2 – 17

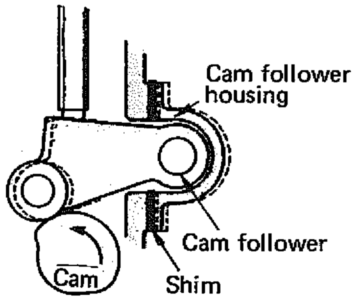


Fig. 2 – 18

Operation of the injector drive mechanism

By taking up the NH-200 engine for example, the angular relationship between the cam and the injector plunger will be explained, by way of describing the injector drive mechanism operation.

On intake stroke, the cam-follower roller rides onto the downhill curvature of the cam, causing the push rod to descend and the rocker arm to rock. This allows the plunger to rise. At 44° after top dead center (ATDC), the metering orifice opens to let fuel oil into the cup.

During the transition from intake stroke to compression stroke, the cam-follower roller is at the lowest point of the cam, with the plunger raised to the top limit. Fuel accumulates progressively within the cup.

At 62° before top dead center (BTDC) on compression stroke, the roller begins to ride uphill on the cam and, at the same time, the plunger begins to go down. At 28° BTDC, the metering orifice is completely closed.

At 22.5° BTDC, the plunger starts forcing the fuel trapped in the cup to spurt out from the spray orifices. At 18°, the roller is at the highest point of the cam and the plunger is down all the way, thereby completing the fuel injection.

Past this highest point stretches a uniformly low cam face, which is 0.36mm (0.014 in.) lower. As the roller rides along on this face, the plunger stays pushed down in slightly relaxed state. During power and exhaust strokes, the plunger remains in that state.

The beginning of fuel injection is at 22.5° BTDC. This is the specified timing for the foregoing instance. The timing can be varied for adjustment by changing the thickness of the shim located at the mounting face of the cam-follower housing. Increasing the thickness of this shim displaces the cam follower outwardly to advance the timing, and vice versa.

Adjustment for non-hammering thrust of plunger

As was stated previously, the injector drive mechanism is required to drive the plunger down in such a manner that the plunger tip will fit into the cup without any hammering action. The adjusting screw arrangement provided on the rocker arm is to be set for satisfying this requirement. The adjusting procedure is as follows:

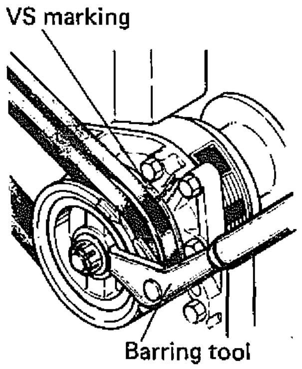


Fig. 2 – 19

(1) Bar the drive pulley to turn it in the direction shown until the VS marking on its rim indexes to the cast-out pointer. This brings the cam-follower roller to the high face of the cam to keep the plunger down. With the 1.6 VS marking, for example, brought to the cast-out pointer, the plunger for No. 1 or No. 6 cylinder is down. (The engine is here assumed to be in cold state.)

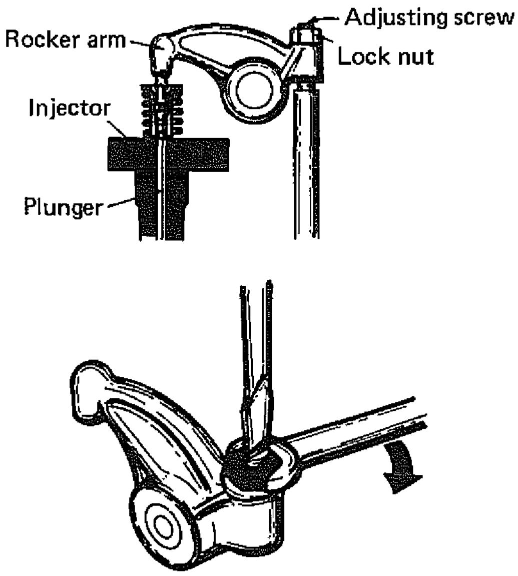


Fig. 2 – 20

(2) At No. 1 or No. 6 cylinder, whichever has its plunger pushed down, loosen the lock nut and adjusting screw. Run in the screw until the plunger tip reaches its bottom limit, driving out all the remaining fuel oil from the cup.
From that position, tighten the adjusting screw just a crack (15°).

(3) Turn back the adjusting screw one full rotation (360°). From this position, slowly tighten the adjusting screw again with a torque wrench until the torque reading reaches 0.55kg.m. (4.0 ft-lb). Hold the screw with a driver, and tighten the lock nut to a torque between 9.7 and 11.1kg.m. (71 and 81 ft-lb).

Repeat the foregoing procedure at the remaining cylinders, each time barring the drive pulley. Start up the engine and warm it to 60°C (140°F) (lubricating oil temperature). In the hot state of the engine, repeat the steps 1) to 3) at each cylinder. The adjusting screw is to be tightened with the torque wrench to 0.69kg.m (5.0 ft-lb) instead of to 0.55kg.m (4.0 ft-lb) in step 3).

NOTE: 1. The drive pulley will rotate twice as the adjustment is completed sequentially according to the firing order.
2. The firing order is as follows:
1-5-3-6-2-4 6-cylinder engine
1-2-4-3 4-cylinder enigne

Checking and adjusting the injection timing

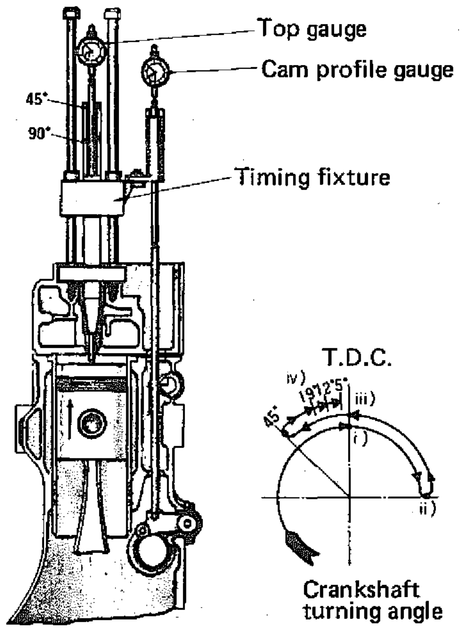


Fig. 2 – 21

We have already seen that the injector drive mechanism has a feature whose setting determines the injection timing. How to verify this setting and what requirements to be satisfied for meeting the injection timing specification — these are our concern here.

The timing fixture (a device consisting of a mounting fixture and two gauges, as shown) must be used to check the timing.

It is not necessary to check and adjust at all of the cylinders of the engine: No. 1, No. 5 and No. 3 cylinders are all we have to deal with in completing the work on a 6-cylinder engine. The procedure, starting with No. 1 cylinder, is as follows:

Take down the rocker arm housing; remove the injectors; and mount the timing fixture at No. 1 cylinder.

(1) Index the 1.6 TC marking on the drive pulley to the stationary pointer by barring. Be sure the rocker arms for intake and exhaust valves in No. 1 cylinder are down. If not, lower the rocker arms by turning the pulley one complete rotation.

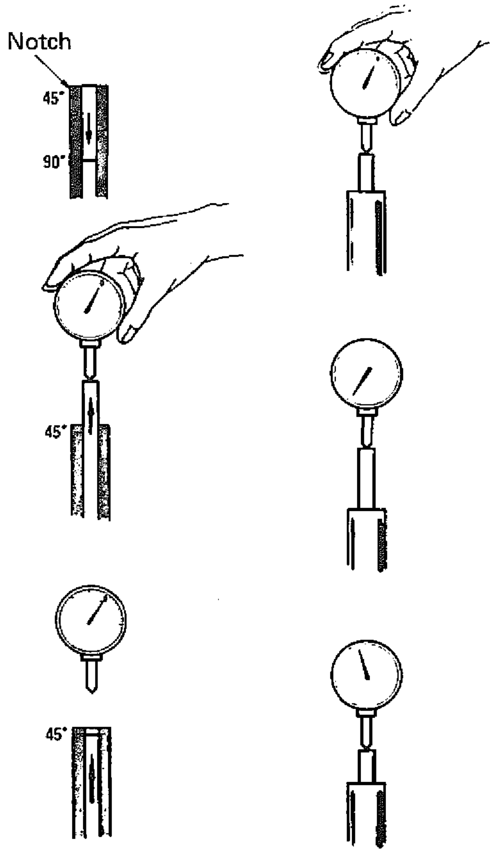


Fig. 2 – 22

(2) With the 1.6 TC marking at the pointer, bar the pulley clockwise until the top end of the sensing rod (which extends into the combustion chamber) comes to the 90° position. Set the cam profile gauge to zero, as shown.

(3) Turn back (counterclockwise) the pulley until the 1.6 TC marking comes to a point 10mm (0.4 in.) from the stationary pointer. Secure the top gauge in place, with its spindle retracted about 5mm (0.2 in). (Leave the top gauge in that secured position for the remaining duration of the operation.)
Slowly turn the pulley further (counterclockwise) to raise the sensing rod. When this rod has reached its top position (corresponding to the TDC of the piston), set the gauge to zero. (Tolerance is 0.25mm (0.1 in)).

(4) Turn the pulley still further until the top end of the sensing rod comes to the 45° position (corresponding to 45° BTDC). From this position, turn the pulley back (clockwise) in steps, stopping at the position where the top gauge reads –5.161 (corresponding to 19° BTDC). At this position, the cam profile gauge should indicate a value within the range listed in the chart below:

Unit: mm

Top gauge reading	Range of cam profile gauge reading	
	NHC-4, NH-220	NRTO-6
–5.161 (19° BTDC)	–0.800 ~ –0.699	–1.105 ~ –1.003

The injector drive mechanism is in the correctly set condition as far as injection timing is concerned, if, in the foregoing checking operation, the top gauge and cam profile gauge change their indications as shown in the chart above.

To bring the cam profile gauge reading into the ranges shown in the chart, the cam follower must be adjusted, as described previously, by varying the thickness of the shim used at the mounting face of the cam follower housing.

2.6 Injector Removal and Installation

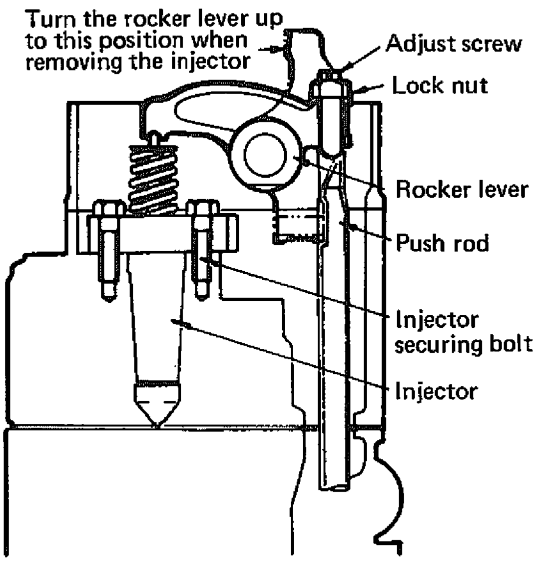


Fig. 2 – 23

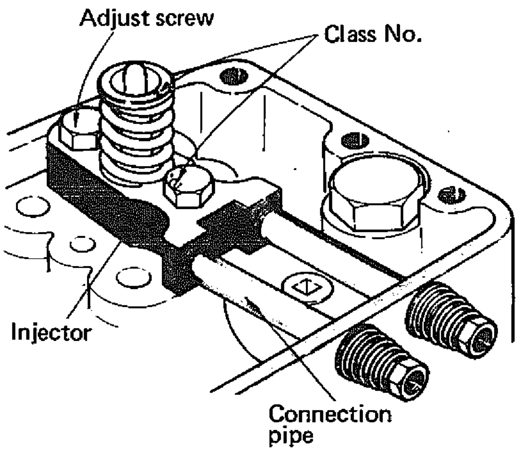


Fig. 2 – 24

Removal

Removal of the rocker arm assembly is not necessary for allowing the injectors to be removed, except when injectors are to be removed for injection timing check or adjustment.

Loosening the adjusting screw on the rocker arm and turning the arm up, as shown, clears the arm away from the injector in place.

Each removed injector should be tagged for identification. Handle the injectors with greater care: dropping an injector onto hard floor of rubbing its nozzle against hard surface can deliver serious damage to the injector.

Installation

With the injector fitted in place, secure it in the following manner:

First, finger-tighten the securing bolts and screw the connection pipes into the injector body by hand; adjust the positions of the injector and pipes; tighten the securing bolts in steps and alternately to a torque between 1.7 and 1.9kg.m (12.4 and 13.9 ft-lb); and finally tighten the connection pipes to a torque between 2.8 and 3.5kg.m (20.5 and 25.6 ft-lb).

The plunger class number marking should be brought to the side where the injector body class number is provided, as shown.

After securing each injector, be sure to test its plunger for movement by picking it up and down several times with figures. If the plunger refuses to move, it is an indication of the securing bolts being unequally tight.

Excessive torquing of the securing bolts will stress the valve seat and cylinder head unduly and can crack these parts. Do not exceed the torque limit stated above.

The securing bolts are NYLOCK bolts. They are good for about 10 cycles of tightening and loosening. This means that they must be replaced by new ones when they have been loosened and removed for the 10th time.

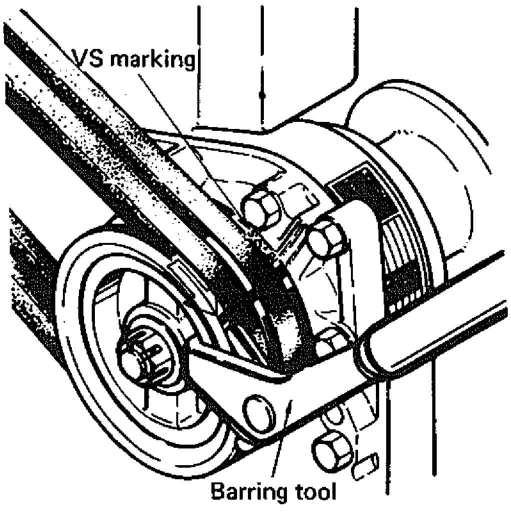


Fig. 2 – 25

Timing markings

When the TC marking provided on the drive pulley is indexed to the cast-out pointer on the case, the corresponding piston is at its TDC (top dead center).

The VS marking in the similarly indexed position means that the piston is at 90° ATDC (after top dead center). The numerals prefixed to "VC" and "TC" refer to the cylinder numbers.

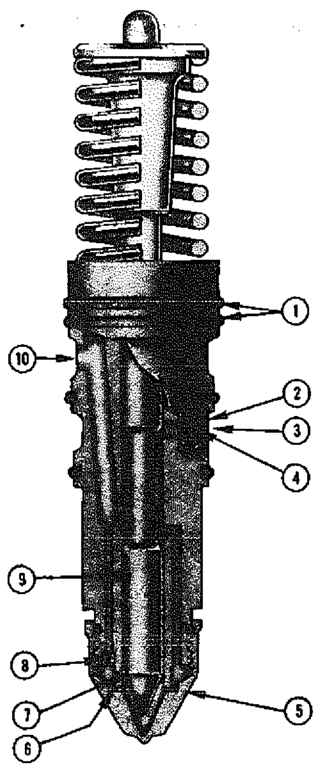
When barring the pulley, be sure that the engine is in "decompressed" state. Use no other tool than the special barring tool.

2.7 Cylindrical PT (type D) Injector

The injectors used with the PT fuel system are grouped into two basis groups, cylindrical in shape without a flange or flange type. The details of the flange type has been covered in the preceeding paragraphs. Cylindrical injectors are used in engines with the cylinder head with internal fuel drillings. Cylindrical PT (type D) will be described in details following the brief description of cylindrical injectors of other types.

- Cylindrical PT Injector

A limited number of engines with internal fuel drillings in the cylinder head used this type. An adjustable orifice plug was contained in the inlet passage.



1. O-ring seals
2. Screen
3. Fuel in
4. Delivery orifice
5. Cup
6. Gasket
7. Metering orifice
8. Drain orifice
9. Plunger
10. Fuel out

Fig. 2–26
Cylindrical PT Injector

- Cylindrical PT (type B) Injector

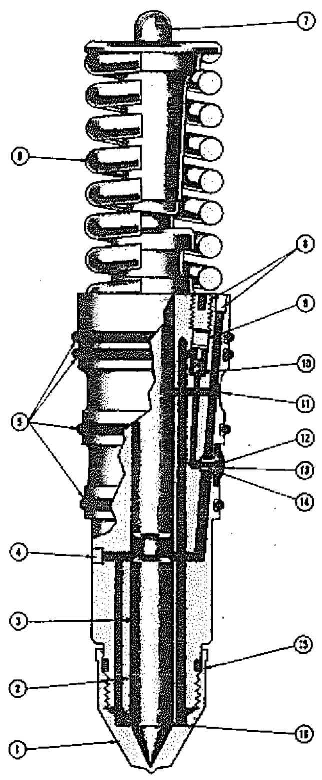


Fig. 2—27
Cylindrical PT (type B)

A ball valve (10) (Fig. 2-27) is included to aid in the control of fuel flow and the adjustable orifice plug is burnished to size during testing.

1. Cup
2. Metering orifice
3. Plunger
4. Plug
5. O-ring seals
6. Injector spring
7. Injector link
8. Plugs
9. Stop
10. Check ball
11. Fuel out
12. Fuel in
13. Fuel screen
14. Orifice plug
15. O-ring seal
16. Gasket

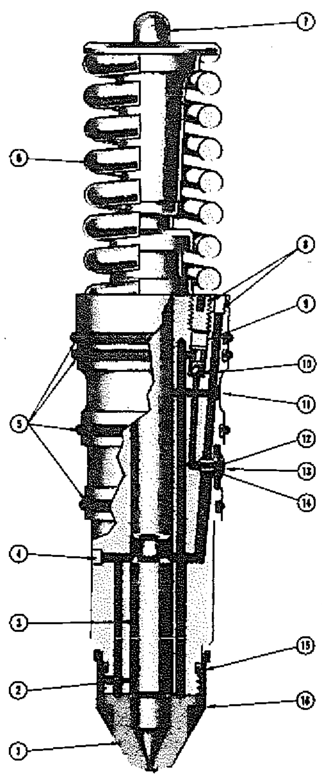
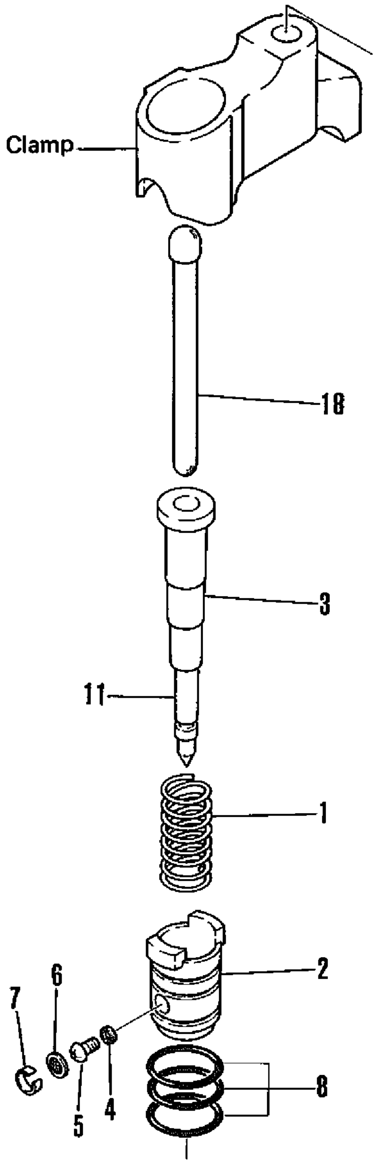


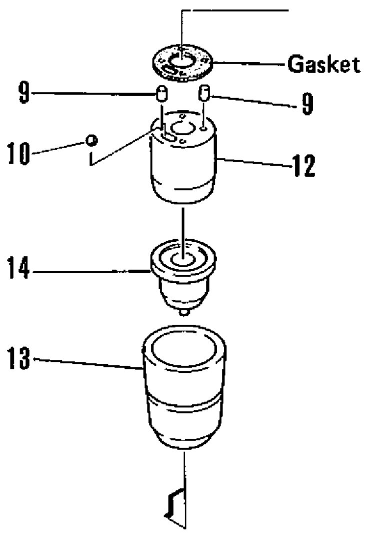
Fig. 2—28
Cylindrical PT (type C)

This type has the same features as the PT (type B) injector, plus a two-piece cup consisting of a cup (1) and cup retainer (16) (Fig. 2-28).

1. Cup
2. Metering orifice
3. Plunger
4. Plug
5. O-ring seals
6. Injector spring
7. Injector link
8. Plugs
9. Stop
10. Check ball
11. Fuel out
12. Fuel in
13. Fuel screen
14. Orifice plug
15. O-ring seal
16. Cup retainer

- PT (type D) Injector





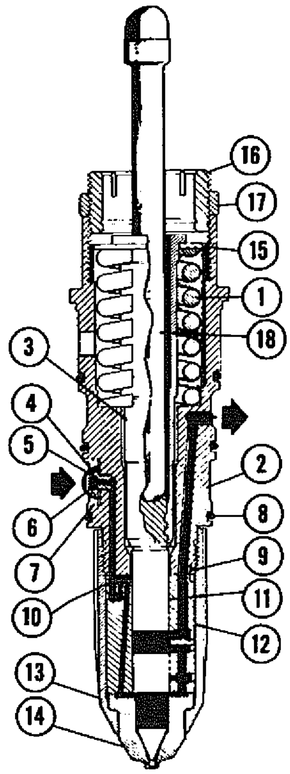


Fig. 2–29
PT (type D) Injector

1. Spring
2. Adapter
3. Coupling
4. Gasket
5. Orifice
6. Screen
7. Clip
8. O-ring
9. Spiral pin
10. Check ball
11. Plunger
12. Barrel
13. Cup retainer
14. Cup
15. Spring washer
16. Top stop screw
17. Lock nut
18. Link

The PT (type D) is a refinement of the PT (type B and C) cylindrical injectors. The changes in parts design of PT (type D) provides more parts interchangeability, and the areas of the parts subject to wear are localized in smaller parts for easier servicing.

While former injectors have a body with the moving part or plunger running the full length, the PT (type D) has a short barrel and plunger to provide the same function. The shorter barrel plunger bore made it possible to use materials of greater wear resistance and result in smaller replacement assembly.

The barrel and plunger assembly is made up of a coupling (3), plunger (11) and barrel (12). The coupling (3) and plunger (11) are swaged assembly. Plunger and barrel kit part number——— AR-40063 (Cummins Parts No.), CUAR-40063 (Komatsu Part No.)——— is available as follows;

Komatsu Part No.	Cummins Part No.	Description
CUAR–40063	AR-40063	Plunger and Barrel Kit
CUAR–40062	AR-40062	Barrel and Plunger
CU185782	185782	Gasket
CU167157	167157	Check Ball

Injector parts—flange type and PT (type B and C)

- Adjustable orifice plug

  Orifice plug used in inlet drilling of flanged injectors and cylindrical injectors to adjust fuel delivery. Fuel delivery is adjusted by changing the orifice plug or by burnishing the plug in operating position, see injector description. Some orifice plugs have a flange and required a gasket beneath the flange.
- Drain Orifice

  The drilled orifice in cup end of the injector is the drain drilling. This orifice is fixed in size and must not be altered in any way.
- Metering Orifice

  The orifice in cup end of the injector allowing fuel to enter injector plunger bore and cup. This orifice is fixed in size and must not be altered in any way.
- Cup Gasket

  When PT fuel system injectors are fitted with oversize plungers, thicker cup gaskets must be used to provide the original relationship between the plunger and metering orifice. PT (type C) injectors do not use a cup gasket.

Injector parts—PT (type D)

- Adapter

  In Fig. 2-29, the adapter (2) houses the plunger return spring (1), adjustable orifice (5), orifice gasket (4), fuel screen (6) and screen retainer (7) and carries the "O" ring seals (8) on the outside which seal against the head to form fuel inlet and drain passages. Fuel enters through orifice (5) and flows to barrel (12), pass check ball (10) to the cup-to-barrel passage up to the metering orifice where it is metered into the cup (14). Fuel not used circulates past the metering orifice, around the plunger and out the drain passage while the plunger is seated in the cup. The cup, adapter and barrel are held in assembled position by the cup retainer (13).
- Metering Orifice of PT (type D) Injector

  The metering orifice near the cup end of the barrel is of fixed size and must not be altered in any way, barrels differ for engine model in relation to the size of the metering orifice as governed by engine fuel requirements.

PT (type D) is found in three forms. These being identified by the plunger diameters and found on the following engine models:

Plunger Diameter	Engine Model
5/16"	V504, V555
3/8"	NH/NT, V903, V12 1710
7/16"	K6 and KV12 2300

The Model No. marking carries the following meanings.

Example:

Flow rate	Number of injecting orifices	Size of injecting orifice	Fuel spray angle
183 (183cc for 1000 strokes)	9	9 (0.009")	18 (18°)

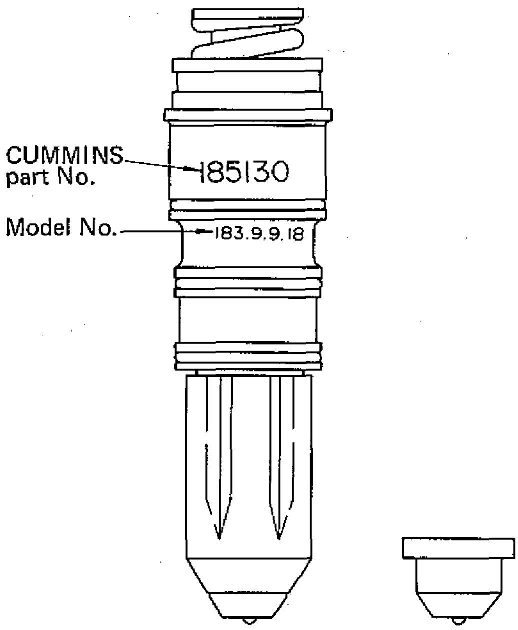


Fig. 2–30

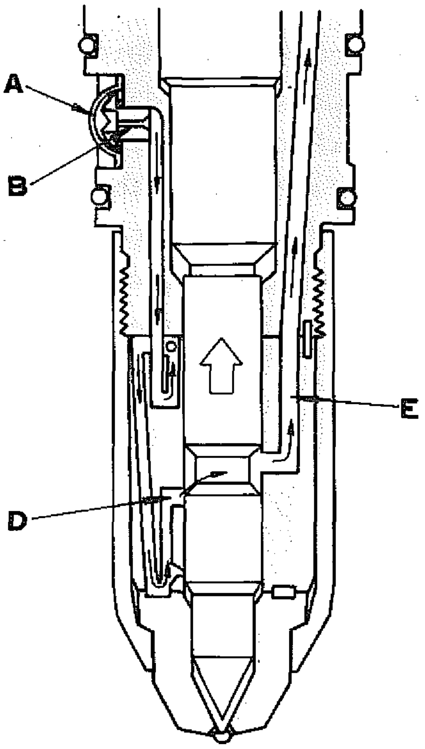


Fig. 2 — 31

Upstroke start (fuel circulates)

Fuel at low pressure enters the injector through screen (A) and flows through inlet orifice (B), internal drillings and drain passage (D) and to the fuel tank.

The amount of fuel flowing through the injector is determined by the fuel pressure at the inlet orifice and the inlet orifice diameter. Fuel pressure is also determined by engine speed, governor and throttle.

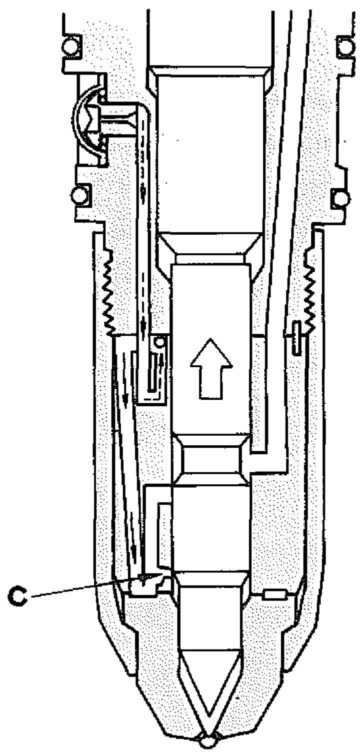


Fig. 2 — 32

Upstroke complete (fuel enters injector cup)

As the injector plunger moves upward, the metering orifice is uncovered and fuel enters the injector cup. The amount is determined by the fuel pressure. The drain passage is blocked momentarily, stopping circulation of fuel and isolating the metering orifice from pressure pulsations.

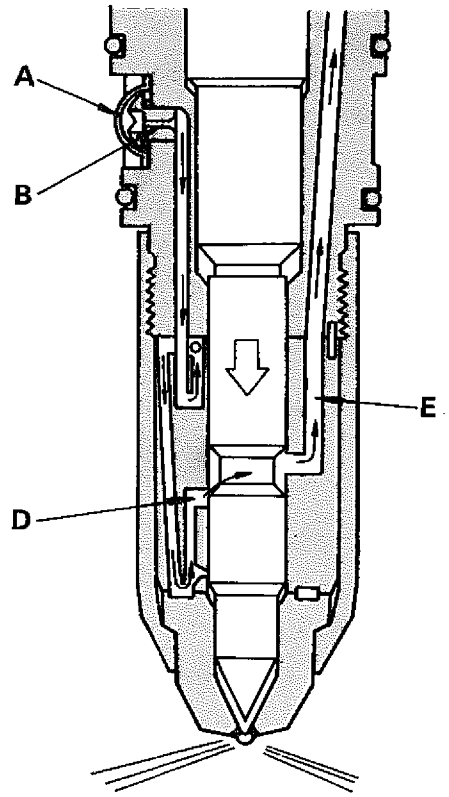


Fig. 2 – 33

Downstroke (fuel injection)

As the plunger moves down and closes the metering orifice, fuel entry into the cup is cut off. As the plunger continues down, it forces fuel out of the cup through tiny holes at high pressure as a fine spray. This assures complete combustion of fuel in the cylinder. When the drain passage is uncovered by the plunger undercut, fuel again begins to flow through the return passage to the fuel tank.

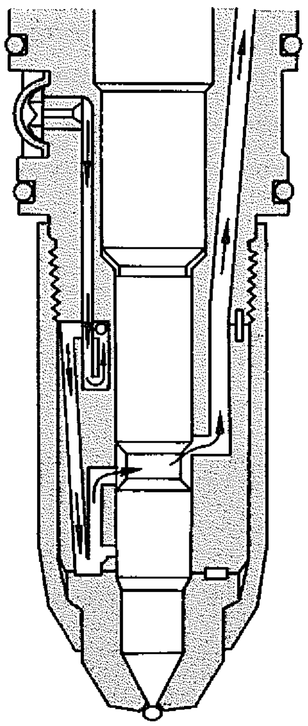


Fig. 2 – 34

Downstroke complete

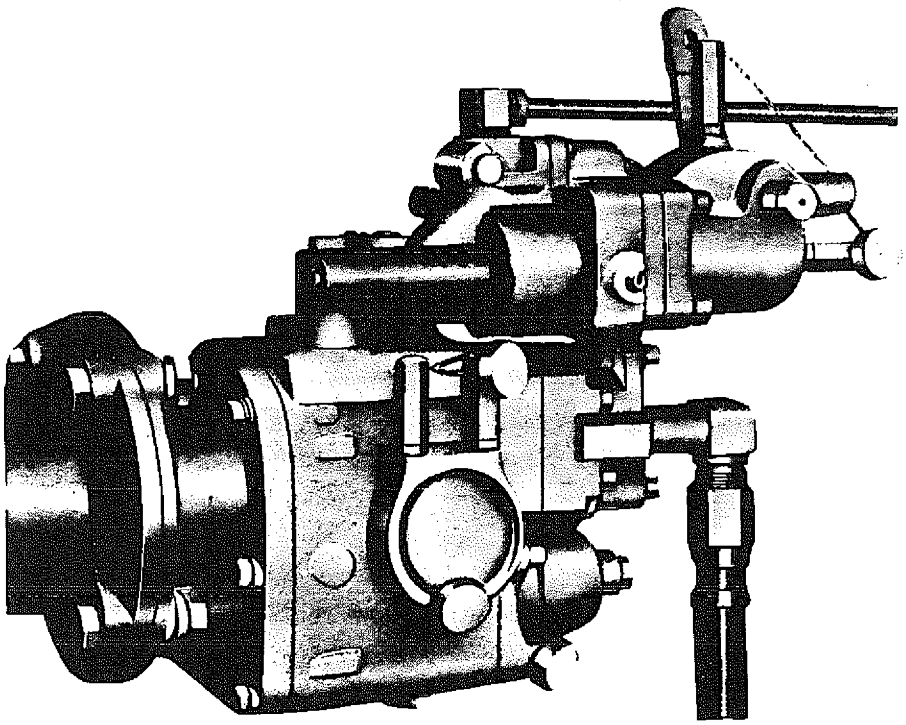
After injection is complete the plunger remains seated until the next metering and injection cycle. No fuel is reaching the injector cup. However, it does flow freely through the injector and returns to the fuel tank.

3. PT PUMP

3.1 General

The function of the PT fuel pump (or PT pump for short) is to pressurize fuel oil and supply it to the injectors. The PT pump is the principal component of the fuel system for the CUMMINS-model engines.

The PT pump pressurizes fuel oil and varies its pressure. Load requirement on the engine with the PT fuel system is met by varying the fuel supply pressure to the injectors in order thereby to vary the injection quantity.



Life and performance of the PT pump depends largely on the use of clean fuel oil free from foreign particles, particularly from water.

Many of PT-pump complaints received by the service shop have been found due to the presence of water in the fuel oil. This is because the running parts of the PT pump depend on the fuel oil for lubrication. Fuel oil carrying water is very poor in lubricating property.

3.2 Construction of the PT Pump

In the cutaway view of the PT pump below, various working elements which have relation to control the path of fuel flow are indicated. The operation of each working element in the path of fuel flow will be described in the next and subsequent pages.

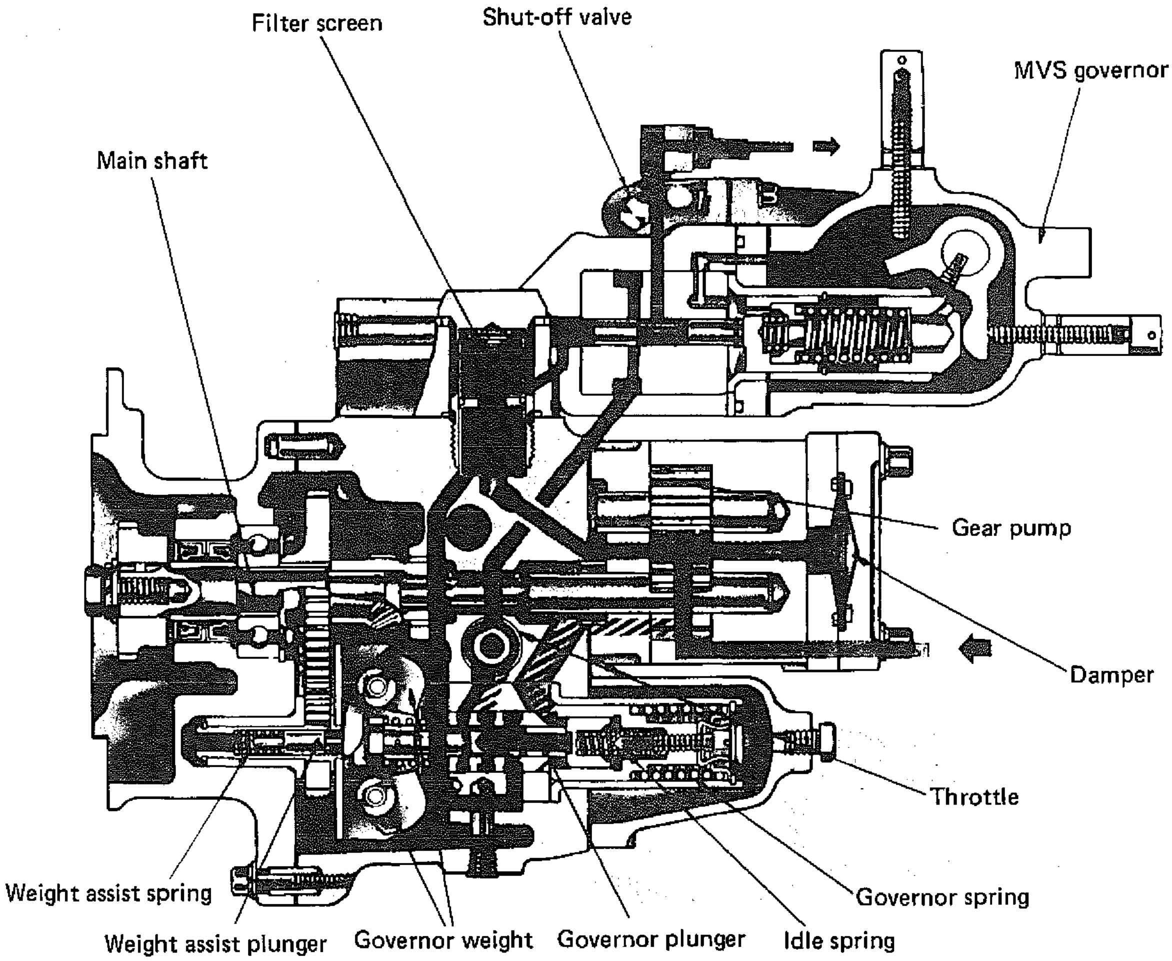


Fig. 3 — 1

GEAR PUMP

The driving shaft of this pumping element is coupled with the PT pump main shaft, which is driven from engine crankshaft. its discharge side is provided with a damper for absorbing pulses.

FILTER SCREEN

The fuel oil discharged by the gear pump flows through this filter before entering the PTG governor. The filter has a built-in permanent magnet for removing even finest ferrous particles from fuel oil.

PTG GOVERNOR

This is a centrifugal governor operating with a speed proportional to the engine speed. By regulating the fuel oil pressure being produced by the gear pump, this governor limits the highest engine speed to its maximum-speed setting.

In automotive applications, the PTG governor operates to provide a finer regulating performance for stabilizing the idling speed of the engine.

THROTTLE

The throttle is a means of reducing the pressure being transmitted from the PTG governor. In automotive applications, the accelerator pedal used by the operator is linked to this valve. In construction-machine applications, the throttle is fixed in a given position, there being no interconnection with any external control.

MVS GOVERNOR

The maximum-speed setting of the PTG governor does not permit any variation by an external means. This setting is superseded by the maximum-speed setting which the MVS governor provides.

The fuel control lever at the operator's console of an earth-moving machine is connected to the MVS governor.

In automotive applications, the MVS governor is ommited.

SHUT-DOWN VALVE

This valve is used for stopping a running engine by interrupting the fuel supply being transmitted to the injectors.
The way each component part of the PT pump operates will be explained in greater detail.

3.3 PTG Governor

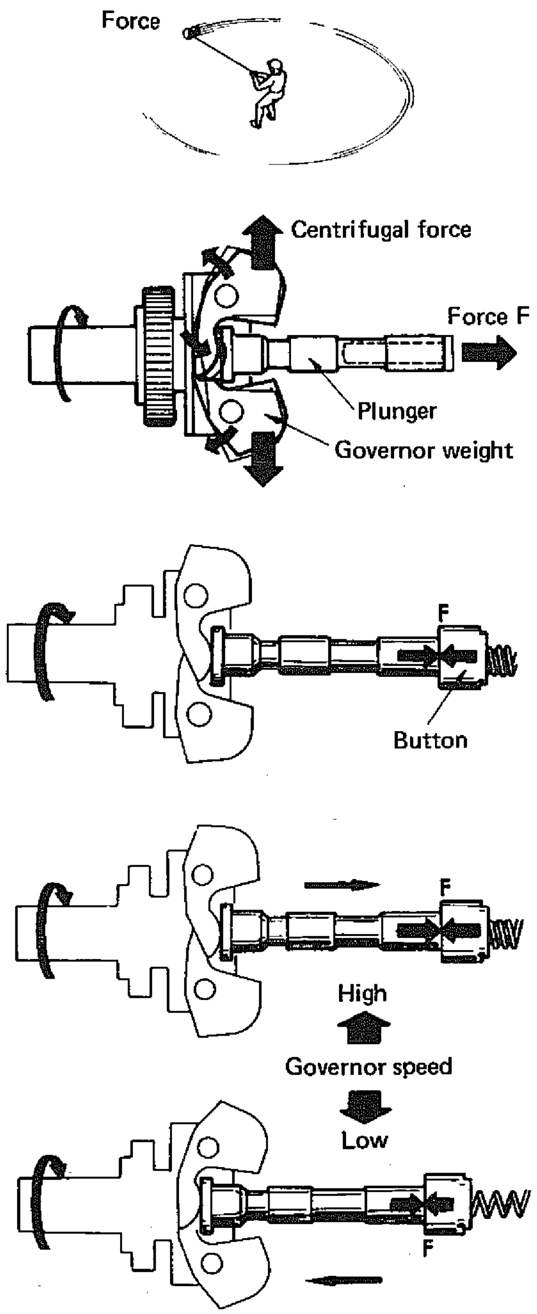


Fig. 3 – 2

Rising engine speed increases the force F available from the governor plunger.

1. When you fling a ball and sling around yourself, centrifugal force comes into play in the system. The ball tends to fly away.

2. In the PTG governor, two flyweights are set into revolving motion. Their sum centrifugal force is transmitted to and appears at the plunger.

3. The plunger exerts the force on a idle spring plunger (or "button") which is backed by a compression spring. The plunger and button remain stationary when the two forces are in balance. The force F refers to the plunger.

4. As engine speed rises, the force F overcomes the reactive force. Balance then breaks, and the plunger and button move toward the right until the reactive force due to the spring being compressed further increases to balance againt the active force F.

   As engine speed falls, the active force F decreases. Balance breaks again, and the button and plunger move toward the left until the reactive force becomes equal to the force F.

   Thus, according as the engine speed is high or low, the plunger positions itself near the left end or right end of a certain range.

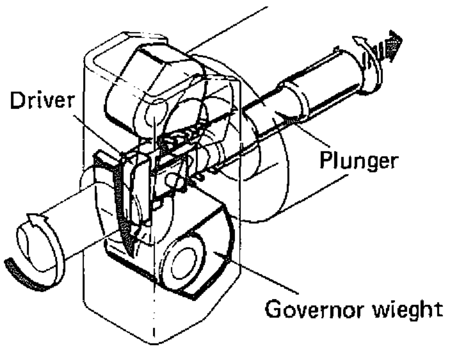


Fig. 3 – 3

NOTES:

1) The plunger rotates together with the governor weights, so that the friction loss at the force imparting portion of the governor is minimized.
2) Centrifugal force varies as the square of speed. Hence, the active force F increases rapidly even for a relatively small rise in engine speed.
3) A shear pin is used in the driver. Should the plunger become seized in place or excessively rusty to offer greater resistance, the pin would fail to prevent other parts from getting over-stressed.

Fuel supply pressure is modified according to changes in the force F.

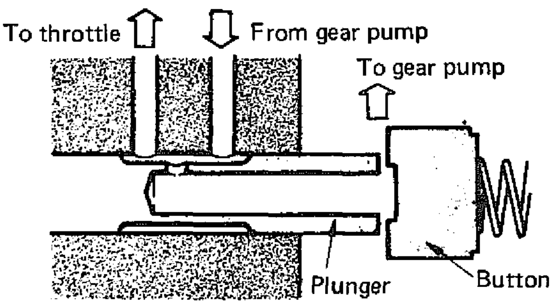
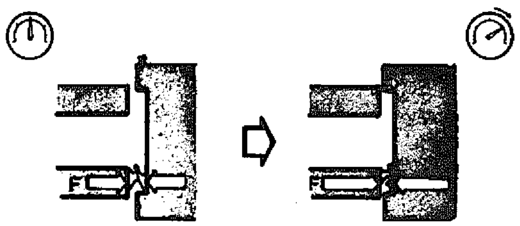


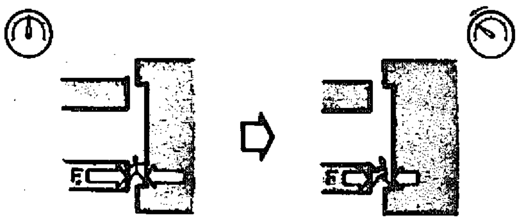
Fig. 3 – 4

5. The plunger has an annual recess on its outer surface and an internal or hollow space communicating to the recess. This recess serves as a linking path of fuel flow from inlet port to outlet port, as shown. The open end of the internal space, filled with fuel, is covered by the end face of the button.

The pressure within the plunger – internal pressure – is nearly equal to the pressure with which the fuel oil flows into the outlet port, except under extreme operating conditions. Equilibrium occurring at the plunger end holds the internal pressure at a level proportional to force F. We shall next see how and why:



If force F increases



If force F decreases

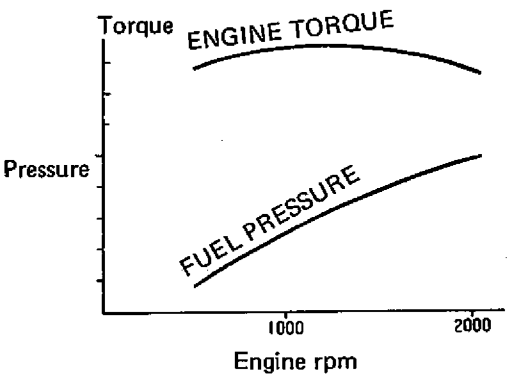


Fig. 3 – 5

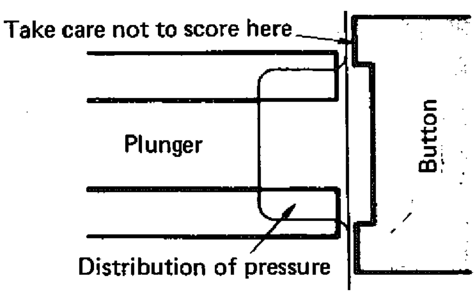


Fig. 3 – 6

6. Because of the internal pressure, a clearance occurs between the plunger end and the button face, and fuel oil leaks out through the clearance. When button and plunger are at standstill, the following equation exists:

   Force F = force due to internal pressure
   = reactive force (by button)

   If force F increases, the clearance narrows to decrease the amount of leakage, so that internal pressure will rise. A decrease in force F widens the clearance to increase the amount of leakage, resulting in a lowered internal pressure.

7. As engine speed rises, force F increases to raise internal pressure and, hence, supply pressure (being transmitted to the injectors through the throttle), thereby preventing the injection quantity from decreasing. The sum-total effect is a constant torque output of the engine.

   In the graph given on the left, the relationship among TORQUE, SPEED and FUEL SUPPLY PRESSURE is illustrated for a typical engine. Note that the PT-controlled fuel pressure varies with engine speed.

NOTE:

The internal pressure acts on a projected area of the recess provided in the end face of the button. This means that, if the type of button is changed, that is, if its recessed area is increased or decreased, the operating characteristic of the PT pump will change. Furthermore, any alteration of the two abutting faces (of plunger and button) by scoring or nicking, for example, will affect the PT pump performance materially.

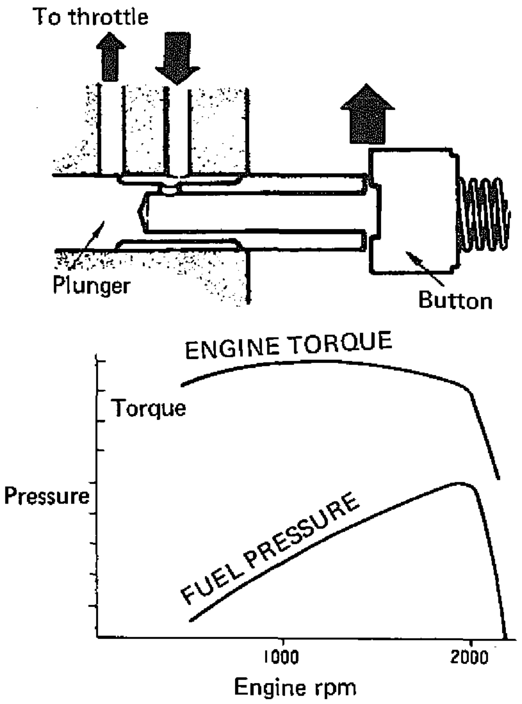


Fig. 3 – 7

As engine speed nears the limit, fuel supply pressure starts falling rapidly.

8. Suppose the speed gradually approaches the limit. The plunger will move progressively toward the right. At each point during this movement, equilibrium exists at the leaking clearance but the level of equilibrium rises as the clearance diminishes in step with the rising speed.

   In time, the highest level of supply pressure will be reached and then the force **F** will have taken the maximum value. Under this condition, the annular recess of the plunger is ready to throttle the fuel flow at the outlet port.

   Just before the maximum engine speed is reached, the plunger starts throttling at the outlet port, as shown. When the maximum engine speed is reached, the supply pressure will be so low that no further rise in speed is possible.

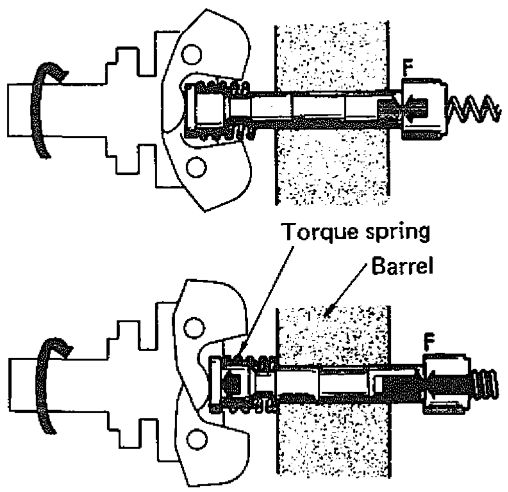


Fig. 3 – 8

The torque spring improves high-speed engine performance.

9. The torque spring mounted on the plunger is idle when the plunger is at or near the left end of its travel range. As the speed rises, the plunger moves toward the right and, in time, begins to compress the torque spring.

   From this point, the increasingly large force F due to centrifugal action is countered by two forces, one by the torque spring and the other by the button.

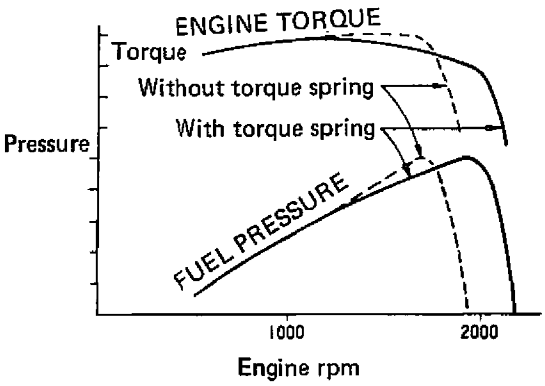


Fig. 3 – 9

Without the torque spring, rising engine speed would sooner bring the plunger to the position where its annular recess starts throttling at the outlet port. In other words, the speed level at which the maximum supply pressure occurs would be lower than when the torque spring is incorporated. This relationship is represented by the obvious difference between the two sets of curves, dot-line and solid-line, in the graph on the left.

The object of modifying the operating characteristic by means of the toruqe spring is to make greater torque output available in the higher-speed range. The torque spring begins to be compressed at an engine speed slightly above the maximum-torque speed (1100 – 1200 rpm in the graph).

The weight assist spring improves low-speed engine performance.

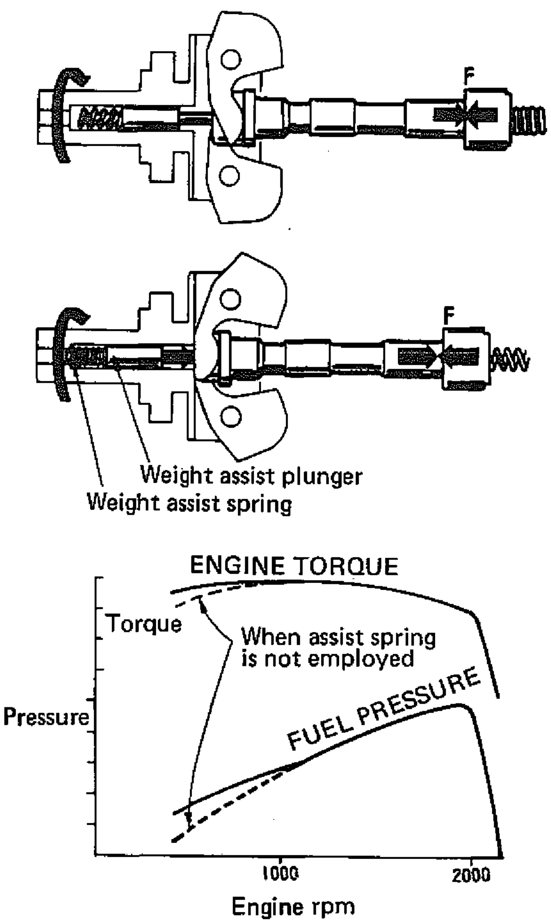


Fig. 3 – 10

10. The assist spring, installed in the bore of the driver shaft and backing the weight assist plunger, is in free relaxed state when the main plunger is displaced toward the right during high-speed operation.

    As the speed falls, the main plunger moves back toward the left and starts compressing the assist spring. This occurs at a speed slightly below the maximum-torque speed (1100 – 1200 rpm in the graph). From this point on, the assist spring exerts force increasingly for, not against, the force F that is now decreasing. Thus, the assist spring prevents the force F from decreasing rapidly. Stated differently, fuel supply pressure will decrease more slowly with falling engine speed than when the assist spring is not employed.

    The effect of this manner of modification is a greater torque output available in the low-speed range, as will be noted in the graph given on the left.

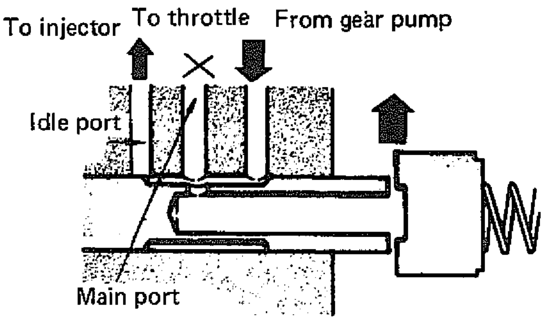


Fig. 3 — 11

PTG governor stabilizes the idling speed (in automotive applications).

11. The throttle is actuated from the accelerator pedal to decrease the fuel supply pressure being transmitted to the injectors. When throttling is effected increasingly, the engine comes down in speed on account of the resultant reduction in injection quantity, thereby causing the main plunger to move toward the left and open another port (idle port) which communicates directly to the injectors.

    The fuel flow through the idle port keeps the engine idling. Should the idling speed fall for one reason or another, the plunger moves further to the left to open the idle port more and thereby increase the injection quantity to restore the speed.

NOTE:

Idling speed stabilization is accomplished by the MVS governor in construction-machine applications.

Minor speed fluctuation or hunting during the engine idling maintained in the foregoing manner would be inevitable. Such hunting, however, is eliminated by one of the two springs located behind the button. This feature will be discussed next.

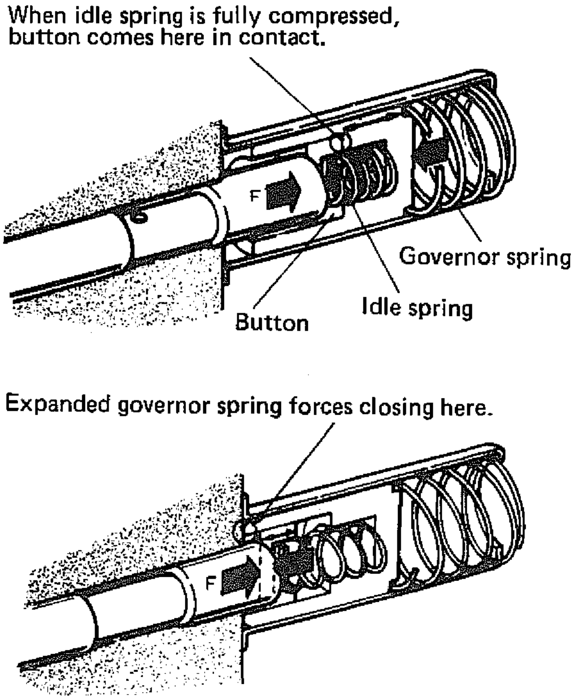


Fig. 3 – 12

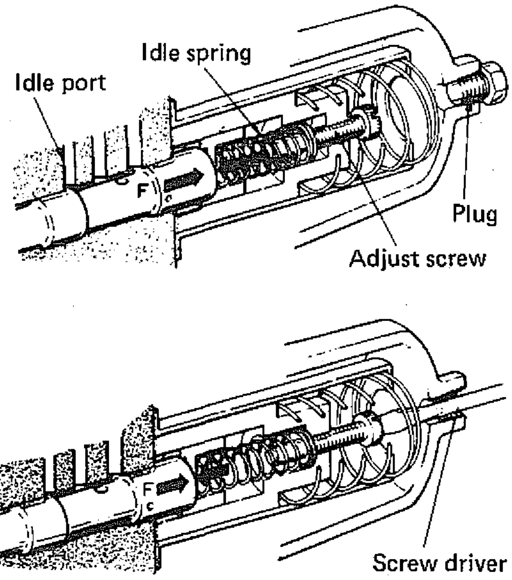


Fig. 3 – 13

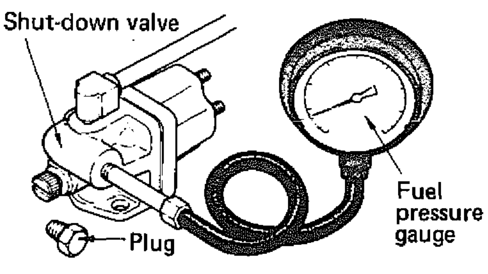


Fig. 3 – 14

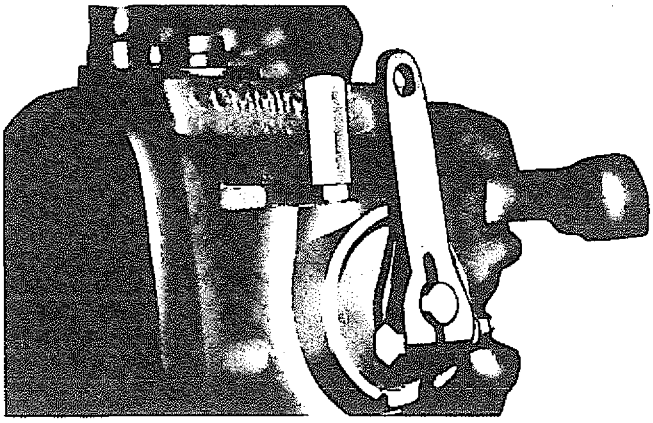
12. As will be noted in the cutaway view shown on the left, both the idle and governor springs back up the button. When the force **F** increase during a speed rise from idling to the normal operating range, the idle spring soon becomes fully compressed and thereafter the governor spring counters the increasingly large force F. With the engine in idling condition, force F is small and the idling spring is only partially compressed. Under this condition, the idling spring plays with minor cyclic changes in the small force F, and enables the plunger to move back and forth through a greater stroke.
Why a greater stroke? The answer lies in the fact that a weak spring shrinks or contracts more than a strong spring where the force applied to the spring is kept constant for both cases.
Because of the greather plunger movement, the governor action for holding the idling speed steady is quicker in response.

13. The engine idling speed must be capable of being set at a desired speed level. This requirement is met by means of the adjusting screw for preloading the idle spring more or less.
Turning the adjusting screw in will increase the preload of this spring to raise the idling speed, and vice versa. The screw is accessible through a normally-closed opening provided in the casing.

NOTE: **Checking the supply pressure**

When an abnormally low fuel supply pressure from the PT pump to the injectors is suspected because of a noticeably low power output of the engine, check the supply pressure by means of a test gauge. The test gauge is to be connected into the shut-down valve. The gauge connection is provided in the valve casing. It is normally closed with a screw-in plug.

3.4 Throttle



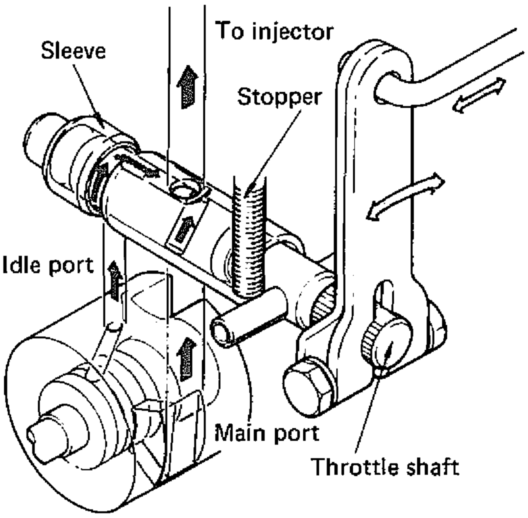
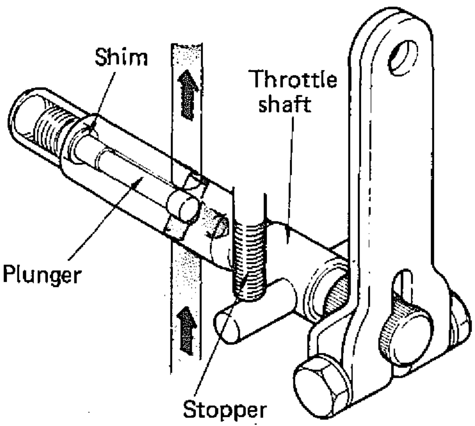


Fig. 3 — 15



14. The throttle is a rotary cock located in the path of fuel flow from the PTG governor to the injectors. Throttling the flow of fuel at this point reduces the injection quantity and decreases the torque output of the engine.
    The throttle shaft is turned by the accelerator pedal through a system of linkage. Depressing the accelerator pedal turns the shaft in the direction for decreasing the resistance which the throttle offers to the flow of fuel.

15. Oilways in the form of groove and drilled hole are provided in the throttle shaft. An adjusting rod, inserted into the axial hole, has its tip extending into the oilway leading to the injectors and obstructs the flow of fuel there. The rod is to be so adjusted, when the throttle is in full-open position, as to lower the supply pressure to the specification value in order to secure the prescribed maximum injection quantity. The rod can be repositioned by changing the thickness of its shim.

    The stopper limits the angular position of the throttle shaft for the minimum fuel flow.

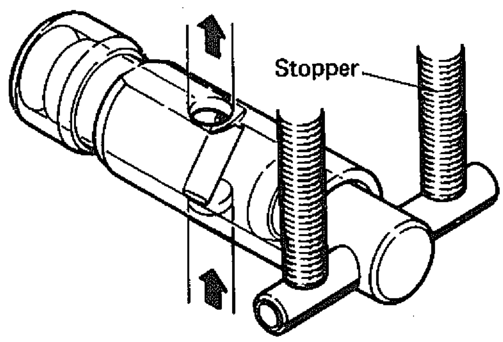
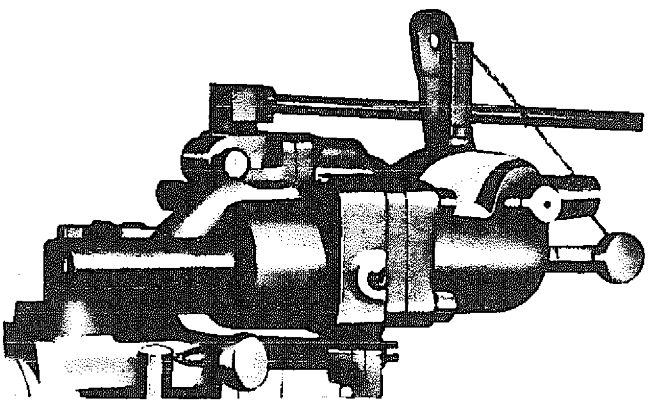


Fig. 3 — 16

16. The throttle arrangement shown here is for the PT system applicable to construction machines. The throttle shaft is not equipped with the adjusting rod. By means of two stoppers, it is locked in a fixed position for providing the specification supply presure. The fixed position is to be determined by testing, that is, by taking pressure readings on the PT pump being operated in the test equipment; and the two stoppers are to be set and secured to lock the shaft in the determined positon.

3.5 MVS Governor



MVS govenor, included in the PT pump for construction-machine applications, is a means of readily varying MAXIMUM ENGINE SPEED.

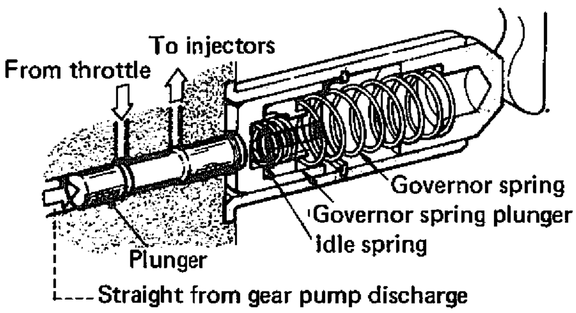


Fig. 3 — 17

17. In the cutaway view on the left, fuel pressure (straight from the gear pump discharge) acts on the end face of the plunger, as indicated by the arrow, and forces the plunger against the button. The button is backed by the idle spring (for minor pressure fluctuation during idling) and the governor spring (for pressure change in the normal operating range). As in the PTG governor, equilibrium occurs between the force due to fuel pressure and the spring force.

The plunger takes its position depending on the level of equilibrium. When the gear pump is running fast, the plunger will be displaced toward the right and opposed by the governor spring with a greater force.

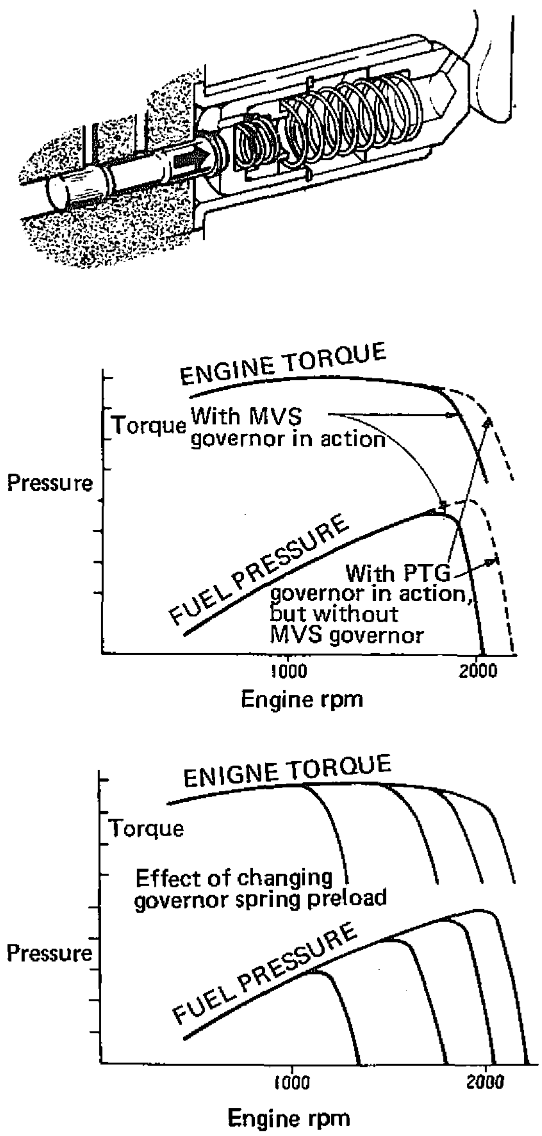


Fig. 3 – 18

When the engine is idling, the plunger will be displaced toward the left, with the governor spring nearly fully expanded, and the rightward force of the plunger will be countered by the idle spring.

The mid-section recess of the plunger communicates both the inlet port (from the throttle) and outlet port (to the injectors). Governor action here is accomplished through the above-mentioned movement of the plunger.

In the higher fuel pressure range (corresponding to the higher range of engine speed), the plunger throttles the fuel flow at inlet port more or less. As the speed approaches the limit, the fuel supply pressure to the injector decreases rapidly owing to greter throttling action at inlet port. Consequently the injection quantity decreases similarly, and so does the torque output of the engine. A point will be reached where the engine cannot run any faster. That point is the maximum engine speed for the given setting of the governor spring.

If the governor spring is preloaded more, the maximum speed will occur at a higher level of speed. This connection will be discussed more fully.

18. Consider the plunger locating itself in throttling position: the plunger is at standstill in that position, and this means that the two forces are in balance. Such balanced or equilibruim state could occur with different magnitudes of force, but can occur only with one magnitude where the preload of the governor spring is held constant.

The effects of changing this preload are represented by a number of droops or dips in the torque and fuel-pressure curves.

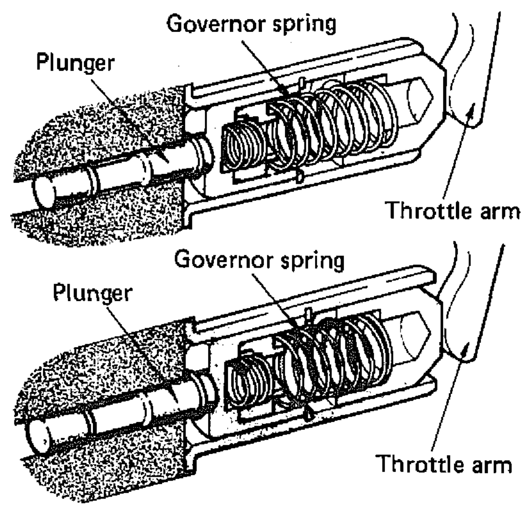


Fig. 3 – 19

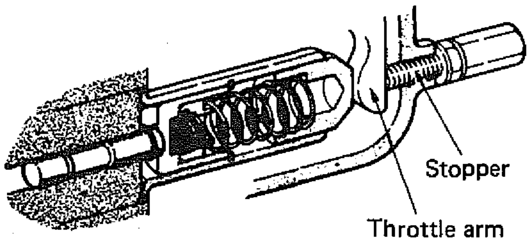


Fig. 3 – 20

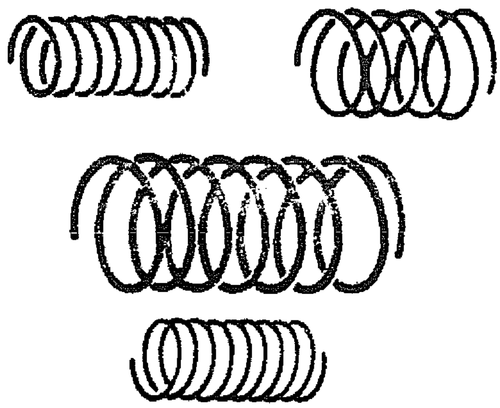


Fig. 3 – 21

19. The throttle arm located behind the seat of the governor spring is the means of changing the preload of this spring. The arm is actuated from the fuel control lever (at the operating console of the machine) through a linkage. With the governor spring compressed (preloaded) more, the throttling action mentioned above begins to occur at a higher engine speed, and vice versa.

Idling

20. Under idling condition, fuel pressure acting on the plunger is low, the governor spring is in relaxed (nearly de-compressed) state, and the idling spring opposes the thrust of the plunger. Changes in the fuel pressure (representing the idling speed fluctuations) will be quickly responded to by the plunger, since the plunger under this condition moves through a greater stroke for a given change in idling speed, just as in the case of the PTG governor under similar condition, to quickly stabilize the idling speed.

    Preloading the governor spring just slightly will sufficiently preload the idling spring and will thus raise the idling speed maintained by the MVS governor.

NOTE:

Springs accurately dimensioned and sized for specified spring rates are used in the PT pump. These springs must not be tampered with or replaced by wrong springs. The control characteristics of the PT pump are determined largely by these springs. Taking the PTG governor, for instance, its springs named below closely affect the following engine performance items:

Springs	Performance items
TORQUE SPRING	Maximum speed and high-speed torque output
WEIGHT ASSIST SPRING	Low-speed torque output
GOVERNOR SPRING	Maximum speed
IDLE SPRING	Idling speed stability

3.6 Shutoff Valve

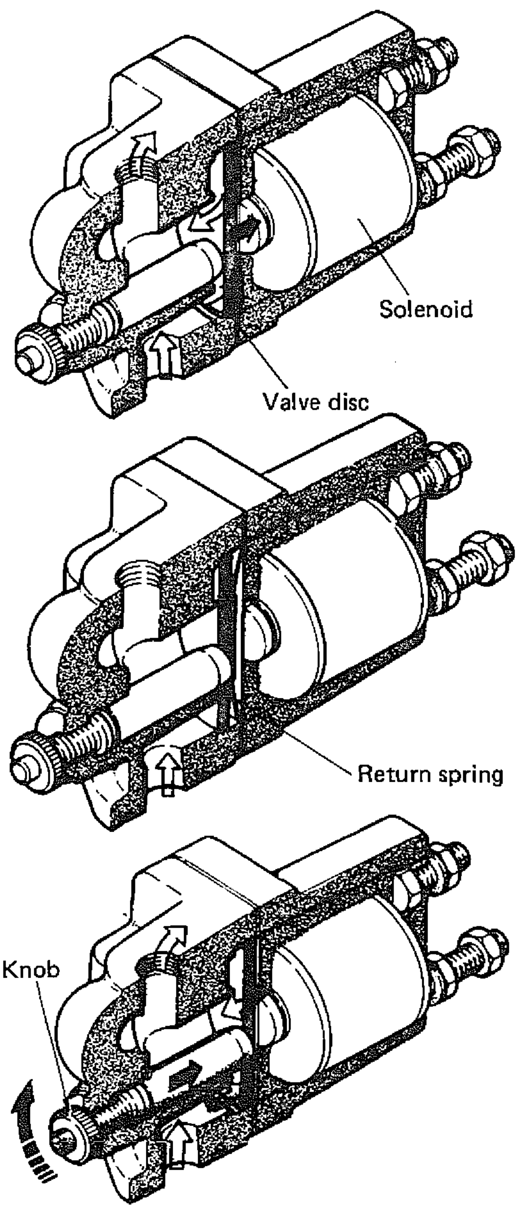


Fig. 3 – 22

21. The shut-down valve is a solenoid-operated unit taking either "OPEN" or "CLOSED" position according as the solenoid is energized or deenergized. Turning the starting switch on at the operating console energizes the solenoid to pull the valve disc against the force of the return spring.

    Two threaded studs, unequal in length, are used as the terminals. The positive side of the battery is connected to the long stud. The short stud is in the grounding circuit and does not take up any wiring. If the source of electricity is lost, as when the battery or electrical system has failed, the engine may have to be started by cranking from the drive line. This is usually done by towing the machine with the clutch engaged. In such a case, the shut-down valve is to be gagged open by turning in its manual knob. To stop the engine, then, the knob must be turned back.

    Suppose the starting switch is turned off accidentally during downhill coasting with the engine being driven from the drive line. The shut-down valve may refuse to open thereafter as long as the gear pump is running with the engine under coasting condition. This refusal is due to the fact that the fuel pressure in the shut-down valve will keep the valve disc pushed hard against the seat with a much greater force than the pull the solenoid can develop. In such a case, the machine must be brought to a halt and then the engine re-started in the usual manner.

NOTE: Filter cleaning (at intervals of 500 operating hours)

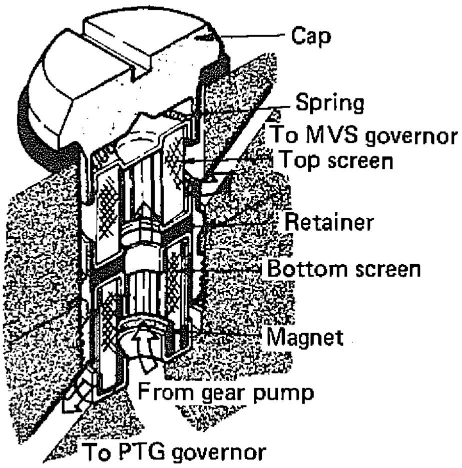


Fig. 3 – 23

To service the filter, remove its cap, take out the screens and wash them clean with a washing fluid. Dry the washed screens with compressed air.
The torque limit on the cap is 3.5 – 4.2kg.m (25.6 – 30.6 ft-lb).

The PT pump for construction machines has two screens in its filter. One screen is finer in mesh than the other. The fine-mesh screen is the top screen and the coarse-mesh screen is the bottom one. Be sure to discriminate one from the other.
These screens should be handled with greater care so as not to rupture their mesh.

The top screen in place has its closed end brought to the top side. An inverted top screen in place will close the path of fuel flow.

3.7 Integral Type PT (type G) Fuel Pump Cooling Feature

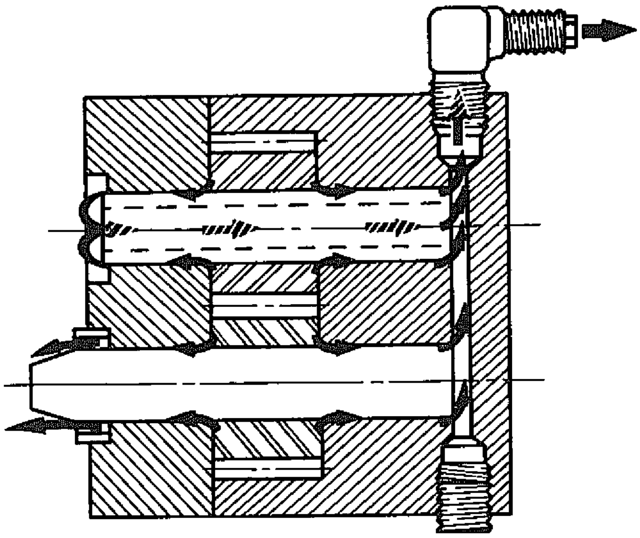


Fig. 3 – 24

Fuel pumps have been revised to incorporate a new fuel pump cooling feature as an integral part of the gear pump.

The small amount of fuel which this new cooling device routes back to the fuel tank, previously was recirculated internally. Therefore, this method of cooling does not use any of the normal delivery of the gear pump and present fuel pump calibration specifications will still apply.

This bleed fuel is that fuel which flows through and lubricates gear pump bearing bores. Previously, this fuel was dumped back into the suction side of the gear pump. With the integral bleed gear pump, the lubricating fuel flow through three gear pump bearings is bled off through an external tapped drain hole. The former internal pump drillings which permitted this fuel to return to the suction side, have been eliminated.

The inboard main shaft bearing bore still returns its fuel to the gear pump suction. The inboard idler shaft bearing fuel flows through the hollow idler shaft to the external drain line. As can be seen from the sketch both outboard gear pump bearings drain externally.

Since three of the bearing bores drain externally, it is apparent that both tapped holes in the gear pump housing cannot be plugged. Plugging both tapped openings will prevent lubricating and cooling fuel flow through the three bearing bores and gear pump seizure will occur.

Both ends of the through drain drilling are tapped so that gear pumps can be converted from R.H. to L.H. in the normal manner.

Under no circumstances should the pump be operated with the cooling return flow plugged. This fuel flow is necessary to lubricate the bearing surfaces within the gear pump.

It has to be noted that the spring loaded check valve is included in the elbow fitting at the outlet of the gear pump to prevent the reverse flow.

3.8 Aneroid Control Valve

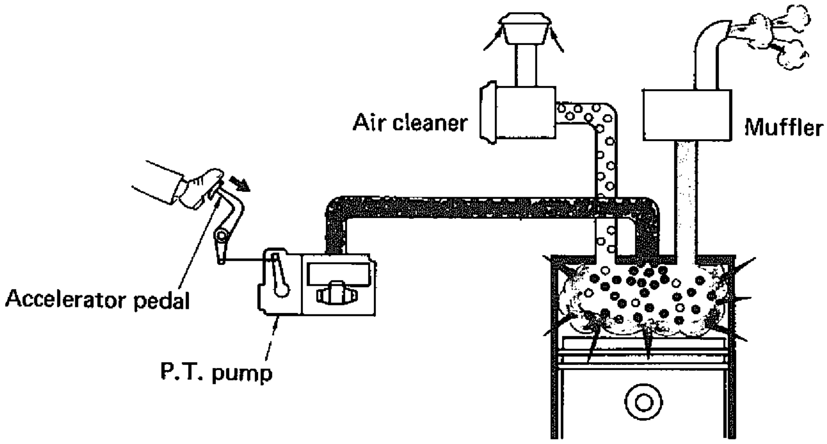


Fig. 3 – 25

When an engine is running at low speeds, and an accelerator pedal is depressed quickly, intake air does not increase in volume appropriate to increased fuel. Since the fuel control system is connected mechanically by linkage, fuel supply can be increased almost simultaneously. On the other hand, air intake increases only after engine speed rises.

In order to prevent black smoke, which easily arises from a lack of air, the aneroid control valve controls fuel supply so that only fuel appropriate to air volume supplied to the engine is injected.

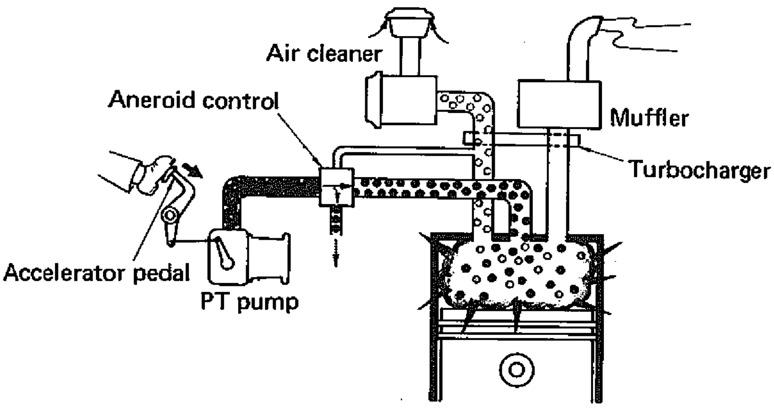


Fig. 3 – 26

- **Structure and function**

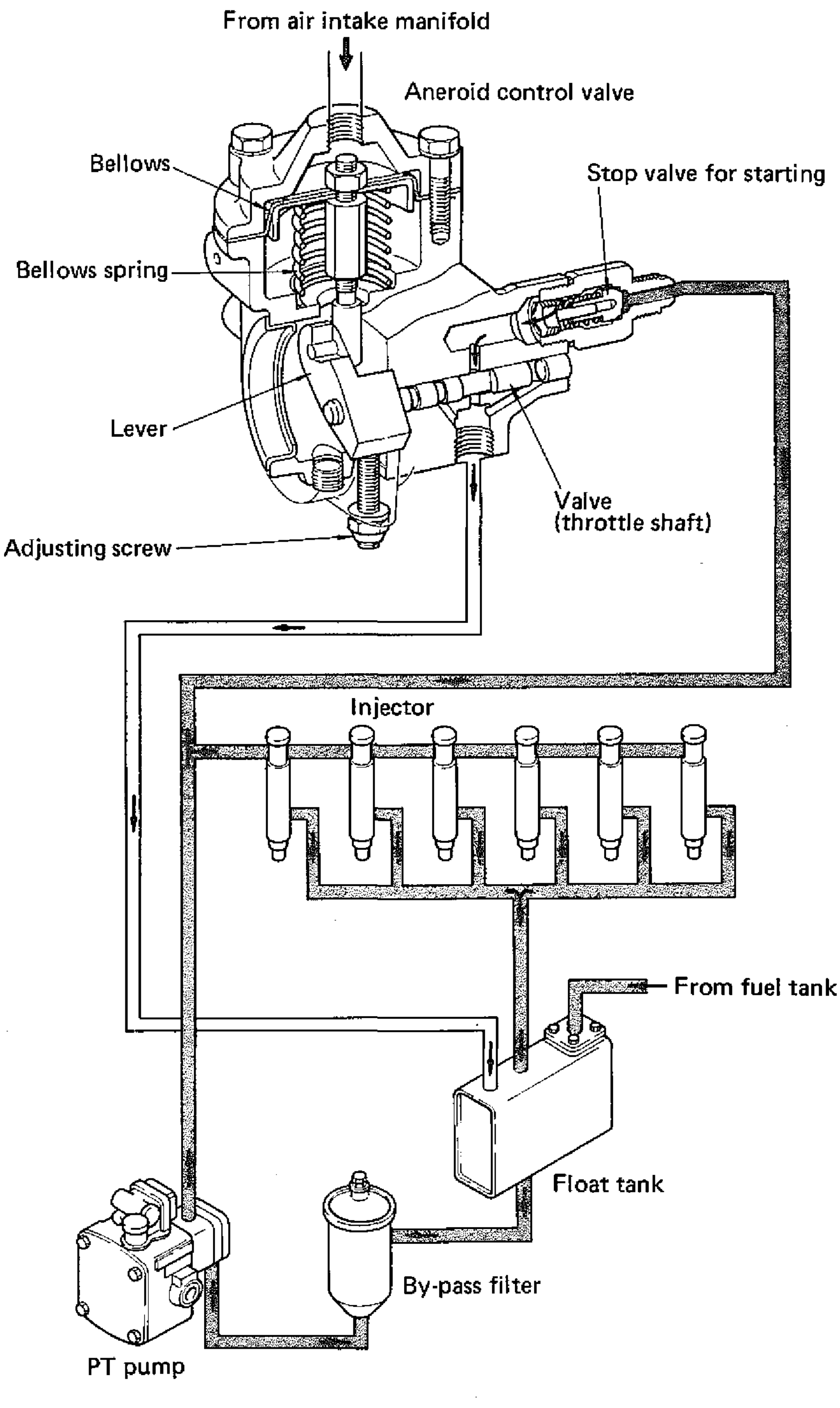


Fig. 3 – 27

Fuel flow is as in drawing above. A part of the fuel under the pressure from the PT pump goes to the aneroid control valve to make by-pass circuit.

- **Starting;**

  When the engine is started with a starting motor, volume of fuel supplied by the PT pump is small and its pressure also is low. Consequently the stop valve for starting remains closed, fuel is not by-passed and starting is made easy.

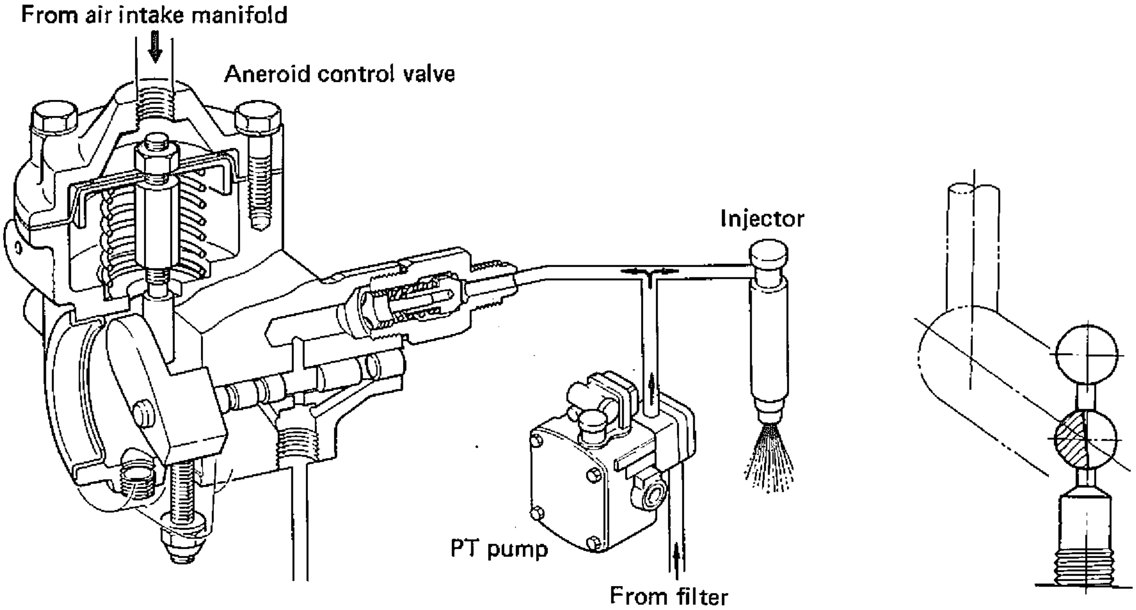


Fig. 3 – 28

- **Idling;**

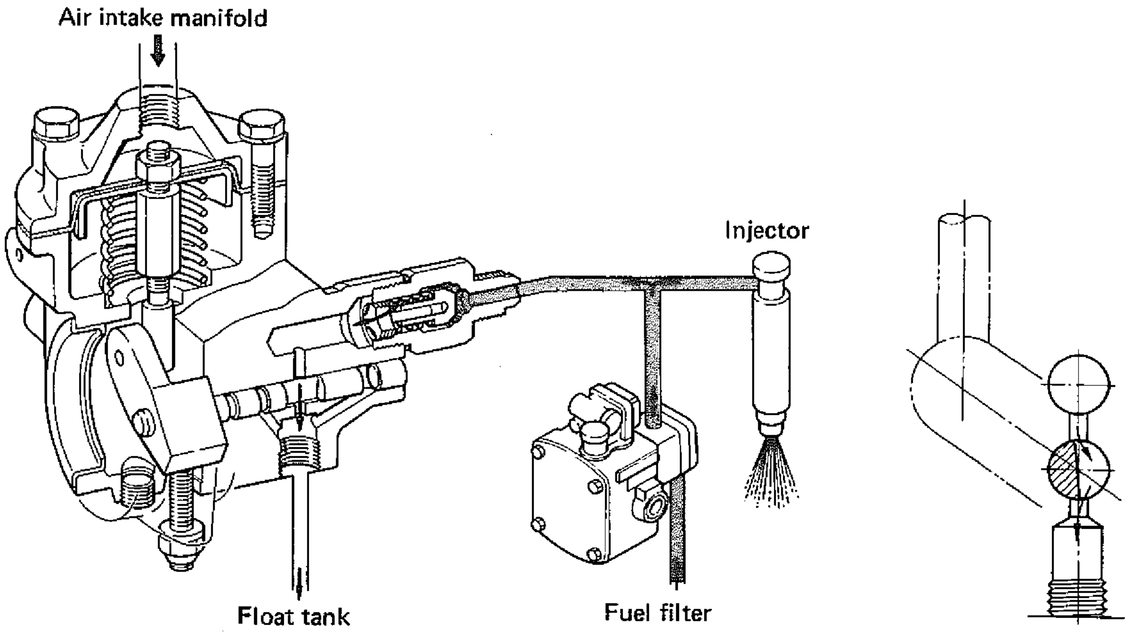


Fig. 3 – 29

Once the engine starts fuel pressure overcomes the force of the spring of the stop valve for starting, pushes the valve up, and a some of the fuel flows into the valve (throttle shaft).

When running at low speed, the valve is fully open because air intake manifold pressure is low, and fuel passes through the notches and is by-passed to the float tank.

- **Rapid acceleration**

When engine speed is increased rapidly (when accelerator pedal is depressed suddenly) the turbo-charger speed cannot be increased fast enough, and air intake manifold pressure is low. Therefore, the valve is open and fuel is by-passing.

As air intake manifold pressure rises and becomes greater than the bellows spring force, the bellows are pushed up, the valve (throttle shaft) is rotated by a lever and the notch begins to close. Until before the notch is fully closed, the fuel continues to by-pass through the valve that the fuel pressure to the injection is low not to cause the black smoking.

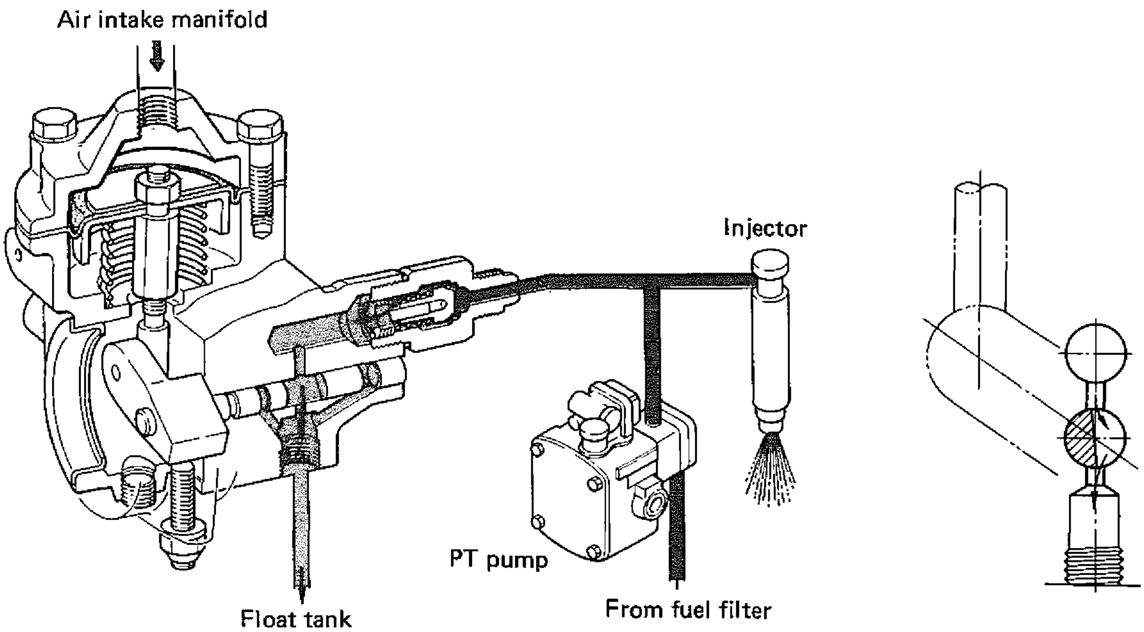


Fig. 3 — 30

- **Normal driving**

  During normal running when engine speed increases (turbocharger revolutions also increase) and air intake manifold pressure is greather than the set pressure of the bellows spring, the notch of the valve (throttle shaft) is shut. Therefore, since fuel cannot by-pass, the engine gives the same performance (output) as an engine without an aneroid control valve.

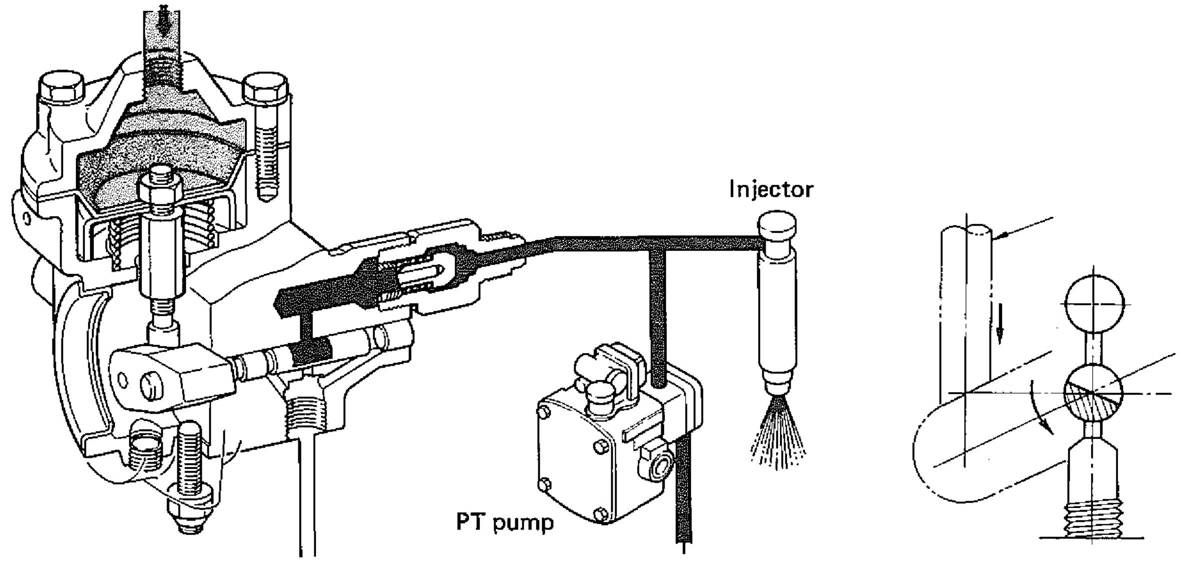


Fig. 3 – 31

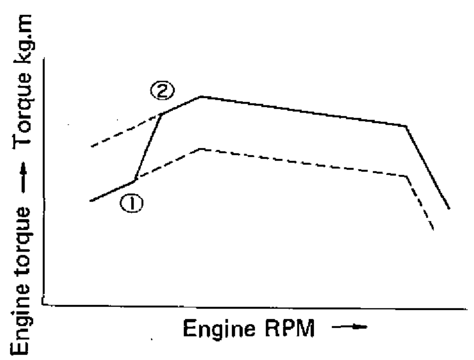


Fig. 3 – 32

The graph on the left indicates torque to engine RPM relationship of a particular cummins engine. It shows that this engine performs in the same manner as the engine without a turbocharger at RPMS higher than that shown by (2).

(1): Point where notch begins to close (air intake manifold pressure .... 100 ~ 130mmHg)

(2): Point where notch has finished closing (air intake manifold pressure .... 355mmHg)

3.9 AFC Control

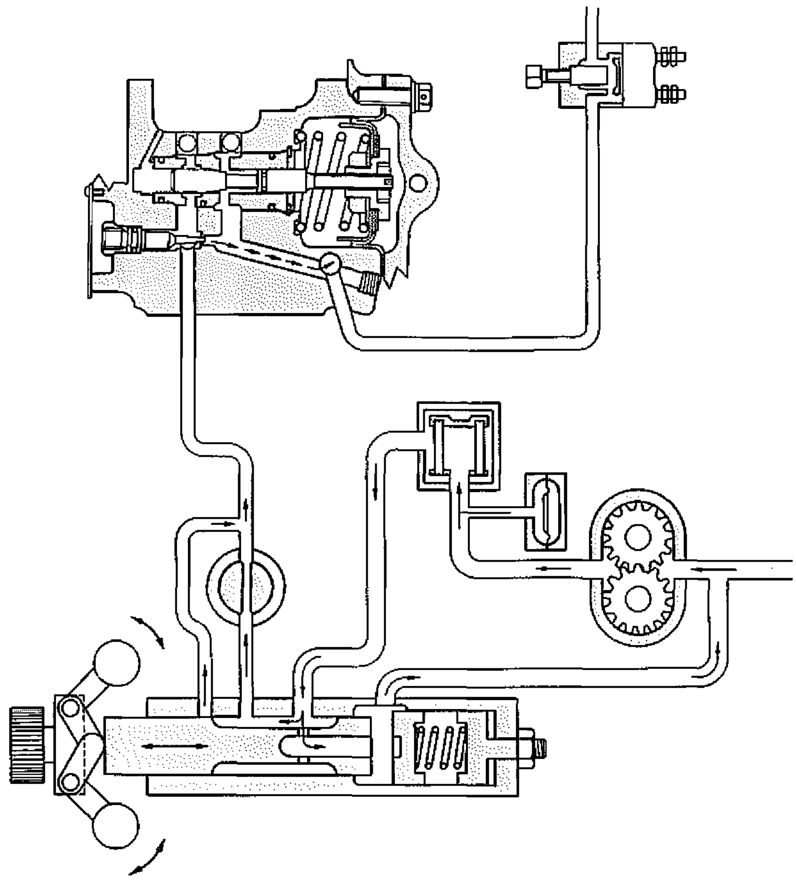


Fig. 3 – 33

The new model PT (type G) AFC fuel pump has been newly designed as an alternate to the PT (type G) fuel pump plus aneroid combination for engines with turbocharger. It basically differs from the aneroid valve which by-passes fuel pressure in on or off manner. Its function is to control the air to fuel mixture rate by limiting fuel pressure and fuel flow so that during engine acceleration period air and fuel mixture rate are in the correct proportion.

There is an particular plug to be installed in the housing of fuel pumps for engines which do not require a air/fuel mixture control. All engines have this housing as a standard.

Functional principle

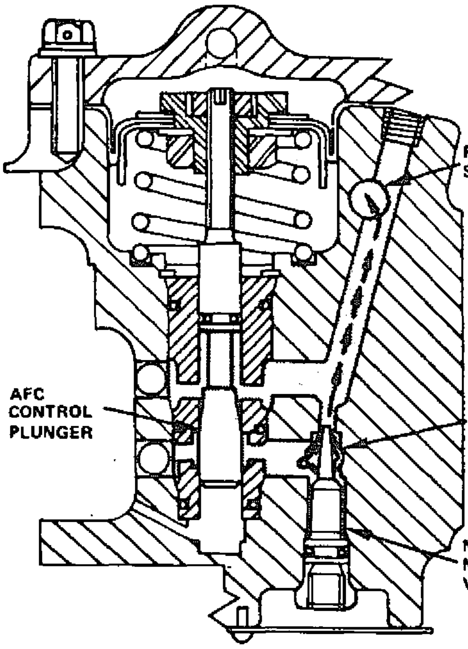


Fig. 3 – 34

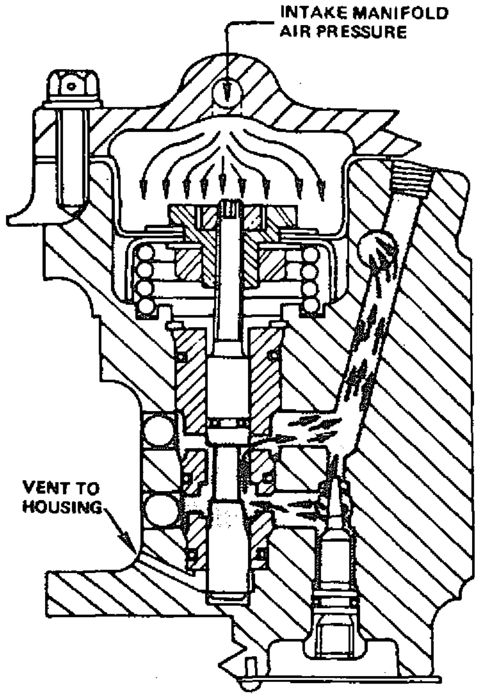


Fig. 3 – 35

The difference between the PT (type G) and PT (type G) AFC fuel pumps is in the line between the fuel pump throttle shaft and fuel shutoff valve. Fuel flows from the throttle shaft directly to the fuel shut-off valve in the PT (type G) fuel pump.

In the PT (type G) AFC fuel pump, fuel leaving the throttle shaft passes through the AFC unit to the fuel shut-off valve. (See above left figure).

Above right figure shows the fuel flow when the AFC control plunger is in "NO-AIR" position. It shows the condition when an engine (with turbocharger) starts and its speed is low so intake manifold pressure is too low to overcome AFC spring force. Fuel flows from the throttle shaft along the "NO-AIR" needle valve passage. The needle valve acts to check pressure and flow. The AFC plunger blocks the passage of fuel flow through the AFC barrel.

3.10 PTG-VS Governor

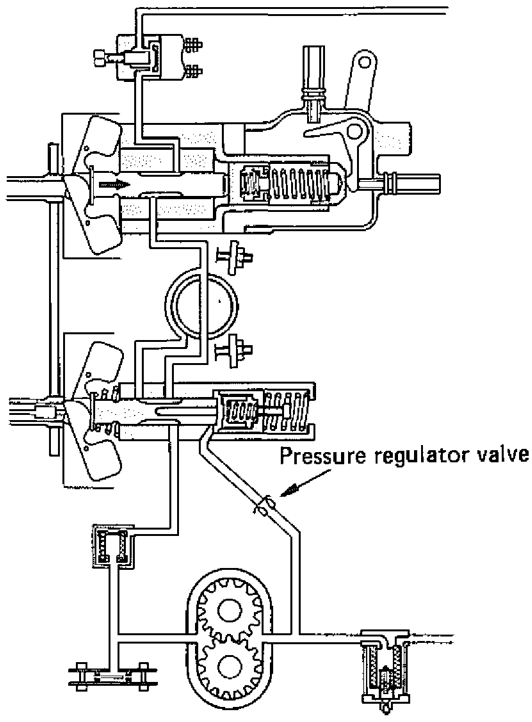


Fig. 3 – 36

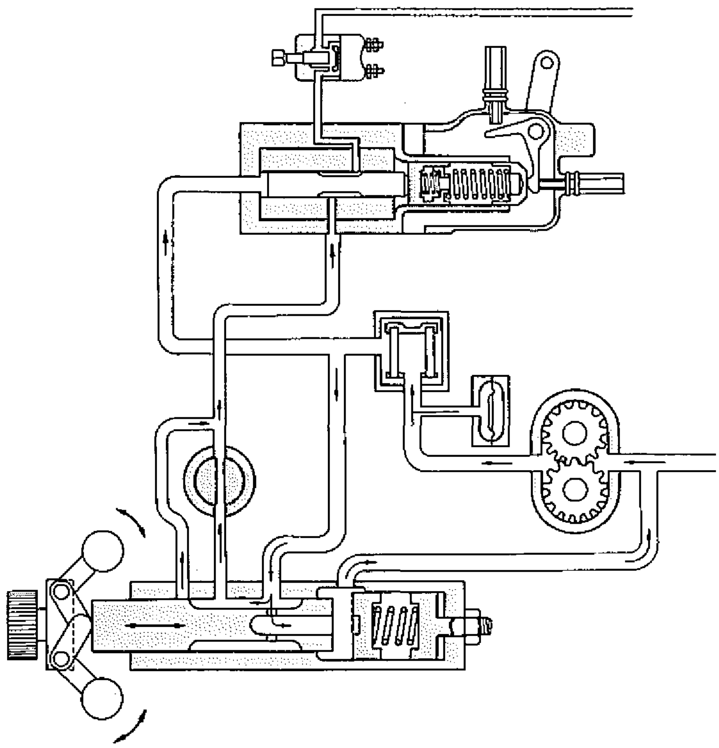


Fig. 3 – 37

Comparing the arrangement of the PTG-VS governor and the PTG-MVS governor

The VS governor has been designed to supplement the current PT (type G) standard automotive governor. This pump plays a role of PT (type G) MVS.

This pump regulates speed over the total engine speed range without surging. With PTG-VS governor engine speed droop rate is less than that with all previous pumps as shown in Fig. 3–38.

Also, when compared with MVS governor its stability and response is superior. (Movement of the VS governor plunger is smooth because it rotates.)

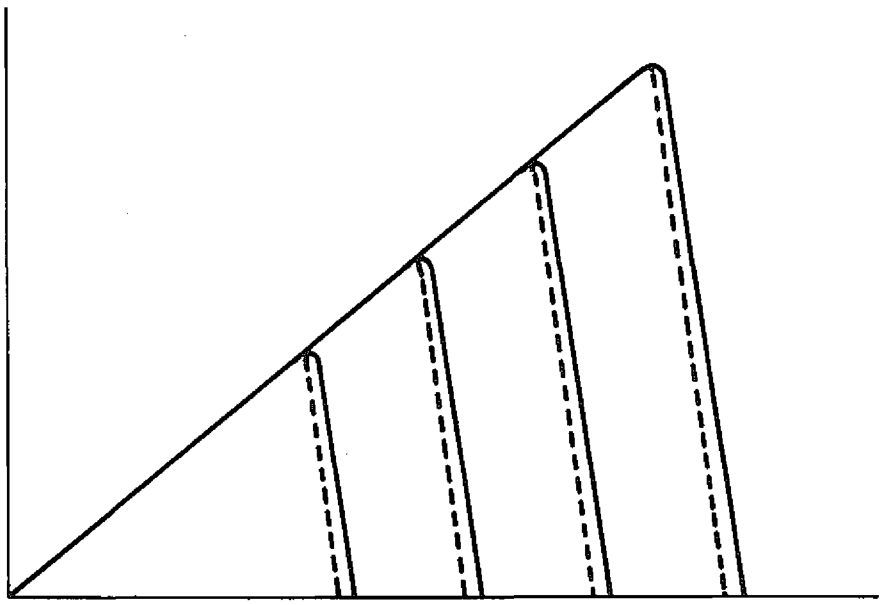


Fig. 3 – 38 Comparison of engine output curves
The solid line shows output with PTG-MVS governor
The dotted line shows output with PTG-VS governor

The governor spring of the VS governor assembly is balanced with thrust of the centrifugal force due to the revolution of the VS governor weight. The PTG-MVS governor spring is balanced by the oil pressure of oil discharged from the gear pump.

The pressure regulater valve (as shown in Fig. 3–36) is for the purpose of pressurizing inside the PTG-VS governor housing assembly.

The VS governor assembly is located above the fuel pump housing and front cover. The VS governor weight is inside the upper front cover, and is gear-driven by the fuel pump main shaft via an idler gear assembly. PT (type G) governor is located inside the bottom of the housing as previously.

Since engine acceleration performance is very closely related to the adjustment of the aneroid control valve, the bellows spring and shims, which control opening of the valve (throttle shaft), under various engine running conditions are specified to the engines respectively and are adjusted precisely with much attention.

3.11 Fuel Flow of PTG-VS Fuel Pump with AFC

The following schematics show how the fuel flow situations vary with PTG-VS fuel pump with AFC which was covered previously, depending on the running conditions.

Engine stopped

Solenoid valve is closed with ignition switch open. Turbo boost pressure is not available to act upon diaphragm to deffect AFC spring. AFC plunger is in the closed position.

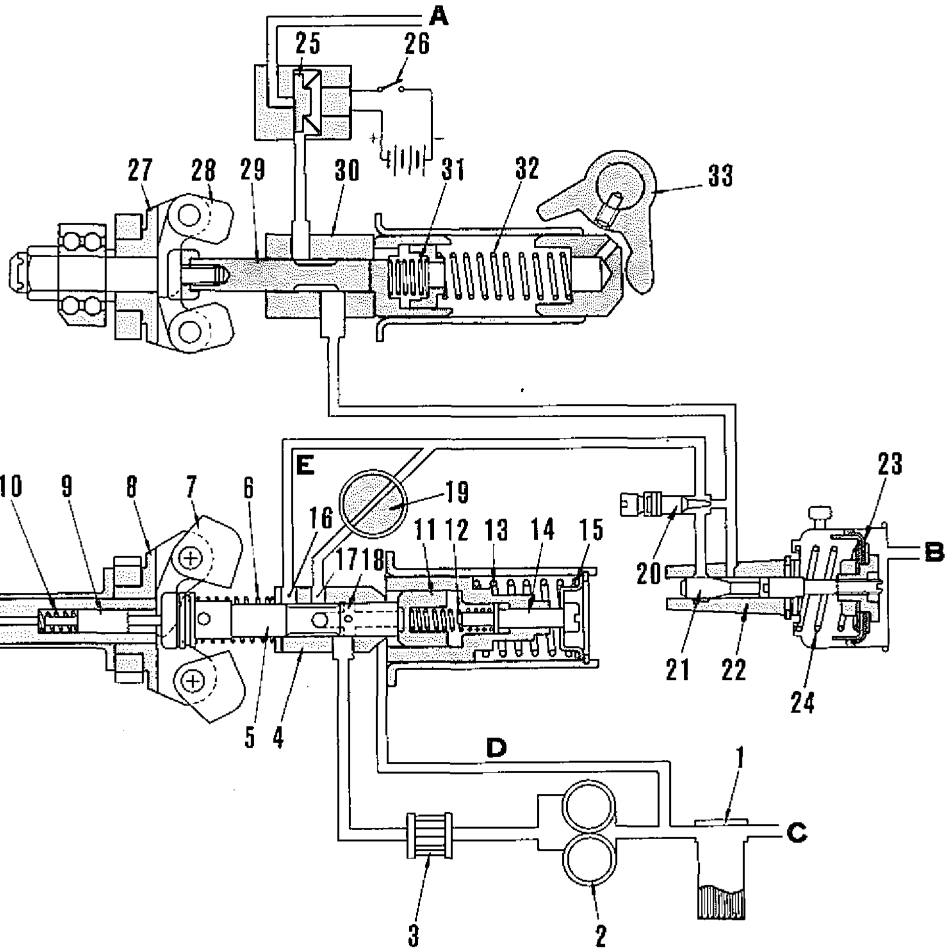


Fig. 3—39

1. Primary fuel filter
2. Gear pump
3. Filter screen
4. Governor sleeve
5. Governor plunger
6. Torque control spring
7. Governor weights
8. Governor weight carrier
9. Weight assist plunger
10. Weight assist spring
11. Idle spring plunger
12. Idle speed spring
13. Maximum speed governor spring
14. Idle speed adjusting screw
15. Maximum speed governor shims
16. Idle speed governor port
17. Main governor port
18. Governor dump ports
19. Throttle
20. AFC needle valve
21. AFC control plunger
22. AFC barrel
23. Diaphragm (bellows)
24. AFC spring
25. Solenoid valve
26. Ignition switch
27. VS governor weight carrier
28. VS governor weights
29. VS governor plunger
30. VS governor sleeve
31. VS idle speed spring
32. VS maximum speed governor spring
33. VS throttle

A. Fuel to injectors
B. Air from intake manifold
C. Fuel from tank
D. By-passed fuel
E. Idle fuel passage

Starting and idling

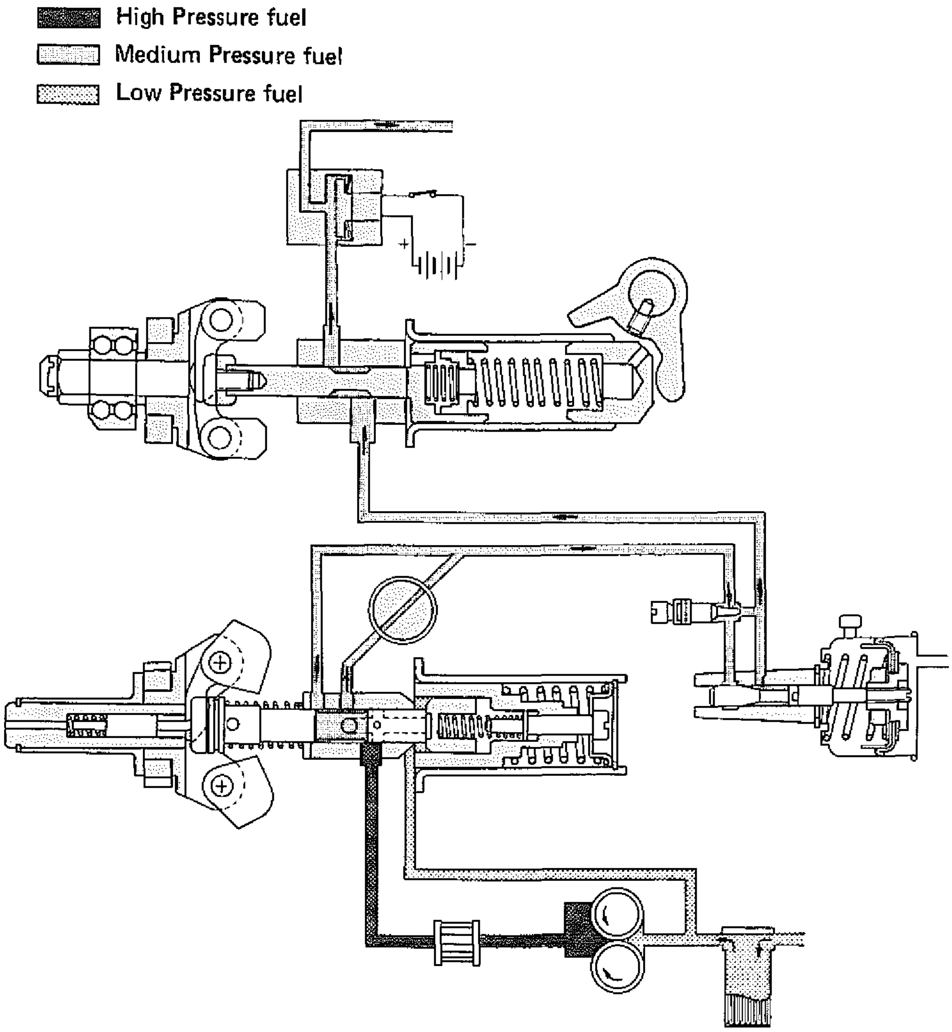


Fig. 3 – 40

With the ignition switch closed and solenoid valve caused to open, the fuel needed for idling at low speeds flows through the stricted "NO-AIR" needle valve, VS governor and solenoid valve (shut-off valve). The AFC plunger blocks fuel from passing through the AFC barrel due to insufficient turbo "boost" pressure available to act upon the diaphragm to deflect the AFC spring.

Normal driving

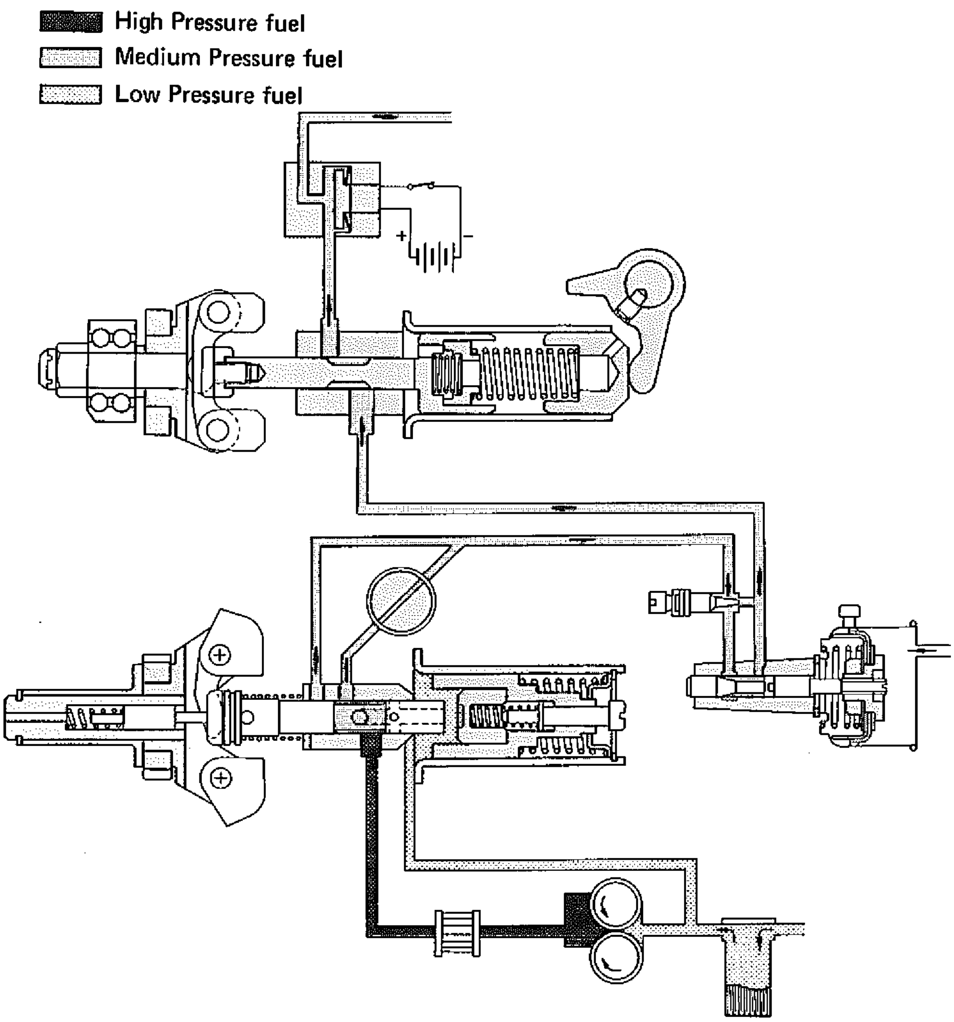


Fig. 3 – 41

Operator controls fuel flow and rail pressure to the injectors by an throttle pedal or lever. The position of VS governor plunger controls the fuel flow and the rail pressure. VS governor weight force and the counter acting forces by the VS governor spring force determine the position of the VS governor plunger.

The governor weight force increases as speed increases. The amount of fuel delivered to the VS governor depends upon the regulating counteracting forces of the governor spring and torque spring which influences the amount of fuel by-passed at the end of the governor plunger and idle spring plunger.

The maximum fuel pressure and fuel flow are regulated in the speed range of the engine by the governor itself. Fuel is passing through the needle valve and AFC barrel since sufficient turbo "boost" is available to act upon the diaphragm and overcome the AFC spring. The final fuel flow is regulated at the VS governor and passes through the solenoid valve on to the injector.

Beginning of high speed governing

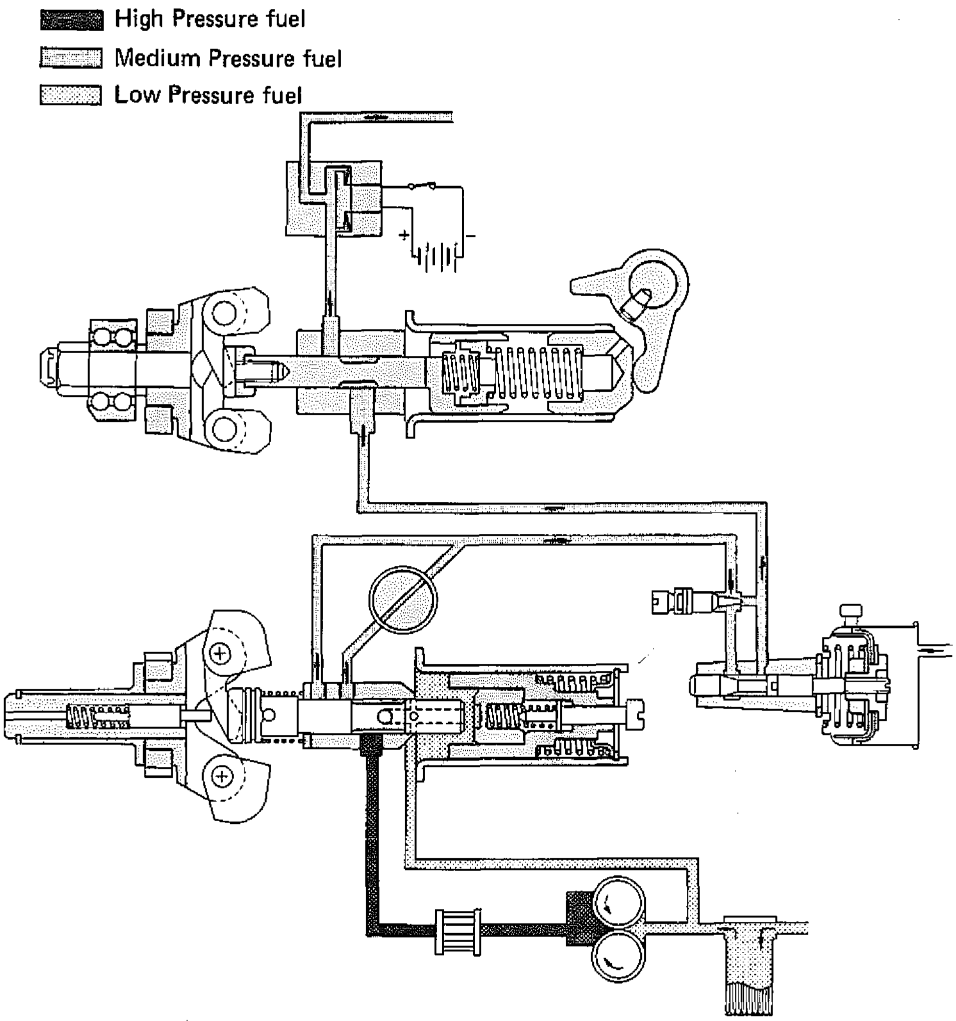


Fig. 3 – 42

Fuel is flowing from PTG governor through both the needle valve and AFC barrel to the VS governor. However, it can be noticed that the VS governor port is being closed which causes more fuel to be by-passed by the governor plunger (5) and idle spring plunger (11), in Fig. 3–39. The VS plunger and port thereby control governor regulation on the droop curve by restricting fuel flow.

Complete high speed governing

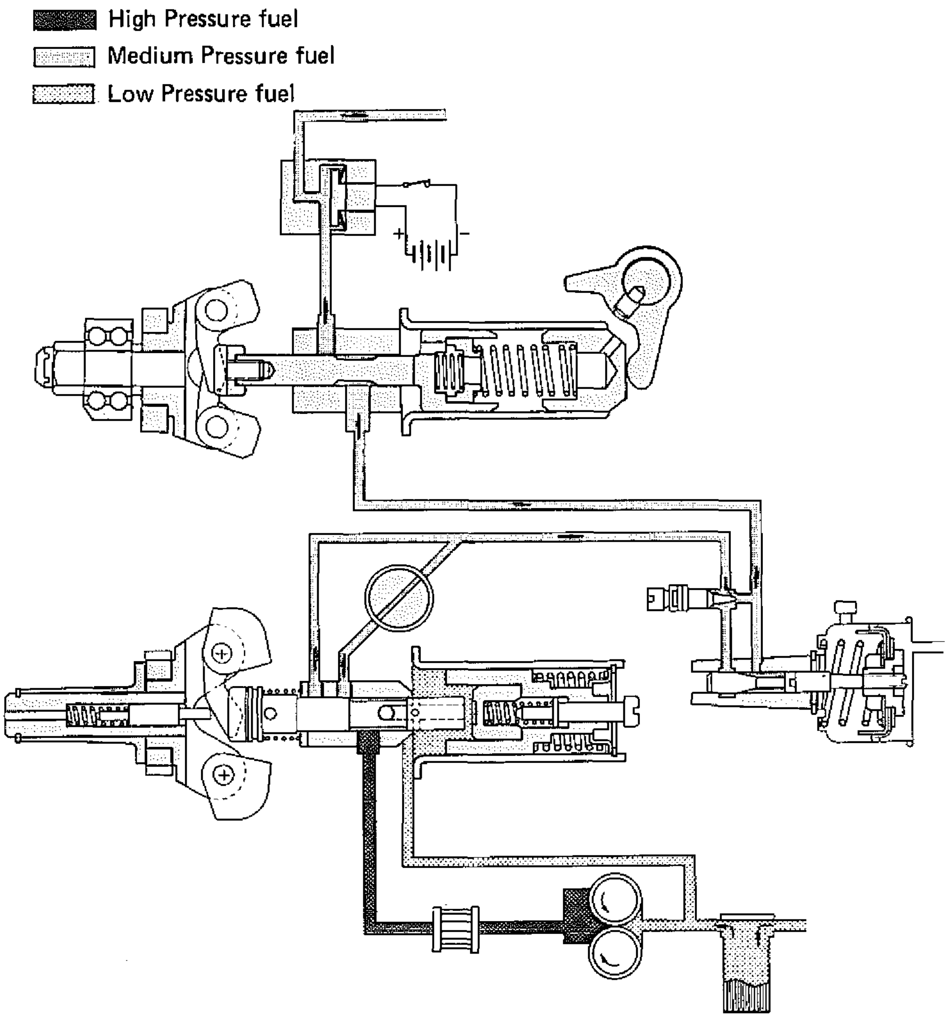


Fig. 3 – 43

The fuel flow provided by the gear pump is restricted by VS governor. The supplied fuel is being by-passed by the governor plunger (5) and idle spring plunger (11) and dump ports (18), in Fig. 3–39, thus the fuel sufficient to maintain only high idle speed passes through restricted "NO AIR" needle to the VS governor. AFC plunger blocks fuel from passing through AFC barrel. Turbo boost pressure is not available to act upon diaphragm to deflect AFC spring.