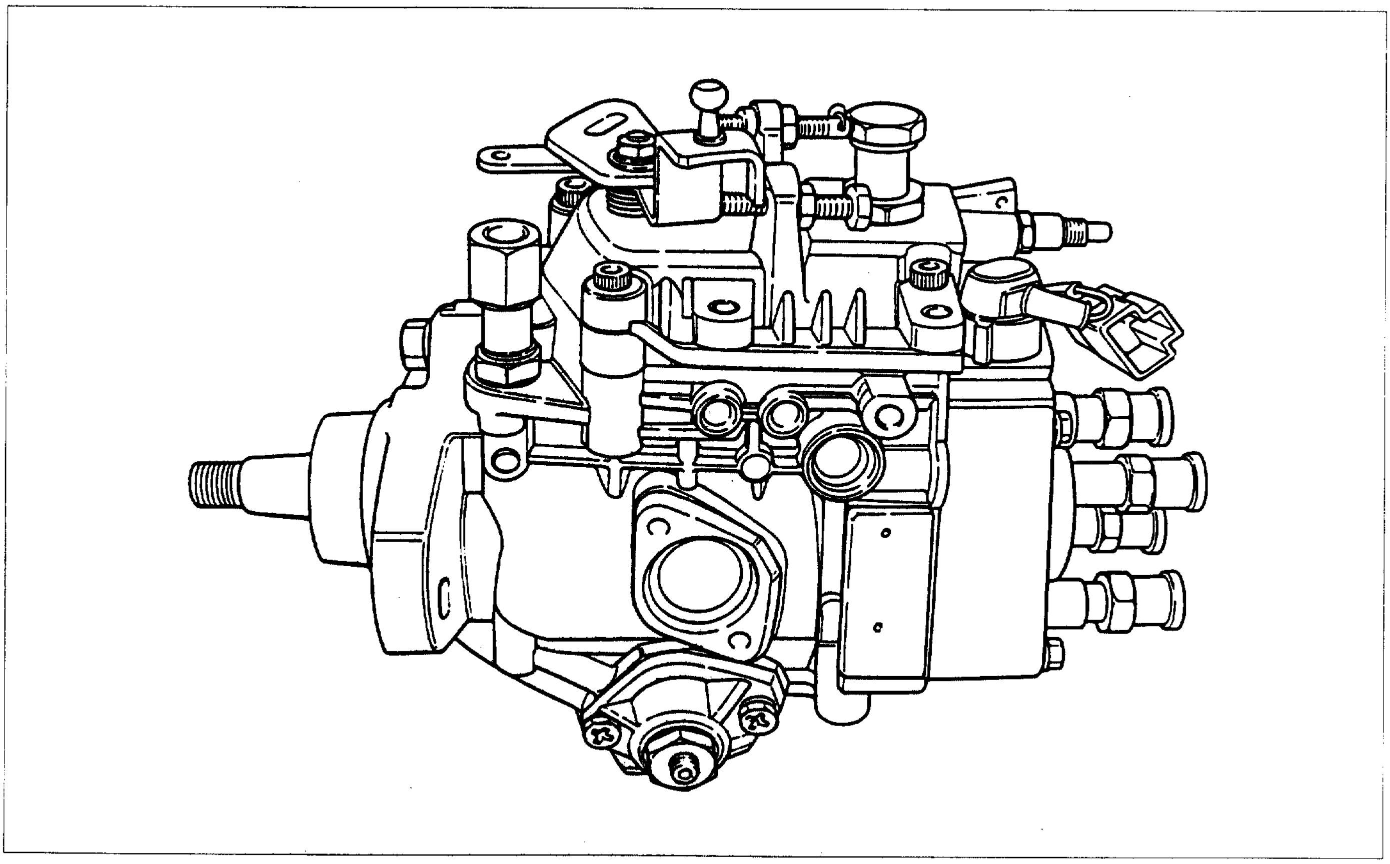
1. INTRODUCTION

Today's high speed-diesel engines have been making great progress towards higher fuel economy while maintaining driveability and performance. In addition to meeting these demands, it has been necessary to reduce the size and the weight of the fuel injection pump as well as increase it's reliability.

The VE-type/distributor pump differs from the conventional/In-line pump in several ways. The main difference is that the VE pump uses only one pumping plunger for all engine cylinders while the In-line type pump has one pumping element for each cylinder. This feature alone allows for fewer parts as well as reduced size.

The purpose of this manual is to provide the basics in design features, construction, operation, disassembly, assembly, and adjustment of the VE-type fuel injection pump and it's "additional devices."



Distributor (VE type) Fuel Injection Pump

2. GENERAL

The distributor type fuel injection pump is unique in it's design, in that it uses a single high pressure pumping plunger to accurately meter and distribute the fuel to each of the engine cylinders in the proper combustion order.
The VE-type pump has been developed to meet the requirements of the small high speed diesel engine. In it's development the VE pump was made smaller and lighter than it's In-line counterpart.

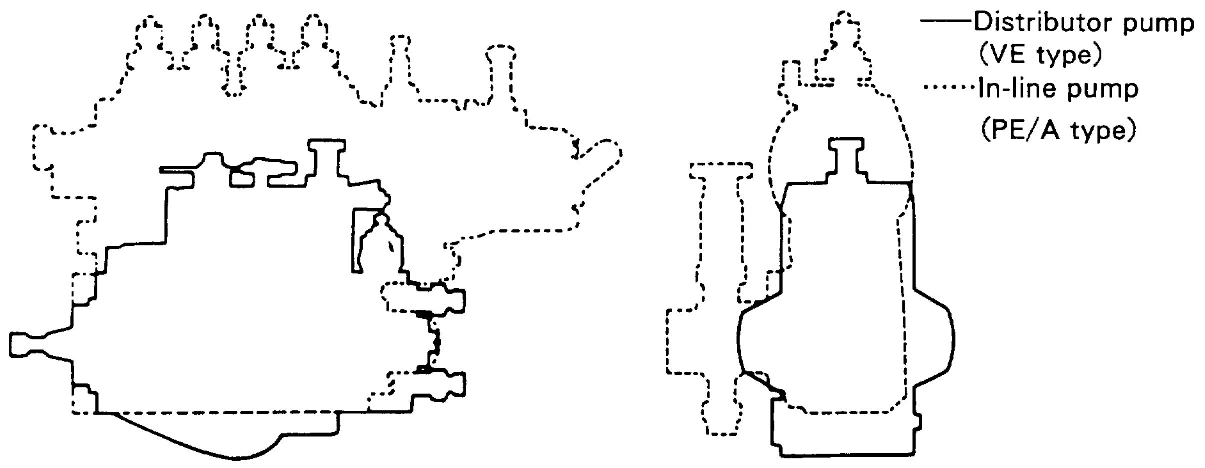


Fig. 2-1 Comparison of dimensions of Distributor and In-line pump

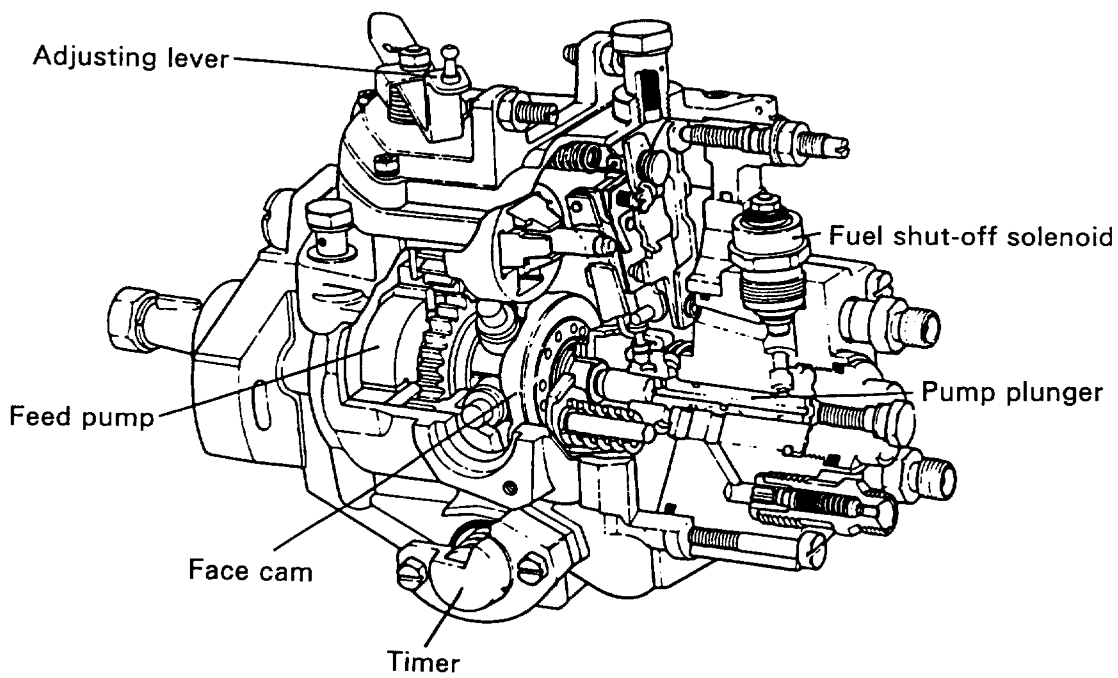


Fig. 2-2 Cross-section of VE pump

3. FEATURES

The following design features of VE-type pump has made it more suitable than the conventional In-line type pump for the modern high speed diesel engine.

1) **COMPACT AND LIGHTWEIGHT WITH FEWER PARTS**
The four cylinder VE pump is slightly smaller than a four cylinder In-line pump, while the six cylinder VE pump is about half the size of a six cylinder In-line pump.

2) **HIGH SPEED CAPABILITY**
Engine speed of 5000rpm or greater may be achieved using the VE-type pump, while the upper limits of an engine using an In-line type pump peak at around 4000rpm.

3) **UNIFORM FUEL DELIVERY**
By using a single plunger to distribute fuel to all the cylinders, less cylinder to cylinder variation is achieved. One advantage to uniform fuel delivery is the reduction of engine noise levels.

4) **IMPROVED STARTING**
A start spring (leaf type) in the pump acts to provide additional fuel when starting the engine. This feature facilitates engine starting in cold weather, especially when used on engines that incorporate a pre-combustion design.

5) **IDLE STABILITY**
Uniform fuel delivery ensures stability and smoother engine idle speeds.

6) **LUBRICATION**
The internal working parts of the pump are lubricated by the filtered diesel fuel that is supplied by the feed pump. This design eliminates the need for engine oil type lubrication of the injection pump.

7) **EXTERNAL FUEL ADJUSTMENT**
Ease of adjustment is achieved by the external location of the maximum fuel delivery adjustment screw.

8) **SHUT-OFF SOLENOID**
The fuel supply is shut-off by merely turning off the engine ignition switch.

9) **COMBINED CAPABILITY**
As a unit the VE pump incorporates the combined features of an injection pump, a feed pump, and a hydraulic timing device.

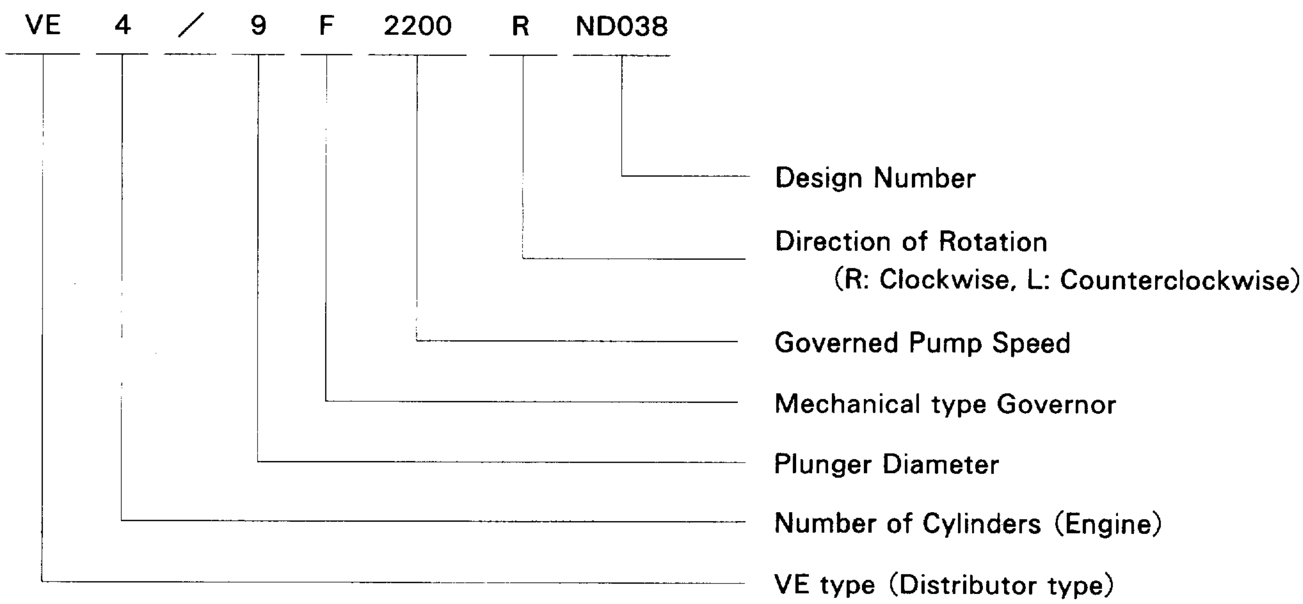
10) **NON-REVERSING**
Due to internal pump design the engine will not run in the reverse direction.

11) **ADDITIONAL DEVICES**
Several control devices may be fitted to the VE pump to achieve different fuel delivery characteristics as may be desired. (Automatic Cold Start Device, Load Sensing Timer, etc.)

12) **VERSATILE MOUNTING**
The VE pump may be mounted to an engine either horizontally or vertically.

4. PUMP SPECIFICATIONS

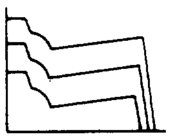
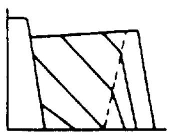
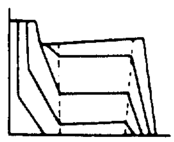
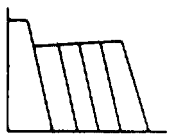
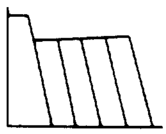
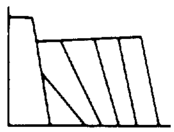
4-1. PUMP TYPE NUMBER



4-2. FUNDAMENTAL SPECIFICATIONS

ITEM		SPECIFICATION	
Number of Cylinders		3, 4, 5, 6, cylinder	
Installation		Flange Type	
Drive		Gear or Toothed Belt	
Rotation		Clockwise or Counter-clockwise (Viewed from drive end)	
Max. Speed		3000rpm (Varies with Cam Profile)	
Plunger Diameter		3 Cylinder 9mm	
		4 Cylinder 8, 9, 10, 11, 12, 13, 14mm	
		5 Cylinder 10mm	
		6 Cylinder 9, 10, 11, 12, 13, 14mm	
Cam Lift		2.0, 2.2, 2.5, 2.8mm	
Lubrication System		Self-Lubrication by Fuel	
Fuel Pipe		Screw size	Pipe Inner Dia. (mm)
	High Pressure	M12×1.5	–
	Inlet	M12×1.5	ϕ6
	Over Flow	M12×1.5	ϕ6
Timer	Control System	Hydraulic Type (Pump Inner Pressure)	
	Max. Advance Angle	11.5° (Pump Cam Angle)	
Governor	Type	Mechanical	
	Control	All-speed, Min./Max.-speed (M-M)	
Shut-off		Shut-off by Fuel Shut-off Solenoid by the Ignition Switch	

5. COMPARISON OF IN-LINE TYPE AND DISTRIBUTOR TYPE PUMP

Function \ Pump		In-line	Distributor	
		PE/A Type	VM TYPE	VE TYPE
Fuel Pumping Mechanism		Plunger's reciprocating motion, outer cam	Plunger's rotary and reciprocating motions, face cam	←
Fuel Metering Method		Determined by plunger's effective stroke	Determined by open ing of fuel inlet passage	Determined by plunger's effective stroke
Governor	Type	Pneumatic, mechanical, electronic, etc.	Mechanical, electronic. etc.	←
	Control	All-speed, Min./Max. speed	All-speed, Min./Max. speed	←
Timer		Mechanical	Hydraulic	←
Feed Pump		Plunger Type	Vane Type	←
Max. Delivery (mm^3/st)		120	60	140
Max. Pump Speed (rpm)		2000	3000	3000
Lubrication System		Oil Lubrication	Fuel Lubrication	←
Fuel Delivery vs. Pump Speed	Min./Max. Speed Control			
	All-Speed Control			

6. PRECAUTIONS

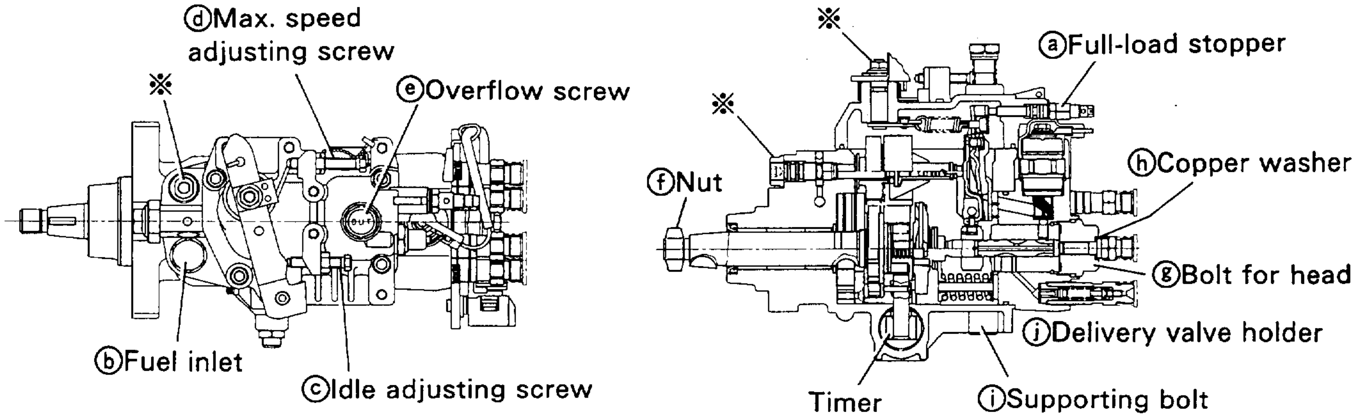


Fig. 6-1 Precausions

To ensure trouble-free operation for a prolonged period of time, it is essential that the following steps be observed when handling injection pumps:

1) Since the pump distributor plunger and the engine nozzles have precision lapped surfaces, proper fuel system maintenance is essential. The requires checking the fuel filter, sedimentor/water separator, and fuel tank periodically for contaminates, such as dirt and moisture.

2) The use of anything other than the proper diesel fuel will adversely effect engine performance and possibly damage the fuel injection pump. Always use the proper fuel as specified by the engine manufacturer.

3) Extreme care should be exercised during pump installation to prevent foreign particles from entering the fuel piping. Proper adjustment of timing must be performed at the time of pump installation.

4) Torque values are always important, an especially critical value would be the delivery valve holder.

5) Factory sealed adjusting screws should be adjusted only with the use of the proper test equipment.

  a. Improper full-load stopper (See ill. ⓐ in Fig.6-1) adjustment will result in either low or lack of power, or excessive engine speed and/or smoke.

  b. Improper maximum speed adjusting screw (See ill. ⓑ in Fig.6-1) setting may cause engine over speeding.

6) Observe the following steps during installation of the injection pump to engine.

  a. Do not loosen or tighten the yellow painted nuts or bolts (See ill. "※" in Fig.6-1) as damage or leaking may occur.

  b. Every time the distributor head bolts (See ill. ⓖ in Fig.6-1) is loosened for the purpose of setting the timing, the copper washer (See ill. ⓗ in Fig.6-1) should be replaced.

c. The use of excessive torque on the pump support bolts (See ill. ⓘ in Fig.6-1) may cause binding of the timer piston in the pump housing.

d. The following tightening torque specifications should be used:

Part	Torque kg.m (ft.lbs)
(a) Full-load stopper nut	0.7 - 0.9 (4.34-6.51)
(b) Fuel inlet screw	3.5-4.0 (14.5-21.7)
(c) Idle adjusting screw nut	0.7-1.0 (3.62-4.34)
(d) Maximum-speed adjusting screw nut	0.5-0.9 (3.62-4.34)
(e) Overflow screw	2.0-3.0 (14.5-21.7)
(f) Pump drive gear fitting nut	M14: 6.5-7.8 (47.0-56.4) M12: 6-7 (43.4-50.6)
(g) Head bolt	1.5-1.9 (10.1-14.5)
(j) Delivery Valve Holder	4.4-5.5 (32.5-39.8) Applicable until Apr.1990 (production codes: 4K and earlier code) 5.5-6.5 (39.8-46.0) Applicable from May 1990 (production codes: 5K onwards)

7. FUEL SYSTEM

Diesel fuel is drawn from the fuel tank through the sedimentor/water separator and fuel filter by the feed pump which is incorporated in the front of the injection pump. The feed pump not only supplies fuel to the injection pump, but also circulates fuel to lubricate the moving parts of the pump. The single pump plunger meters and distributes the fuel (under pressure) through the nozzle to the combustion chamber, and does so in the correct combustion order. Excess fuel from the pump and nozzles returns to the tank by way of the overflow valve and pipeline. This system of fuel circulation cools and lubricates the injection pump while warming the fuel in the tank to help prevent fuel waxing in cold weather.

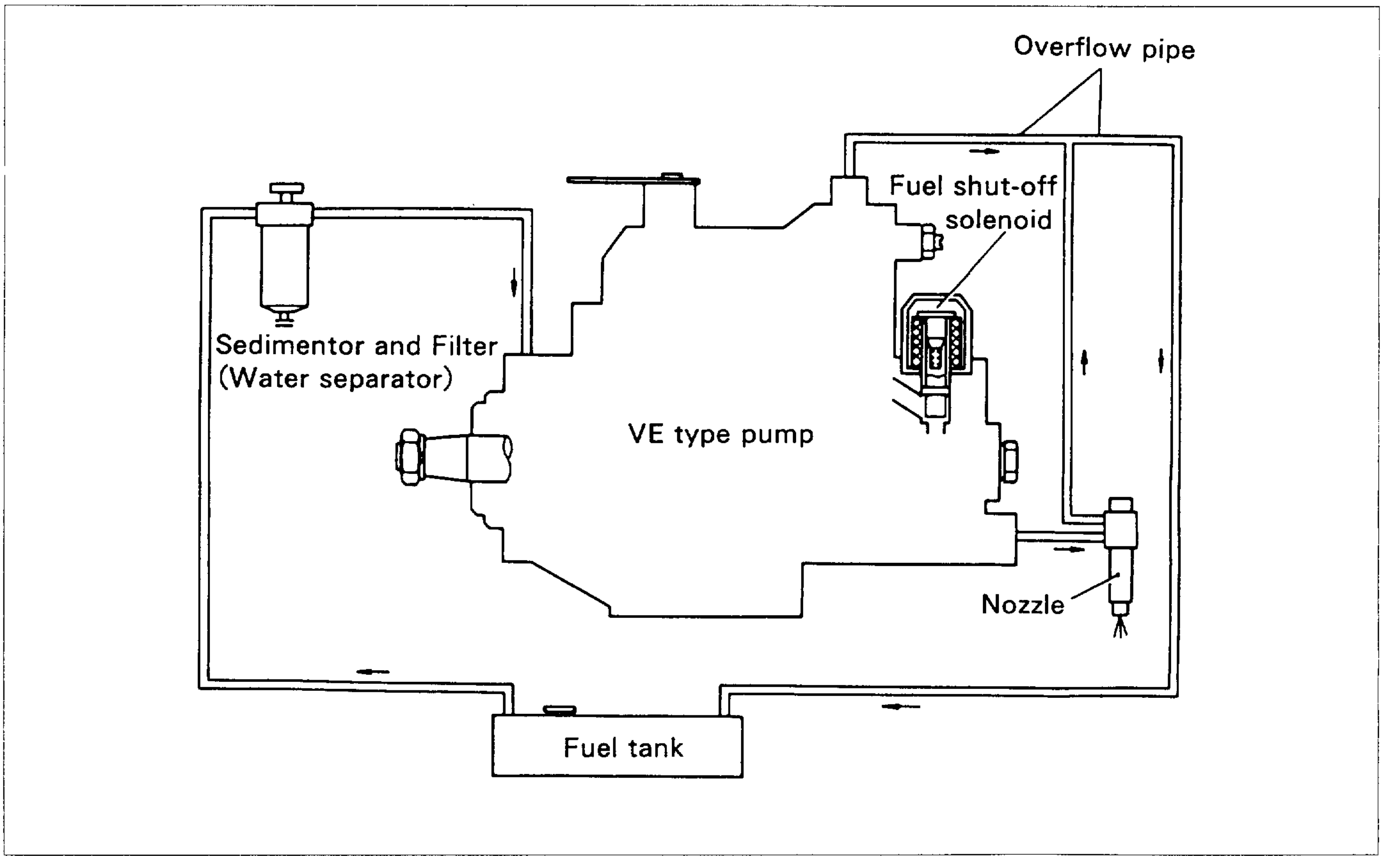
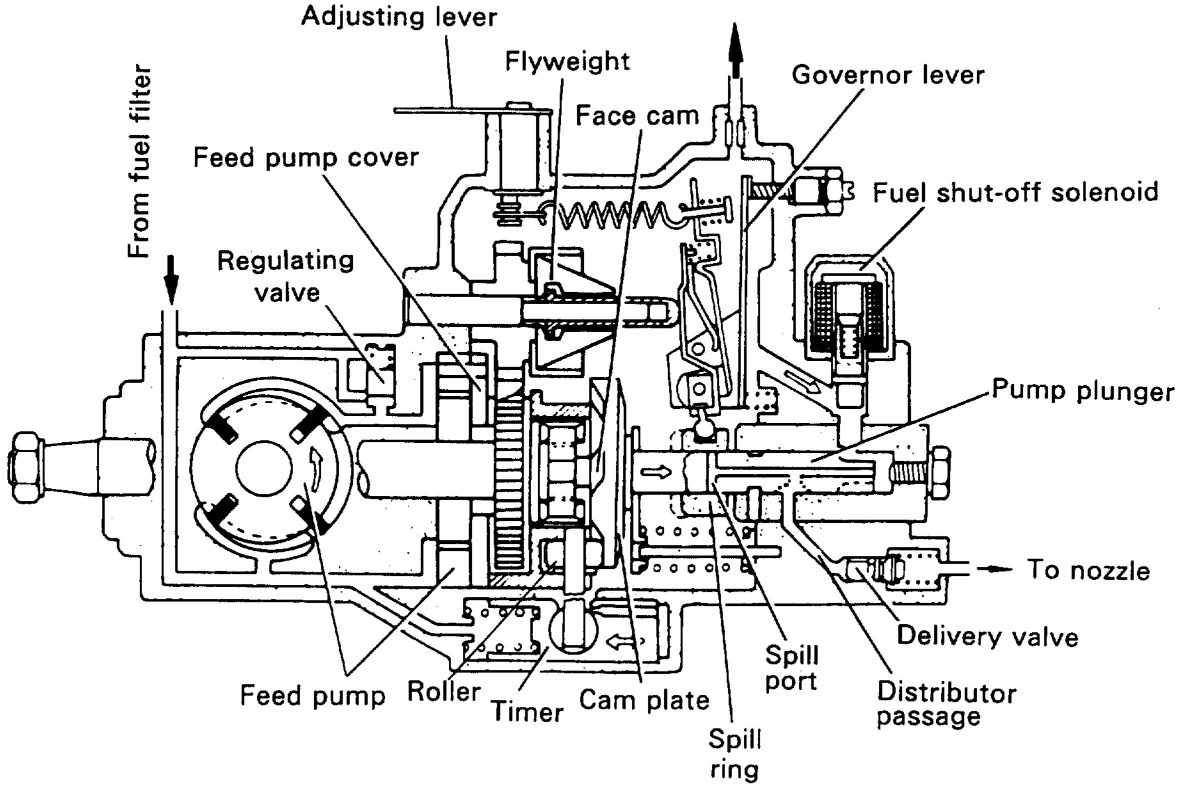


Fig.7-1 Fuel system

8. CONSTRUCTION AND OPERATION

8-1. SECTIONAL DIAGRAM



Note: In this figure, a VE pump is shown with feed pump and timer rotated by 90 degrees.

Fig.8-1 Sectional view of VE pump (with All-speed governor)

The filtered fuel is drawn by the vane-type feed pump and delivered at a constant volume per revolution regardless of pump speed. The fuel feed pressure is controlled by the pressure regulating valve that is located in the upper part of the feed pump. The pressure-regulated fuel is fed into the injection pump chamber through the delivery port in the feed pump cover.

The VE pump driveshaft is driven by the engine. The feed pump, located just inside the pump housing, is driven by the pump driveshaft. The face cam is also driven by the driveshaft. The face cam rides on the rollers of the roller ring assembly, which is located between the face cam and the feed pump. The position of the roller ring assembly is determined by the position of the automatic timer. The position of the automatic timer is determined by the feed pump pressure, and is used to advance the injection timing. The distributor plunger and the face cam are held against the roller ring assembly by the distributor plunger return springs. As the face cam and the distributor plunger rotate, they reciprocate back and forth over the rollers, a distance equal to the height of the lobes of the face cam. The distributor plunger moves inside the distributor head, which is attached to the pump housing. The motion of the distributor plunger, within the distributor head, delivers high pressure fuel to the combustion chamber of each cylinder, by way of a delivery valve, a high pressure line, and a nozzle holder assembly. The quantity of high pressure fuel delivered to each cylinder is determined by the position of the spill ring located in the area of the spill ports of the distributor plunger. A gear attached to the pump driveshaft spins the centrifugal flyweight assembly. This assembly in turn slides the governor sleeve on the governor shaft, to move the governor arm that is attached to the spill ring on the distributor plunger. The spill ring position is further determined by the position of the adjusting lever and shaft, located in the governor cover, and the governor control spring. With the ignition switch in the off position, shut-off is accomplished by an electric solenoid (energize to run) located on the top of the distributor head.

8-2. FEED PUMP

The rotary-vane type feed pump, located inside the injection pump, draws fuel from the fuel tank through the sedimentor and fuel filter and supplies it to the pump chamber.
The feed pump rotor is connected to the driveshaft by a woodruff key, and is driven by the pump driveshaft. As the rotor spins, centrifugal force holds the vanes against the wall of the concentric ring (pressure chamber) that is held stationary against the pump housing. Due to the off-center location of the concentric ring, with respect to the rotor, fuel becomes trapped between the vanes and is pressurized and forced out through the delivery port in the feed pump cover and into the pump chamber.

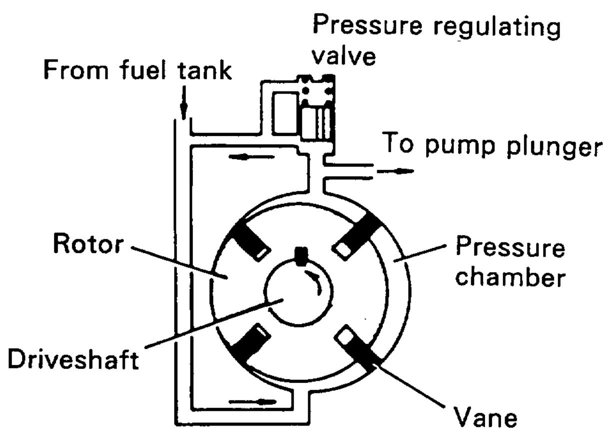


Fig.8-2 Operation of feed pump

8-3. PRESSURE REGULATING VALVE

The pressure regulating valve is located in the upper portion of the injection pump housing on the drive end. The fuel pressure regulating valve is designed to provide an increase in fuel pressure within the pump cavity, proportional to pump speed increase. (See graph, Fig.8-4)

As fuel pressure increases with pump speed, the piston within the pressure regulator is forced against the tension of the regulator spring. At a predetermined value, the valve will begin to open a port in the regulator to allow excess fuel to by-pass back to the intake port. (See Fig.8-3) With this feature, the fuel pressure can be kept directly proportional to pump speed.

This fuel pressure is also used to actuate the timing advance mechanism by acting directly against the timer piston. (See Section 8-8 Automatic Timer)

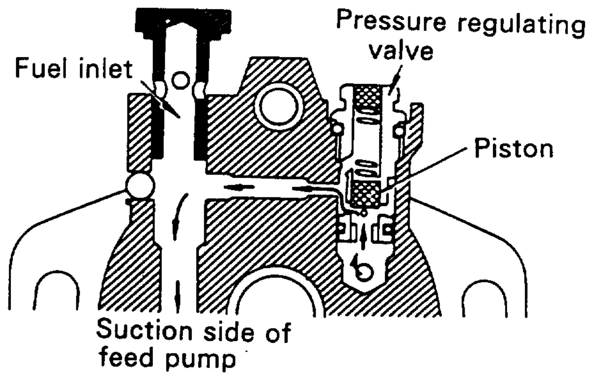


Fig.8-3 Function of pressure regulating valve

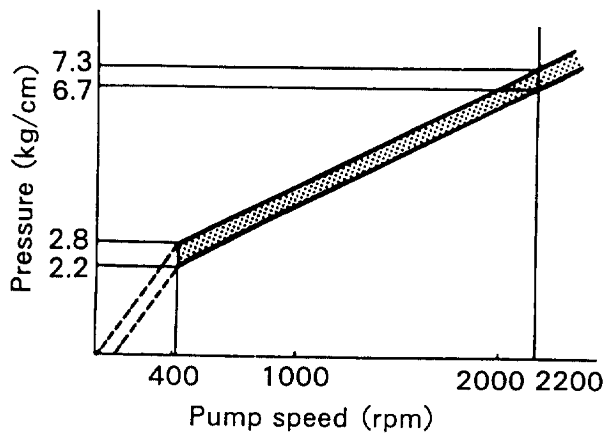


Fig.8-4 Feed pump pressure versus pump speed

8-4 FUEL INJECTION AND DISTRIBUTION

Section 8-1. describes the basic rotating and reciprocating motion that takes place once the engine begins to turn the pump driveshaft. (See Fig.8-5)

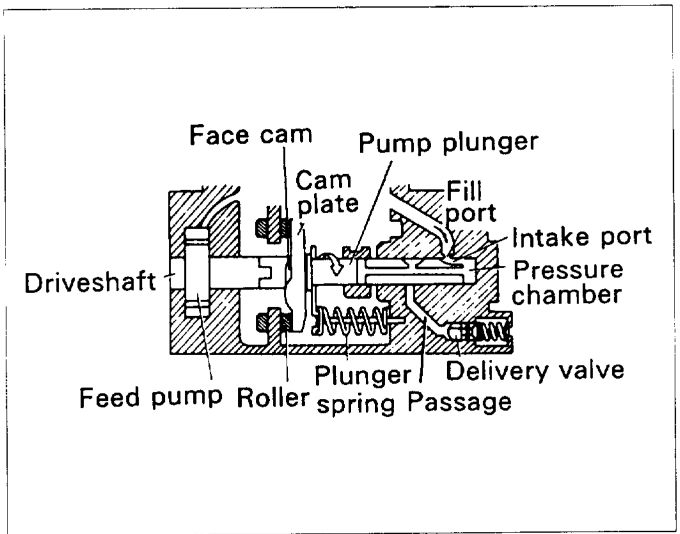


Fig.8-5 Plunger and camplate

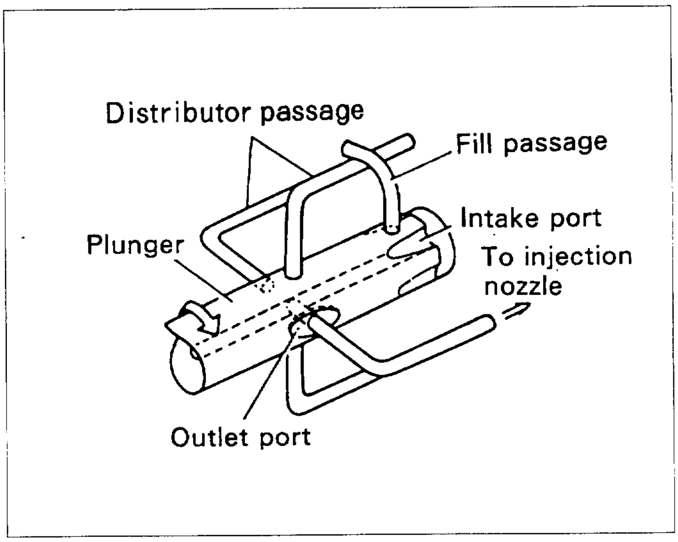


Fig.8-6 Plunger delivering fuel to each nozzle

(1) Intake Stroke

Fuel, under pump housing pressure, fills the pressure chamber of the head as the plunger moves toward the drive end of the pump and rotates to align the plunger intake port with the fill port in the distributor head. (See Fig.8-7)

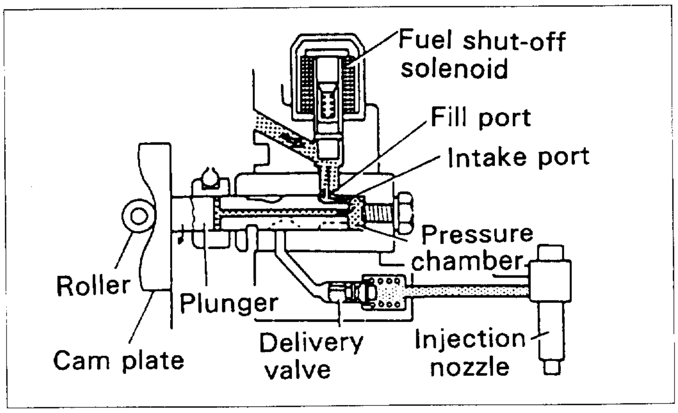


Fig.8-7 Intake stroke

(2) Injection Stroke

As the plunger further rotates, the intake port is closed and fuel becomes trapped within the pressure chamber. With the continued rotation and now forward motion of the plunger (away from the drive end) caused by the profile of the face cam acting on the roller assembly, fuel pressurization and delivery begins. At this point, the outlet port aligns with a distributor passage in the distributor head and injection begins. (See Fig.8-8) (See also Fig.8-6)

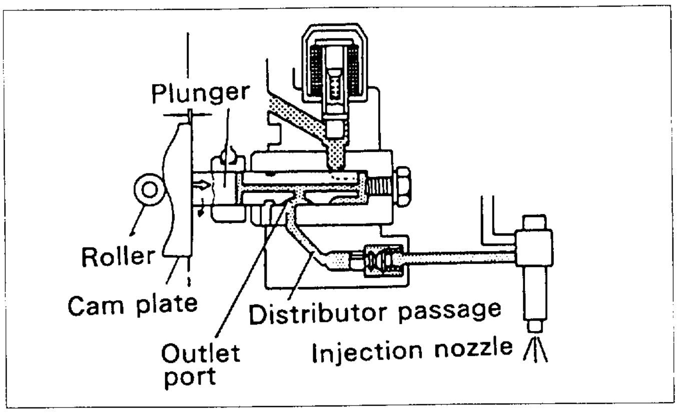


Fig.8-8 Injection stroke

(3) End of Injection

At a point of forward motion (away from drive end), the spill port of the distributor plunger moves out of the spill ring, pressure is released and injection is stopped. (See Fig.8-9)

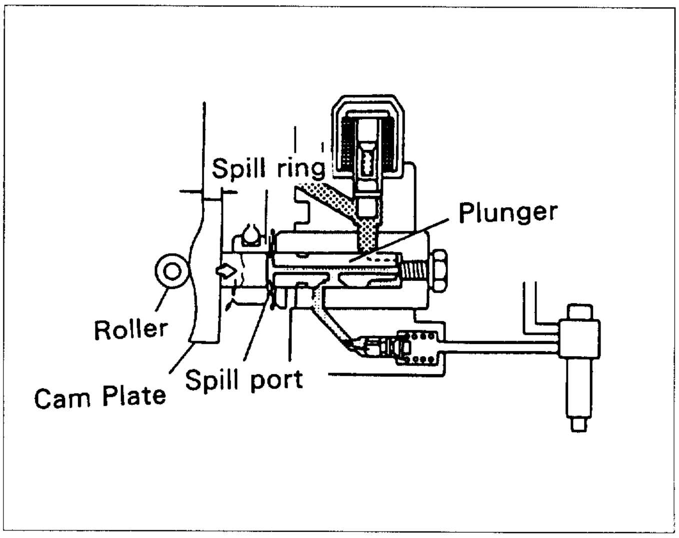


Fig.8-9 End of injection

(4) Pressure Equalization

An additional 180° degrees of rotation of the distributor plunger aligns the pressure equalization groove with the distributor passage of the head. This allows the pressure in the distributor passage to equalize to that of the pressure in the pump housing. This pressure equalization minimizes fuel delivery spread between cylinders (See Fig.8-10) and allows for a smoother running engine.

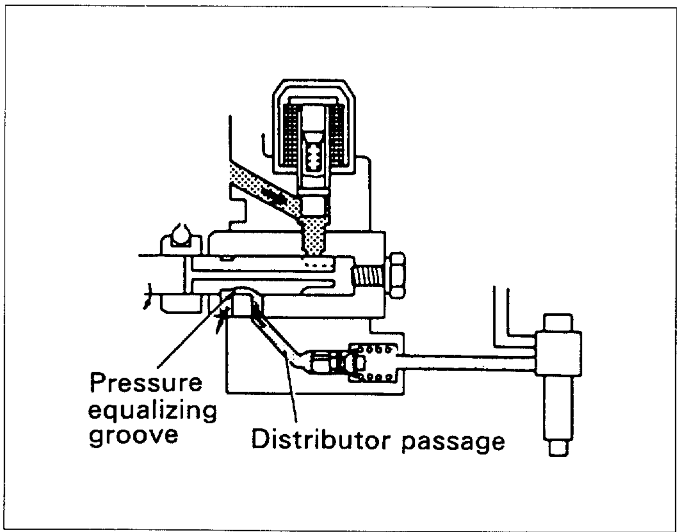


Fig.8-10 Pressure equalization

(5) Non-Reversing

As illustrated in Fig.8-11, if the pump is rotated in the wrong direction, fuel pressurization cannot take place because the fuel intake port is open during cam lift. This Non-Reversing feature in the pump prevents the engine from running backwards.

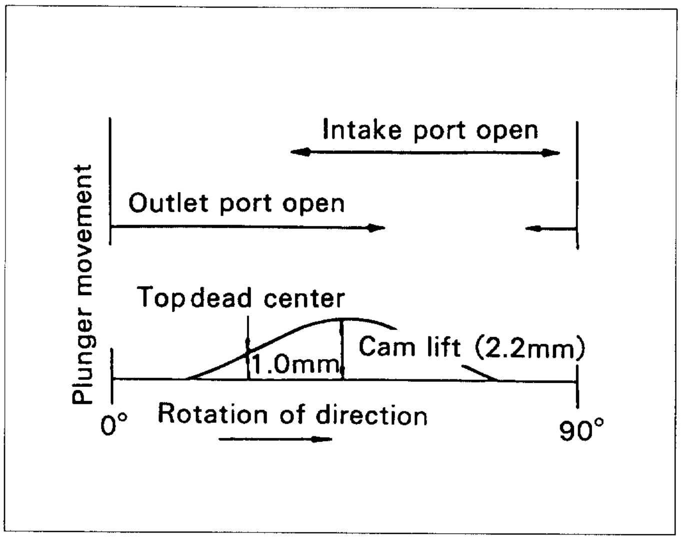


Fig.8-11 Timing of intake and outlet port opening (As an example)

8-5. EFFECTIVE STROKE / FUEL METERING

The quantity of fuel injection is controlled by the position of the spill ring on the plunger. The plunger stroke remains constant while the spill ring position can be changed by turning the governor adjusting lever. For less fuel, the effective stroke is reduced by moving the spill ring away from the head, thus allowing the trapped fuel pressure to release sooner. For increased fuel, moving the spill ring closer to the head keeps the fuel pressure trapped longer, thereby increasing the effective stroke.

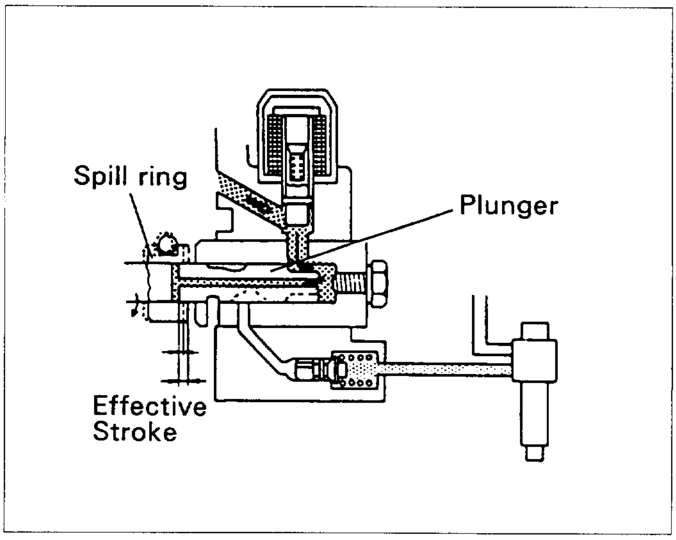


Fig.8-12 Effective stroke

8-6. FUEL SHUT-OFF SOLENOID

When the ignition switch is turned to the "START" position, the fuel solenoid is energized and the solenoid valve lifts against the spring and opens the fill port to the pressure chamber. (See Fig.8-13) When the switch is returned to the "ON" position, after the engine has started, the current flows through a resistor to the solenoid, reducing the current slightly but maintaining enough energy to hold the valve open. (See Fig.8-14 left)

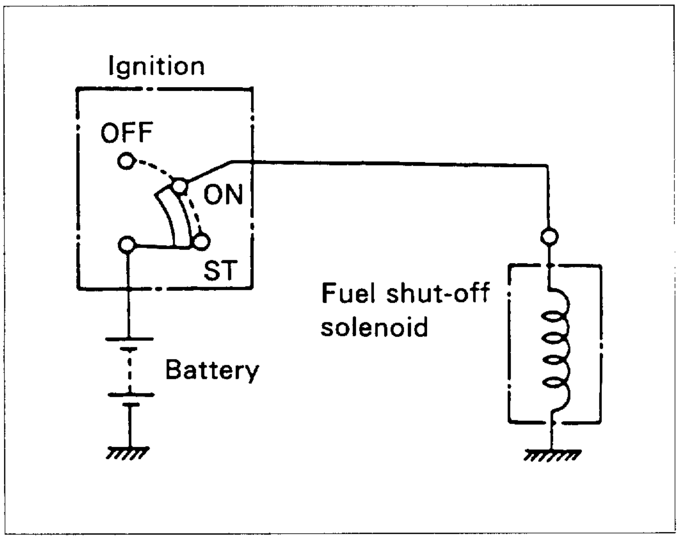


Fig.8-13 Circuit for fuel shut-off solenoid

Turning the ignition switch to the "OFF" position shuts off the current to the solenoid. With no current to hold the valve, the spring forces the valve to close the fill port, thus shutting off the fuel supply and the engine. (See Fig.8-14 right)

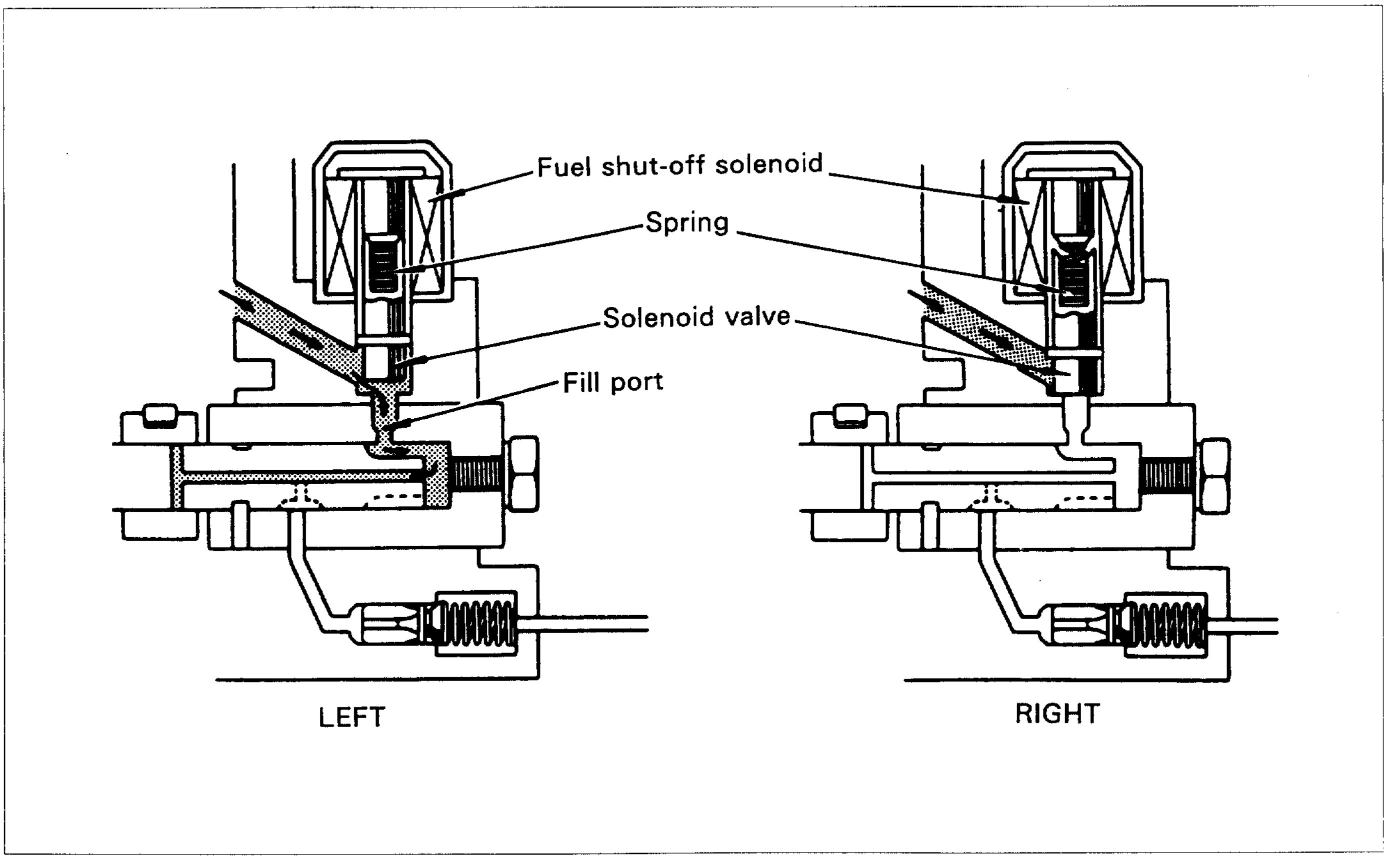


Fig.8-14 Fuel shut-off solenoid

8-7. GOVERNOR

The main purpose of a governor is to control the engine speed, within limits, during various load conditions throughout the entire predetermined speed range of the engine. The VE type pump uses two types of governor, the "All-Speed" and "Min. / Max. speed." (See Fig.8-15)

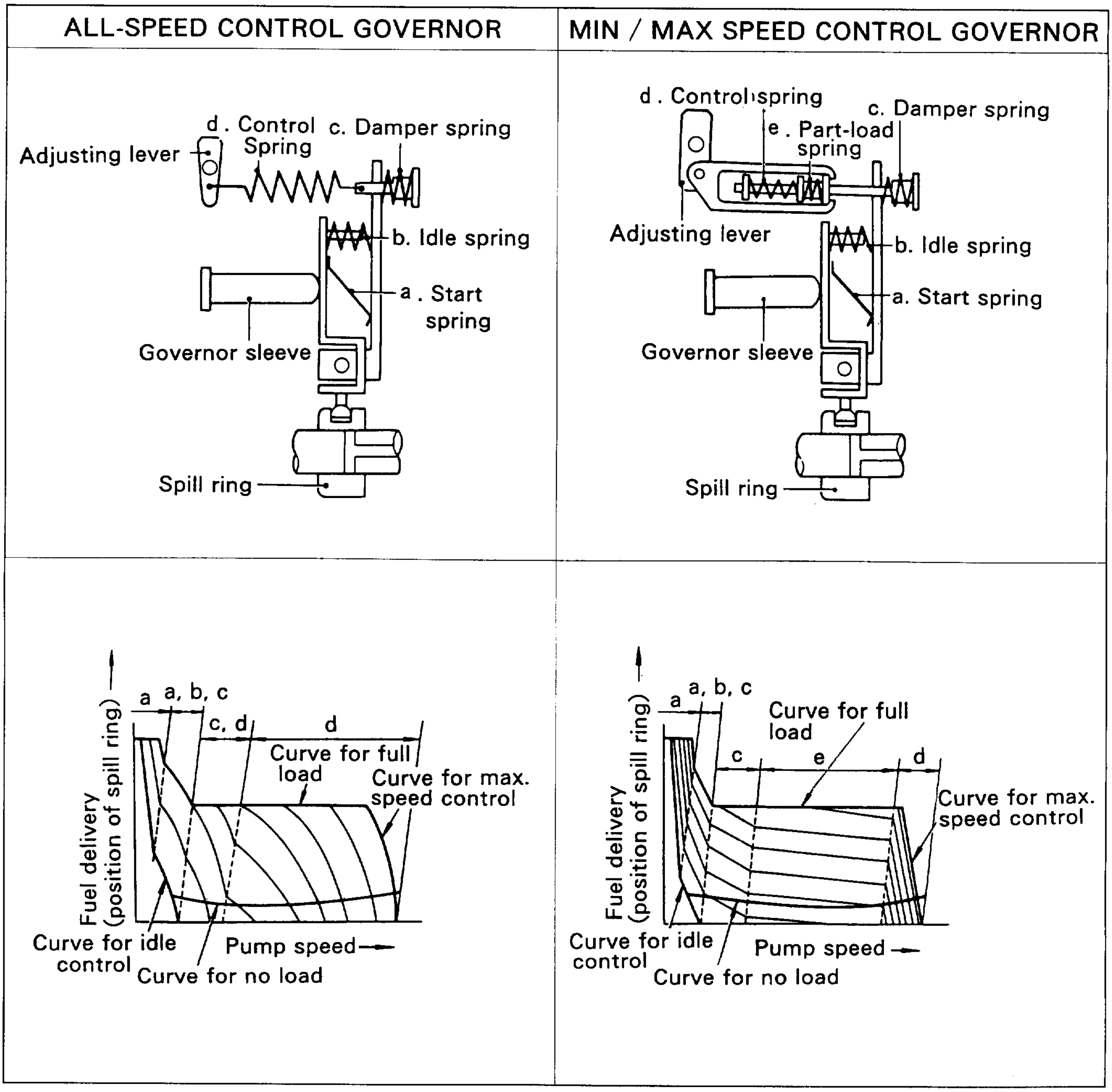


Fig.8-15 Characteristics of an All-speed and Min. / Max.speed governor

8-7-1. ALL-SPEED CONTROL GOVERNOR

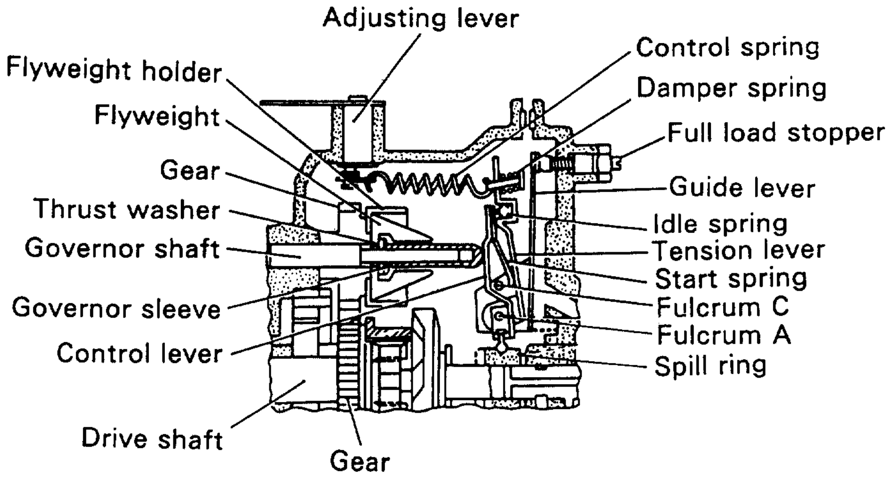


Fig.8-16 All-speed governor construction

(1) Construction

The "All-Speed" control governor is built into the upper part of the VE type pump, incorporating a centrifugal flyweight type of arrangement, a governor lever, a control spring, and adjusting lever. (See Fig.8-16)

(2) Principle of Operation

The flyweight assembly, located on the governor shaft, is rotated approximately 1.6 times the speed of the pump driveshaft, driven by a gear on the driveshaft and a gear on the flyweight assembly. As the driveshaft rotates it spins the flyweight assembly causing the flyweights to move outward. The four flyweights move against the thrust washer and the governor sleeve on the governor shaft. The governor sleeve acts on the governor lever assembly. Through a series of pivot points and springs, the governor lever acts on the control spring and the adjusting lever.

The All-speed governor controls the speed at which breakaway or governor control takes place, at any and all speeds between idle and maximum speed. (See Fig.8-17)

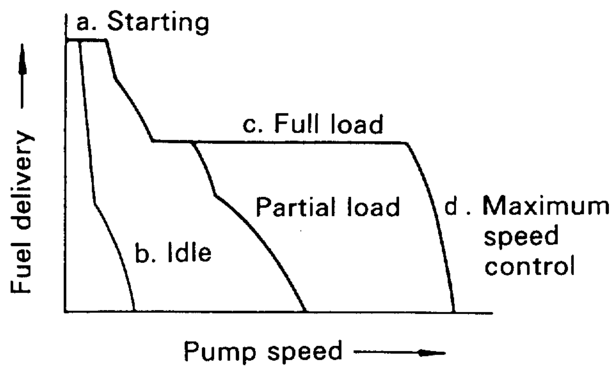


Fig.8-17 Fuel delivery characteristics

a. Starting

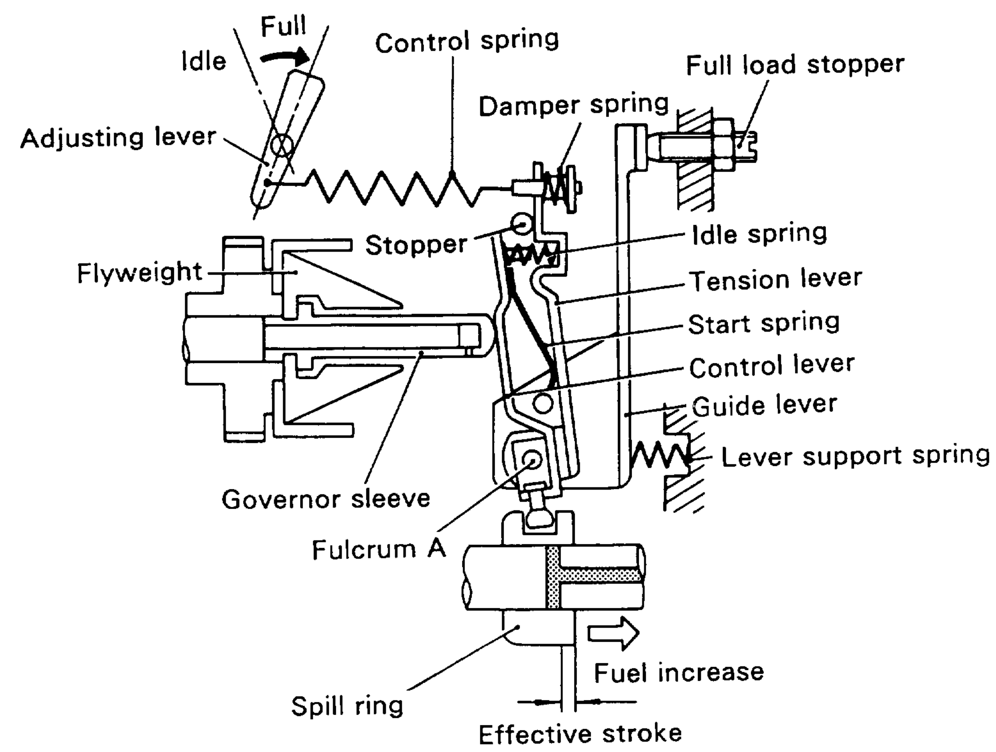


Fig.8-18 Starting

Moving the adjusting lever to the full fuel position puts tension on the control spring, pulling the governor lever assembly against the stopper. (See Fig.8-18) The start spring (leaf type spring) holds the control lever against the governor sleeve at the low cranking speed. This holds the flyweights closed while providing maximum travel of the spill ring and creating maximum effective stroke of the plunger.

b. Idling

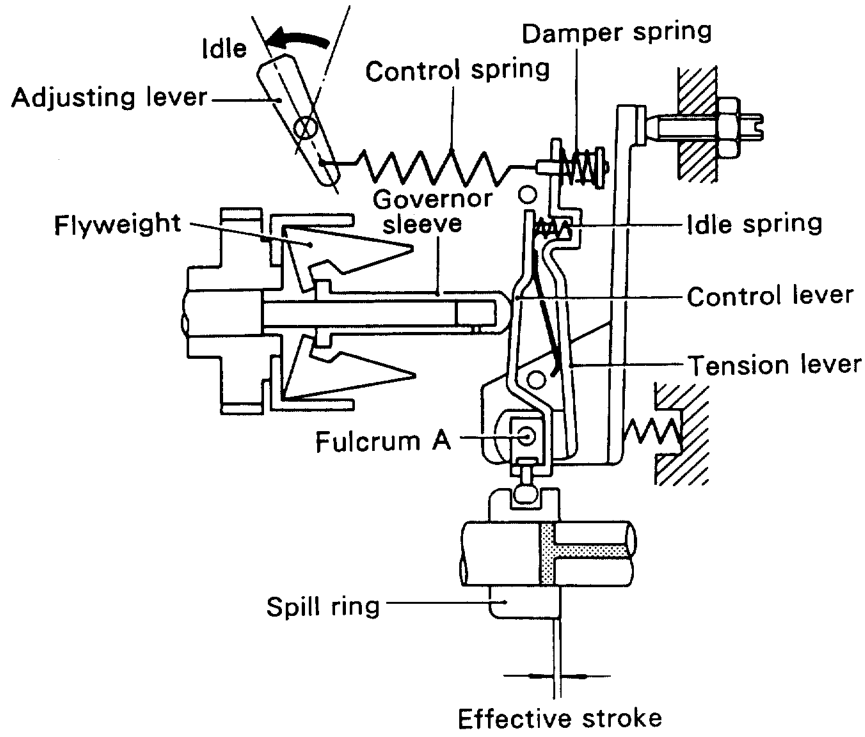


Fig.8-19 Idling

Once the engine has started, the adjusting lever is returned to the idle position. With little or no tension on the control spring, the centrifugal force of flyweight is counterbalanced by the force of the idle and damper springs. (See Fig.8-19) This balance of force is sufficient to maintain stability, under normal conditions, at idling speed.

c. Full Load

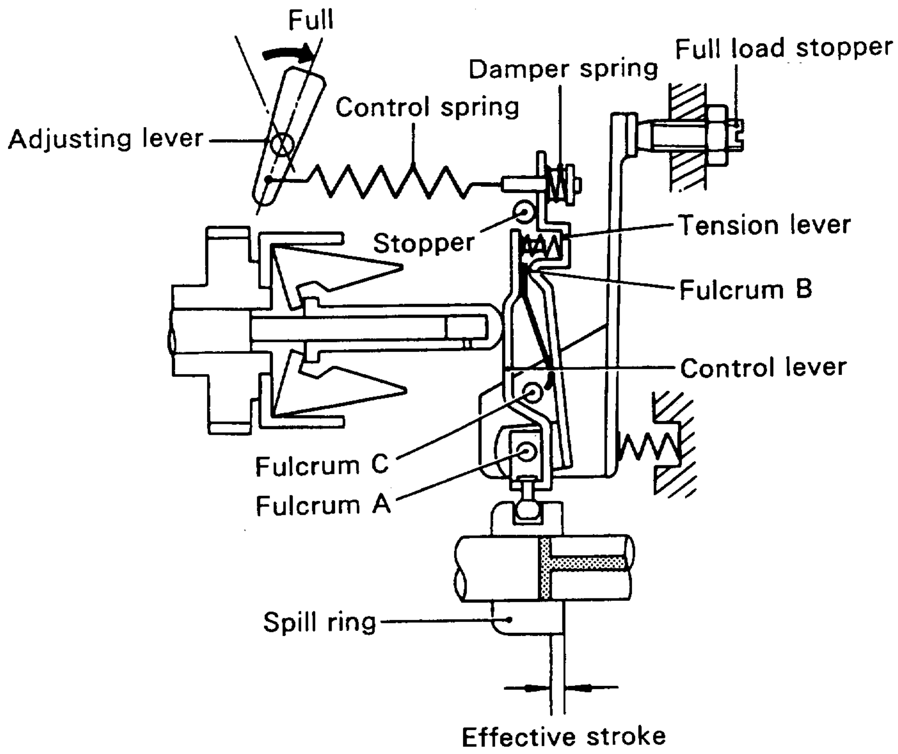


Fig.8-20 Full Load

With the adjusting lever moved to the full load position, the control spring tension is increased. The damper spring is completely pressed, and the tension lever is pulled to the stopper. As the control lever touches the tension lever at fulcrum B, spill ring keeps a position that the effective stroke obtains fuel delivery quantity under full load.

d. Maximum Speed Control

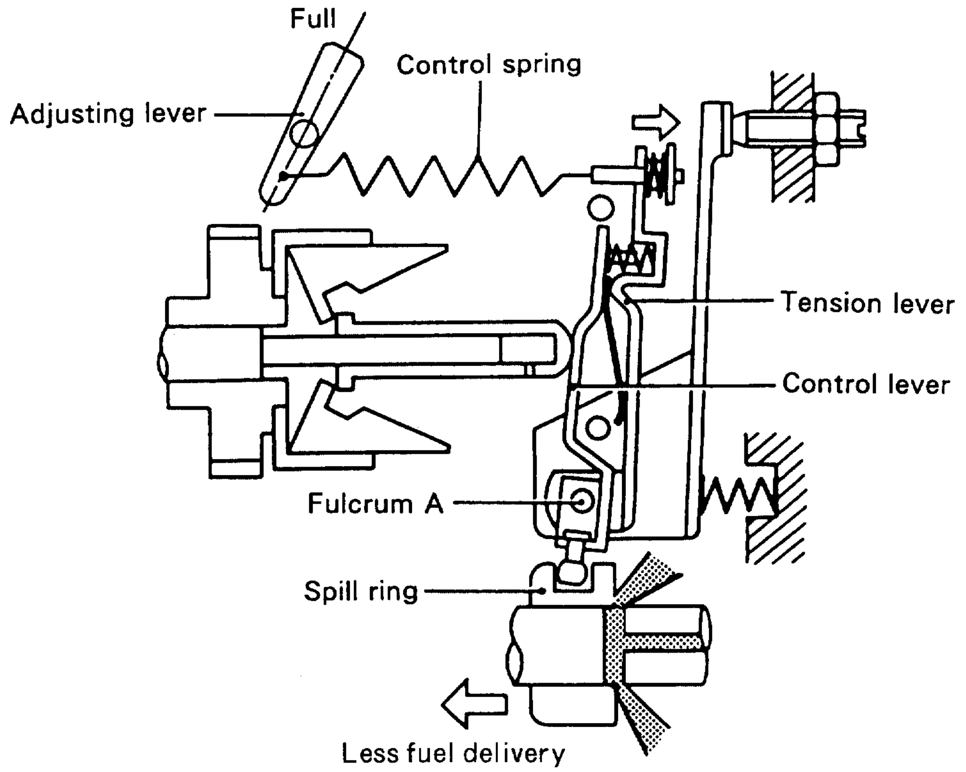


Fig.8-21 Maximum speed control

When engine speed overcomes the predetermined maximum speed, flyweight force overcomes the tension of the control spring. At this point, the governor lever assembly pivots to move the spill ring toward a "Less fuel position." With this sction engine maximum speed is controlled.

e. Reverse Adaptation

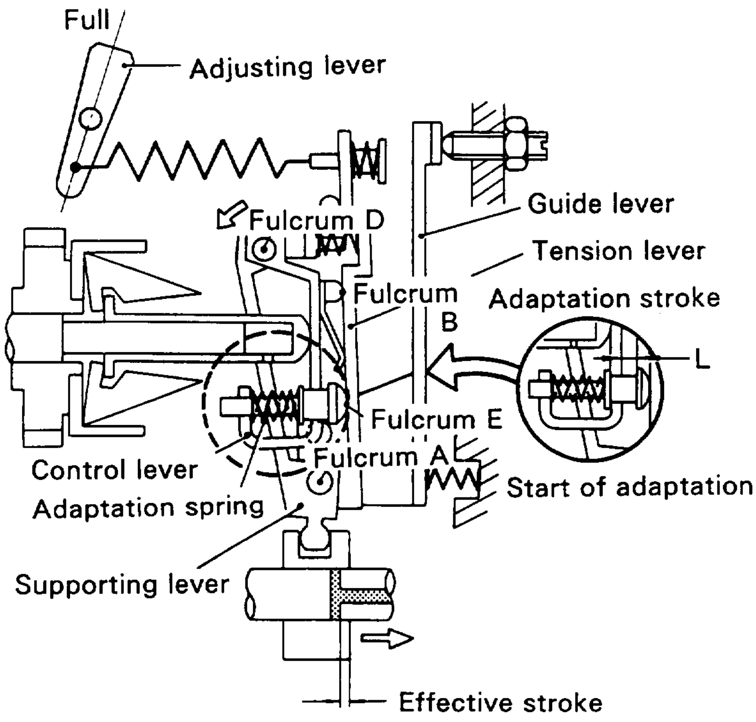


Fig.8-22 Reverse adaptation

For reverse adaptation type governor, the governor lever differs from that of the standard type governor as illustrated in Fig.8-22. The governor lever comprises a guide lever, tension lever, control lever and supporting lever, and the reverse adaptation spring is used in the control lever. The tension lever and supporting lever pivot on the shaft A that is fixed on the guide lever.

When the pump speed increases and the flyweight's centrifugal force overcomes the reverse adaptation spring's pre load, the inner reverse adaptation spring is compressed first, then the outer reverse adaptation spring is compressed, and moving the tension lever for the reverse adaptation stroke. In the meantime, since the control lever pivots counter-clockwise on fulcrum B, and fulcrum D moves in the direction shown by the arrow in Fig.8-22, the supporting lever pivots counter-clockwise on fulcrum A causing the spill ring to move in the direction in which fuel quantity increases. The quantity of fuel increase is determined by the reverse adaptation stroke (L). (See Fig.8-22, stroke "L")

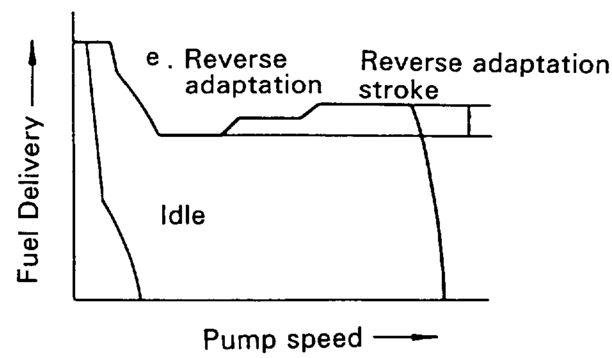


Fig.8-23 Fuel delivery characteristics

8-7-2. MINIMUM / MAXIMUM SPEED CONTROL

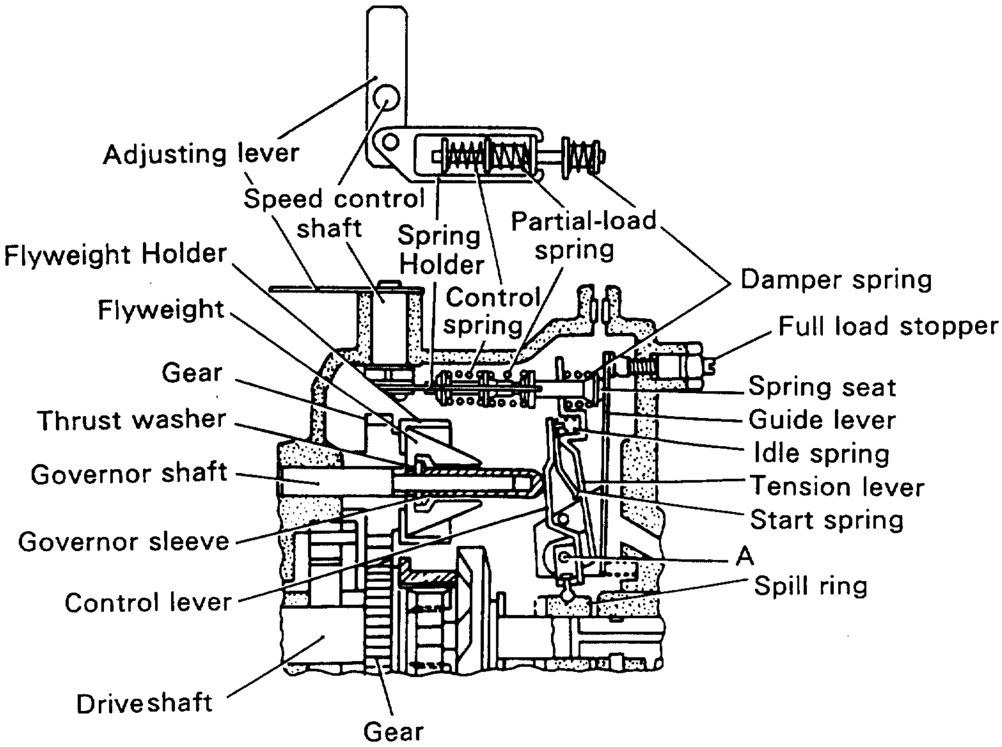


Fig.8-24 Construction of Min./Max. speed governor

(1) Min. / Max. Construction

The main difference between an "All-Speed" and a "Min. / Max. speed" type governor is the spring holder found in the "Min. / Max.". In the "Min. / Max." type governor the spring holder incapsulates the control spring and a partial load spring. (See Fig.8-24)
Where the "All-Speed" type has a single free length control spring.

(2) Principal of Operation

The "Min. / Max." spring holder or capsule provides more of a semi-solid link between the adjusting lever and the governor lever assembly. The effective stroke / delivery quantity is directly controlled according to adjusting lever position, while the spring force within the "Min. / Max." capsule provides for governor control at full load. The idle spring allows for governor control at idle speed. Hence the term "Min. / Max." (See Fig.8-25)

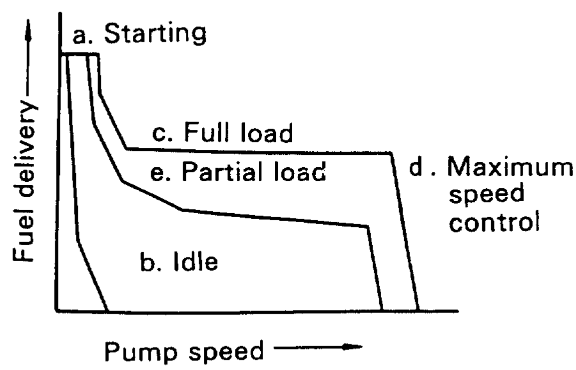


Fig.8-25 Fuel delivery characteristics

a. Starting

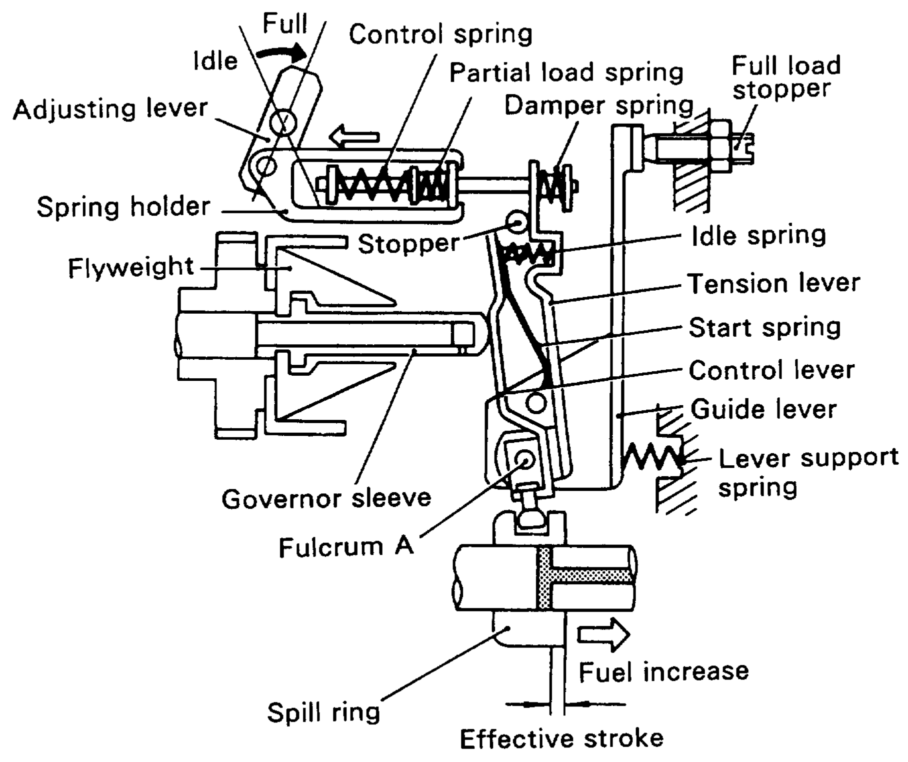


Fig.8-26 Starting

The "Min. / Max." type governor functions identically to the All-Speed when the adjusting lever is moved to the full load position while cranking the engine. (See Fig.8-26) The control spring and partial load spring are preloaded in this position.

b. Idling

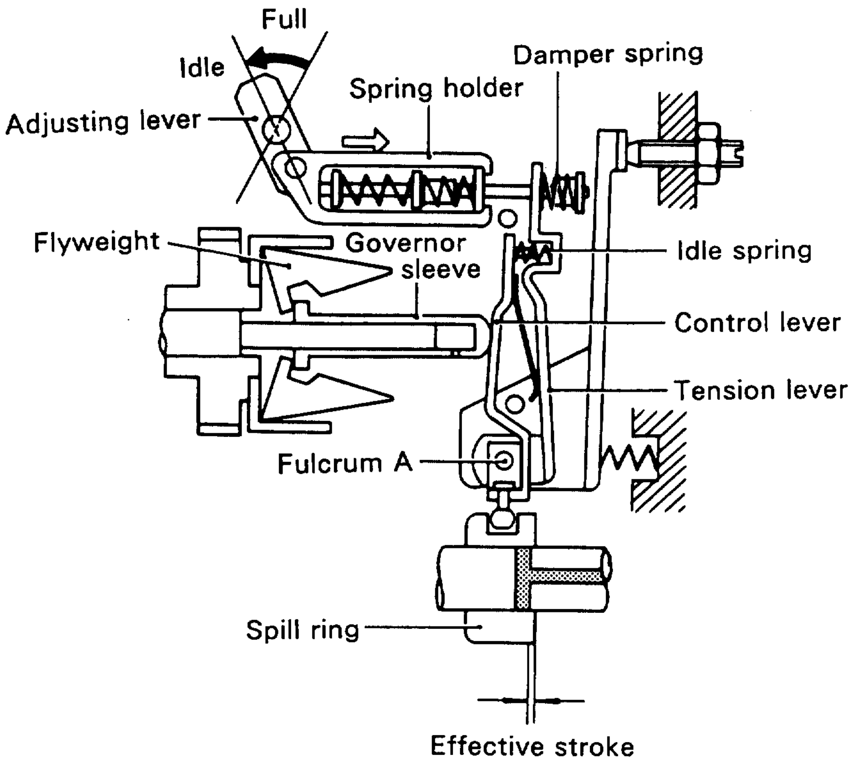


Fig.8-27 Idling

In the idling position, the "Min. / Max." governor functions identically to the "All-Speed" type governor. The idle spring and the damper springs are the balancing force used to maintain proper spill ring position for idling stability. (See Fig.8-27)

c. Full Load Speed

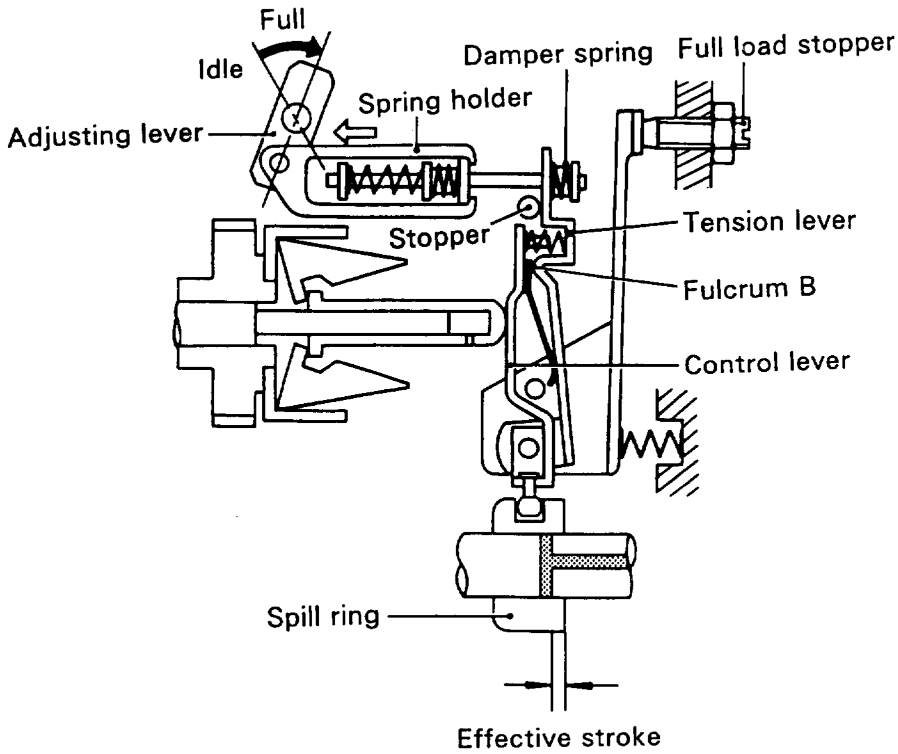


Fig.8-28 Full load speed

Full load speed in the "Min. / Max." governor is controlled basically the same way as the "All-Speed" governor. When flyweight force overcomes the spring tension of the springs in the capsule or spring holder, the governor lever assembly pivots to move the spill ring toward the "no fuel position".
(See Fig.8-28)

d. Maximum Speed Control

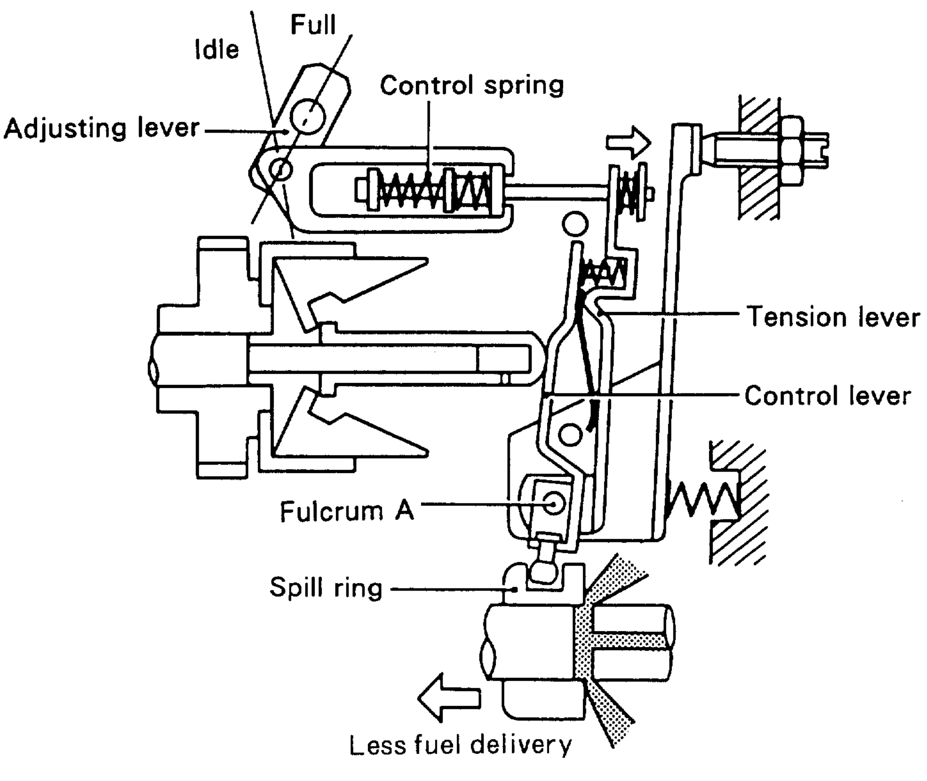


Fig.8-29 Maximum speed control

Flyweight force overcomes the force of the control spring located within the spring holder or capsule. This action moves the spill ring to the "Less fuel position". (See Fig.8-29)

e. Partial Load

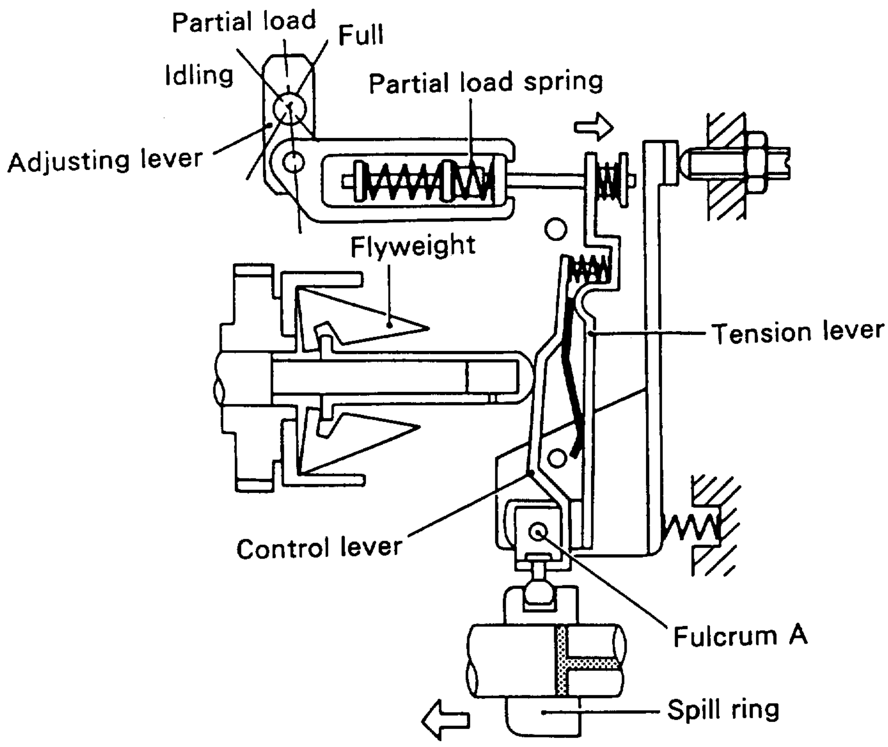


Fig.8-30 Partial load

Unlike the "All-Speed" when the adjusting lever is placed between the idle speed position and the full load position, the partial load spring becomes the balancing force. (See Fig.8-30) This type of action in the "Min. / Max." governor creates engine response similar to that of a gasoline engine. In the "Min. / Max." type, the control spring holder or capsule acts more as a solid link between the adjusting lever and governor lever assembly. This type of action provides a more direct metering control by the driver / operator at all the speeds between the idle speed control and the maximum speed control.

8-8. AUTOMATIC TIMER

8-8-1 CONVENTIONAL TIMER

(1) Function

The VE pump's internal pressure increases as its speed increases. The VE pump detects the stabilized point in the internal pressure and sets injection timing automatically according to the the stabilized point.

(2) Operation

The automatic timer is located in the lower part of the pump housing and moves from one side to the other during operation.

When static, the timer piston is held against the timer cover plate by the tension of the timer spring. As pump speed increases and therefore increased feed pump pressure, the feed pump / housing pressure acts against the timer piston to move it against the timer spring. This motion pivots the roller ring assembly by way of the slide pin that links the roller ring and the timer piston. The pivoting motion of the roller ring against the timer spring causes injection timing to advance. (See Fig.8-31)

Since feed pressure is proportional to pump speed, timer movement is also proportional to pump speed. (See Fig.8-32)

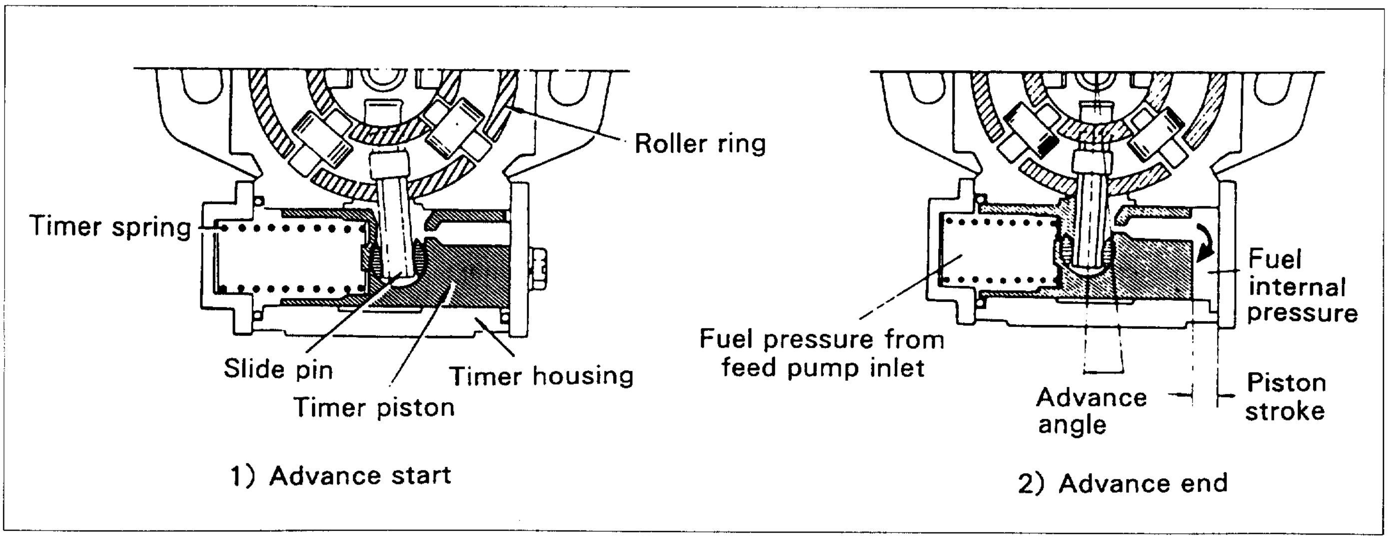


Fig.8-31 Operation of hydraulic timer

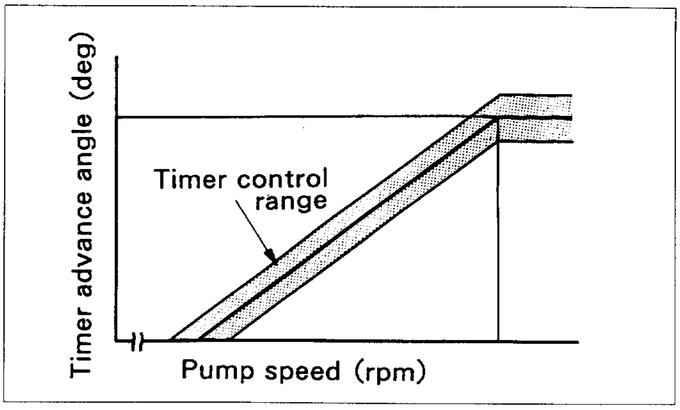


Fig.8-32 Timer advance characteristics

8-8-2 SERVO TIMER

(1) Outline

To improve the stability and responsiveness of timer which controls the fuel injection timing, a servo timer which has a built-in servo valve is employed.

(2) Construction

Differences between the servo timer and conventional timer are shown in Fig.8-33. The servo timer is located in the same position of the pump housing as the conventional timer.

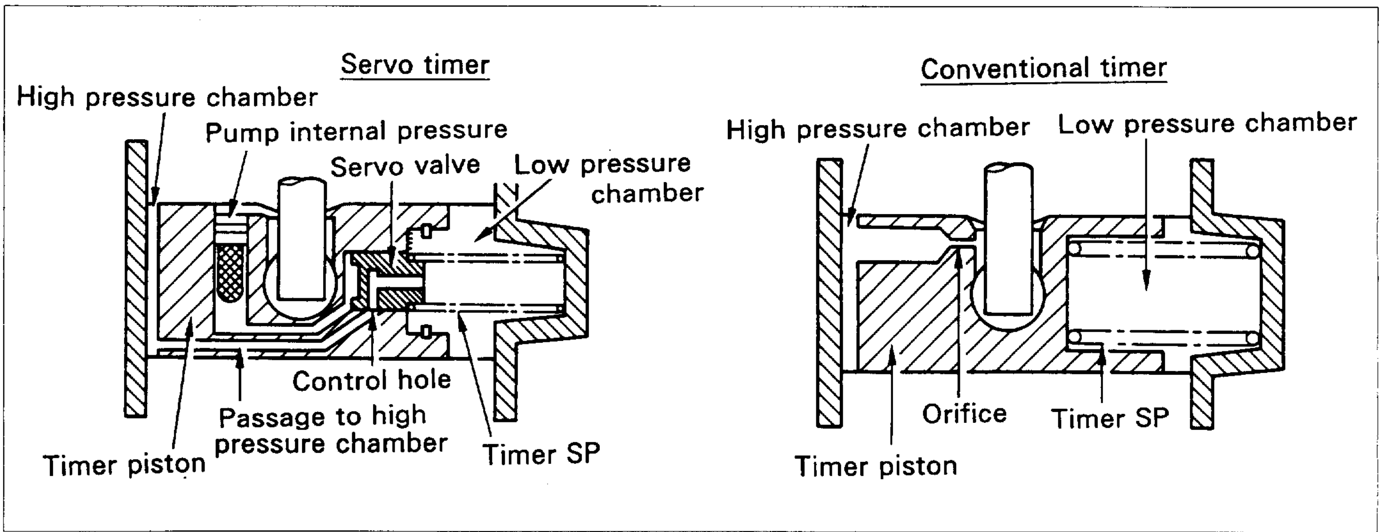


Fig.8-33 Differences between the servo timer and conventional timer

(3) Operation

1) When Injection Timing is Advanced

When the pump speed increases, incleasing the pressure inside the pump, the servo valve presses on the timer spring, causing it to contract and move to the right, and the control hole opens. Then the fuel flows in through the passage to the high pressure chamber and the timer piston moves to the right side (injection timing is advanced). When the timer piston moves to the right, causing the servo valve to close the control hole, the fuel stops flowing, the timer piston stops, and the timing advance is complete. (See Fig.8-34)

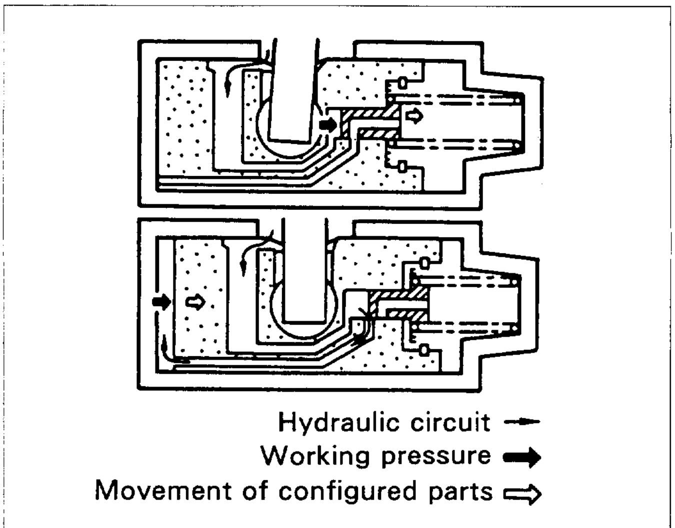


Fig.8-34 When injection timing is advanced

2) When Injection Timing is Retarded

When the pump speed decreases, lowering the pressure inside the pump, the timer spring presses on the servo valve, causing it to move to the left and opening the control hole. Then the fuel in the high pressure chamber flows out to the low pressure chamber side through the passage, and the timer piston moves to the left side (injection timing is retarded).

When the timer piston moves to the left, causing the servo valve to close the control hole, the fuel stops flowing out, the timer piston stops, and the injection timing retardation is complete. (See Fig.8-35)

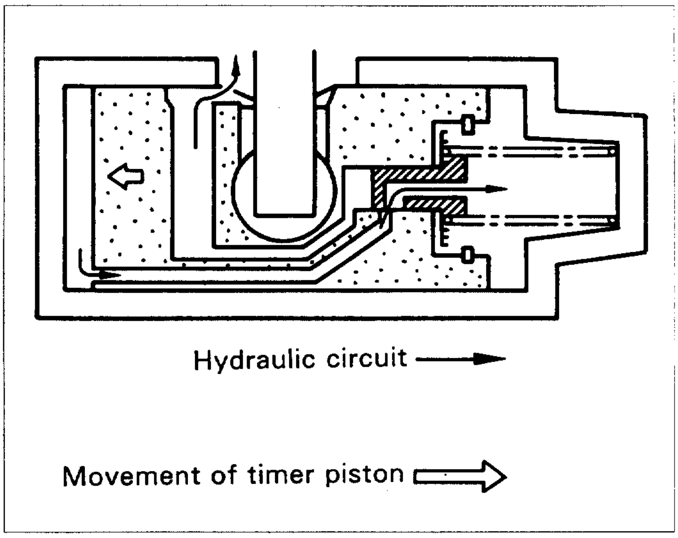


Fig.8-35 When injection timing is retarded

(4) Special Features

With the servo timer as explained above:

First, the positioning of the servo valve is determined by the balance of a) the pump internal pressure applied to the servo valve and b) the pressure applied to the servo valve from the low pressure chamber combined with the force of the timer spring.

Next, when the servo valve position has been determined, the timer piston position has been determined accordingly.

With the conventional timer:

The positioning of the timer piston is determined by the balance of a) the pressure of the high pressure chamber and b) the combination of 1) the pressure of the low pressure chamber 2) the force of the timer spring, and 3) the reverse driving force.*

Since the servo timer is not affected by the reverse driving force in the positioning of the timer position, it is superior to the conventional timer in terms of stability and responsiveness.

* Reverse driving force: The force from the pump drive system is applied to the timer slide pin, obstructing the timer piston movement and inhibiting operation.

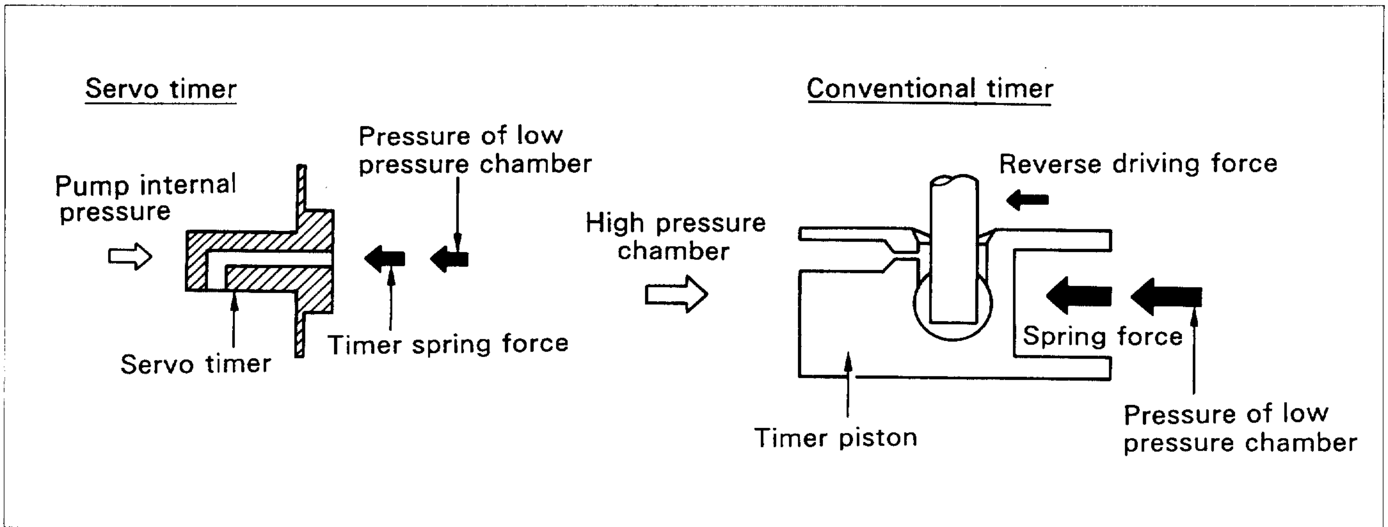


Fig.8-36 Pressure on timer

9. ADDITIONAL DEVICES

9-1. INJECTION TIMING DEVICE

9-1-1. LOAD SENSING TIMER (L.S.T.)

(1) Function

The load sensing timer was created to retard the injection timing as the load decreases at a certain speed.

(2) Operation

(See Fig.9-1) At a certain speed under no load, the fuel pressure in the pump chamber is released through the orifice on the governor sleeve to the inlet side of the feed pump, this effects the timer piston, retarding the injection timing. Conversely, when the load on the engine increases, the adjusting lever is pulled up against the stopper. As a result, the orifice on the sleeve is closed and again the injection timing advances as shown by an arrow in Fig.9-3.

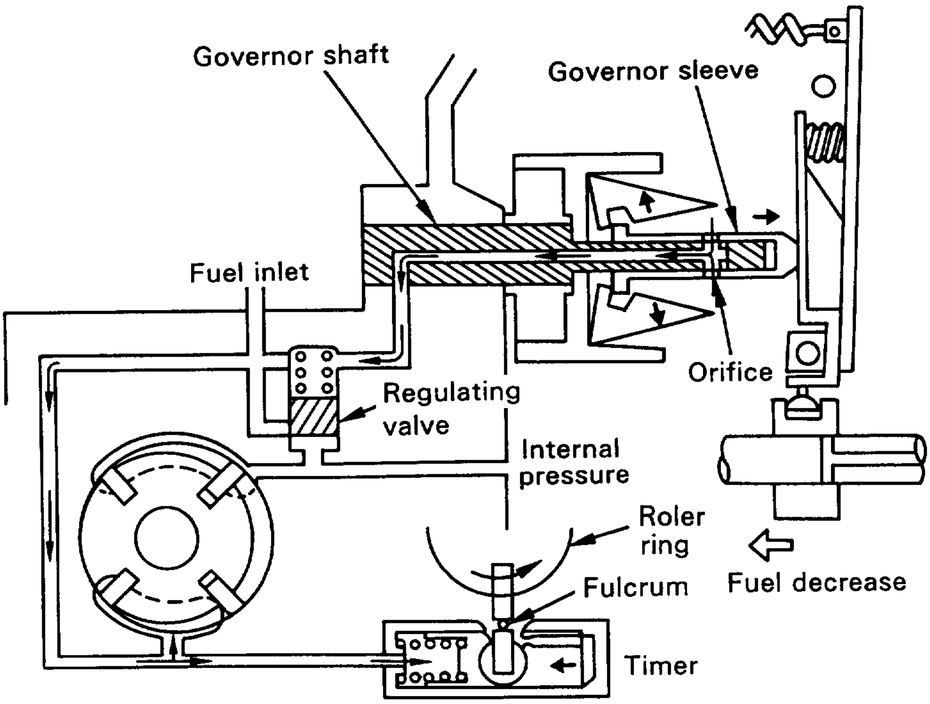


Fig.9-1 Load sensing timer

As shown in Fig.9-2, the load sensing timer can operate under a load between 25 and 70% of full load. Maximum retarding angle is related to the size of orifice on the governor sleeve.

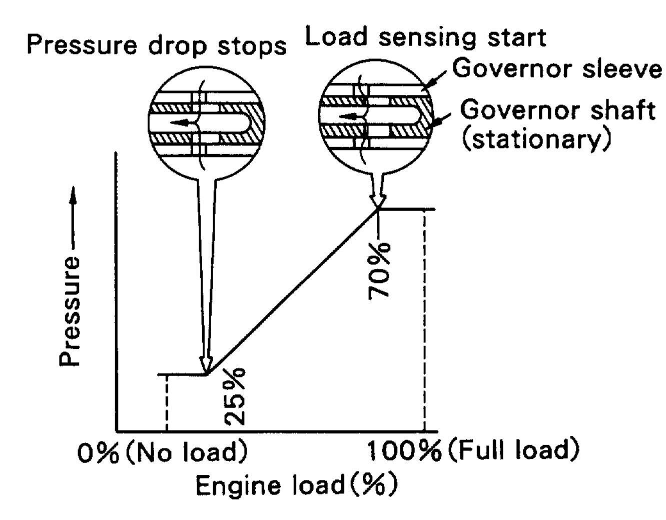


Fig.9-2 Engine load and pressure

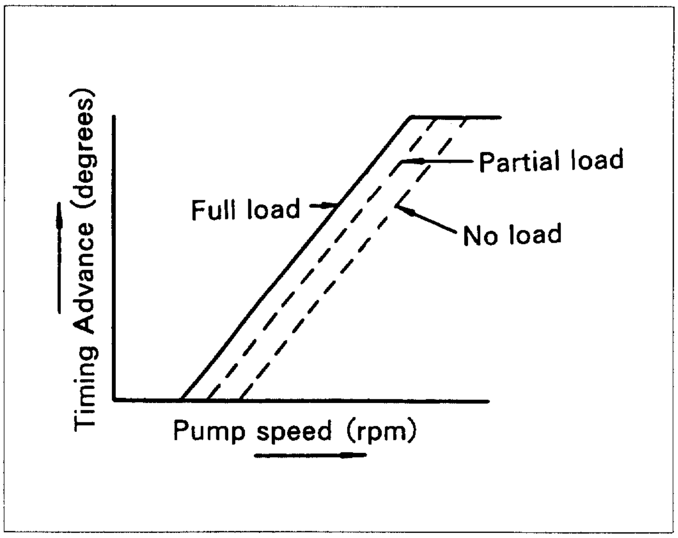


Fig.9-3 Characteristics of load sensing timer

9-1-2. TIMING CONTROL VALVE (T.C.V.)

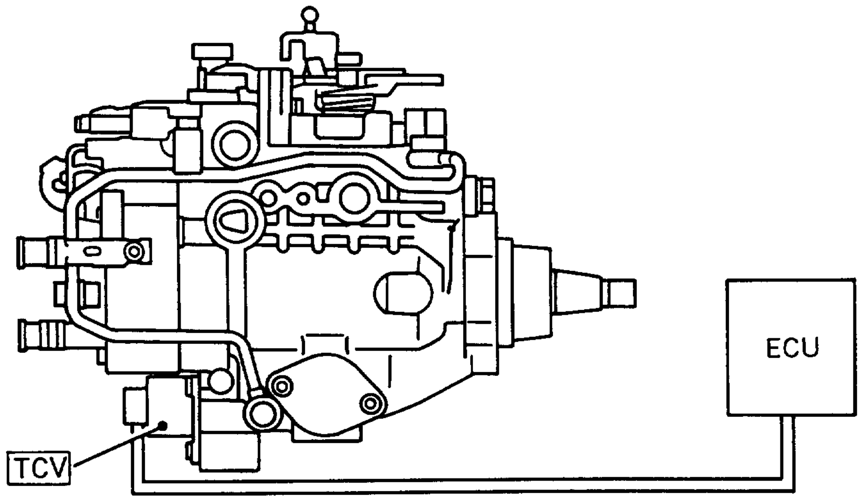


Fig.9-4 External view of VE pump with TCV

(1) Function

The timing control valve de-activates the load sensing timer when the engine coolant temperature is low (below 60 ℃) or when the pump is used at high altitudes (where atmospheric pressure is 700mmHg or less).

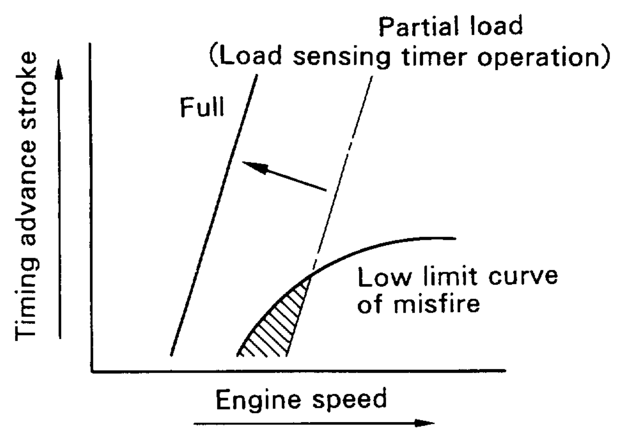


Fig.9-5 Timer advance angle by TCV

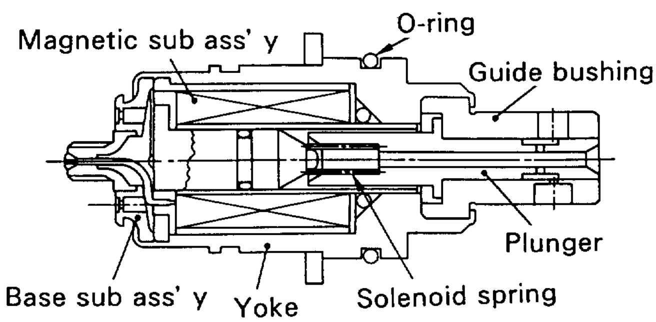


Fig.9-6 Construction of TCV

(2) Operation

1) Normal Operation of Load Sensing Timer

After the engine is warmed up (coolant temperature is higher than 60 ℃) and the vehicle is located at low altitude where atmosphere pressure is more than 700mmHg, when the acceleration lever returns, the engine load decreases. Accordingly, pump internal pressure returns to the intake side due to the operation of the load sensing timer, therefore, hydraulic pressure to the timer piston decreases and the injection timing delays consequently. At this time, TCV is in the OFF condition to ensure the fuel passage. (Operation of TCV: OFF-The fuel passage is open ON-The fuel passage is closed.) (See Fig.9-8, 9-10)

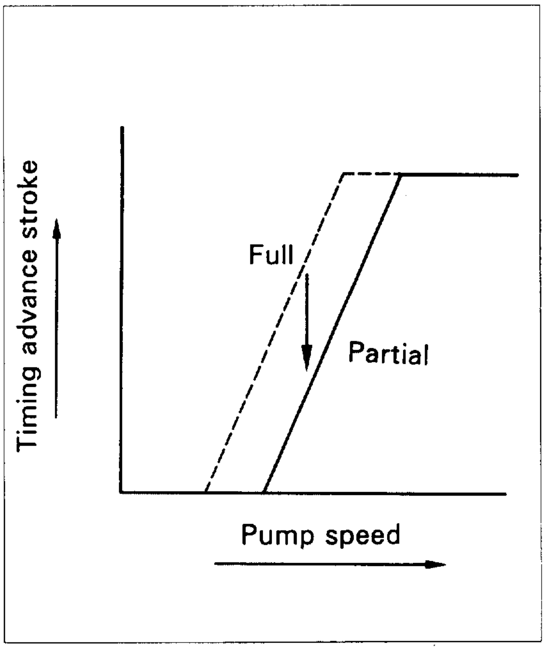


Fig.9-7 Fuel injection timing characteristics

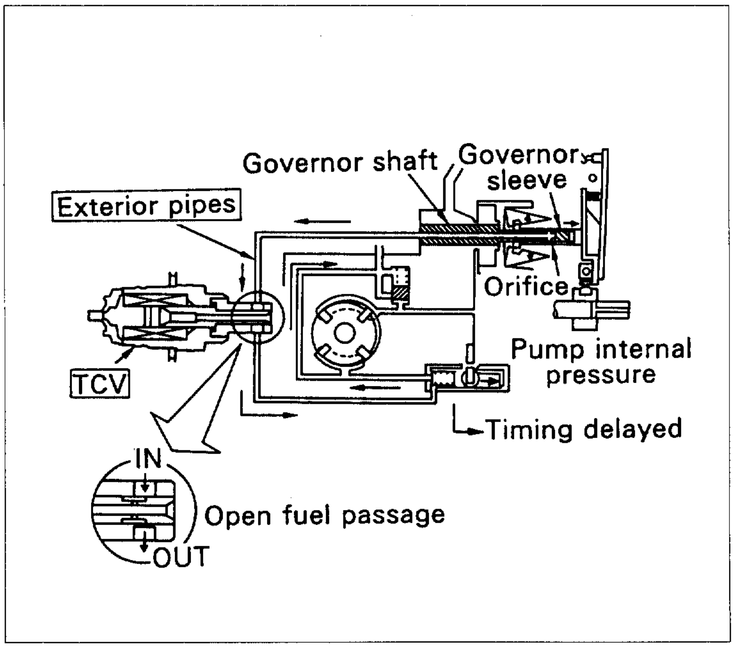


Fig.9-8 Operation of TCV-OFF

2) Cancellation Of Load Sensing Timer

When the engine coolant temperature is lower than 60℃ or vehicle is located at a high-altitude where atmosphere pressure is less than 700mmHg, the coolant temperature sensor and the atmosphere pressure sensor send a signal to the ECU. Receiving the signal, the ECU sends a signal to operate the TCV and pull in the plunger inside the TCV to close off fuel passage. Due to the operation, internal pump pressure cannot return to the intake side. Therefore, even when the engine load decreases, the pump internal pressure does not decrease. Accordingly, the fuel injection timing does not change toward retard side. (See Fig.9-9, 9-10)

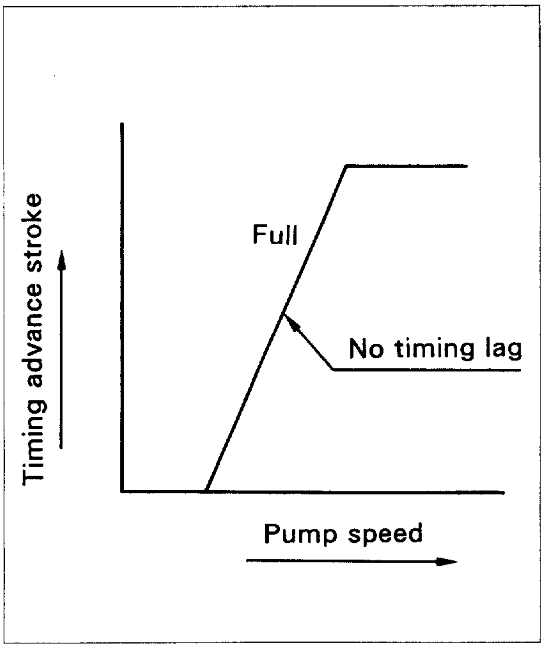


Fig.9-9 Fuel injection timing characteristics

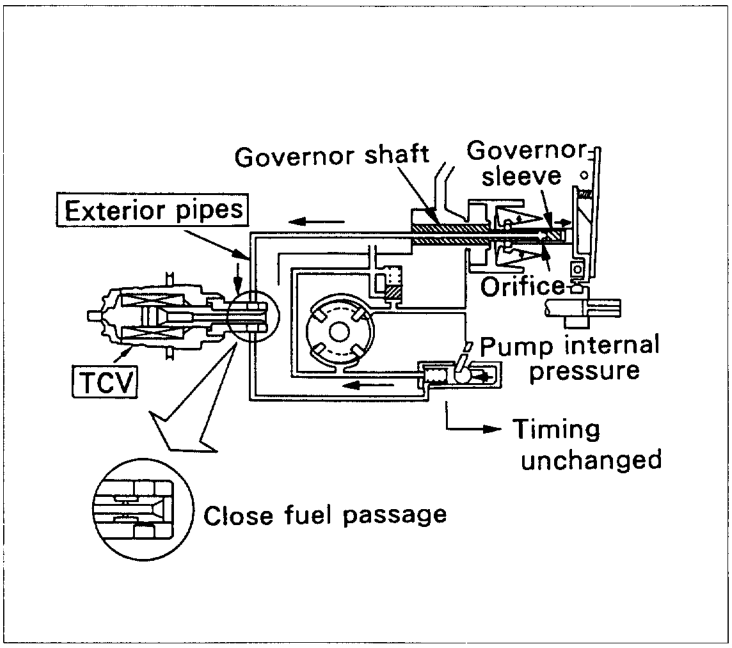


Fig.9-10 Operation of TCV-ON

9-1-3. COLD START DEVICE (C.S.D.)

(1) Function

The Cold Start Device advances the injection timing to make starting easier in cold weather when the control lever is pulled by a driver.

(2) Operation

When turning the C.S.D. lever, the actuating cam on the C.S.D. shaft, rotates the roller ring in the opposite direction of pump rotation.
As a result, the injection timing is advanced relative to cam position (θ). (See Fig.9-12)

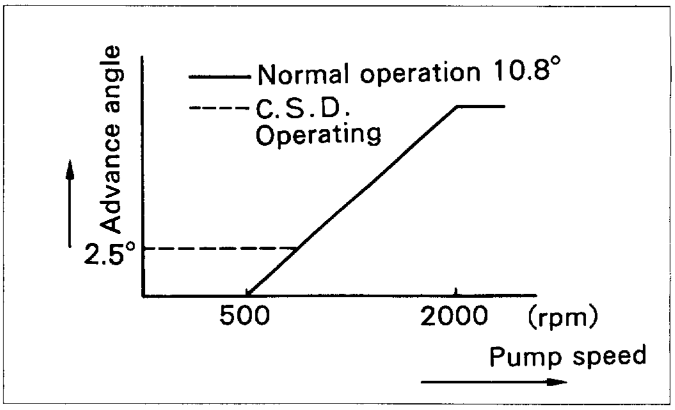


Fig.9-11 Advance characteristics

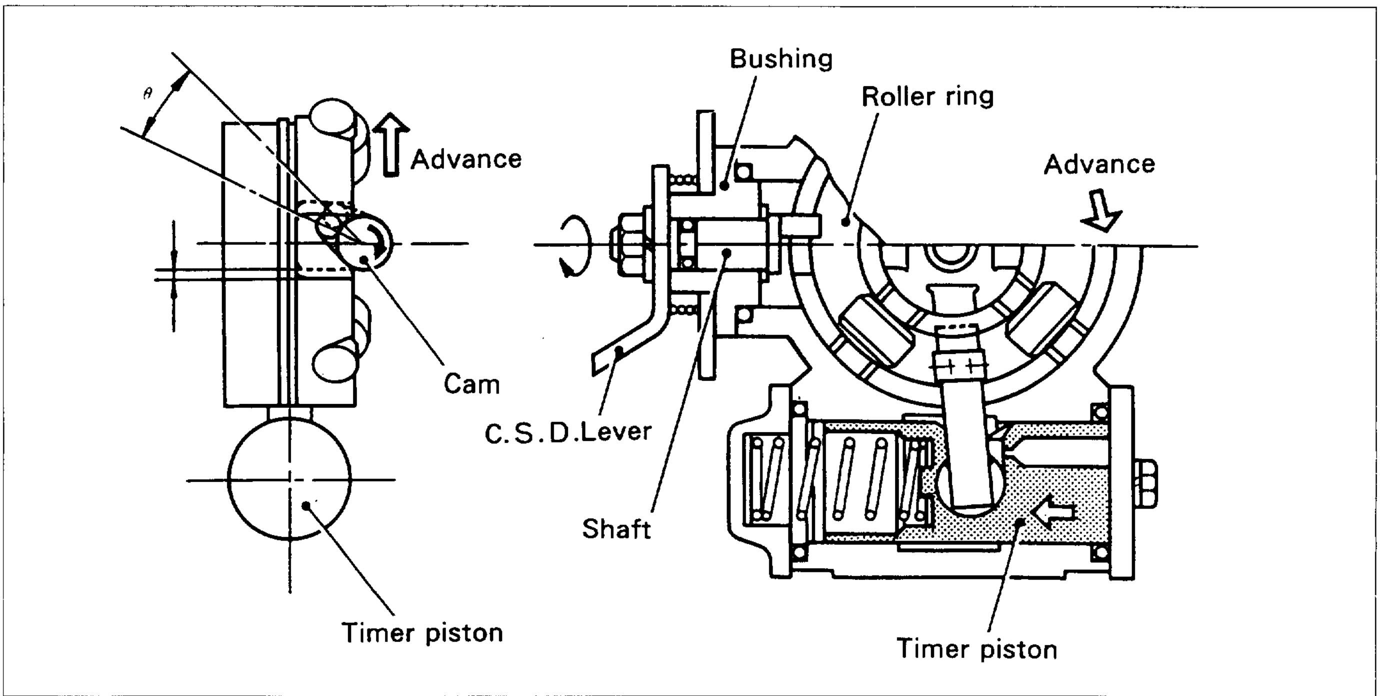


Fig.9-12 Construction and operation of C.S.D.

(REFERENCE)
C.S.D. lever is operated by pulling the lever (A) which is linked through the spring (B).

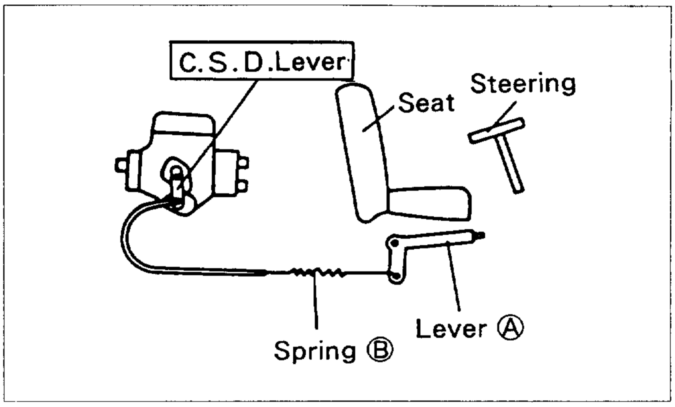


Fig.9-13 Lever linkage

9-1-4. AUTOMATIC COLD START DEVICE (A.C.S.D.)

(1) Function

The A.C.S.D. eases the starting of a cold engine
by 1) advancing the injection timing
2) increasing the idle speed.

(2) Construction

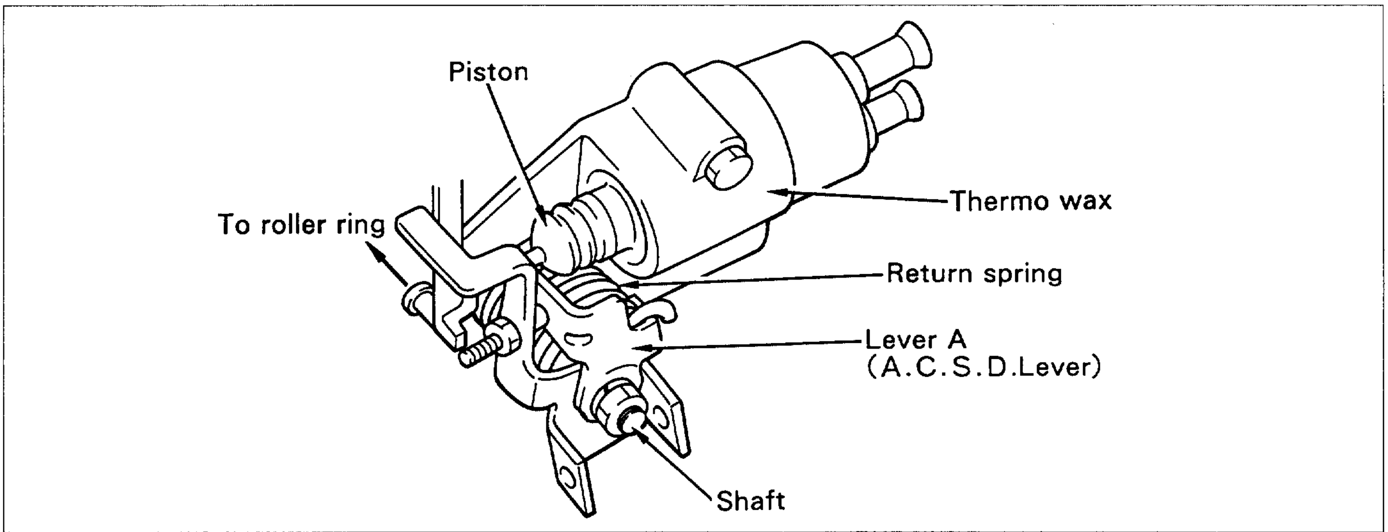


Fig.9-14 Construction of A.C.S.D.

The A.C.S.D. consists of a thermo wax piston, a return spring, levers A and B and a shaft whose attached cam connects the roller ring to the A.C.S.D.

NOTE: The lever A is called the A.C.S.D. lever.

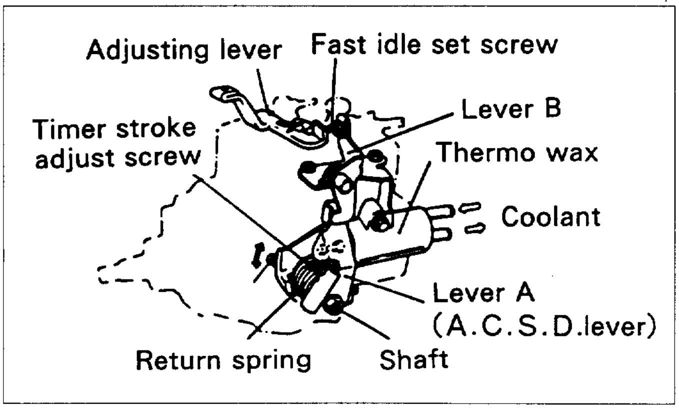


Fig.9-15 Outline of A.C.S.D.

Thermo Wax Characteristics
The thermo Wax piston contains a wax that changes its volume according to the temperature changes of the engine coolant which flows through the unit at all times. Above A ℃ the wax expands in proportion to the coolant temperature; below A ℃ it contracts.

REMARK

Coolant temperature A is classified as −20, −10 and 0 ℃.

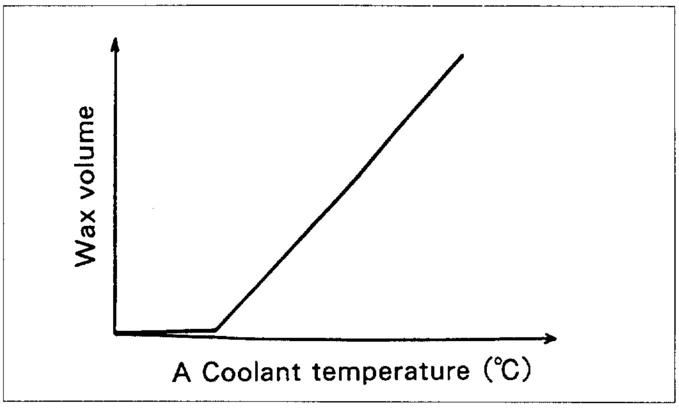


Fig.9-16 Thermo wax characteristics

(3) Operation

Below A ℃ coolant temperature, the return spring forces lever A and lever B to the fast idle position, as the wax contracts. In addition, the cam fitted to the shaft rotates to push the roller ring upwards (opposite pump rotation) against the timer spring tension. This advances the injection timing to its maximum amount.

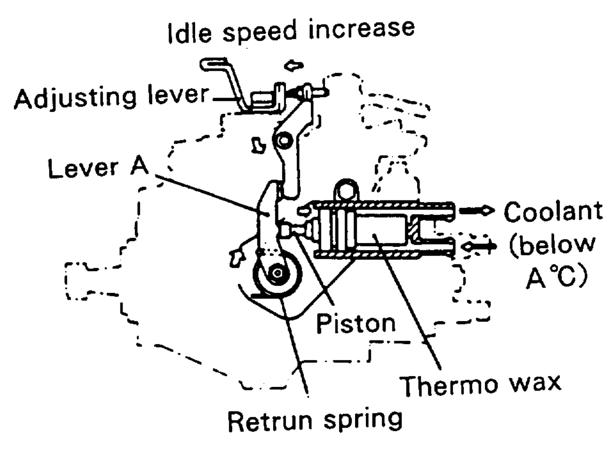


Fig.9-17 Operation of A.C.S.D. (Below A ℃)

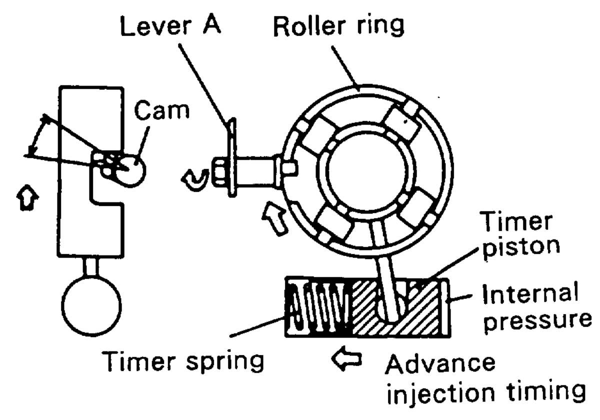


Fig.9-18 Operation of A.C.S.D. (Below A ℃)

Above A ℃ coolant temperature and after engine start up, the thermo wax expands and pushes the thermo wax piston against the lever A. As the wax expands lever A continues to be pushed against the return spring tension. This allows the timer piston and roller ring to return to a less advanced position during start up and idle.

This operation continues until a coolant temperature of B ℃ is reached.

Coolant temperature B varies depending on the engine.

NOTE: Under full load and semi-full load conditions, in higher speed, the timing advance will follow its normal curve even when the engine coolant is cold. The A.C.S.D. works during idle and start up only.

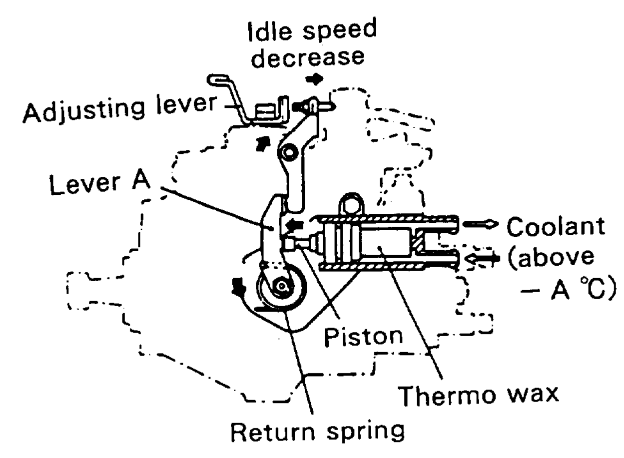


Fig.9-19 Operation of A.C.S.D. (Above A ℃)

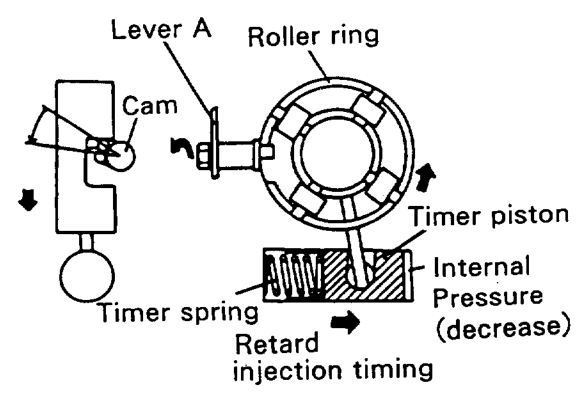


Fig.9-20 Operation of A.C.S.D. (Above A ℃)

9-1-5. ALTITUDE COMPENSATING TIMING ADVANCER (A.C.T.A.)

(1) Function

The A.C.T.A. advances the injection timing according to altitude.

(2) Construction

A.C.T.A. is mounted at the bottom of the pump next to the timer. (See Fig.9-21)

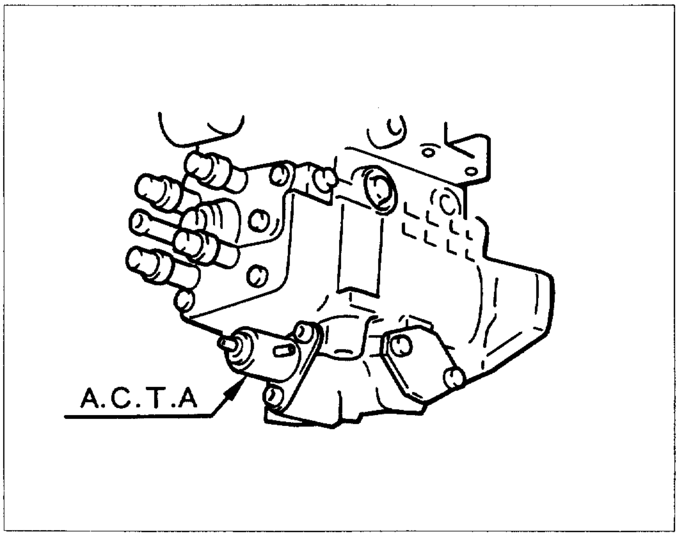


Fig.9-21 External view of A.C.T.A.

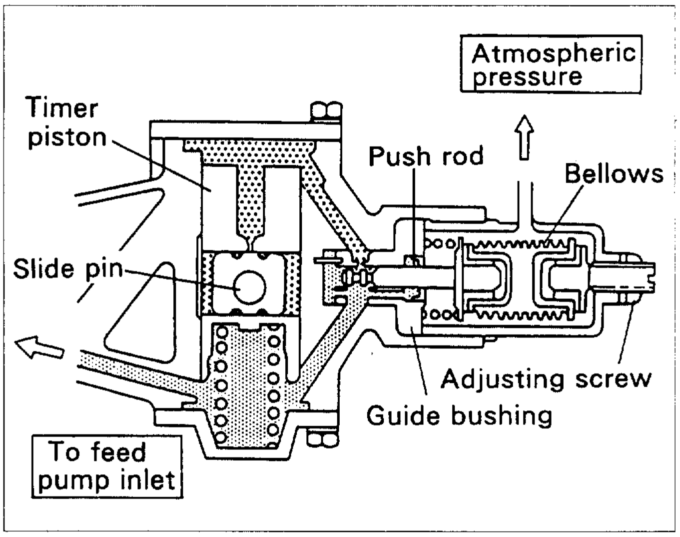


Fig.9-22 Construction of A.C.T.A.

(3) Operation

In high altitudes the lowering of atmospheric pressure causes the bellows to expand resulting in the push rod movement. (See Fig.9-24) This causes the orifice port to be shut. Therefore the internal pump housing pressure increases, which moves the timer to advance the injection timing.

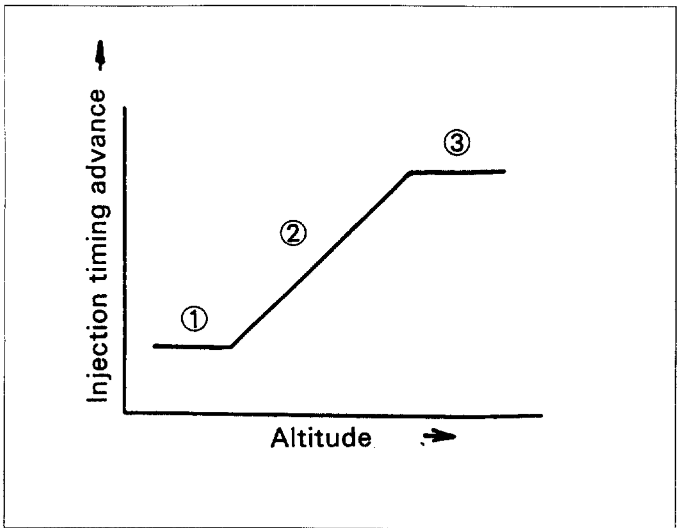


Fig.9-23 Advanced angle characteristics

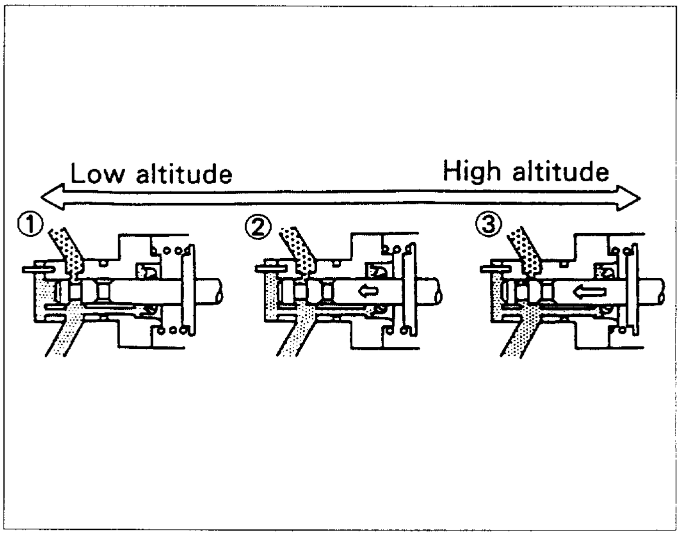


Fig.9-24 Operation of A.C.T.A

9-2. FUEL DELIVERY CONTROL DEVICE

9-2-1. DIESEL ALTITUDE COMPENSATOR (D.A.C.)

(1) Function

At high altitude, an engine tends to emit more black smoke due to enriched mixture in the combustion chambers, resulting from lowering of atmospheric pressure. To prevent this, the diesel altitude compensator automatically reduces the delivery quantity according to the altitude.

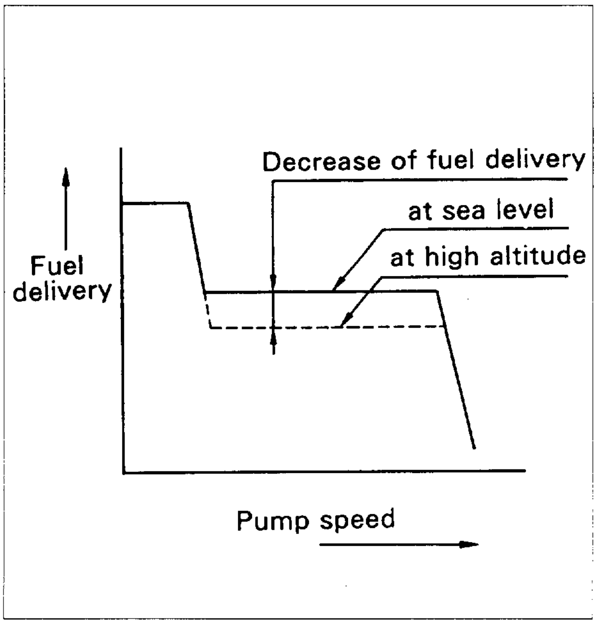


Fig.9-25 Fuel delivery characteristics

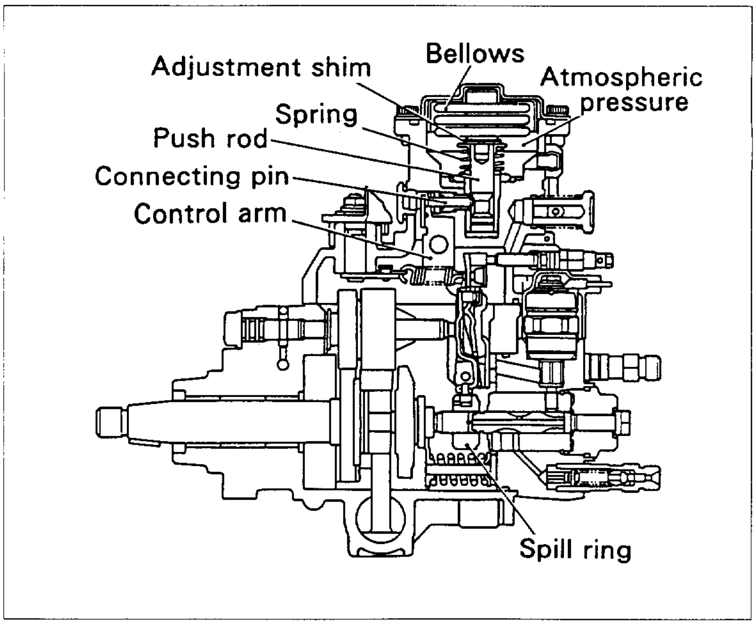


Fig.9-26 D.A.C. construction

(2) Operation

At high altitude the lowering of atmospheric pressure causes the bellows to expand, resulting in downward movement of the push rod. This downward movement of the push rod moves the spill ring to the fuel decrease direction by rotating the control arm through the connecting pin. (As indicated by arrows direction.)

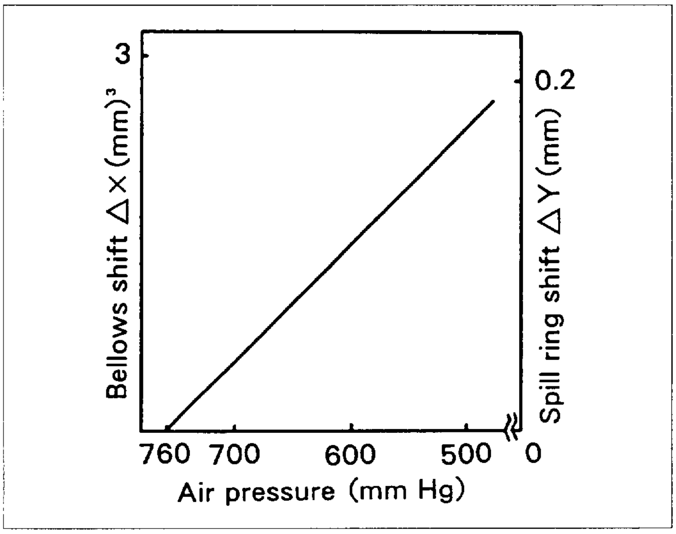


Fig.9-27 D.A.C. characteristics (Example)

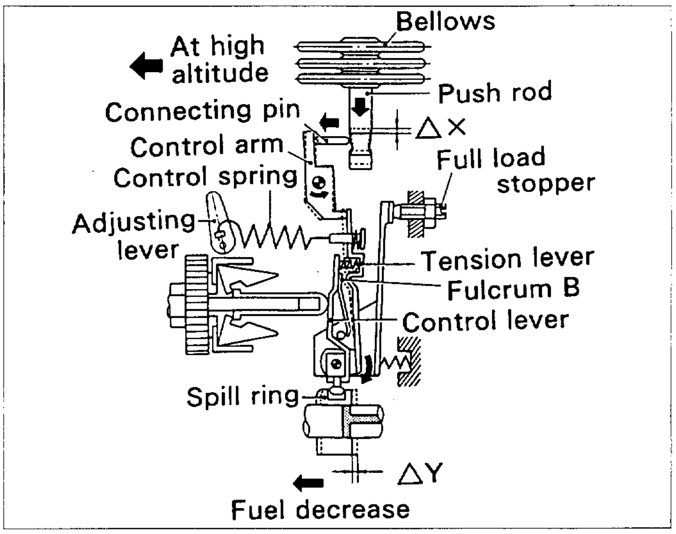


Fig.9-28 Operation of D.A.C.

9-2-2. BOOST COMPENSATOR (B.C.)

(1) Function

The boost compensator is used only in vehicles equipped with a turbo charger, and increases fuel injection quantity according to boost pressure resulting from start of the turbocharger.

(2) Construction

The boost compensator is comprised as illustrated in Fig.9-29, and mounted on top of the pump (governor cover).

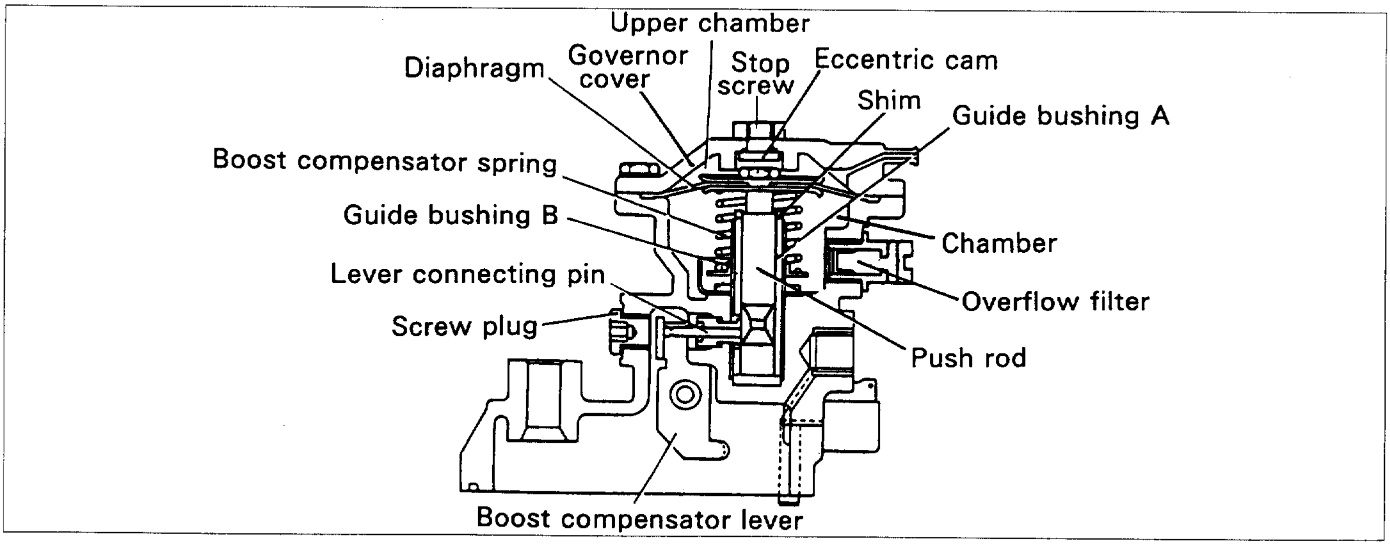


Fig.9-29 Construction of boost compensator (B.C.)

The following types of push rod and stop screw that are used for the boost compensator are available.

1) Tapering types of push rod

① Standard push rod (Fig.9-30)
② Push rod with OLP (Over Load Protector) (Fig.9-31)
OLP : Tapering is also provided on the upper side to reduce injection quantity when boost compensator abnormal.
③ Eccentric push rod (Fig.9-32)

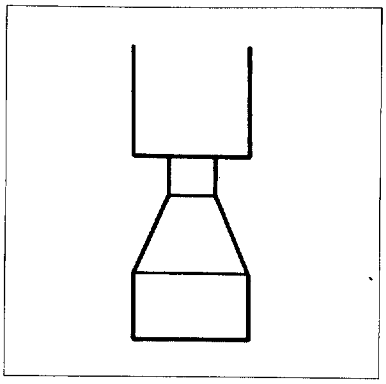


Fig.9-30

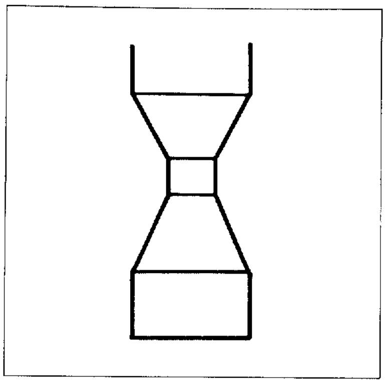


Fig.9-31

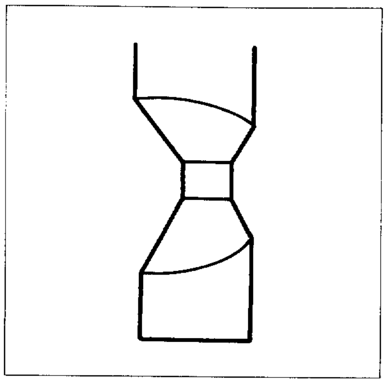


Fig.9-32

2) Types of stop screw

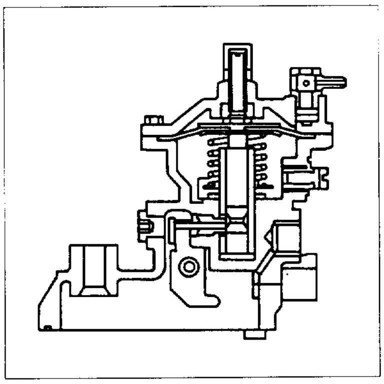


Fig.9-33

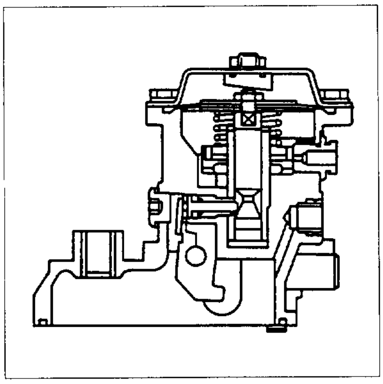


Fig.9-34

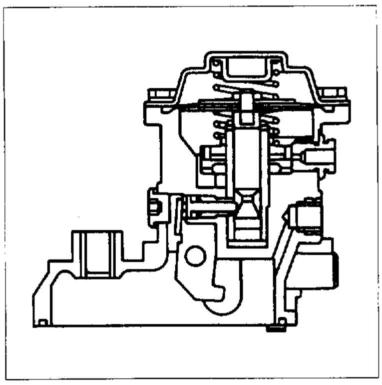


Fig.9-35

① Screw type is used so that adjustment can be performed from outside. (Fig.9-33)

② Eccentric cam type is used so that adjustment can be performed from outside. (Fig.9-34)

③ A spring is used at both top and bottom of the diaphragm to enable control of negative pressure. (Fig.9-35)

(3) Operation

Operation of the boost compensator that uses a push rod with OLP is described below.

1) When Boost Pressure Is Low

① Because the pressure inside the upper chamber is low, the diaphragm is forced upward by the spring until it contacts the stop screw.

② The lever connecting pin contacts the lowest side of the push rod tapered portion.

③ The B.C. lever operates as the tension lever stopper and is moved by the lever connecting pin.

B.C.: Boost Compensator

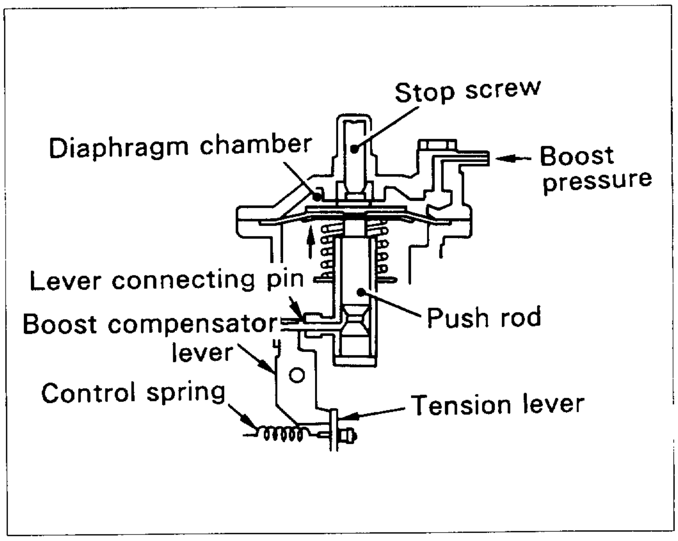


Fig.9-36 When boost pressure is low

2) When Air Charging Boost Pressure Is High

① Pressure in the upper side of the diaphragm chamber becomes high, and moves the diaphragm downward by overcoming the spring force. Then the diaphragm moves to the position where the forces of pressure and spring are balanced.

② Also the push rod moves downward together with the diaphragm.

③ At this time, the lever connecting pin moves to the right and along the tapered shape toward the slenderest position.

④ The tension lever presses the connecting pin to the push rod through the boost compensator lever. Therefore, when the push rod moves from high position to the lower position, the connecting pin moves to the right side as shown in Fig.9-38.

⑤ As a result, the top of the tension lever moves to the left, moving the spill ring to more fuel side.

3) When Abnormal Boost Pressure (higher than the specified level) Is Exerted.

① As pressure inside the diaphragm increases further, the push rod further moves downwards causing the connecting pin's contact point to shift to the top of the push rod tapered portion.

② As a result, the connecting pin slides to the left and the boost compensator therefore rotates counter-clockwise. This causes the tension lever to rotate clockwise, making the spill ring move in the direction by which delivery quantity is reduced.

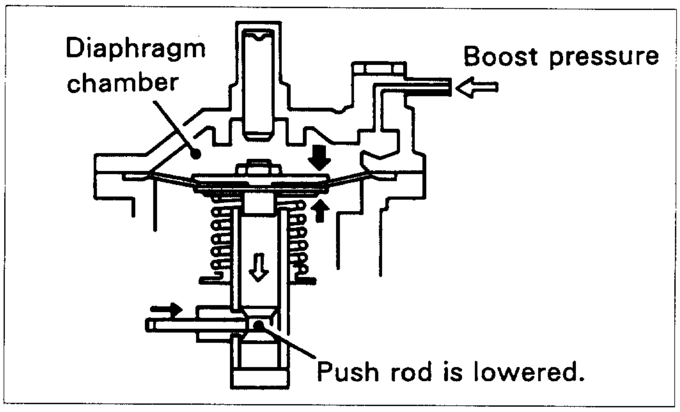


Fig.9-37 When boost pressure is increasing

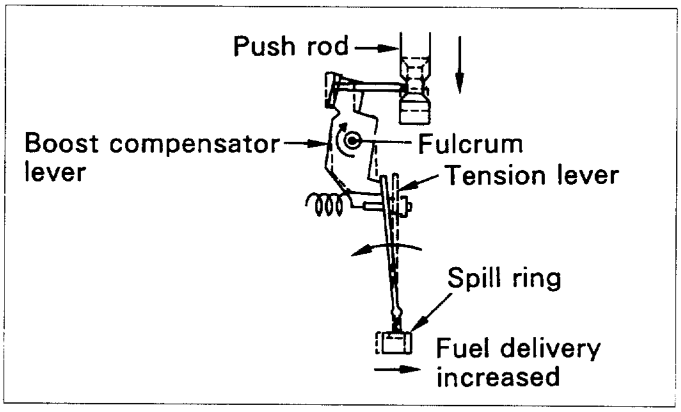


Fig.9-38 When boost pressure is increasing

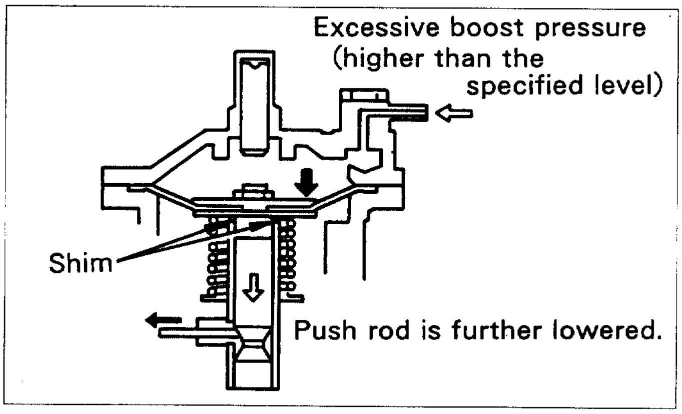


Fig.9-39 When abnormal boost pressure is applied

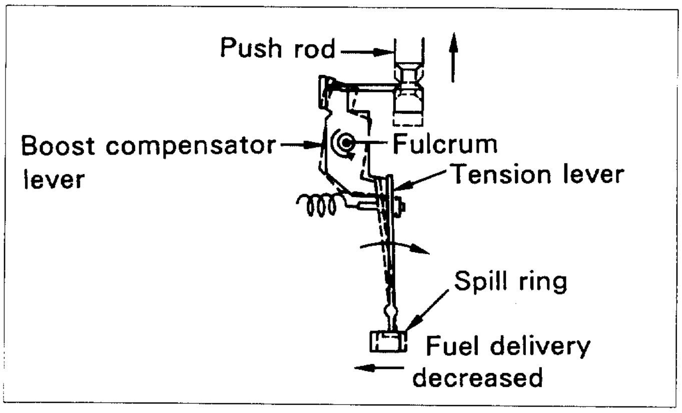


Fig.9-40 When abnormal boost pressure is applied

9-2-3. BOOST & ALTITUDE COMPENSATOR (B.A.C.S.)

(1) Function

The boost & altitude compensator is designed to compensate delivery quantity according to the altitude in order to prevent discharge of black smoke from the turbo charger engine when it is used at high altitudes.

(2) Construction

The boost & altitude compensator has the same basic structure as that of the boost compensator, except that a coustant pressure is applied to the lower chamber due to the constant pressure valve.

Differences between BC and BACS

BC : Injection quantity is not affected by changes in atmospheric pressure.

BACS : Injection quantity is affected by changes in atmospheric pressure.

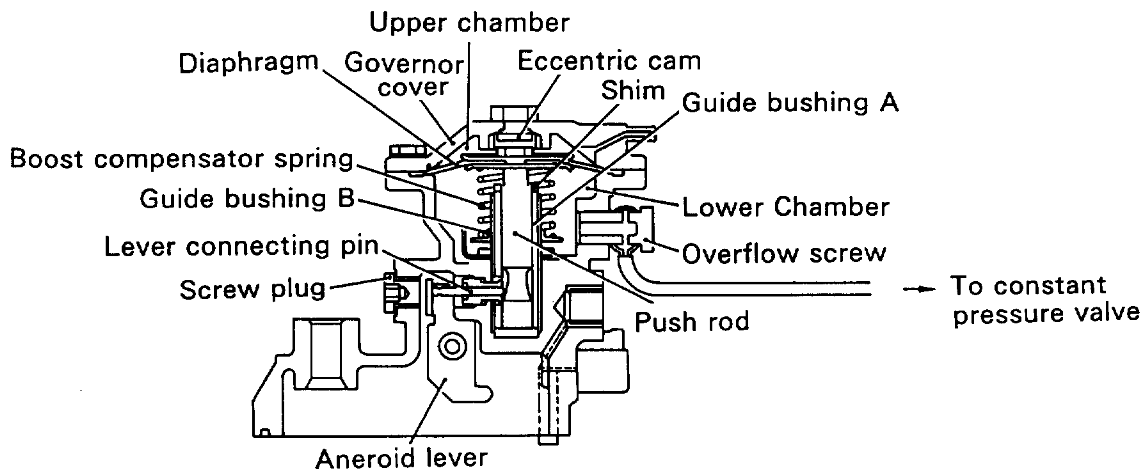


Fig.9-41 Construction of B.A.C.S.

(3) Operation

1) When Boost Pressure Is Increased

When boost pressure increases, pressure inside the upper chamber increases. This moves the diaphragm downwards causing the push rod to also move downwards.

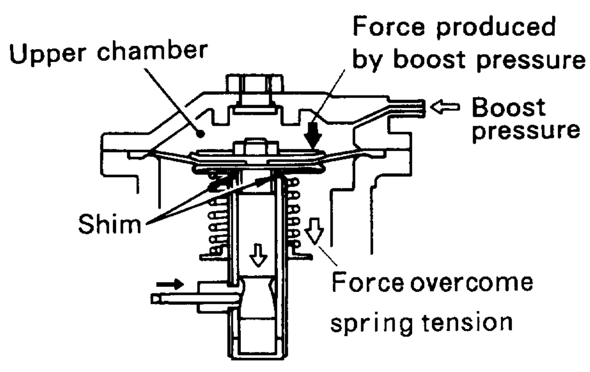


Fig.9-42 When boost pressure is increased

When the push rod reaches the end of the downward movement, the aneroid lever begins to pivot clockwise on the fulcrum. As a result, the tension lever rotates counter-clockwise, causing the spill ring to move in the direction in which injection quantity is increased.

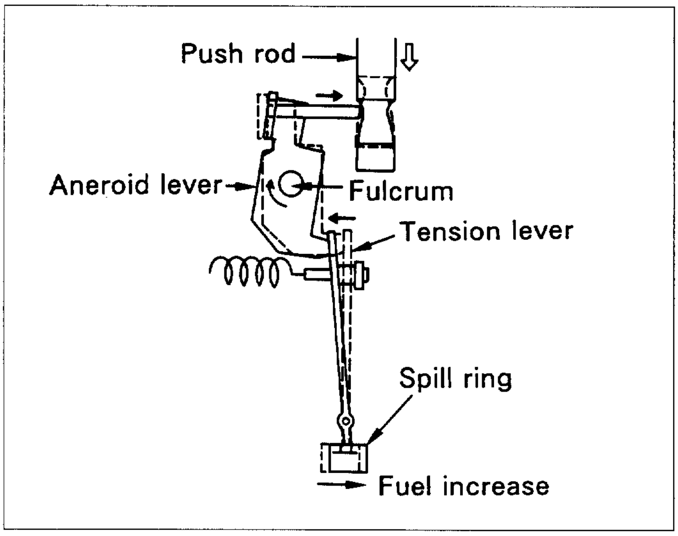


Fig.9-43 When boost pressure is increased

2) When Atomospher Pressure Is Low (at high altitude)

Since atmospheric pressure is low at high altitudes, intake air pressure lowers therefore boost pressure also lowers. On the contrary, pressure in the lower chamber is maintained at certain level due to the constant pressure valve, as a result the diaphragm is pushed upwards, causing the push rod to move upwards. This rotates the aneroid lever counter-clockwise and the tension lever clockwise, causing the spill ring to move in the direction in which injection quantity is reduced.

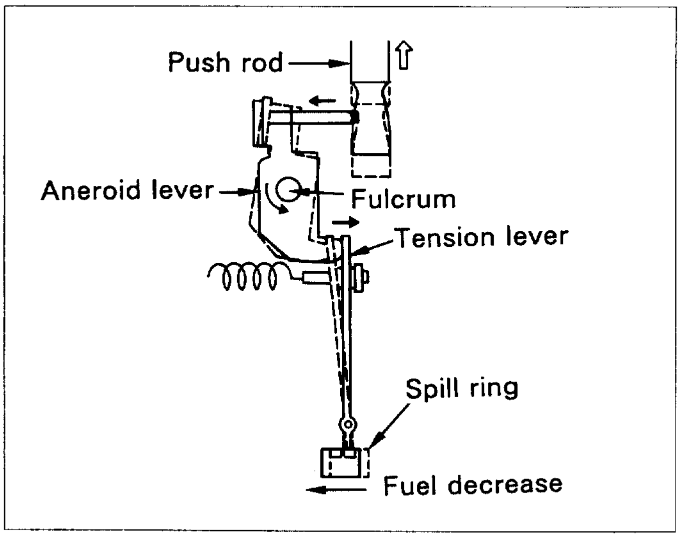


Fig.9-44 When boost pressure is low (At high altitude)

<Constant Pressure Valve>

(1) Function and Construction

The constant pressure valve is constructed as illustrated in Fig.9-45, and is designed to maintain pressure of the lower chamber of the BAC at a certain level.

(2) Operation

Chamber C, which has an orifice, is joined to the vacuum pump via the valve. When air inside chamber C is drawn out by the vacuum pump, the pressure inside chamber C drops below the bellows' preset pressure, therefore the bellows begin to expand and close the valve.

This causes outside air to be drawn into chamber C through the orifice. As a result, the pressure inside chamber C increases, the bellows stop expanding, and the valve is opend to connect chamber C to the vacuum pump.

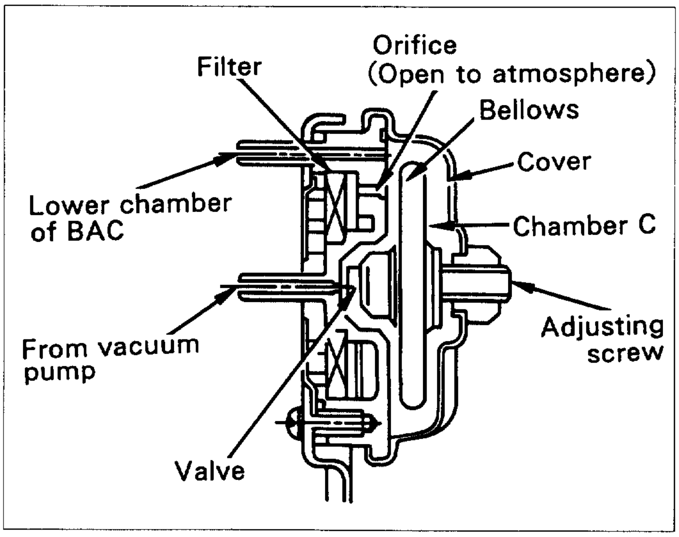


Fig.9-45 Construction of constant pressure valve

9-3. OTHER SPECIAL DEVICE

9-3-1. DASH POT

(1) Function

The dash pot reduces shock on the vehicle which is generated when the driver releases the accelerator pedal, when the pump operation changes rapidly from full to idle state. This changes injection characteristic smoothly from full to idle as illustrated in Fig.9-46.

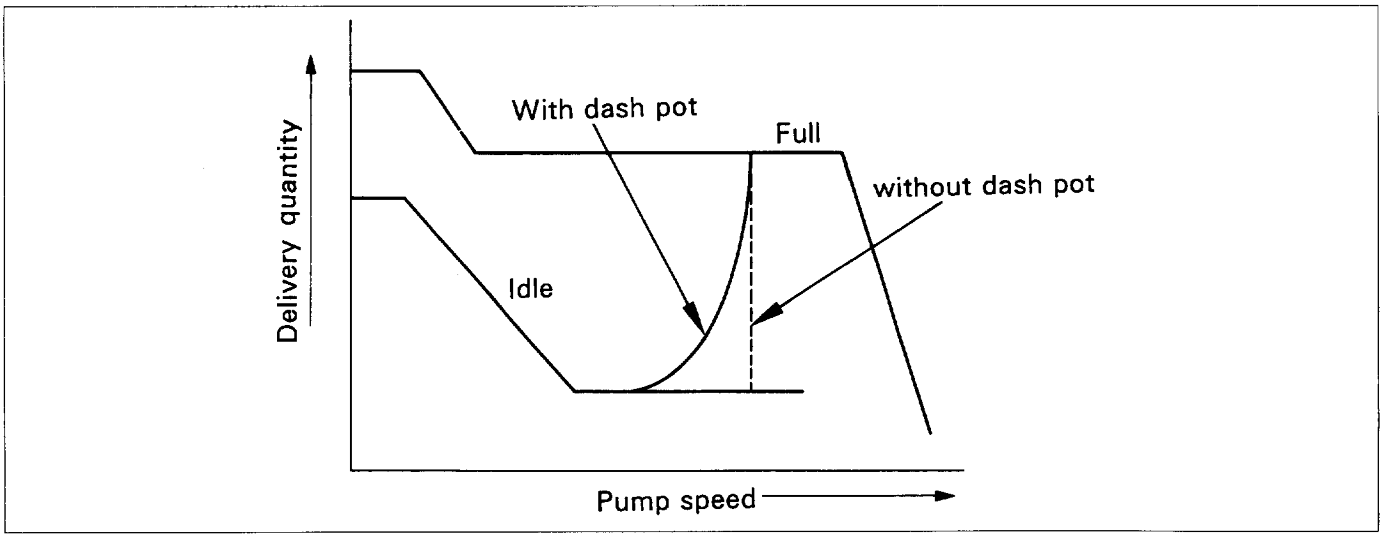


Fig.9-46 Injection characteristics of pump with dash pot

(2) Construction and operation

A piston type dash pot, built into the pump, is very compact (total length approx. 35mm) and uses fuel to dampen the piston motion.
It is installed from the outside to contact the upper part of the tension lever.

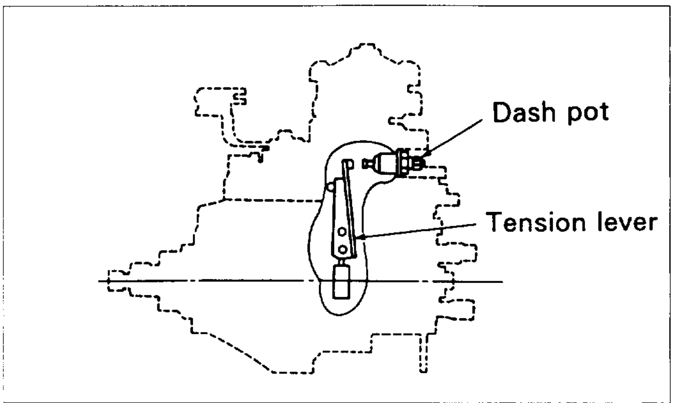


Fig.9-47 Dash pot installation position

The piston moves left and right, as shown in Fig.9-48.
The left end, total travel position of the piston, is set by the adjusting screw.
The piston has an orifice, through which fuel passes, between the pump and the dash pot for dampening movement of the piston.

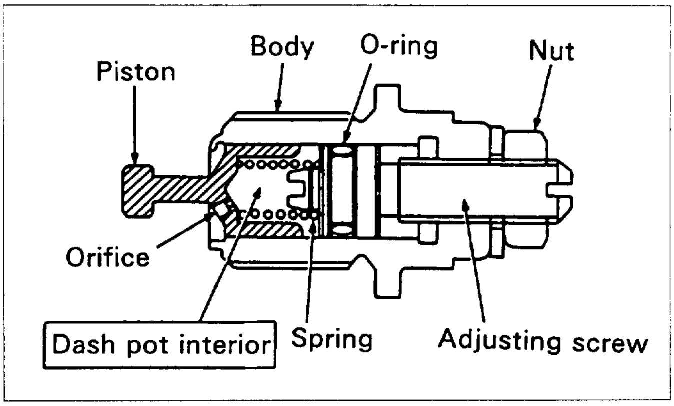


Fig.9-48 Dash pot construction

(3) Operation

When the adjusting lever is suddenly released back to idle, the tension lever contracts the dash pot piston at about half the distance of it's travel. The tension lever and piston gradually shift to the idle position forcing fuel through the piston orifice and compressing the spring.
With this, the fuel delivery decreases slowly to prevent a sudden drop. (See Fig.9-50)

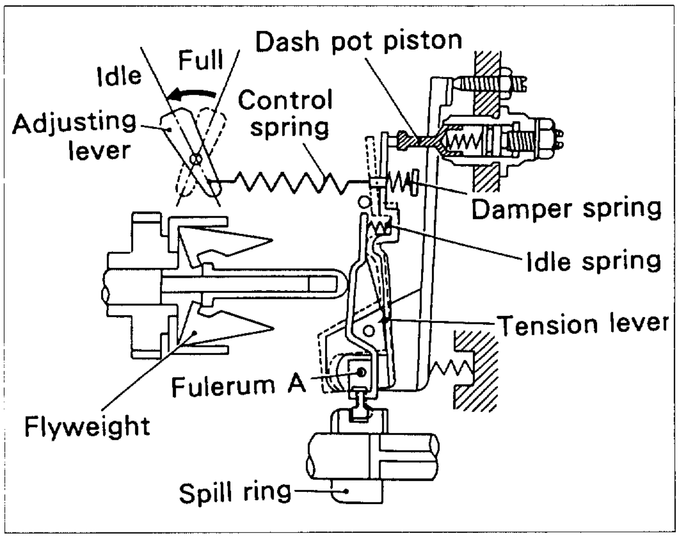


Fig.9-49 Dash pot function diagram

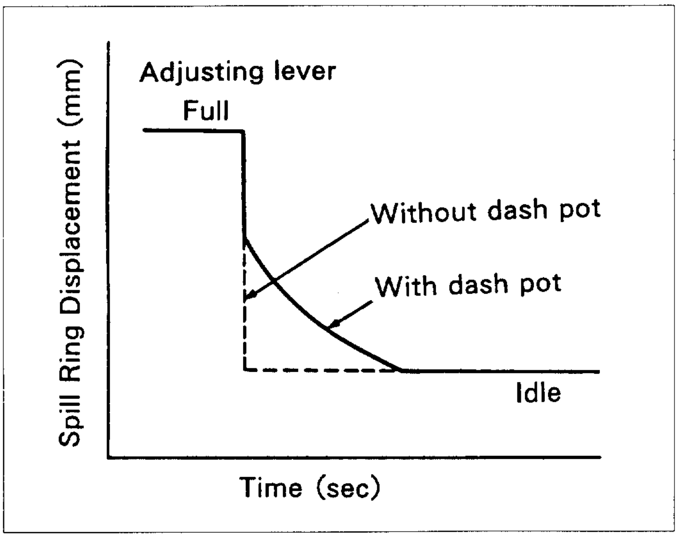


Fig.9-50 Dash pot characteristics

9-3-2. SNUBBER VALVE

(1) Function

The snubber valve is located in the delivery valve holder and prevents secondary injection which may occur when the reaction of the reisidual pressure in the high pressure pipe increases.

(2) Construction and Operation

Fig.9-51 shows the construction and operation of the snubber valve. The snubber valve, with orifice, is installed at the fuel passage to the high pressure pipe.

During the injection process, the snubber valve opens immediately, creating no restriction to the fuel flow (See Fig.9-51A). At end of injection, the snubber valve closes, The back flow from the injection tubing resulting from the residual pressure can return only through the small orifice in the snubber valve. (See Fig.9-51B)

The snubber valve serves primarly to dampen the pressure oscillations in the injection tubing.

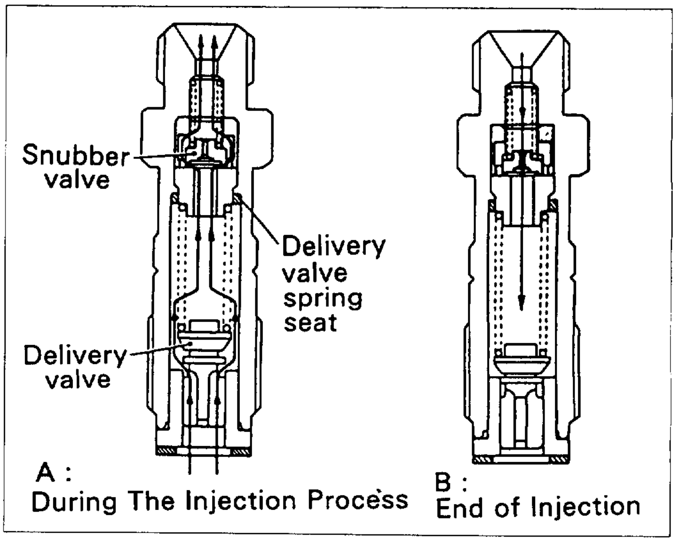


Fig.9-51 Snubber valve operation

9-3-3. CONSTANT PRESSURE VALVE (C.P.V.)

(1) Function

The constant pressure valve (C.P.V.) is a special delivery valve and maintains pressure inside the high pressure pipe at a constant level to stabilize the pressure.

(2) Construction and Operation

Fig.9-52 shows the construction and operation of the constant pressure valve (C.P.V.).

The C.P.V. is a mechanism that maintains stabilize residual pressure in the high pressure pipe. It stabilizes overall delivery quantity characteristics and especially delivery quantity characteristics at low speed range.

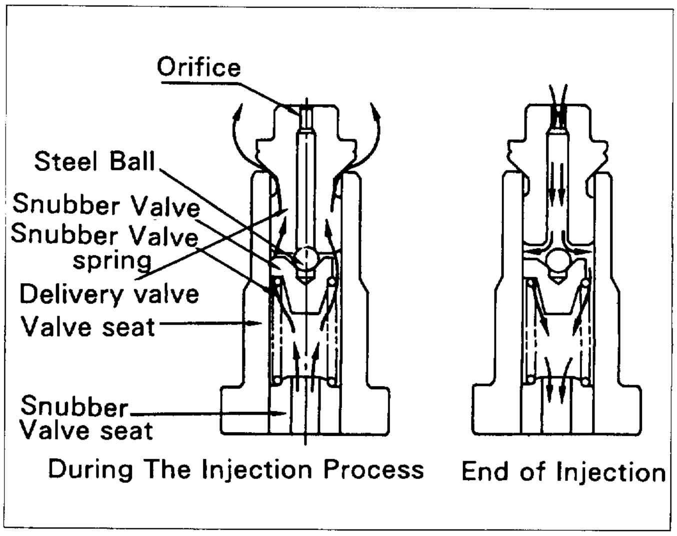


Fig.9-52 C.P.V. operation

9-4. SYSTEM DEVICE

9-4-1. ROTARY POSITION SENSOR (THROTTLE POSITION SENSOR)

(1) Function&Construction

The rotary position sensor (throttle position sensor) detects the position of the adjusting lever. The detected voltage (position) is then used as a signal to control systems such as EGR and ECT.

EGR: Exhaust Gas Recirculation
ECT: Electric Control Transmission

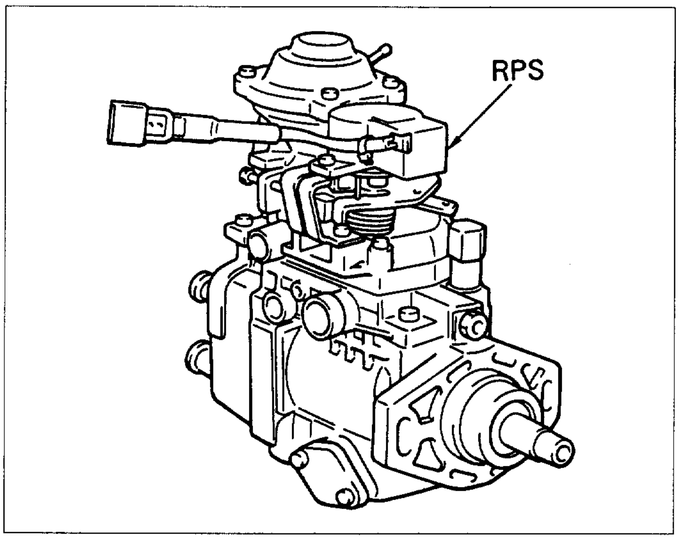


Fig.9-53 R.P.S. mount position

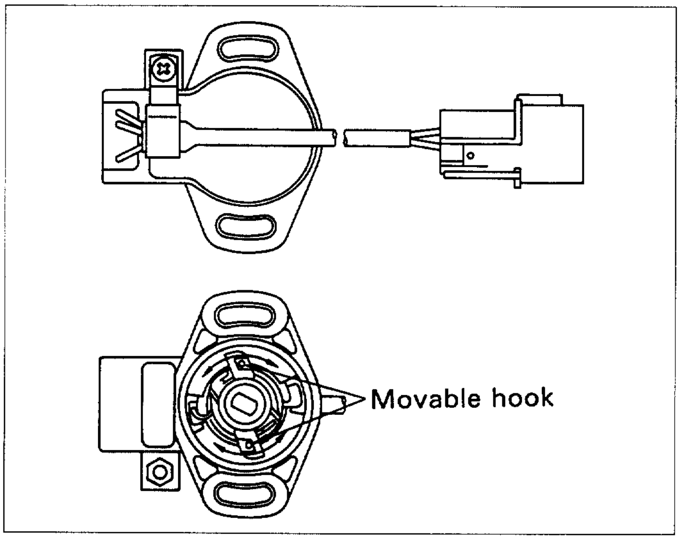


Fig.9-54 External view of R.P.S.

(2) Operation

The movable hook on the back of the RPS is connected to the adjusting lever as illustrated in Fig.9-54, and the movable terminal built into the RPS moves as the adjusting lever rotates. This changes variable resistor's resistance value, therefore causing the output voltage to change.

Voltage between V_C and E_2: Constant
Voltage between V_A and E_2: Output voltage

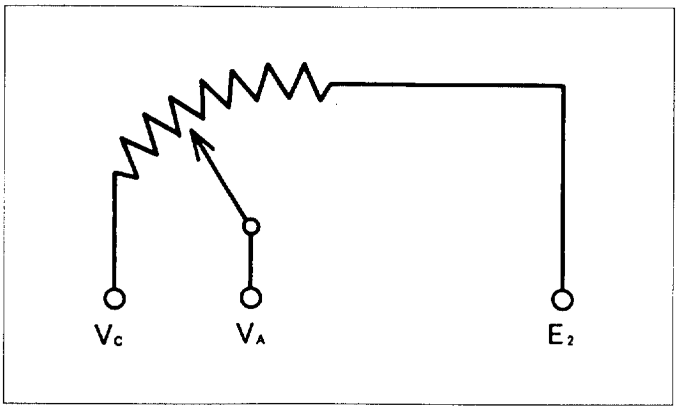


Fig.9-55 R.P.S. internal circuit