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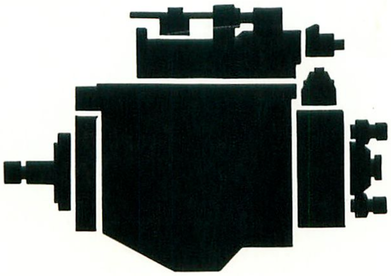
SERVICE MANUAL CONSTRUCTION & OPERATION

FUEL INJECTION PUMP MODEL VE



DIESEL KIKI

FOREWORD

This service manual has been prepared for the purpose of assisting service personnel in providing efficient and correct service and maintenance on the VE type fuel injection pump for diesel engine passenger cars and small and medium-sized diesel commercial vehicles.
This manual describes the features, construction and operation of the VE type injection pump and also describes the standard variable speed and combination governors.
The contents of this manual, including illustrations, drawings and specifications are the latest available at the time of printing.
The right is reserved to make changes in specifications and procedures at any time without notice.

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OUTLINE

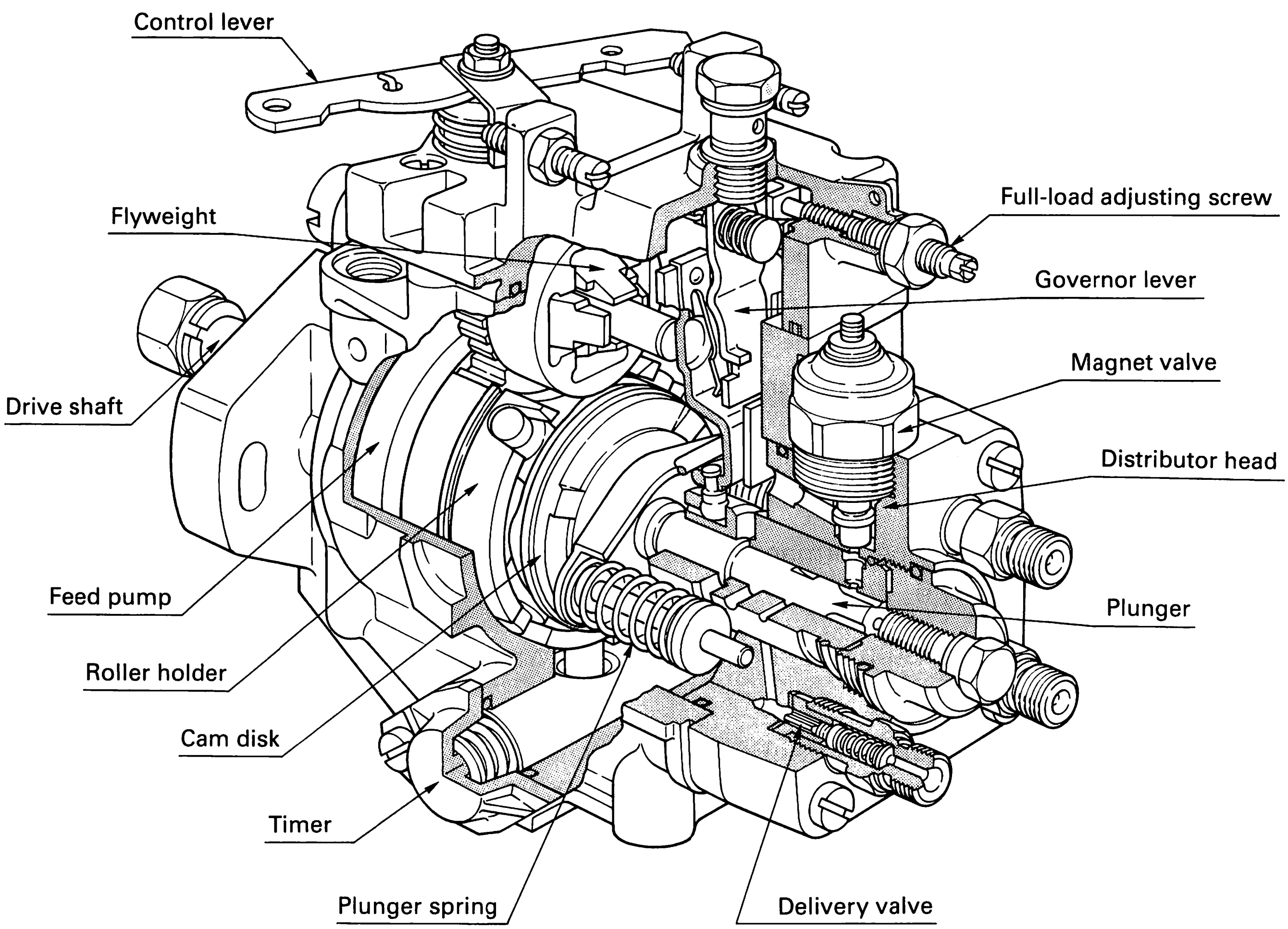

Fig. 1 VE type injection pump construction

With the PE type (in-line type) injection pump, the number of pump elements (plunger assemblies) must be the same as the number of engine cylinders. However, with the VE type (distributor type) injection pump, the number of plungers has no relationship to the number of engine cylinders, and there is only one plunger. This single plunger reciprocates while rotating, and fuel oil is injected into each cylinder through the injection pipes in accordance with the engine's firing order.
As well as this, the governor, timer, feed pump etc. installed on the outside of the PE type injection pump are equipped within the VE type injection pump.

In comparison with the PE type, the VE type injection pump has less than half the number of component parts, and was developed in order to satisfy the need for a small, lightweight and high-speed injection pump.
In response to operator requirements, it was possible to design a pump with accelerator "feeling" close to that of gasoline vehicles.
A VE type injection pump for direct injection system engines has recently been developed, and is expected to be adopted in a wide range of fields, including construction machinery, medium-sized trucks etc.

Features

1. The injection pump is small and lightweight, and has a small number of component parts (compared to conventional in-line injection pumps).

Injection pump type	Weight (kg)	Size (mm.) Length×Height	Number of Parts	Remarks
VE Distributor type	5.5	207×181	196	
VM Distributor type	4.9	189×182	238	
PE4A In-line type	11.6	293×210	326	
PE6A In-line type	13.3	347×210	368	

2. The injection pump may be installed on the engine in either an upright or a horizontal position.

3. High speed operation up to engine speeds of 6000 r.p.m. is possible.

4. Matching of the engine's torque characteristics can be easily performed.

5. Its construction prevents fuel injection if by any chance the direction of engine rotation is reversed.

6. Adaption to various engine performance requirements is simplified. Control mechanisms can be independantly installed e.g. torque control device, load timer, boost compensator.

7. Because injection is stopped by turning the ignition switch (key) off, immediate stopping of the engine is possible.

8. Fuel oil lubrication (maintenance free)
   As lubrication of the inside of the injection pump is performed by fuel oil contained in the pump chamber, special lubricating oil is not necessary. Because of this, no time is lost through the usual inspections.

Specifications

Item	Specification
Number of cylinders	2, 3, 4, 5 or 6
Direction of rotation	Clockwise/counterclockwise (viewed from the drive side)
Maximum allowable speed (pump)	3000 r.p.m (2, 4, 5 cylinders) 2500 r.p.m (3, 6 cylinders)
Plunger diameters	8, 9, 10 11 or 12 mm
Injection timing control	Speed timer 2, 4, 5 cylinders: 11° Maximum 3, 6 cylinders: 7° Maximum Load Timer Maximum: 3° to 4° Speed-load timer 2, 4, 5 cylinders: 11° Maximum 3, 6 cylinders: 7° Maximum
Speed governing	Variable speed governor (All speed governor) Minimum-maximum speed governor (limited speed governor) Combination governor (Half-all speed governor)
Speed droop	4% (750 r.p.m.)
Weight	Approx. 5.5 kg
Lubrication system	Fuel oil lubrication
Control lever position	Right or Left side of governor cover (viewed from the drive side)
Stop lever position	Right or Left side of governor cover (viewed from the drive side)
Maximum allowable in-pipe pressure	Approx. 550 kg/cm^2
Engine reverse rotation prevention	Because the inlet port opens during the compression stroke if the engine rotates in the reverse direction, fuel cannot be delivered and injection cannot occur.
Additional devices	Installation of boost compensator, pump speed sensor, cold start device etc. is possible.

FUEL SYSTEM

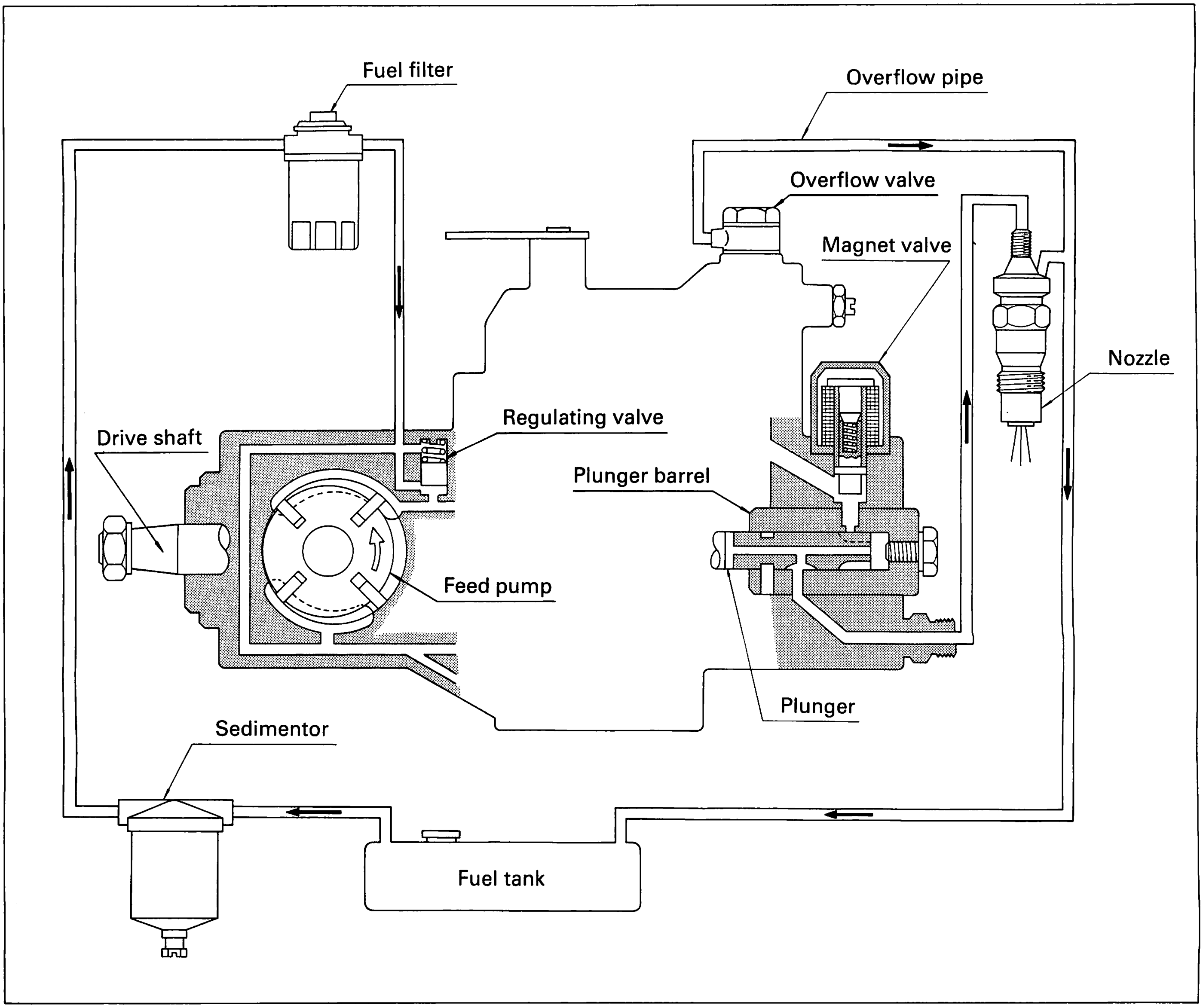

Fig. 2 Fuel system

Figure 2 shows an example of a fuel system.
The injection pump drive shaft is turned by the engine's timing belt (or gear) and fuel oil is drawn by the injection pump's feed pump through the sedimentor and fuel filter to the injection pump's fuel oil inlet.
The fuel filter acts to filter the fuel oil, and the sedimentor is located in the lower portion of the fuel filter to remove moisture from the fuel system.
With drive shaft rotation the fuel oil sucked into the feed pump is pressurized by the feed pump and fills the injection pump chamber. The fuel oil pressure is proportional to drive shaft speed, and when it exceeds a specified pressure excess fuel again returns to the inlet side through a regulating valve located at the feed pump's fuel oil outlet.
The fuel oil in the injection pump chamber flows through the distributor head inlet into the pressure chamber, where plunger rotation and reciprocating motion increase its pressure. The fuel oil is then delivered through the injection pipe to the nozzle and nozzle holder.
An overflow valve located at the top of the injection pump functions to maintain a constant fuel oil temperature in the pump chamber by returning excess fuel oil to the fuel tank.

INJECTION PUMP CONSTRUCTION AND OPERATION

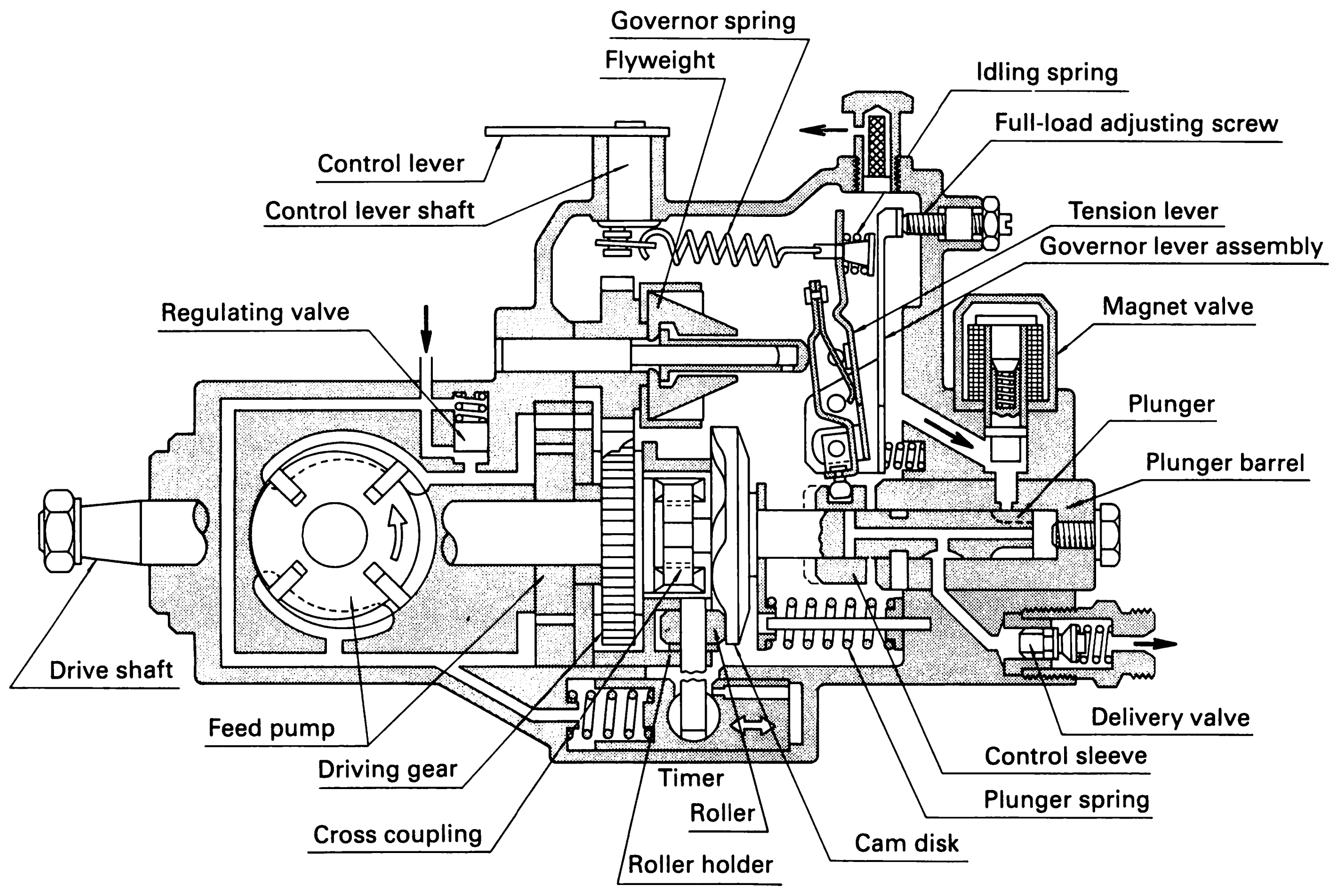

Fig. 3 Cross-sectional view of VE type injection pump

Fuel Delivery

The drive shaft, rotated by the engine's timing belt (or gear), rotates the cam disk through a cross coupling. The cam disk's press-fitted pin fits into a groove in the plunger to rotate the plunger. To reciprocate the plunger, the cam disk is also equipped with raised face cams, arranged uniformly around the circumference of the cam disk. The cam disk's face cams are always in contact with the roller holder assembly's rollers because the cam disk and the plunger are pressed against the roller holder assembly by the set force of the two plunger springs. Because of this the plunger can follow cam disk movement. Therefore, as the cam disk is rotated on the roller holder assembly by the drive shaft, simultaneous plunger rotation and reciprocating movement is possible.

The roller holder assembly construction is such taht it can only rotate in a certain angle range in accordance with timer operation.

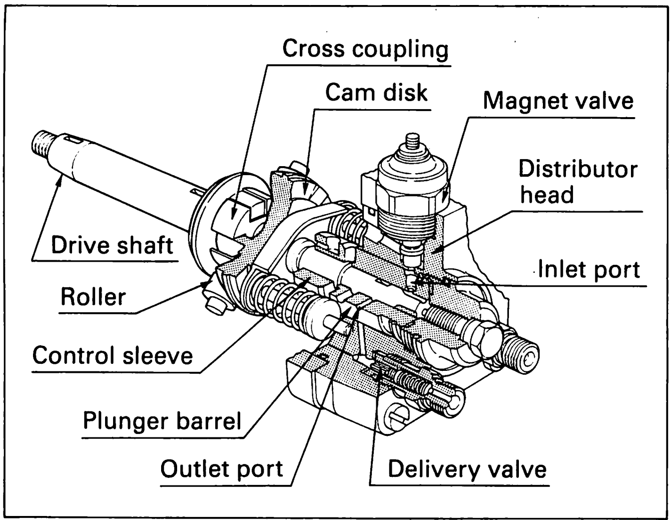

Fig. 4 Cutaway view of fuel delivery

Because the plunger rotates and reciprocates simultaneously, suction of the fuel oil into the pressure chamber, pressurization in the pressure chamber, delivery into the engine cylinder are possible.

Speed Governing

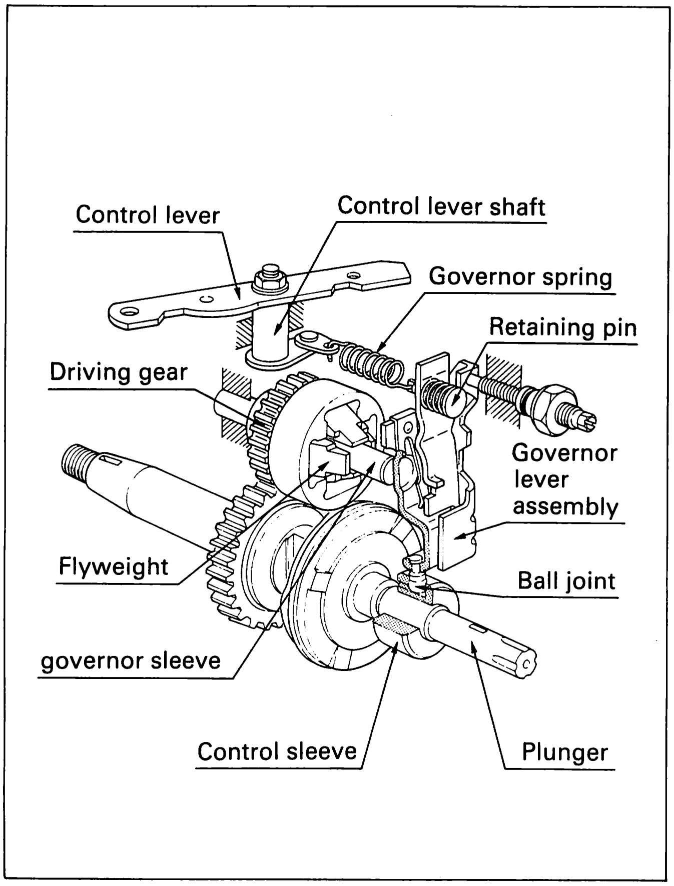

Fig. 5 Cutaway view of speed governing

The governor is located in the upper part of the injection pump chamber. Four flyweights and a governor sleeve are held in the flyweight holder, which is mounted on the governor shaft.
The flyweight holder is rotated and accelerated by the drive shaft gear, through rubber dampers.
The governor lever assembly is supported by pivot bolts in the pump housing, and the ball joint at the bottom of the lever assembly is inserted into the control sleeve, which slides over the outside surface of the plunger. The top of the lever assembly (the tension lever) is connected to the governor spring by a retaining pin, while the opposite end of the governor spring is connected to the control lever shaft. The control lever shaft is inserted into the governor cover and a control lever is attached to the control lever shaft. The accelerator pedal is connected directly to the control lever by a linkage, and the governor spring set force changes in response to the control lever position (i.e. accelerator pedal position).
Injection quantity control is governed by the mutually opposing forces of the flyweights' centrifugal force and the governor spring's set force.
The flyweights' centrifugal force, which changes in response to engine speed, acts on the governor lever through the governor sleeve.
The governor spring's set force, which is dependant on control lever position, i.e. accelerator pedal position, acts on the governor lever through the retaining pin.

Injection Timing Control

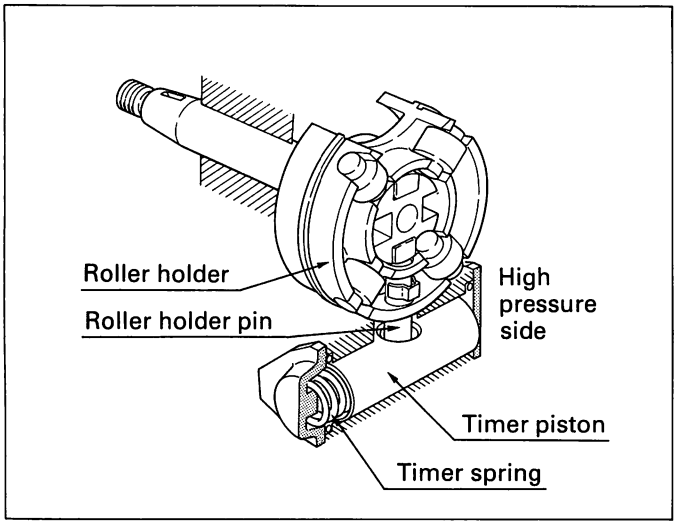

Fig. 6 Cutaway view of injection timing control

In the lower part of the injection pump is the timer, in the centre of which the timer piston is positioned.
On the low pressure side of the timer piston is a timer spring with a predetermined set force; the pump chamber fuel oil pressure acts on the opposite side (high pressure side). The timer piston position changes in accordance with the balance of these two forces, to rotate the roller holder via the roller holder pin. When the timer piston compresses the timer spring, the injection timing is advanced (the roller holder rotates in the reverse rotation direction), and through timer piston movement in the opposite direction the injection timing is retarded. Injection timing is controlled by the above.

Feed Pump

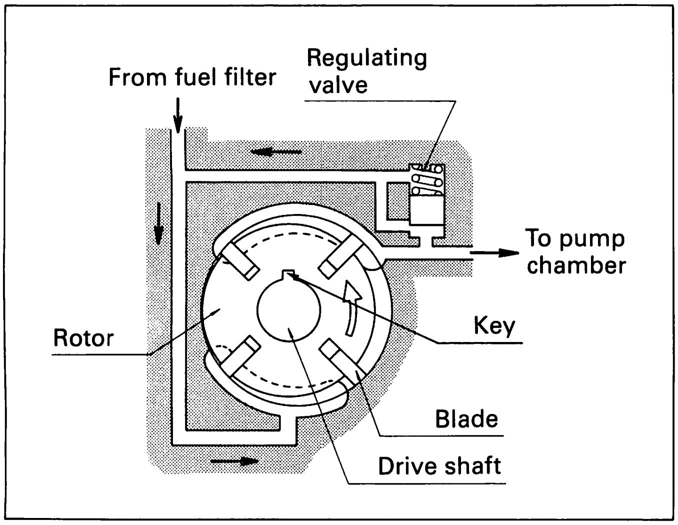

Fig. 7 Feed pump operation

The feed pump comprises a rotor, blades and liner.
Drive shaft rotation is transmitted through a key to the rotor to rotate the rotor.
The inside circumference of the liner is eccentric to the centre of rotor rotation. Four blades are installed in the rotor. Centrifugal force forces the blades outwards during rotation to contact the inside surface of the liner and form four fuel oil chambers. Therefore, the volume of these four chambers increases through rotor rotation to suck fuel oil from the fuel tank. Conversely, when the volume of these four chambers decreases fuel oil is pressurized.

Regulating Valve

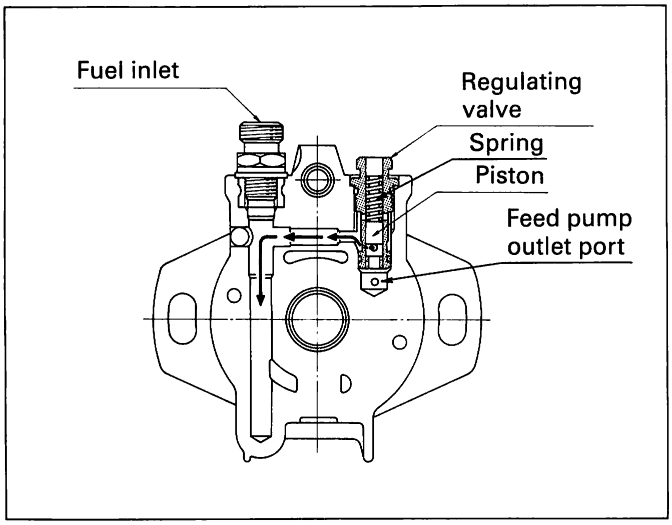

Fig. 8 Regulating valve operation

Feed pump fuel oil delivery pressure increases proportionately with an increase in injection pump speed.
However, the total fuel oil injection quantity necessary for the engine is considerably less than that delivered by the feed pump. Therefore, in order to prevent an excessive increase in the pump chamber pressure caused by the excess fuel oil, and to adjust the pump chamber pressure so that it is usually within the specified limit, a regulating valve is installed near the feed pump outlet. The timer performs timing control using the pump chamber pressure, which is regulated by the regulating valve.

Plunger Operation

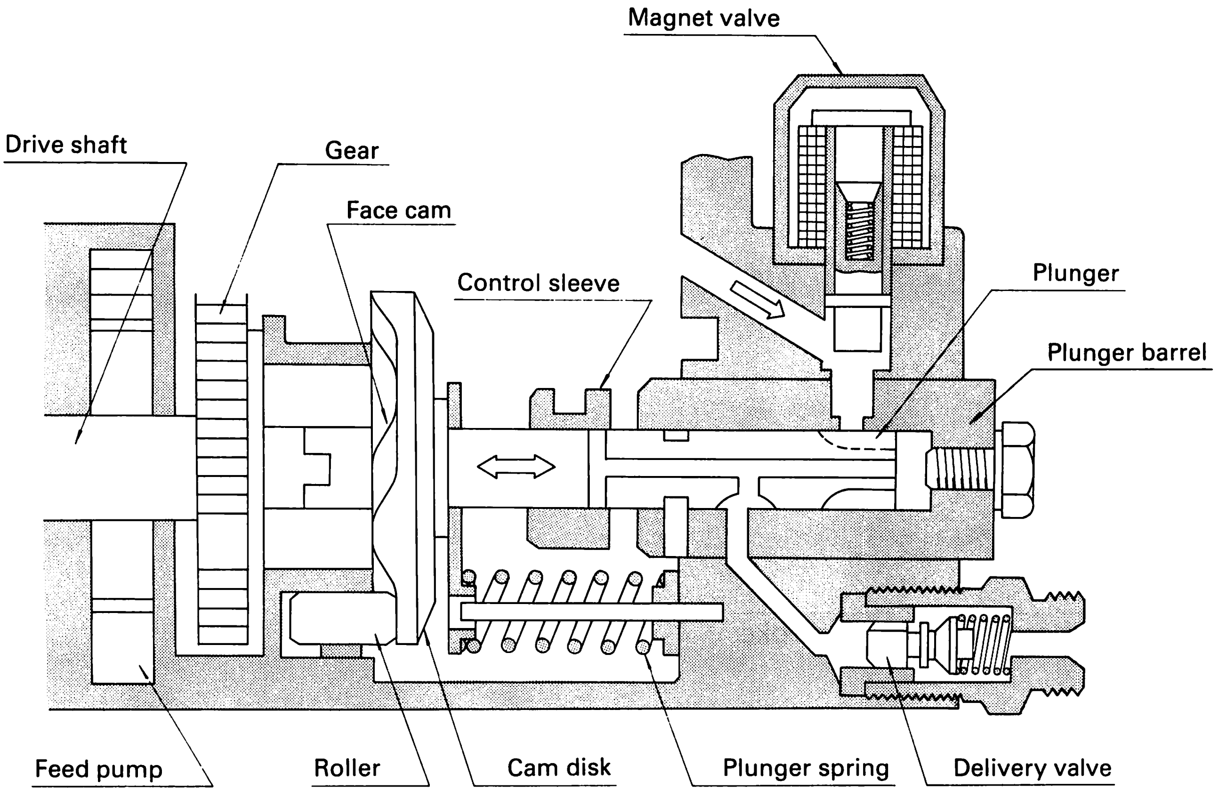

Fig. 9 Plunger operation

The drive shaft drives the feed pump, the cam disk and the plunger simultaneously. Plunger reciprocating movement is accomplished through the movement of the cam disk's face cams over the roller holder assembly's rollers.
When the plunger's inlet slit and the inlet port of the plunger barrel press-fitted to the distributor head align, fuel oil is sucked into the pressure chamber. After the plunger barrel's inlet port has been closed by the plunger, the plunger lifts.
After the plunger's outlet slit and the plunger barrel's outlet port align, and the pressure chamber pressure exceeds the injection pipe's in-line residual pressure and the delivery valve spring's set force, the delivery valve opens, fuel oil flows to the injection pipe, and is then injected from the nozzle into the engine cylinder.
Then, when the plunger's cut-off port aligns with the control sleeve's end face, plunger fuel delivery is completed.
The plunger barrel has only one inlet port, but has an outlet port for each engine cylinder.
However, although the plunger has the same number of inlet slits as engine cylinders, it has only one outlet slit and one equalizing slit.

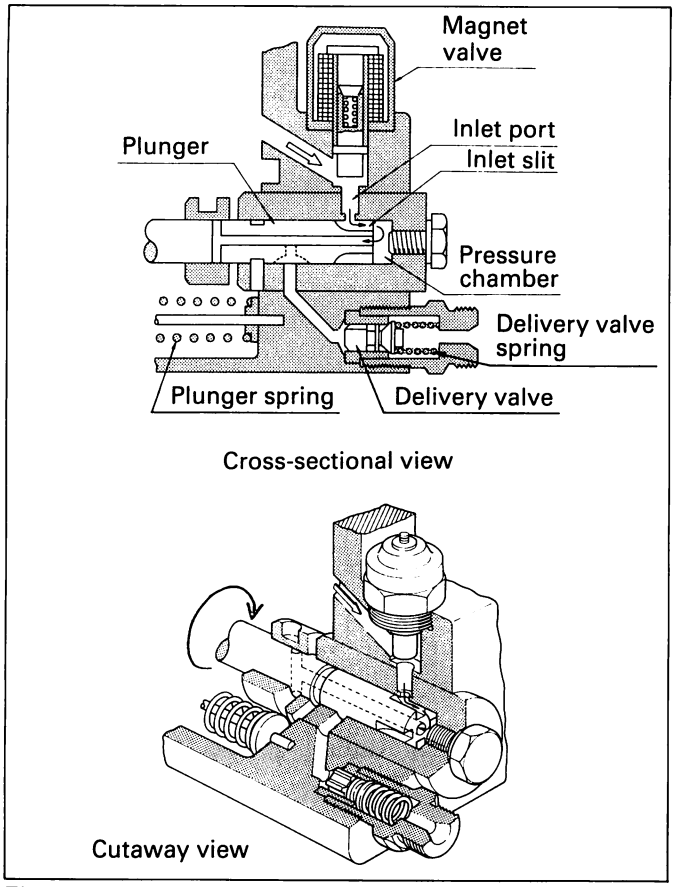

Fig. 10 Plunger operation: suction stroke

Suction stroke

During the plunger's return stroke, when the plunger barrel's inlet port and the plunger's inlet slit are aligned, pressurized fuel oil in the pump chamber is sucked into the pressure chamber. (Fig. 10)

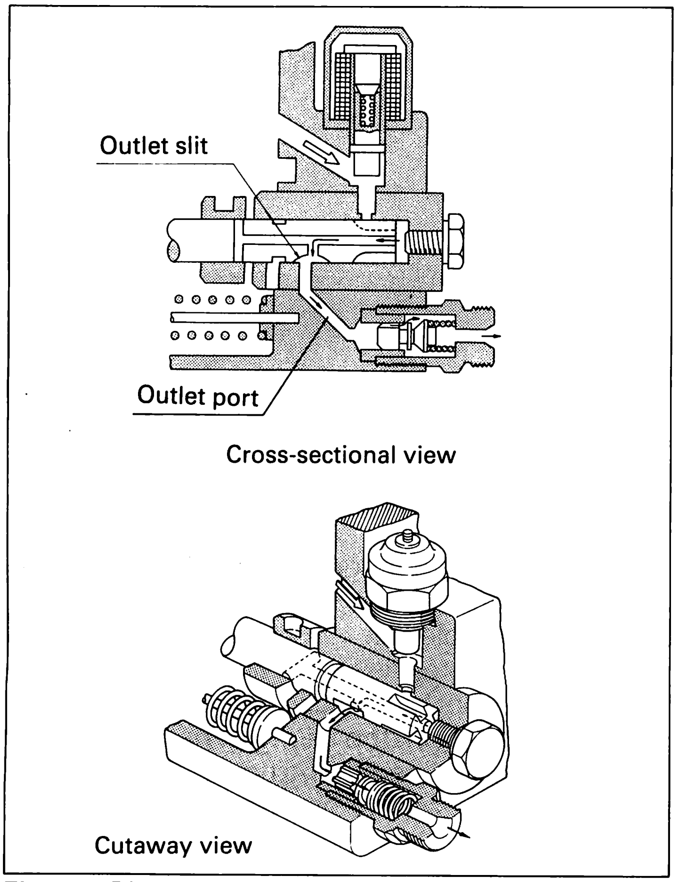

Fig. 11 Plunger operation: delivery stroke

Delivery stroke

As the plunger is rotated and lifted by the cam disk, the plunger's outside face blocks the plunger barrel's inlet port and compression of fuel oil begins. At almost the same time the plunger's outlet slit meets the plunger barrel's outlet port. As a result of this, the fuel oil pressurized by the plunger lift overcomes the set force of the delivery valve spring and the injection pipe's in-line residual pressure, and opens the delivery valve. The fuel oil is then injected through the nozzle and nozzle holder into the engine's combustion chamber. (Fig. 11)

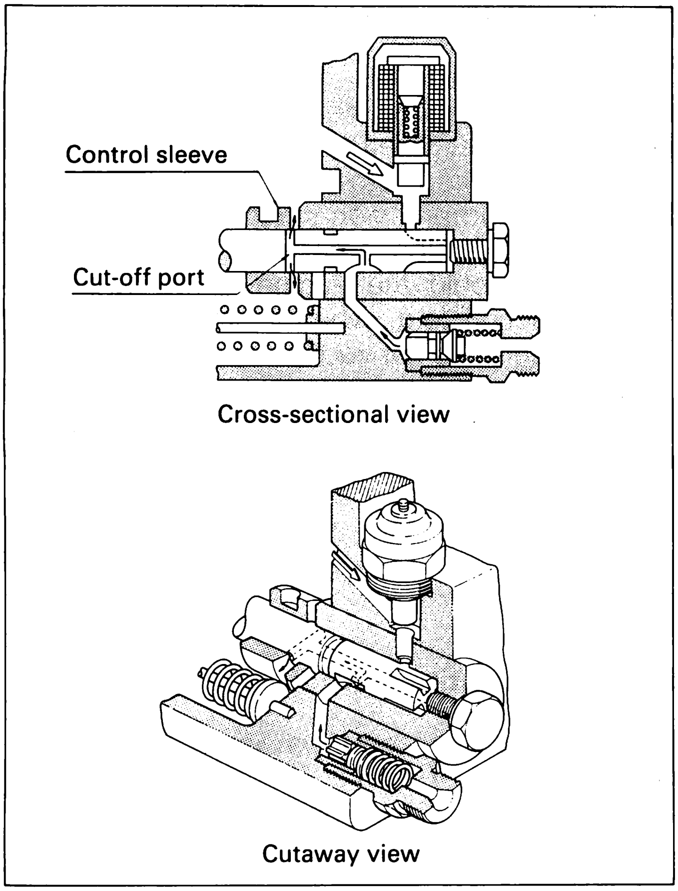

Fig. 12 Plunger operation; end of injection

End of injection

When the end face of the control sleeve meets the plunger's cut-off port, the fuel oil in the plunger (i.e. the pressure chamber), which is at a much higher pressure than that in the pump chamber, returns to the pump chamber through this cut-off port. The pressure then suddenly decreases, the delivery valve is closed by the spring, and fuel oil delivery finishes. These operations occur instantaneously. (Fig. 12)

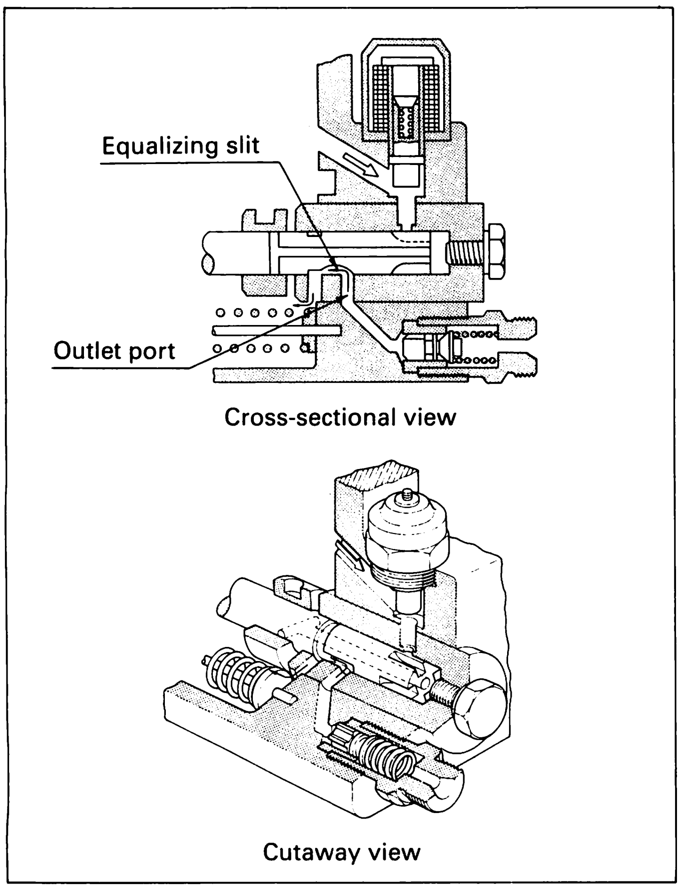

Fig. 13 Plunger operation; equalizing stroke

Equalizing stroke

Following the end-of-injection the plunger rotates 180° and the plunger barrel's outlet port meets the plunger's equalizing slit.
Then, the pressure of the fuel oil in the injection passage between the plunger barrel's outlet port and the delivery valve decreases to that of the fuel oil in the pump chamber.
This stroke equalizes each cylinder's outlet port pressure at injection for every revolution, thereby assuring stabilized injection (Fig. 13)

The above operations are performed in the order of injection for each (pump) revolution.

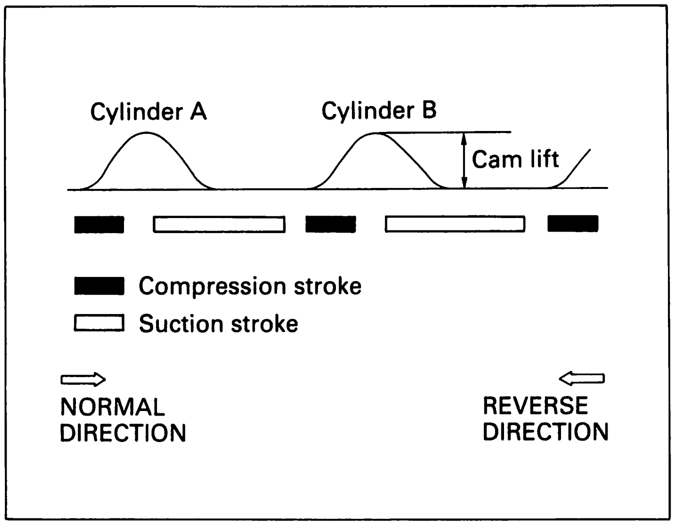

Fig. 14 Plunger strokes for cylinders A and B

Reverse rotation prevention

While the plunger is moving in the normal direction of rotation, the inlet port is open during the plunger's return stroke and sufficient fuel oil is sucked into the pressure chamber. During the compression stroke the inlet port is closed and injection is performed.
However, should the engine rotate in the reverse direction (e.g. when a stationary, parked vehicle begins to move backwards and the engine is rotated, etc.) the plunger barrel's inlet port and the plunger's inlet slit will align during plunger lift, the fuel oil cannot be pressurized and non-injection will result.
Because of this the engine will immediately stop.

Injection quantity control

Fuel injection quantity is increased or decreased by the effective stroke, which is varied by the position of the control sleeve.

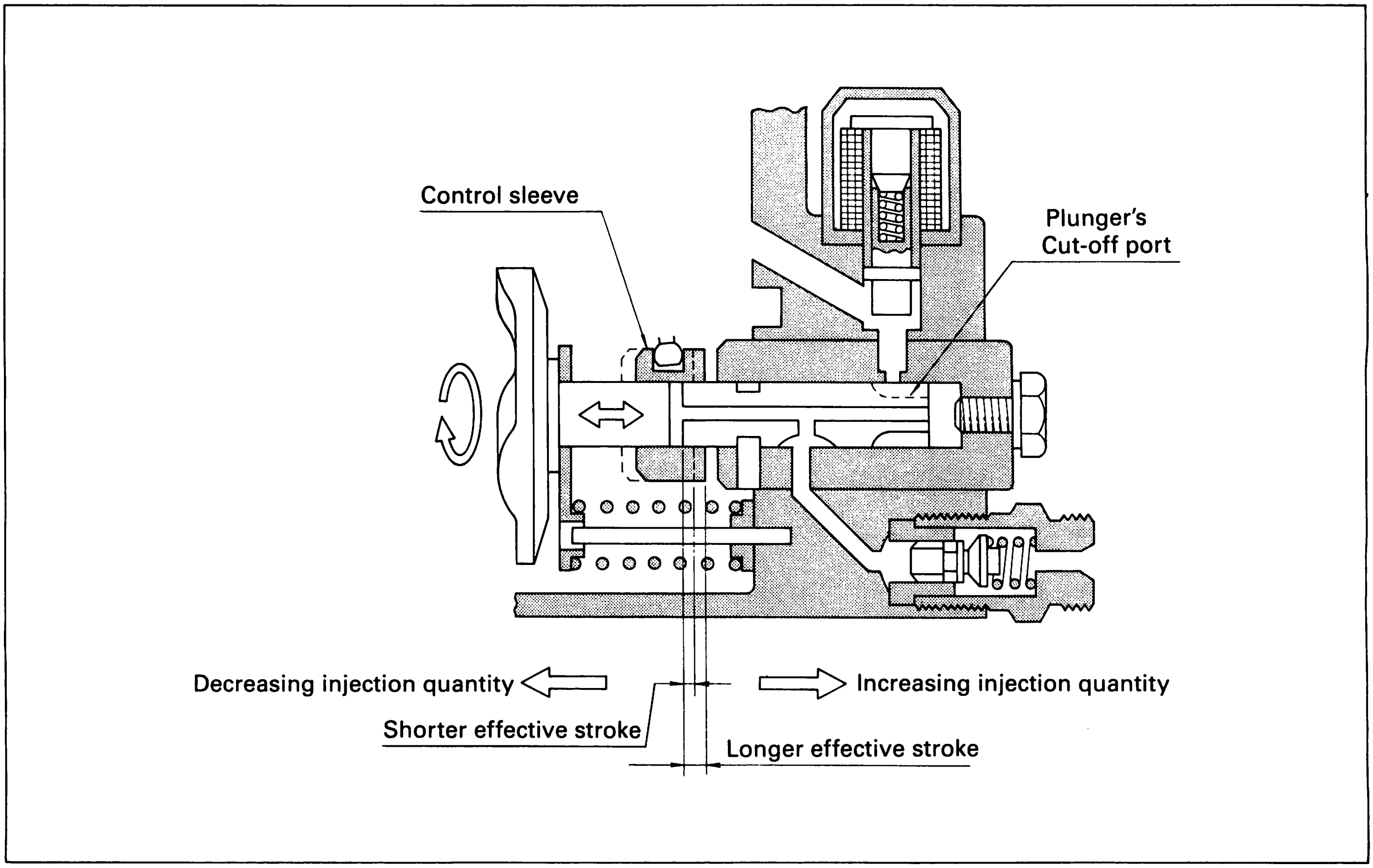

Fig. 15 Plunger's effective stroke

This effective stroke is the plunger stroke from the plunger's cut-off port to the control sleeve's end-face during the delivery stroke, after the plunger barrel's inlet port and the plunger's inlet slit are closed.
It is proportional to the fuel injection quantity.
As can be seen in Fig. 15, control sleeve travel to the left decreases the effective stroke, and conversely control sleeve travel to the right increases the effective stroke and the fuel injection quantity.
Although the beginning-of-injection position is constant, end-of-injection varies according to the control sleeve position. The control sleeve position is determined by the governor.

Delivery Valve and Damping Valve

When the increased fuel oil pressure resulting from the plunger's compression stroke has overcome the delivery valve spring's set force and the injection pipe's in-line residual pressure, the delivery valve opens and fuel oil is delivered to the nozzle holder and the nozzle. (Fig. 16-A)
Then, when nozzle opening pressure is reached, initial injection into the engine cylinder occurs.

When the plunger has lifted and injection has ended, the pressure in the pressure chamber suddenly decreases and the delivery valve spring closes the delivery valve. In order to prevent delayed injection it is necessary to maintain the residual pressure of the fuel oil in the injection pipe for the next injection. The delivery valve functions to prevent reverse fuel oil flow during the plunger's suction stroke.

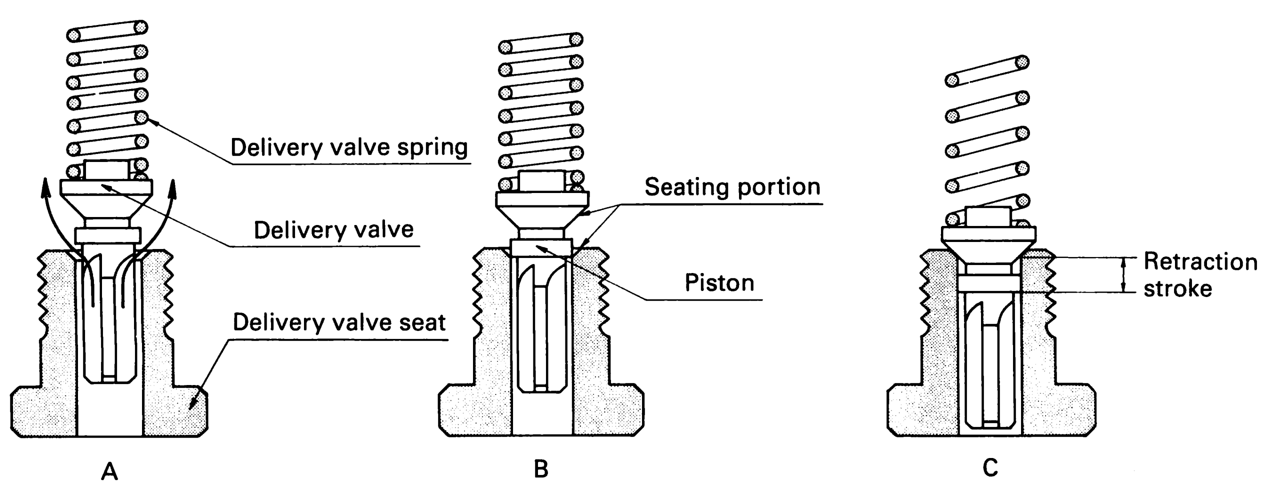

Fig. 16 Delivery valve operation

In the centre of the delivery valve is a piston. After injection has ended and the piston edge is contacting the top of the valve seat (Fig. 16-B), the amount that the injection pipe's in-line pressure is reduced is proportional to the volume of fuel retracted up to the time that the delivery valve is completely seated.

$$\left[\frac{\pi(\text{piston diameter})^2}{4} \times \text{retraction stroke}\right]$$

Because of this, cut-off of injection occurs immediately after the end-of-injection and subsequent dripping is prevented. (Fig. 16-C)

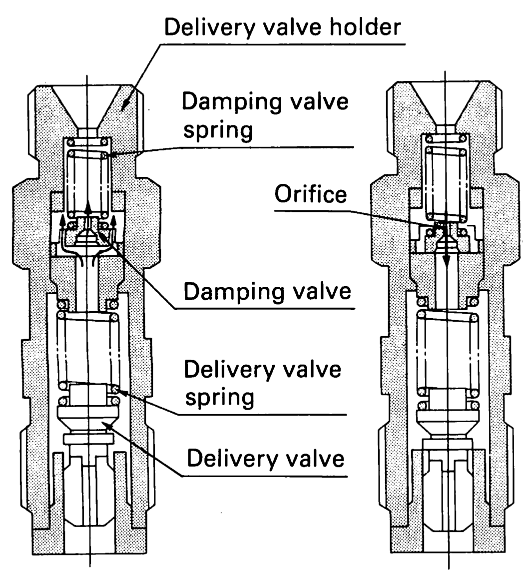

Fig. 17 Damping valve operation

The damping valve is a component of the delivery valve and its construction is shown in Fig. 17.

The damping valve compresses the damping valve spring and opens almost simultaneously with the opening of the delivery valve. Fuel oil delivered by the plunger through the injection pipe is then delivered to the nozzle holder and the nozzle. After the end-of-injection the damping valve is closed more quickly (seated) than the delivery valve by the set force of the damping valve spring.

Following this, because only the retracted fuel oil is returned through the small orifice in the centre of the damping valve up until the time that the delivery valve is seated, a sudden reduction in the injection pipe's in-line pressure can be prevented.

A sudden reduction in pressure may sometimes result in negative pressure, thereby causing cavitation. This may result in corrosion of the injection pipes and finally the danger of pipe breakage.

The damping valve is installed to prevent the above problems.

GOVERNING MECHANISM

Depending on the purpose of use, mechanical governors (those utilizing a flyweight) are divided into three types:

1. The variable speed governor (All speed governor)
2. The combination governor (Half-all speed governor)
3. The minimum-maximum speed governor (Limited speed governor)

Variable Speed Governor Construction and Operation

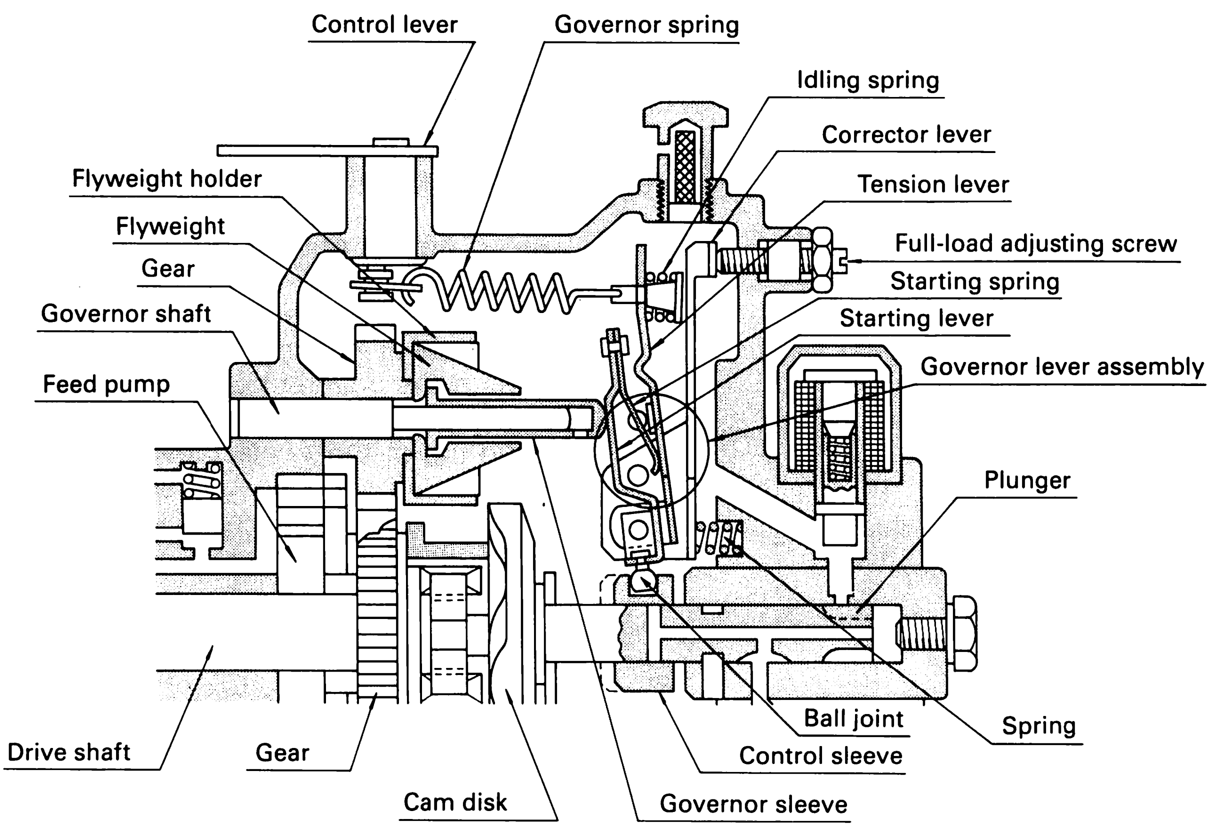

Fig. 18 Variable speed governor construction

The construction of the variable speed governor is shown in Fig. 18.
The rotation of the drive shaft (equipped with two rubber dampers) is conveyed through an acceleration gear to the flyweight holder mounted on the governor shaft.

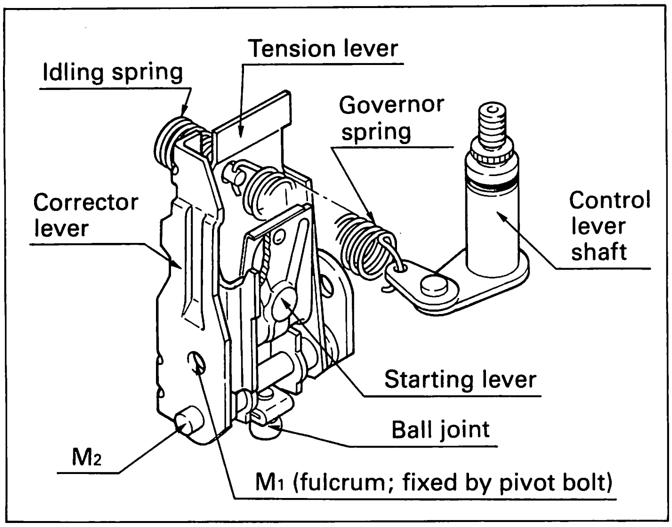

Fig. 19 Variable speed governor lever assembly

Four flyweights are mounted in the flyweight holder, and with rotation these open outward through centrifugal force. This movement moves the governor sleeve in an axial direction, resulting in the governor sleeve pushing the governor lever assembly.
The governor lever assembly consists of the corrector lever, tension lever, start lever, start spring and the ball joint. (Fig. 19)

The corrector lever's fulcrum M_1 is fixed at the pivot bolts in the pump housing and as its bottom portion is being pushed by the springs in the distributor head, and the top portion is being pushed by the full-load adjusting screw, the corrector lever cannot move at all.
The starting lever, separated from the tension lever by the starting spring only at engine starting, moves the governor sleeve to close the flyweights. As a result of this the ball joint at the bottom of the starting lever, pivoting around the tension and starting levers' common fulcrum M_2, can move the control sleeve in the fuel-increase direction (i.e. toward the distributor head side) for engine starting.

During engine operation the starting lever and the tension lever are in contact and move together as a single component. The top of the tension lever is connected to the control lever through the governor spring.
An idling spring is mounted on the retaining pin at the top of the tension lever.
Governor construction is such that governor control over the entire speed range is performed by the operation of all these springs.

Engine starting

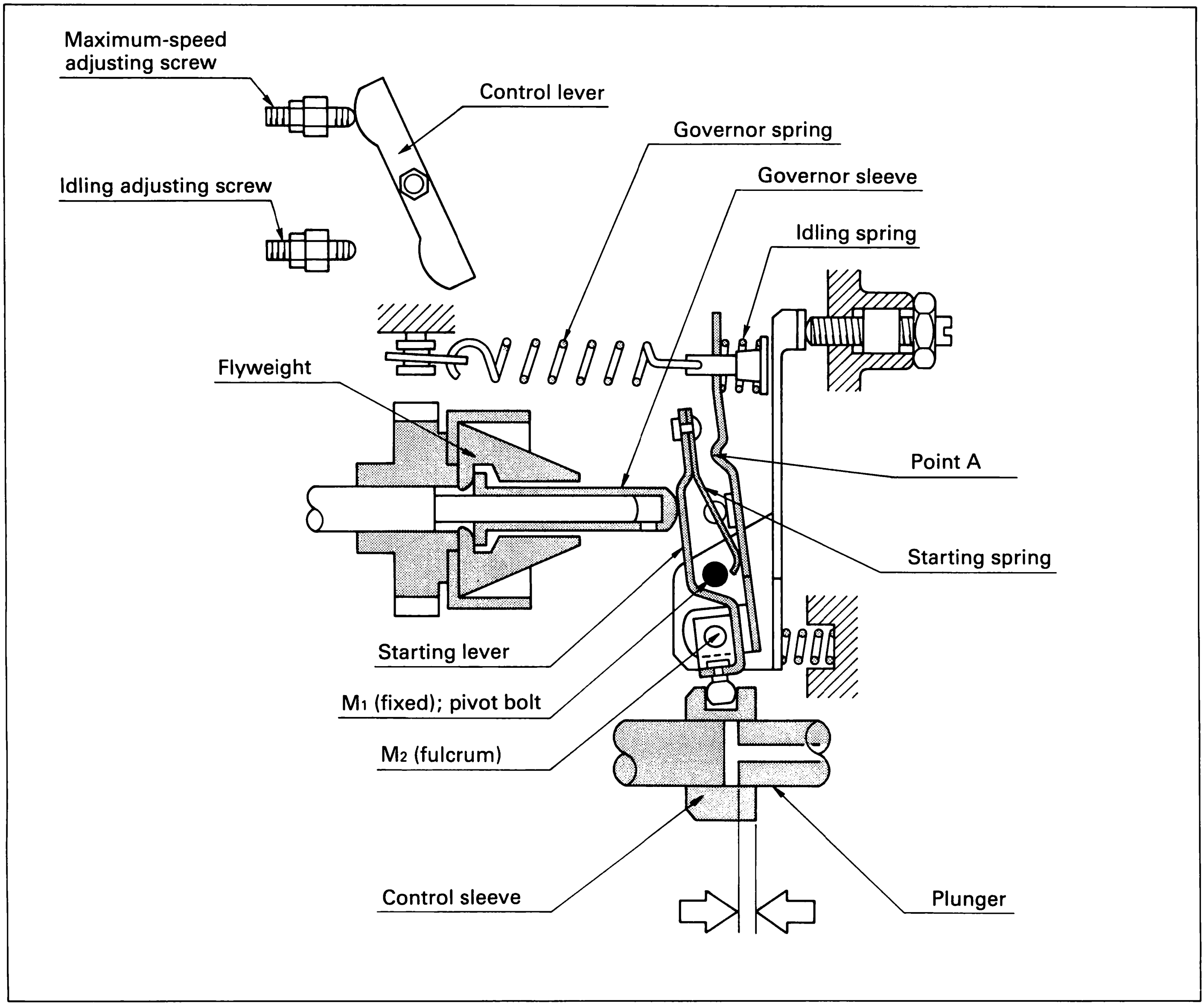

Fig. 20 Variable speed governor operation: engine starting

To improve starting characteristics at engine starting, the normal full-load injection quantity is exceeded and excess fuel for starting is supplied.
When the accelerator pedal is depressed while the engine is stationary, the starting lever is separated from the tension lever by the starting spring and moves to push the governor sleeve.
Because of this the control sleeve is moved to the right (the maximum injection quantity direction; Fig. 20) by the starting lever pivoting around M_2.
Therefore, through lightly depressing the accelerator the engine can be easily started.

After engine starting centrifugal force is generated by the flyweights, the governor sleeve acts to compress the weak starting spring and the starting lever is pressed against the tension lever.
Through this movement the control sleeve is moved in the fuel-decrease direction, injection is returned to the full-load injection quantity range and the supply of excess fuel for starting is completed. Following this, the tension lever and the starting lever, in contact at point A (Fig. 20), move together as a single component.

Idling operation

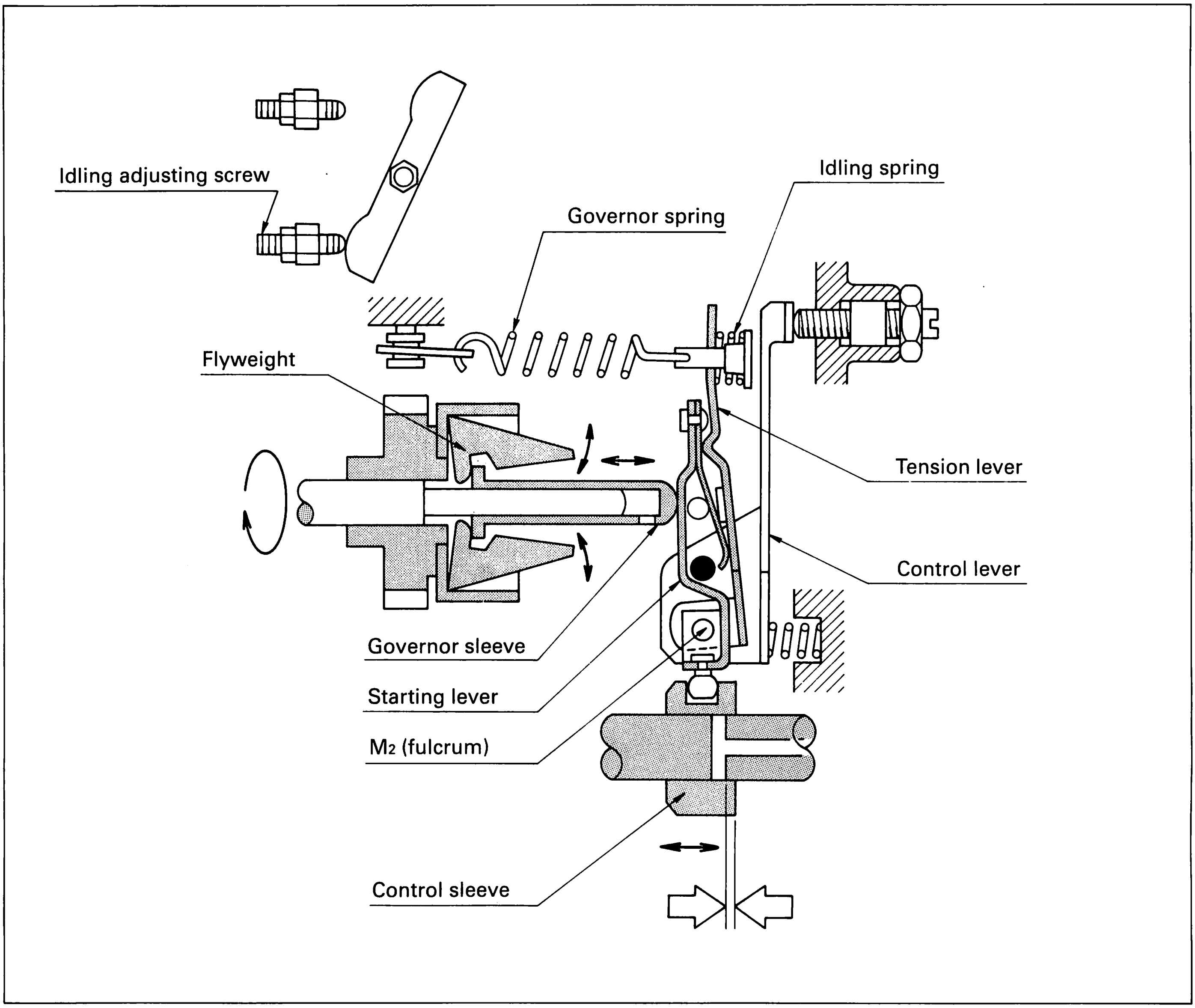

Fig. 21 Variable speed governor operation: idling operation

Once the engine has started the accelerator pedal is returned to its original position. The control lever is also returned to its original position and the governor spring tension becomes "0". The flyweights then open, the starting lever is pressed against the tension lever and compression of the idling spring begins.

The control sleeve then travels in the fuel-decrease direction and stops in the position where the flyweights centrifugal force and the idling spring force are balanced. In this position stable idling operation can be obtained.

Full-load and no-load maximum speed control

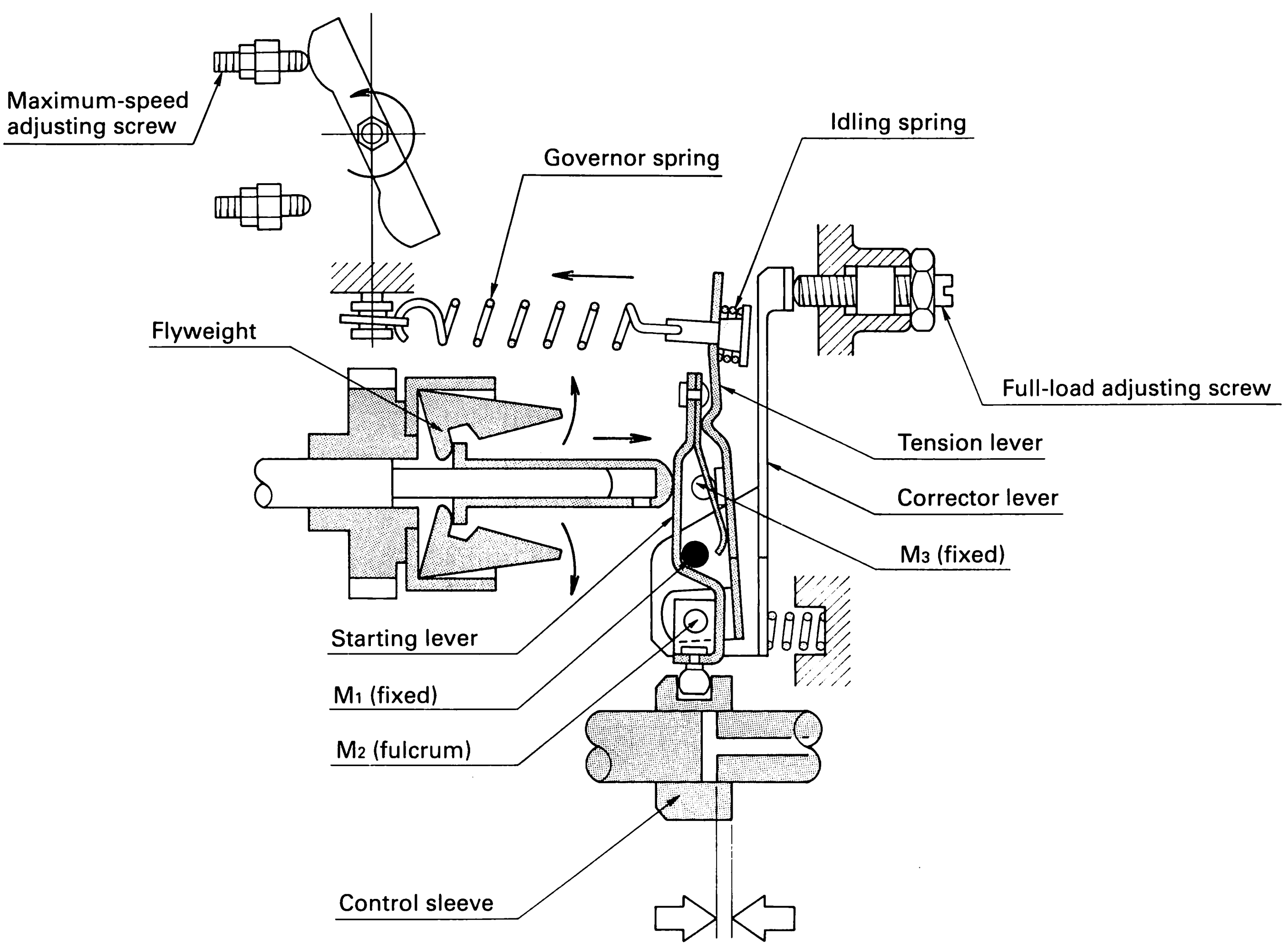

Fig. 22 Variable speed governor operation: full-load operation maximum speed control

When the accelerator pedal is fully depressed and the control lever has contacted the maximum speed adjusting screw, the tension lever contacts the pin (M_3) press fitted to the pump housing (i.e. where the full-load injection quantity is obtained) and can move no further. At this time the governor spring set force is at a maximum. Because of this, the idling spring is fully compressed and the flyweights, being pushed by the governor sleeve, are closed. Then, although the centrifugal force of the flyweights increases with the increase in engine speed, the flyweights cannot move the governor sleeve until the governor spring's set force has been overcome.

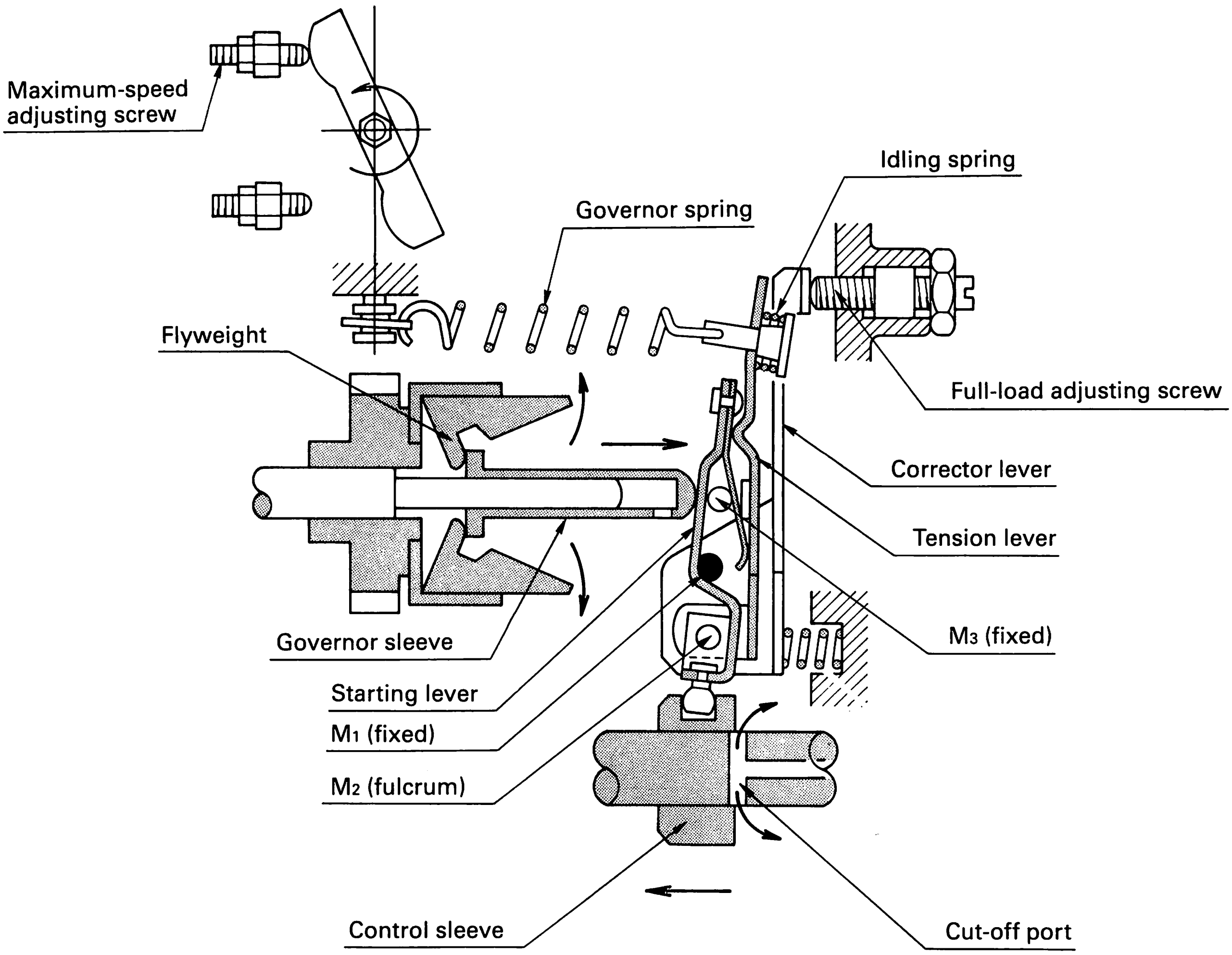

Fig. 23 Variable speed governor operation: no-load maximum speed control

Furthermore, with an increase in engine speed after both are balanced, the flyweights' centrifugal force will overcome the governor spring's set force, and will extend the spring while moving the governor lever assembly.
Therefore, the fuel injection quantity will be decreased and high speed control will be performed so that the specified maximum speed is not exceeded.
When the accelerator pedal is not fully depressed, the governor spring set force may be varied freely so that governor control may be performed in response to partial load conditions.
The full-load injection quantity is determined according to the amount that the full-load adjusting screw is screwed in. When the full-load adjusting screw is screwed in, the corrector lever pivots to the left (Fig. 22; counterclockwise direction) around point M_1 and the control sleeve moves in the fuel-increase direction. Unscrewing the full-load adjusting screw moves the control sleeve in the fuel-decrease direction.

Combination Governor Construction and Operation

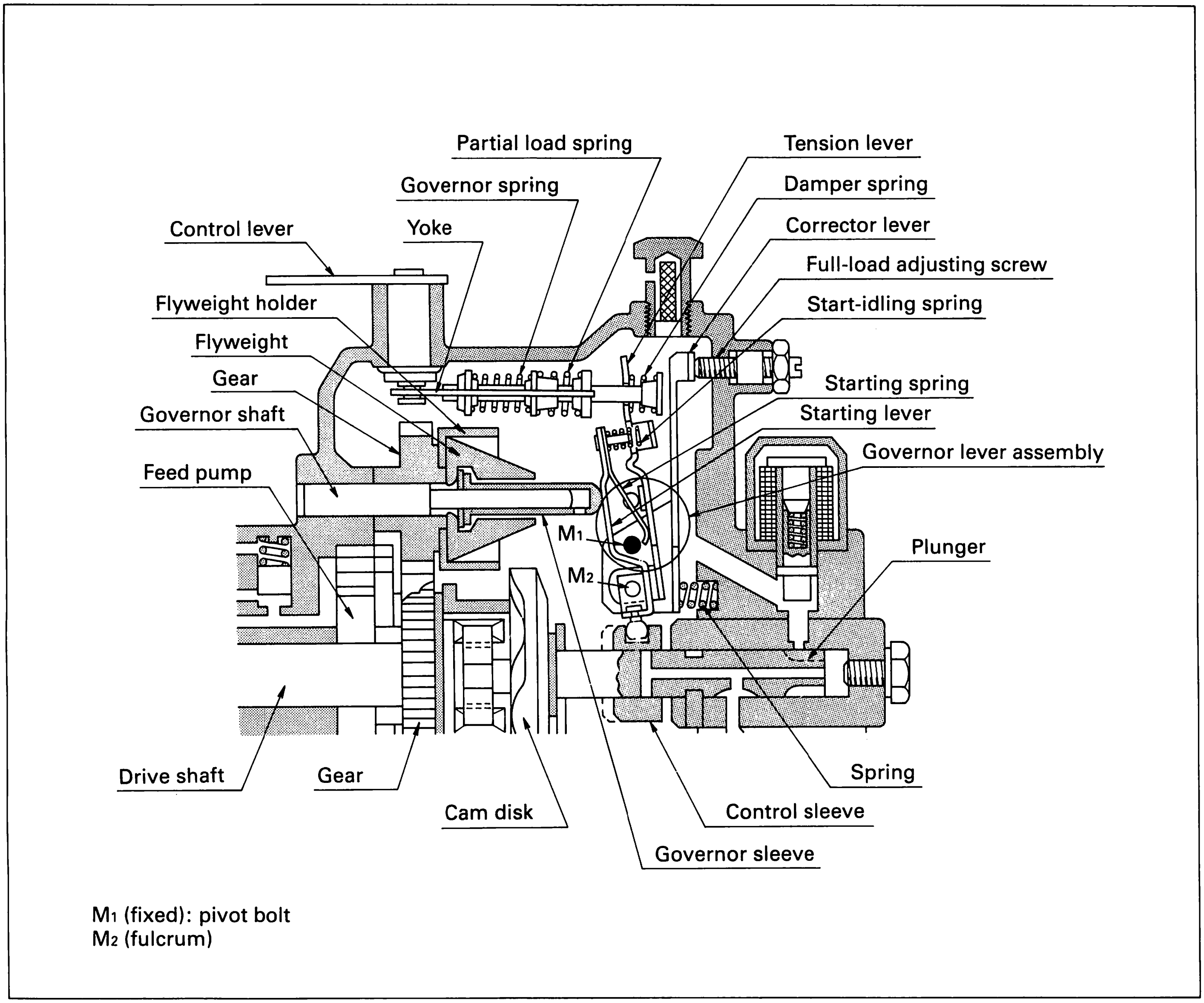

Fig. 24 Combination governor construction

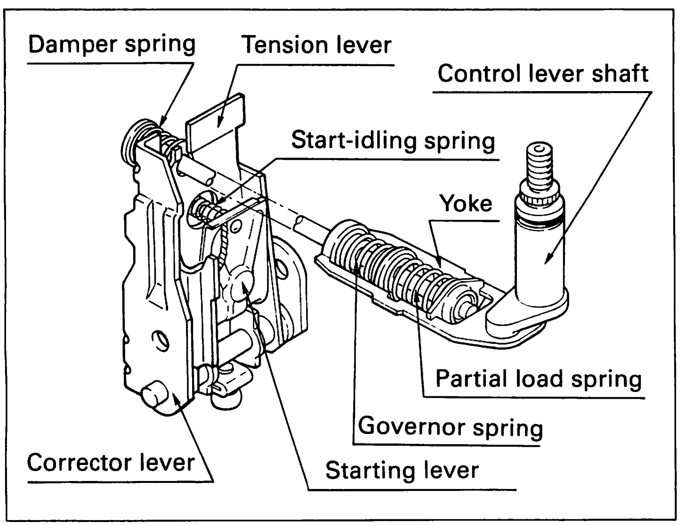

Fig. 25 Combination governor lever assembly

When comparing the construction of the combination governor with that of the variable speed governor, the governor spring and the governor lever assembly of the combination governor differ from those of the variable speed governor.

As shown in Fig. 24 a yoke is attached to the control lever shaft assembly, and the governor spring and the partial load spring, with a preset force, are installed inside the yoke. A damper spring is installed at the end of the yoke.

Idling control is performed by the start-idling spring, which is installed between the top of the tension lever and the starting lever in the governor lever assembly.

Engine starting

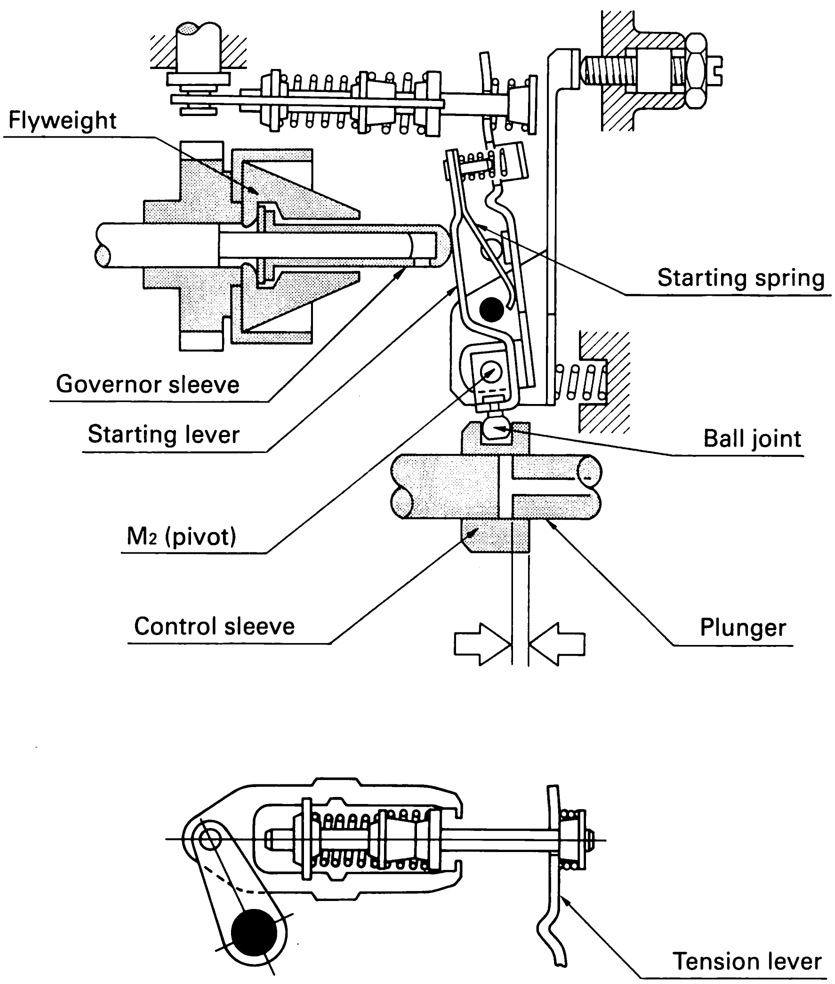

Fig. 26 Combination governor operation: engine starting

Depressing the accelerator pedal lightly at engine starting results in the control lever shaft assembly pulling the tension lever to the left (Fig. 26), and through the action of the starting spring (leaf spring) the starting lever pushes the governor sleeve. Through this movement the ball joint, with point M_2 as the fulcrum, moves the control sleeve to the position where excessive fuel for starting can be obtained, and the engine can be easily started.

Once the engine has been started, the centrifugal force generated by the flyweights pushes the governor sleeve against the weak force of the starting spring. The control sleeve is then moved in the fuel-decrease direction and the supply of excessive fuel for starting is completed.

Idling operation

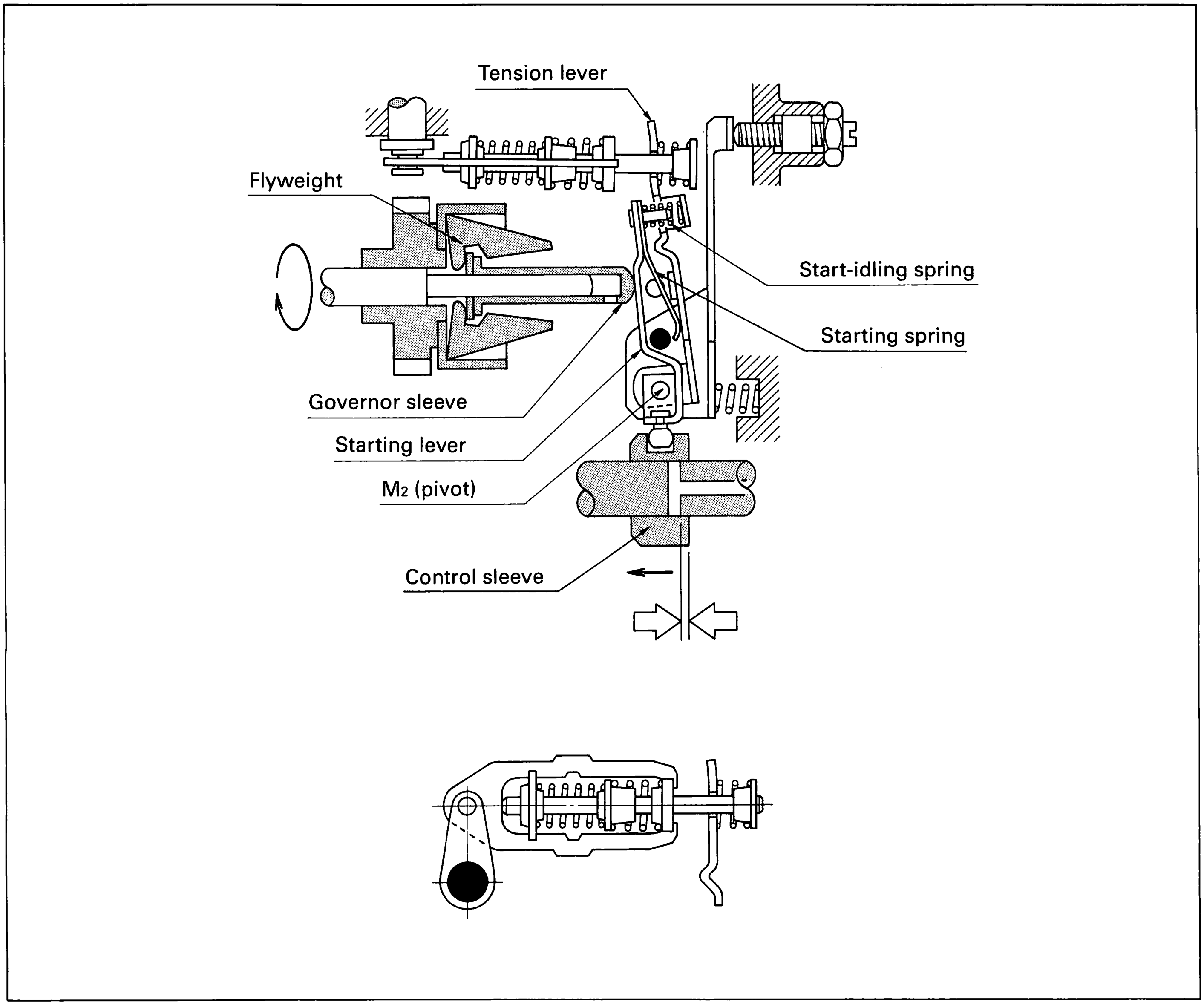

Fig. 27 Combination governor operation: idling operation

On releasing the accelerator pedal the control lever is returned to the idling position and the tension lever is freed.
Through the flyweights' centrifugal force the governor sleeve pushes the starting lever. After the start-idling spring has contacted the tension lever, the combined forces of the start-idling spring and the starting spring balance the flyweights' centrifugal force and the starting lever becomes stationary.
This starting lever movement moves the control sleeve directly in the fuel-decrease direction and stabilized idling operation can begin.

Partial load operation

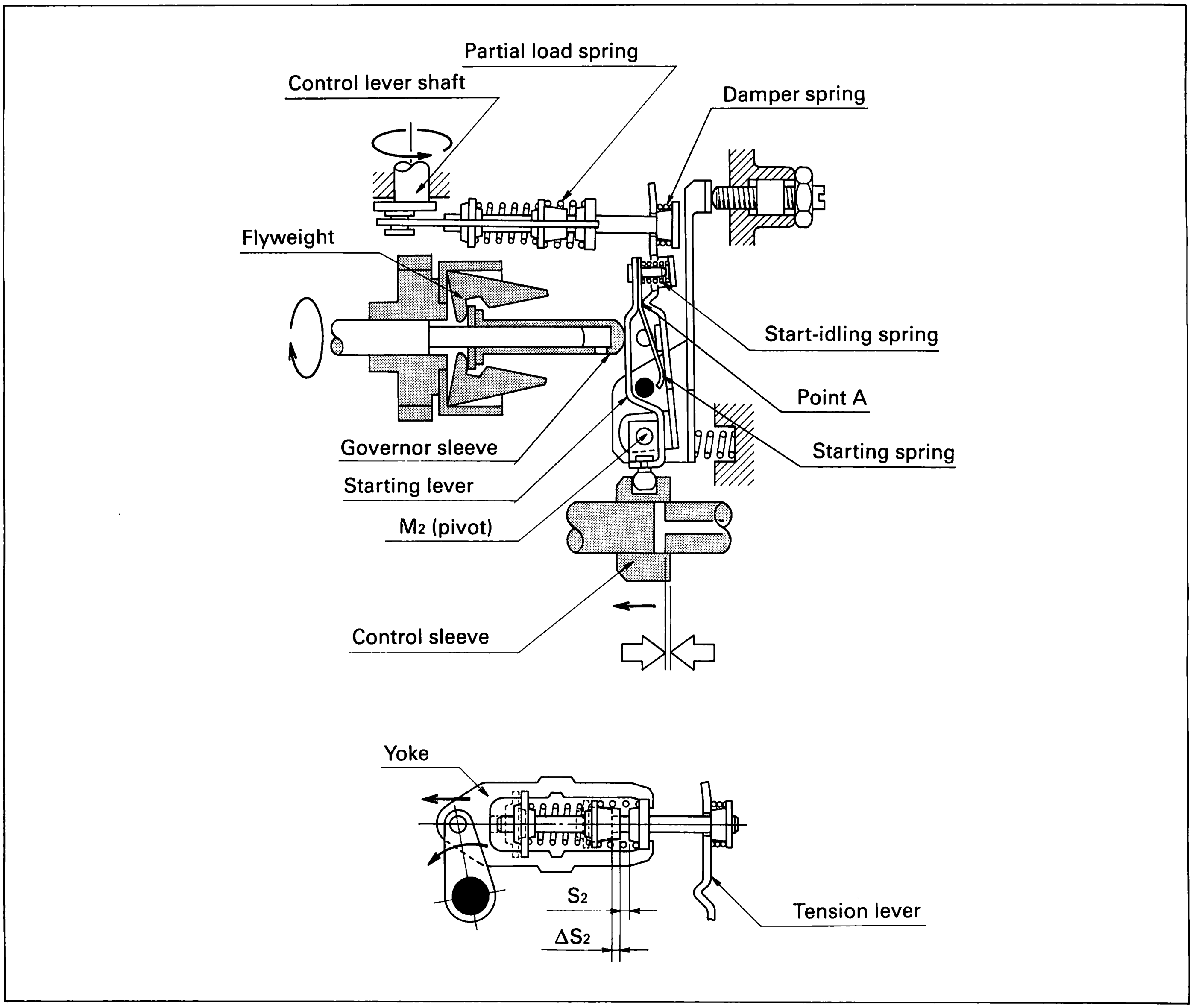

Fig. 28 Combination governor operation: partial load operation

In the speed range exceeding idling the starting spring and the start-idling spring are already compressed, and the starting lever and the tension lever, which are in contact at the convex point A, both move together as one. (Fig. 28)

Therefore, during partial load operation the damper spring and the partial load spring are acted upon by (and oppose) the flyweights' centrifugal force.

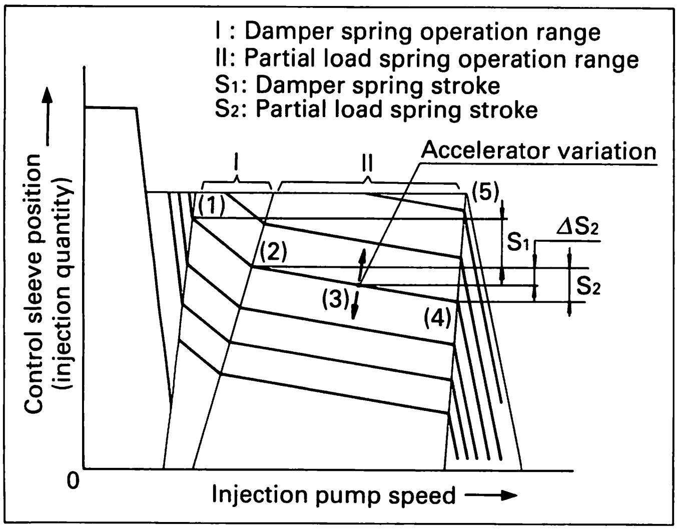

Fig. 29 Combination governor characteristics

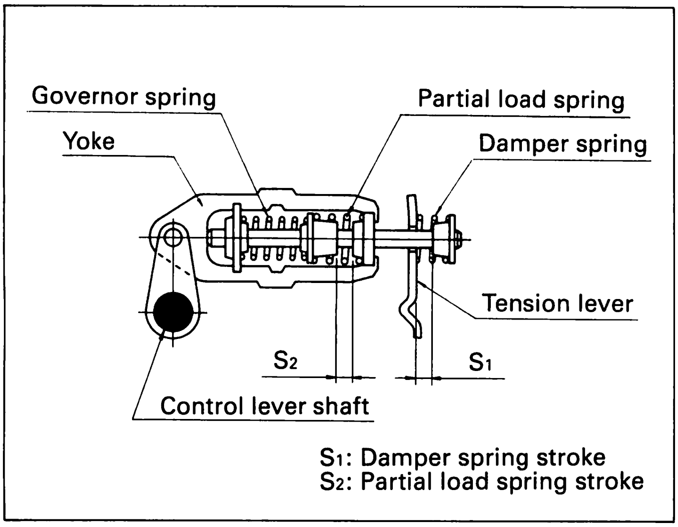

Fig. 30 Control lever shaft assembly

In low speed range I the control sleeve's position is controlled by the balance of the flyweights' centrifugal force and the damper spring force.
(e.g. control sleeve movement from (1) to (2) in Fig. 29)
In the intermediate-high speed range II (where the flyweights' centrifugal force exceeds the damper spring force, but is less than the governor spring's set force) the damper spring is fully compressed, and the partial load spring in the yoke is compressed an amount equal to ΔS_2 (Fig. 29). ΔS_2 varies according to the balance of the flyweights' centrifugal force with each spring's set force (i.e. engine speed and engine load).

If an uphill slope is negotiated after travelling on a level road with the control lever position fixed and the control sleeve positioned at point (3), because the engine speed decreases, the control sleeve position will shift in the direction of point (2) through the action of the partial load spring and the fuel injection quantity will be increased.
Conversely, if a downhill slope is negotiated, the fuel injection quantity will be decreased as engine speed increases.
Furthermore, if the amount that the accelerator pedal is depressed is altered, the control sleeve position will move in the direction of the arrow in Fig. 29.

Full-load and no-load maximum speed control

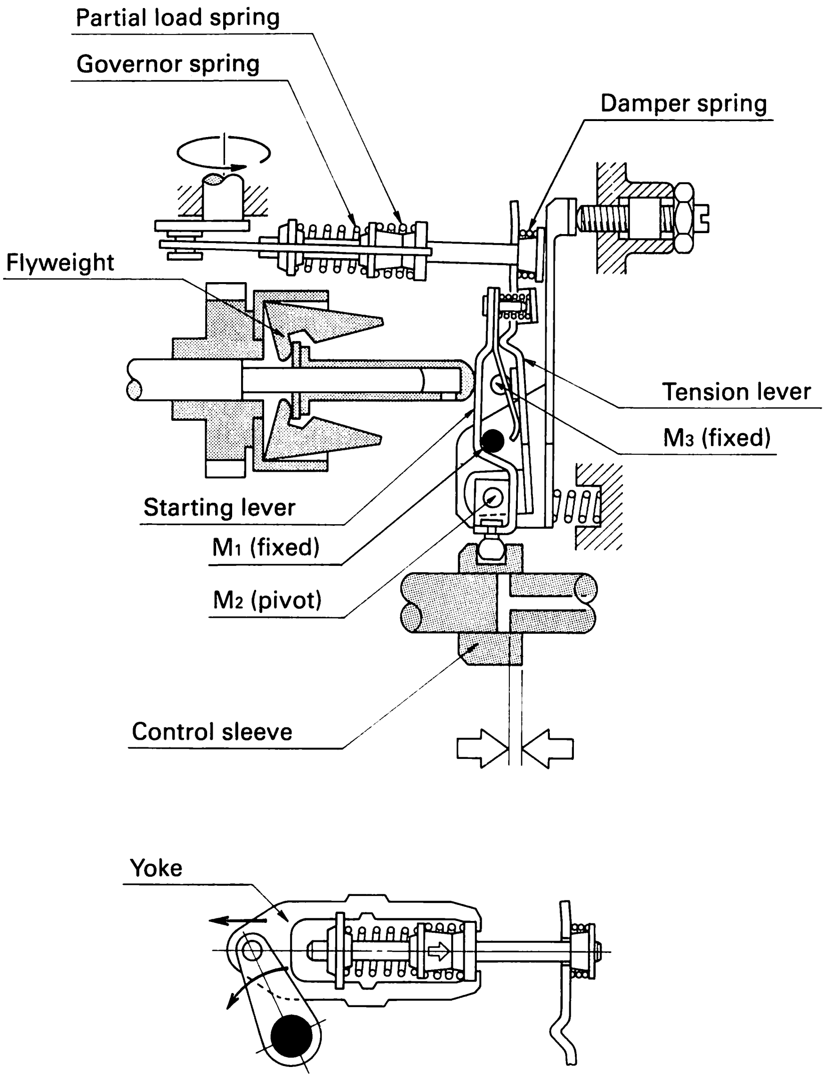

Fig. 31 Combination governor operation: full-load maximum speed operation

On moving the control lever until it contacts the maximum speed stopper bolt, the tension lever contacts the pin (or the stop lever of the BCS or ACS) M_3 press-fitted to the pump housing and can move no further. Consequently, the damper spring and the partial load spring are fully compressed and the control sleeve travels to the position where the full-load injection quantity can be obtained.

Following this engine speed increases and, at the point where the flyweights' centrifugal force balances the combined forces of the yoke springs (point (5) in Fig. 29), the full-load maximum speed capable of maximum engine output is reached.

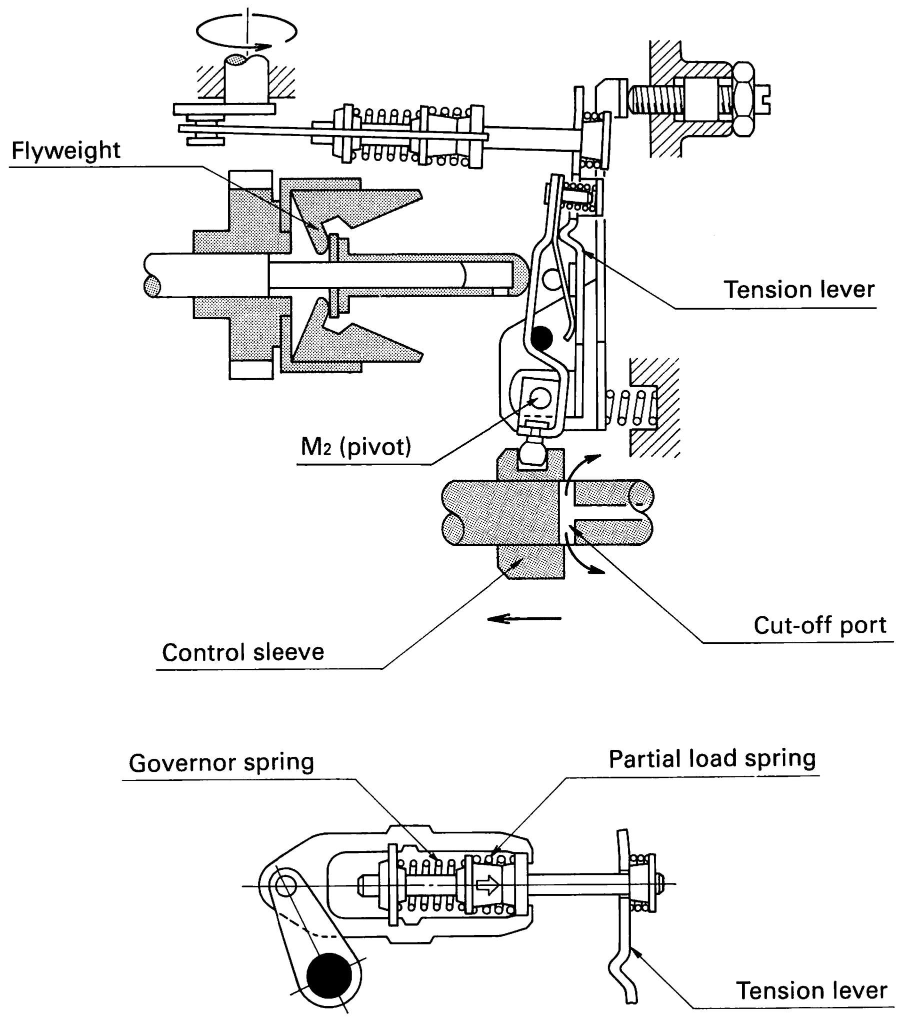

Fig. 32 Combination governor operation: no-load maximum speed control

To prevent the engine from exceeding the specified maximum speed when pump speed increases further, due to variations in load etc, the flyweights begin to compress the governor spring and the tension lever is pivotted clockwise around point M_2 to move the control sleeve in the non-injection direction.

The governor therefore controls the engine speed so that it does not exceed the engine's specified maximum speed.

Variable Speed Governor and Combination Governor

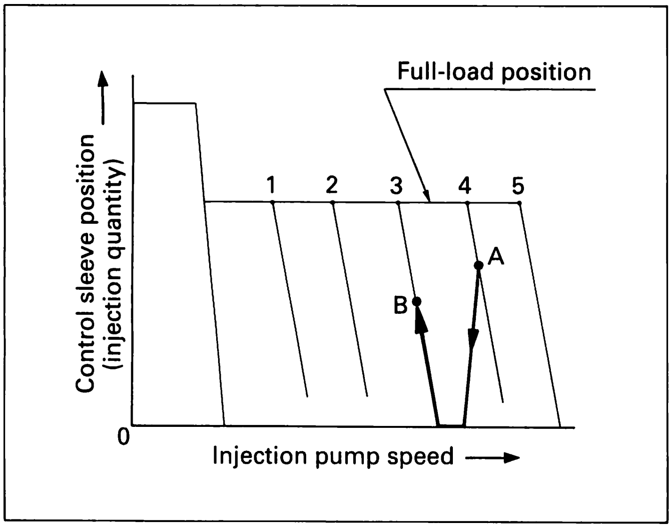

Fig. 33 Variable speed governor characteristics

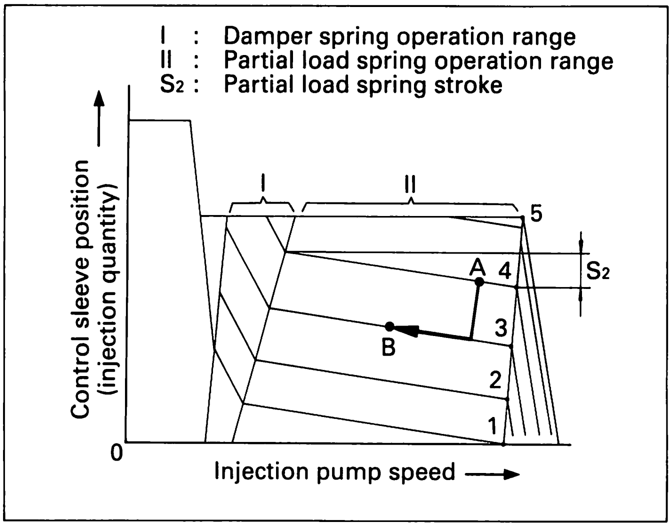

Fig. 34 Combination governor characteristics

The governor spring's set force in a variable speed governor changes in accordance with changes in the accelerator pedal position. (Fig. 33: points 1–5).
For example, when the flyweights' centrifugal force and the governor spring's set force are balanced (Fig. 33; point A) and the accelerator pedal is released a little to decrease speed, the control sleeve will move to the non-injection position as shown by the solid line in Fig. 33.
Then, in response to the change in the governor spring's set force (gradient 3), the control sleeve will move in the fuel-increase direction and will stop in the positon where the injection quantity necessary for the load at this time can be obtained (i.e. point B ; the flyweights' centrifugal force and the governor spring's set force are balanced). The variable speed governor governs in the engine's all-speed range in response to accelerator pedal position or variations in engine load.

With the combination governor the set force of the partial load spring and the control sleeve position (Fig. 34 : lines 1–5) are varied in response to accelerator pedal position to regulate the fuel injection quantity.
If the accelerator pedal is released slightly to decrease speed during partial load operation (Fig. 34 : point A), when the flyweights' centrifugal force and the partial load spring's set force are balanced, the control sleeve will move from point A to point B, as shown by the solid line in Fig. 34.
As can be seen from the solid line in Fig. 34 showing control sleeve movement when speed decreases, the combination governor's control sleeve travel is less, and the variation in fuel injection quantity is also decreased.
This results in a reduction in the shock caused by sudden variations in fuel injection quantity and an improvement in accelerator "feeling" when speed is reduced.

Governor Equipped with Negative Torque Control Device

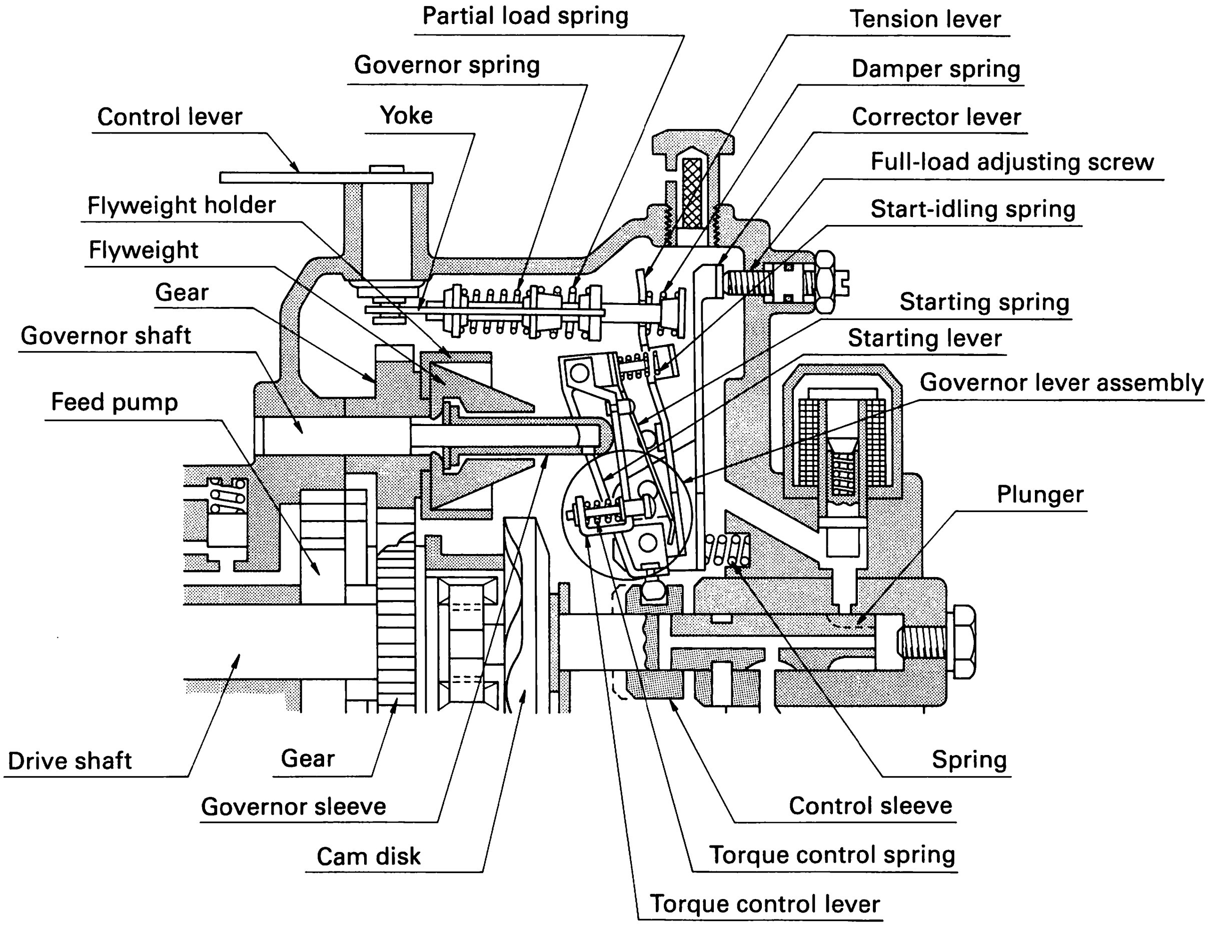

Fig. 35 Construction of governor equipped with negative torque control device

A negative torque control device is provided through the installation of a torque control lever to the governor lever assembly's starting lever.

The torque control lever is fitted with a torque control spring, the set force of which varies according to the torque control stroke.

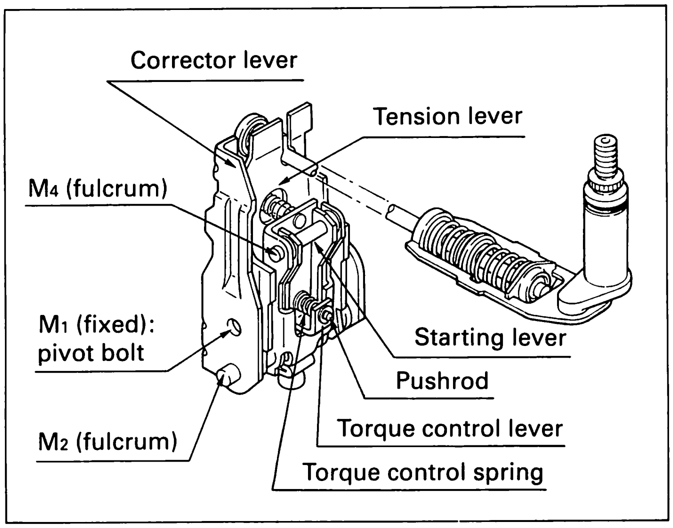

Fig. 36 Governor lever assembly equipped with negative torque control device

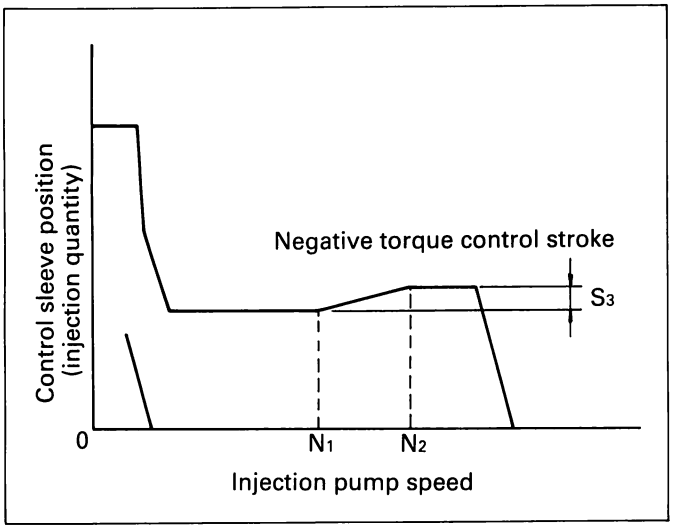

Fig. 37 Negative torque control characteristic

The negative torque control device moves the control sleeve through the torque control stroke (S_3 in Fig. 37) in the governor's intermediate-speed control range to increase the injection quantity in proportion to engine speed and therefore prevent insufficient engine output resulting from insufficient fuel injection at high speeds. (Refer to Fig. 37.)
Figure 37 shows the control characteristics of a combination governor equipped with the negative torque control device.

Engine starting

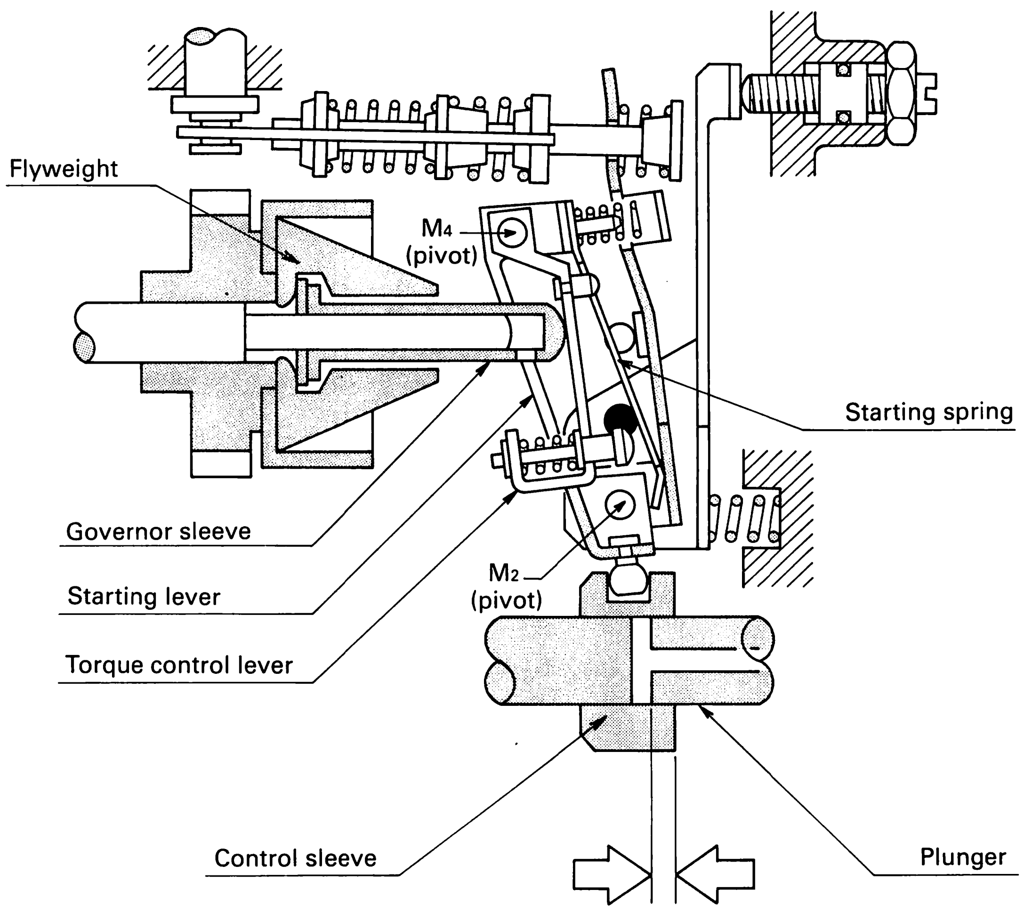

Fig. 38 Operation of governor equipped with negative torque control device: engine starting

As in the variable speed governor or the combination governor, the governor equipped with the torque control device controls starting through the action of the starting spring (a leaf spring) mounted on the starting lever.
At starting the action of the starting spring pivots both the starting lever and the torque control lever (connected at M_4) in a counter-clockwise direction around point M_2, thus moving the control sleeve in the fuel-increase direction to supply a fuel injection quantity sufficient for starting.

Idling operation

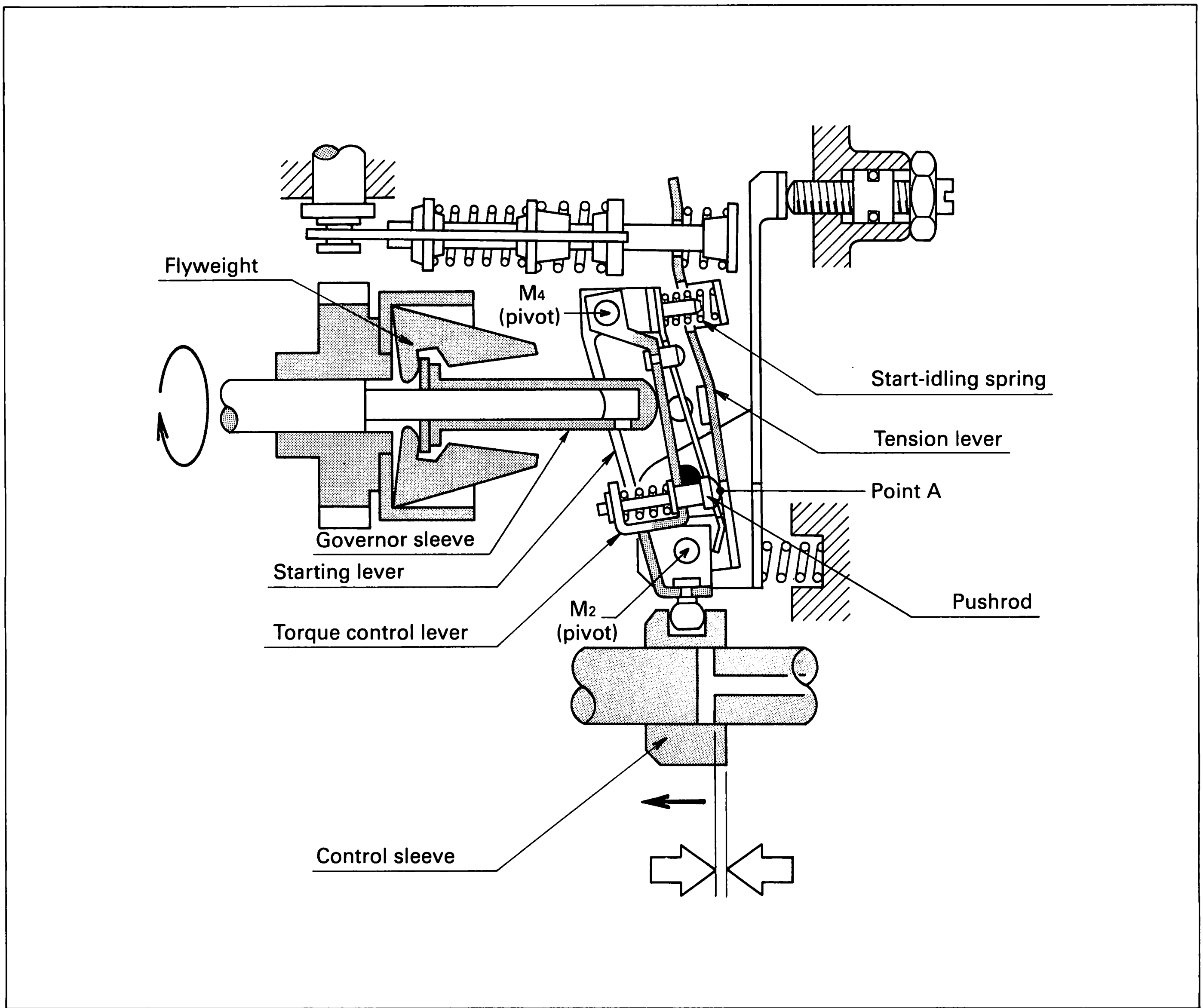

Fig. 39 Operation of governor equipped with negative torque control device: idling operation

On starting, the centrifugal force of the flyweights causes the governor sleeve to move to the right (Fig. 39). The governor sleeve then contacts and moves the torque control lever.
The torque control lever pushrod then contacts the tension lever at point A, and the torque control lever then pivots around point A to compress the start-idling spring until its set force is overcome by the flyweights' centrifugal force. Consequently the starting lever will pivot clockwise around M_2, thus moving the control sleeve in the fuel decrease direction until an injection quantity suitable for idling is attained.

Partial load operation

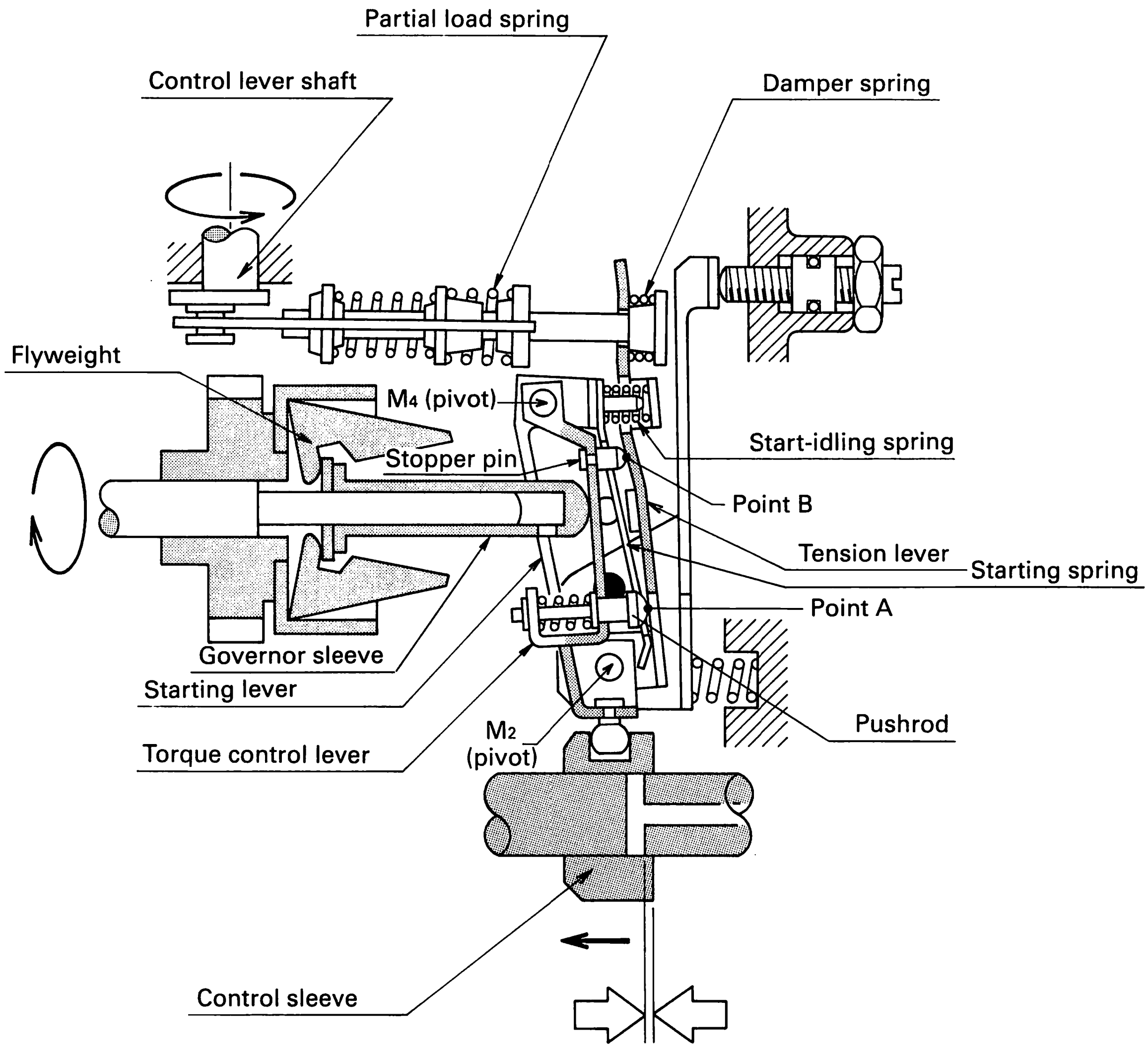

Fig. 40 Operation of governor equipped with negative torque control device: partial load operation

In the speed range exceeding idling operation, and the range where the control lever is positioned between the idling position and the maximum speed position, the starting spring and start-idling spring are already fully compressed, and the torque control lever and the tension lever (which are in contact at points A and B through the torque control lever pushrod and stopper pin), and the starting lever, move together as one (Fig. 40).

Therefore, during partial load operation the damper spring and the partial load spring are acted upon by (and oppose) the flyweights' centrifugal force.

If the speed increases during partial load operation in accordance with a change in the control lever position (i.e. the control sleeve position) after the accelerator pedal is depressed, the consequent increase in the flyweights' centrifugal force moves the governor sleeve to the right, thereby pushing the torque control lever to the right. Then, as the torque control lever, the starting lever and the tension lever behave as one component, movement of the governor sleeve by the flyweights' centrifugal force compresses the damper spring and the partial load spring, and pivots the starting lever around M_2. Thus, the control sleeve is moved to the left to decrease the fuel injection quantity. As a result of this, the speed is decreased to maintain a suitable engine speed, and an injection quantity corresponding to the engine load etc. is obtained at the point where the flyweights' centrifugal force is balanced with the combined forces of the damper and partial load springs.

Full-load maximum speed operation

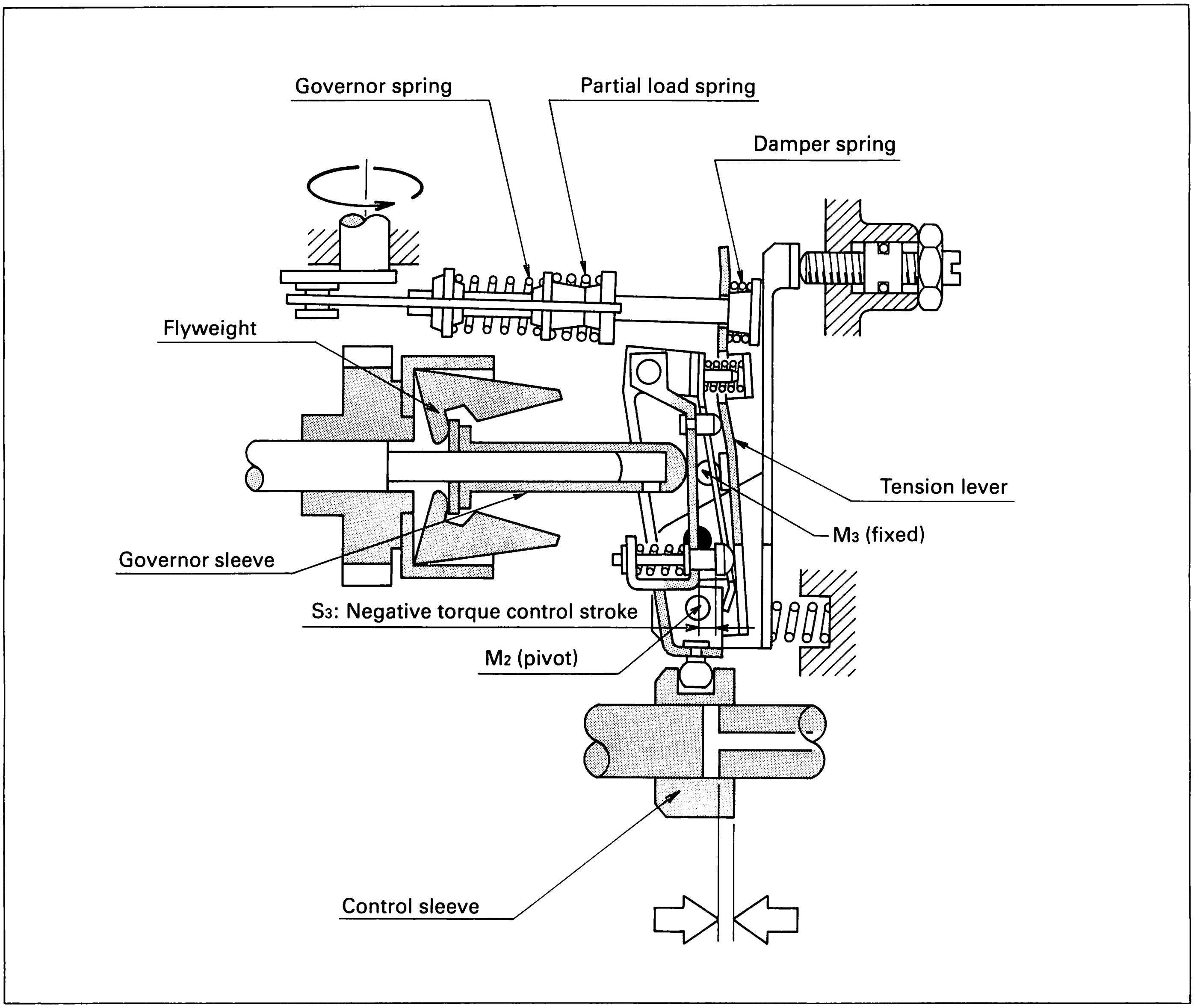

Fig. 41 Operation of governor equipped with negative torque control device: full-load maximum speed operation

When the control lever is moved until it contacts the maximum speed stopper, engine speed is increased until the full-load maximum speed is reached. At this time the yoke is pulled to the extreme left (refer to Fig. 41), the partial load spring is fully compressed, the governor spring is compressed and the tension lever is pulled to the left until it contacts the stopper pin M_3 (i.e. where the full-load injection quantity is obtained).

With an increase in speed the flyweights' centrifugal force increases and the governor sleeves acts to move the tension lever against the force of the governor spring to move the control sleeve and maintain full-load maximum speed operation.

Negative torque control stroke operation

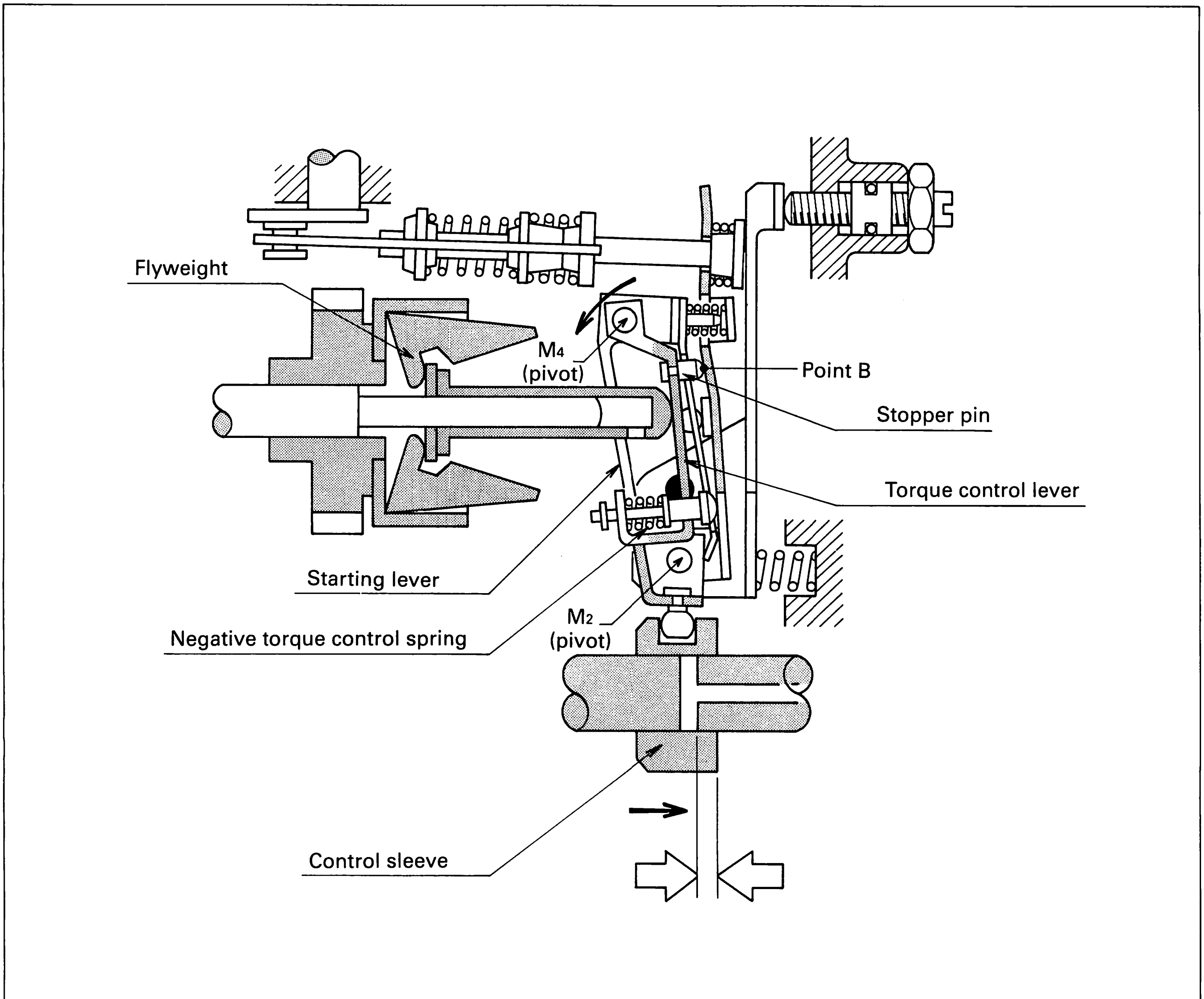

Fig. 42 Operation of governor equipped with negative torque control device: negative torque control stroke operation

When the engine speed exceeds N_1 r.p.m (refer to Fig. 37) the centrifugal force of the flyweights will continue to increase, resulting in compression of the negative torque control spring.
The torque control lever will therefore pivot counterclockwise around point B (the torque control lever stopper pin), pivoting the starting lever counterclockwise around M_2 to move the control sleeve in the fuel-increase direction. The increase in the fuel injection quantity is determined by the negative torque control stroke S_3 (refer to Fig. 41).

No-load maximum speed operation

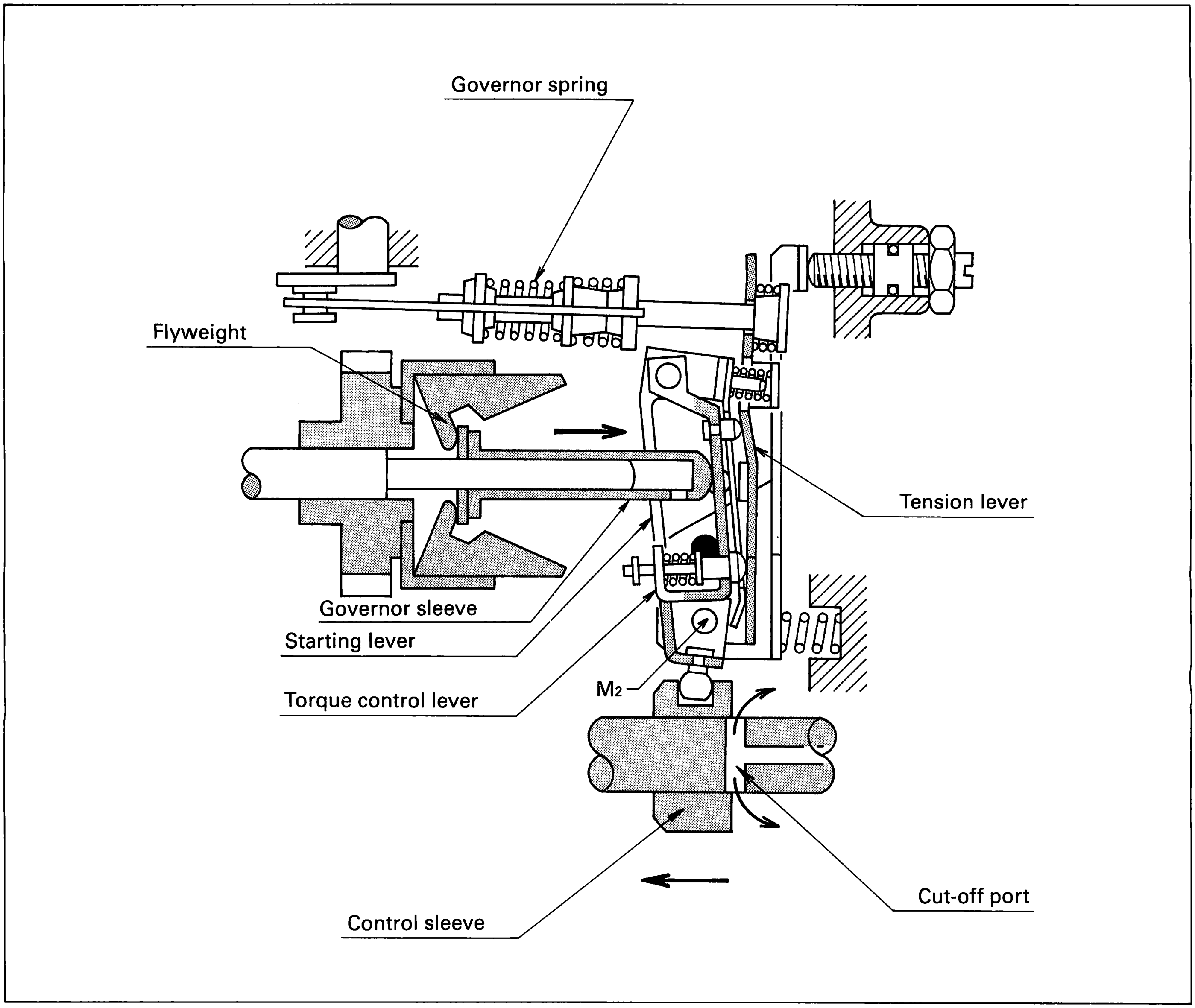

Fig. 43 Operation of governor equipped with negative torque control device: no-load maximum speed control

When the negative torque control stroke is completed and engine speed increases further, the flyweights' centrifugal force will move the governor sleeve to the right (Fig. 43). The starting lever and the tension lever (through the torque control lever) are then moved to compress the governor spring until the governor spring tension is balanced with the flyweights' centrifugal force in the no-load maximum speed position. If engine speed further increases, the control sleeve will move to the left until the plunger's cut-off port enters the pump chamber, resulting in non-injection so that the engine's specified maximum speed will not be exceeded.

TIMER CONSTRUCTION AND OPERATION

It is well-known that the relationship between fuel injection timing and engine performance (power, exhaust gas, engine vibration) is very important.
If actual fuel injection timing differs only slightly from the standard specified timing, then diesel engine performance will be adversely effected.
Because the ignition lag arising during diesel engine combustion increases as engine speed increases, it is necessary to compensate for this ignition lag by advancing injection timing.
To do this, a timer is installed at the bottom of the injection pump.

Standard Type Timer (Speed Timer)

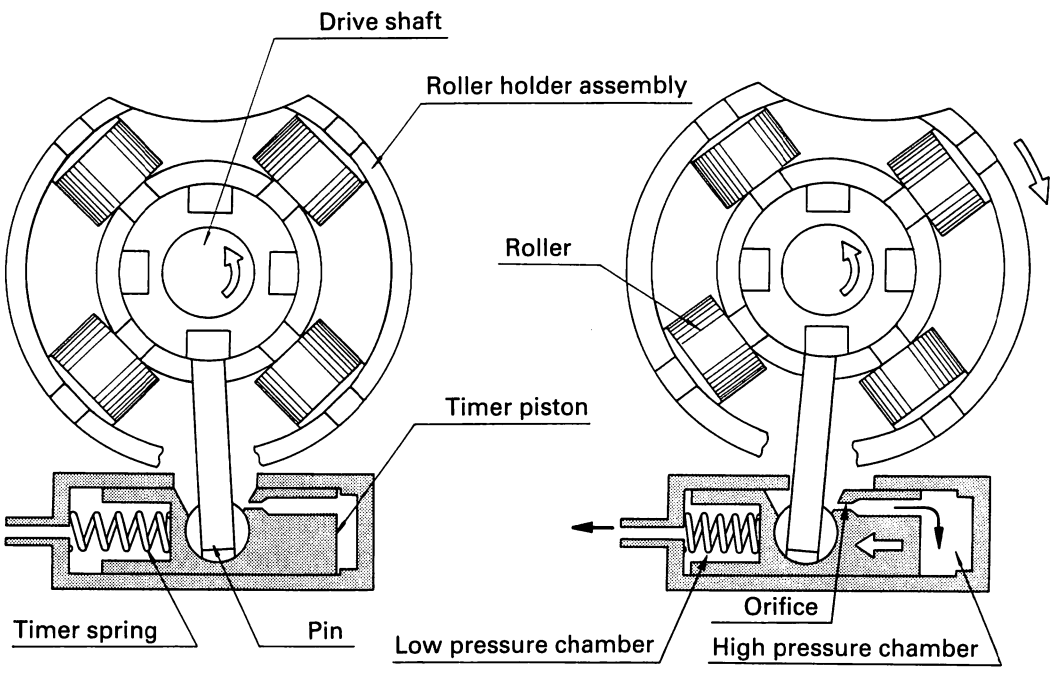

Fig. 44 Speed timer construction and operation

As shown in Fig. 44, a timer spring is installed in the low pressure chamber of the timer. Pump chamber pressure, passing through the timer piston orifice, acts on the high pressure side of the timer piston.
This timer piston orifice acts to prevent timer piston pulsation generated by fuel pressure fluctuations.
Timer piston movement results in the pin moving the roller holder assembly in the direction opposite to injection pump rotation.
When pump chamber pressure exceeds the set force of the timer spring due to an increase in pump speed, the timer piston compresses the timer spring and turns the roller holder assembly in the direction opposite to that of injection pump rotation. With this movement the cam disk's face cams more quickly contact the roller holder's rollers and injection timing is advanced.

When pump speed decreases and the timer spring set force exceeds the pump chamber pressure, the roller holder assembly is moved in the direction to retard injection timing.
Additional devices such as the solenoid timer, cold start device (C.S.D.) and the load timer etc. are also used with this standard-type timer to vary the injection timing in the specified range of engine speeds and loads.

Servo Valve Timer

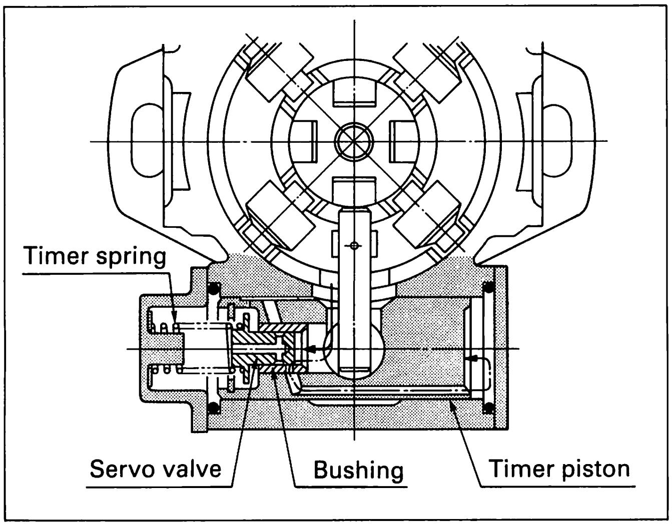

Fig. 45 Servo valve timer construction

As shown in Fig. 45, through the addition of some parts (e.g. servo valve), the alteration of other parts (e.g. timer piston, cover and spring) and alterations to the fuel oil transfer passage, the servo valve timer differs from the standard type timer.
With the servo valve timer, pump chamber pressure does not act directly on the timer's high pressure chamber, but flows through the servo valve before acting on the timer's high pressure chamber.
The timer spring force does not push the timer piston, but pushes the servo valve against pump chamber pressure. The servo valve position depends on the balance of these two opposing forces, and timer characteristics in turn depend on the servo valve position.

For example, if the timer piston is moved in the retard direction by fluctuations in the driving reaction force, the servo valve position will not change, as the pump chamber pressure does not change. The servo valve then functions to compensate for the fluctuations in the driving reaction force by allowing the supply of pump chamber pressure to the high pressure side of the timer piston. The timer piston is therefore returned to its original position. In other words, the timer piston position is dependant on servo valve position.
From the above, the servo valve timer's absorbing of the effect of the driving reaction force on injection timing can be seen.
As the effective pressure area directly acted upon by the pump chamber pressure decreases, and correspondingly the spring constant decreases, an improvement in response and a decrease in hysteresis can be obtained.

When advance angle is "0" (Low pump chamber pressure)

The pump chamber pressure, compared to the timer spring force, is still low, and the servo valve and the timer piston are pushed fully in the retard direction by the timer spring. The passage between the pump chamber (high pressure side) and the timer's high pressure chamber is closed, and the timer's high pressure chamber is connected to the timer's low pressure chamber (fuel inlet side) by the servo valve.

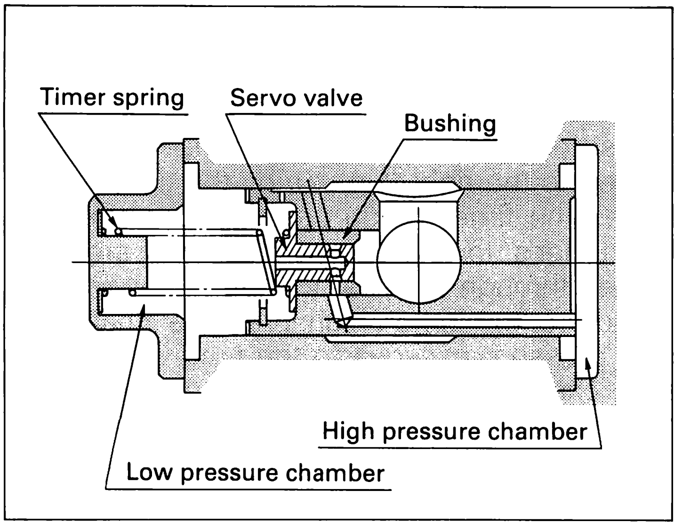

Fig. 46 Servo valve timer operation: when advance angle is "0"

When pump chamber pressure has increased

The pump chamber pressure has increased, the pump chamber pressure exceeds the timer spring set force, and the servo valve has been moved to the left (Fig. 47).
The passage between the pump chamber and the timer's high pressure chamber is open and the pump chamber pressure acts on the timer's high pressure chamber. Due to this the timer piston is moved in the advance direction (to the right in Fig. 47).

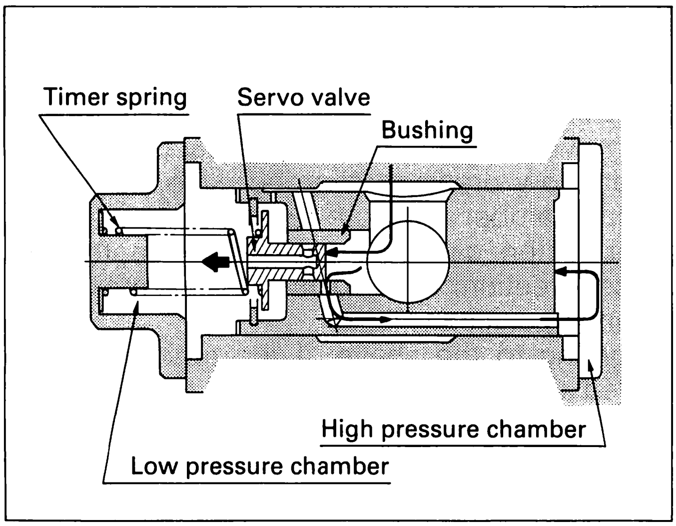

Fig. 47 Servo valve timer operation: when pump chamber pressure has increased

Stable condition (balanced)

The pump chamber pressure and the timer spring force are balanced, and the servo valve is stationary in a suitable position. The timer piston moves until the bushing hole is closed by the servo valve.
When the bushing hole is completely closed, there will be no change in the timer's high pressure chamber pressure and the timer piston will be stationary.

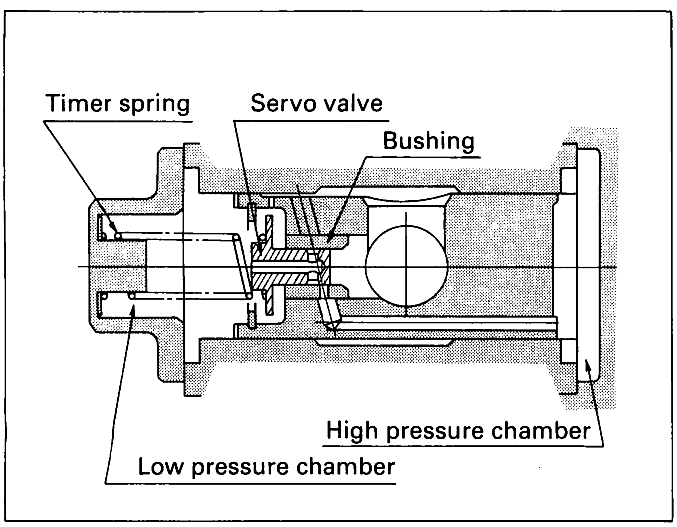

Fig. 48 Servo valve timer operation: stable condition (balanced)

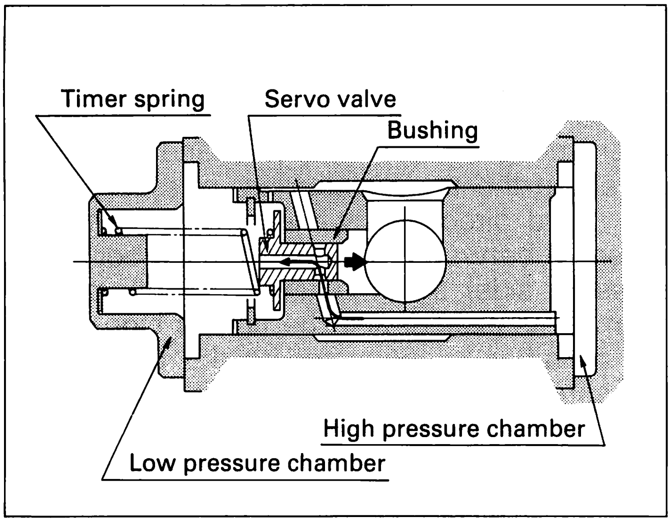

Fig. 49 Servo valve timer operation: when pump chamber pressure has decreased

When pump chamber pressure has decreased

From the stable condition, pump chamber pressure has decreased and the servo valve is moved to the right (Fig. 49) by the timer spring force. The timer's high pressure chamber and the timer's low pressure chamber are connected through the passage in the servo valve. Therefore the timer high pressure chamber's high pressure escapes to the timer's low pressure chamber and the timer piston moves in the retard direction (to the right in Fig. 49), and, as in the above, a stable condition results.

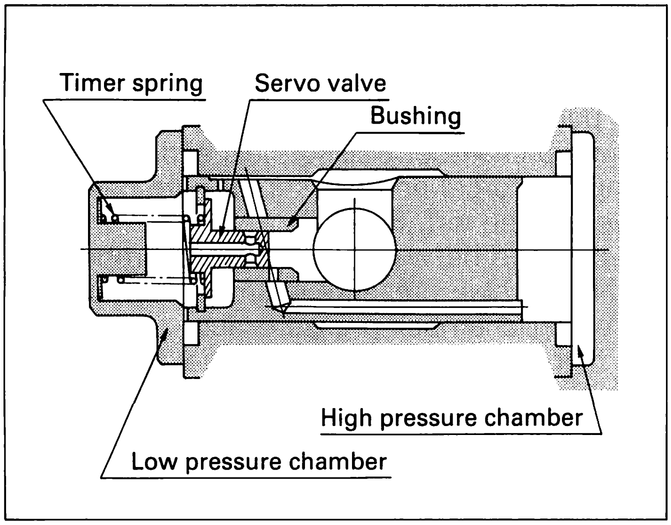

Fig. 50 Servo valve timer operation: maximum advance position

Maximum advance position

As the pump chamber pressure has completely overcome the timer spring force, the timer piston moves until its end face contacts the timer cover's low pressure chamber side. That is, if pump chamber pressure further increases, the timer piston cannot move further in the advance direction. This position is the maximum advance position.
According to the above, if the timer piston is moved through the driving reaction force, operations identical to the above (when pump chamber pressure has increased or decreased) will be repeated until the stable condition is attained.

Load Timer

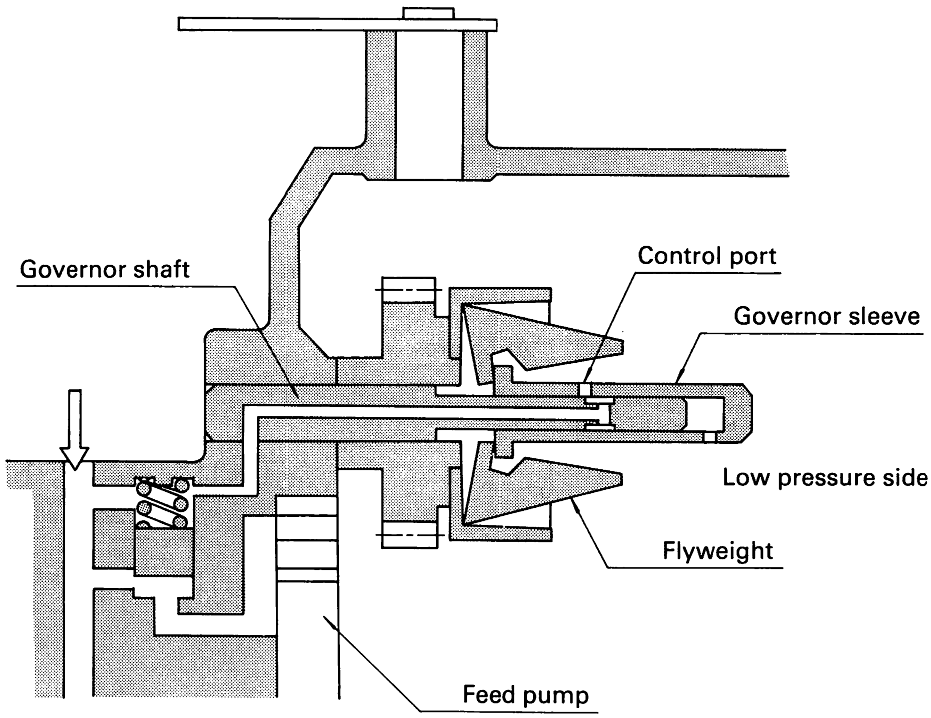

Fig. 51 Load timer construction and operation

The load timer functions to retard injection timing under partial loads in the low and intermediate speed range, and to reduce exhaust emission and engine noise.

With the load timer, the governor sleeve, the governor shaft, and the injection pump housing are specially constructed to facilitate the escape of fuel oil in the injection pump chamber from the governor sleeve control port, through a passage in the governor shaft and pump housing to the low pressure side.

When the flyweights are closed, the control port and the governor shaft passage are not aligned.

When the flyweights begin to open with an increase in the engine speed, the control port and the governor shaft passage barely align and injection pump chamber pressure begins to decrease as the pump chamber fuel oil flows to the fuel inlet (i.e. low pressure side) through this passage. When fully open pressure reduction is complete.

As a result, the timer's advance angle is only retarded an amount equal to the value of the pressure reduction.

Furthermore, the flyweights' (governor sleeve's) position changes in accordance with control lever position (engine load).

MAGNET VALVE

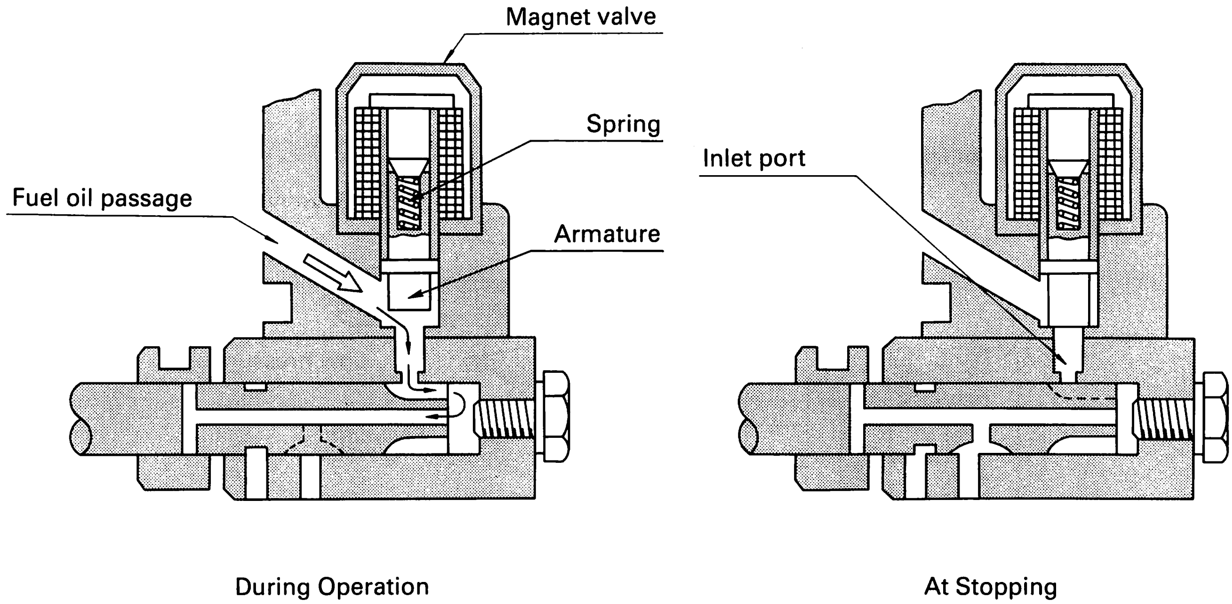

Fig. 52 Magnet valve construction and operation

The magnet valve is turned on and off by the vehicle's ignition switch to open and close the fuel oil passage leading to the plunger barrel's inlet port.

When the ignition switch is ON, current flows through the magnet valve, the armature in the centre of the magnet valve is attracted upwards and fuel oil from the pump chamber is supplied to the plunger barrel's inlet port.

When the ignition switch is turned OFF, the force of the spring inside the armature moves the armature downwards. Therefore, the fuel passage leading to the plunger barrel's inlet port is blocked and, as fuel oil injection to the engine combustion chamber is prevented, the engine can be stopped immediately.

SPEED SENSOR

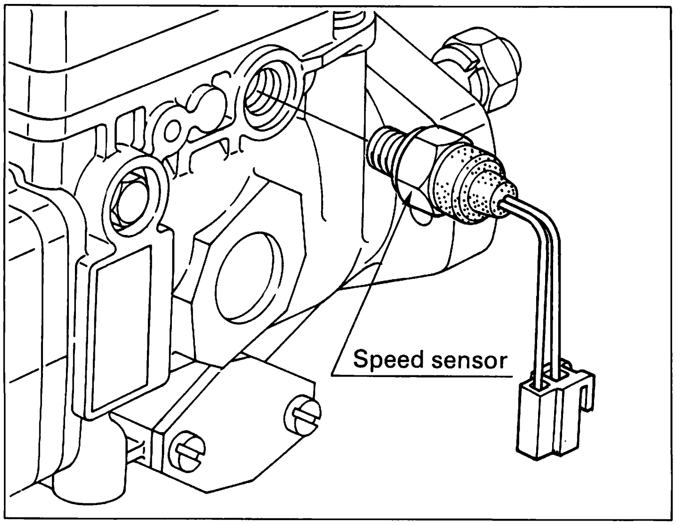

Fig. 53 Installation of speed sensor

Electrical signals (pulses) detected by the speed sensor installed on the injection pump are transmitted to the engine's tachometer in the vehicle's instrument panel.
The speed sensor is installed to utilize the rotation of the flyweight holder gear's teeth.
The speed sensor amplifier is designed to translate the movement of 23 flyweight gear holder teeth into a signal representing one revolution of the engine.
This signal is then outputted to the engine's tachometer.

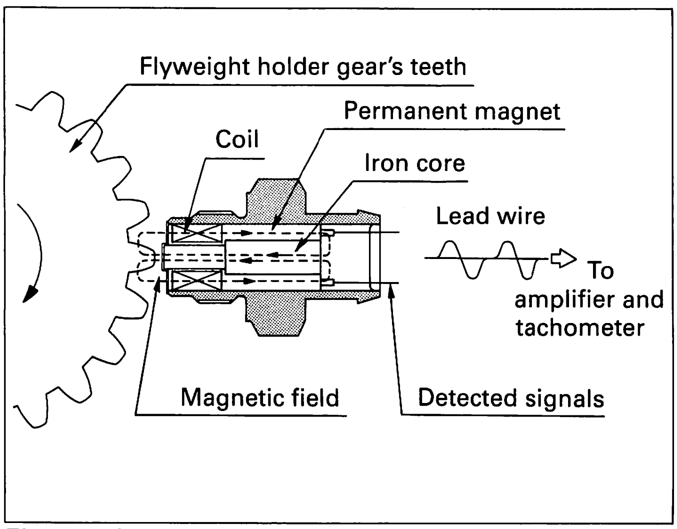

Fig. 54 Speed sensor operation

Note: In relation to ADDITIONAL DEVICES, refer to the "VE injection pump ADDITIONAL DEVICES C&O" service manual

PART NUMBER EXPLANATION

Code Number (10 figures)

1047	.	.	. . . .
(1)	(2)	(3)	(4)

(1) VE type injection pump
1046: Injection pump proper number
1047: Injection pump assembly
1048: Electronically controlled injection pump proper number (COVEC)
1049: Electronically controlled injection pump assembly (COVEC)
(2) Number of cylinders (equal to the number of engine cylinders)
(3) Plunger diameter (mm)
8:8 1:11
9:9 2:12
0:10
(4) Production serial number

Bosch Type Number

NP	–	VE	/	.	.	F	. . . .	A	R	NP . . . .
(1)		(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)

(1) Manufactured by Diesel Kiki
(2) VE type injection pump
(3) Number of cylinders (equal to the number of engine cylinders)
(4) Plunger diameter (mm)
(5) E: Electronically controlled governor
F: Mechanical governor
(6) Governor full-load maximum speed
(7) Design symbol
(8) Direction of rotation (viewed from the drive side)
R: Clockwise rotation
L: Counterclockwise rotation
(9) Production serial number

TROUBLE SHOOTING

Malfunctions	Causes	Remedies
The engine does not operate		
1. Fuel oil is not injected from the injection pump	1. There is no fuel oil in the fuel tank	Supply fuel and bleed the system
	2. The fuel line from the fuel tank is blocked	Clean or replace
	3. The fuel filter is clogged	Clean or replace
	4. There is air in the fuel filter or the pump chamber	Bleed the system
	5. The accelerator linkage is not properly connected	Repair
	6. The magnet valve wiring is broken or its armature is sticking	Repair or replace
	7. The feed pump blades are sticking, and therefore not operating	Repair or replace
	8. The drive gear or woodruff key is broken	Replace
2. Injection timing is incorrect	1. The drive gear or belt connections are incorrect	Repair
	2. The injection pump is incorrectly installed on the engine	Repair and adjust injection timing
	3. The roller holder assembly's roller or pin is worn excessively	Replace the assembly
	4. The plunger is worn excessively	Replace the distributor assembly
3. The nozzle does not operate	1. The nozzle or nozzle holder is functioning incorrectly	Inspect, then repair or replace
The engine operates, but only for a short time	1. The pipe(s) to the injection pump is blocked, or the fuel filter is clogged	Clean or replace the pipe(s) or fuel filter
	2. The fuel oil contains air or water	Bleed of air or replace the fuel oil
	3. The feed pump's delivery quantity (or pressure) is insufficient	Repair or replace
The engine "knocks"	1. The injection timing is too advanced	Readjust the timing
	2. The nozzle or nozzle holder is functioning incorrectly	Inspect, then repair or replace

Malfunctions	Causes	Remedies
The engine exhaust contains smoke and the engine "knocks"	1. The injection timing is incorrect	Readjust the timing
	2. The nozzle or nozzle holder is functioning incorrectly	Inspect, then repair or replace
	3. The injection quantity is excessive	Readjust
The engine output is unstable	1. The fuel filter element is clogged and fuel oil delivery is poor	Clean or replace
	2. The amount of fuel or pressure delivered by the feed pump is too little	Inspect and repair
	3. The injection pump is sucking air	Inspect and repair
	4. The regulating valve is stuck in the open position	Replace
	5. The plunger is sticking and does not travel its full stroke	Replace the distributor assembly
	6. The plunger spring is broken	Replace
	7. The control sleeve is not sliding smoothly	Repair or replace
	8. The governor lever is not operating properly or is worn excessively	Repair or replace
	9. The delivery valve spring is broken	Replace
	10. The delivery valve is not sliding properly	Repair or replace
	11. The nozzle or the nozzle holder is not functioning properly	Inspect, and then repair or replace
	12. The injection timing is incorrect	Readjust
Insufficient output		
1. The injection quantity is insufficient	1. The specified full-load injection quantity is not delivered	Readjust
	2. The control lever is not reaching the maximum speed position	Readjust
	3. The governor spring is weak and therefore the governed speed is too low	Replace
	4. The plunger is worn	Replace the distributor assembly
	5. The delivery valve seating portions are damaged	Replace
2. The injection timing is too advanced and the engine is "knocking"		Readjust

Malfunctions	Causes	Remedies
3. The injection timing is too retarded and the engine is overheating or the exhaust contains smoke		Readjust
4. The nozzle or the nozzle holder is not functioning properly		Inspect, and then repair or replace
The engine cannot reach its maximum speed	1. The governor spring is too weak or is improperly adjusted	Readjust or replace
	2. The control lever is not reaching the maximum-speed position	Readjust
	3. The nozzle's injection operation is poor	Repair or replace
The engine's maximum speed is too high	1. The governor spring is too strong or is improperly adjusted	Readjust or replace
	2. The governor flyweights or governor sleeve movement is not smooth	Repair or replace
Idling is unstable	1. The injection quantities are not uniform (the delivery valve is not operating properly)	Inspect or replace
	2. The governor's idling adjustment is improperly adjusted	Readjust
	3. The plunger is worn	Replace the distributor assembly
	4. The plunger spring is broken	Replace
	5. The rubber damper is worn.	Replace
	6. The governor lever shaft pin is worn excessively	Replace
	7. The feed pump blades are not operating properly	Repair or replace
	8. The regulating valve is stuck in the open position	Replace
	9. The fuel filter element is clogged and therefore fuel oil delivery is poor	Clean or replace
	10. The nozzle or the nozzle holder is not functioning properly	Inspect and then repair or replace

Malfunctions	Causes	Remedies
The engine cannot be stopped	1. The magnet valve armature is stuck in the open position	Repair or replace
	2. Foreign matter is lodged on the magnet valve armature's seating portion	Repair

Note: Main points related to troubleshooting are noted above. Items related to "Additional Devices are not included.

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