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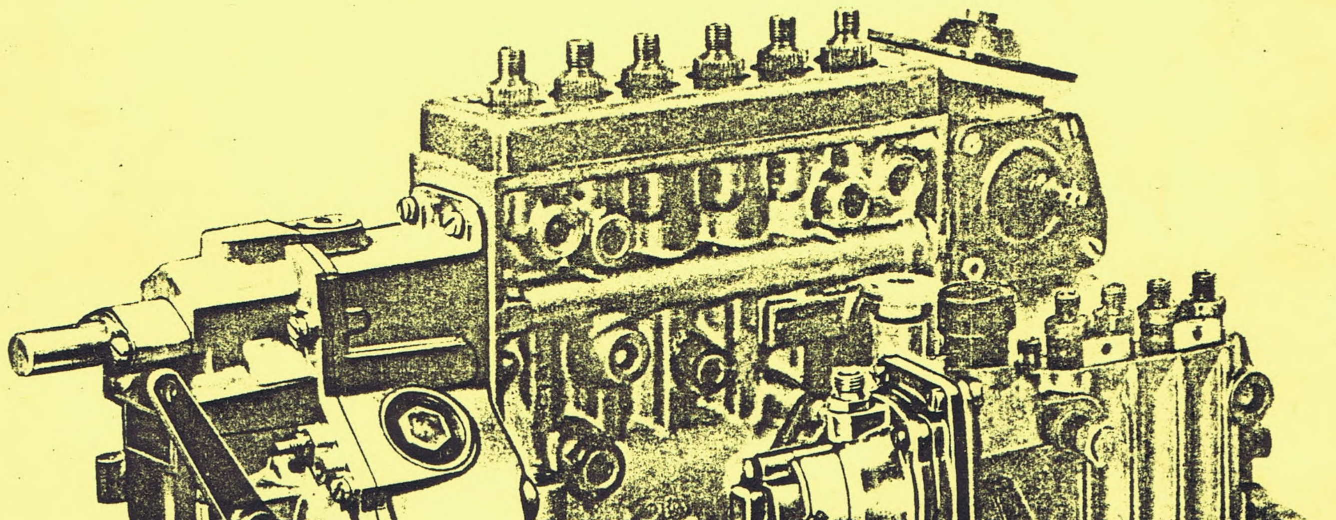
Technical Instruction



Fuel Injection Equipment for Diesel Engines
Governors for In-Line Pumps

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for Diesel Engines
Governors
for In-Line Pumps

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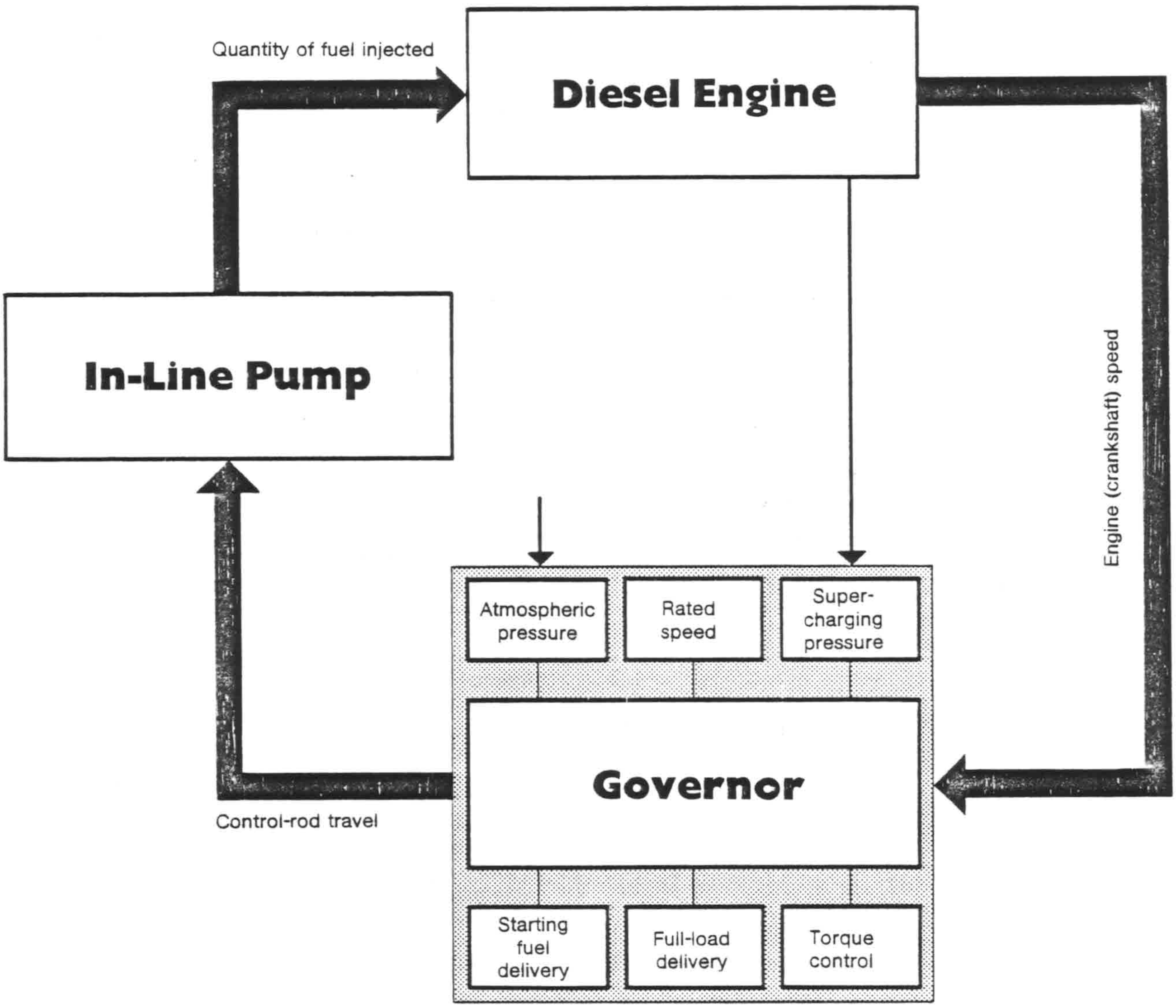


Quantity of fuel injected
Diesel Engine
In-Line Pump
Engine (crankshaft) speed
Atmospheric pressure
Rated speed
Super-charging pressure
Governor
Control-rod travel
Starting fuel delivery
Full-load delivery
Torque control

We provided information on in-line pumps for you in the booklet in this series entitled "Diesel Fuel-Injection Pumps Types PE and PF". The in-line pump, however, is only one part of the fuel injection system. Equally important is the governor. This device is responsible for ensuring that the engine maintains a certain speed under various load conditions, that the engine speed does not exceed a certain level as protection against self-destruction, and that the engine does not stop during pauses in loaded operation, i.e. during idling. The governor accomplishes all this by controlling the amount of fuel injected into the engine. How the governor performs these as well as a number of other functions is described in this booklet.

Introduction

General

The diesel engine draws only air in during the suction stroke. During the compression stroke this air is heated to such a high temperature that the diesel fuel injected into the engine toward the end of the compression stroke ignites of its own accord. The fuel is metered by the fuel injection pump and is injected under high pressure through the injection nozzle into the combustion chamber.

Fuel injection must take place:

- in an accurately metered quantity corresponding to the engine load,
- at the correct instant in time,
- for a precisely determined period of time, and
- in a manner suited to the particular combustion process concerned.

Maintenance of these conditions is the function of the fuel injection pump and the governor. The quantity of fuel injected into the engine during each plunger lift is approximately proportional to the torque of the engine. This fuel delivery is adjusted by turning of the pump plungers, each of which has an inclined helix machined into it. As a plunger is turned, its effective stroke is varied. The plungers are turned by means of the control rod acting through either a set of gear teeth or some other transmission part. (See Technical Instruction VDT-UBP 001/15 B for a detailed description of the construction and operation of the Bosch PE-type in-line injection pump.) In a motor vehicle the control rod is connected to the accelerator pedal through the governor and a linkage; when the accelerator pedal is pressed down, the pedal travel is converted to a corresponding control-rod travel (Fig. 2). Stationary engines can be operated with the governor control lever or by an electric speed-control device.

Why is a governor required with a diesel engine?

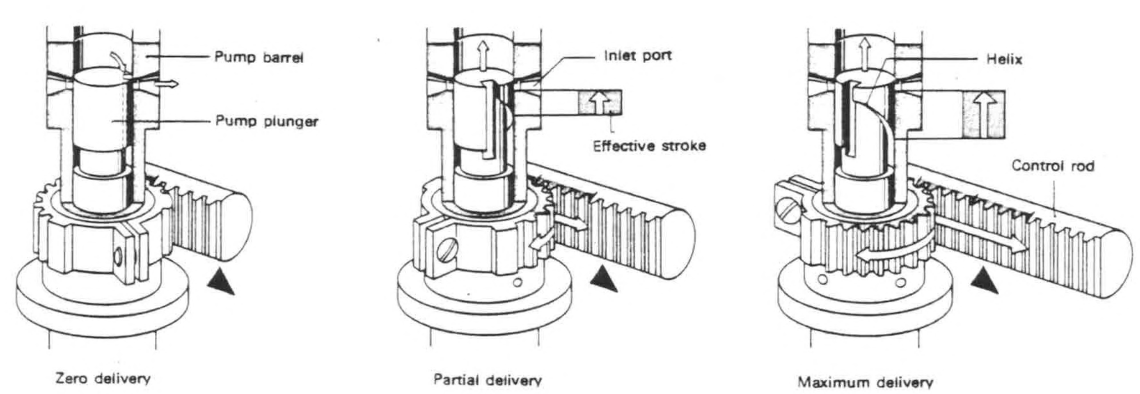
In a diesel engine there is no fixed position of the control rod at which the engine will maintain its speed accurately without a governor. During idling for example, the engine speed without a governor would either drop to zero or would increase continuously until the engine races, and runs completely out of control. The latter possibility results from the fact that the diesel engine operates with an excess of air and consequently effective throttling of the cylinder charge does not take place as the speed increases.

If a cold engine is started, for example by the starting motor, and if it is permitted to continue idling with a corresponding amount of fuel injected, the inherent friction in the engine as well as the transmission resistance of parts driven by the engine such as the generator, air compressor, fuel injection pump, etc. decrease after a certain length of time. As a result, if the position of the control rod were to remain unchanged without a governor, the engine speed would constantly increase and could rise to a level at which the engine would ultimately destroy itself.

A governor is therefore required for operation of the injection pump because of the reasons stated above.

The governor operates dependent either on the rotational speed of the engine (mechanical governor) or on the intake manifold pressure (pneumatic governor). In both cases, the governor varies the amount of fuel injected into the engine and thereby regulates the engine speed.

Fig. 1 Fuel-delivery regulation by the injection pump, accomplished through turning the pump plunger by means of a toothed control rod.



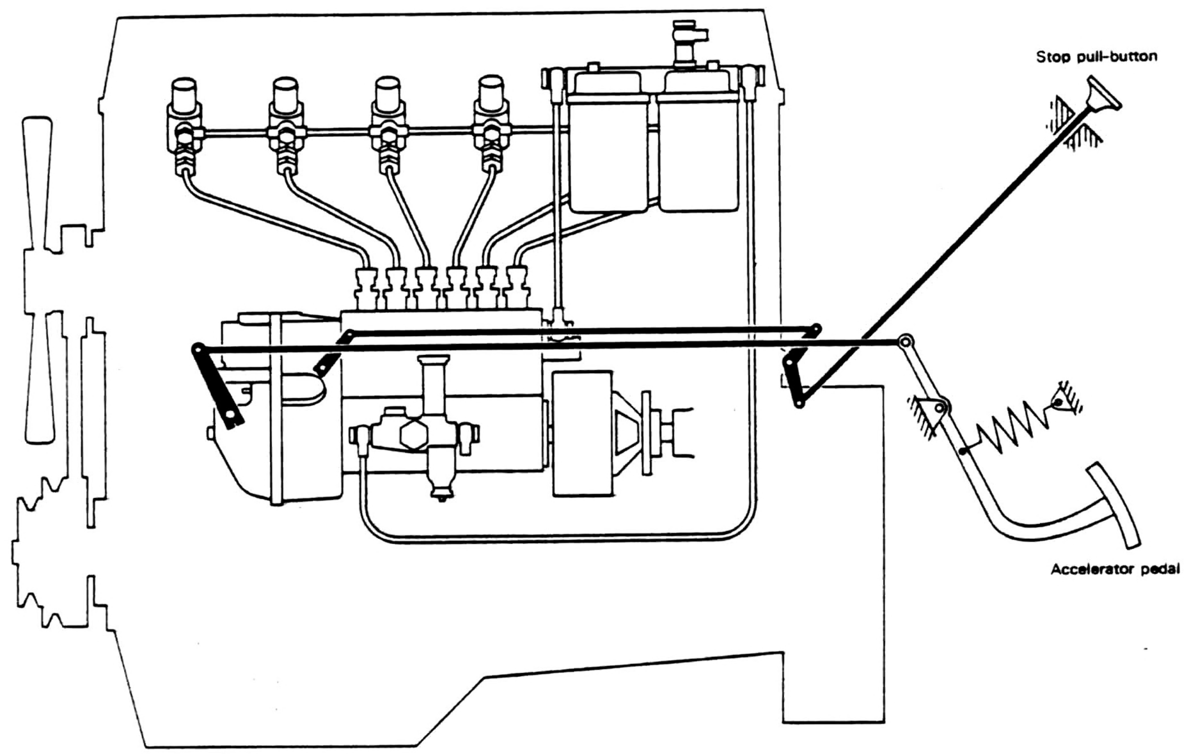


Fig. 2 Fuel injection system with PE-type injection pump.

Fig. 3 Type PE 6 P injection pump with governor.

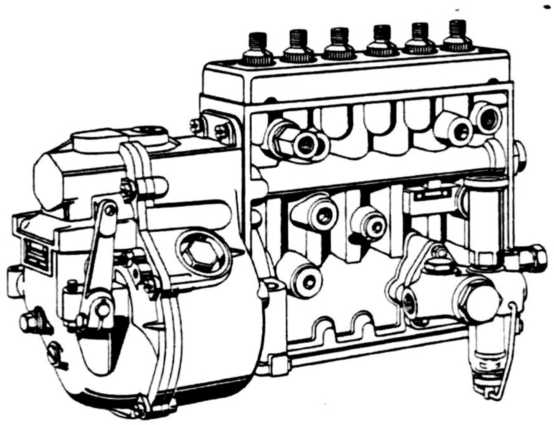
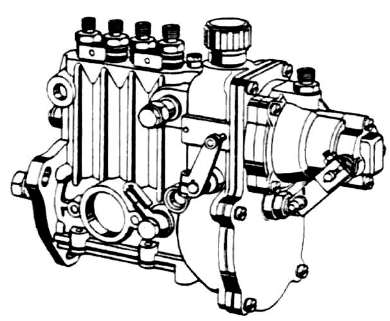


Fig. 4 Type PES 4 M injection pump with governor.



Speed Droop

Every engine has a torque characteristic curve corresponding to its maximum loading capacity. A certain maximum torque is associated with every speed. If the load on an engine is removed with no change in the position of the control lever, the engine speed may increase within the control range by only a certain permissible amount as determined by the engine manufacturer (for example from n_v = any full-load speed to n_l = any idle speed). The increase in speed is proportional to the change in load, i.e., the greater the reduction in load, the greater the increase in speed. Conversely of course, when the engine is idling and a load is applied, the speed will decrease somewhat, hence the designation of this characteristic as "speed droop".

The speed droop of the governor is generally related to the maximum full-load speed (= rated speed) and is calculated as follows:

$$\delta = \frac{n_{lo} - n_{vo}}{n_{vo}},$$

or, in %:

$$\delta = \frac{n_{lo} - n_{vo}}{n_{vo}} \cdot 100\%.$$

In the above equations,
δ = speed droop
n_{lo} = high idle speed
n_{vo} = maximum full-load speed
Example:
(pump speeds)
$n_{lo} = 1000\ \text{min}^{-1}$ (rev/min)
$n_{vo} = 920\ \text{min}^{-1}$

$$\delta = \frac{1000 - 920}{920} \cdot 100\% = 8.7\%.$$

As the speed decreases, the speed droop increases, and is at its greatest in the idle-speed range.

Generally, more stable behavior of the entire control circuit (governor, engine, and driven machine or vehicle) can be attained by a fairly large speed droop. On the other hand, the speed droop is limited by operating conditions, for example to
about 2–5% for generators,
about 6–10% for vehicles and
about 10–15% for excavators with a storage flywheel.

Fig. 8 shows the effect of the speed droop using a practical example.

With the nominal speed set to a constant value, the actual speed varies within the speed-droop range as the load on the engine is changed (resulting, for example, from a change in the slope of the road).

Because of these changes in engine speed resulting from changes in load, the speed droop was also known previously as "cyclic irregularity".

Functions of the Governor

The basic function of every governor is to limit the high idle speed, i.e., it must ensure that the speed of the diesel engine does not exceed the maximum value specified by the manufacturer. Depending on the type of governor, further functions can be the maintenance of certain specified speeds, e.g. the idle speed, or speeds within a particular rotational-speed range or the entire range between idle speed and high idle (= maximum) speed.

1. Maximum-speed regulation (Fig. 9)
When the load is removed from the engine, the maximum full-load speed, n_{vo}, may rise no higher than n_{lo} (high idle or no-load speed) in accordance with the permissible speed droop. The governor accomplishes this by drawing back the control rod in the shutoff direction.

The range $n_{vo} - n_{lo}$ is designated the maximum-speed regulation.

The greater the speed droop, the greater is the increase in speed from n_{vo} to n_{lo}.

2. Intermediate-speed regulation (Fig. 10)
If required by the intended application of the governor (for example, in vehicles with an auxiliary drive), the governor can also maintain constant, within certain limits, various speeds between the idle and maximum speeds.

Depending on the load therefore, the speed n would only fluctuate between n_v (at full load) and n_l (with no load placed on the engine) within the performance range of the engine.

The following terms are used in Figs. 5 to 10:

n_{vu} = minimum full-load speed
n_v = any full-load speed
n_{vo} = maximum full-load speed
n_{lu} = low idle speed
n_l = any idle speed
n_{lo} = high idle speed

Fig. 5 Full-load speed with the corresponding regulated idle speeds (no-load speeds).

Fig. 6 Increase in speed with 2 different speed droops. Left: small speed droop, right: large speed droop.

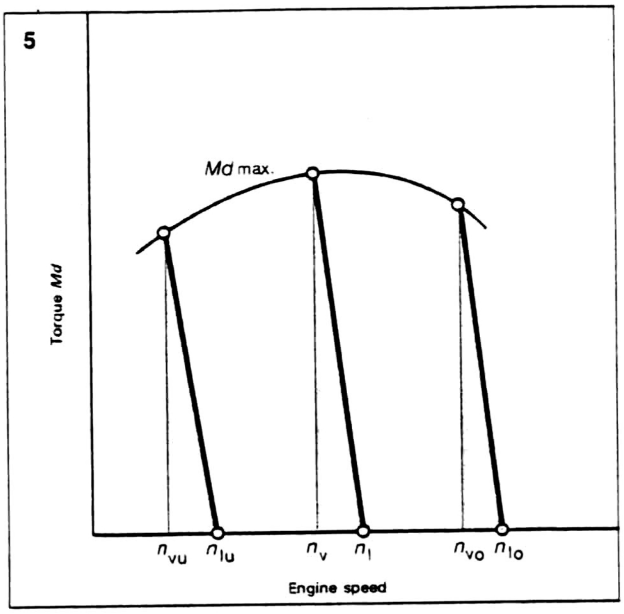
Fig. 7 Speed droop of an RQV governor at various speeds set by the control lever.

Fig. 8 Effect of the speed droop on the actual speed as the engine load is changed.

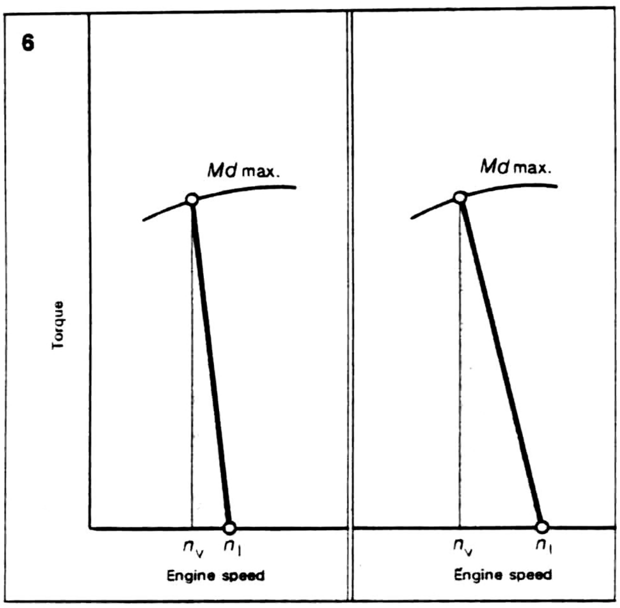
Fig. 9 Control range of a maximum-speed governor. n_{vo} = maximum full-load speed, n_{lo} = idle speed.

Fig. 10 Intermediate-speed regulation (variable-speed governor). n_{vu} = minimum full-load speed.

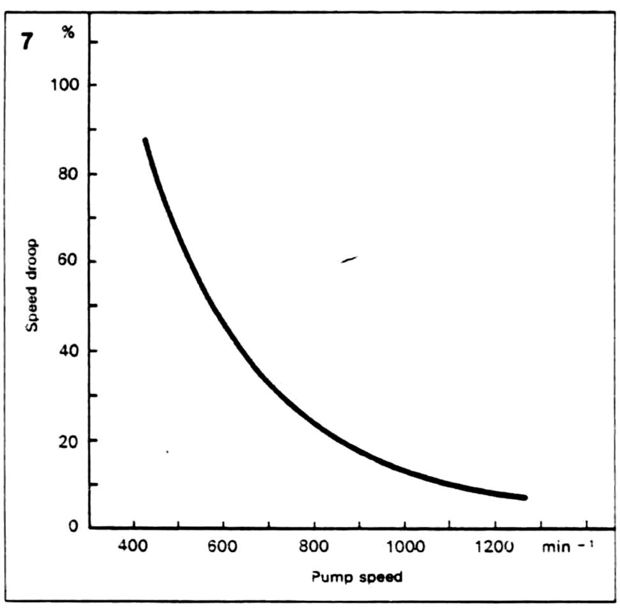
5


Md max.
Torque Md
n_{vu} n_{lu} n_v n_l n_{vo} n_{lo}
Engine speed

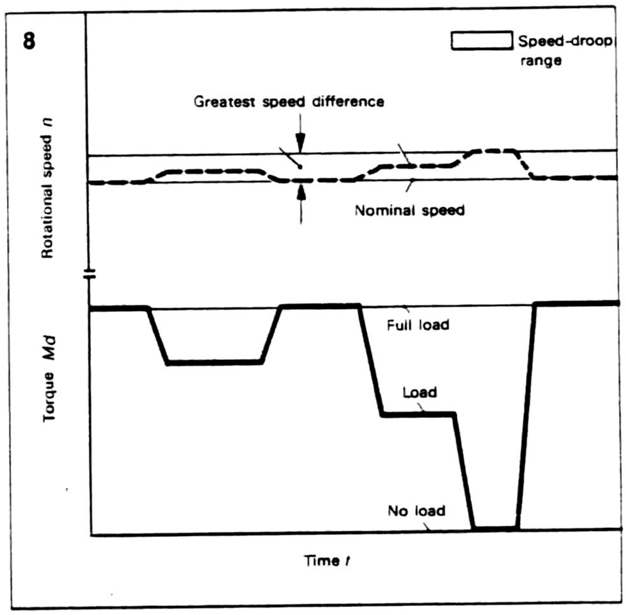
6


Md max.
Md max.
Torque
n_v n_l
Engine speed
n_v n_l
Engine speed

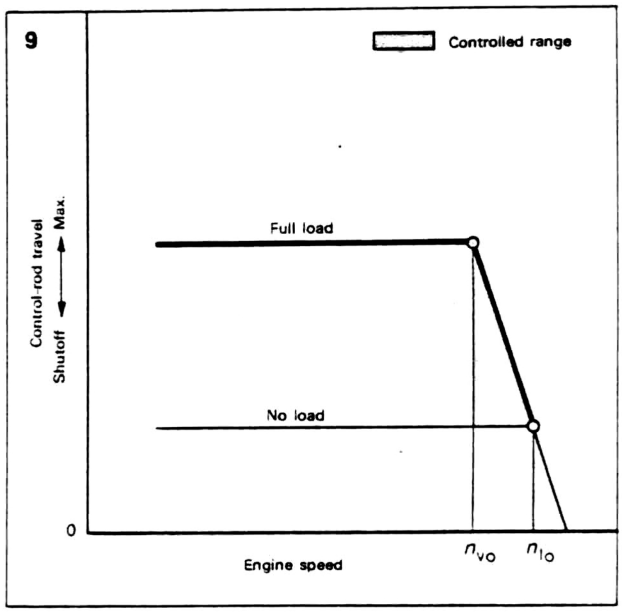
7


%
100
80
60
40
20
0
Speed droop
400
600
800
1000
1200
min ⁻¹
Pump speed

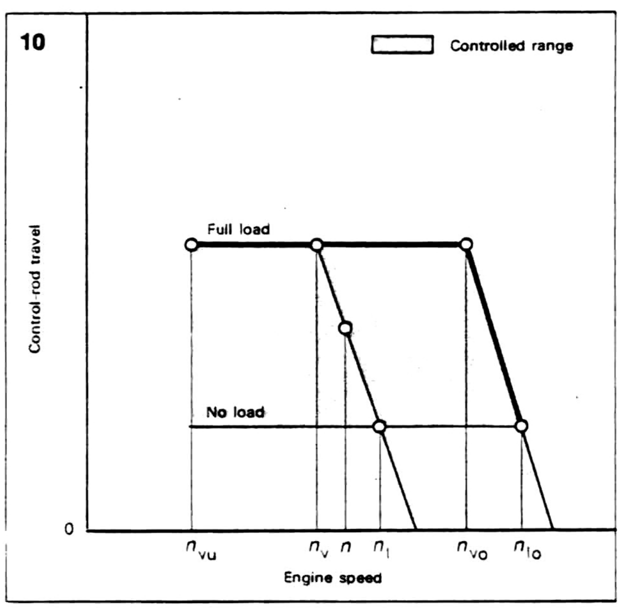
8


Speed-droop range
Greatest speed difference
Rotational speed n
Nominal speed
Torque Md
Full load
Load
No load
Time t

9


Controlled range
Control-rod travel
Shutoff ← → Max.
Full load
No load
0
Engine speed
n_{vo} n_{lo}

10


Controlled range
Control-rod travel
Full load
No load
0
n_{vu} n_v n n_l n_{vo} n_{lo}
Engine speed

3. Low-idle-speed control (Fig. 11)
The speed of a diesel engine can also be regulated in the lowest speed range. If the control rod returns from the starting position to position B after a cold diesel engine is started, the frictional resistance of the engine is still relatively high. The amount of fuel required to keep the engine in operation is therefore somewhat larger, and the speed is somewhat lower, than would normally correspond to the idle-speed adjustment point, L.

After the friction during the warm-up period has diminished, the speed increases and the control rod moves back to point L, where the idle speed for the warm engine is reached.

The various demands made on governors have led to the development of the following different types:

- Maximum-speed governors

These governors are designed to limit the maximum speed only.

- Minimum–maximum–speed governors

These governors control the idle speed as well as the maximum speed.

- Variable-speed governors

These governors control the idle and maximum speeds as well as the speed range between them.

- Combination governors

These governors are a combination of the minimum–maximum–speed governor and the variable-speed governor.

In addition to its basic function, the governor must also fulfil control functions, such as automatically providing or cutting off the starting fuel delivery (the increased fuel quantity which is required for starting), and varying the full-load delivery as a function of speed (torque control), charge-air pressure, or atmospheric pressure.

In order to carry out these functions, supplementary equipment is required in some cases which will be described in detail in later sections of this booklet.

Torque Control

Optimum exploitation of the engine torque can be achieved by means of torque control. Torque control is not an actual control process, but is one of the regulation functions carried out by the governor. It is designed for the full-load delivery, i.e., the maximum amount of fuel delivered in the loadable range of the engine which can burn smoke-free.

The fuel requirement of the non-pressure-charged diesel engine (see Glossary of Technical Terms) generally decreases as the speed increases (lower relative rate of air flow, thermal limiting conditions, changed mixture formation), while the amount of fuel delivered by the Bosch injection pump increases within a certain range as the speed rises, as long as the control rod remains in the same position, because of the throttling effect at the control port in the pump plunger-and-barrel assembly. If too much fuel is injected into the engine, smoke will be developed as the engine overheats.

The amount of fuel injected into the engine must therefore be matched to the actual fuel requirement (Fig. 12).

In governors with torque control, the control rod is shifted within the torque-control range in the shutoff direction by the amount of the fixed torque-control travel (Fig. 13). Thus as the speed increases (from n_1 to n_2), the fuel

Fig. 11 Control in the idle range.

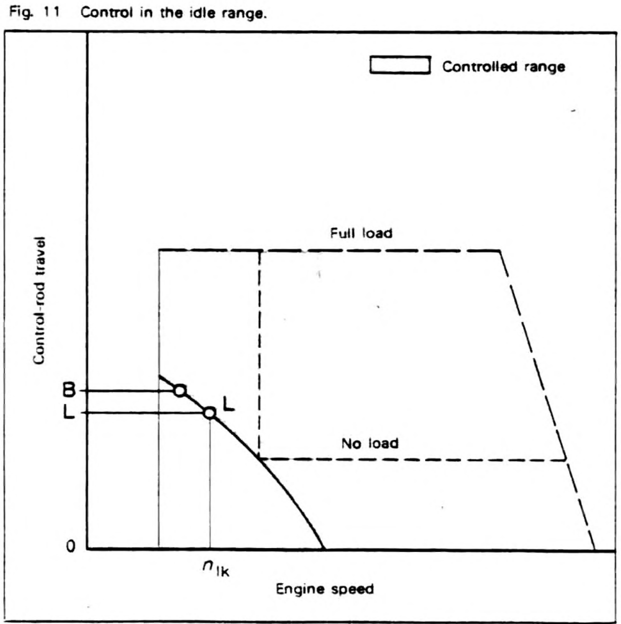
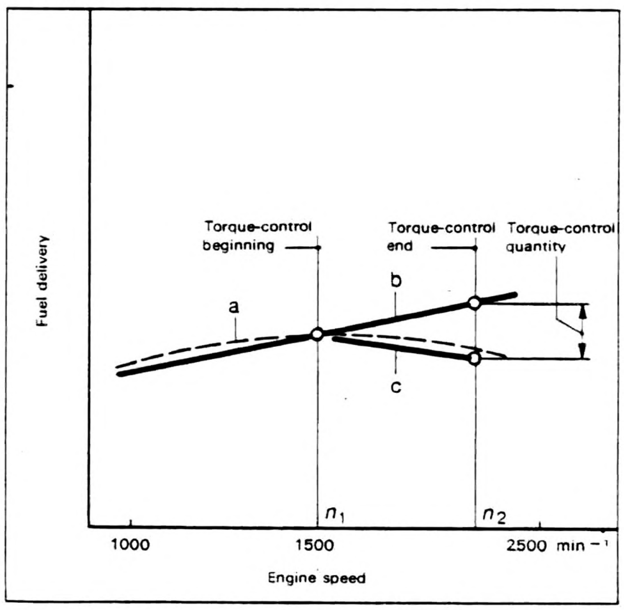


Fig. 12 Fuel requirement and fuel-delivery characteristic with torque control.
a = fuel requirement of engine, b = full-load delivery without torque control, c = full-load delivery with torque control.



delivery decreases (positive torque control or torque control "in the direction of control"); as the speed drops (from n_2 to n_1), the fuel delivery increases.

Torque-control systems are arranged and designed according to the particular type of governor. Details are given with the description of each type of governor below.

Fig. 14 shows the differences in the torque developed by a diesel engine with and without torque control; the maximum torque is developed in the entire speed range and the smoke limit is not exceeded thereby.

In engines with an exhaust turbo-supercharger achieving a high measure of supercharging, the fuel requirement for full load in the lower speed range rises so sharply that the natural increase in fuel delivered by the fuel injection pump is no longer adequate. In such cases, torque control must be carried out as a function of speed or charge-air pressure; depending on the prevailing conditions, this can be accomplished either with the governor, or with the manifold-pressure compensator (LDA), or with both operating together.

This form of torque control is called negative. Negative torque control means an increase in the fuel delivery as the speed rises (Fig. 15).

This type of torque control is clearly the opposite of the common positive torque control in which the quantity of fuel injected is reduced as the speed increases.

Fig. 13 Control-rod travel characteristic in the fuel injection pump, with positive torque control (in the "direction of control").

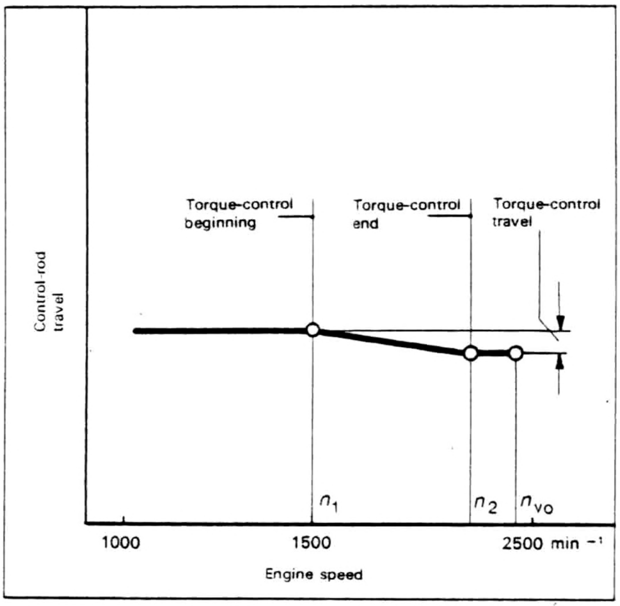


Fig. 14 Torque characteristic of a diesel engine, with and without torque control.

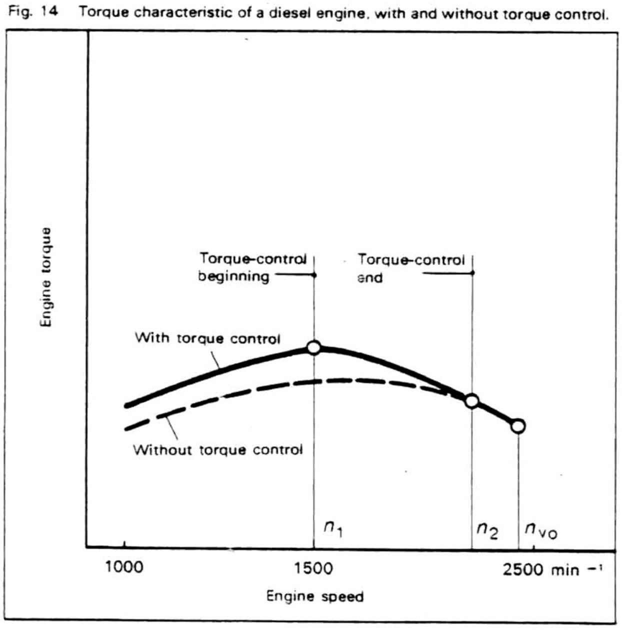
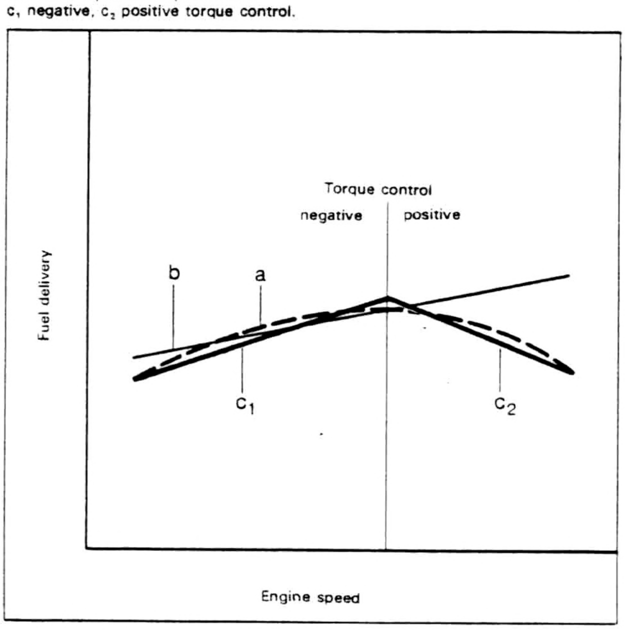


Fig. 15 Fuel-delivery characteristic.
a = fuel requirement of engine, b = full-load delivery without torque control, c = full-load delivery with torque control.
c_1 negative, c_2 positive torque control.



Types of Governor

Designation	Type of governor	Operating principle	For pump size	Used for
RQ	Minimum-maximum-speed or maximum-speed only	Centrifugal	A, P	Road vehicles, locomotives, assemblies of equipment
RQU*			ZW	
EP/RS	Minimum-maximum-speed	Centrifugal	A, P	Road vehicles
RQV	Variable-speed and combination	Centrifugal	A, P	Vehicles with auxiliary drive, trucks
RQUV*			ZW	Machine systems
RQV-K	Variable-speed with any type of torque control	Centrifugal	A, P	Road vehicles
EP/RSV	Variable-speed	Centrifugal	A, M, P	Tractor vehicles, machine systems, motor vehicles
EP/RSUV*			P, ZW	Machine systems
EP/M	Variable-speed	Pneumatic	A, M	Automobiles, tractor vehicles

* with step-up gear for slow-speed engines

Maximum-Speed Governors

Maximum-speed governors are designed for diesel engines which drive machines or machine systems, for example engine-generator sets, at a fixed rated speed. Here the governor must ensure only that the maximum speed is maintained; there is no idle control or control of a particular starting fuel delivery. If the engine speed rises above the rated speed, n_{vo}, as a result of a decreasing load on the engine, the governor shifts the control rod in the shutoff direction, i.e., the control-rod travel becomes smaller, and the fuel delivery decreases. The increase in speed and the decrease in control-rod travel follow the connection line A–B in Fig. 16. The high idle speed, n_{lo}, is reached when the entire load is removed from the engine. The steepness of the path A—B is determined by the speed droop of the governor.

For engine-generator sets a governor design is used in which the maximum speed can be adjusted within narrow limits. These limits have been defined in Guideline VDMA 6280 issued by the Verband Deutscher Maschinenbau-Anstalten (Association of German Mechanical Engineering Institutes) (speed-adjustment range shown in Fig. 17).

Fig 16 Governor characteristic curves, maximum-speed governor.

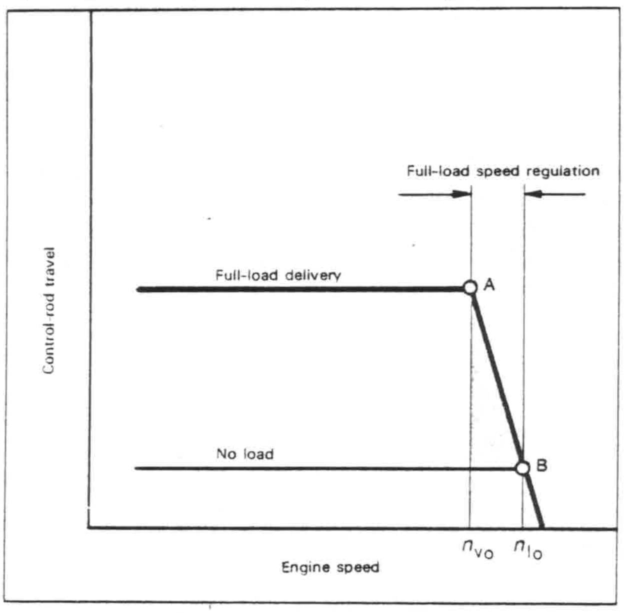
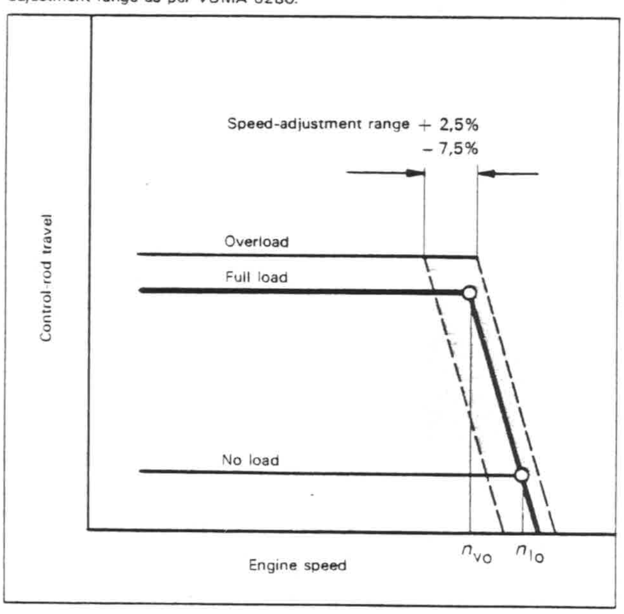


Fig. 17 Governor characteristic curves, maximum-speed governor with speed-adjustment range as per VDMA 6280.



Minimum-Maximum-Speed Governors

With diesel engines used in trucks, speed control in the range between idle and the maximum speed is often not required. In this rotational-speed range the driver operates the control rod in the fuel injection pump directly by means of the accelerator pedal, and thus sets the required torque. The governor ensures that the engine does not stall in the idle-speed range, and it also controls the maximum speed.

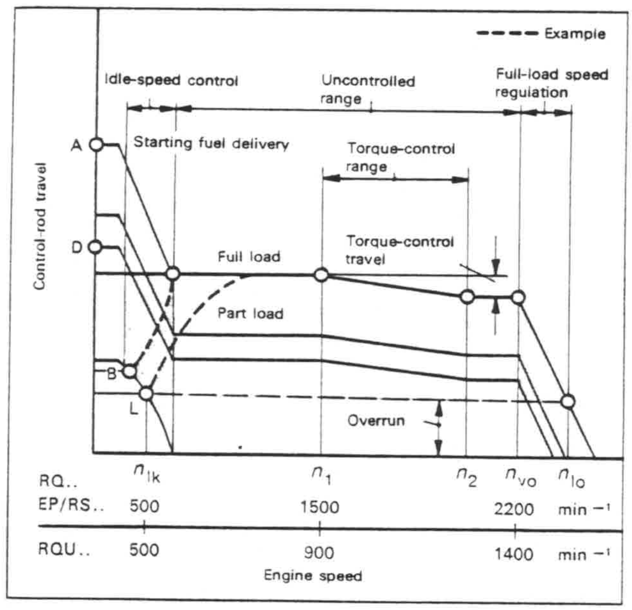
The governor characteristic curves (Fig. 18) show the following: The cold engine is started with the starting fuel delivery (A). Here, the driver has pressed the accelerator pedal all the way down. If he now releases the accelerator pedal, the control rod returns to the idle position (B). During the warm-up period the idle speed fluctuates along the idle-speed control curve and evens out to L.

When the engine has warmed up, the greatest starting fuel delivery is generally not required for a restart; many engines can even be started when the governor control lever is in the idle position.

If the driver presses the accelerator pedal all the way down with the engine operating, the control rod moves to the full-load delivery position. As a result, the engine speed increases, and torque control of the fuel delivery starts at n_1, i.e., the full-load delivery is slightly reduced. If the engine speed increases further, torque control is completed at n_2.

The full-load delivery is injected into the engine with the accelerator pedal pressed all the way down until the maximum full-load speed, n_{vo}, is reached. Full-load speed regulation corresponding to the speed droop of the governor starts at n_{vo}, whereby the engine speed rises somewhat, the control-rod travel is reduced, and as a result the fuel delivery is decreased. The high idle speed, n_{lo}, is reached when the entire load is removed from the engine. During overrun (e.g. vehicle travelling downhill), the control-rod travel can become zero and the engine speed can increase somewhat further.

Fig. 18 Governor characteristic curves, minimum-maximum-speed governor with torque control.



Variable-Speed Governors

Vehicles with auxiliary drives (for example, for cistern pumps, or for extending fire-fighting ladders) and agricultural tractors, which must maintain a certain operating speed, as well as boats and stationary assemblies of equipment, are equipped with variable-speed governors.

These governors control not only the idle and maximum speeds but also speeds between them independent of the engine load. The desired speed is set with the control lever. The governor characteristic curves (Fig. 20) show the following: starting of the engine with the starting fuel delivery, variation of the full-load regulation along the full-load characteristic curve, and the torque-control range extending until the onset of speed regulation at the maximum full-load speed, along the line from n_{vo} to n_{lo}.

The other curves show the breakaway characteristic at intermediate speeds. An increase in the speed droop as the speed decreases can be noted here. The dashed curves apply for vehicles with auxiliary drives operating in the lower speed range. As the load is increased, the speed decreases less than with a normal governor (unbroken curves). This characteristic is achieved by a higher lever ratio.

Combination Governors

If the normal speed droop in the upper or lower adjustment range of variable-speed governors RQV or RQUV is too great for the particular intended use, but control in the intermediate range is nevertheless not necessary, then the measuring mechanism is designed for stepped regulation, whereby torque control is not possible in the uncontrolled range of the maximum-speed-governor section.

The governor characteristic curves show that the graph on the left below (Fig. 19) represents the first type of governor mentioned: the uncontrolled range is located in the lower speed range while the controlled range is located in the upper speed range.

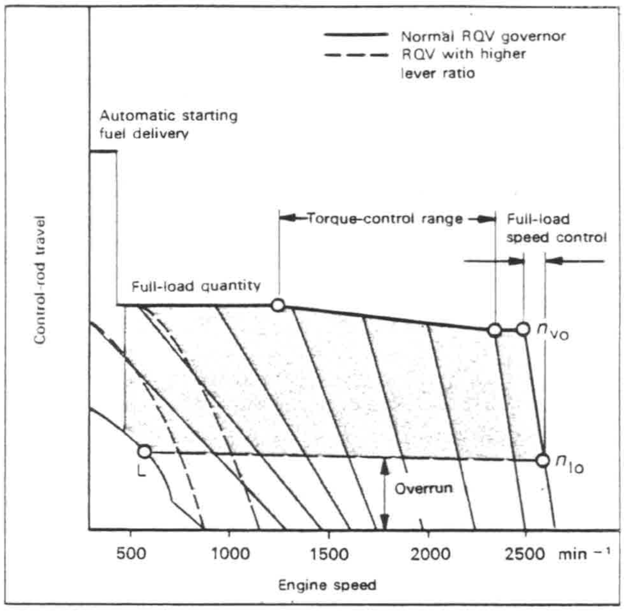


Fig. 20 Governor characteristic curves, variable-speed governor (RQV).

It can be seen from the governor characteristic curves in the graph on the right below that these curves represent a governor which operates as a variable-speed governor in the lower speed range, this being followed by an uncontrolled range until full-load speed regulation takes effect.

In both graphs below, the horizontal parts of the "curves" represent the control-rod travel characteristic for various part-load positions of the control lever. The curves running downward from the full-load line correspond to speed regulation starting from intermediate speeds set accordingly.

Fig. 19 Governor characteristic curves, combination governor, lower speed range uncontrolled.

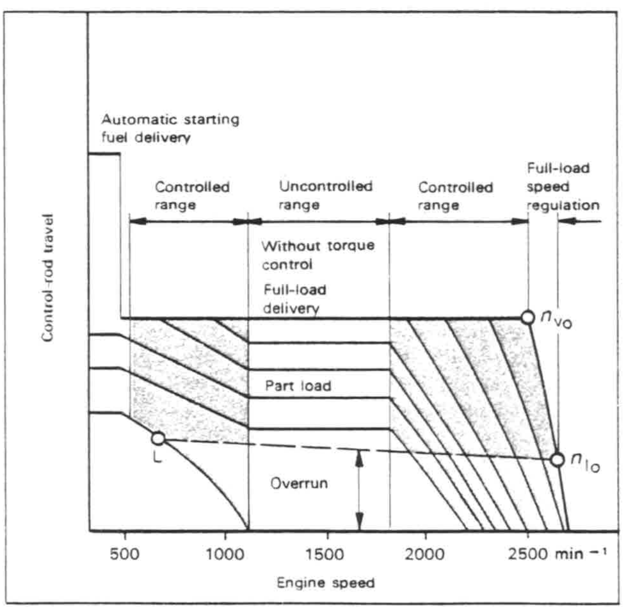
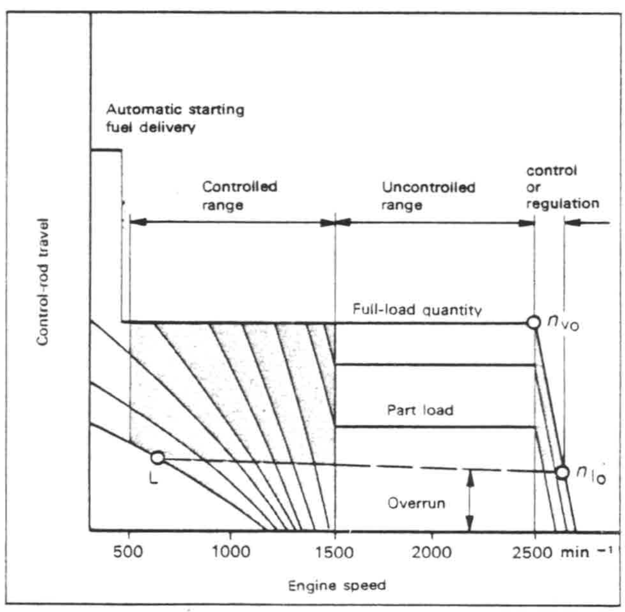


Fig. 21 Governor characteristic curves, combination governor, upper speed range not controlled.



Mechanical Governors

Mechanical governors, i.e., governors employing the principle of centrifugal force, are used most widely with larger diesel engines.

The Bosch mechanical governor is mounted on the fuel injection pump. The injection-pump control rod is connected with the governor linkage through a flexible joint, and the connection to the accelerator pedal is made through the governor control lever.

Metering Units

Two different designs of metering unit are used in mechanical governors:

- RQ, RQV:

the governor springs are built into the flyweights.

- RSV, RS:

the centrifugal force acts through a system of levers on the governor spring located outside the two flyweights.

In mechanical governor types RQ and RQV (Fig. 22), each of the two flyweights acts directly on a spring set which is designed specifically for a given nominal speed.

In mechanical governors of type RS/RSV (Fig. 23), the action of the two flyweights presses the sliding bolt against the tensioning lever, which is drawn in the opposite direction by the governor spring. When the speed is set by the control lever, the governor spring is tensioned by an amount corresponding to the desired speed.

In both types of metering unit the governor springs are so selected that at the desired speed the centrifugal force and the spring force are in equilibrium. If this speed is exceeded, the increasing centrifugal force of the flyweights acts through a system of levers to move the control rod, and the fuel delivery is decreased.

Fig. 22 Metering unit, RQ and RQV governors.

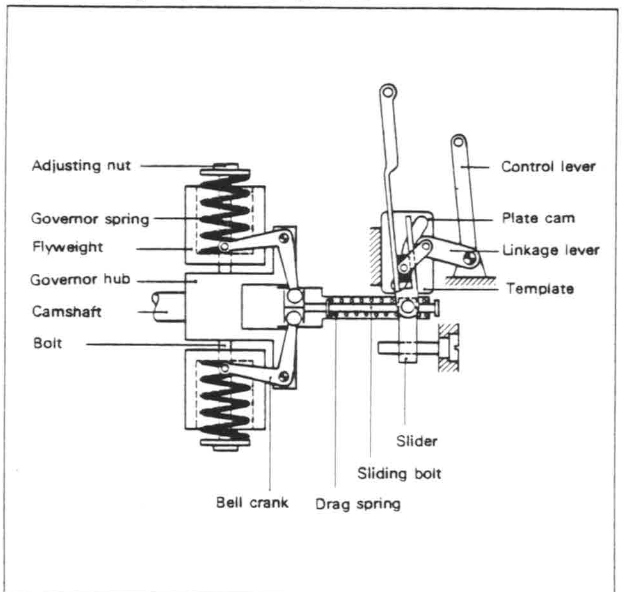
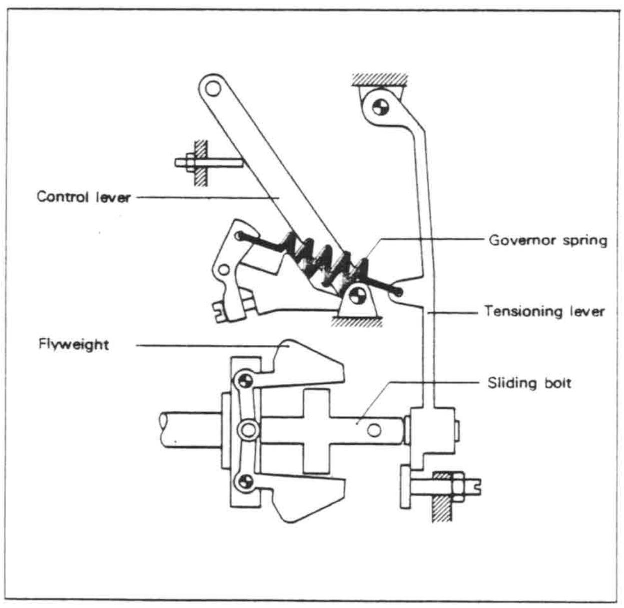


Fig. 23 Metering unit, RS and RSV governors.



Minimum-Maximum-Speed Governor RQ

Construction

The schematic drawing below shows the most important components in this governor and the functional relationships between them: the fuel-injection-pump camshaft drives the governor hub through a vibration damper. The two flyweights with their bell cranks are supported in the governor hub, with one spring set built into each flyweight. By means of the bell cranks, the radial travel of the flyweights is converted to axial movements of the sliding bolt, which in turn transmits these movements to the slider. Movement of the slider is held in a straight line by the guide pin; the slider itself, operating through the fulcrum lever, forms the connection between the flyweight metering mechanism and the control rod. The lower end of the fulcrum lever is fastened to the slider.

In the fulcrum lever there is a coulisse. The movable guide block is guided radially by the linkage lever; this lever is connected with the control lever on the same axle. The control lever is operated either manually or through a linkage system from the accelerator pedal.

When the control lever is moved, the guide block is shifted, and the control lever is tilted around the pivot at the slider; if the governor takes effect, the pivot for the fulcrum lever is at the guide block (see operating characteristics). Because of the template, the transmission ratio of the fulcrum lever changes. As a result, even in the idle range where the centrifugal forces are still low, there is more than sufficient adjustment force for the control rod.

The spring sets (governor springs) built into the flyweights consist generally of three cylindrical helical springs arranged concentrically. The outer spring is supported between the flyweight and the outer spring seat, while the two inner springs are positioned between the outer and inner spring seats. During low-idle-speed control only the outer spring (the idle-speed spring) takes effect; as the speed increases, the flyweights, after surpassing the idle-speed travel path at the inner spring seat, are pressed against the inner spring seat and remain in this position until maximum-speed regulation begins. During control of the maximum speed all springs act together. The two inner springs are designated maximum-speed control springs.

Fig. 24 Schematic drawing of the minimum-maximum-speed governor type RQ: rest position (shutoff).

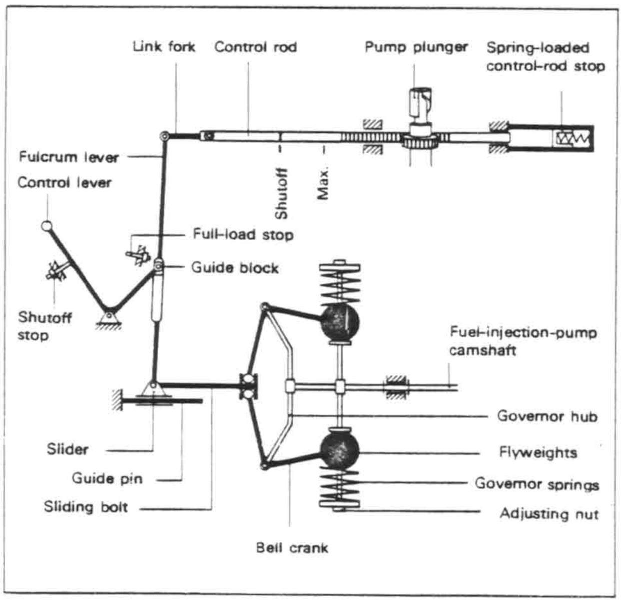
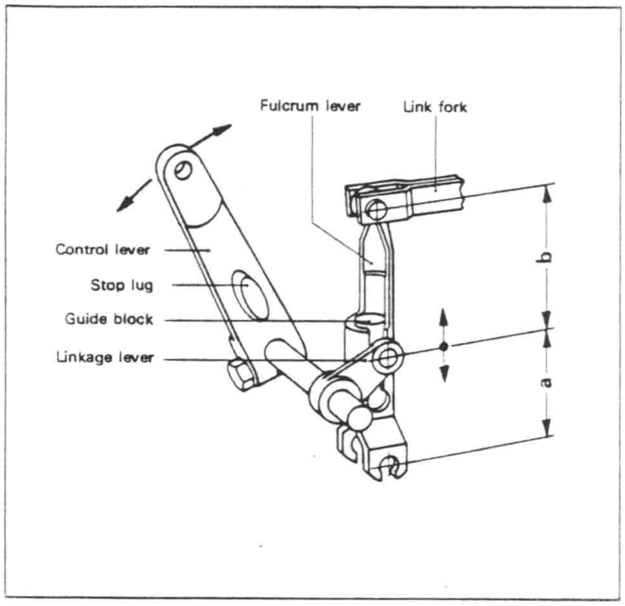


Fig. 25 Change in transmission ratio a/b at fulcrum lever in RQ governor.



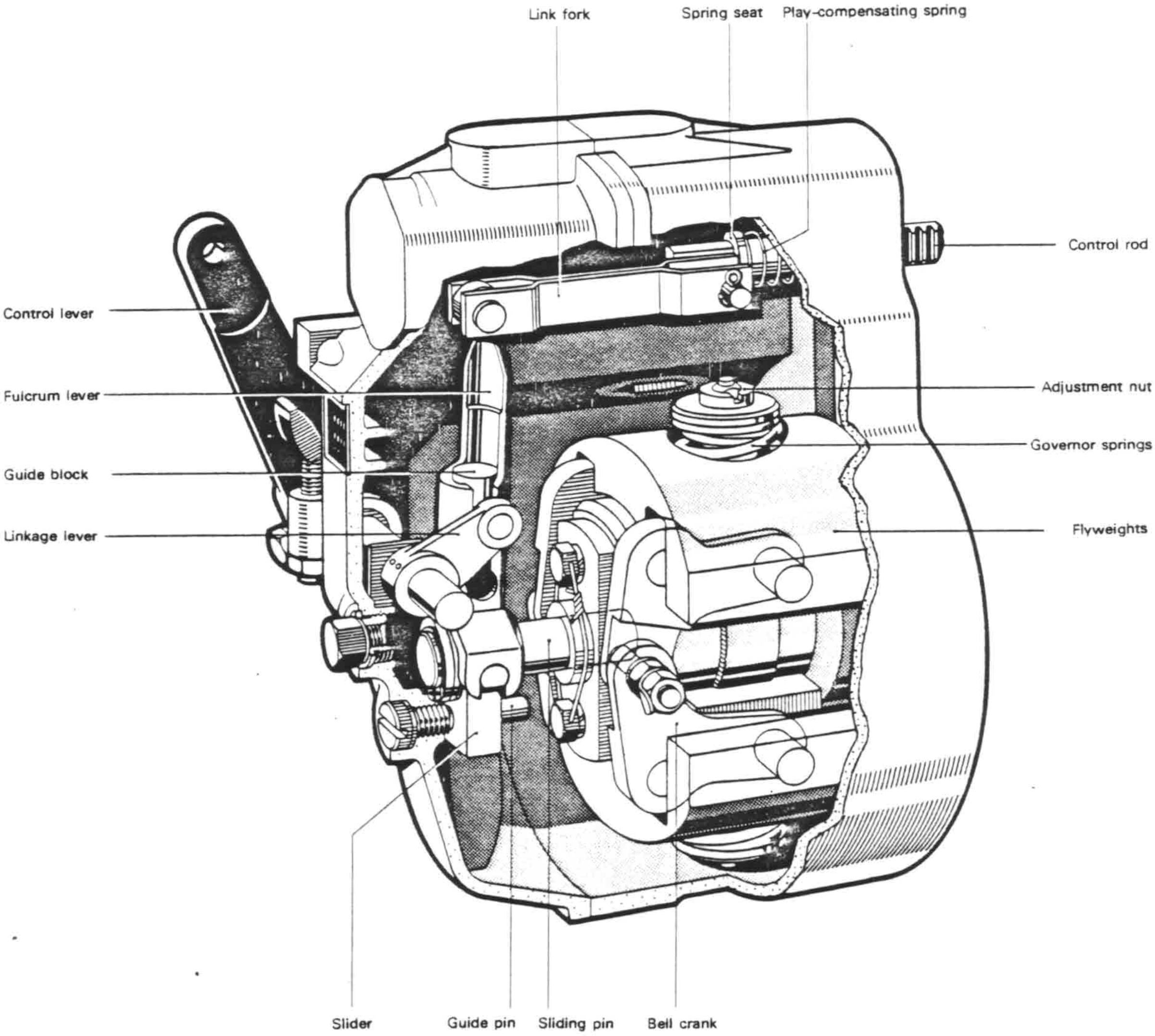
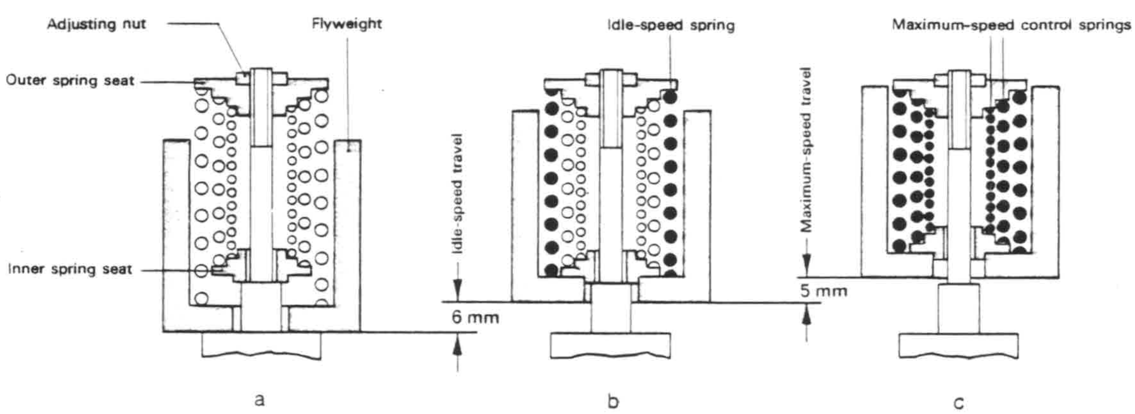


Fig. 26 (above) RQ governor.

Fig. 27 (below) Flyweight travel and governor spring set in the RQ governor.



Operating Characteristics

Engine stopped

The control lever is positioned against the shutoff stop, the control rod is in the shutoff position, and the flyweights are positioned all the way in.

Start position (control lever at full load)

After the control rod overcomes the force of the return spring in the spring-loaded control-rod stop, it moves all the way to the starting-fuel-delivery position.

Idle position

After the engine starts to operate and the control lever (accelerator pedal) is released, this lever returns to the idle position (a corresponding stop should be provided in the vehicle or on the engine). The control rod also returns to the idle position, which is determined by the now operating governor. The term "idle speed" of an engine is understood here to mean the lowest speed at which the engine will continue to operate reliably under no load; in this condition the engine is loaded only by its own internal friction and by the other equipment permanently connected to it such as the generator, fuel injection pump, fan, etc. In order to be able to overcome this idle load, the engine requires a certain amount of fuel, and receives this fuel at a position of the control lever corresponding to the specified idle position.

Fig. 28 Governor characteristic curves, minimum-maximum-speed governor RQ.
n_{lk} = idle speed, n_{vo} = maximum full-load speed,
n_1 = beginning of torque control, n_2 = end of torque control, n_{lo} = high idle speed.

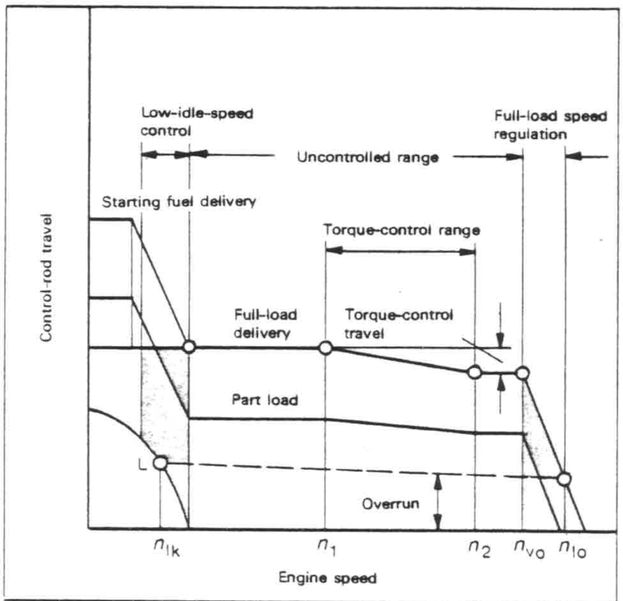


Fig. 29 RQ governor, start position.

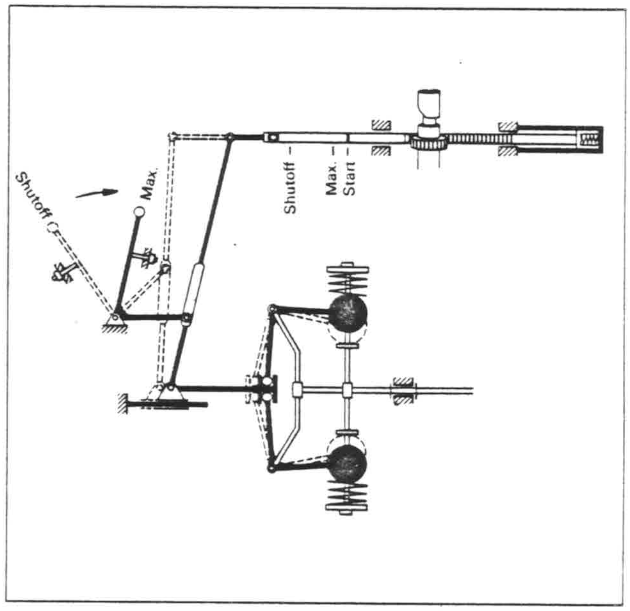
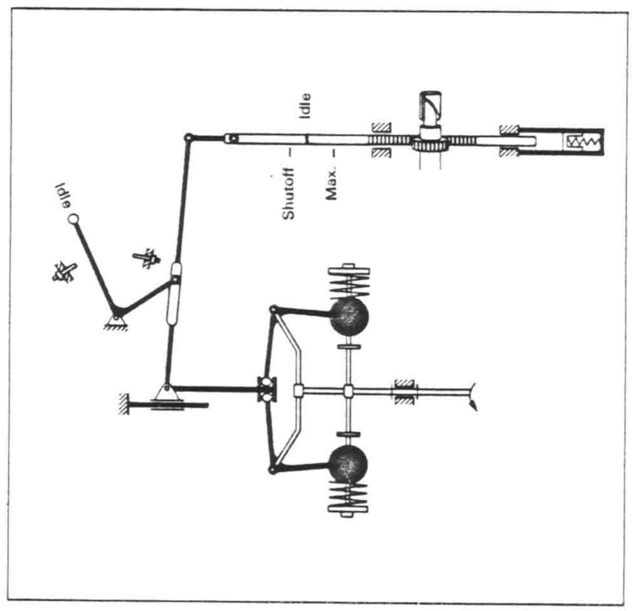


Fig. 30 RQ governor, idle position.



Part-load position
When the engine is loaded (between no-load and full-load). As the driver presses the accelerator pedal down somewhat, the engine speeds up. As a result, the fly-weights are forced outward. In other words, the governor initially tends to prevent this increase in engine speed. However, after the speed exceeds the idle speed by only a slight amount, the flyweights are brought up against the spring seats, which are loaded by the maximum-speed control springs, and they remain in this position until the maximum speed is reached; this is because the maximum-speed control springs yield to the centrifugal force only when the engine tends to exceed its nominal speed. For this reason, the governor has no effect between the idle speed and the maximum speed. In this intermediate range the position of the control rod, and thus the torque developed by the engine, is influenced only by the driver.

The torque-control phase which is traversed during this process will be described later.

Fig. 31 RQ governor, part load.
The position of the flyweights remains unchanged until the maximum speed is reached.

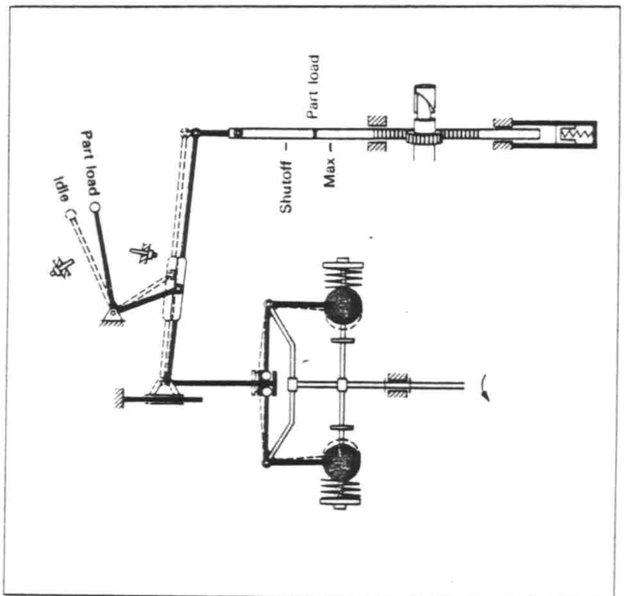
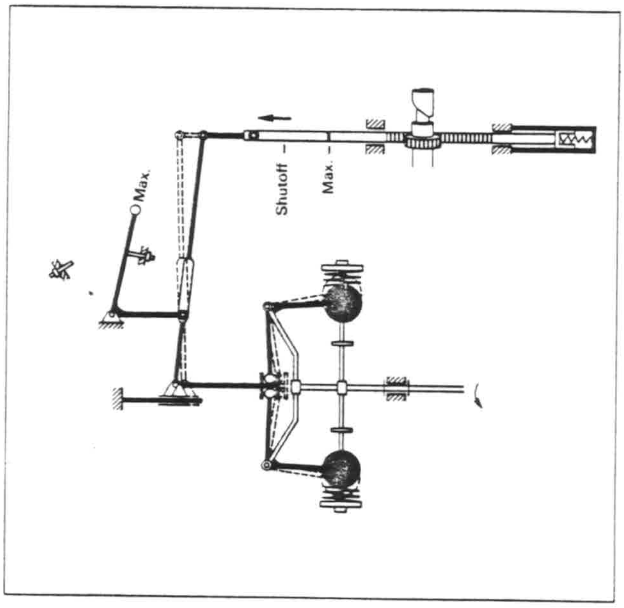


Fig. 32 RQ governor, maximum-speed regulation at full load. Control rod begins to move in the shutoff position.

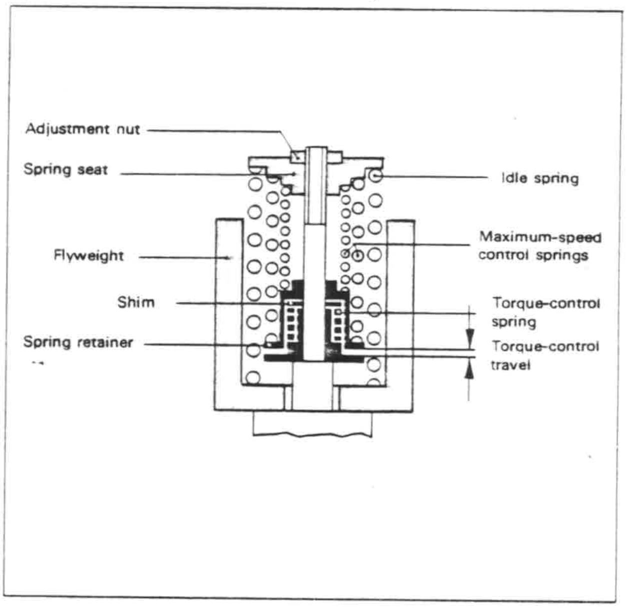


In the highest speed range of the engine (maximum-speed regulation)
Maximum-speed regulation begins when the engine exceeds the nominal speed, n_{vo}. This can occur, therefore, at full-load or part-load depending on the position of the control lever. For this reason, as soon as maximum-speed regulation has started, the position of the control rod no longer depends solely on the driver but also on the governor. The maximum-speed regulation travel of the fly-weights is 5 mm. This results in a control-rod travel of about 16 mm (with a lever ratio of 1:3.23) which is sufficient to regulate fuel delivery from maximum delivery to shutoff.

Torque-control mechanism in the RQ governor
In the RQ governor the torque-control mechanism is built into the flyweights, between the inner spring seat and the maximum-speed control springs. The torque-control spring is installed in a spring retainer on the outside of which the two maximum-speed control springs are supported. For operating purposes, therefore, the torque-control spring is connected in series with the maximum-speed control springs. The space between the inner spring seat and the spring retainer is the torque-control travel (0.3–1 mm). The width of this space can be adjusted with compensating shims.

The start of torque control, n_1, depends on the fuel-requirement characteristic curve of the engine. At a point somewhat below the maximum speed, the torque-control spring is compressed to the extent that the inner spring seat and the spring retainer are pressed against each other (n_2). Without the torque-control spring, the governor has no effect between the idle speed and the maximum speed. However, since the torque-control springs yield, the fly-weights can now move outward by the distance of the torque-control travel in the range between the idle and maximum speeds also, and therefore shift the control rod accordingly in the shutoff direction (positive torque control).

Fig. 33 Torque-control mechanism in the RQ governor.



Minimum-Maximum-Speed Governor RQU

The RQU governor is suitable for controlling very low speeds. It is fitted with a transmission gear effecting a speed-increasing ratio (of about 3:1) between the fuel-injection-pump camshaft and the governor hub. Governor type RQU was developed for PE. .Z fuel injection pumps which are used for larger, usually slow-speed engines. The operation and operating characteristics of this governor are similar to those of the RQ governor.

The linkage lever in the RQU governor is constructed of two parts, as in the RQV governor, and is guided by a plate cam, also as in the RQV governor.

Maximum-Speed Governors RQ and RQU

Construction of the maximum-speed governor differs from the construction of the minimum-maximum-speed governor primarily in that the idle-speed stage is not incorporated. In operation, the maximum-speed governor functions in a similar manner to the maximum-speed stage of the RQ or RQU minimum-maximum-speed governor, i.e. maximum-speed regulation starts if the engine exceeds the maximum rated speed.

The characteristic curves shown apply for a governor which is designed to permit an adjustment to overload, i.e., a governor which permits an increase in the full-load fuel delivery.

Fig. 34 Schematic drawing of the minimum-maximum-speed governor type RQU, rest position (shutoff).

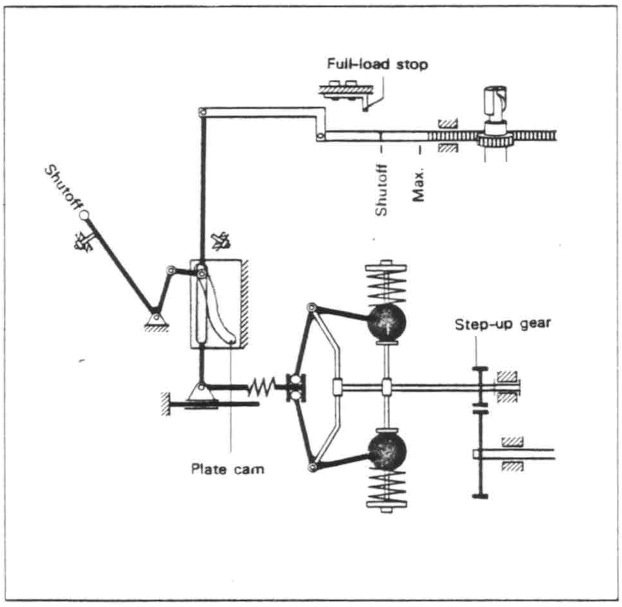


Fig. 35 Governor characteristic curves for maximum-speed governor RQ 750.. for use with assemblies of equipment.

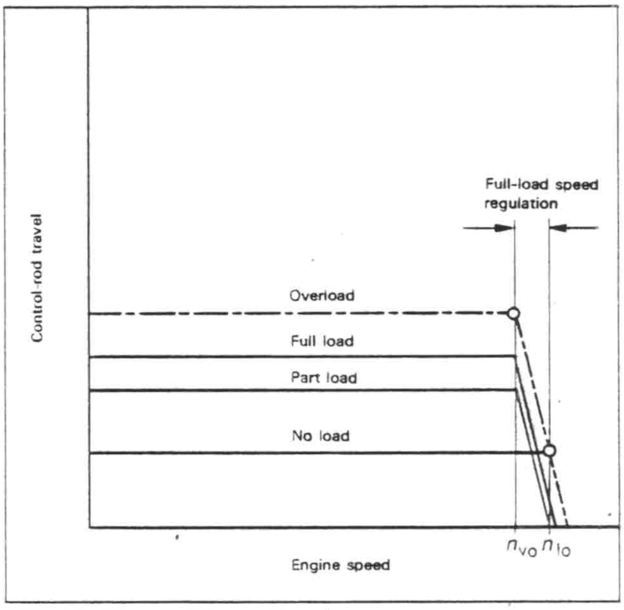
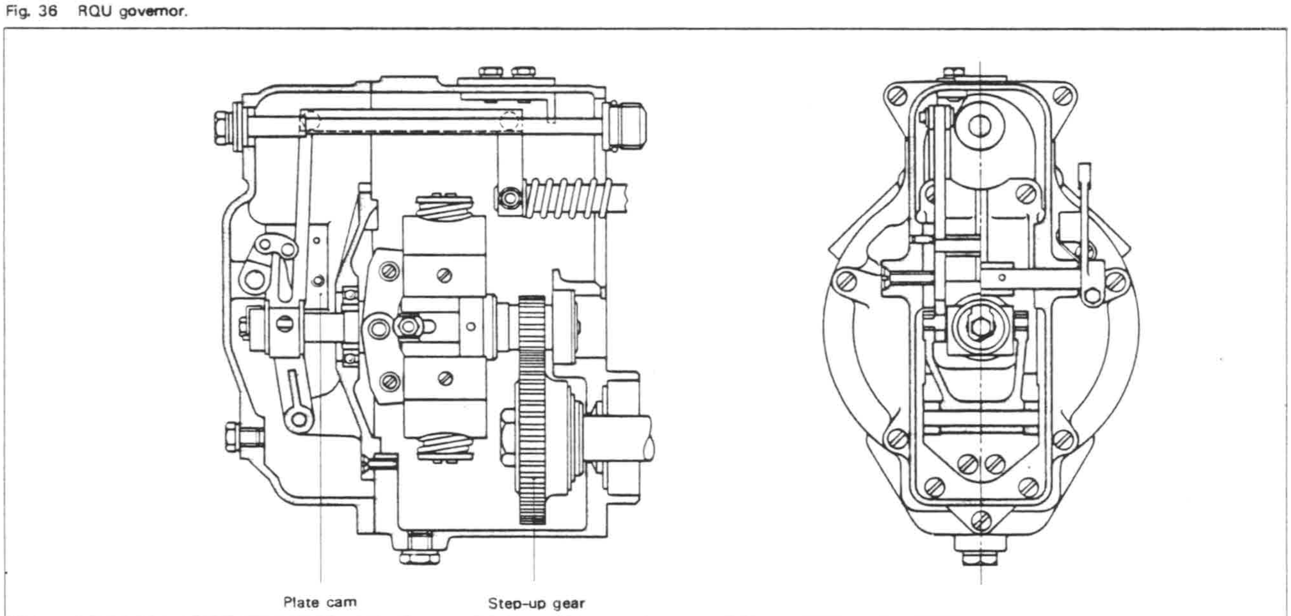


Fig. 36 RQU governor.



Variable-Speed Governor RQV

Construction

The RQV governor is constructed similarly to the RQ governor, but is not identical: in the RQV, the governor springs are built into the flyweights, but the flyweights move continuously outward within the specified adjustment range as the speed increases. A certain speed at which speed regulation begins is associated with each position of the control lever. Movements of the control lever are transmitted through the two-part linkage lever (toggle lever) and the guide block to the fulcrum lever, and thus to the control rod. The pivot point of the fulcrum lever can be shifted in the coulisse; in addition, the pivot point is guided in a plate cam fastened on the governor housing so that the transmission ratio of the fulcrum lever changes in the range of 1:1.7 to 1:5.9.

The sliding bolt, being the connecting element between the flyweight assembly and the fulcrum lever, is spring-loaded for pressure and tension (drag spring).

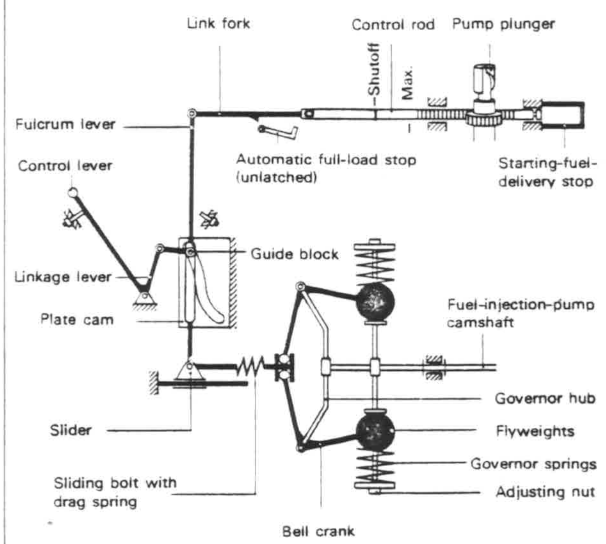
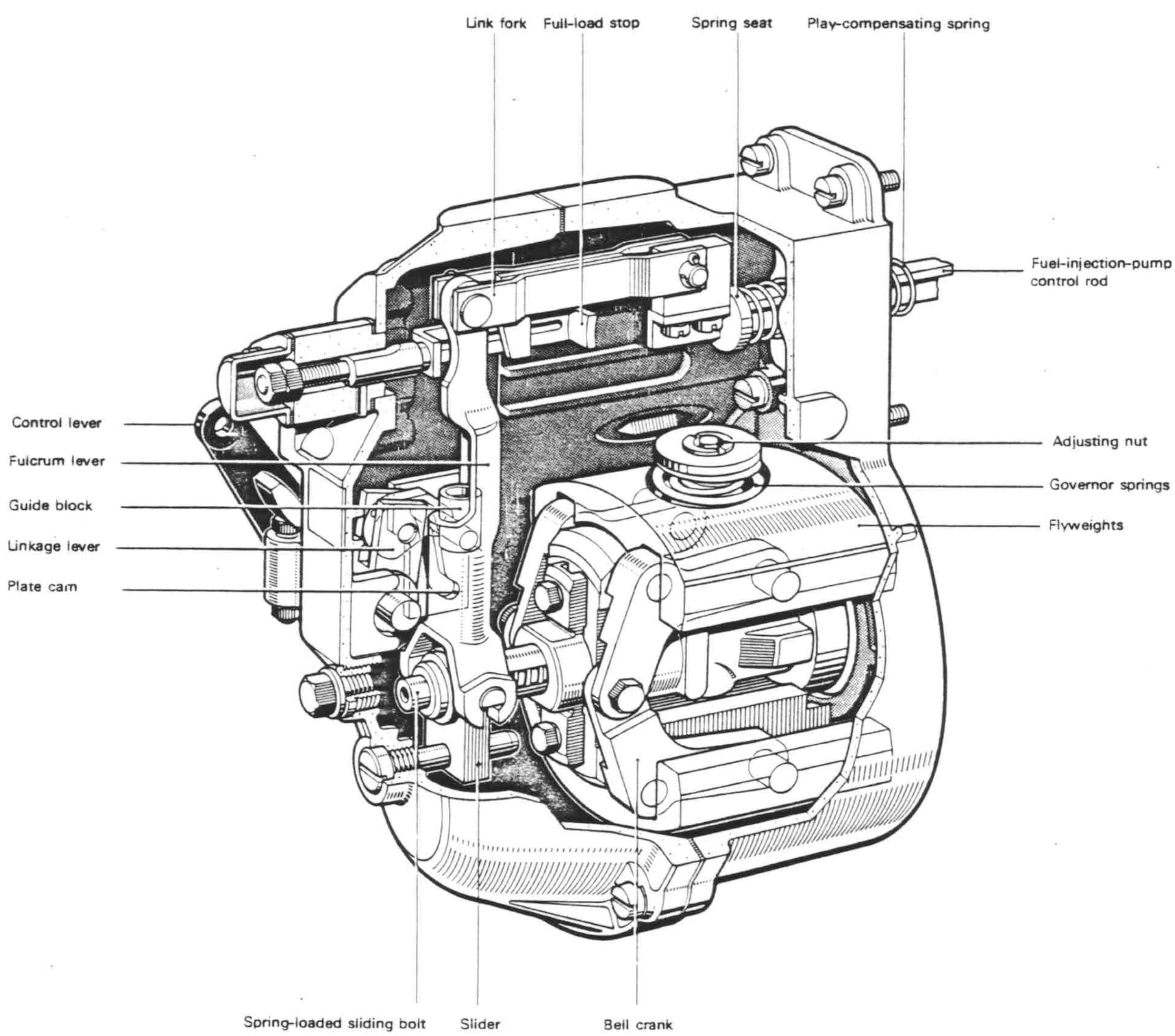


Fig. 37 Schematic drawing of the variable-speed governor RQV.

Fig. 38 RQV variable-speed governor.



As in the RQ governor, the spring sets built into the flyweights consist generally of three concentrically arranged cylindrical helical springs. The outer spring serves for low-idle-speed control and is supported between the flyweight and the adjusting nut for the spring preload. After moving across the short idle-speed travel path, the flyweight is positioned against the spring seat, and the inner springs, which are installed between the spring seat and the adjusting nut, also take effect. From this point on, all the springs act together to control the speeds set by the control lever.

Operating Characteristics

Engine stopped.

The control lever is positioned against the shutoff stop, and the control rod is in the shutoff position.

Starting position (Fig. 41)

The control lever is positioned against the maximum-speed stop, the control rod moves to the starting-fuel-delivery stop (Point A_1, Fig. 40).

Idle position (Fig. 42)

After the engine has started to operate and the control lever (accelerator pedal) has been released, this lever returns to the idle position. The control rod also returns to the idle position, which is determined by the now operating governor (Point A or L, Fig. 40).

Load on engine (Fig. 43)

If the load on the engine at any speed set by the control lever (accelerator pedal) is increased or decreased, the variable-speed governor maintains the set speed by increasing or decreasing the amount of fuel delivered within the associated speed droop.

Fig. 39 Flyweight in the RQV governor.

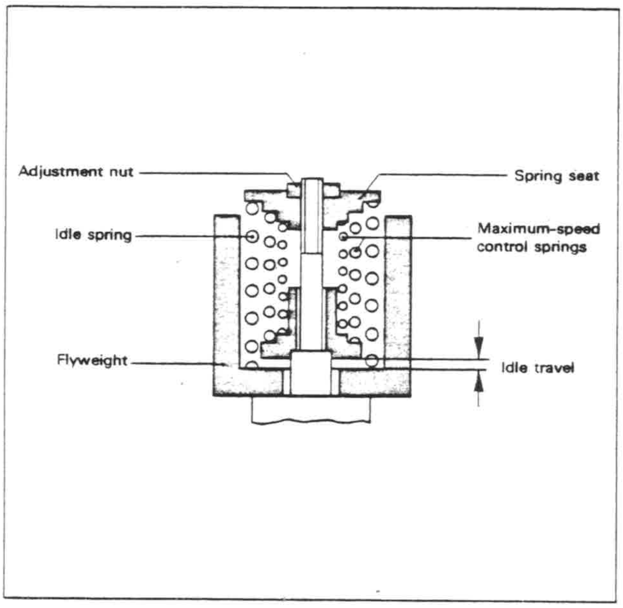


Fig. 41 RQV governor, start position.

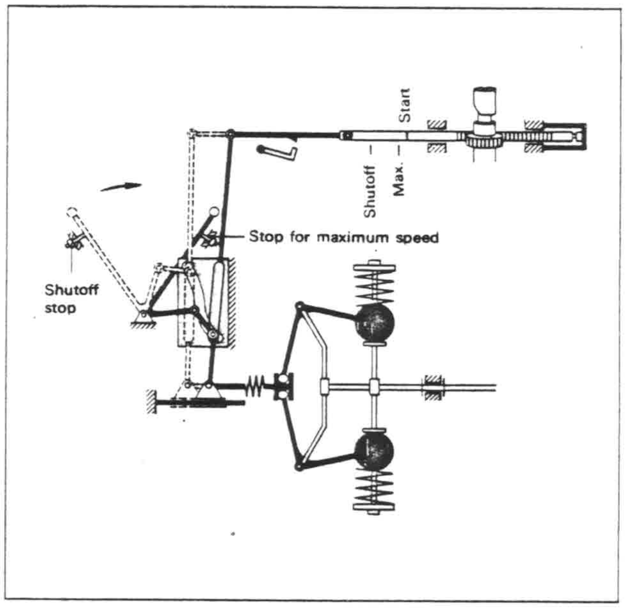


Fig. 40 Governor characteristic curves, RQV governor.

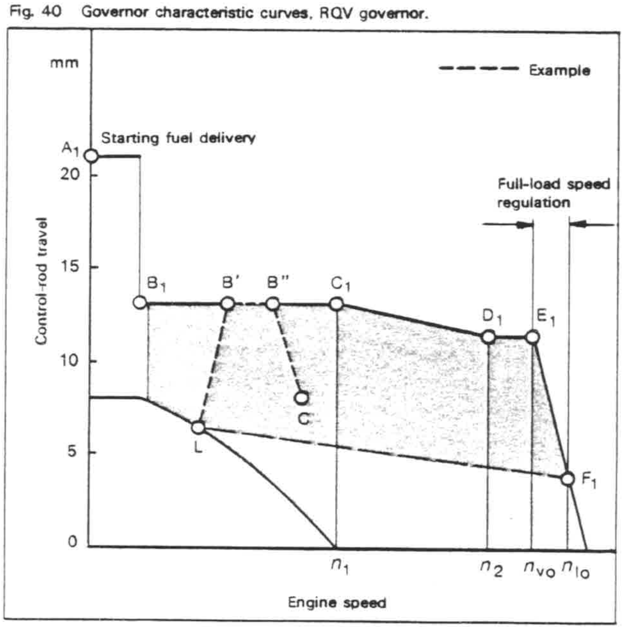
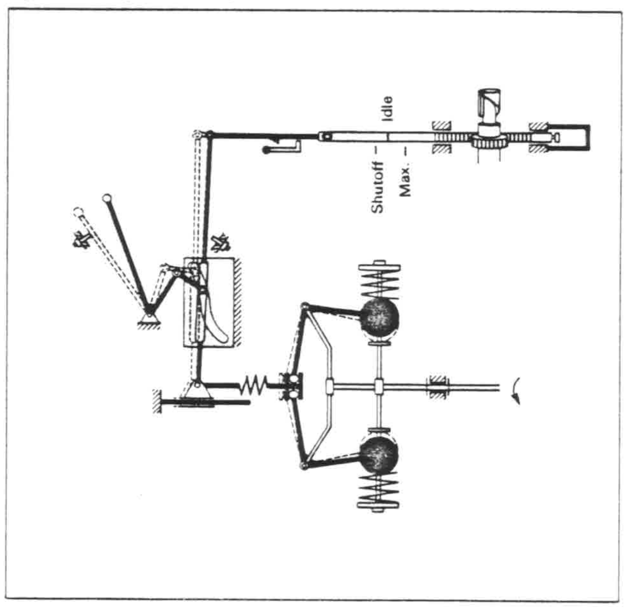


Fig. 42 RQV governor, idle position.



Example: the driver has moved the control lever from the idle position to a position intended to correspond to a desired vehicle speed. The movement of the control lever is transmitted through the linkage lever to the fulcrum lever. The transmission ratio of the fulcrum lever is variable and immediately above the idle-speed range becomes so large that even a relatively small part of the total control-lever or flyweight travel is adequate to shift the control rod to the set full-load stop (path LB' in Fig. 40); a control-rod stop (fixed or adjustable by hand, in no case spring-loaded) must therefore be available. Additional swivelling movement of the control lever results in the drag spring being tensioned. The control rod remains temporarily in the maximum-fuel-delivery position, and this results in a rapid increase in engine speed (B'B"); this in turn forces the flyweights outward, but the control rod remains in the maximum-fuel-delivery position until the tension on the drag spring is released. Then the flyweights start to act on the fulcrum lever and the control rod is thereby shifted in the shutoff direction. As a result, the amount of fuel delivered becomes smaller and the engine speed is restricted. This engine speed limit corresponds to the position of the control lever and to the flyweight stop (path B"C in the graph).

During operation, therefore, one specific rotational-speed range is associated with every position of the control lever as long as the engine is not overloaded or driven by the vehicle when travelling downhill (overrun). If the engine loading now becomes somewhat greater, for example when travelling uphill, the engine and governor speeds decrease. As a result, the flyweights move inward and shift the control rod in the maximum-delivery direction. This holds the engine speed constant at a level which is determined by the position of the control lever and by the speed droop. However, if the uphill slope (=loading) is so great that, even though the control rod is shifted all the way to the maximum-fuel-delivery stop, the speed nevertheless still decreases, the flyweights are brought farther inward in accordance with this speed, and they shift the sliding bolt to the left.

The flyweights therefore tend to shift the control rod farther in the maximum-fuel-delivery direction. However, since the control rod is already positioned against the full-load stop and cannot move farther in the maximum-fuel-delivery direction, the drag spring is tensioned. This means that the engine is overloaded. In this case the driver must shift to a lower gear.

When travelling downhill the opposite situation prevails. The engine is driven by the vehicle and its speed increases. As a result, the flyweights are forced outward and the control rod is shifted in the shutoff direction until it reaches the stop. If the engine speed then increases still further, the drag spring is tensioned in the opposite direction (control rod in shutoff position!)

The behavior of the governor described above applies basically for all positions of the control lever should for any reason the engine loading or speed change so greatly that the control rod is brought up against one of its terminal stops, i.e., maximum fuel delivery or shutoff.

Torque control

Torque control takes place between n_1 and n_2 (Fig. 40) in the full-load case along the line $C_1 — D_1$.

In the RQV governor, the torque-control mechanism is built into the control-rod stop. For additional information on this point see "Control-Rod Stops" below.

Fig. 43 RQV governor, engine loaded (part load).

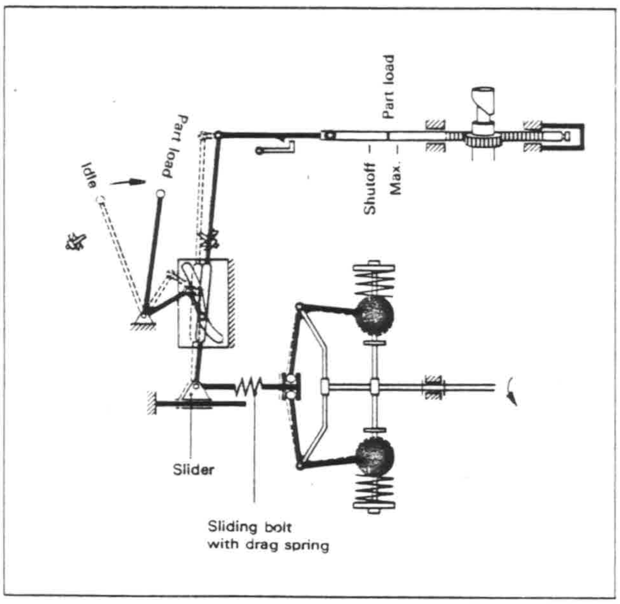
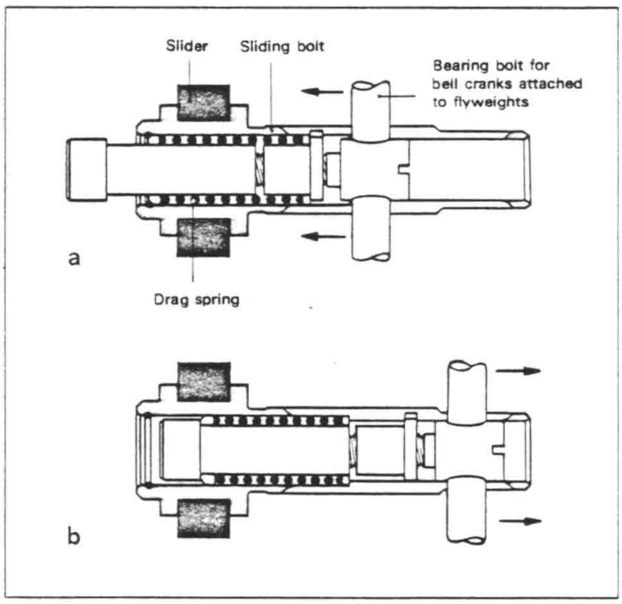


Fig. 44 Sliding bolt with drag spring.
a) During acceleration or when the engine is overloaded, the flyweights have shifted the control rod to the full-load stop. The drag spring is tensioned.
b) Vehicle travelling downhill, engine driven by vehicle. The flyweights have shifted the control rod to the shutoff stop, the drag spring is tensioned and absorbs further movement of the flyweights.



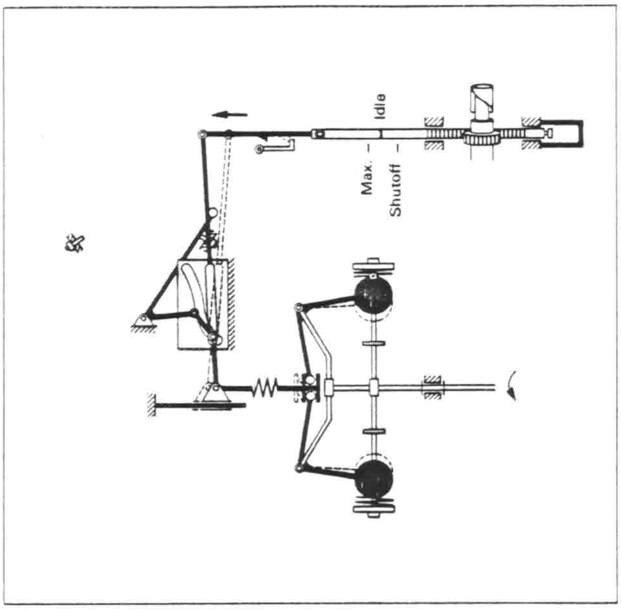


Fig. 45 RQV governor, maximum-speed regulation under full load.

Full-load speed regulation (Fig. 45)
If the engine exceeds its maximum speed, full-load speed regulation starts, $E_1 - F_1$ (Fig. 40). During this process the flyweights move outward and the control rod shifts in the shutoff direction. If the entire load on the engine is removed, the high idle speed, n_{lo}, is attained.

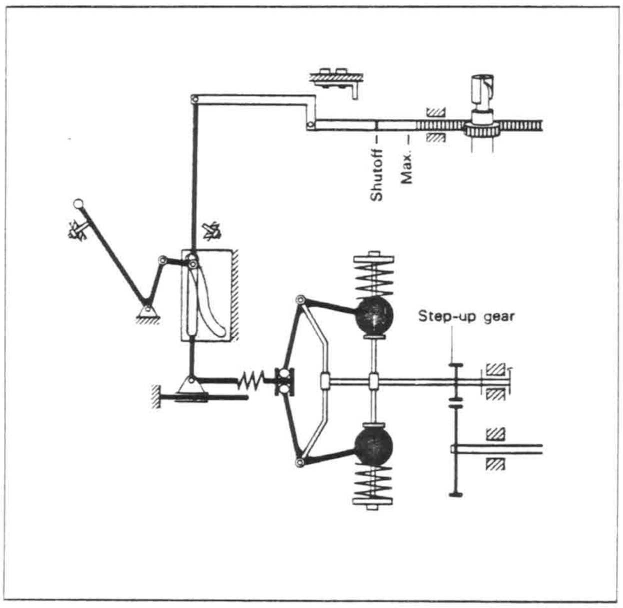
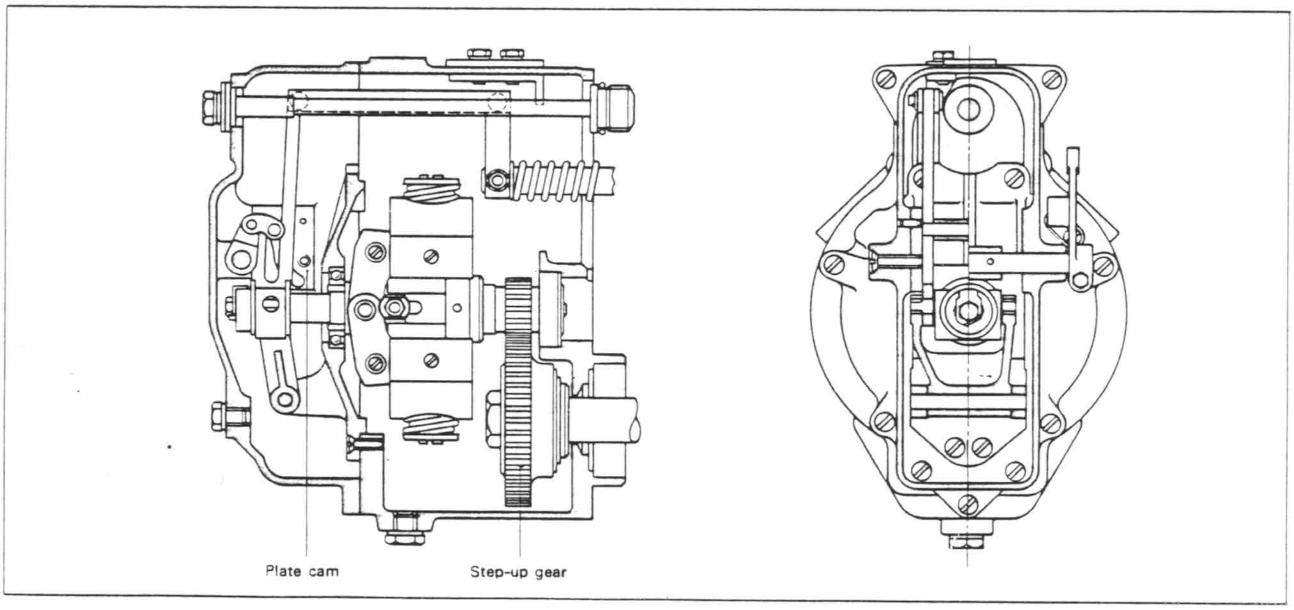


Fig. 46 Schematic drawing of the variable-speed governor RQUV.

Variable-Speed Governor RQUV

The RQUV governor is used for regulating very low rotational speeds, for example the speeds at which marine engines operate. It is a variant of the RQV governor and effects two different speed-increasing ratios (about 1:2.2 or 1:3.76) between the driving element, i.e., the fuel-injection-pump camshaft, and the governor hub. Similar to the lever ratio in the RQV governor, the ratio of the fulcrum lever is variable here also (from 1:1.85 to 1:7). The RQUV governor can be used for PE..P and PE..ZW fuel-injection pumps. The operation and operating characteristics of this governor are similar to those of the RQV governor, though no provision is made for a starting fuel delivery.

Fig. 47 RQUV variable-speed governor.



Variable-Speed Governor RQV . . K

The RQV-K governor has basically the same flyweight assembly, with governor springs built into the flyweights, as the RQV governor. The essential point of difference lies in the type of torque control. While in all other governors torque control is based for practical purposes on a certain reduction in the amount of fuel delivered at full load and when the speed increases, the full-load delivery with the RQV-K design can be increased somewhat as well as decreased.

Torque control takes place in the RQV-K governor as a result of the fact that the rocker on the upper end of the fulcrum lever runs along a rocker guide (i.e. a curved track) at the full-load stop, the guide being designed to reflect the varying fuel requirement of the engine. The strap forming the connection between the fulcrum lever and the control rod transmits this movement to the control rod. As a result, a full-load fuel delivery corresponding to the desired variations in torque is developed.

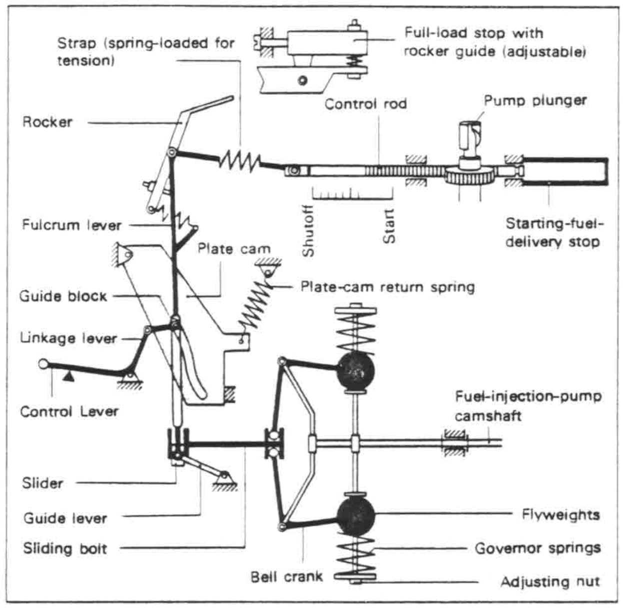
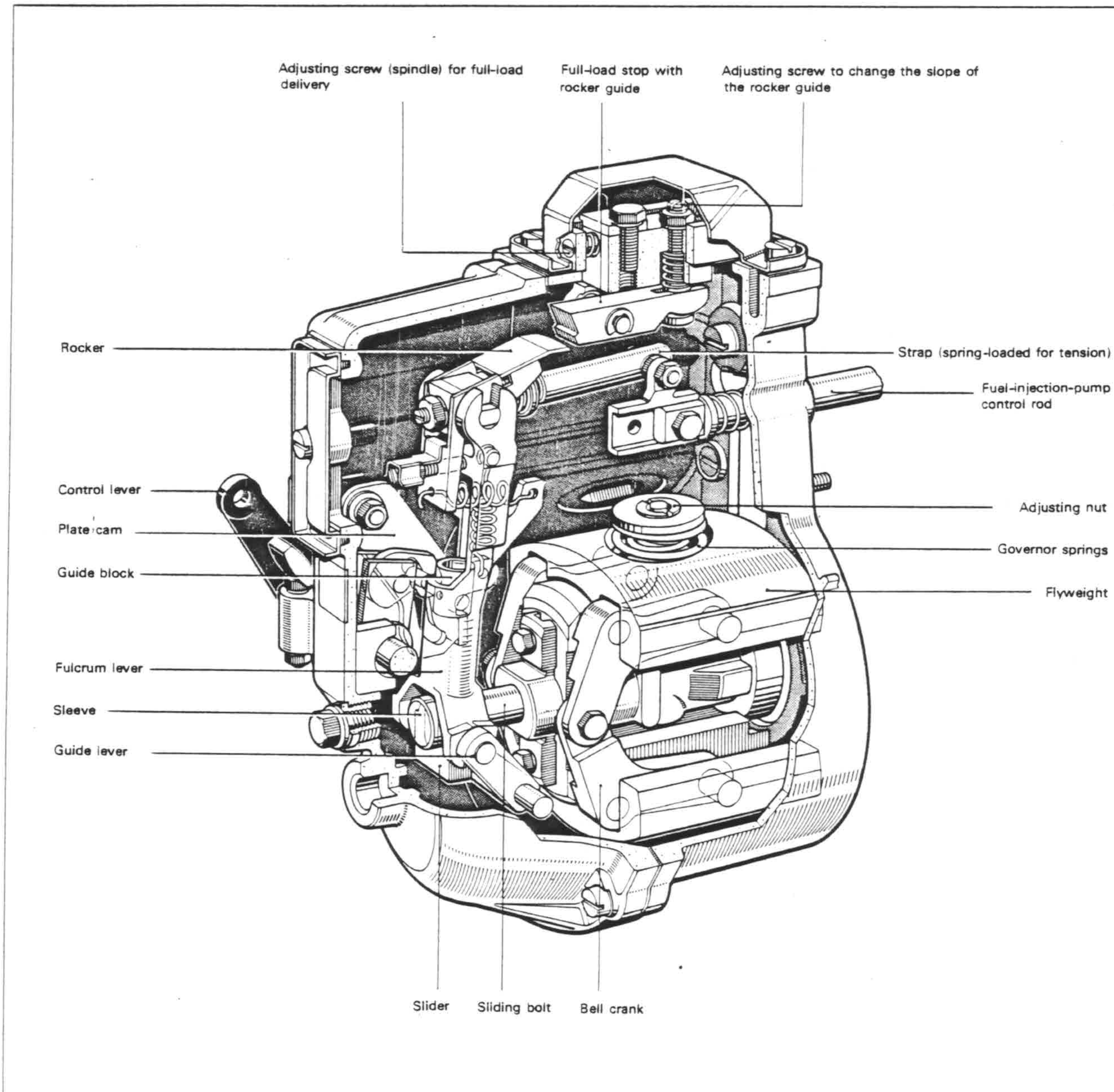


Fig. 48 Schematic drawing of the variable-speed governor RQV-K.

Fig. 49 RQV-K governor.



Depending on the shape of the curve, the fuel delivery can be increased as well as decreased.

The full-load stop can be shifted in a longitudinal direction by an adjusting screw in order to set the fuel delivery; by means of another adjusting screw, the inclination of the rocker guide, and thus the steepness of the torque-control characteristic, can also be varied.

Operating Characteristics

Engine stopped

The control lever is positioned against the shutoff stop, and the control rod is in the shutoff position.

Starting the engine (Fig. 50)

Move the governor control lever to the maximum-speed position. As this is done, the rocker swings under the full-load stop and the control rod shifts to the starting-fuel-delivery position A_1 (Fig. 52). A stop for the starting fuel delivery is located on the fuel injection pump.

Fig. 50 RQV-K governor, start position.

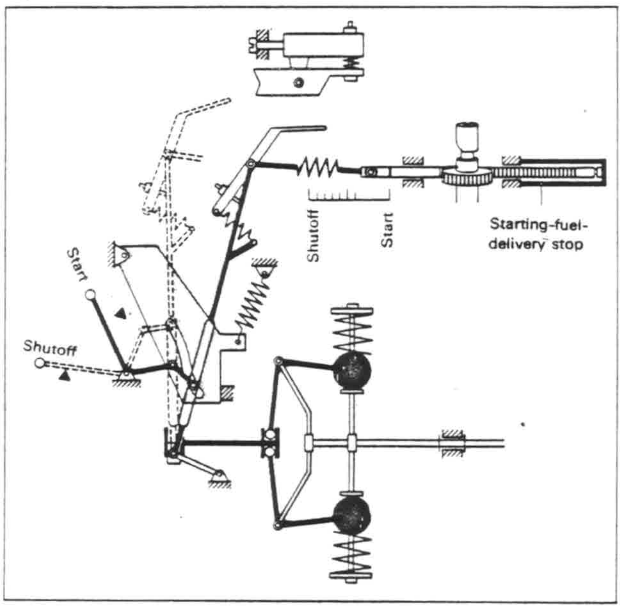
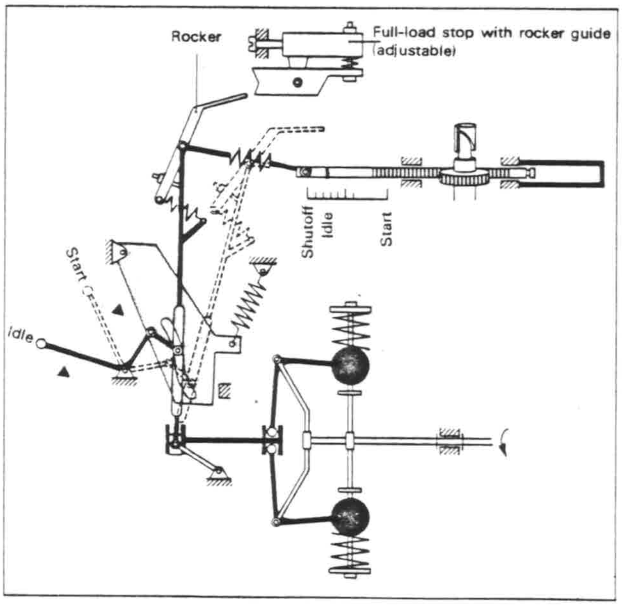


Fig. 51 RQV-K governor, idle position.



When the starting motor has been switched on, the fuel injection pump delivers the quantity of fuel required for starting (starting fuel delivery) through the injection nozzle into the engine.

Idle (Fig. 51)

When the engine has started to operate independently, the control lever is brought back to the idle position. As this takes place, the spring-loaded rocker slides back under the full-load stop to the idle position. The engine now operates at its idle speed.

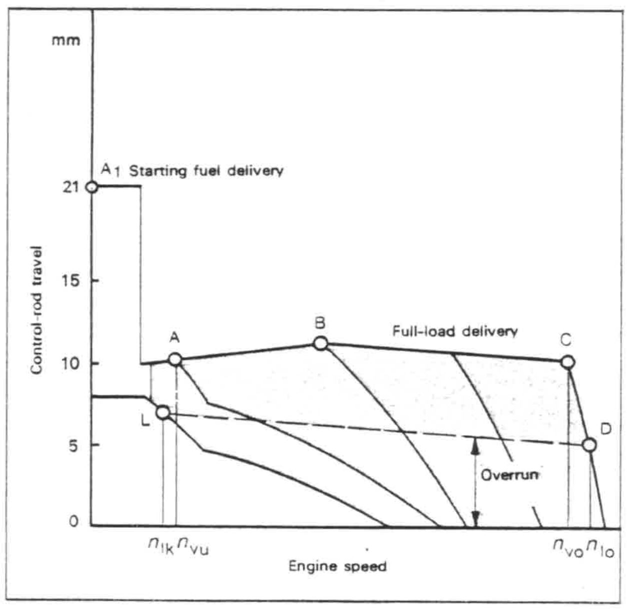
Full-load delivery at low speed (Fig. 53)

If the control lever is moved e.g. from the idle position to the maximum-speed position, the guide block moves along the rocker guide in the plate cam and simultaneously downward in the fulcrum lever guide. As this movement takes place, the fulcrum lever swings to the right around the pivot point at the slider and, acting through the strap, shifts the control rod in the full-load direction. Fuel delivery increases and the engine speed rises.

The flyweights move outward and the sleeve is shifted somewhat to the right. As a result, a swivelling movement is developed; the guide lever and the fulcrum lever are raised so that the rocker slides along the rocker guide at the full-load stop (A – B on the characteristic curve, Fig. 52).

As the slider moves downward in the fulcrum-lever guide track, the plate cam was raised from its stop on the housing against the force of the return spring.

Fig. 52 Governor characteristic curves, RQV-K governor.



Full-load delivery at medium speed (Fig. 54) (with torque control)
If the speed continues to rise, the flyweights are forced farther outward and the rocker slides along the rocker guide at the full-load stop. Until the curve changes direction at B, torque control takes place in the sense of increasing the full-load fuel delivery as the speed rises (negative torque control), and after the curve changes direction torque control takes place in the sense of decreasing the full-load delivery (positive torque control, B – C on the governor characteristic curve, Fig. 52).

End of torque control, start of speed regulation
At the end of torque control, when speed regulation starts, the plate cam is again positioned against the stop on the housing.

If the speed continues to increase, regulation of the high idle speed starts. The flyweights move farther outward, and the sleeve moves correspondingly to the right. As a result, the fulcrum lever swings around the pivot point at the guide block with its upper part to the left. As these actions take place, the control rod moves in the shutoff direction (C – D on the governor characteristic curve, Fig. 52).

During operation, one specific rotational-speed range is associated with every position of the control lever as long as the engine is not overloaded or driven by the vehicle when travelling downhill. If the engine loading now becomes somewhat greater, for example when travelling uphill, the engine and governor speeds decrease. As a result, the flyweights move inward and shift the control rod in the maximum-delivery direction. This holds the engine speed constant at a level which is determined by the position of the control lever (or accelerator pedal). However, if the engine loading (=uphill slope) is so great that, even though the control rod is shifted all the way to the maximum-fuel-delivery stop, the speed nevertheless still decreases, the flyweights are brought farther inward in accordance with this speed, and they shift the sleeve farther in the maximum-fuel-delivery direction.

However, since the control rod cannot move any farther in the maximum-fuel-delivery direction, the lower part of the fulcrum lever moves to the left against the resistance of the return spring for the plate cam and thereby raises the plate cam from its stop.

When travelling downhill the opposite situation prevails: the engine is driven by the vehicle and its speed increases. As a result, the flyweights are forced outward and the control rod is shifted in the shutoff direction. If the engine speed then increases further (control rod in shutoff position!), the spring-loaded strap, which connects the fulcrum lever with the control rod, yields. If the driver slows the vehicle down somewhat by applying the brakes or if he shifts into a higher gear, the strap is again shortened to its normal length.

The behavior of the governor described above applies basically for all positions of the control lever should for any reason the engine loading or speed change so greatly that the control rod is brought up against one of its terminal stops, i.e., maximum-fuel-delivery or shutoff.

Control of medium speeds
The family of curves, for example at B, shows the possibilities for control of the intermediate speeds.

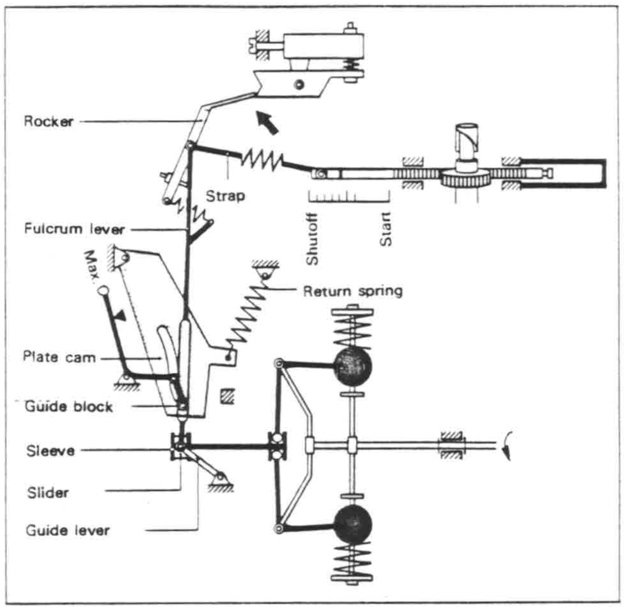


Fig. 53 RQV-K governor, full-load delivery at low speed. Start of negative torque control.

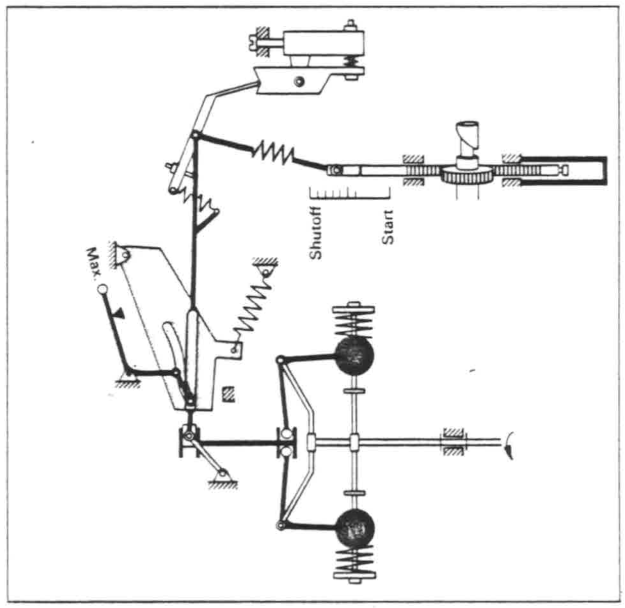


Fig. 54 RQV-K governor, full-load delivery at medium speed, reversal of torque control.

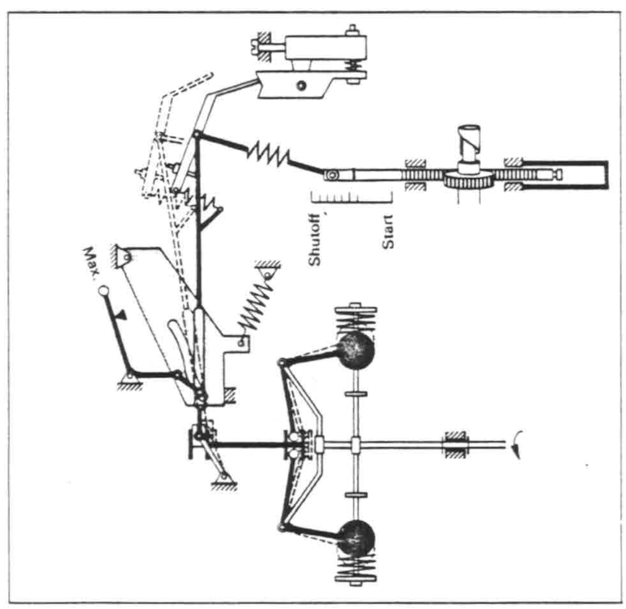


Fig. 55 RQV-K governor, maximum full-load speed, end of positive torque control (dotted pattern: speed regulation).

Combination Governors RQV and RQUV

The combination governor is a variant of the variable-speed governor in which a certain speed range remains uncontrolled. Depending on the design, this range can be immediately adjacent to the idle speed, or it can start at an intermediate speed and continue to the maximum speed. In the rest of the speed range the combination governor controls all speeds set with the control lever. The governor characteristic curves provide information on the controlled and the uncontrolled ranges.

In terms of construction, the combination governor differs from the variable-speed governor only in the utilization of different governor springs.

Variable-Speed Governor EP/RSV

Construction
Governor EP/RSV is constructed differently from the comparable type RQV. It has only one governor spring, and this spring can swivel. When setting the speed at the control lever, the position and tension of this spring change so that the effective torque at the tensioning lever is in equilibrium with the torque developed by the flyweights at the desired speed. All adjustments of the control lever and the flyweight travel are transmitted through the governor linkage to the control rod.

The starting spring attached at the upper end of the fulcrum lever pulls the control rod to the starting position, automatically setting the starting fuel delivery.

Fig. 56 Governor characteristic curves, combination-governor, lower speed range not controlled.

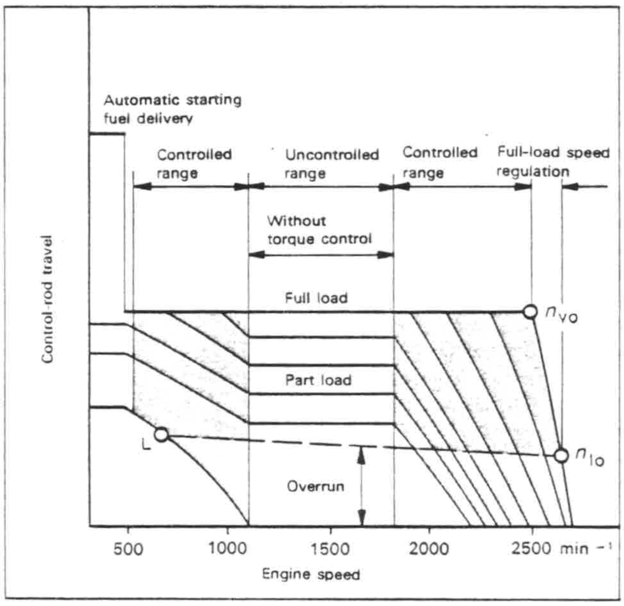


Fig. 57 Governor characteristic curves, combination governor, upper speed range not controlled.

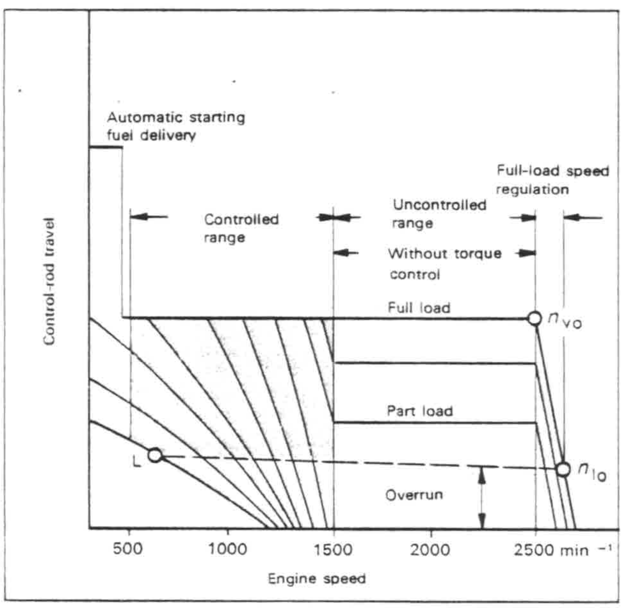


Fig. 58 Schematic drawing of variable-speed governor EP/RSV.

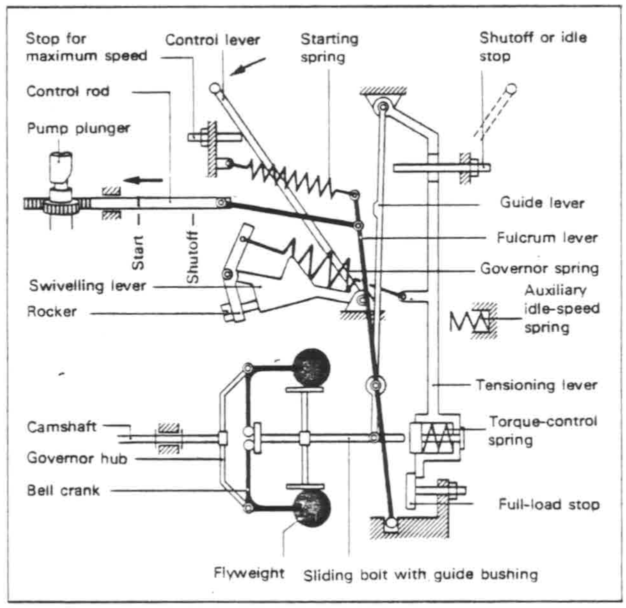
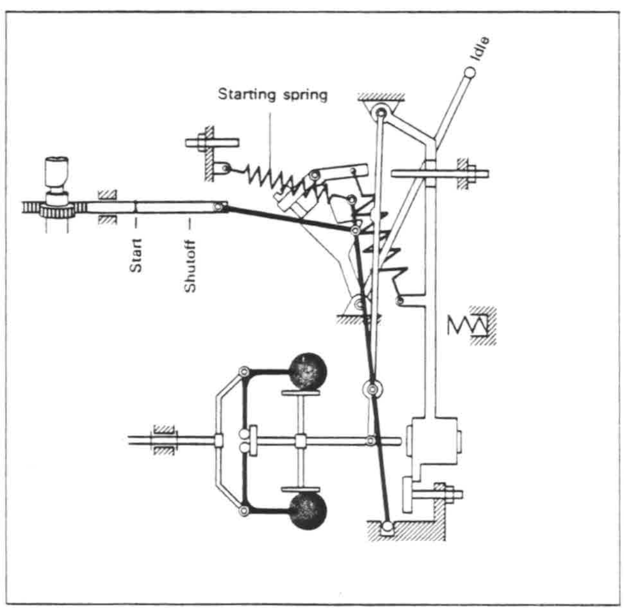


Fig. 59 EP/RSV governor, starting position.



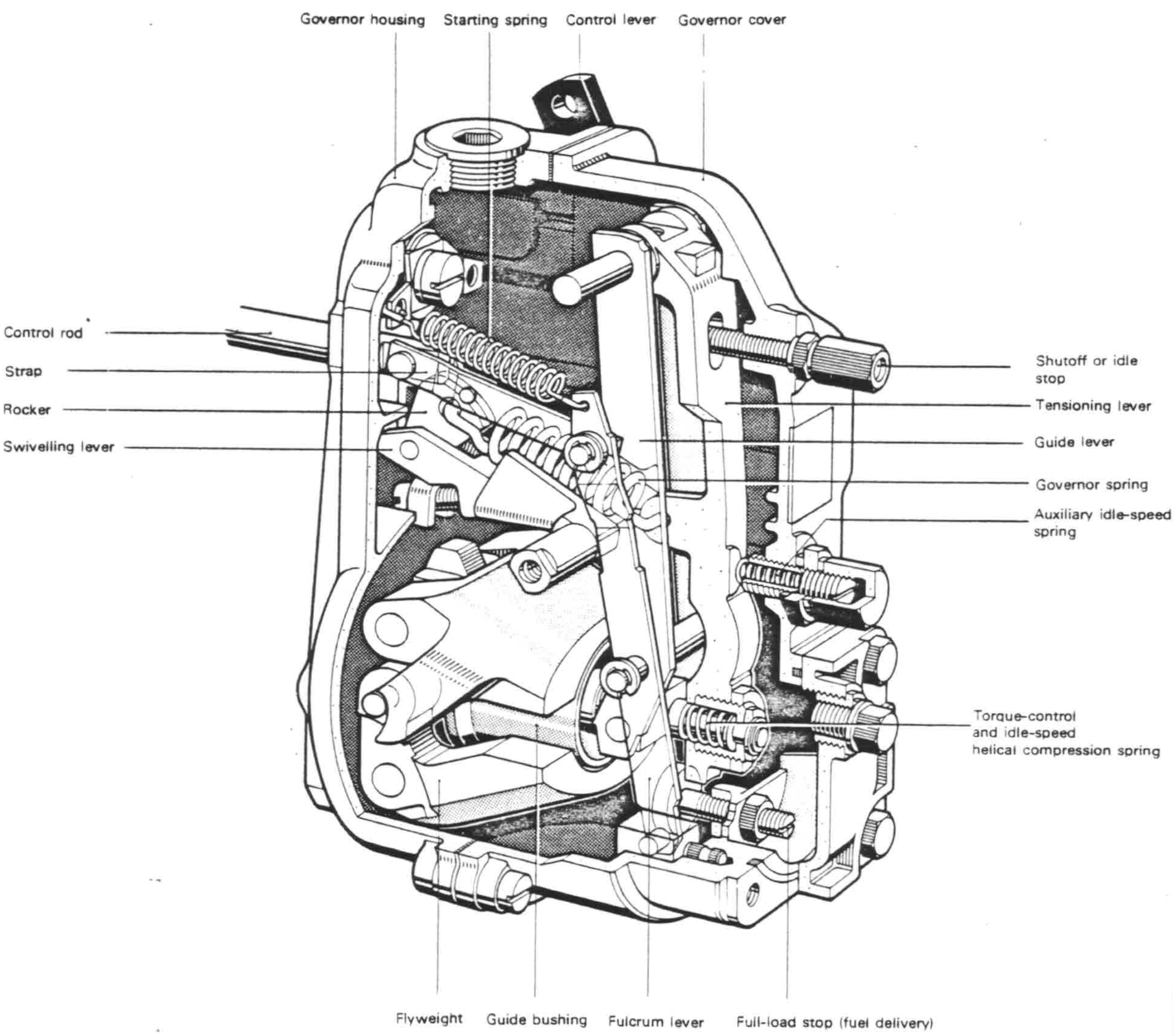
A full-load stop and a torque-control mechanism are built into the governor. In order to stabilize the idle speed, an auxiliary idle-speed spring with an adjusting screw is built into the governor cover. The speed droop can be varied within certain limits by means of the governor spring adjusting screw. Lighter flyweights are required for higher speed ranges; using springs that are under less tension it is possible to set a smaller speed droop at lower speeds.

Operating Characteristics

Starting the engine (Fig. 59)

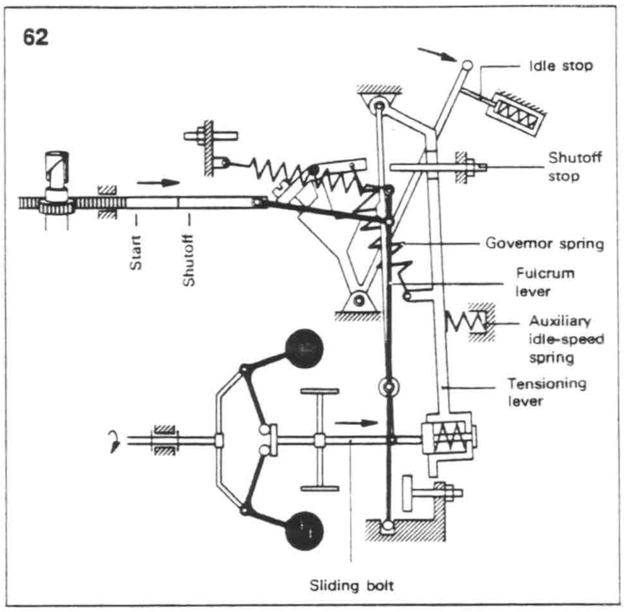
When the engine is stopped, the control rod is in the starting-fuel-delivery position so that the engine can be started with the control lever in the "Idle" position.

Fig. 60 Variable-speed governor EP/RSV.



Idle position (Fig. 62)
The control lever is positioned against the idle stop. As a result, the governor spring is almost completely relaxed and stands almost vertical. It has a very weak effect, so the flyweights swing outward at even a low speed. The sliding bolt, and with it the guide lever, therefore move to the right. In turn, the guide lever swings the fulcrum lever to the right, so that the control rod is moved in the shutoff direction to the idle position. The tensioning lever is positioned against the auxiliary idle-speed spring which assists the low-idle-speed control.

Regulation of low speeds (Fig. 63)
Even a relatively small shift of the control lever from the idle position is sufficient to move the control rod from its initial position (Point L in Fig. 61) to its full-load position (Point B′ in Fig. 61). The fuel injection pump delivers the full-load fuel quantity into the engine cylinders and the speed rises (B′B″). As soon as the centrifugal force is greater than the tension of the governor spring corresponding to the position of the control lever, the flyweights swing outward and shift the guide bushing, sliding bolt, fulcrum lever, and control rod back to a point of smaller fuel delivery (Point C on the graph). The speed of the engine does not increase further and is held constant by the governor as long as external conditions remain uniform.



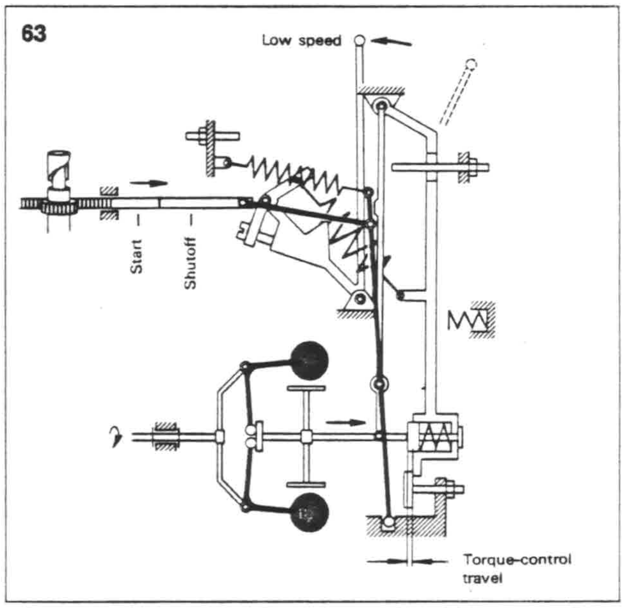
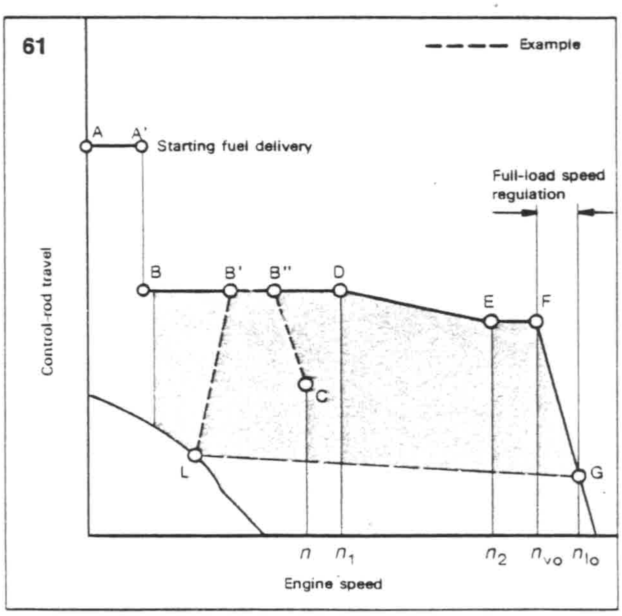
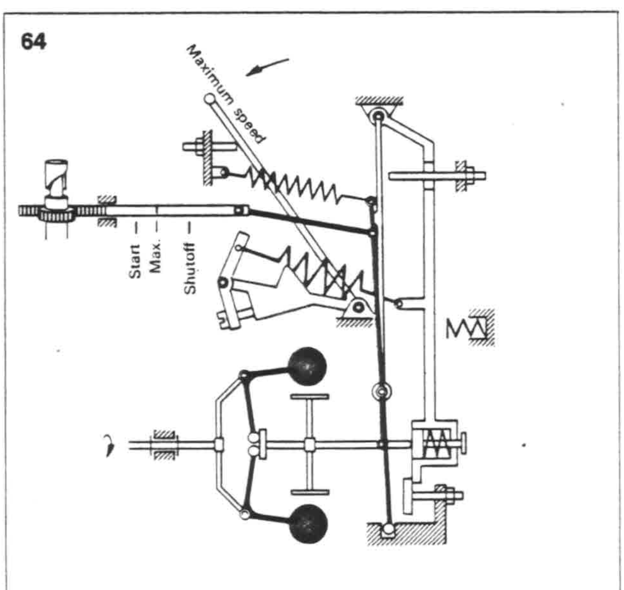


Fig. 61 Governor characteristic curves, EP/RSV governor.
Fig. 62 EP/RSV governor, idle-speed position.
Fig. 63 EP/RSV governor, full load at low speed, start of torque control.
Fig. 64 EP/RSV governor, full load at maximum speed, end of torque control, start of full-load speed regulation.





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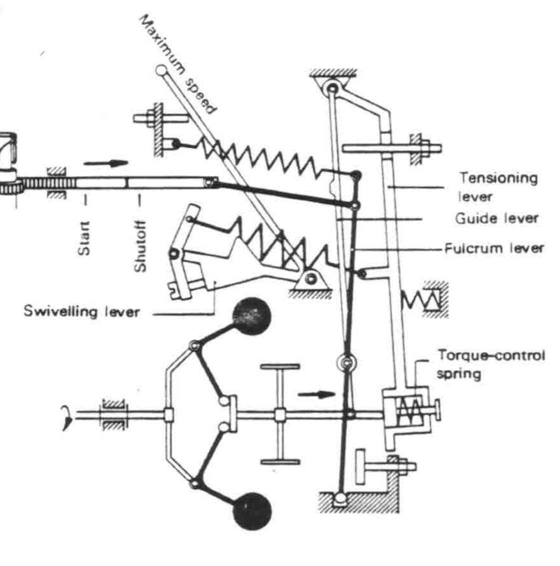

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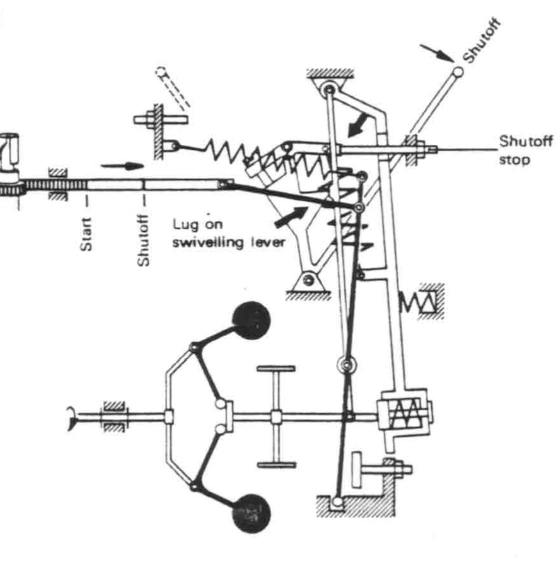

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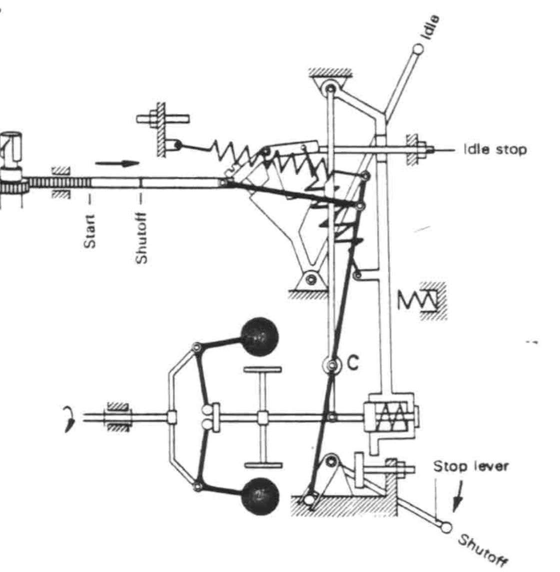


Regulation at high idle speed (Figs. 64 and 65)
If the control lever is moved to the maximum-speed stop, the governor operates in basically the same manner as described above. In this case, however, the swivelling lever tensions the governor spring completely.

The governor spring thus acts with a greater force, drawing the tensioning lever to the full-load stop and the control rod to maximum fuel delivery. The engine speed increases and the centrifugal force steadily rises.

In governors equipped with torque control, as soon as the tensioning lever is positioned against the full-load stop, the torque-control spring is steadily compressed as the speed increases (D – E in Fig. 61). As a result, the guide lever, fulcrum lever, and control rod move in the shutoff direction accordingly and "torque-control" the fuel delivery, i.e., they reduce the delivery by an amount corresponding to the torque-control travel.

When the maximum full-load speed, n_{vo}, is reached, the centrifugal force overcomes the governor spring tension, and the tensioning lever is deflected to the right. The sliding bolt with the guide lever and the control rod, coupled through the fulcrum lever, move in the shutoff direction (F – G in Fig. 61) until, under the new loading conditions, a correspondingly lower fuel delivery has been established.

If the entire load on the engine is removed, the high idle speed, n_{lo}, is attained.

Stopping the engine
a) with the control lever (Fig. 66)
Engines with governors that do not have a special stopping mechanism are stopped by moving the governor control lever to the shutoff position. As this is done, the lugs on the swivelling lever (inclined arrow) press on the guide lever. This lever swings to the right, taking the fulcrum lever, and thus the control rod as well, to the shutoff position with it. Since the tension exerted by the governor springs on the sliding bolt is released, the flyweights swing outward.
b) with the stop lever (Fig. 67)
In the case of governors fitted with a special shutoff mechanism, the control rod can be set to shutoff if the stop lever is moved to the shutoff position.

When the stop lever is pressed to shutoff, the upper part of the fulcrum lever is swung to the right around the pivot point C in the guide lever. As a result, the control rod is drawn by the strap to shutoff. When the stop lever is released, a return spring not shown in the drawing brings it back into its initial position.

Fig. 65 EP/RSV governor, no load, regulated from full load.

Fig. 66 EP/RSV governor, stopping the engine with the governor control lever.

Fig. 67 EP/RSV governor, stopping the engine with the shutoff mechanism.

Variable-Speed Governor EP/RSUV

The RSUV governor is used to control very low speeds, for example those at which low-speed marine engines operate. In terms of its construction, it differs essentially from the EP/RSV governor in its transmission gear for speed-increasing ratio (step-up gear), which is installed between the driving element, i.e., the fuel-injection-pump camshaft, and the governor hub. The operation of this governor is basically the same as that of the EP/RSV. It is used with fuel injection pumps of sizes P and Z.

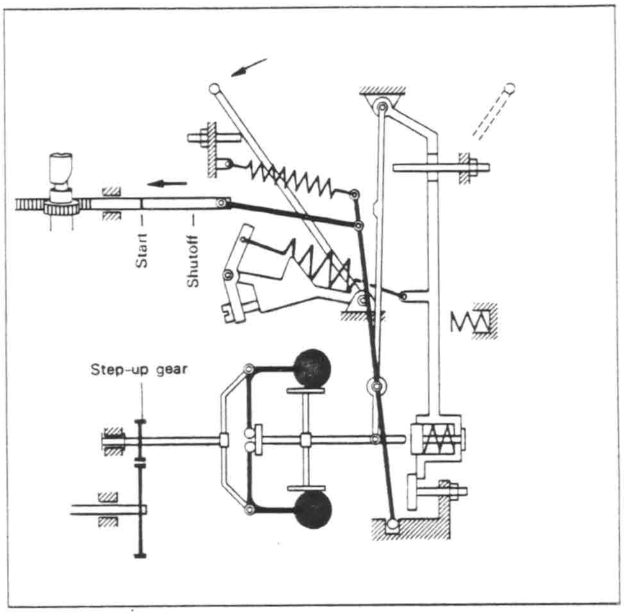
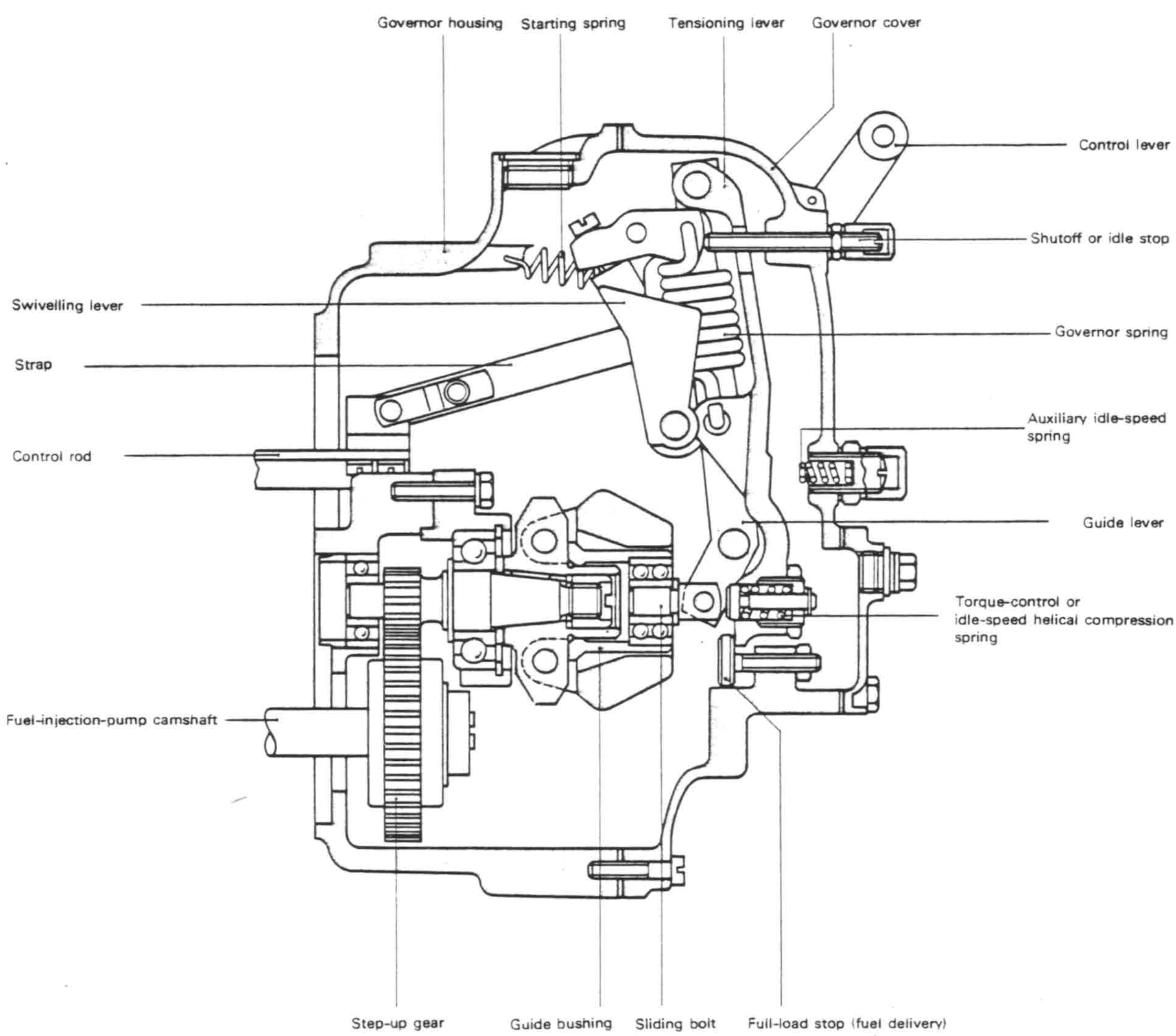


Fig. 68 Schematic drawing of the variable-speed governor EP/RSUV, max. speed.

Fig. 69 EP/RSUV variable-speed governor



Minimum-Maximum-Speed Governor EP/RS

Construction

The EP/RS minimum-maximum-speed governor is a governor with only slight control-lever forces, and was developed from the EP/RSV variable-speed governor. The control lever which tensions the swivelling spring in the EP/RSV governor, thus serving to set the speed, is blocked in the current design of the EP/RS in the maximum-speed position by means of an adjustable stop on the governor cover. It is also possible to set an intermediate speed, for example in the case of vehicles with an auxiliary drive. The stop lever used with the EP/RSV governor (Fig. 67) operates in the EP/RS as an accelerator pedal (lever) with a reversed actuating direction.

In addition to the torque-control spring, a supplementary idle-speed spring is built into the spring retainer for low-idle-speed control; this supplementary spring brings the control rod to the starting-fuel-delivery position, thus controlling the idle speed. The idle-speed stop screw and the auxiliary idle-speed spring in the EP/RSV governor have been eliminated.

Operating Characteristics

Start position (Fig. 73)
Set the accelerator lever (pedal) to the full-load position. The idle-speed spring in the spring retainer shifts the control rod, acting through the sliding bolt, guide lever, fulcrum lever, and strap, to the start position.

Fig. 70 Minimum-maximum-speed governor EP/RS, external view

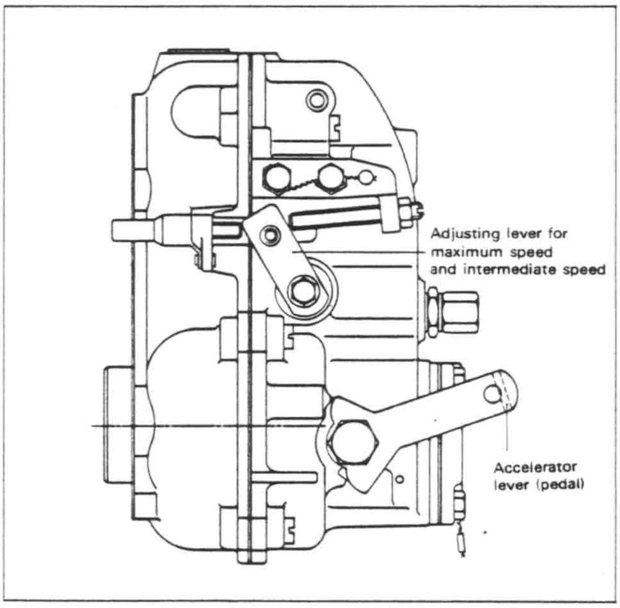


Fig. 72 EP/RS governor, cross-sectional drawing.

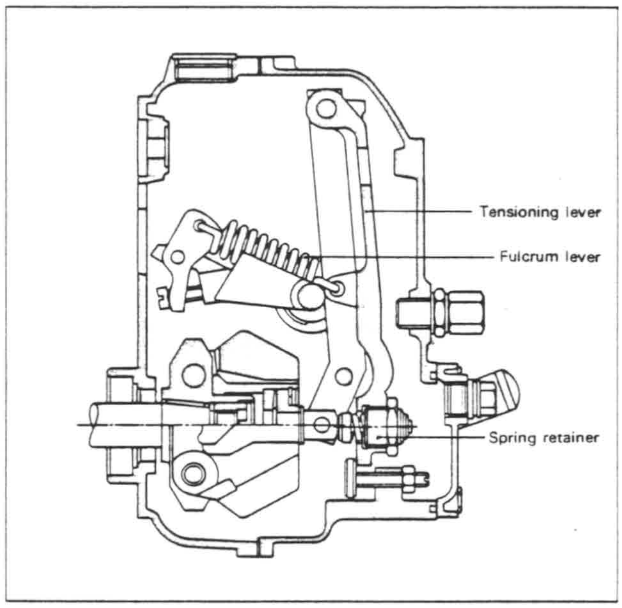


Fig. 71 Spring retainer

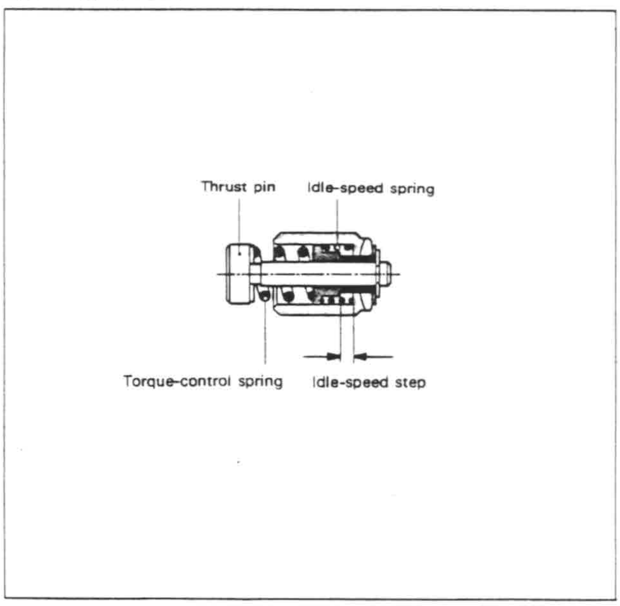
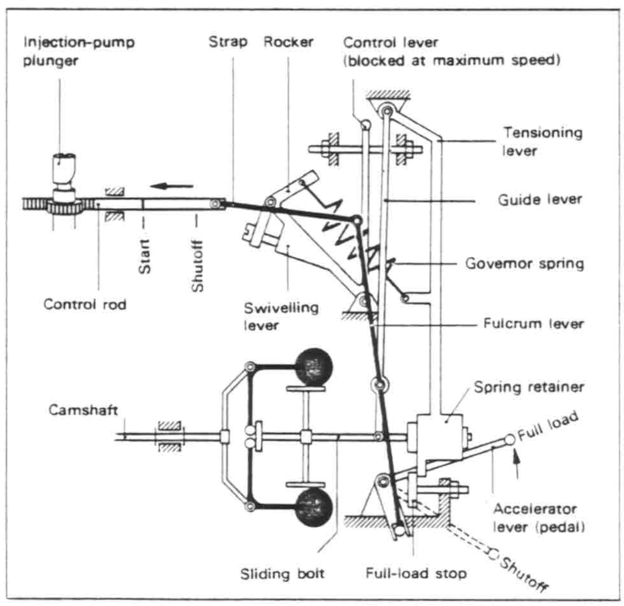


Fig. 73 EP/RS governor, start position.



Idle-speed position (Fig. 75)

After the engine has started to operate, the accelerator lever (pedal) is moved to the idle-speed position. The idle-speed spring built into the spring retainer presses against the sliding bolt through the thrust pin and controls the idle speed.

Loading the engine
(between the idle speed and the maximum speed)

The range B – E (Fig. 74) is not controlled. In this range the driver sets the fuel delivery with the accelerator pedal according to the torque required. If he wants to increase his driving speed or if he must drive up a hill, he must "give more gas", and similarly he must ease off the accelerator pedal if a lower engine power is required. Torque control of the fuel delivery takes place in the range C – D between speed ranges n_1 and n_2 because the centrifugal force acting on the sliding bolt exceeds the force of the torque-control spring built into the spring retainer. The torque-control spring yields in accordance with the centrifugal force acting through the sliding bolt, and the fulcrum lever shifts the control rod in the shutoff direction by the amount of the torque-control travel.

Fig. 74 Governor characteristic curves, EP/RS governor.

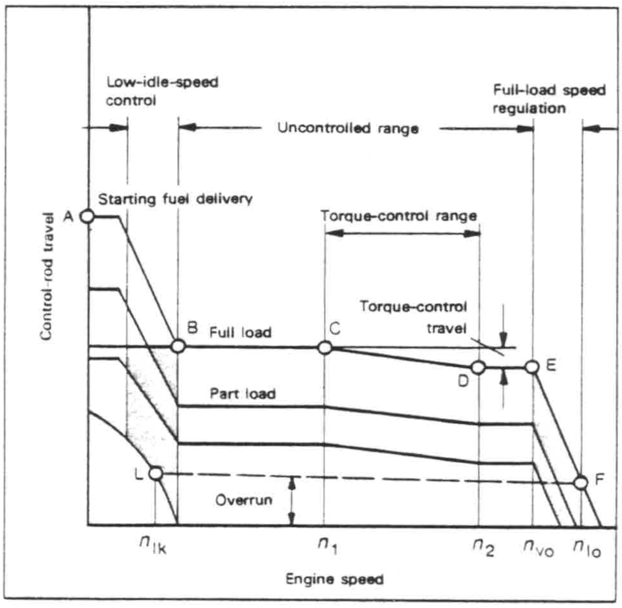


Fig. 75 EP/RS governor, idle-speed position.

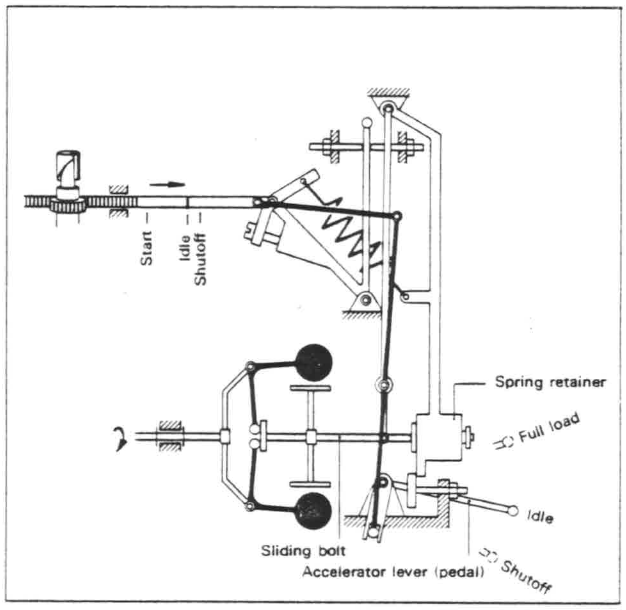
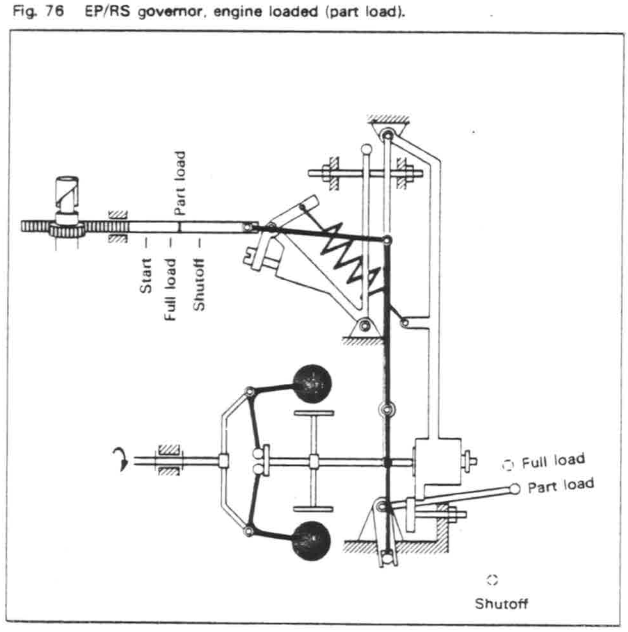


Fig. 76 EP/RS governor, engine loaded (part load).



Maximum-speed regulation at full load (Fig. 77)
The accelerator lever (pedal) is in the full-load position, the maximum speed, n_{vo}, is reached. Now the centrifugal force exceeds the force of the governor spring. For this reason, the sliding bolt and the guide lever move to the right. The fulcrum lever pulls the control rod in the shutoff direction. When the entire load is removed from the engine, the engine reaches the high idle speed, n_{lo} (E–F in Fig. 74).

Stopping the engine (Fig. 78)
Move the accelerator lever (pedal) to the shutoff position. The fulcrum lever swings around the bearing point C and pulls the control rod to shutoff. The flyweights move inward.

Fig. 77 EP/RS governor, maximum-speed regulation at full load, start of speed regulation.

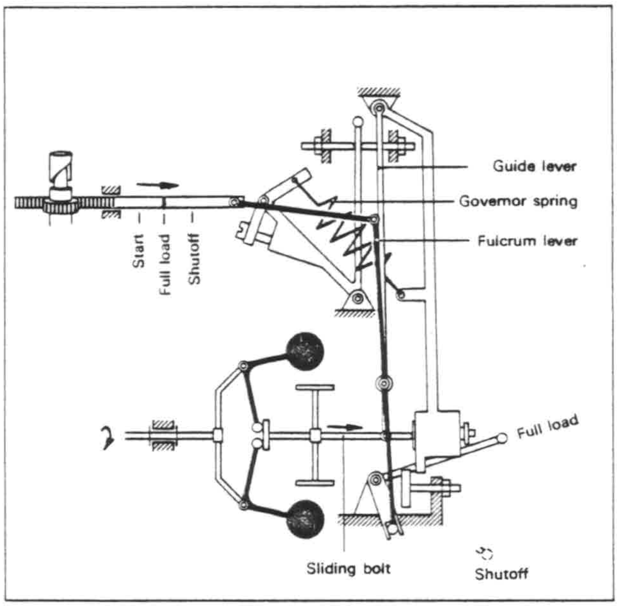
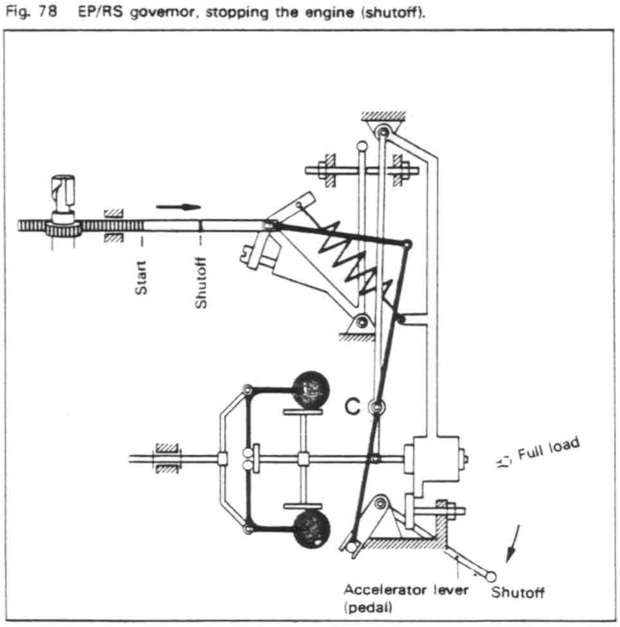


Fig. 78 EP/RS governor, stopping the engine (shutoff).



Control-Lever and Control-Rod Stops for Mechanical Governors

Control-Lever Stops

On the governor cover are two stop screws, one for shutoff and one for the full-load delivery (maximum speed).

If desired, and depending on the type of governor (RQ or RQV), a stop can also be installed for the low idle speed or for an intermediate speed (fuel delivery) which is lower than the full-load delivery.

Spring-Loaded Idle-Speed Stop

The spring-loaded idle-speed stop (see cross-sectional drawing) consists of a sleeve with an external thread and from which a bolt under spring tension projects.

At the idle-speed fuel delivery, the stop lever is positioned against the spring-loaded bolt. In order to stop the engine, the governor control lever must be moved into the shutoff position against the force of the helical compression spring until the engine has come to a stop.

Reduced-Delivery Stop

This stop serves as a fixed adjustment point for a fuel delivery lower than the full-load delivery or for an intermediate speed (depending on the type of governor). It is mounted on the governor cover and acts together with a short lever fastened on the control-lever shaft in such a way that it can be adjusted.

Fig. 79 Stop screws for the control lever.

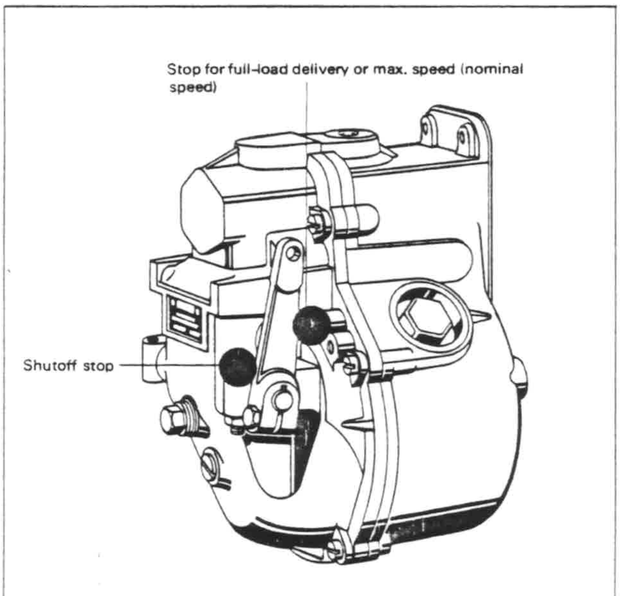


Fig. 81 Reduced-delivery stop (external view).

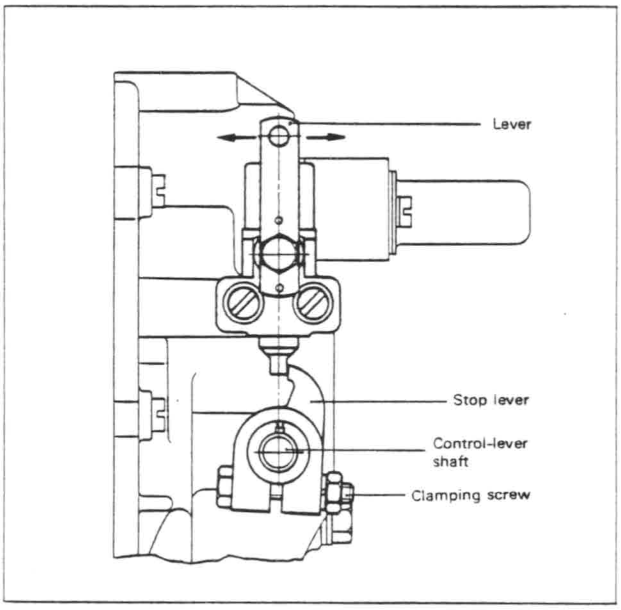


Fig. 80 Spring-loaded control-rod stop (RQ and RQV).

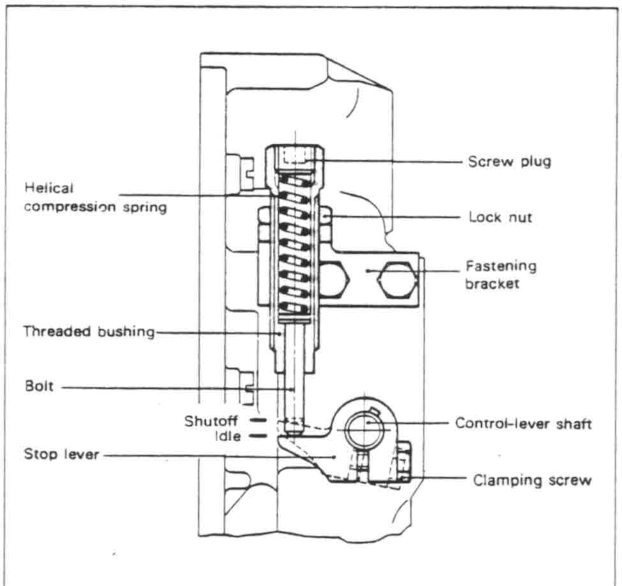
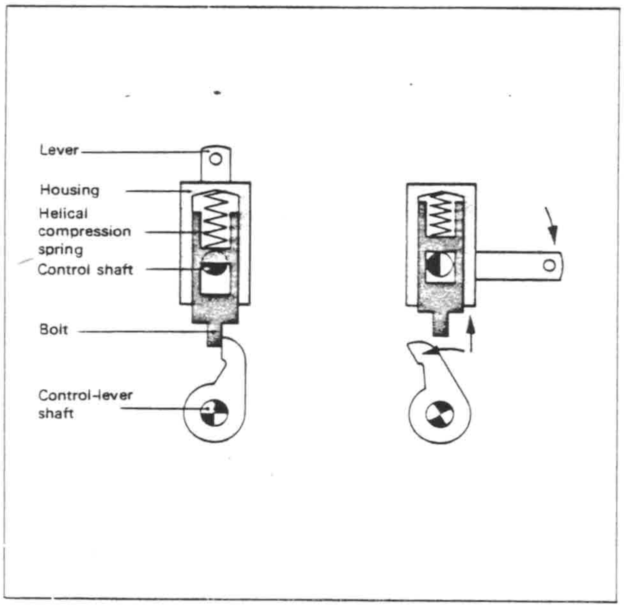


Fig. 82 Reduced-delivery stop, operation shown schematically.



The schematic cross-sectional drawing shows a spring-loaded bolt which can be shifted in the housing by means of a shaft with a furrow. In one end position, the lever strikes against the bolt and limits the travel of the control lever.

In the other end position, the bolt releases the lever, and the control lever can reach its end position.

Control-Rod Stops

In addition to the stops for shutoff and for full-load delivery or maximum speed (parts required in every governor to define the control-lever travel), a special stop is required for the control rod which limits the travel of this rod at full-load or starting fuel delivery. Depending on the particular purpose and use, there are various designs of control-rod stop: rigid and spring-loaded designs, stops for the full-load delivery with mechanical or electromagnetic unlocking for the starting fuel delivery, as well as stops with a built-in torque-control mechanism. In addition, there are full-load stops designed to carry out special compensation functions. Control-rod stops are produced for mounting on the fuel injection pump or on the governor. Some of the designs intended for mounting on the governor will be described in detail below.

Fig. 83 Rigid control-rod stop for RQ governors to limit the starting fuel delivery.

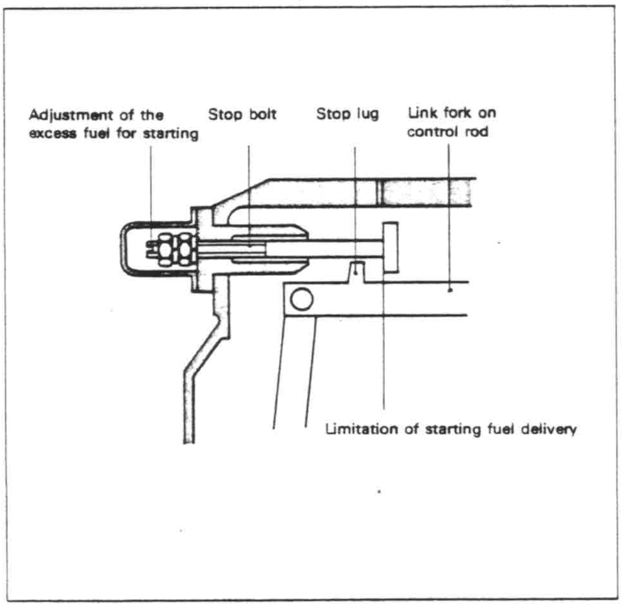
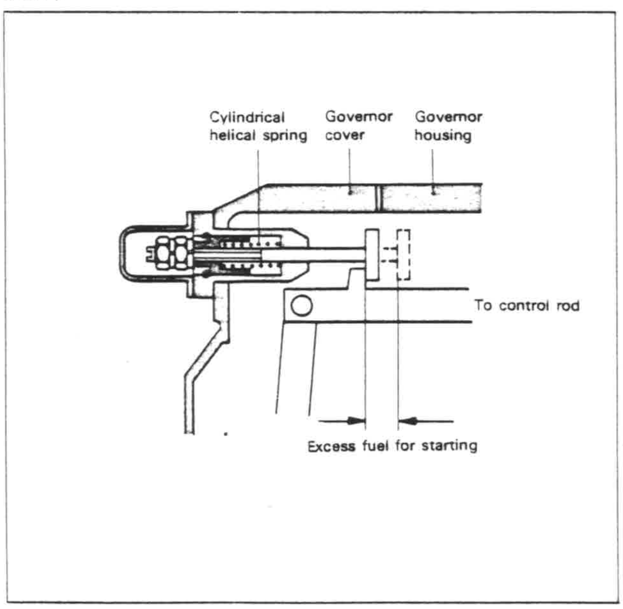


Fig. 84 Spring-loaded control-rod stop for RQ governors to limit the starting fuel delivery.



Rigid Excess-Fuel Stop for Starting

The rigid stop for starting fuel delivery is used mainly in RQ governors with a low idle speed. When the engine is running, the excess fuel for starting is withdrawn through the governor and cannot have a damaging effect (such as would be caused by the development of smoke).

Spring-Loaded Control-Rod Stop for RQ Governors

If the accelerator pedal is pressed all the way down during the starting process, the stop bolt moves against the resistance of the spring to the set starting-fuel-delivery position. The spring built into the stop acts against the idle-speed spring and thus causes an early shift of the control rod back from the start position. This prevents occurrence of a brief interim period of starting fuel delivery if the engine is accelerated rapidly from idling.

Automatic Full-Load Control-Rod Stop

When the engine is at rest, the flyweight governor springs, acting through the sliding bolt, press on the rocker-arm spring, and as a result the rocker arm forces the stop strap with the full-load stop lug downward (arrows).

Therefore, when the engine is started, the control rod can be shifted to the start position when the accelerator pedal is pressed down (Fig. 85, upper drawing).

After the engine has been started, the sliding bolt moves away from the rocker arm under the influence of centrifugal force. For the same reason, the control rod moves back from the starting-fuel-delivery position to a position of smaller delivery. As a result, the rocker-arm spring presses the rocker arm with its long lever arm upward, and the lug on the stop strap again limits the travel of the control rod at the stop piece on the link fork to the full-load delivery (lower drawing).

Control-Rod Stop with External Torque-Control Mechanism (for RQV Governors)

The control-rod stop with a draw lever for the starting fuel delivery and with torque control is used with RQV governors. When the control-rod travel is limited to the full-load delivery, the adjusting screw is positoned against the edge of the locking bolt. When the draw lever is pulled, this locking bolt is turned 90°. As a result, the control rod can shift toward the starting position by the dimension of the milled section on the locking bolt (release of the excess fuel for starting).

Torque control takes place as a result of the interaction between the drag spring in the governor and the torque-control spring; these two springs must be matched exactly to each other for this purpose (Fig. 86).

If a higher speed is set at the control lever, the drag spring is tensioned for the duration of the acceleration—

Fig. 85 Automatic full-load control-rod stop for RQ governors. Upper drawing: release of starting fuel delivery; lower drawing: limitation to full-load delivery.

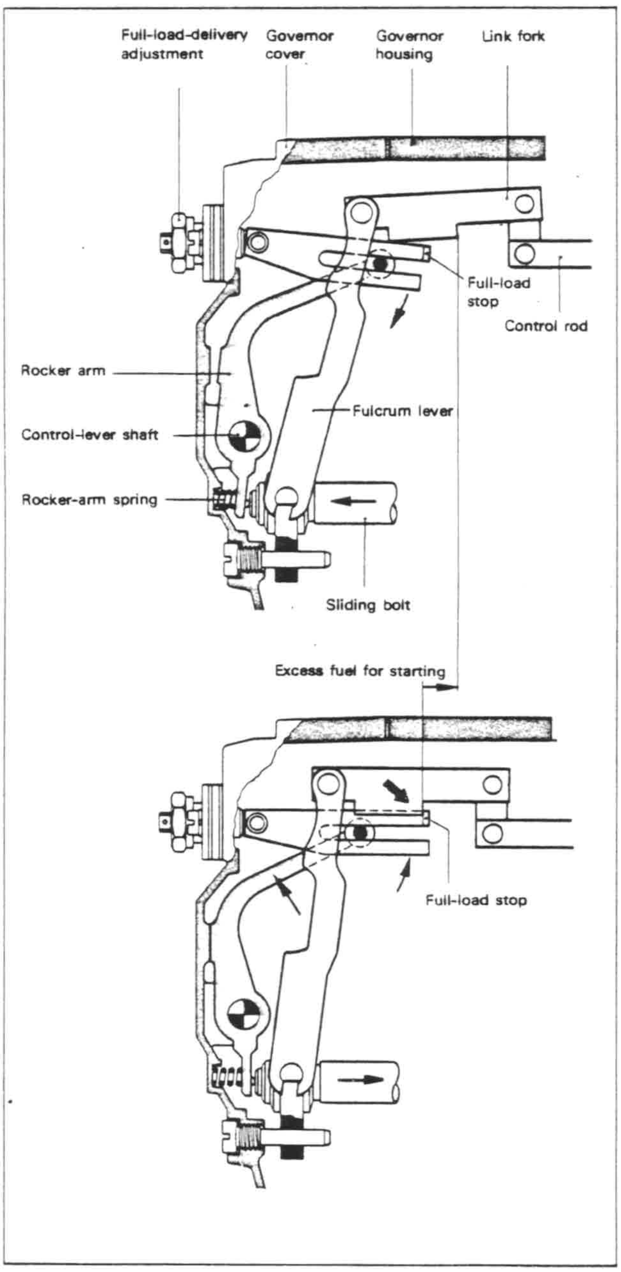
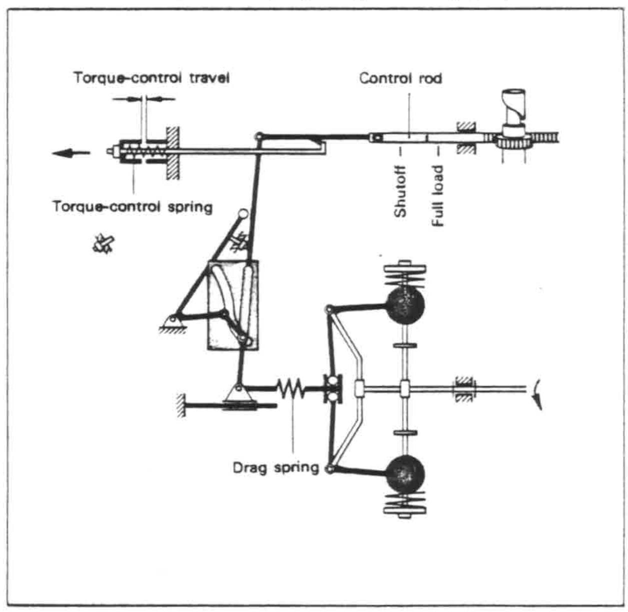


Fig. 86 Schematic drawing of the control-rod stop with torque-control mechanism (RQV), torque-control spring stronger than drag spring.

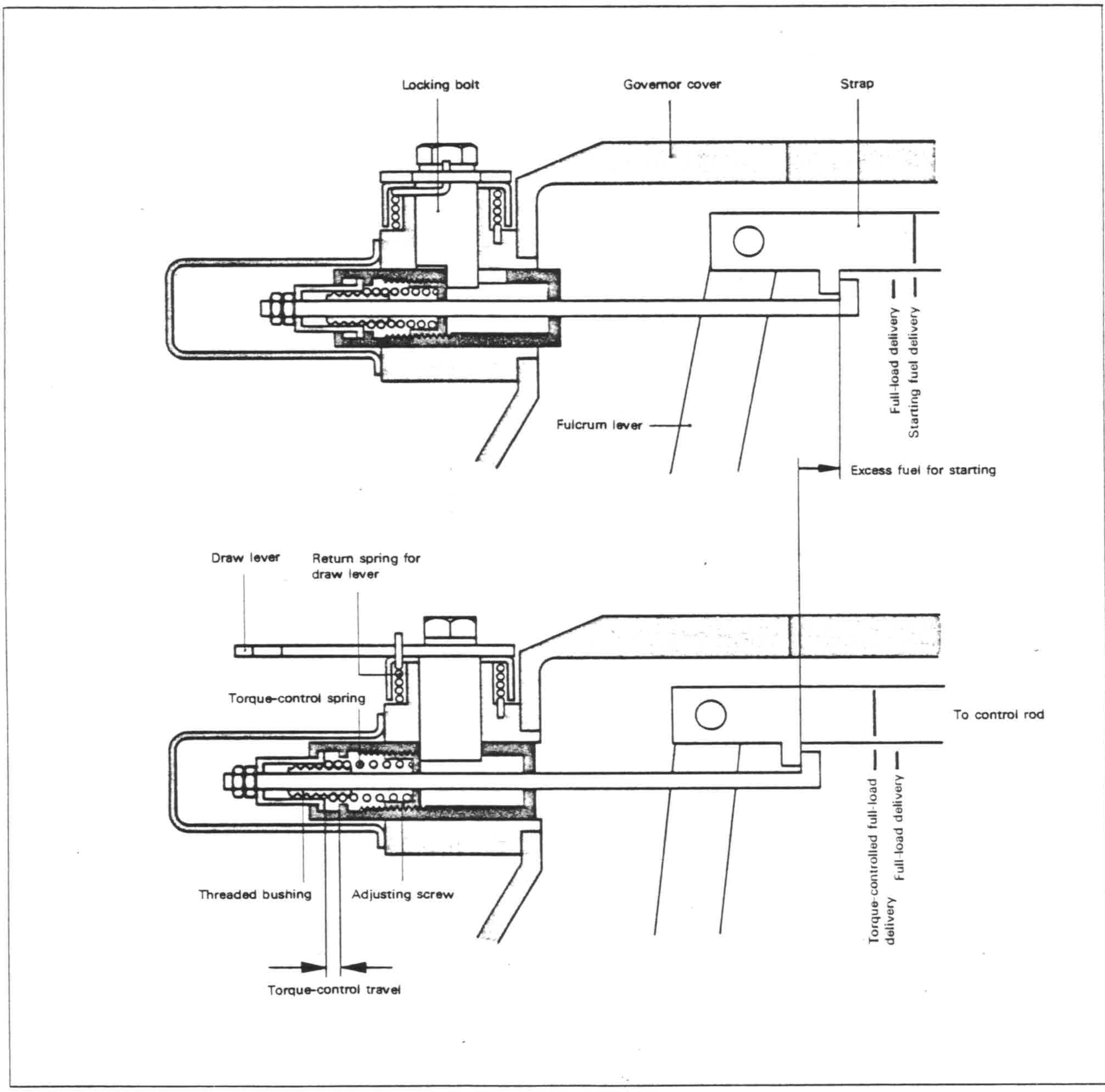


as a result, the torque-control spring is also compressed and sets a greater control-rod travel. As the speed increases, the flyweights move outward and the drag spring is relaxed. The force of the torque-control spring is now stronger, so this spring shifts the control rod in the direction of smaller fuel delivery.

Adjustment of torque control

The start of torque control (speed n_1) can be set by varying the initial tension of the torque-control spring. This initial tension of the torque-control spring is varied with the adjusting screw. The torque-control spring is screwed onto a threaded bushing by one or more thread turns, and the torque-control characteristic can be varied by turning this bushing to change the number of threads holding the spring. The torque-control travel is set by using shims of different thicknesses.

Fig. 87 Control-rod stop for RQV governors with draw lever for starting fuel delivery and with torque-control mechanism. Upper drawing: starting-fuel-delivery position; lower drawing: full-load-delivery position with torque control.



Control-Rod Stop with Internal Torque-Control Mechanism (for RQV Governors)

In those cases where there is not enough room available for installation of the control-rod stop for RQV governors with external torque control, the control-rod stop with internal torque control can be used. The installed length of this control-rod stop is less than a quarter of the installed length of the stop with external torque control.

When the engine accelerates, the control rod is shifted in the maximum-fuel-delivery direction by the fulcrum lever acting through the strap (Fig. 89). At the same time the drag spring in the sliding bolt is tensioned, the stop bolt is brought up against the full-load stop, and the torque-control spring is compressed through the rocker (start of torque control). When the flyweights move outward as the speed increases, the drag spring relaxes again. Starting at a certain speed, the force of the torque-control spring overcomes the force of the drag spring and the torque-control spring relaxes. As a result, the rocker turns and the stop bolt positioned at the full-load stop pulls the control rod in the shutoff direction until it reaches the other end of the torque-control path. The rocker is then positioned against its upper stop (end of torque control).

Manifold-Pressure Compensator (LDA)

In pressure-charged engines the full-load delivery is determined in accordance with the charge-air pressure. In the lower speed range, however, the charge-air pressure is lower, and therefore the weight of the air charge in the engine cylinders is also lower. For this reason, the full-load delivery must be matched in a corresponding ratio to the reduced weight of the air. This function is carried out by the manifold-pressure compensator (abbreviated LDA) which reduces the full-load delivery in the lower speed range starting from a certain (selectable) charge-air pressure. Various designs of the LDA are produced for mounting on fuel-injection pumps and on either the side or the top of governors. The description below refers to an LDA designed for mounting on the RSV governor.

The construction of all these special control-rod stops is basically identical. Between the housing bolted onto the top of the governor and a suitable cover is a diaphragm that is tensioned and air-tight. A connector fitting for the charge-air pressure is located in the cover. From below, a helical compression spring acts on the diaphragm; this spring is supported at its other end on a guide bushing attached to the housing by means of a thread. The initial tension of this spring can therefore be changed within certain limits.

Fig. 88 Partial drawings of the RQV governor with external torque-control mechanism (above) and internal torque-control mechanism (below).

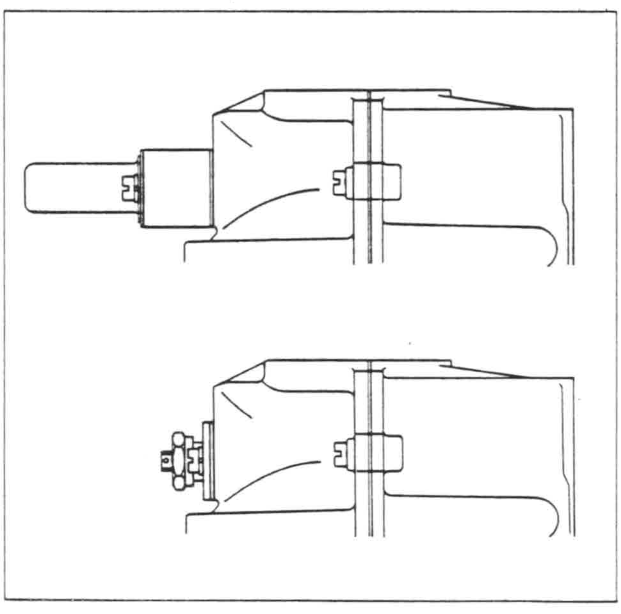
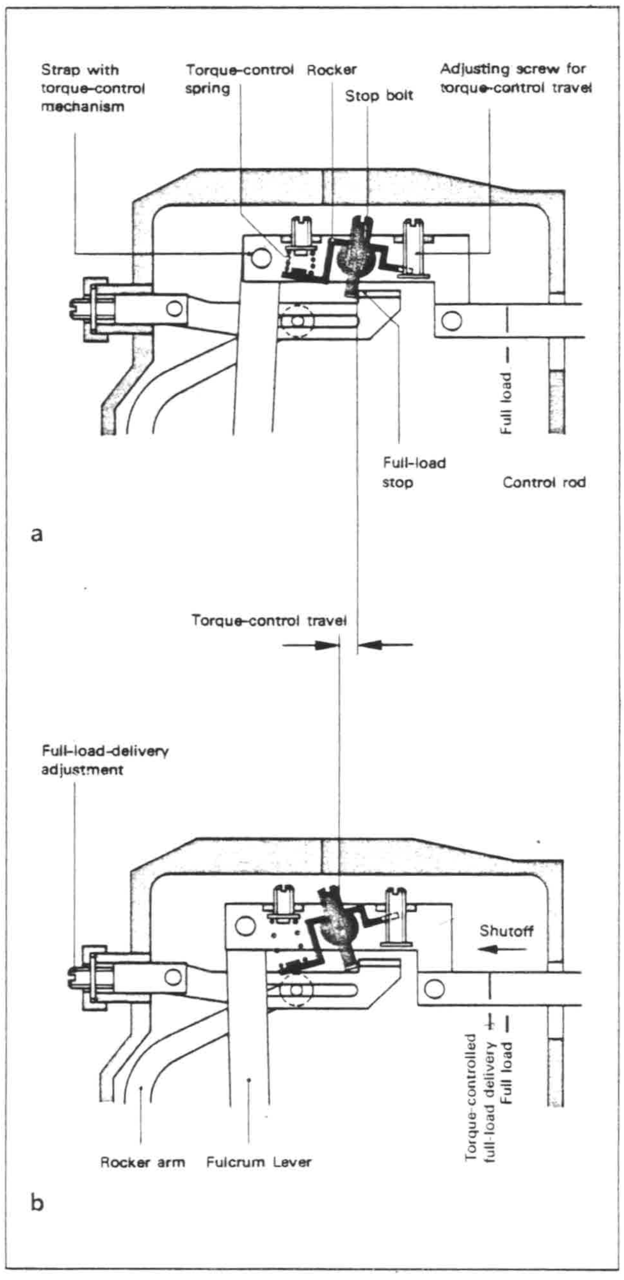


Fig. 89 RQV governor with internal torque-control mechanism; a: start of torque control; b: end of torque control.



A threaded pin is attached to the diaphragm through a plate washer and a guide washer; at the lower end of this pin, which projects out of the housing, a screw with a lock nut is attached. The head of this screw is set to a certain distance from the housing surface and transmits the movement of the threaded pin through a bell crank to the control rod. This distance is preset, but after the LDA has been mounted corrections can be made with the headless setscrew.

If charge-air pressure is applied to the diaphragm, the threaded pin moves against the force of the helical compression spring, travelling the greatest distance at the full charge-air pressure. Movement of the threaded pin is transmitted through the bell crank, which is supported in the governor housing on an axle so that it can turn, to the strap attached to the fuel-injection-pump control rod. As the charge-air pressure decreases, the control rod is moved in the shutoff direction.

In order to permit the control rod to be moved into the starting-fuel-delivery position when the engine is started, the bell crank can be disengaged from the strap by lateral movement of the control shaft. This can be done manually either with a control cable or through a linkage system; governor designs also exist, however, with electromagnetic activation of the control shaft; in these designs, the electromagnet takes effect only during starting.

Altitude-Pressure Compensator (ADA)

In countries or regions where road traffic is subject to extremely wide variations in altitude, the amount of fuel injected into the engine must be matched to the worsening air charge in the engine cylinders from a certain altitude upward. This function is carried out by the altitude-pressure compensator (ADA), see Fig. 93.

The ADA is used in conjunction with mechanical governors RQ or RQV and is mounted on the governor cover.

Fig. 90 Cross-sectional drawing of the manifold-pressure compensator (LDA).

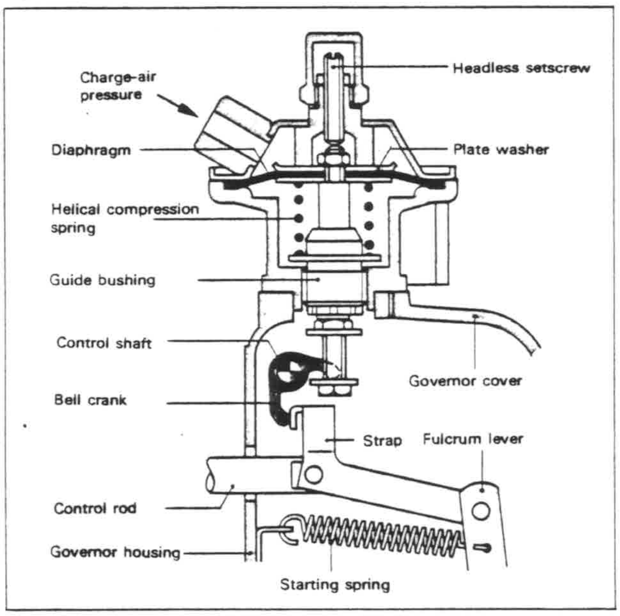


Fig. 92 LDA; left: operating position; right: start position of the strap with respect to the bell crank.

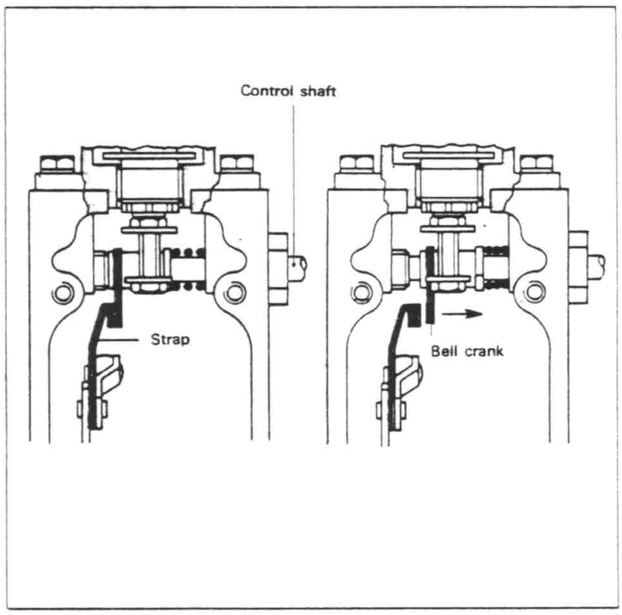


Fig. 91 Effect of the LDA on the control-rod travel.

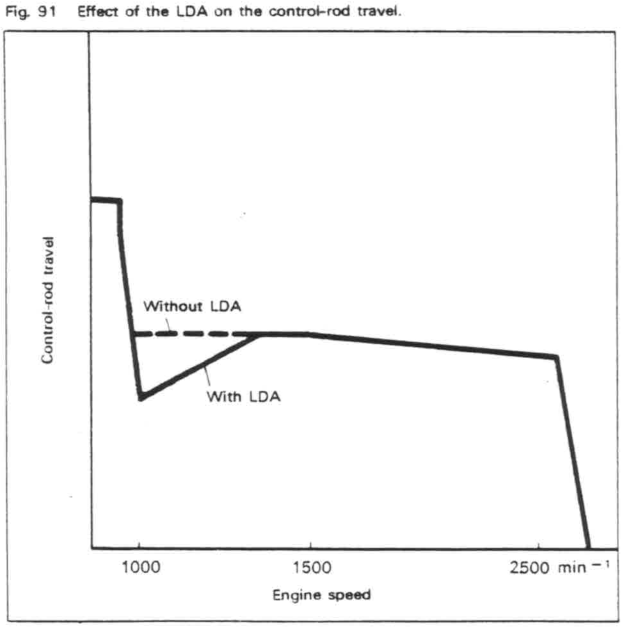
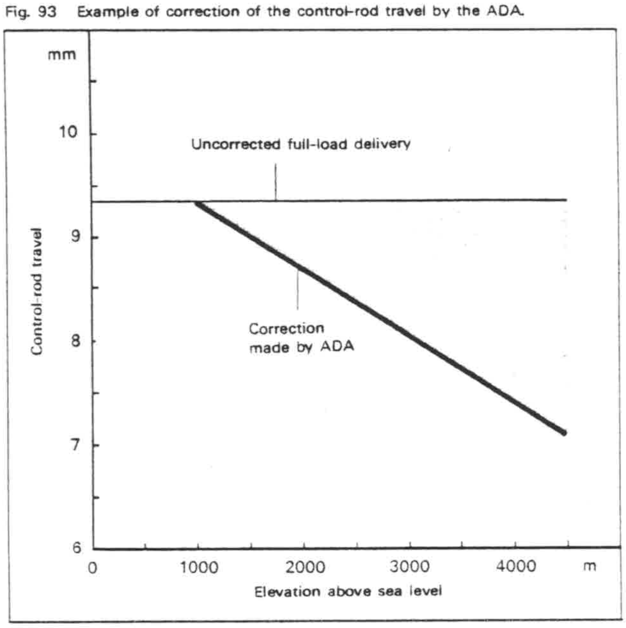


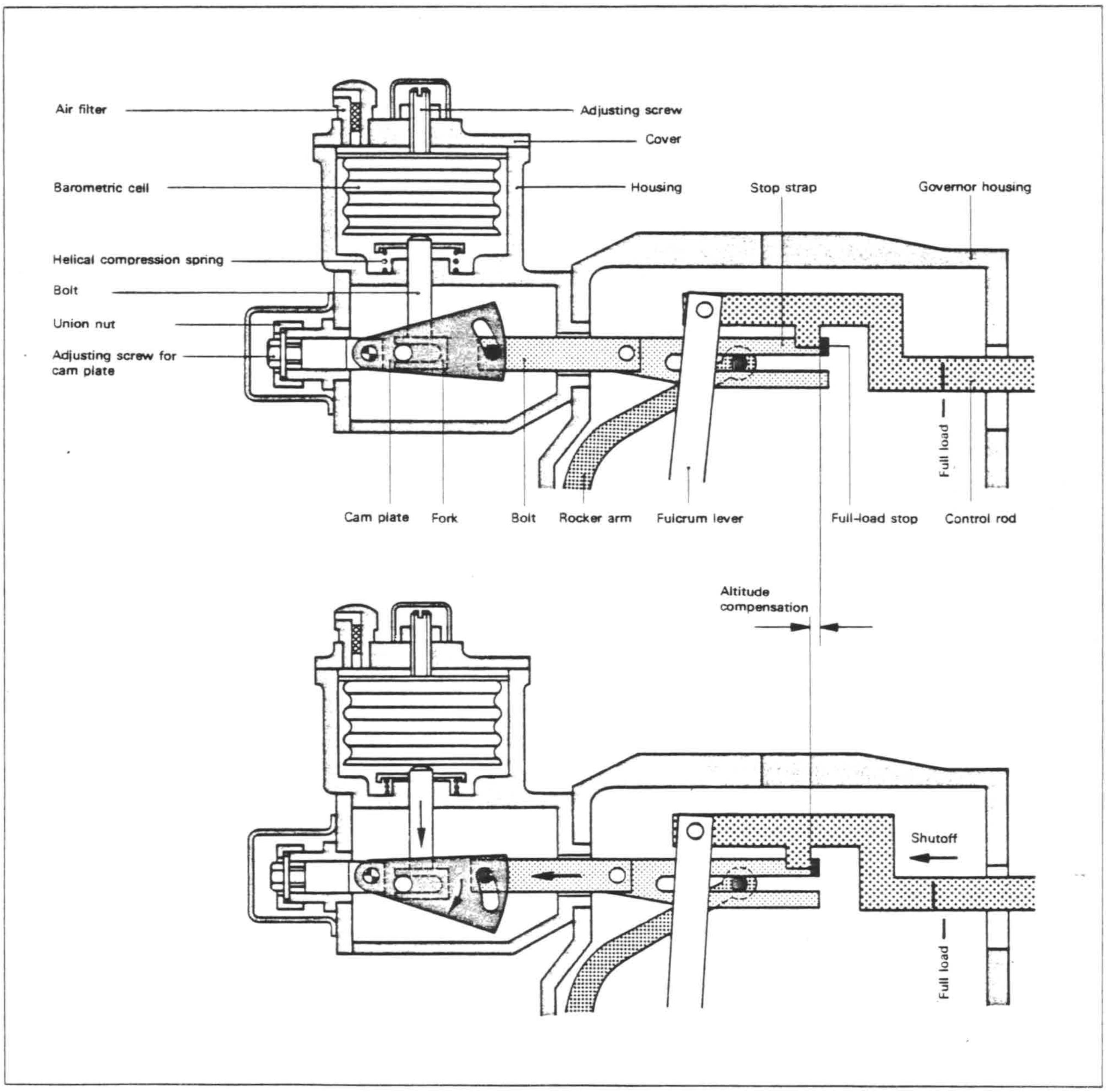
Fig. 93 Example of correction of the control-rod travel by the ADA.



Basically, the ADA consists of an aneroid capsule installed vertically in a housing, and which can be set to a certain altitude by means of an adjusting screw and an opposing spring-loaded threaded bolt. Within the effective range of the aneroid capsule the length of the cell increases as the air pressure decreases. The spring-loaded threaded bolt at the bottom of the aneroid capsule and the fork attached to the threaded bolt transmit the changes in length to the swivel-mounted cam plate. This cam plate acts on the bolt which is connected to the fuel-injection-pump control rod.

As the aneroid capsule expands, the cam plate swings downward. The bolt connected with the stop strap pulls the control rod in the shutoff direction and the fuel delivery decreases; if the length of the aneroid capsule shortens, the amount of fuel delivered increases. In order to adjust the full-load delivery, the cam plate is adjustable in the horizontal plane by means of a screw.

Fig. 94 Altitude-pressure compensator (ADA). Upper drawing: normal position; lower drawing: operating position at low air pressure.



Electric Speed-Control Device

Use

Electric speed-control devices are used for remote-controlled adjustment of the speeds of engines used with assemblies of equipment.

Various mounting parts are required to attach such a device to a fuel-injection-pump governor; the exact choice of mounting parts will depend on the type of governor concerned.

Design

The electric speed-control device is fitted with a base plate on which is mounted a 24-volt reluctance motor; this motor is connected through a clutch with a threaded spindle which can move a threaded nut back and forth in guide rails depending on the direction of motor rotation. The governor control lever is attached to the threaded nut by a positive mechanical connection developed either by a torsion spring mounted on the governor-control-lever shaft (RQV and RQUV governors) or by a tension spring attached to the control lever. The spring forces the control lever in the full-load direction in the RQV and RQUV, and in the shutoff direction in the RSV and RSUV governors. The motor and the adjustment spindle are joined by a releasable clutch fitted with overload protection. When the motor clutch has been released, the adjustable spindle can be turned by the handwheel.

The adjustment travel is restricted by electric limit switches in both directions.

In order to stop the diesel engine, the governor control lever is drawn to the shutoff position. The shutoff stop is adjusted in similar fashion to the full-load stop on the governor cover. Two models of the electric speed-control device are produced: one for left-hand mounting (see drawing) and one for right-hand mounting.

Fig. 95 Electric speed-control device, model designed for l.h. mounting.

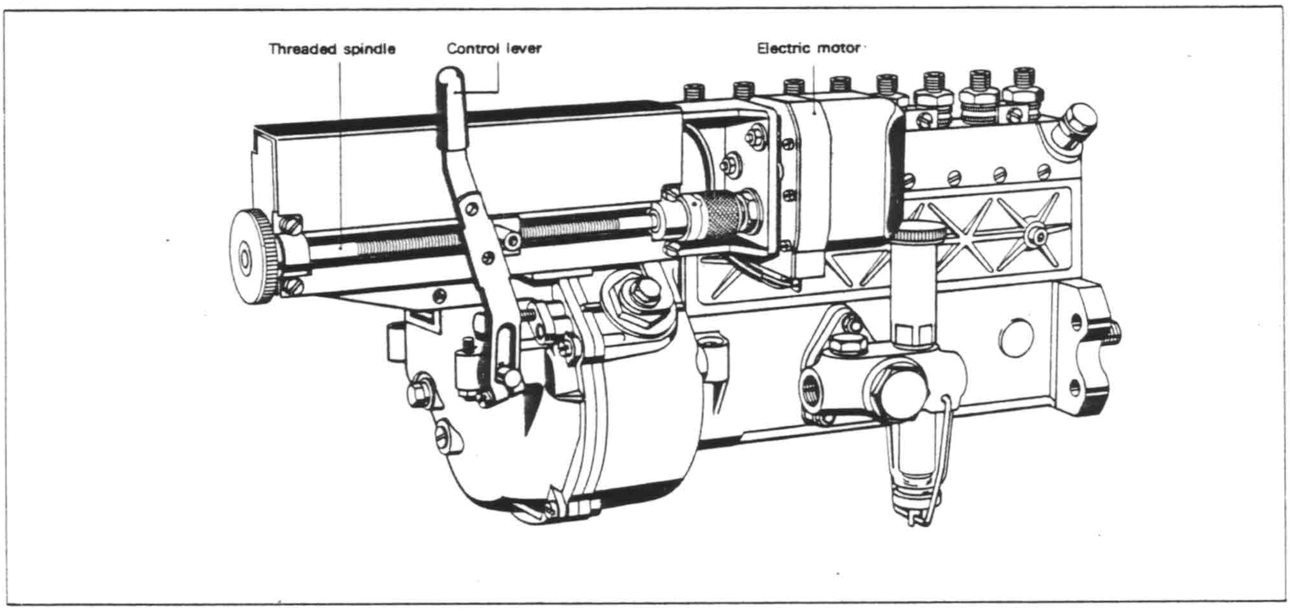


Fig. 96 Speed-control device for RQV.

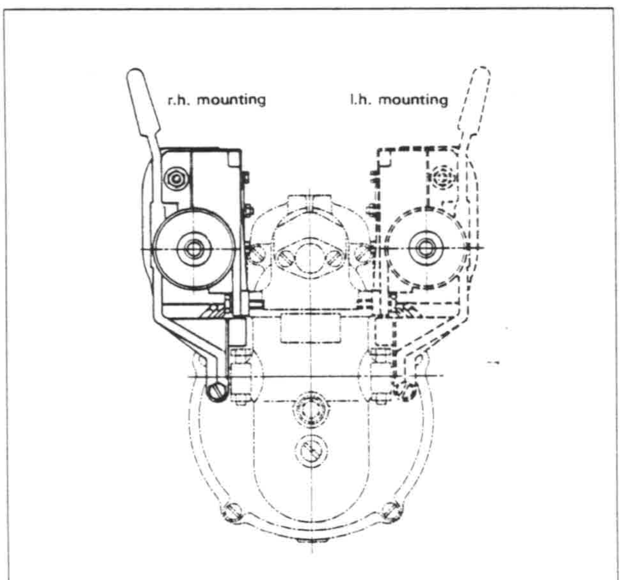
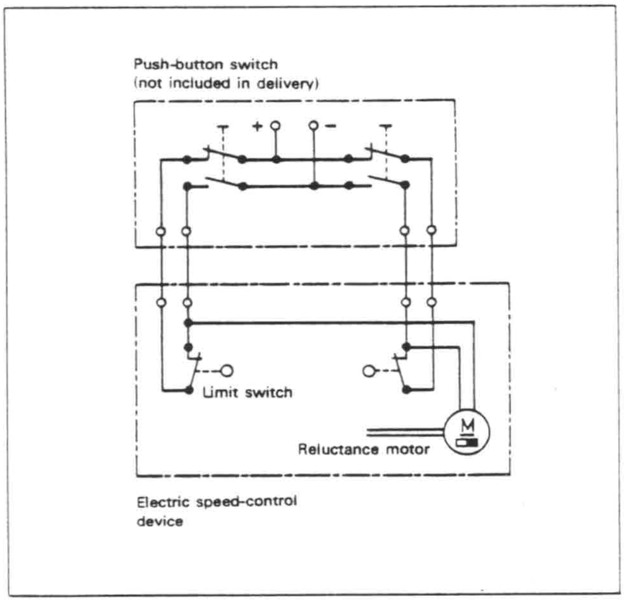


Fig. 97 Wiring diagram of a speed-control device.



Pneumatic Governor

Variable-Speed Governor EP/M

Operating Principle

The pneumatic governor consists of two main parts:

- the venturi assembly fastened to the engine intake manifold on the inlet side, and
- the diaphragm block mounted on the fuel injection pump.

Air drawn into the engine flows through the air filter and then through the venturi-shaped channel in the venturi assembly. At the narrowest point in this channel are a throttle valve and the connector fitting for the vacuum line leading to the diaphragm block. The throttle valve is connected with the accelerator pedal through the control lever and the linkage system.

Depending on the position of the throttle valve, the vacuum necessary for regulation is set (at full-load about 400 mm water column) at a lower, medium, or higher speed. The diameter of the venturi channel must be so chosen that when the throttle valve is completely open the required nominal speed can still be reached without bother. A stop screw serves to set the nominal speed accurately (limitation of the throttle valve opening).

Pneumatic governors are used mainly in automobiles and agricultural tractors. The purpose of the auxiliary venturi at the point where the vacuum is taken is to ensure that if the engine should start to operate in the reverse direction it does not run out of control, i.e., that it can be stopped.

A diaphragm, connected with the fuel-injection-pump control rod through a linkage system, divides the diaphragm block into two chambers:

- the vacuum chamber (connected by a hose or pipe with the venturi assembly) in which the governor spring tends to shift the diaphragm, and thus the control rod, in the maximum fuel direction, and
- the atmospheric chamber which is connected with the outside air.

When the engine is operating, the position of the diaphragm, and consequently the position of the control rod as well, depends on the magnitude of the difference between the pressures prevailing on the two sides of the diaphragm and developed by the engine loading at a particular time. This is because the engine speed rises or falls respectively if the load on the engine is increased or decreased at a certain position of the throttle valve. This results in the differing pressures in the vacuum chamber. If the initial tension of the governor spring is greater than the vacuum acting on the diaphragm, the control rod is shifted in the direction of increased fuel delivery. If the vacuum increases, the diaphragm is moved by the effect of the atmospheric air pressure against the spring pressure, and the control rod is shifted in the shutoff direction.

Speed regulation starts when the engine reaches that speed at which the vacuum is able to overcome the pressure exerted by the governor spring, or vice versa. The pneumatic governor is effective from the idle speed to the maximum speed.

Fig. 98 Vacuum in the vacuum chamber at various speeds and positions of the throttle valve.

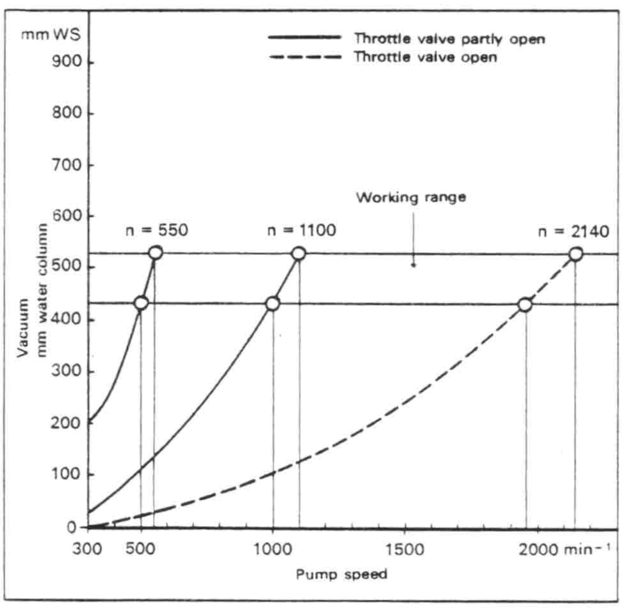
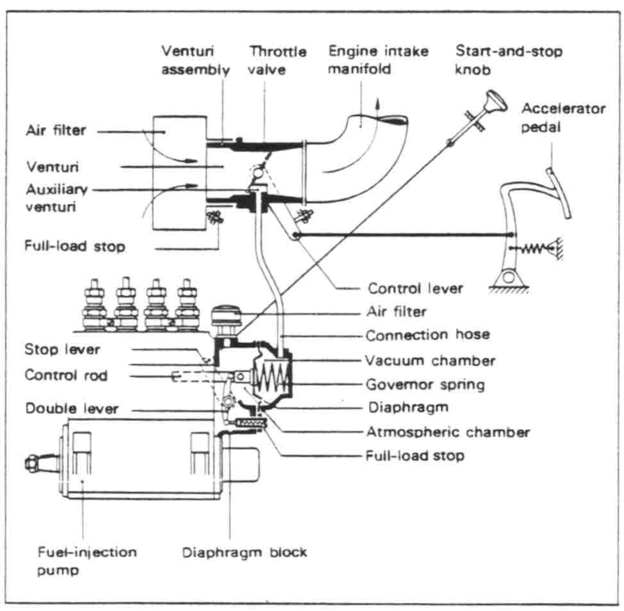


Fig. 99 Schematic drawing of the pneumatic governor (rest position).



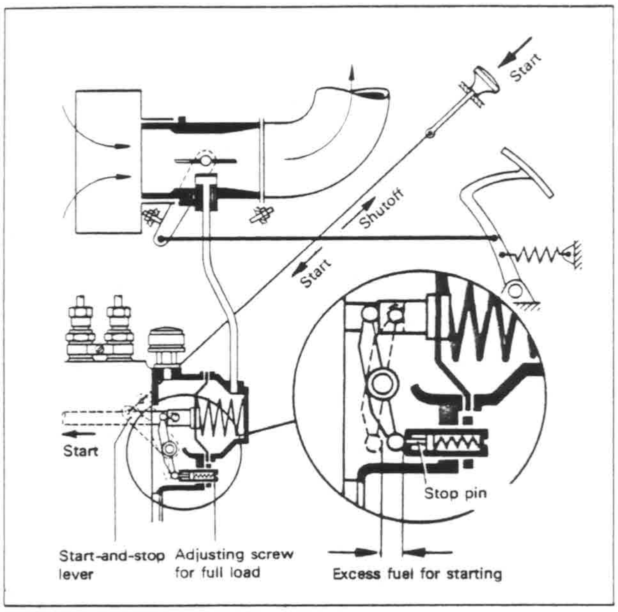


Fig. 100 Diaphragm block in pneumatic governor with built-in control-rod stops for full load and for the excess fuel for starting.

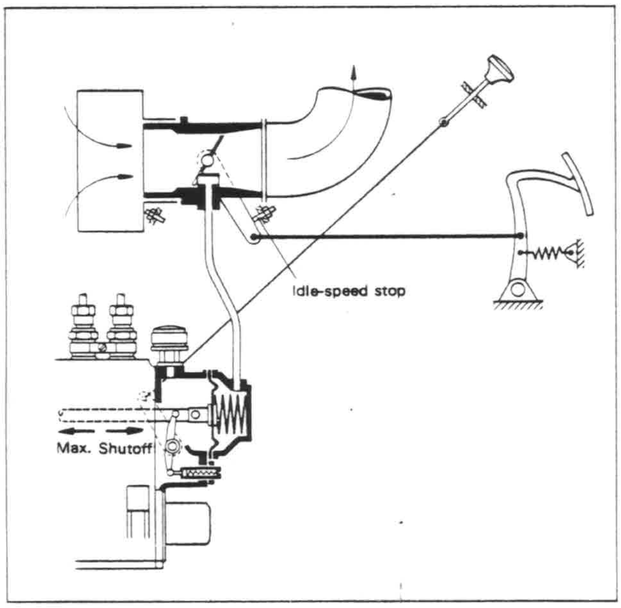
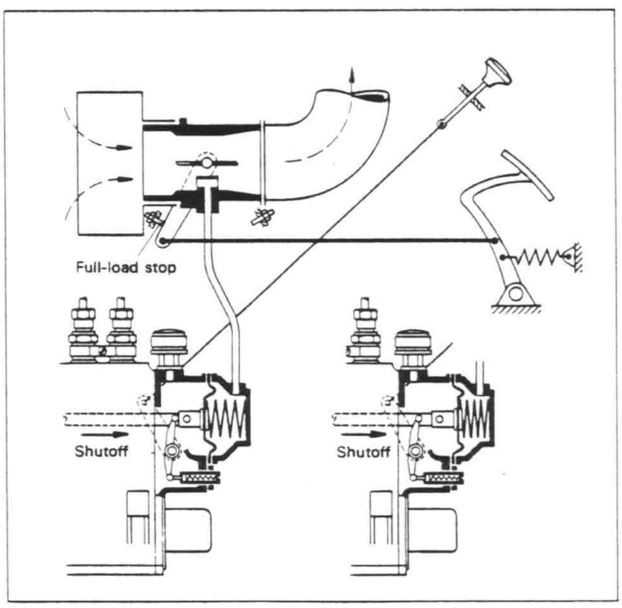


Fig. 101 Idle position.



Operating Characteristics

Starting the engine (Fig. 100)

A stop for excess-fuel delivery during starting is built into the diaphragm block; it can be adjusted by means of a thread.

In order to start the engine, the start-and-stop lever is moved in the start direction. As a result, a spring-loaded stop pin is pressed into the adjusting screw by the two-armed lever (double lever), and the governor spring can shift the diaphragm, and thus the control rod, in the maximum-fuel-delivery direction. More fuel is therefore fed to the engine during starting than at full load.

In the idle-speed range of the engine (Fig. 101)

When the engine is idling, the control lever at the throttle valve is positioned against the adjustable idle stop, and the venturi channel is almost completely closed. Even at the idle speed, a vacuum is developed in the vacuum chamber which is sufficient to draw the control rod, against the pressure of the governor spring, into its idle position. If the load on the engine is reduced, the engine accelerates and the vacuum therefore increases. As a result, the diaphragm shifts the control rod still farther in the shutoff direction and the engine runs more slowly again. If, on the other hand, the load on the engine is increased, the engine is slowed down and the vacuum decreases; the governor spring therefore shifts the control rod in the maximum-fuel-delivery direction and the engine runs faster again. In other words, the governor limits the idle speed in both an upward and downward direction, i.e., it regulates the idle speed.

In the top speed range of the engine (Fig. 102)

(Full-load speed regulation)

If the driver wants to bring the engine up to the nominal speed (full output power) he must press the accelerator pedal all the way down. The control lever at the throttle valve is then brought up against its (adjustable) full-load stop and the throttle valve itself is completely open. Initially, only a slight vacuum prevails in the vacuum chamber, and the vacuum required to regulate the maximum speed is only developed at the nominal speed. When the nominal speed is exceeded, the control rod moves away from its full-load stop and is shifted in the shutoff direction until the amount of fuel delivered has become so small that the high idle speed can no longer be exceeded.

Between the idle speed and the maximum speed

The pneumatic governor also maintains—just as a mechanical variable-speed governor does—every speed between the idle speed and the maximum speed constant within the limits of the speed droop. The farther the accelerator pedal (and thus the throttle valve) is shifted in the maximum-fuel-delivery direction, the higher the engine speed rises.

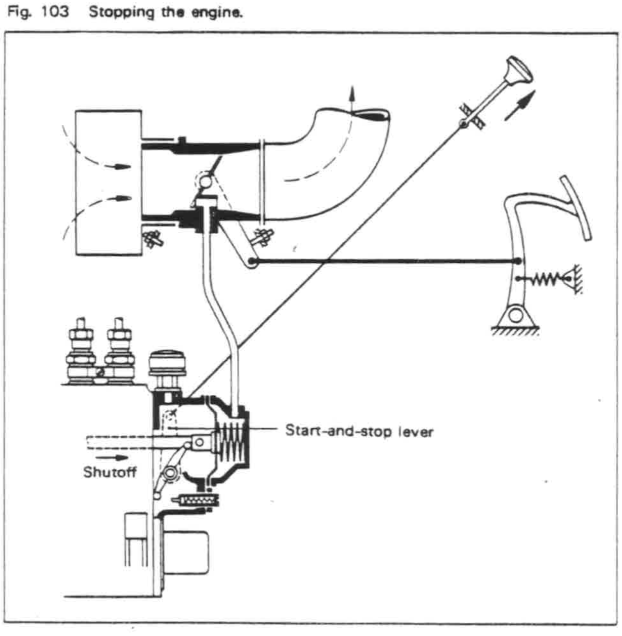
Fig. 102 Full-load speed regulation.
Left: nominal speed, full load; right: high idle speed.

Stopping the engine (Fig. 103)
The stop lever at the diaphragm block can be connected to a draw knob or a shutoff device which is combined with the glow-plug-and-starter switch. When the engine is stopped, the double lever connected to the stop lever forces the control rod to shutoff. Delivery of fuel is thus cut off and the engine stops (for an exception to this see "Reverse operation of the engine" immediately below).

Reverse operation of the engine
In most cases, the engine manufacturer installs, as a standard feature, some method of protecting the engine against starting to operate in the reverse direction. However, cases can arise where engines without this protection that have warmed up (especially prechamber engines) start to operate in the reverse direction, for example as a result of a recoil during starting or if the vehicle rolls backward down a slope. In such a case the pneumatic governor does not operate correctly because when an engine runs in the reverse direction the intake line becomes the exhaust. Since the throttle valve is only slightly opened during idling, the exhaust gases would now accumulate in the intake line. However, an overpressure in the intake line means that an overpressure also develops in the governor vacuum chamber. No suction forces then act on the diaphragm, but instead pressure forces act on it. Assisted by the governor spring, the control rod is therefore shifted very strongly in the maximum-fuel-delivery direction. The result of these actions is that the engine accelerates rapidly and tends to run out of control; under these conditions the engine cannot be stopped even with the stop draw knob because of the large counteracting forces.

In order to prevent the accumulation of exhaust gases in the intake line in such a case, an auxiliary venturi is built into the venturi assembly at the connection point where the vacuum is transmitted to the governor. This auxiliary venturi bypasses the throttle valve so that even when the throttle valve is closed the exhaust gases can escape during reverse operation of the engine. If, however, the throttle valve is opened briefly during reverse operation of the engine, the engine tends to run out of control even if the throttle valve is immediately closed again.

Fig. 103 Stopping the engine.



An engine that starts to operate in the reverse direction, recognizable by development of dense smoke from under the vehicle hood, must be stopped immediately because otherwise damage can be caused to bearings as a result of inadequate lubrication, and the air filter can burn up. The most effective and reliable method to stop the engine quickly in this case is to engage a gear (preferably third or fourth), press the brake pedal down as far as it will go, and then force the engine to come to a stop by releasing the clutch. Other possible methods of stopping the engine are to hold the exhaust pipe closed or to operate the shutoff device and at the same time press the accelerator pedal all the way down.

Speed droop in the pneumatic governor
In the pneumatic governor the speed droop is fairly uniform throughout the entire speed range. Speed droops common in motor vehicle engines range from 6 to 12%.

Fig. 104 Air flow in the venturi assembly during forward and reverse operation of the engine.

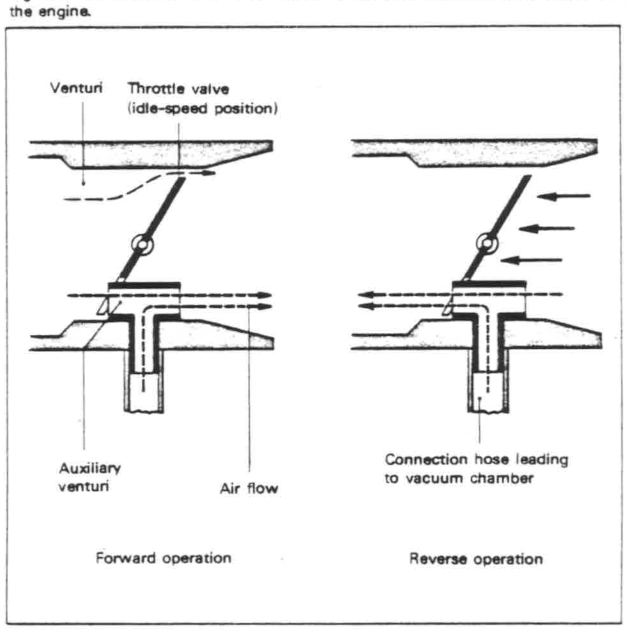
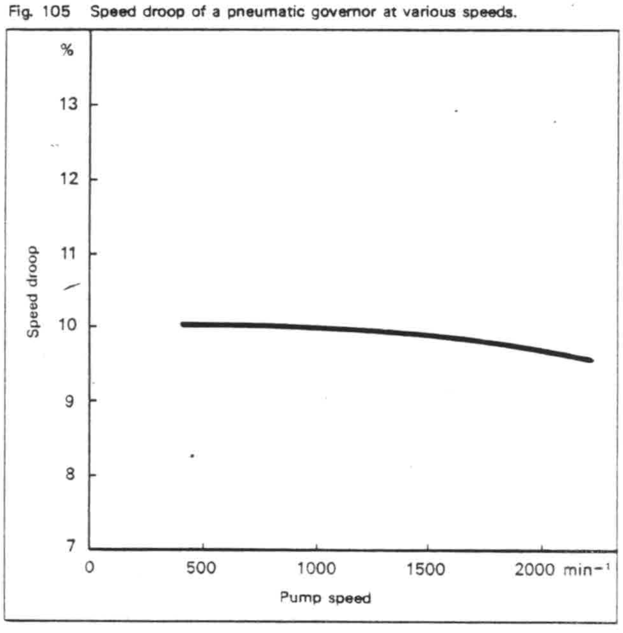


Fig. 105 Speed droop of a pneumatic governor at various speeds.



Special Designs

Diaphragm block with auxiliary idle-speed spring (spring capsule)

The auxiliary idle-speed spring operates only when the engine is idling. This spring is much stiffer than the maximum-speed control spring and serves to stabilize the idle speed. Figs. 108 and 109 below show a diaphragm block in which the auxiliary spring is automatically switched into operation by a cam during idling and switched off at full load. As a result, reliable speed regulation is achieved, for example during overrun.

Fig. 106 Schematic drawing of a pneumatic governor; diaphragm block with auxiliary idle-speed spring in the idle-speed adjusting screw.

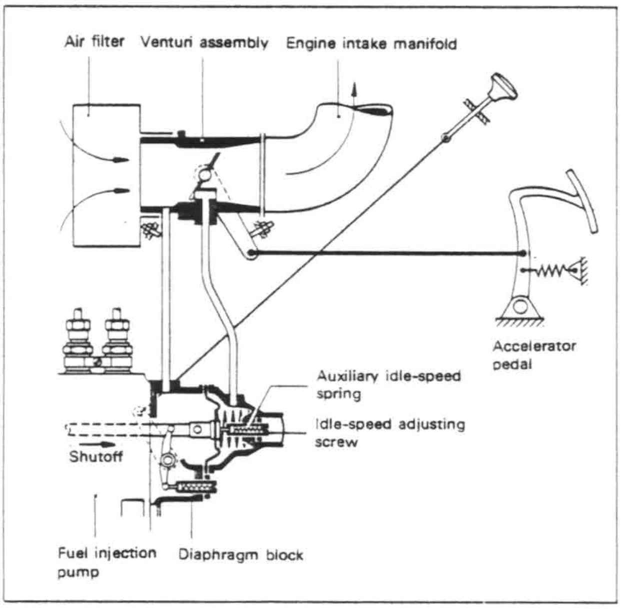


Fig. 108 Schematic drawing of a pneumatic governor; diaphragm block with auxiliary idle-speed spring and switching cam.

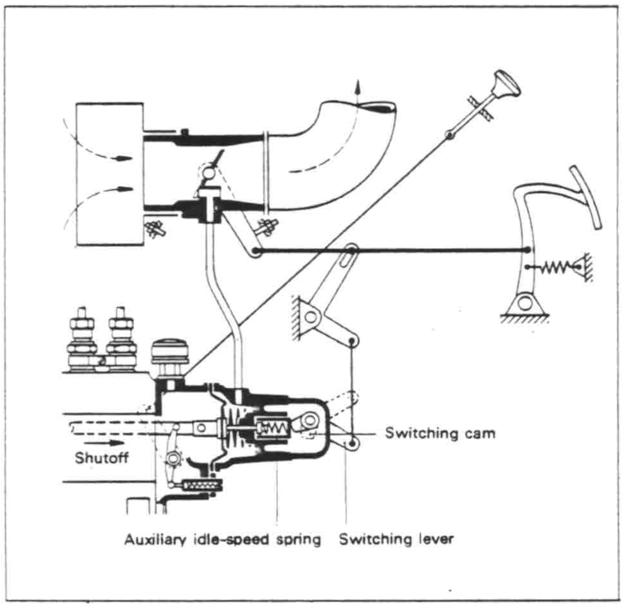


Fig. 107 Diaphragm block EP MZ 60 A (with auxiliary spring), adjusting screw inside, adjustable from outside.

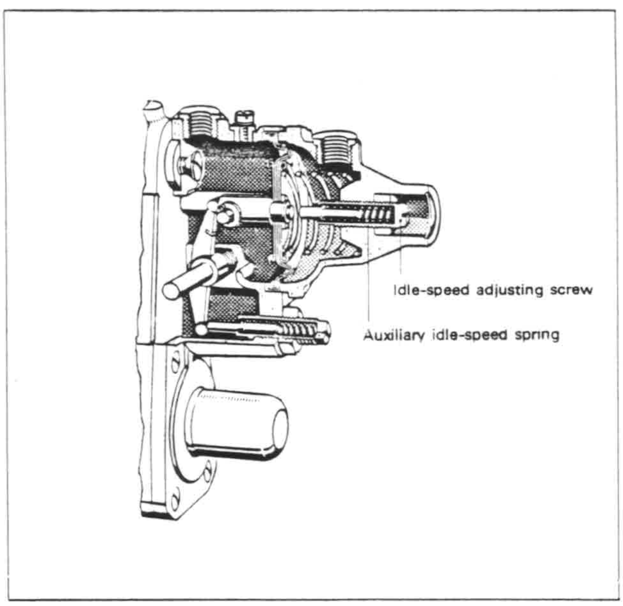
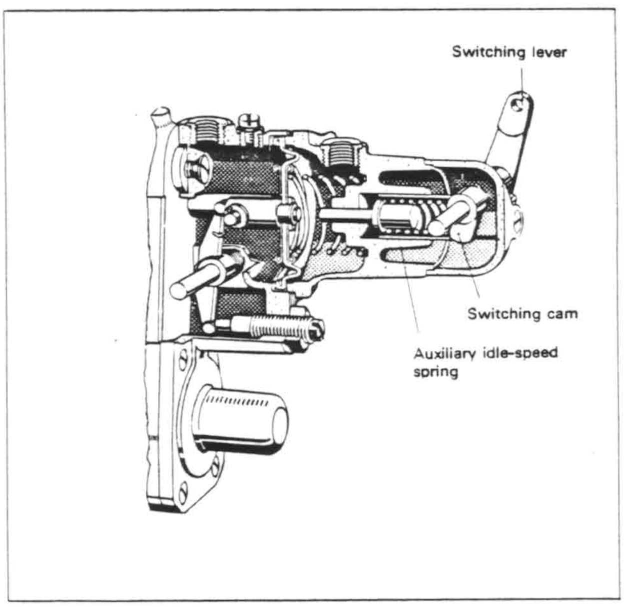


Fig. 109 Diaphragm block EP MN 60. . A with auxiliary idle-speed spring and switching cam.



Damping of fluctuations
In engines with four or fewer cylinders, excessive fluctuations in the vacuum can occur in the diaphragm block, causing irregular operation of the engine. In order to keep these fluctuations within bounds, a throttle is installed in the connection screw for the vacuum line at the diaphragm block (see Fig. 110).

In order to prevent any small diaphragm fluctuations which may still occur from being transmitted to the control rod, the control rod and the diaphragm bolt are not connected rigidly together. The connector bolt joining the control rod and the diaphragm is therefore not fixed in a hole but instead is positioned in a slot in the diaphragm bolt. The diaphragm bolt can thus move axially back and forth a certain distance without taking the control rod with it. This measure results in smoother operation of the engine (Fig. 111).

In order to damp noises during idling (in governors with an auxiliary idle-speed spring), the diaphragm bolt is fitted with a rubber damper on the vacuum side.

Fig. 110 Damping throttle in hose connection.

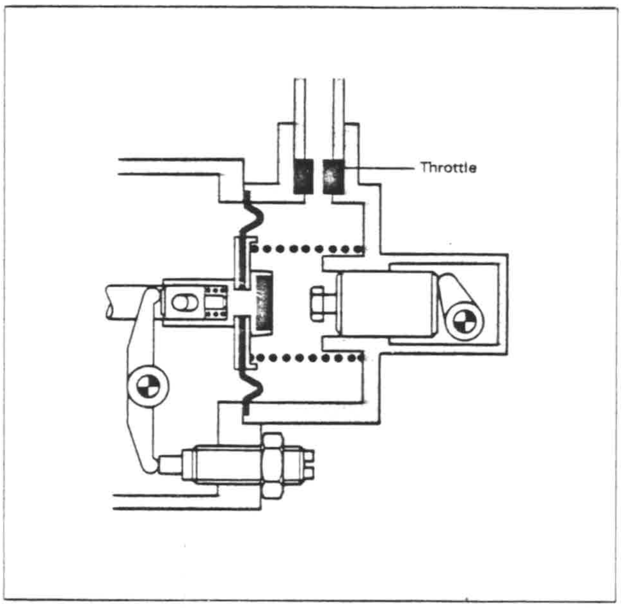


Fig. 112 Installation of auxiliary idle-speed spring.

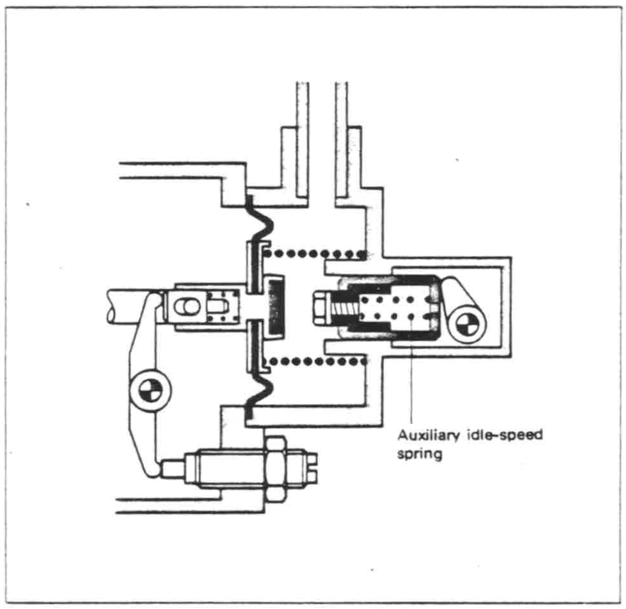
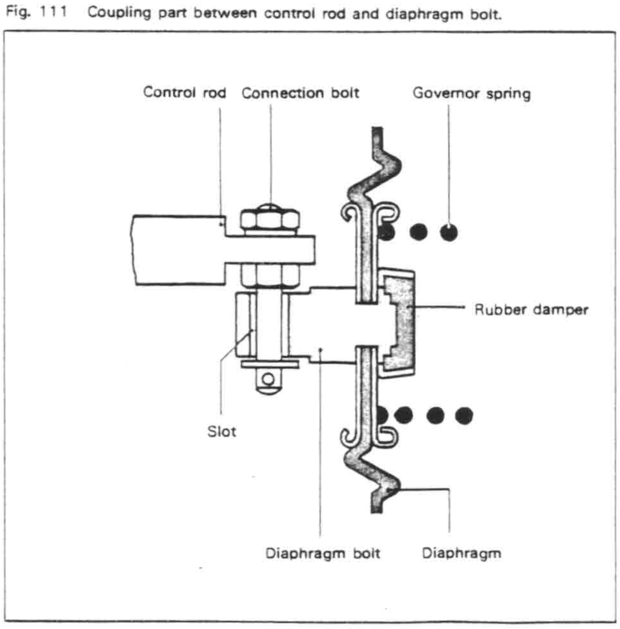
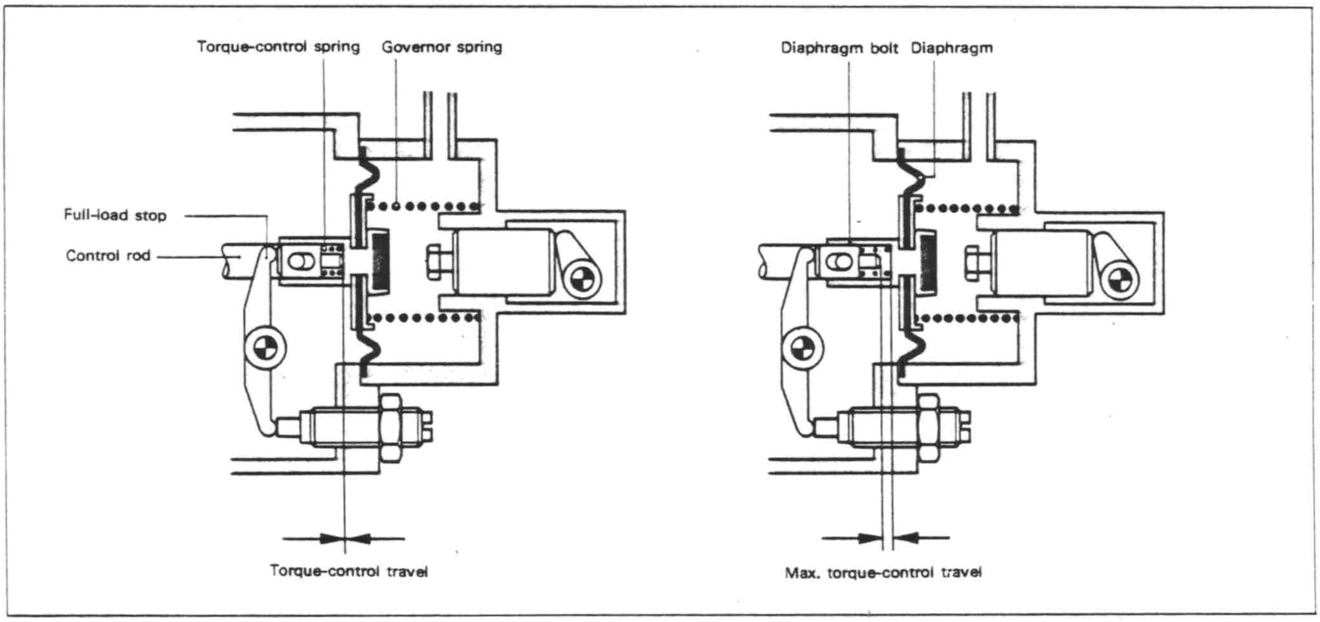


Fig. 111 Coupling part between control rod and diaphragm bolt.



Torque control with the pneumatic governor.
If the full engine power is required, the driver must press the accelerator pedal all the way down. As this is done, the butterfly (throttle) valve is fully opened and a slight overpressure develops in the vacuum chamber because of the relatively low speed. As a result, the governor spring presses the control rod against its full-load stop and the torque-control spring is compressed until the torque-control travel is 0, i.e., the control rod travels farther in the maximum-fuel-delivery direction by the amount of the torque-control travel. The engine reacts to the additional fuel by speeding up. The more the speed increases, the greater the vacuum becomes, and as a result the pressure exerted by the governor spring on the torque-control spring decreases. The torque-control spring begins to relax and shifts the diaphragm with the control rod in the shutoff direction by the amount of the torque-control travel.

Fig. 113 Pneumatic governor with torque-control mechanism.



Maintenance of Governors

Nearly all mechanical governors are supplied with lubricating oil from the fuel injection pump. In special cases, for example when a governor is installed in an inclined position, oil-sump lubrication is provided, with separate oil supplies for the fuel injection pump and governor. Pumps and governors with separate oil supplies each have a dipstick or an oil-level inspection port to monitor the oil level. Before it is put into initial operation, the governor should be filled with the same type of lubricating oil that is used in the engine. The oil level is set using the dipstick or by observing the level through the oil-level inspection port. Check the oil level after every 1500 km of driving or 50 hours of operation; on these occasions drain out any excess oil or add oil if required. After about 15,000 km or 500 hours of operation replace all the oil in the governor with fresh oil.

Pneumatic governors of recent design, i.e. without a grease fitting, do not require lubrication.

Testing and Repair

The testing and repair of governors require detailed theoretical knowledge.

Appropriate training is therefore a prerequisite for all work on fuel injection pumps with governors. Moreover, the test specifications we have issued and the special tools we have developed, as well as the use of Bosch test benches, are additional requirements for effective work. At our after-sales-service training center the required technical knowledge is taught and practically applied.

Summary

1. The governor for the diesel fuel injection pump is as important as the fuel injection pump itself because without a governor, which controls the amount of fuel injected into the diesel engine, operation of the engine is not possible. A diesel engine without a governor would either come to a stop in the low rotational-speed range, or it would accelerate to the point of self-destruction.

2. The Bosch governor is attached to PE-type in-line fuel injection pumps and, depending on the design, is controlled either by centrifugal force or by the vacuum in the diesel-engine intake manifold.

3. Different types of governor have been developed corresponding to their various intended uses or functions:
a) Maximum-speed governors control only the maximum speed, i.e., the maximum full-load speed, of the engine.
b) Minimum-maximum-speed governors control the idle speed and the maximum speed.
c) Variable-speed governors control all speeds from the idle speed to the maximum speed depending on the setting of the control lever. These governors can be designed to be controlled either mechanically or pneumatically.
d) Combination governors are variants of the variable-speed governor. With this type of governor, a certain speed range between the idle and maximum speeds remains uncontrolled; depending on the particular design of the governor, this uncontrolled range can begin immediately after the idle speed or it can begin at some intermediate speed and extend up to the maximum speed. In the remainder of the rotational-speed range the speed of the engine is set directly by the control lever.

4. The control process is basically the same in all types of governor. If the speed of the engine exceeds a speed set with the control lever within the control range, the governor acts to draw the fuel-injection-pump control rod to a position of smaller fuel delivery; if the engine speed falls below the set speed, the governor acts to shift the control rod to a position of greater fuel delivery.

5. Increases or decreases in the rotational speed, and the corresponding changes in the amount of fuel delivered, take place in accordance with the so-called "speed droop" of the governor. The speed droop indicates as a percentage the decrease in rotational speed of an engine when a load is suddenly applied to it, and is determined by the engine manufacturer. The change in fuel delivery is approximately proportional to the change in rotational speed.

6. In addition to its basic function(s), other control functions must be carried out by the governor, such as automatically releasing or cutting off the larger amount of fuel required for starting (the starting fuel delivery), as well as correcting the full-load delivery as a function of rotational speed (torque control), charge-air pressure, or atmospheric pressure. For these purposes supplementary equipment is required which can be mounted either inside or on the governor.

7. Most governors are fitted with a torque-control mechanism, i.e., a mechanism to match the amount of fuel delivered by the fuel injection pump to the full-load amount of fuel burned in the engine with no development of smoke above a certain rotational-speed range. Torque control is required because the fuel requirement of the non-supercharged diesel engine decreases as the rotational speed increases, but on the other hand the amount of fuel delivered by the fuel injection pump increases within a certain range with the control rod in the same position as the rotational speed increases. The torque-control mechanism decreases the fuel delivery within a certain rotational-speed range as the speed increases. This type of torque control is designated "positive torque control" or torque control in the "sense of control". In engines fitted with exhaust gas turbochargers with a fairly high degree of supercharging, the fuel requirement of the engine at full load rises so sharply above a certain speed that the natural increase in fuel delivered by the fuel injection pump is no longer adequate. In such a case the fuel delivery must be increased correspondingly as the rotational speed increases ("negative torque control").

Both positive and negative torque control within one family of governor operating characteristics can be achieved with the RQV..K governor. The letter "K" here comes from a German expression describing the basic operating principle of the torque-control mechanism (where use is made of a curved track) in this type of governor.

8. Suitable stops are provided on the governor or on the fuel-injection pump to set the full-load delivery, idle delivery, starting fuel delivery, full-load speed, or intermediate speeds. In addition, the following control-rod stops are produced for special compensation functions:
a) The manifold-pressure compensator (LDA). It reacts to the charge-air pressure of an exhaust turbo-supercharger and is designed to match the full-load delivery continuously to the reduced charge-air pressure in the lower rotational-speed range.
b) The altitude-pressure compensator (ADA). It ensures that the full-load delivery of fuel injected into the engine is matched to the air density which decreases as the altitude increases.

Glossary of Technical Terms

Accelerator pedal
The pedal used to control the delivery of fuel to internal-combustion engines.

ADA
Abbreviation for altitude-pressure compensator.

Air charge
The amount of air drawn into the engine cylinder during the suction stroke.

Altitude-pressure compensator (ADA)
A full-load stop controlled by atmospheric pressure and used in vehicles which are operated at widely varying altitudes. The ADA reduces the full-load delivery as the altitude increases.

Charge-air pressure
The pressure of the compression air delivered by a supercharger in front of the closed intake valve.

Combination governor
A variant of the variable-speed governor with one uncontrolled rotational-speed range.

Combustion chamber
A chamber where combustion takes place; it is enclosed on all sides by the working cylinder, cylinder cover and piston.

Combustion characteristic curve
A graph which shows the amount of fuel the diesel engine can burn smoke-free as a function of rotational speed.

Control lever
A lever which sets the governor to a certain rotational speed or quantity of fuel injected.

Control range
The rotational-speed range within which the governor is effective.

Control rod
Part of the fuel injection pump which, together with a pinion gear or a linkage lever, serves to adjust the ⟶ fuel delivery by rotating the plunger in the fuel injection pump.

Control-rod stop
A device mounted on the governor or ⟶ fuel injection pump designed to limit the ⟶ control-rod travel; it limits the full-load delivery or the starting fuel delivery, and in special cases is fitted with a ⟶ torque-control mechanism.

Control-rod travel
The distance, measured in millimeters, which the ⟶ control rod travels from the stop position.

Coulisse
A cylindrical part with a lateral pin (⟶ guide block) is introduced into a longitudinal hole in the fulcrum lever, which shifts the pivot point of the fulcrum lever depending on the position of the governor control lever, thus changing the transmission ratio of the fulcrum lever.

Cylinder charge
The entire amount of air or mixture delivered during a working cycle.

Diaphragm
A thin plate, foil, or skin made of metal or plastic fitted between two halves of a housing under tension and sealed air-tight at the edge.

Diesel engine
An internal-combustion engine in which the fuel injected into the ⟶ combustion chamber ignites in the air charge after the temperature of the latter has been raised to a sufficiently high level, primarily as a result of compression, to induce ignition.

Diesel fuel
Diesel fuel is a mixture of various types of hydrocarbons which boil between about 200 and 360°C and which are derived by distilling petroleum. It is used for the operation of high-speed ⟶ diesel engines.

Drag spring
A spring which stores a movement and then passes it on after a certain time has elapsed.

Excess air
During each working cycle, the diesel engine draws in up to 40% more air in than is required for combustion of the maximum ⟶ fuel delivery. This excess air is required so that all fuel particles can come into contact as effectively as possible with the oxygen in the air and can burn completely.

Excess fuel for starting
The amount of fuel by which the ⟶ starting fuel delivery exceeds the ⟶ full-load delivery.

Exhaust turbo-supercharger
A turbine driven by the exhaust gases from the internal-combustion engine which drives a centrifugal compressor mounted on the same axle. This compressor compresses the intake air and thus increases the volumetric efficiency.

Flyweights
Actuating elements which give rise to a movement directed against the force of springs, the magnitude of this movement increasing correspondingly as the rotational speed of the governor increases.

Fuel delivery
The amount of fuel delivered by the ⟶ fuel injection pump per cylinder and per working cycle.

Fuel-delivery characteristic
A graph of the fuel delivery per cylinder and working cycle as a function of the rotational speed.

Fuel injection pump
A pump driven by the diesel engine which meters the fuel and delivers it under pressure through the nozzle-holder assembly and ⟶ injection nozzle into the combustion chamber.

Fuel-requirement curve
The ⟶ combustion characteristic curve, a graph of the amount of fuel which can burn smoke-free as a function of the rotational speed of the engine.

Full load
The maximum permissible load on the engine.

Full-load delivery
The maximum amount of fuel delivered in the loadable rotational-speed range of the engine.

Full-load speed
The rotational speed of the engine at which rated power is developed (maximum n_{vo}, minimum n_{vu}); corresponds to rated speed.

Full-load speed regulation (maximum-speed regulation)
Speed regulation from the maximum full-load speed to the high idle speed.

Governor characteristic curves
A graph showing ⟶ control-rod travel and rotational speed which provides information on the type of governor, the ⟶ control range, and the governor characteristics.

Guide block
A cylindrically ground bolt with a lateral pin, guided by the governor control lever within the ⟶ coulisse in the fulcrum lever. The lateral pin constitutes the pivot point of the fulcrum lever in control operations.

Idle delivery
The ⟶ fuel delivery during idling.

Idle speed
The speed of the engine at no-load.

Injection nozzle
Serves to feed and atomize the fuel injected into the cylinders of the diesel engine.

LDA
Abbreviation for ⟶ manifold-pressure compensator.

Manifold-pressure compensator (LDA)
A full-load stop for ⟶ pressure-charged engines controlled by the ⟶ charge-air pressure. It reduces the full-load delivery in the lower speed range at a low charge-air pressure.

Maximum full-load speed
The highest speed possible within the loadable speed-control range; it is the rated speed of the engine, which is the starting point for full-load speed regulation.

Maximum-speed governor
A governor designed to maintain constant the maximum full-load speed of ⟶ diesel engines which must operate at a uniform rotational speed; example: engines to drive assemblies of equipment.

Mechanical governor
The common short term for all mechanical governors that are controlled by centrifugal force. This type of governor operates with a flyweight assembly, the radial position of which varies as a function of rotational speed, and controls the engine speed mechanically by varying the ⟶ fuel delivery from the ⟶ fuel injection pump.

Minimum-maximum-speed governor
A governor designed specially for motor vehicle diesel engines, and which controls the low ⟶ idle speed and the maximum full-load speed (intermediate speeds are not controlled).

No load
A load condition in which the engine only drives the parts permanently connected to it (for example, the generator) and performs no useful work.

Overload
The maximum permissible load to which the engine may be briefly subjected.

Overrun
An operating condition in which the engine is driven by the vehicle, for example when travelling downhill.

Part load
The load range between full load and no load.

Pneumatic governor
A governor which reacts to the difference between the atmospheric pressure and the pressure in the intake manifold of the ⟶ diesel engine, and which controls the speed of a diesel engine by varying the ⟶ fuel delivery of the fuel injection pump.

Pressure-charged engine
A diesel engine in which all or part of the air charge is precompressed by a ⟶ supercharger outside the operating cylinder in order to increase the charge in the operating cylinder.

Racing of the diesel engine
An uncontrollable increase in the rotational speed of the diesel engine resulting from failure of the governor system.

Slider
A sliding part in the governor which transmits the travel of the rotating sliding bolt to the fulcrum lever.

Sliding bolt
A part which transmits the flyweight travel through the lever system to the ⟶ control rod.

Speed droop
A parameter indicating by how much the rotational speed of a ⟶ diesel engine decreases when regulated from the high idle speed n_{lo} to the maximum full-load speed n_{vo}. It is usually expressed as a percentage of the maximum full-load speed, n_{vo}.

Speed regulation
A reduction in the ⟶ fuel delivery by the governor when a specified rotational speed is exceeded.

Spring characteristic
A graph showing spring travel (longitudinal movement) plotted against spring force.

Starting fuel delivery
The largest fuel delivery which can be set on the ⟶ fuel injection pump for starting the cold diesel engine.

Supercharged diesel engine ⟶ Pressure-charged engine.

Supercharger
A compressor which increases the ⟶ air charge in the working cylinder by precompressing the intake air.

Throttle valve (previously known as the butterfly valve)
In the ⟶ pneumatic governor, this valve serves to set the vacuum which, as a function of the rotational speed, acts on the ⟶ diaphragm in the governor as a measure of the amount of intake air.

Torque control
A process of matching the ⟶ fuel-delivery characteristic of the fuel injection pump to the ⟶ fuel-requirement curve of the engine as the rotational speed increases. Positive torque control = a decrease in the fuel delivery as the rotational speed increases, negative torque control = an increase in the fuel delivery as the rotational speed increases.

Torque-control mechanism
A supplementary mechanism in the governor for automatically matching the ⟶ fuel delivery of the fuel injection pump to the fuel requirement of the diesel engine.

Torque-control quantity
The change in the amount of fuel delivered by the fuel injection pump to match the amount of fuel to the ⟶ combustion characteristic curve of the engine; this change is regulated by the ⟶ torque-control mechanism in the governor as a function of rotational speed.

Variable-speed governor
A governor for PE-type fuel injection pumps which holds constant all speeds from the idle speed to the maximum full-load speed that are set by the governor control lever within the performance range of the diesel engine.

Venturi
General: A tube or pipe with a narrow nozzle-shaped section which makes it possible to measure the speed and volume of a medium flowing through it on a basis of the difference in pressures at the narrowest and widest points.
Here: Part of the ⟶ venturi assembly where the throttle valve and the connector fitting for the pneumatic governor are located.

Venturi assembly
The engine air-intake mechanism in the form of a ⟶ venturi at the intake manifold of a diesel engine when a ⟶ pneumatic governor with a throttle valve is used to adjust the rate of air flow.

Vibration damper
Ring-shaped pieces made of an elastic material which transfer the driving torque of the fuel-injection-pump camshaft to the governor hub; they eliminate any effects of torsional vibrations.

Test Page

This test page is intended to give you a chance to test your knowledge of the information presented in this booklet. Mark what you consider to be the correct answer(s) to each question and compare your answers with the correct solutions given on the next page.

1. The governor for the PE-type fuel injection pump exerts a direct influence on
- ☐ a) the fuel delivery
- ☐ b) the engine speed
- ☐ c) the engine torque

2. In the speed regulation range, and with increasing rotational speed
- ☐ a) the governor increases the fuel delivery
- ☐ b) the governor reduces the fuel delivery

3. Every type of governor controls
- ☐ a) the starting speed
- ☐ b) the idle speed
- ☐ c) the maximum speed

4. The maximum-speed governor controls
- ☐ a) the idle speed
- ☐ b) intermediate speeds
- ☐ c) the maximum full-load speed

5. The minimum-maximum-speed governor controls
- ☐ a) the idle speed
- ☐ b) intermediate speeds
- ☐ c) the maximum full-load speed

6. The variable-speed governor controls
- ☐ a) the idle speed
- ☐ b) intermediate speeds
- ☐ c) the maximum full-load speed

7. The term "torque control" is understood to mean
- ☐ a) measures to save fuel
- ☐ b) limiting the speed
- ☐ c) matching the amount of fuel delivered to the fuel requirement of the engine with no development of smoke during combustion

8. Torque control affects
- ☐ a) the starting fuel delivery
- ☐ b) the full-load delivery
- ☐ c) the part-load delivery

9. Depending on the governor, torque-control mechanisms can be built into
- ☐ a) the flyweights
- ☐ b the control-rod stop
- ☐ c) the governor linkage

10. The purpose of the coulisse in the fulcrum lever is
- ☐ a) to change the lever ratios at the fulcrum lever
- ☐ b) to reduce the actuation force at the governor control lever
- ☐ c) to increase the governor control force in the lower rotational-speed range

11. The guide block (RQ and RQV governors)
- ☐ a) depending on its particular position, determines the ratio of the fulcrum lever
- ☐ b) transfers centrifugal forces to the fulcrum lever
- ☐ c) forms the pivot point for the fulcrum lever when the governor is operating

12. The slider
- ☐ a) transfers the flyweight travel through the sliding bolt to the governor lever system
- ☐ b) changes the lever ratio.
- ☐ c) forms the movable bearing around which the fulcrum lever swings when the governor control lever is actuated

13. What is understood by the term "sleeve" (sliding sleeve)?
- ☐ a) a threaded connection part
- ☐ b) the end of the sliding bolt where centrifugal forces and flyweight travel are transferred to the fulcrum lever

14. Full-load delivery results
- ☐ a) when the accelerator pedal is pressed all the way down during starting of the diesel engine in the vehicle
- ☐ b) when the accelerator pedal is pressed all the way down and the diesel engine in the vehicle is operating

15. The starting fuel delivery
- ☐ a) is smaller than the full-load delivery
- ☐ b) is somewhat greater than the full-load delivery
- ☐ c) is usually much greater than the full-load delivery

16. In the RQ governor fitted to the diesel engine in the vehicle, the rigid control-rod stop limits
- ☐ a) the full-load delivery
- ☐ b) the starting fuel delivery

17. In the RQ governor, the function of the spring-loaded control-rod stop is
- ☐ a) limitation of the starting fuel delivery
- ☐ b) limitation of the full-load delivery
- ☐ c) to move the control rod more quickly out of the start position, i.e., to prevent occurrence of a brief interim period of starting fuel delivery if the engine is accelerated rapidly from idling (would result in development of smoke)

18. In the RQV governor the spring-loaded control-rod stop can be used
- ☐ a) for the starting fuel delivery
- ☐ b) for the full-load delivery
- ☐ c) under no circumstances

19. The manifold-pressure compensator (LDA)
- ☐ a) increases the fuel delivery in the upper rotational-speed range
- ☐ b) decreases the fuel delivery in the lower rotational-speed range

20. The altitude-pressure compensator (ADA) matches the full-load delivery to the fuel requirement of the engine for smoke-free combustion as a function of
- ☐ a) high engine speed
- ☐ b) low engine speed
- ☐ c) varying atmospheric pressure resulting from a higher or lower altitude

The correct solutions are given on the next page.

Correct solutions to test questions:

1a, 2b, 3c, 4c, 5a, c, 6a, b, c, 7c, 8b, c, 9a, b, c, 10a, c, 11a, c, 12a, c, 13b, 14b, 15c, 16b, 17a, c, 18c, 19b, 20c.

Technical Instruction

The titles shown below have so far appeared in the Bosch Technical Instruction series.
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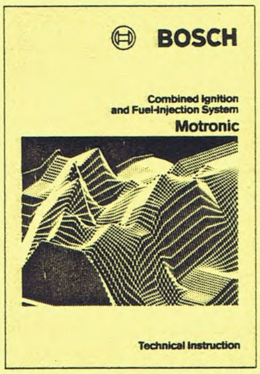

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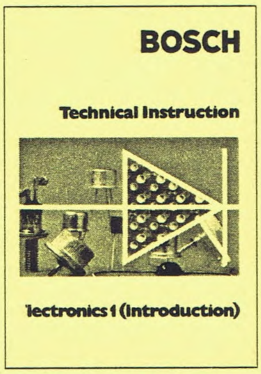

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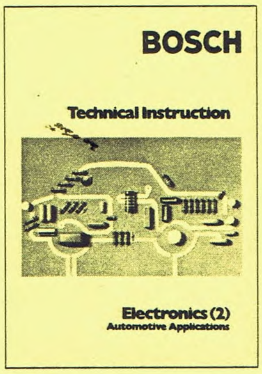

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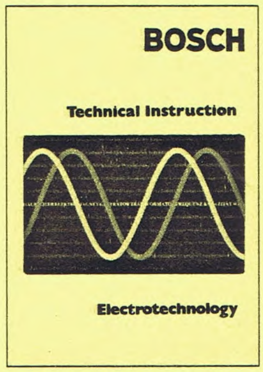

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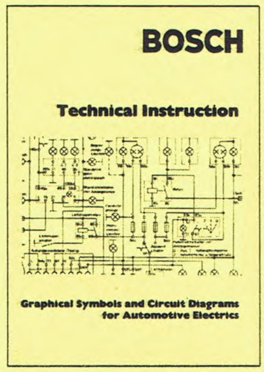

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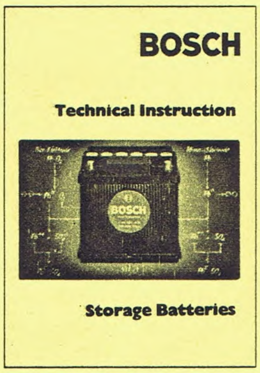

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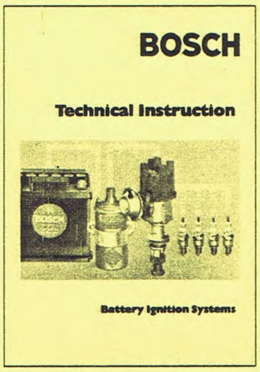

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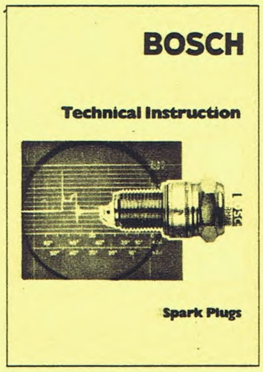

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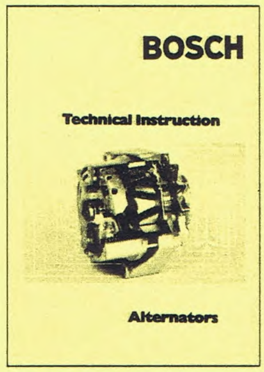

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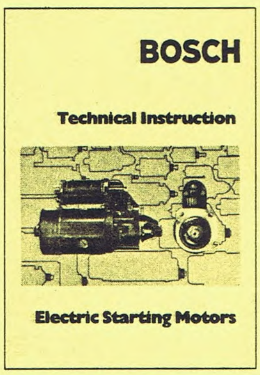

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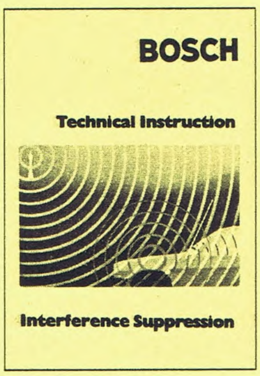

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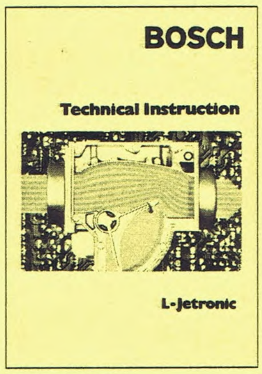

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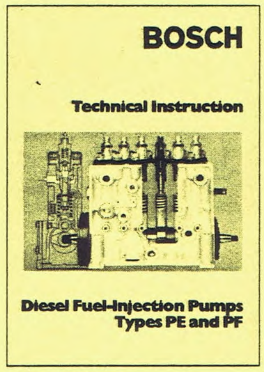

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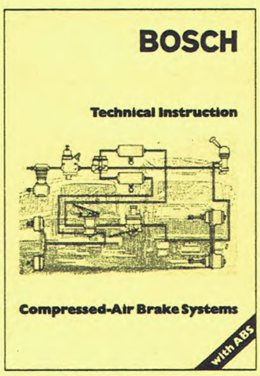

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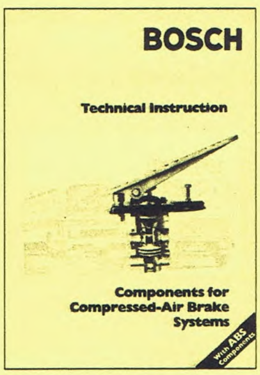

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