S05C-TB ENGINE

■FUEL SYSTEM

1. Outline

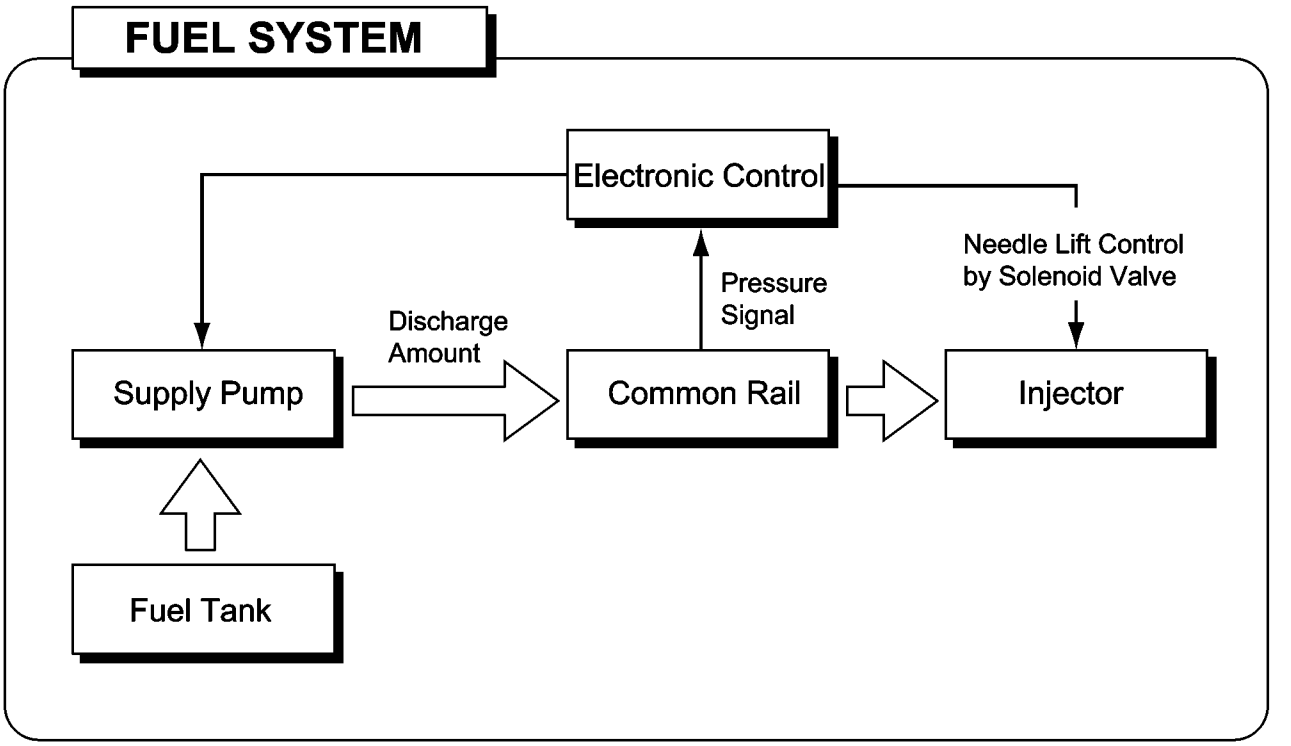
The common rail system is a system which detects the engine conditions (engine speed, accelerator opening, cooling water temperature, etc.) by sensors and performs overall control of the fuel injection amount, the fuel injection timing, the injection pressure, etc. by means of a microcomputer to operate the engine in the best condition.
The computer also has a diagnostics and alarm function which performs self-diagnosis for the main component parts and notifies the driver in case of an abnormality, a fail-safe function which stops the engine depending on the location of the abnormality, a backup function for switching the control method to permit continued operation, etc.

2. Composition

From the functional point of view, the system can be divided into the fuel system and the control system.

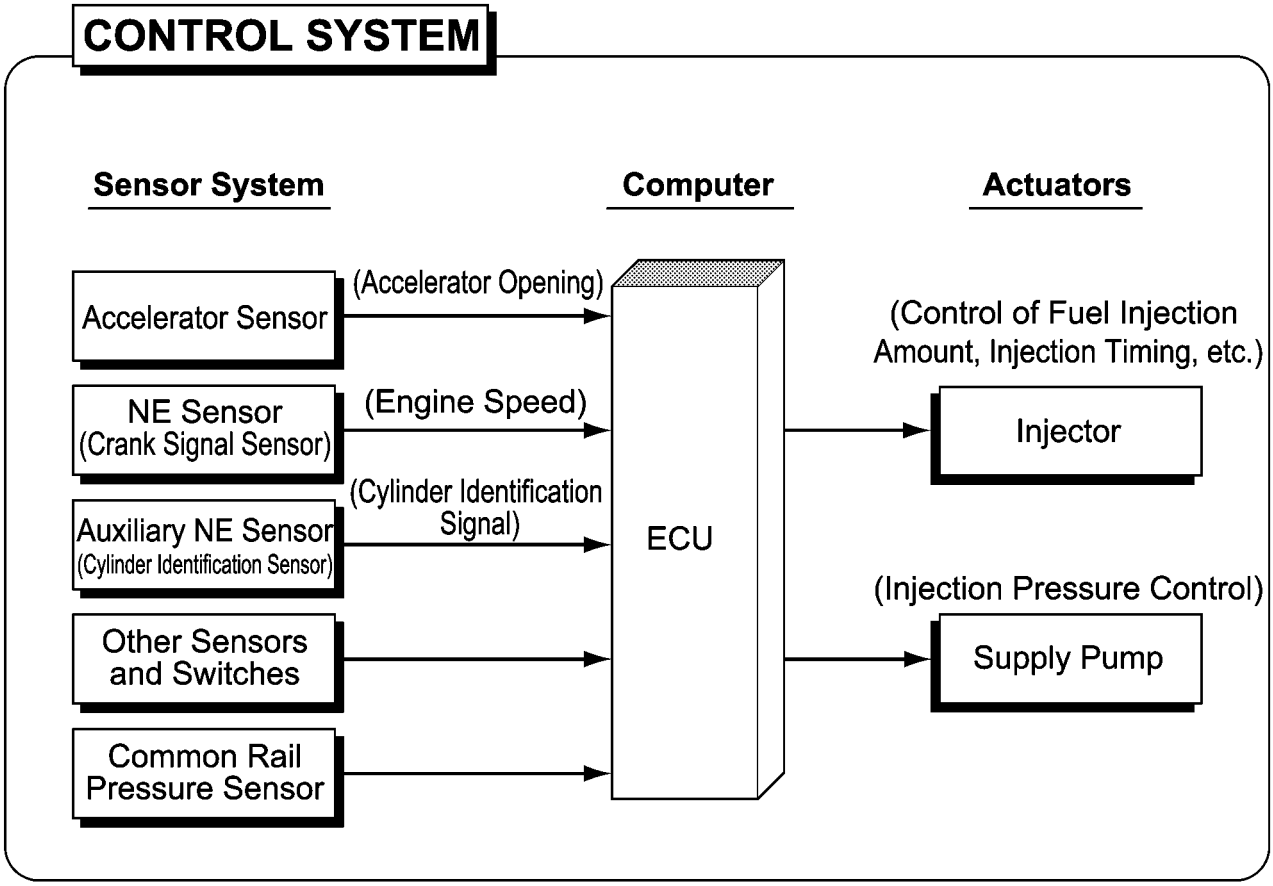
[1] Fuel system

The high-pressure fuel from the supply pump is distributed from the common rail to each cylinders, and injection start and stop are controlled by opening and closing the nozzle needle valve by the solenoid valve in the injector.



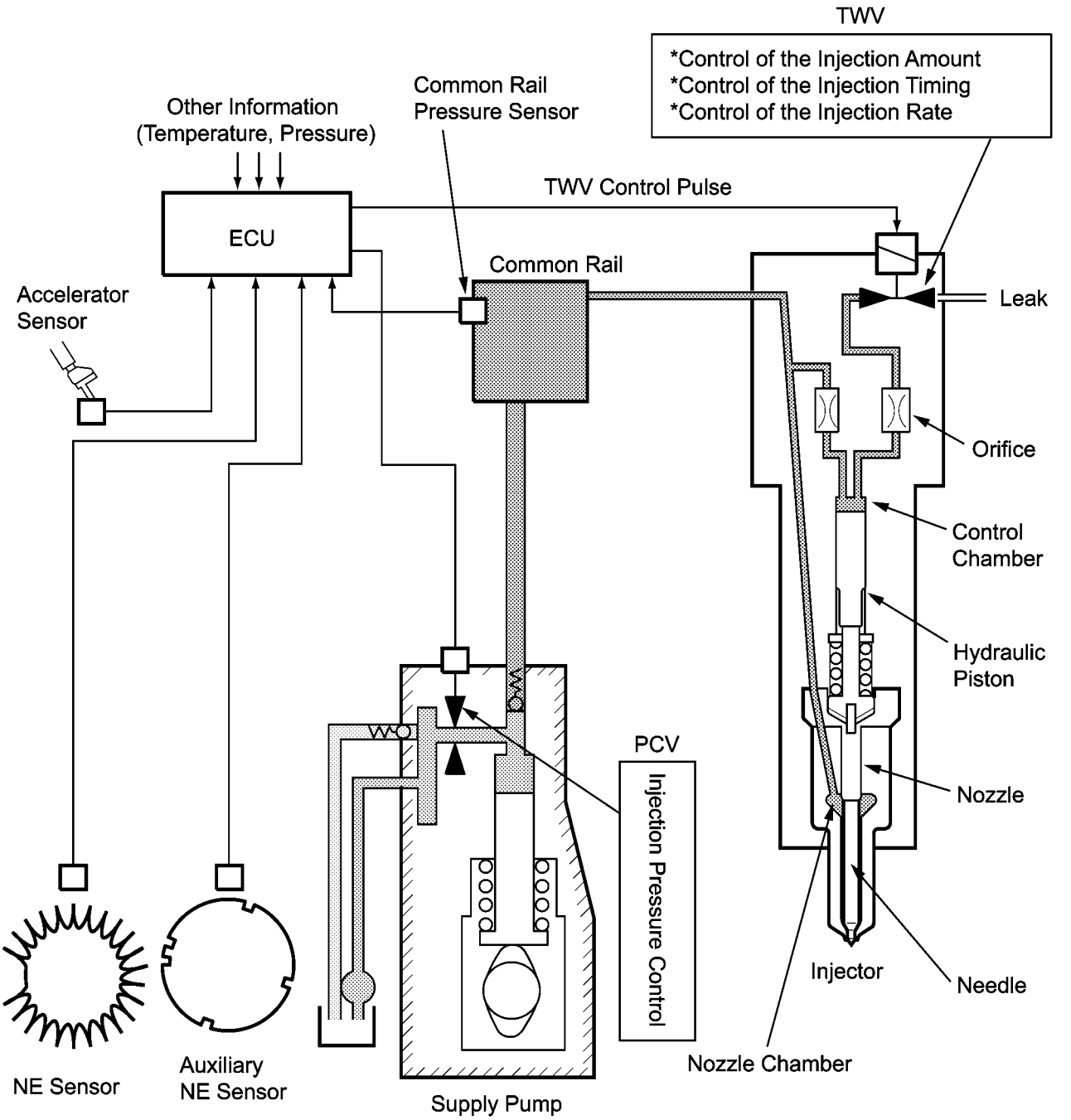
[2] Control system

The ECU uses the signals from the sensors installed on the engine and on the chassis to calculate the energization period and energization duration for the injector in order to inject the most suitable amount at the best time and performs control accordingly.
The control system can be divided roughly according to the electric parts into sensors, computer, and actuators.

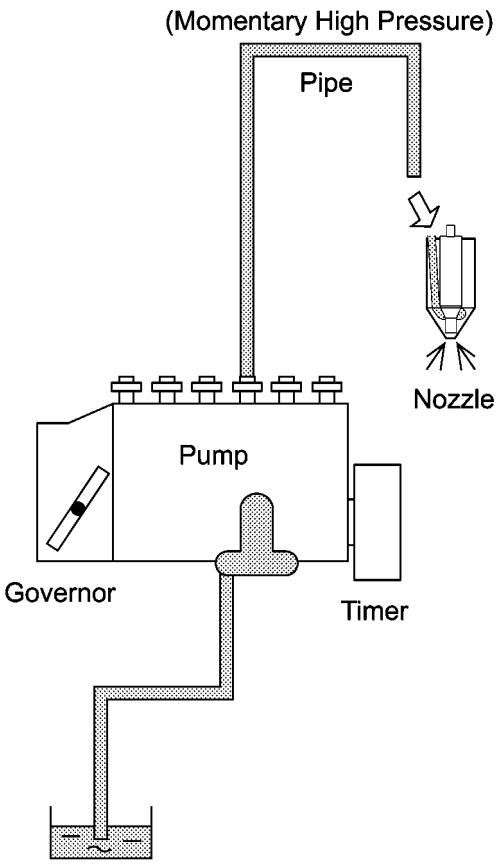
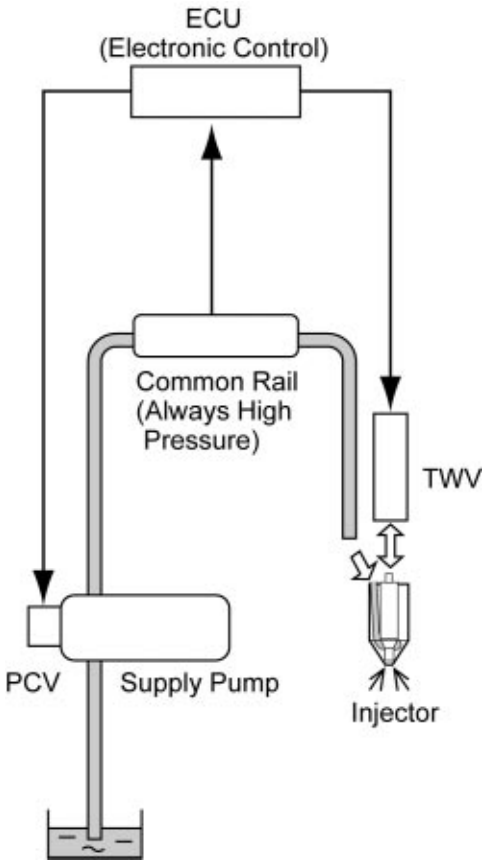


3. Composition and Operation

The common rail system is composed of the supply pump, the common rail, the injector, the ECU controlling these parts, and various sensors.
The supply pump generates fuel pressure in the common rail. The fuel pressure is controlled by the fuel delivery amount. The fuel delivery amount is controlled by ON-OFF control of the PCV (Pump Control Valve) by means of electric signals from the ECU.
The common rail receives the fuel pressure generated by the supply pump and distributes it to the cylinders. The fuel pressure is detected by the common rail pressure sensor installed in the common rail, and feedback control is performed so that the actual pressure coincides with the command pressure value set according to engine speed and engine load.
The fuel pressure of the common rail is impressed through the injection pipe of each cylinder to the nozzle side of the injector and to the control chamber.
The injector controls the injection amount and the injection timing by ON-OFF control for the TWV (Two-Way Valve). When the TWV is energized (ON), the fuel circuit is switched so that the high-pressure fuel from the control chamber flows out through the orifice, the needle valve is pushed up in nozzle opening direction by the high-pressure fuel on the nozzle side, and injection starts. When the TWV is deenergized (OFF), the fuel circuit is switched so that the highpressure fuel is impressed to the control chamber, the needle valve moves down, and the injection ends.
Accordingly, the injection timing is controlled by the TWV energization timing, and the injection amount is controlled by the TWV energization duration.


TWV
*Control of the Injection Amount
*Control of the Injection Timing
*Control of the Injection Rate
Other Information
(Temperature, Pressure)
Common Rail
Pressure Sensor
TWV Control Pulse
ECU
Common Rail
Accelerator
Sensor
Leak
Orifice
Control
Chamber
Hydraulic
Piston
PCV
Injection Pressure Control
Nozzle
Injector
Needle
Nozzle Chamber
NE Sensor
Auxiliary
NE Sensor
Supply Pump

4. Comparison with a Conventional Pump

	Conventional Pump (In-line, jerk type)	Common Rail System
System		
Adjustment of the Injection Amount	Pump (Governor)	ECU, Injector (TWV)
Adjustment of the Injection Timing	Pump (Timer)	ECU Injector (TWV)
Pressure Increase	Pump	Supply Pump
Distribution	Pump	Common Rail
Adjustment of the Injection Pressure	(Depending on Engine Speed and Injection Amount)	Supply Pump (PCV)

EG

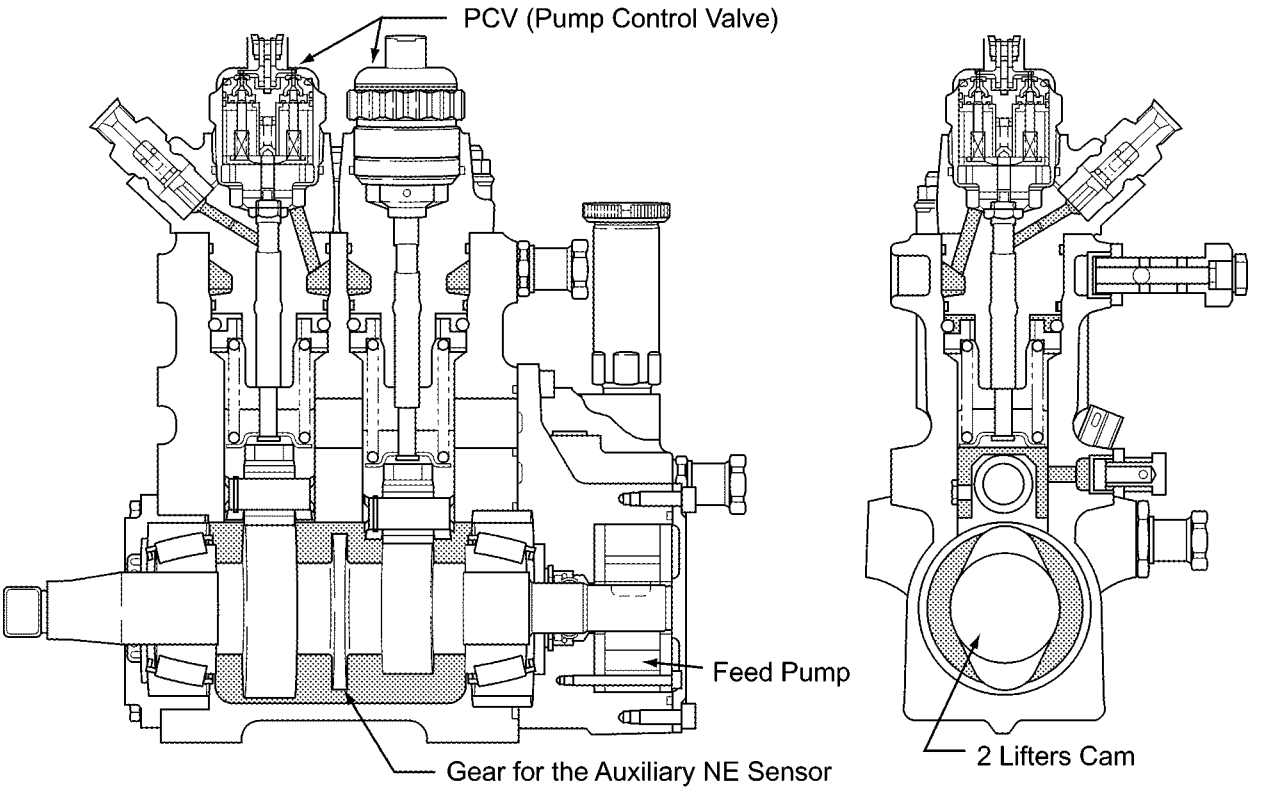
5. Supply Pump

[1] Outline

It is the function of the supply pump to generate fuel pressure in the common rail by control of the fuel delivery amount.

[2] Construction

The supply pump has the same force feed system as the conventional in-line type pump and a pump control valve (PCV) for control of the fuel delivery amount arranged at each cylinder.
By using two lifters cam, the number of cylinders required for the pump is reduced to 1/2 of the number of engine cylinders. As the force feed to the common rail becomes the same as the number of injections, a smooth and stable common rail pressure can be obtained.



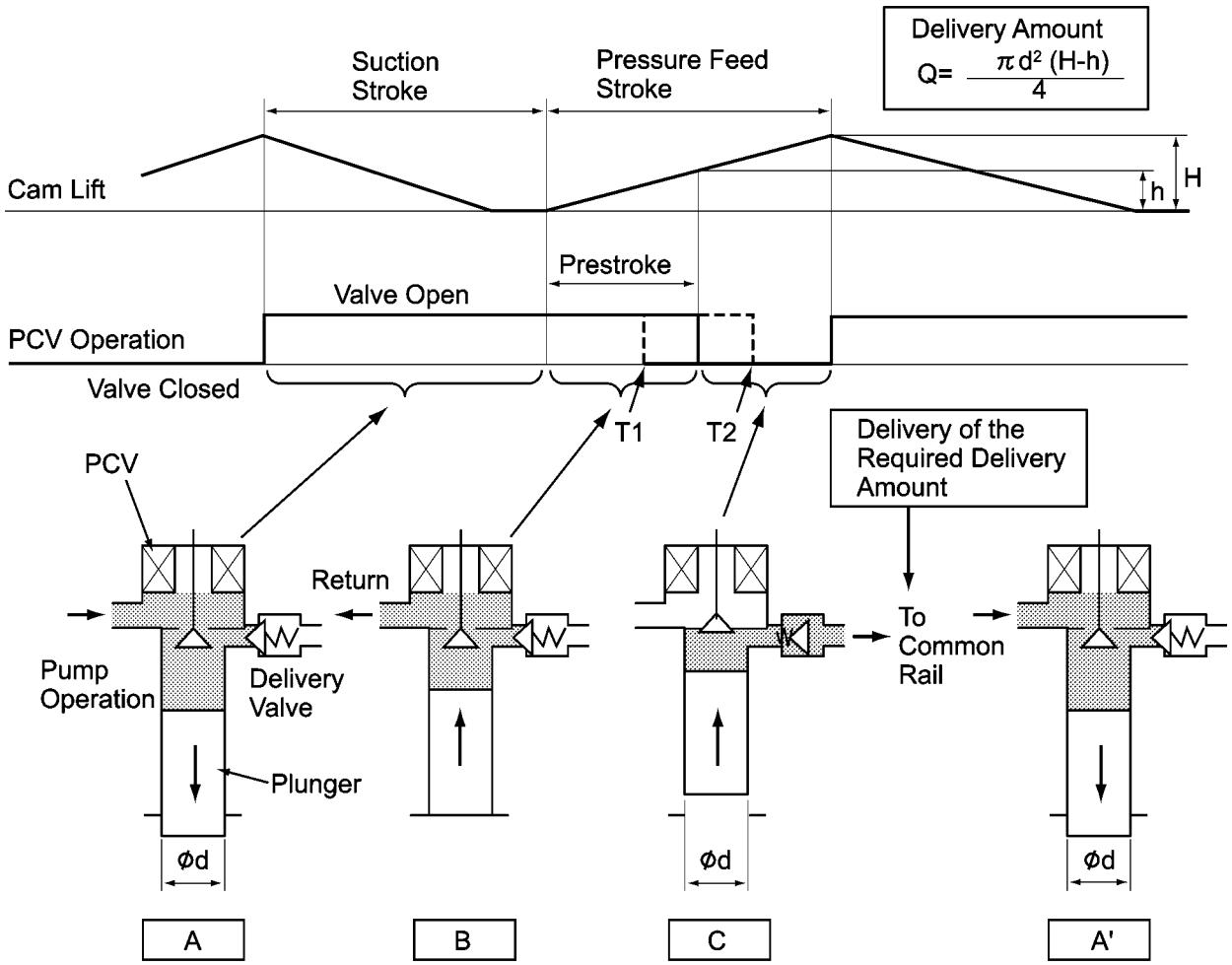
[3] Operation

A During the downward movement of the plunger, the PCV is open and low-pressure fuel is supplied into the plunger chamber via the PCV.

B Even when the plunger enters into the upward movement step, the sucked-in fuel is returned through the PCV without a pressure increase while the valve is open without energization of the PCV.

C When the PCV is energized and the valve is closed with a timing suitable for the required delivery amount, the return path is blocked and the pressure in the plunger chamber rises. Accordingly, the fuel passes through the delivery valve (check valve) and is force-fed to the common rail. In other words, the plunger lift part after closing of the PCV is changed to a delivery amount, and by changing the timing for closing the PCV (the plunger prestroke), the delivery amount can be changed and the common rail pressure can be controlled.

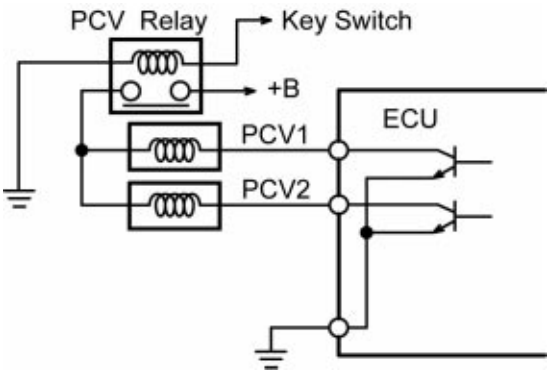
A' When the cam exceeds the max. lift, the plunger starts its downward stroke and the pressure in the plunger chamber decreases. At this time, the delivery valve closes and the fuel pressure feed stops. As energization of the PCV is stopped, the PCV opens and low-pressure fuel is sucked into the plunger chamber. In other words, the status of A is reached.

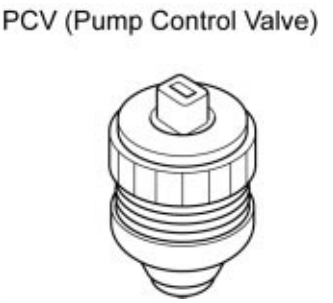


T1: At the time of Increase of the Delivery Amount
T2: At the time of Decrease of the Delivery Amount

6. PCV (Pump Control Valve)

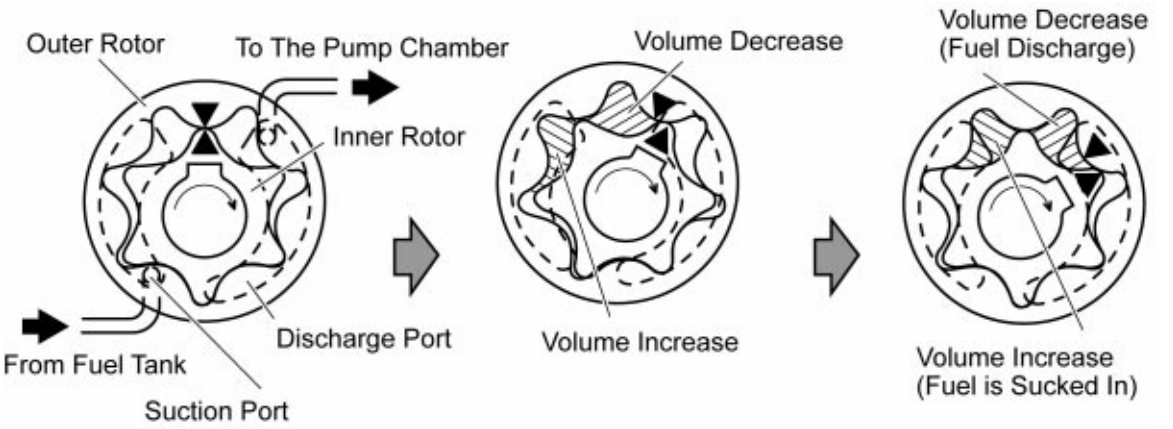
The PCV adjusts the fuel delivery amount from the supply pump to adjust the common rail pressure, the delivery amount from the supply pump to the common rail is decided by the energization timing to the PCV.





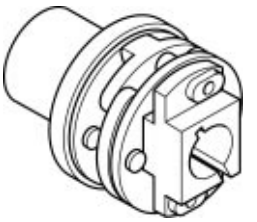
7. Feed Pump

The built-in feed pump of the supply pump sucks fuel from the tank and feeds it through the fuel filter into the pump chamber. The feed pump rotor is driven by the camshaft, and when outer and inner rotor start to rotate, fuel is sucked in at the suction side according to the volume change of the space between outer and inner rotor and it is fed out at the discharge side.



8. Coupling

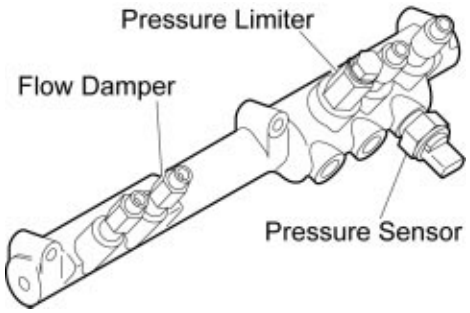
The coupling transmits the drive torque from the engine side to the camshaft of the supply pump.



9. Common Rail

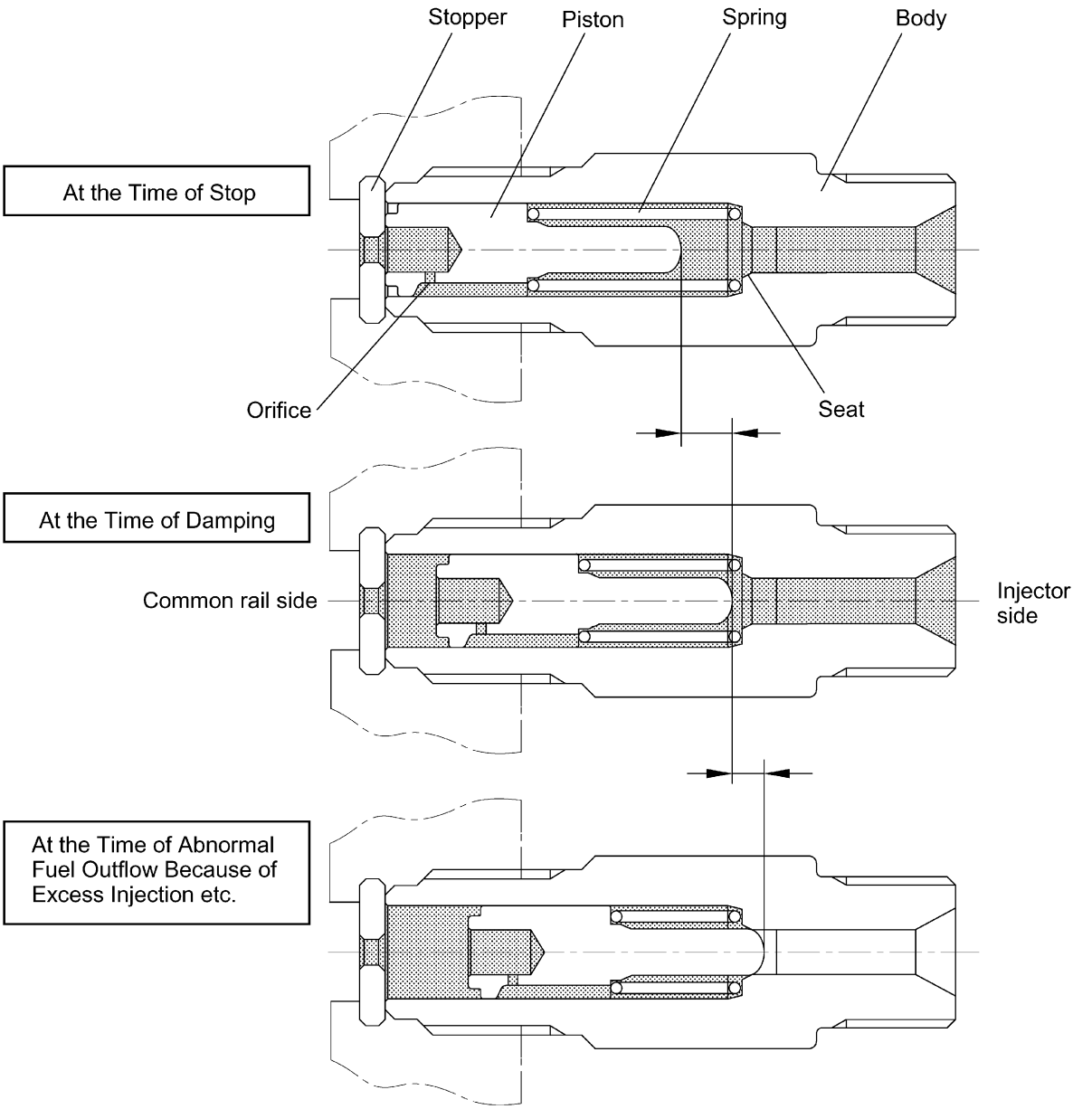
[1] Construction

The common rail serves to distribute the high-pressure fuel generated by the supply pump to the injectors of each cylinders.
The common rail pressure sensor, the flow dampers, and the pressure limiter are installed on the common rail.
The fuel injection pipes are connected to the flow dampers and fed high-pressure fuel to the injectors.
The pipe from the pressure limiter returns to the fuel tank.



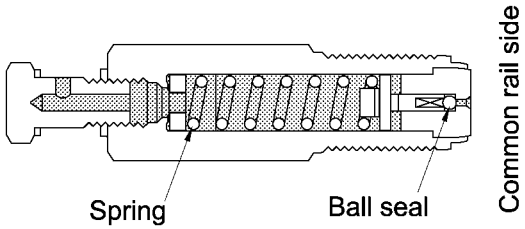
[2] Flow dampers

The flow dampers serve to reduce pressure pulsations in the high-pressure piping and to supply fuel under a stable pressure to the injectors. They also serve to cut off the fuel passage in case of excessive fuel outflow to prevent abnormal outflow of fuel.
The operation is as follows: When abnormal outflow etc. occurs, a high pressure acts onto the piston, so that the piston move to the right side in the figure and reach the seat, thus closing the fuel passage.



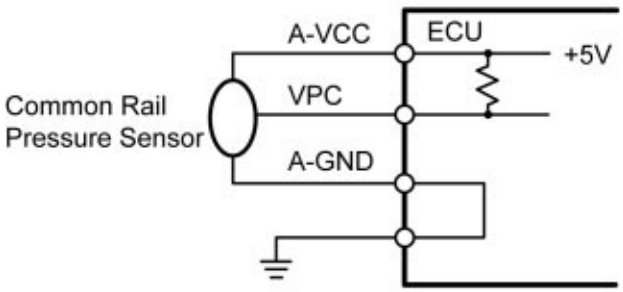
[3] Pressure Limiter

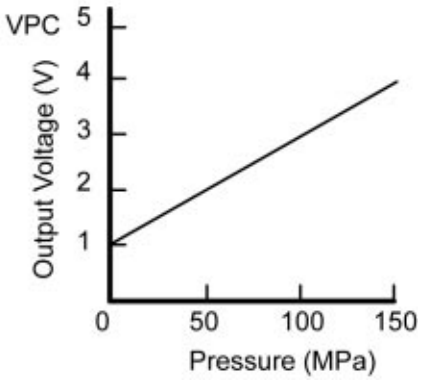
The pressure limiter opens if an abnormally high pressure should occur, and it lets the pressure escape. It operates (opens) when the common rail pressure reaches about 171 MPa (17.44 kgf/cm^2), and when the pressure drops to about 35 MPa (3.57 kgf/cm^2), it recovers (closes) and the pressure is maintained.



[4] Common Rail Pressure Sensor

The common rail pressure sensor is installed on the common rail and detects the fuel pressure.
This is a semiconductor-type sensor which uses the characteristic of silicone, that its electric resistance changes when pressure is applied.

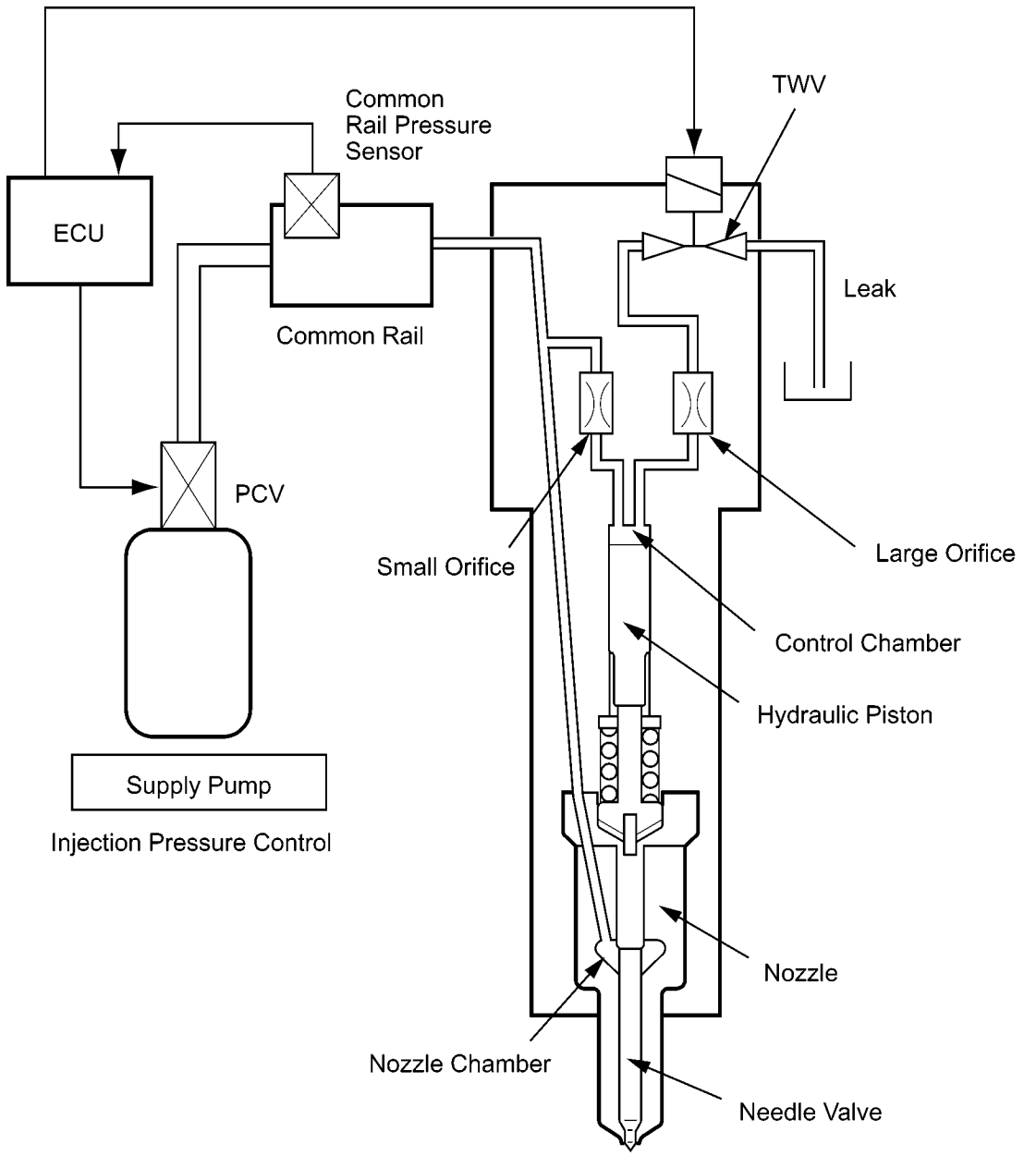




10. Injector

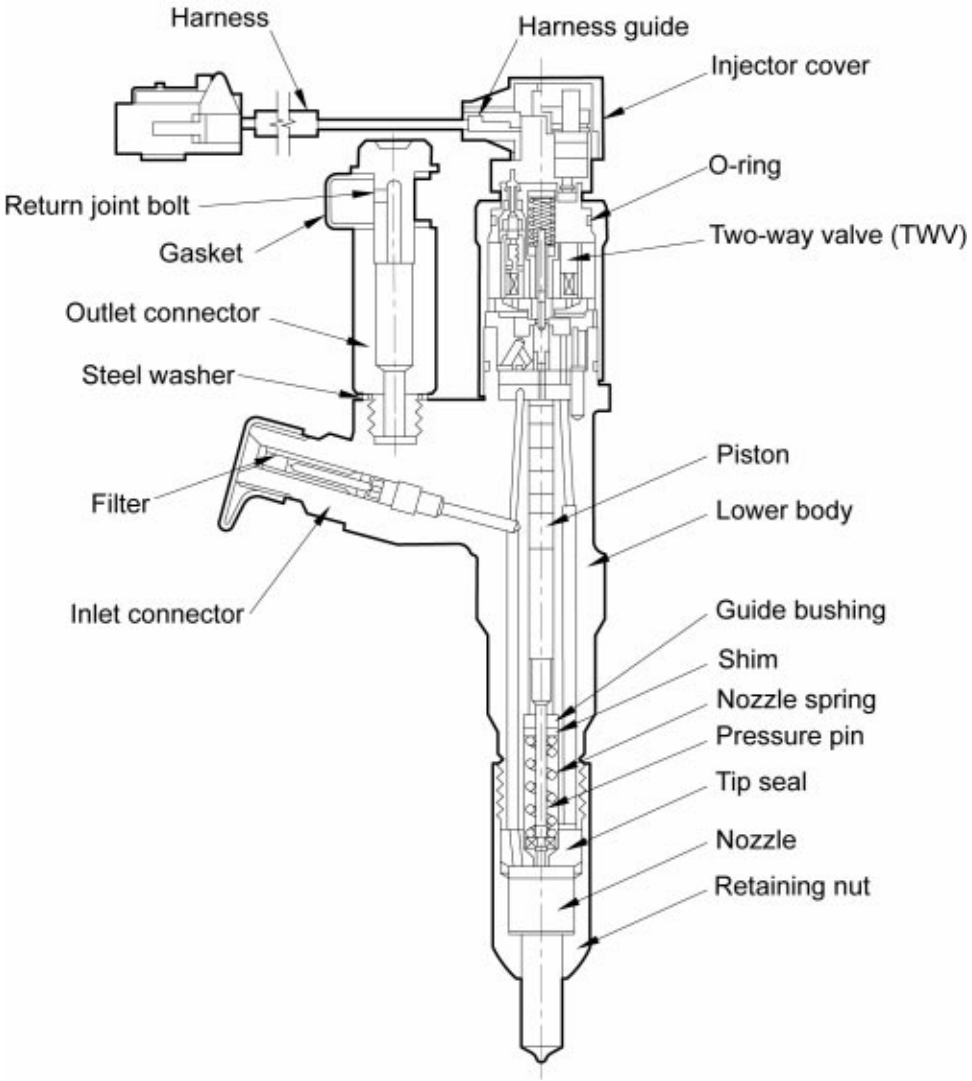
[1] Outline

It is the function of the injector to inject the high-pressure fuel of the common rail according to a signal from the ECU at the most suitable injection timing, injection amount, injection rate, and vaporization status into the engine combustion chamber.
The TWV (Two-Way Valve) controls injection start and end by controlling the pressure in the control chamber. The orifice limits the valve opening speed and controls the injection rate.
When the fuel pressure of the control chamber falls, an hydraulic piston activate with a pressure difference, and fuel is injected.
The nozzle vaporizes the fuel.



[2] Construction

The injector is composed of the same kind of nozzle section as with the conventional method, the orifice controlling the injection rate, the hydraulic piston section, and the two-way solenoid valve.



[3] Operation

The TWV of the injector is composed of two parts, the valve needle (movable), fitted tightly on the same axis center. A valve seat is formed, and either one of them is opened selectively by TWV ON/OFF.

No Injection

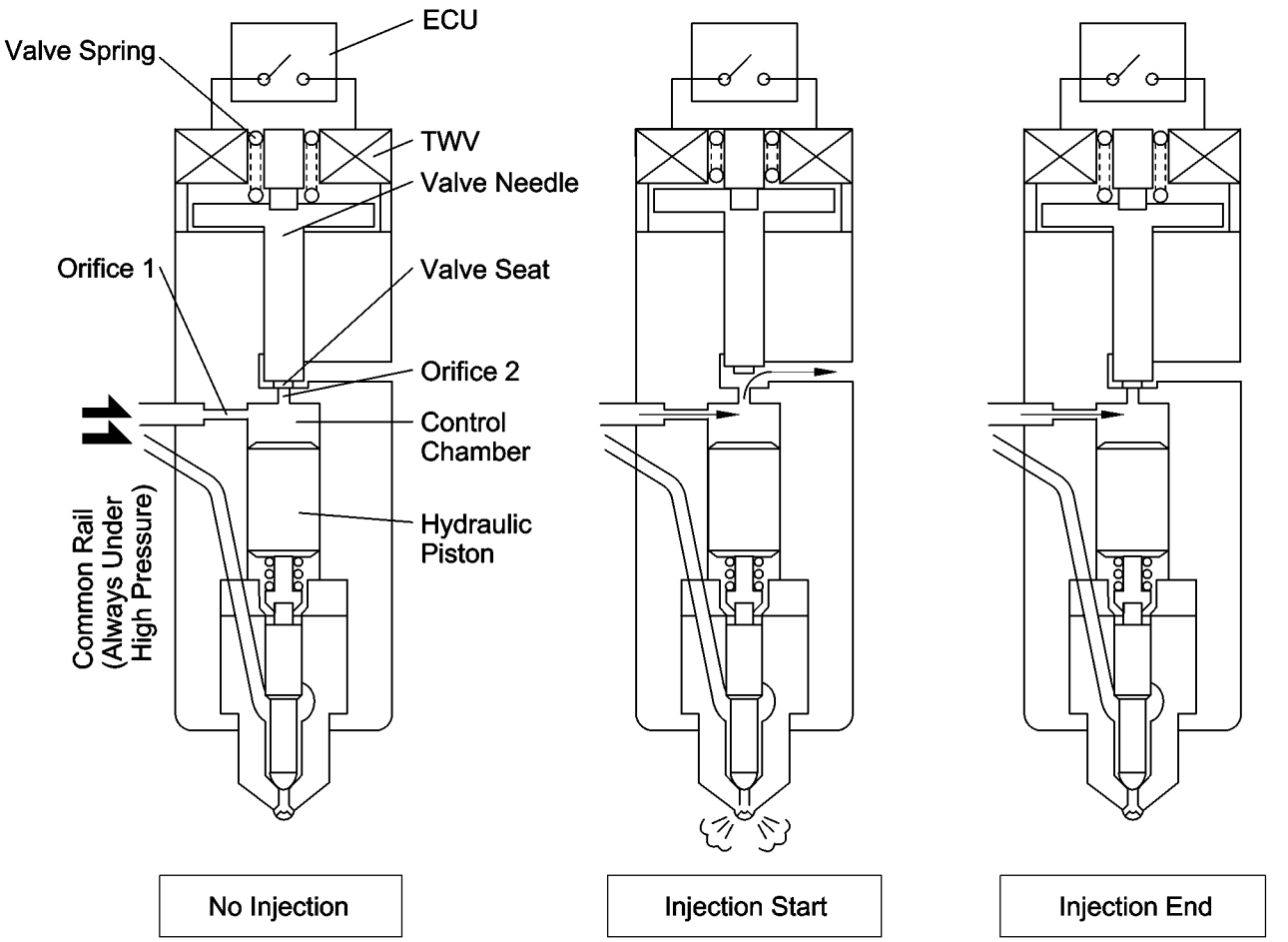
When the solenoid is not being energized, the outer valve is pushed down by the valve spring and the hydraulic pressure, and the valve seat is closed. As the high pressure of the common rail is impressed to the control chamber, the nozzle is closed and injection does not take place.

Injection Start

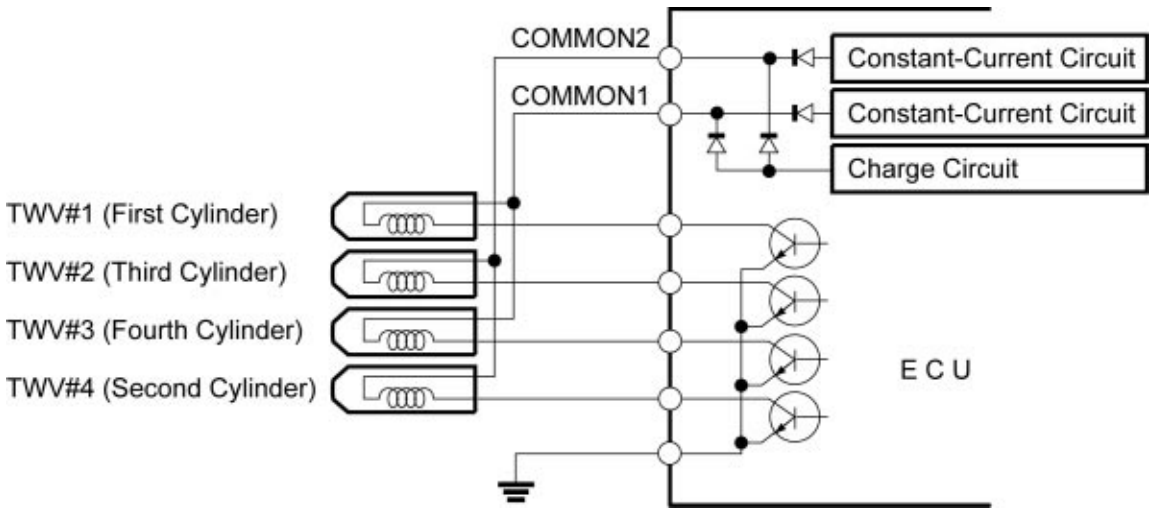
When energization of the TWV is started, the valve needle is pulled up and the valve seat opens.
As the result, the fuel starts to flow out of the control chamber through the orifice and the pressure of control chamber declines, so that the nozzle needle rises and injection starts. The orifice also causes the injection rate to increase gradually. If energization is continued, the max. injection rate will be reached.

Injection End

When energization of the TWV is stopped, the valve needle is moved down by the spring and the hydraulic pressure (fuel pressure), and the valve seat closes. At this time, the high-pressure fuel in the common rail is suddenly impressed to the control chamber, the nozzle is closed rapidly, and a sharp injection end is realized.



[4] Circuit diagram



CAUTION:	The wires attached to COMMON1 and COMMON2 of the EDU or the ECU, and TWV#1 to TWV#4 are under high voltage, and care is required to prevent electric shock.

11. Sensors and Relays

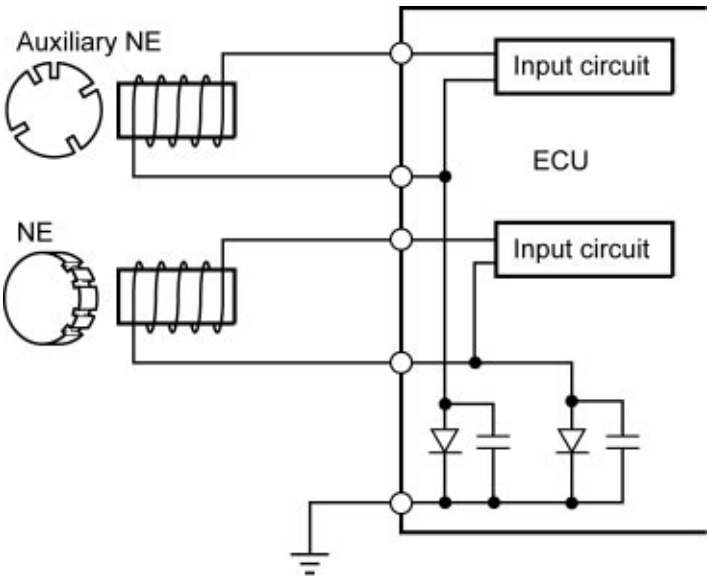
[1] NE sensor (Crankshaft sensor)

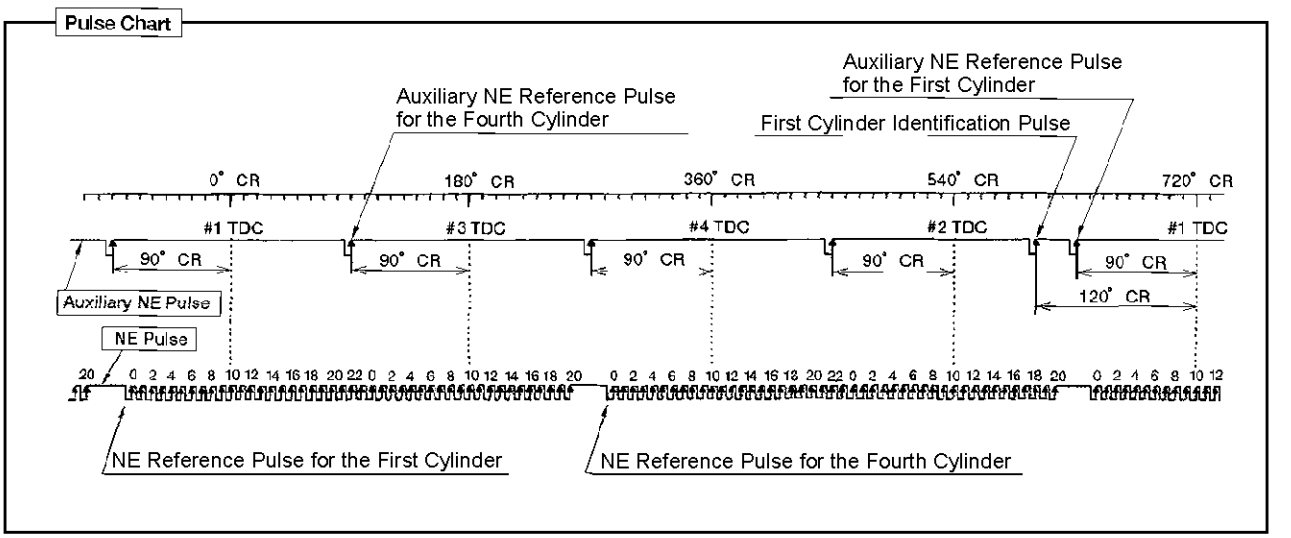
When the signal hole in the flywheel passes the sensor, the magnetic lines passing through the sensor coil change and an AC voltage is generated in the coil.
The flywheel has signal holes at intervals of 7.5° but as there is a part with no holes at three locations, there is a total of 45 holes. Accordingly, there are 90 pulses with two revolutions of the engine. This signal is used to detect the engine speed and the crankshaft angle in steps of 7.5°.

[2] Auxiliary NE sensor (Cylinder identification sensor)

In the same way as with the NE sensor, the generation of an AC voltage by the change of the magnetic lines passing through a coil is used.
The disk-shaped gear at the center of the camshaft of the supply pump has teeth (recessed notches) cut at intervals of 180°, as well as one additional tooth. Accordingly, five pulses are put out with two revolutions of the engine.
The reference pulse for the first cylinder is recognized from the combination of NE pulses and auxiliary NE pulses.

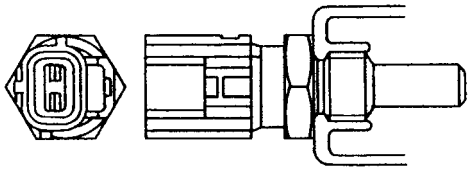


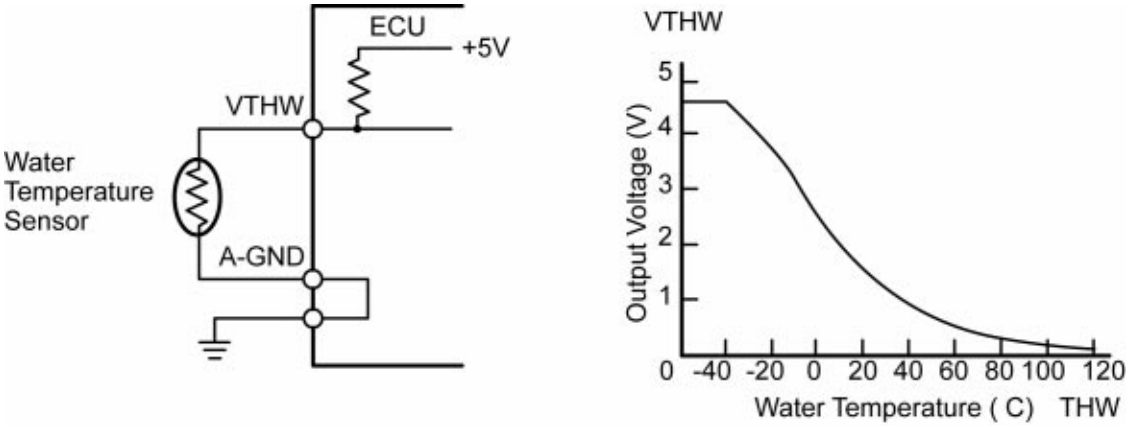




[3] Water temperature sensor

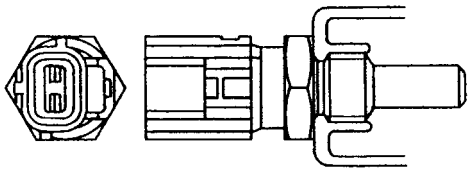
The water temperature sensor detects the temperature of the engine cooling water and sends it to the ECU. The sensor uses a thermistor with a resistance value changing according to the temperature, the ECU applies a voltage to the thermistor and performs detection with a voltage divided by the resistance value in the computer and the resistance value of the thermistor.

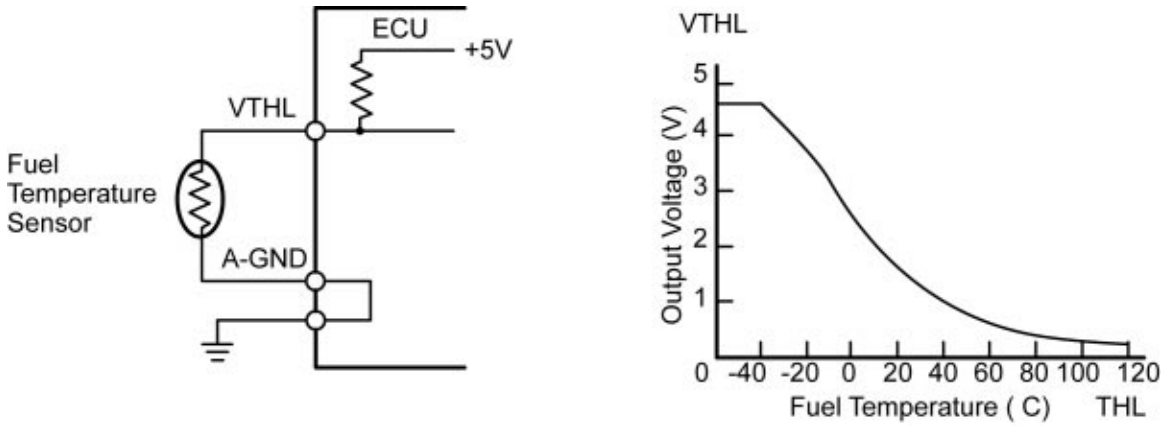




[4] Fuel temperature sensor

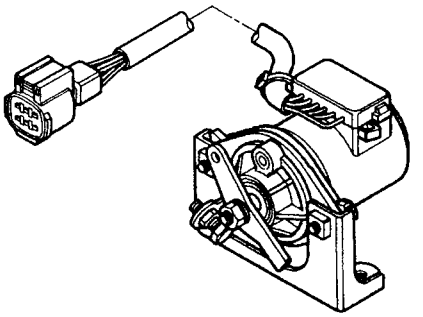
The fuel temperature sensor detects the temperature of the fuel and sends it to the ECU. The sensor uses a thermistor with a resistance value changing according to the temperature, the ECU applies a voltage to the thermistor and performs detection with a voltage divided by the resistance value in the computer and the resistance value of the thermistor.

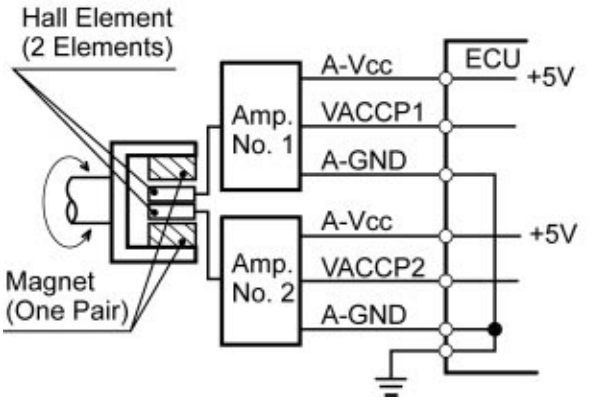


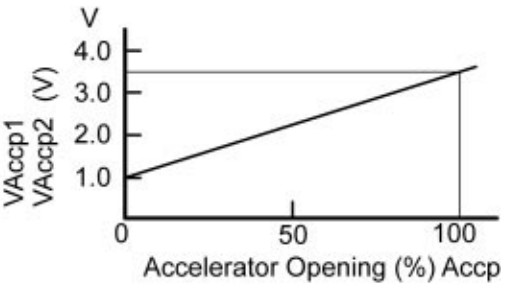


[5] Accelerator sensor

The depression angle of the accelerator pedal is converted to an electric signal and this is sent to the ECU. The accelerator sensor uses a Hall element. A magnet is installed on the shaft moving coupled with the gas pedal, and when the shaft turns, the direction of the magnetic field changes. This change of the direction of the magnetic field generates a voltage.

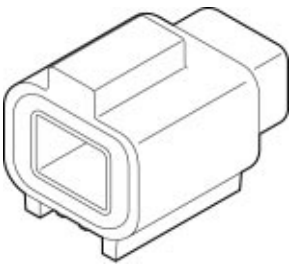






[6] Q adjustment resist (Resistor for adjustment of the max. injection quantity)

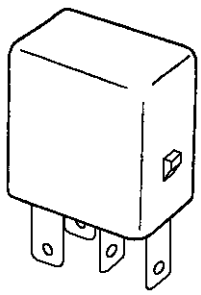
As this system does not have a load control lever, mechanical fine adjustment of the full-load injection quantity is not possible. Instead, the computer must be informed by an electrical signal whether the full-load injection quantity is to be increased or decreased.
As shown in the following list, there are eight types of Q adjustment resistors, each one with a different fixed resistance value, and the ECU performs calculations for parallel shifting of the injection quantity characteristic at the time of full load according to the resistance value. The Q adjustment resistors are inserted into a special connector close to the ECU. In addition, just like the full load stopper seal of a mechanical governor, a seal also is applied to the Q adjustment resistor to prevent inappropriate modification.



No.	Part No.	Ohm (Ω)	Supplementary quantity of injection quantity (object)
1	22385-3210A	180	-6.5%
2	22385-3220A	300	-4.3%
3	22385-3230A	430	-2.2%
4	22385-3240A	620	±0%
5	22385-3250A	820	+2.2%
6	22385-3260A	1.1 k	+4.3%
7	22385-3270A	1.5 k	+6.5%
8	22385-3280A	2.0 k	+8.7%

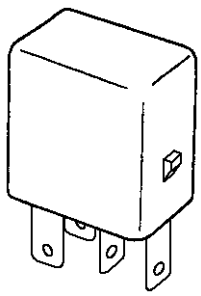
[7] Relay

Main Relay
This relay supplies electric power to the ECU, and it is a normal-open type where the points close when current flows through the coil. It is installed on the relay panel at the front side of the battery.
Color: Dark grey



[8] PCV Relay

This relay supplies electric power to the discharge quantity control valve of the supply pump. It is a normal-open type where the points close when current flows through the coil. It is installed on the relay panel at the front side of the battery.
Color: Dark grey



12. Various Controls

In comparison to the mechanical governor and timers used with conventional injection pumps, the fuel injection amount and the injection timing are controlled more accurately.
For control of the system, the ECU uses the signals from the various sensors installed on the engine and the vehicle to perform the required calculations and controls the injector energization timing and the energization time so that the most suitable amount is injected at the most suitable time.

[1] Control function for the fuel injection rate

The control function for the fuel injection rate is the function which controls the rate at which fuel is injected through the nozzle during a fixed period.

[2] Control function for the fuel injection amount

The control function for the fuel injection amount replaces the function of the conventional governor and uses the signals from the engine speed and the accelerator opening to control the fuel injection to the most suitable injection amount.

[3] Control function for the fuel injection timing

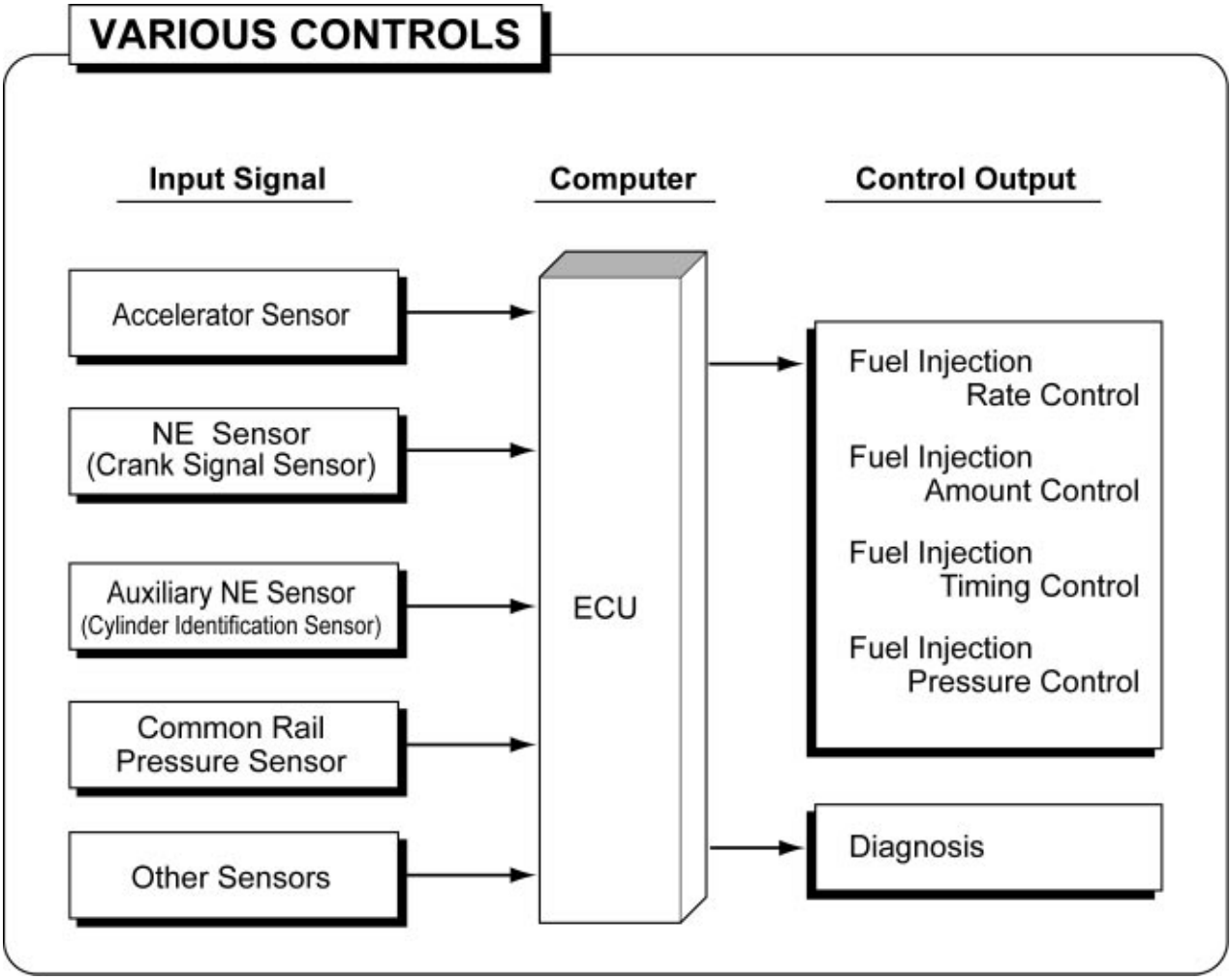
The control function for the fuel injection timing replaces the conventional timer function, and it controls the injection timing to the most suitable timing according to engine speed and injection amount.

[4] Control function for the fuel Injection pressure (Common rail pressure control function)

The control function for the fuel injection pressure (common rail pressure control) measures the fuel pressure with the common rail pressure sensor, sends the pressure as feedback to the ECU, and controls the delivery amount to the pump.
Voltage feedback control is performed so that the most suitable value (command value), set according to engine speed and injection amount, is matched.

[5] FCCB control (Fuel control cylinder balance)

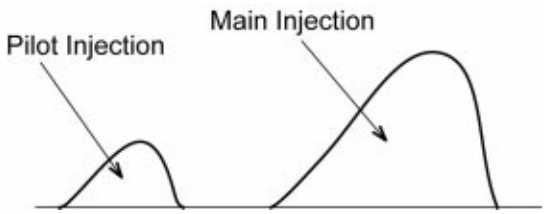
The FCCB control recognizes the speed fluctuations caused by scatter of the injection quantities between the cylinders and by combustion scatter by means of its own speed sensor and adjust the injection quantities between the cylinders.
This makes it possible to reduce speed fluctuations.



13. Fuel Injection Rate Control

[1] Main injection

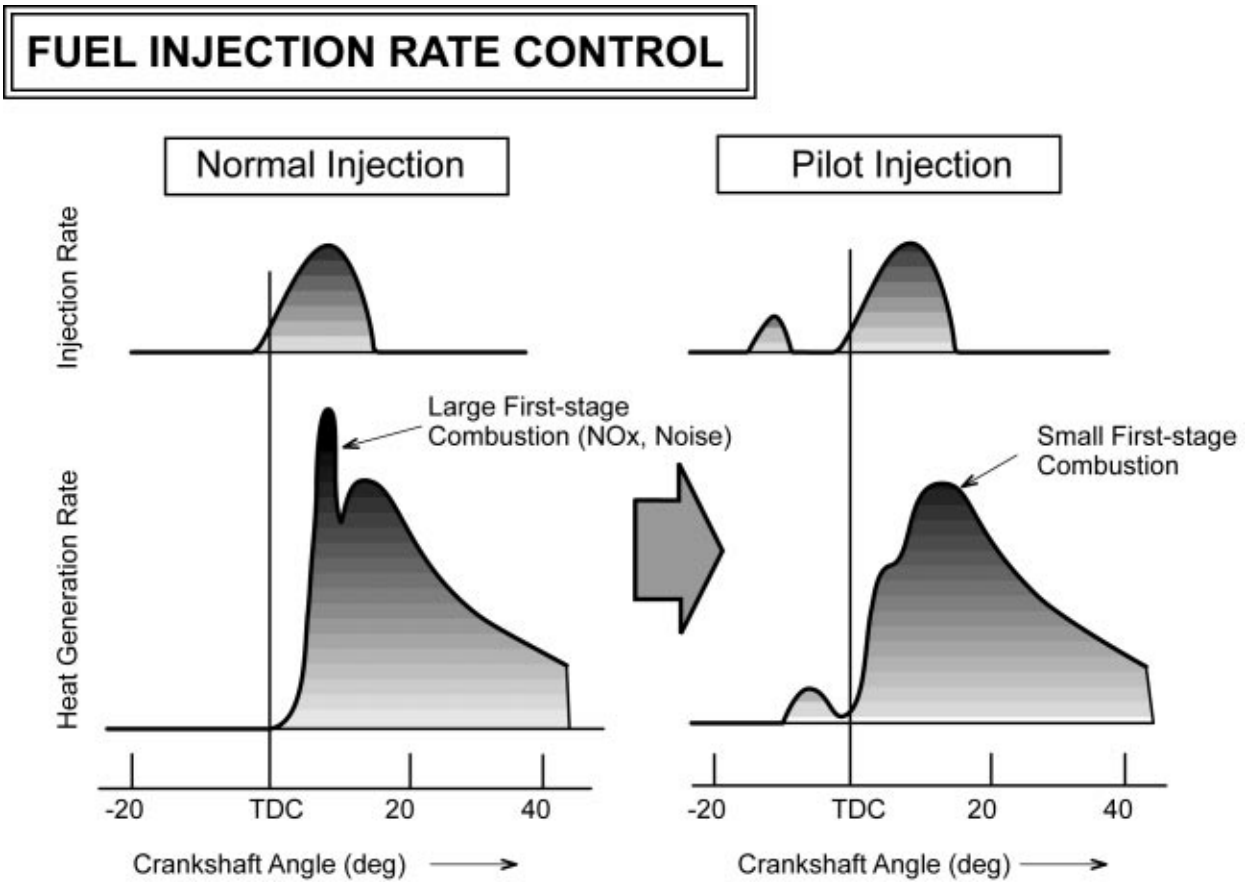
This is the same fuel injection as with the conventional method.



[2] Pilot injection

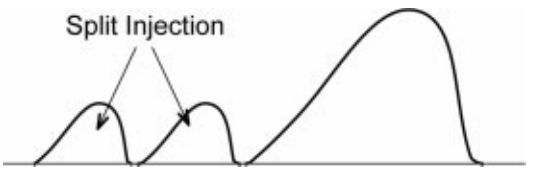
Pilot injection means the injection of a small amount of fuel before the conventional fuel injection (main injection).

Together with the change to higher injection pressures, the injection rate also increases, but the delay from injection to start of combustion (ignition delay) can not be shortened below a fixed value. As the result, the amount of fuel injected until ignition increases, and as sudden explosive combustion occurs simultaneously with ignition, NOx and noise increase. For this reason, pilot injection is performed to limit the initial injection rate to the required minimum, so that the explosive first stage of the combustion is relaxed and NOx and noise are reduced.



[3] Split injection

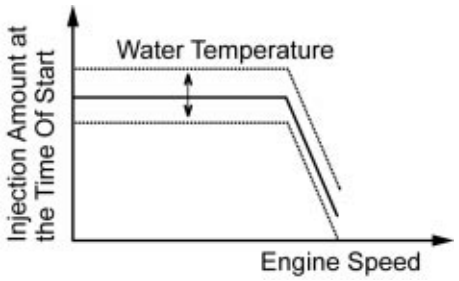
Split injection is performed to improve the starting performance when the engine is cold, and small amounts of fuel are injected at least twice before the conventional fuel injection (main injection).



14. Fuel Injection Amount Control

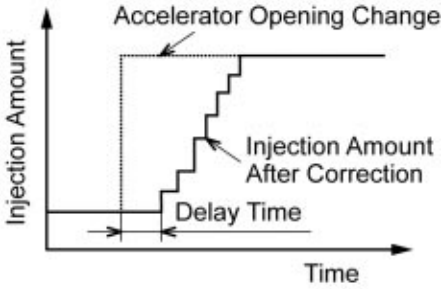
[1] Injection amount at the time of start

When the accelerator pedal at the time of start is depressed by 50% or more, the injection amount is decided according to the engine speed and the water temperature.



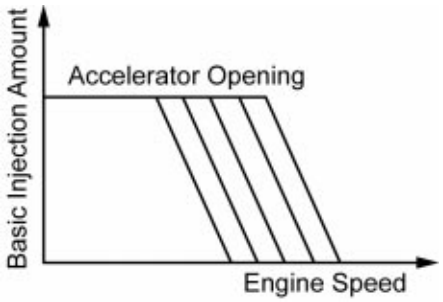
[2] Correction of the injection amount at the time of transition

When the change in the accelerator opening is large at the time of acceleration, the increase in the fuel amount is delayed to suppress the emission of black smoke.



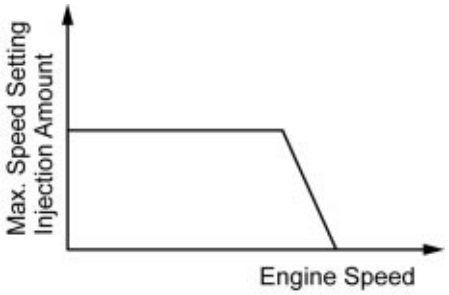
[3] Basic injection amount

This is decided according to the engine speed (NE) and the accelerator opening.
When the engine speed is kept constant and the accelerator opening is increased, the injection amount is increased.



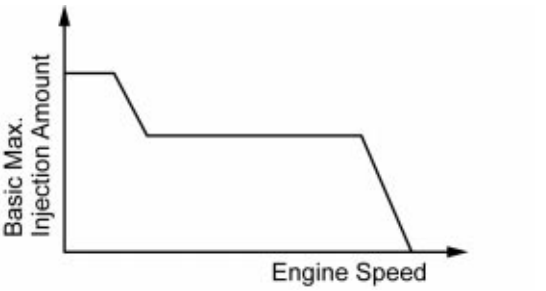
[4] Max. speed setting injection amount

Control is performed to a value decided by the engine speed.



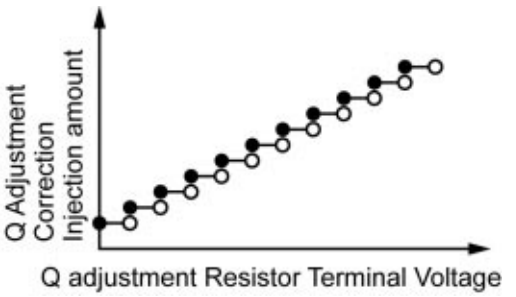
[5] Max. injection amount

This is calculated by adding the Q adjustment resistance correction amount and the injection fuel temperature correction amount to the basic max. injection amount decided by the engine speed.



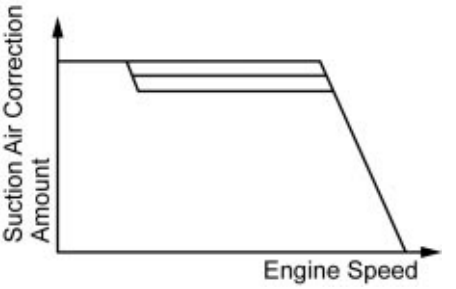
[6] Q adjustment resistance correction amount

The value decided by the full Q adjustment resistance is calculated.



[7] Injection amount suction pressure correction amount

In order to reduce smoke at the time of low suction pressure, the max. injection amount is limited according to the suction pressure.

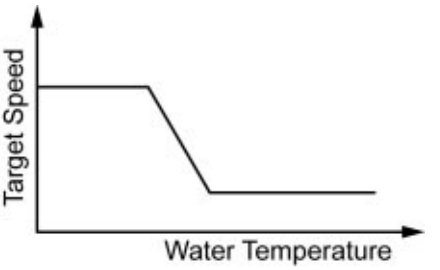


[8] Idle speed control system (ISC)

The idle speed is controlled so that the target speed calculated by the computer and the actual speed coincide.

Automatic ISC

Idle speed control is performed according to the water temperature.

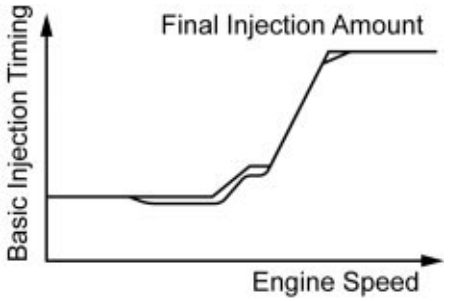


15. Fuel Injection Timing Control

The characteristics of the fuel injection timing differ according to main fuel injection and pilot fuel injection. The NE sensor as well as the auxiliary NE sensor can be used as the basis for the injection timing, but normally the NE sensor is used as the reference.

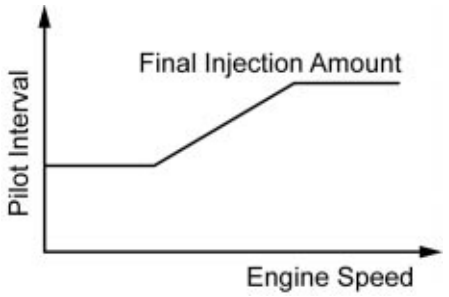
[1] Main injection timing

The basic injection timing is calculated from the final injection amount, the engine speed, and the water temperature.
At the time of start, it is calculated from the water temperature and the engine speed.



[2] Pilot injection timing (Pilot interval)

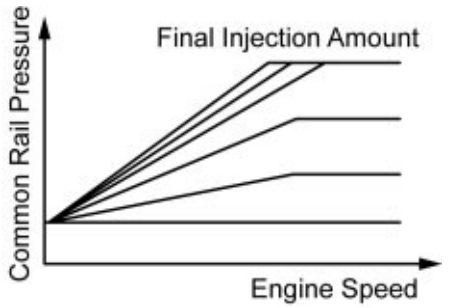
The pilot injection timing is controlled by adding the pilot interval to the main injection timing.
The pilot interval is calculated from the final injection amount, the engine speed, and the water temperature (map correction).
At the time of start, it is calculated from the water temperature and the engine speed.



16. Fuel Injection Pressure Control

[1] Fuel injection pressure

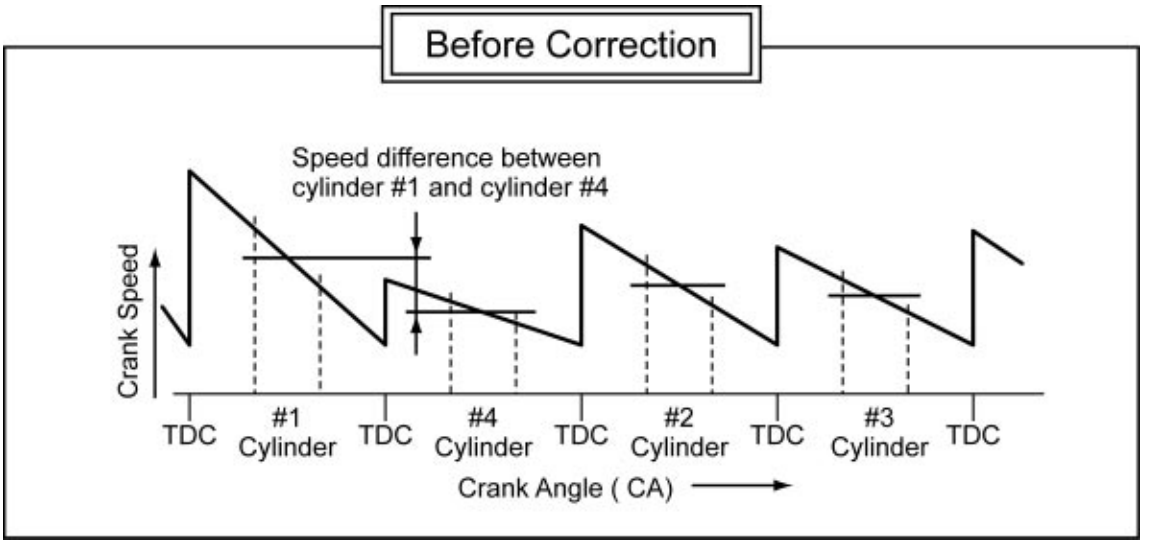
A value decided according to the final injection amount and the engine speed is calculated.
At the time of start, it is calculated from the water temperature and the engine speed.

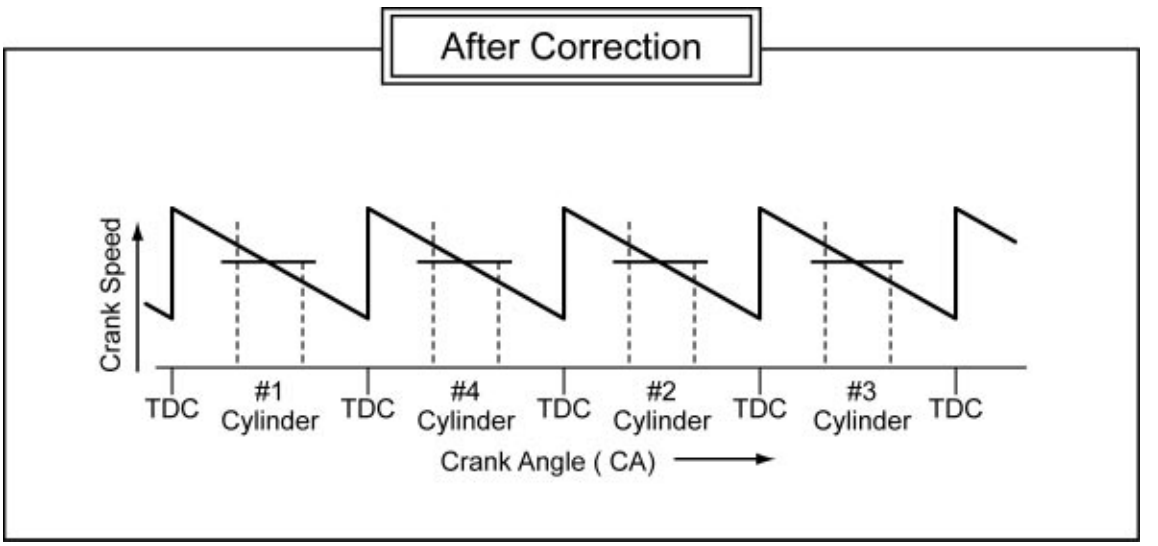


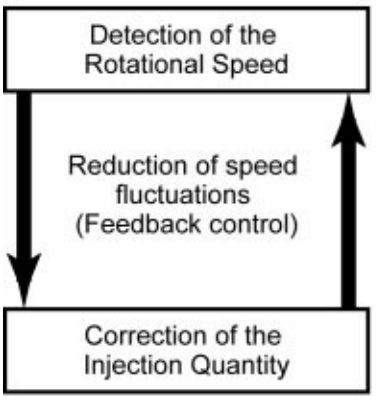
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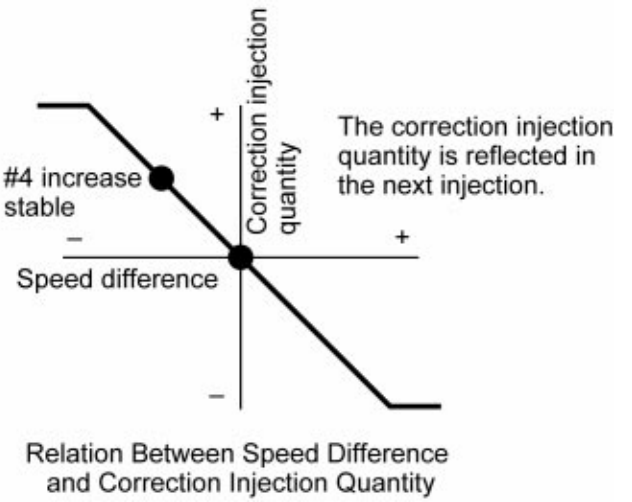
17. FCCB Control (Fuel Control Cylinder Balance)

The FCCB control recognizes the speed fluctuations caused by scatter of the injection quantities between the cylinders and by combustion scatter by means of its own speed sensor and adjust the injection quantities between the cylinders.
This makes it possible to reduce speed fluctuations.





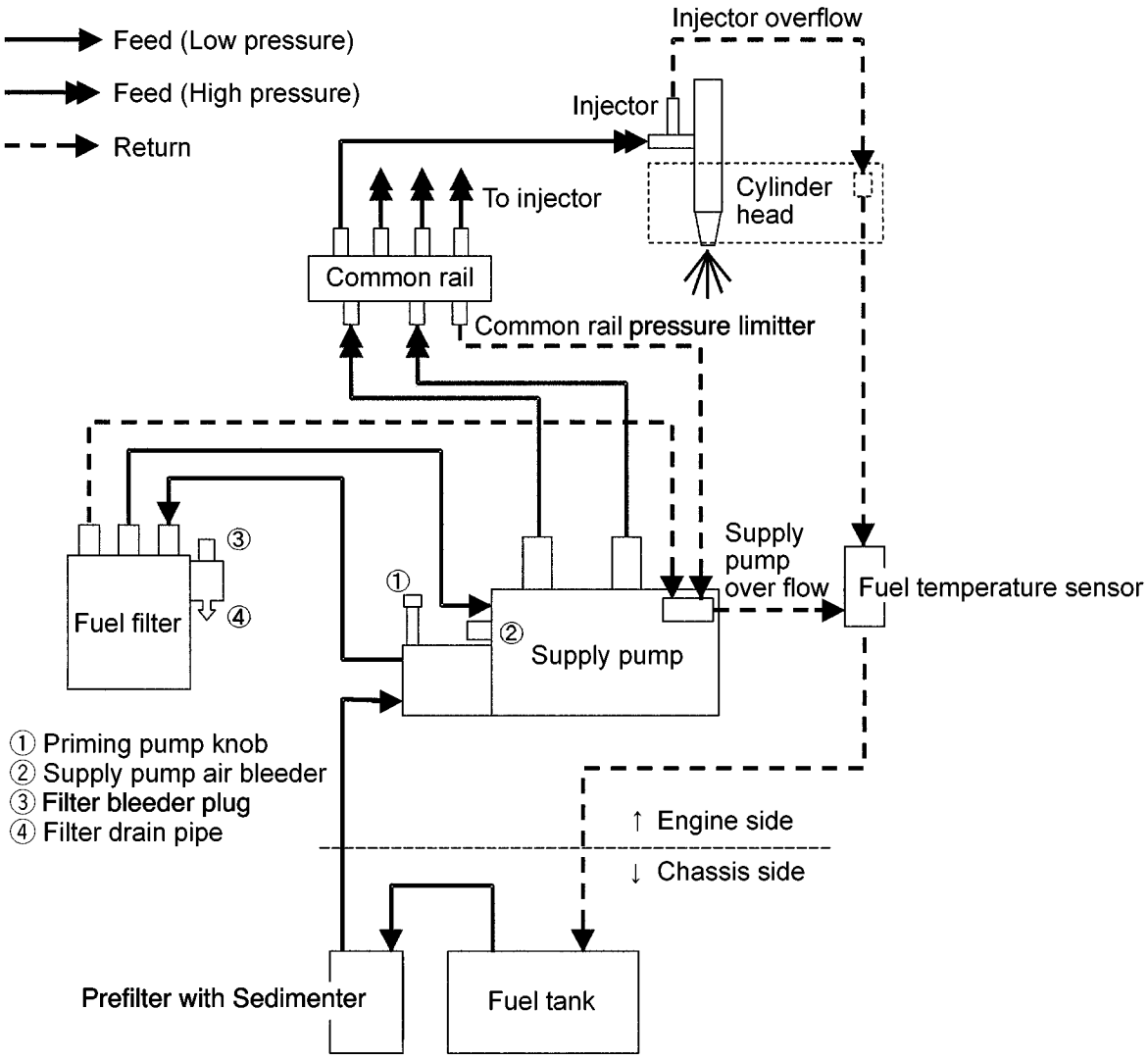




Relation Between Speed Difference and Correction Injection Quantity

18. Manual Fuel Air Venting

[1] Fuel system diagram



[2] Procedure: The basic procedure consists of air venting for the F-filter part, air venting for the supply pump, and start.

1) Loosen the priming pump knob (1) of the supply pump by hand and pull out the knob.
2) Push the knob by hand and move it up and down for pumping.
3) When pushing the knob (1) becomes harder, loosen the F-filter drain bolt (3) and vent the air through the drain pipe (4).
4) Tighten the F-filter drain bolt (3) provisionally.
5) Repeat the steps 2) to 4) until air no longer comes from the drain pipe (4), and then tighten the drain bolt (3) with the correct torque.
6) Again move the priming pump knob (1) of the supply pump up and down for pumping.
7) When pushing the knob (1) becomes harder, loosen the air bleeder (2) of the supply pump and vent the air.
8) Tighten the air bleeder (2) provisionally.
9) Repeat the steps 6) to 8), and when air no longer comes out from the air bleeder (2), tighten the air bleeder with the correct torque.
10) Again pump until pushing the knob (1) becomes harder, and finally lock the knob by tightening it in pushed-in condition.
11) Again confirm the tightening of all parts and then start the engine with the starter.

[3] Caution items: At the time of air venting, pay attention to the following items.

1) Pay attention to fuel spilling from the supply pump air bleeder (2) and the F-filter drain pipe (4) at the time of air venting.
   Apply rags etc. to the respective parts for the work and take care to prevent spilling of fuel to the surroundings.
2) The tightening torque for the respective parts is as follows.

* Priming pump knob (1): Tighten by hand with the knob pushed in: 2.45 ± 0.5 N·m (1.81 ± 0.37 ft-lb, 24.98 ± 5.10 kgf/cm)
* Supply pump air bleeder (2): 5.9 ± 1.0 N·m (4.35 ± 0.73 ft-lb, 60.16 ± 0.10 kgf/cm)
* F-filter drain bolt (3): 6.9 ± 1.9 N·m (5.09 ± 1.40 ft-lb, 70.36 ± 0.19 kgf/cm)

3) If starting is difficult or if the engine stops some time after starting, the air has not been vented sufficiently and should be repeated.
   DST-1 also can be used to confirm whether sufficient air venting has been done or not. Set the key to ON, use the starter to perform cranking, and confirm common rail pressure rise. In case of insufficient air venting, the common rail pressure will not rise.
   If starting still should be difficult, fuel leakage from the piping parts or system trouble can be considered.
   Check all parts for leakage and perform a system check with DST-1.
4) Continuous use of the starter for 15 seconds or longer can cause defects or battery exhaustion.
   When start was not possible once, return the key to the “ACC” position to let the battery recover and wait for at least 30 seconds before starting the engine again.