DENSO

For DENSO Authorized
ECD Service Dealer Only

Diesel Injection Pump

SERVICE MANUAL

Common Rail System for HINO J05D/J08E Type Engine

OPERATION

October, 2003

DENSO CORPORATION

00400041E

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1. Product Application

1.1 Application

Vehicle Name	Vehicle Model	Engine Model	Exhaust Volume	Reference
Medium Truck	HINO145, HINO165, HINO185	J05D	4.73L	Sales from Early '04
	HINO238, HINO268, HINO308, HINO338	J08E	7.68L	

1.2 System Components Parts Number

Part Name	Vehicle Name	DENSO Part Number	Car Manufacturer Part Number	Reference
Supply Pump	Medium Truck HINO238, HINO268, HINO308, HINO338	294050-0011	22730-1311A	
Injector		095000-5281	23910-1360A	
Rail		095440-0480	22760-1180A	
Engine ECU		102758-3010	89560-6540A	
Accelerator Position Sensor		198800-3160	78010-1200A	
Coolant Temp. Sensor		071560-0110	83420-1250A	
Crankshaft Position Sensor		029600-0570	89410-1280A	
Cylinder Recognition Sensor		949979-1360	89410-1590A	
Intake Air Pressure Sensor		079800-5890	89390-1080A	
EGR Valve		135000-7091	17350-1220A	
Air Flow Meter		197400-2000	22204-21010B	For EGR Control
Supply Pump	Medium Truck HINO145, HINO165, HINO185	294000-0251	22730-1321A	
Injector		095000-5391	23910-1310A	
Rail		095440-0530	22760-1220A	
Engine ECU		102758-3010	89560-6540A	
Accelerator Position Sensor		198800-3160	78010-1200A	
Coolant Temp. Sensor		071560-0110	83420-1250A	
Crankshaft Position Sensor		029600-0570	89410-1280A	
Cylinder Recognition Sensor		949979-1360	89410-1590A	
Intake Air Pressure Sensor		079800-5890	89390-1080A	
EGR Valve		135000-7071	17350-1210A	
Air Flow Meter		197400-2000	22204-21010B	For EGR Control

2. Outline

2.1 Features of System

The common rail system was developed primarily to cope with exhaust gas regulations for diesel engines, and aimed for 1. further improved fuel economy; 2. noise reduction; and 3. high power output.

[1] System Characteristics

The common rail system uses a type of accumulation chamber called a rail to store pressurized fuel, and injectors that contain electronically controlled solenoid valves to spray the pressurized fuel into the cylinders. Because the engine ECU controls the injection system (including the injection pressure, injection rate, and injection timing), the system is unaffected by the engine speed or load. This ensures a stable injection pressure at all times, particularly in the low engine speed range, and dramatically decreases the amount of black smoke ordinarily emitted by a diesel engine during start-up and acceleration. As a result, exhaust gas emissions are cleaner and reduced, and higher power output is achieved.

(1) Injection Pressure Control

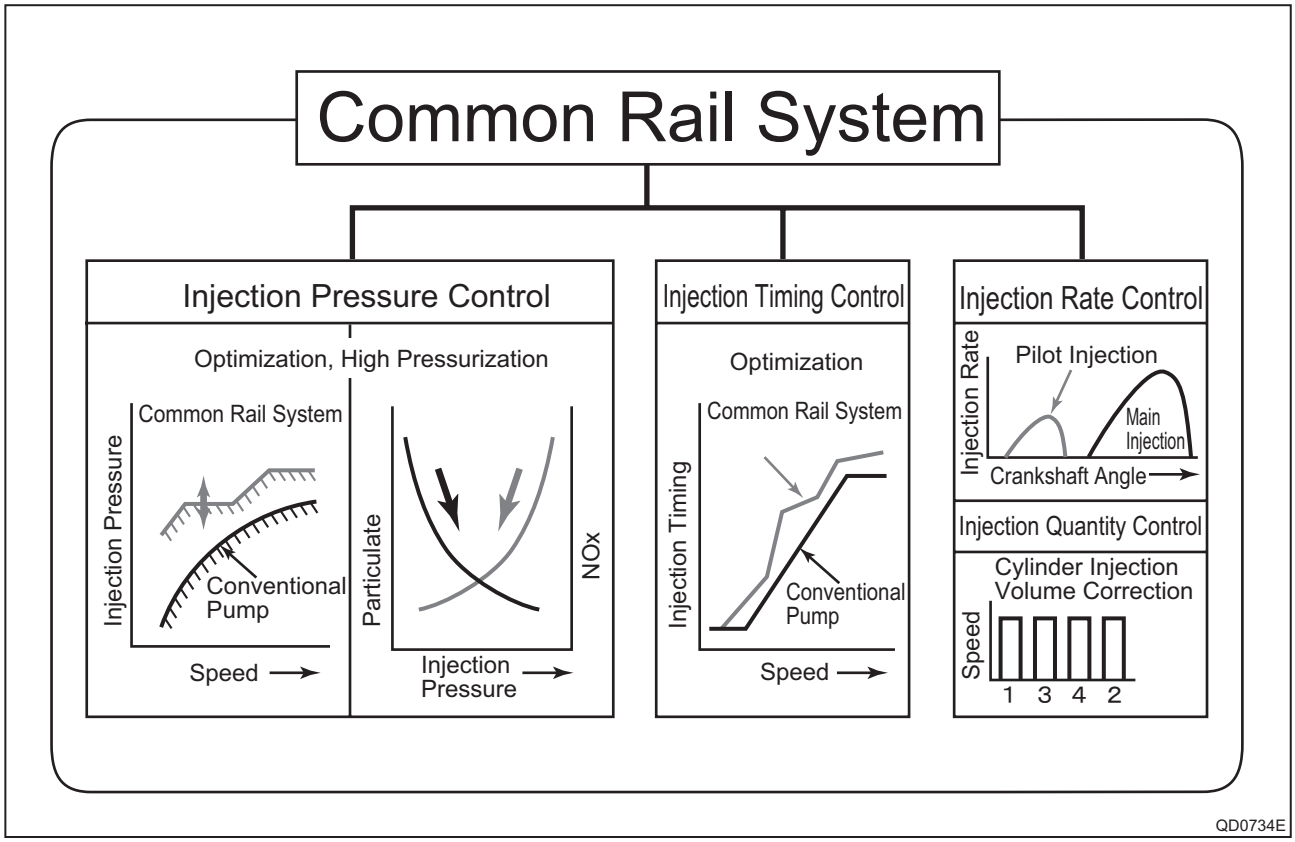
a. Enables high-pressure injection, even in the low engine speed range.
b. Optimizes control to minimize particulate matter and NOx emissions.

(2) Injection Timing Control

a. Optimally controls the timing to suit driving conditions.

(3) Injection Rate Control

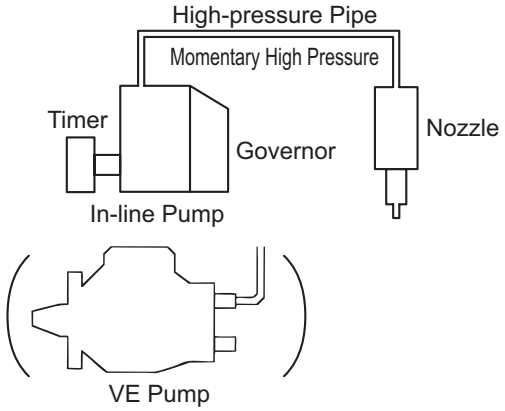
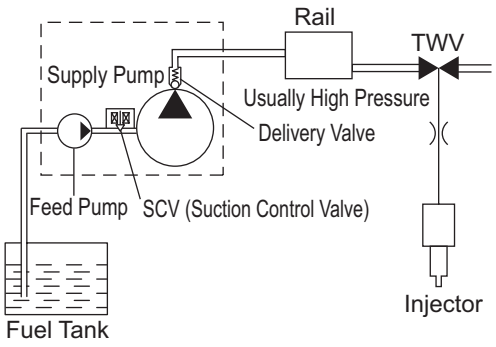
a. Pilot injection control sprays a small amount of fuel before the main injection.



(4) EGR (Exhaust Gas Recirculation) Control

a. By recirculating the exhaust gas into the intake side of the engine, the combustion temperature is reduced and NOx is decreased.

[2] Comparison to the Conventional System

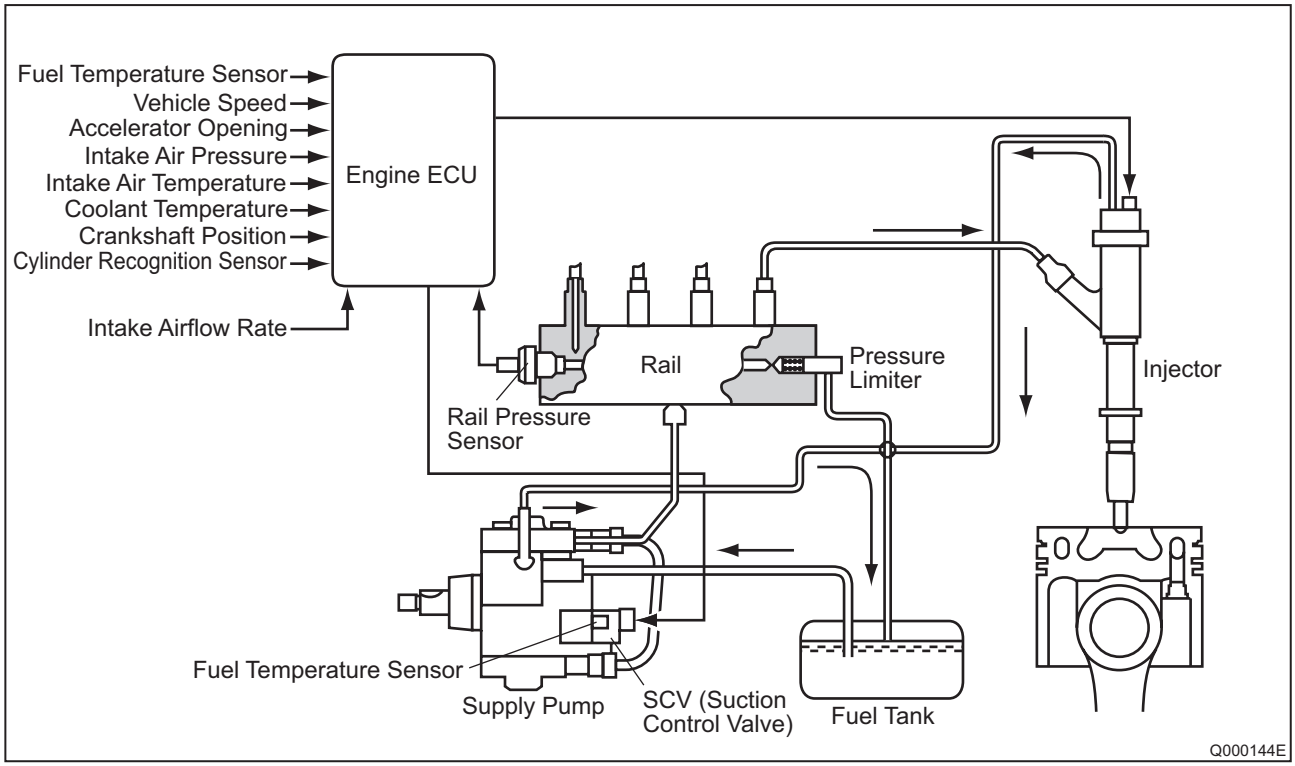
System	In-line, VE Pump	Common Rail System
		
Injection Quantity Control	Pump (Governor)	Engine ECU, Injector (TWV)*1
Injection Timing Control	Pump (Timer)	Engine ECU, Injector (TWV)*1
Rising Pressure	Pump	Engine ECU, Supply Pump
Distributor	Pump	Engine ECU, Rail
Injection Pressure Control	Dependent upon Speed and Injection Quantity	Engine ECU, Supply Pump (SCV)*2

*1 TWV: Two Way Valve *2 SCV: Suction Control Valve QD2341E

2.2 Outline of System

[1] Composition

The common rail system consists primarily of a supply pump, rail, injectors, and engine ECU.



[2] Operation

(1) Supply pump (HP3)

a. The supply pump draws fuel from the fuel tank, and pumps the high pressure fuel to the rail. The quantity of fuel discharged from the supply pump controls the pressure in the rail. The SCV (Suction Control Valve) in the supply pump effects this control in accordance with the command received from the ECU.

(2) Rail

a. The rail is mounted between the supply pump and the injector, and stores the high-pressure fuel.

(3) Injector (G2 type)

a. This injector replaces the conventional injection nozzle, and achieves optimal injection by effecting control in accordance with signals from the ECU. Signals from the ECU determine the length of time and the timing in which current is applied to the injector. This in turn, determines the quantity, rate and timing of the fuel that is injected from the injector.

(4) Engine ECU

a. The engine ECU calculates data received from the sensors to comprehensively control the injection quantity, timing and pressure, as well as the EGR (exhaust gas recirculation).

2.3 Fuel System and Control System

[1] Fuel System

This system comprises the route through which diesel fuel flows from the fuel tank to the supply pump, via the rail, and is injected through the injector, as well as the route through which the fuel returns to the tank via the overflow pipe.

[2] Control System

In this system, the engine ECU controls the fuel injection system in accordance with the signals received from various sensors. The components of this system can be broadly divided into the following three types: (1) Sensors; (2) ECU; and (3) Actuators.

(1) Sensors

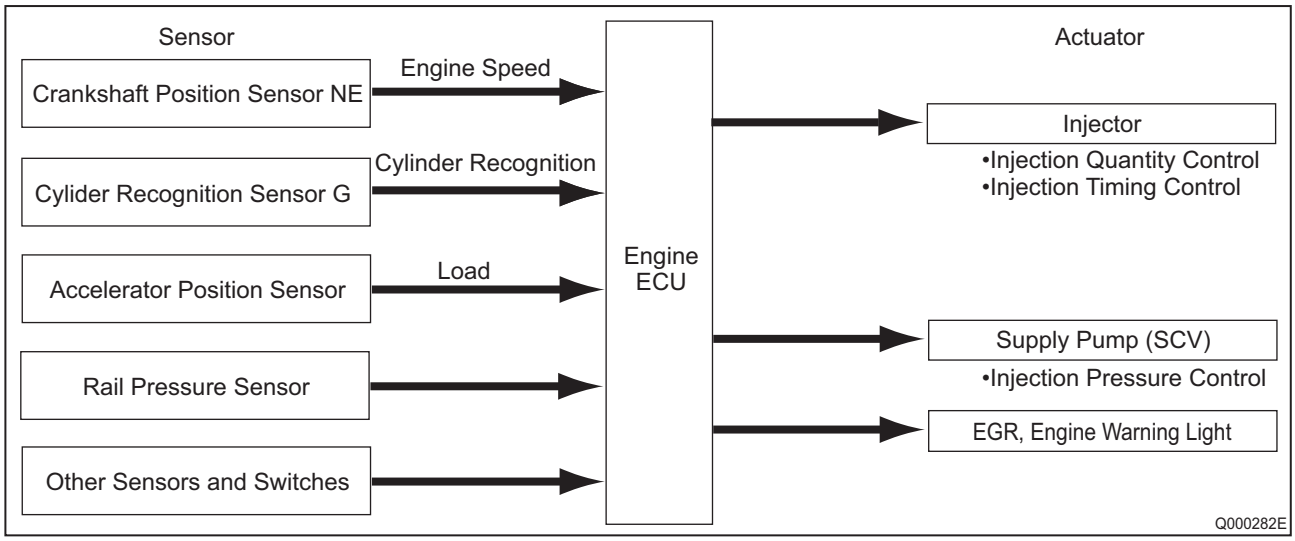
a. Detect the engine and driving conditions, and convert them into electrical signals.

(2) Engine ECU

a. Performs calculations based on the electrical signals received from the sensors, and sends them to the actuators in order to achieve optimal conditions.

(3) Actuators

a. Operate in accordance with electrical signals received from the ECU. Injection system control is undertaken by electronically controlling the actuators. The injection quantity and timing are determined by controlling the length of time and the timing in which the current is applied to the TWV (Two-Way Valve) in the injector. The injection pressure is determined by controlling the SCV (Suction Control Valve) in the supply pump.



3. Construction and Operation

3.1 Description of Main Components

[1] Supply Pump (HP3, HP4)

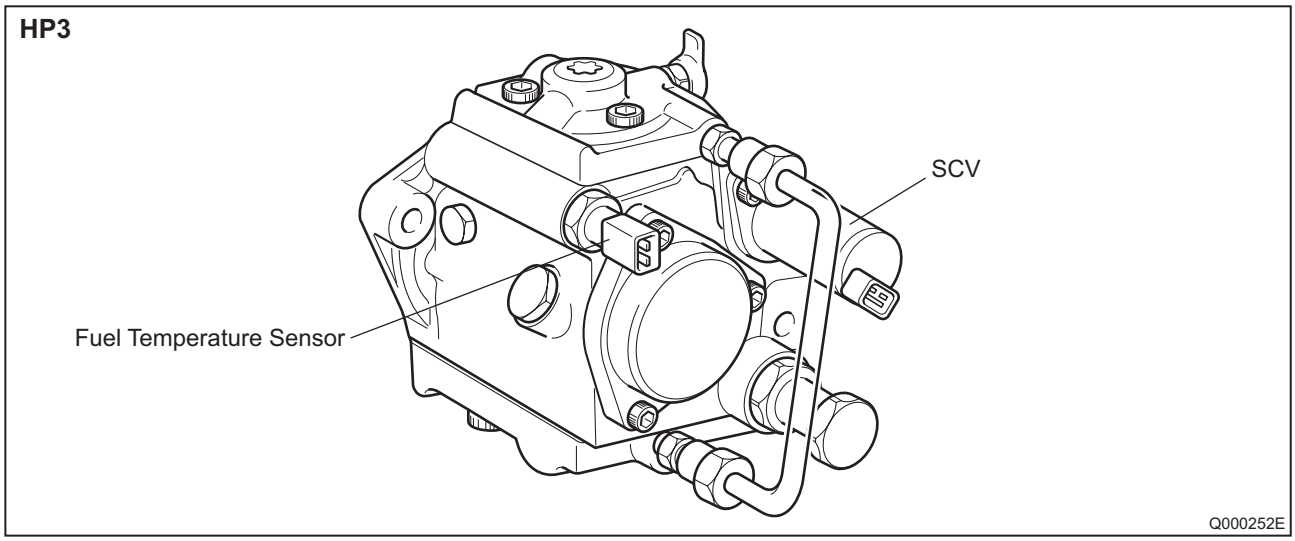
(1) Outline

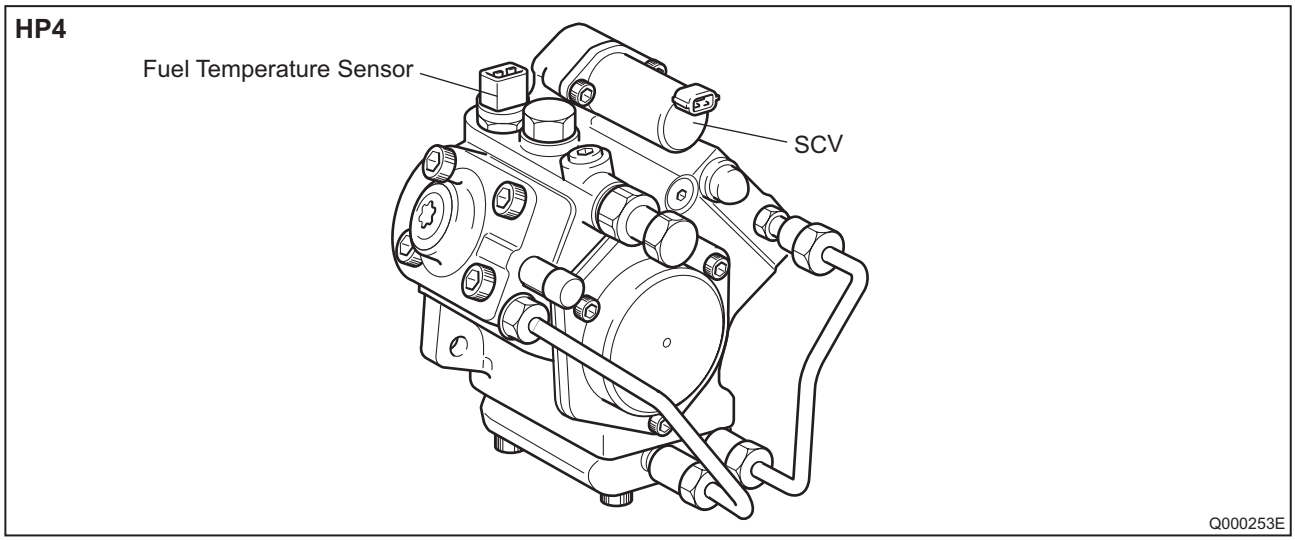
a. The supply pump consists primarily of the pump body (cam shaft, ring cam, and plungers), SCV (Suction Control Valve), fuel temperature sensor, and feed pump.

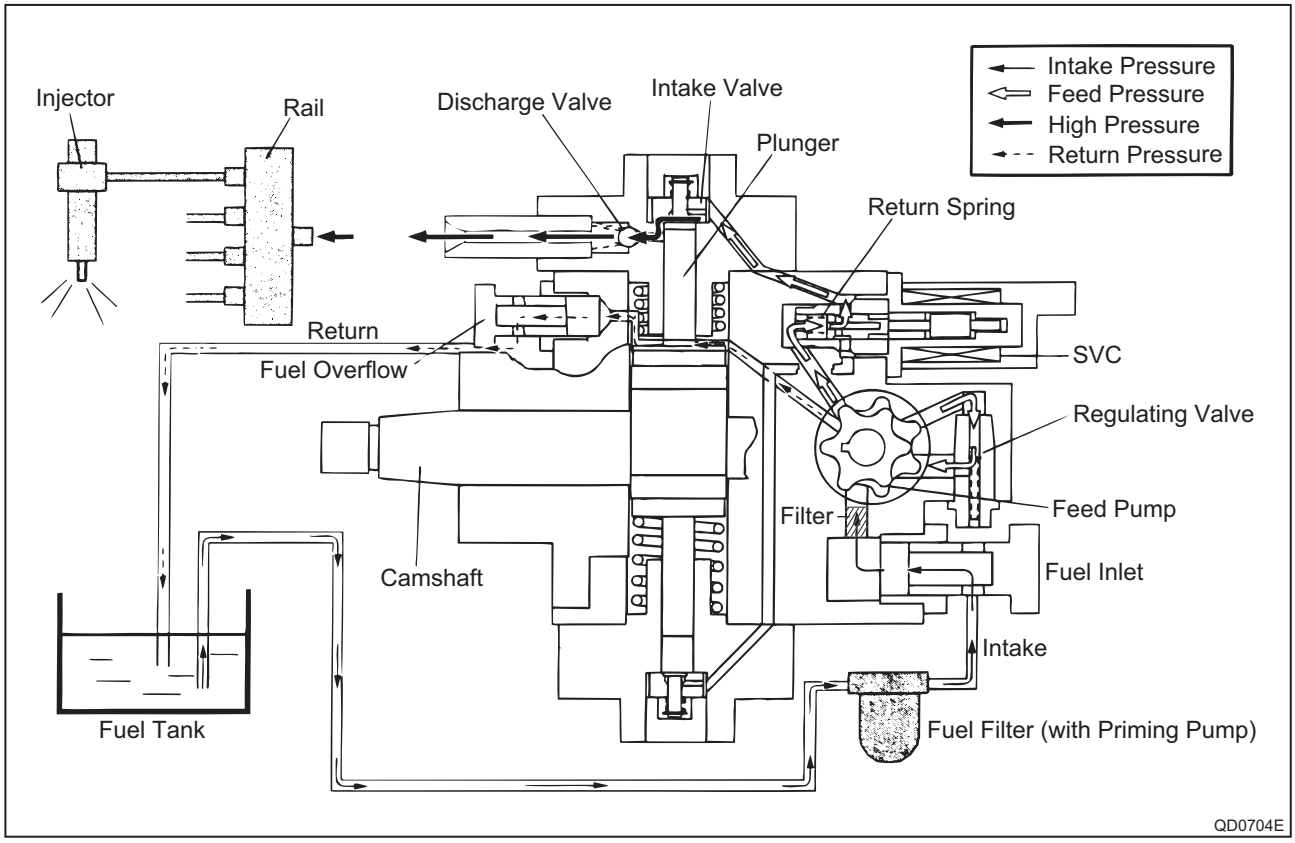
b. The two plungers for HP3 or the three plungers for HP4 are positioned vertically on the outer ring cam for compactness.

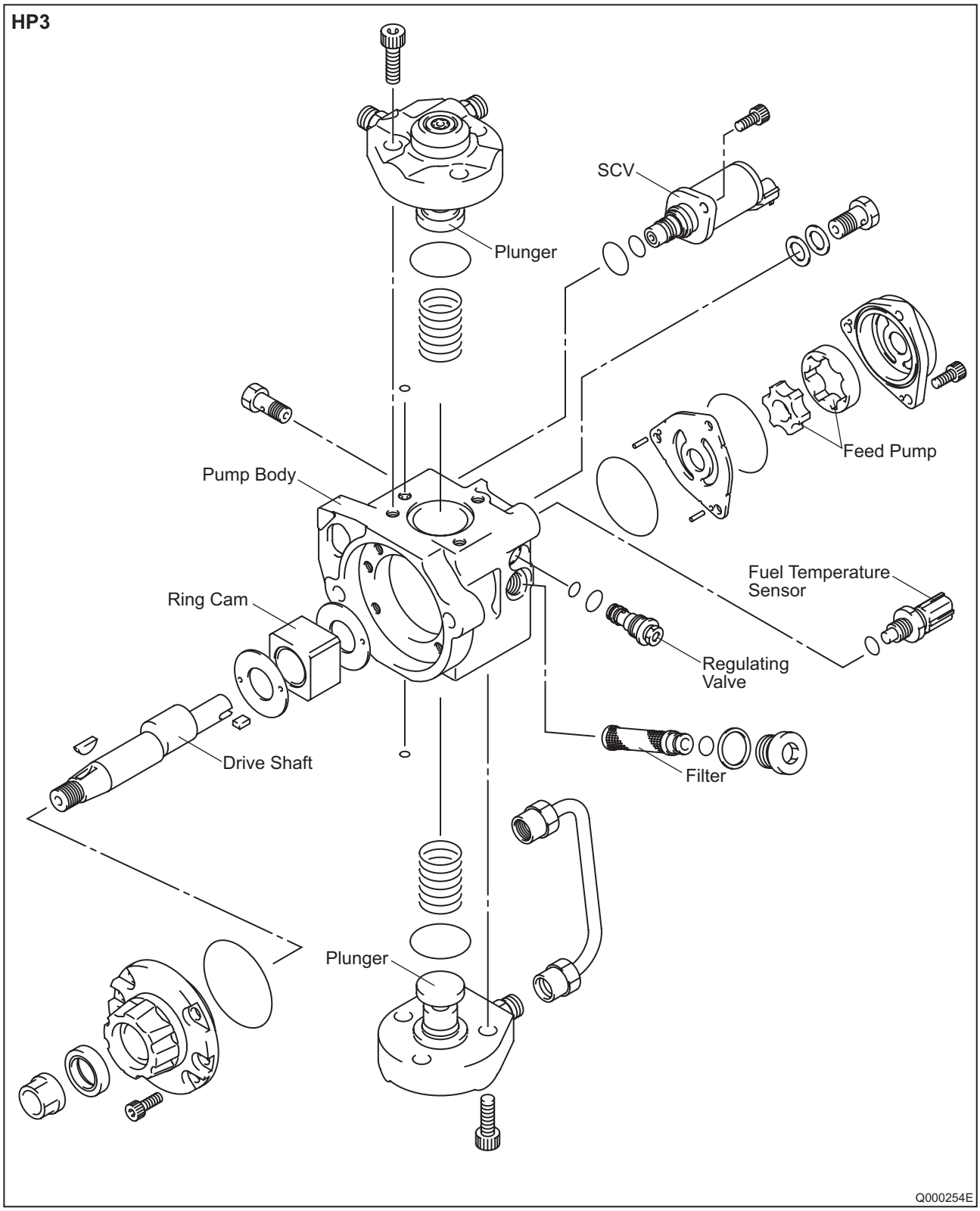
c. The engine drives the supply pump at a ratio of 1:1. The supply pump has a built-in feed pump (trochoid type), and draws the fuel from the fuel tank, sending it to the plunger chamber.

d. The internal camshaft drives the two plungers, and they pressurize the fuel sent to the plunger chamber and send it to the rail. The quantity of fuel supplied to the rail is controlled by the SCV, using signals from the engine ECU. The SCV is a normally opened type (the intake valve opens during de-energization).

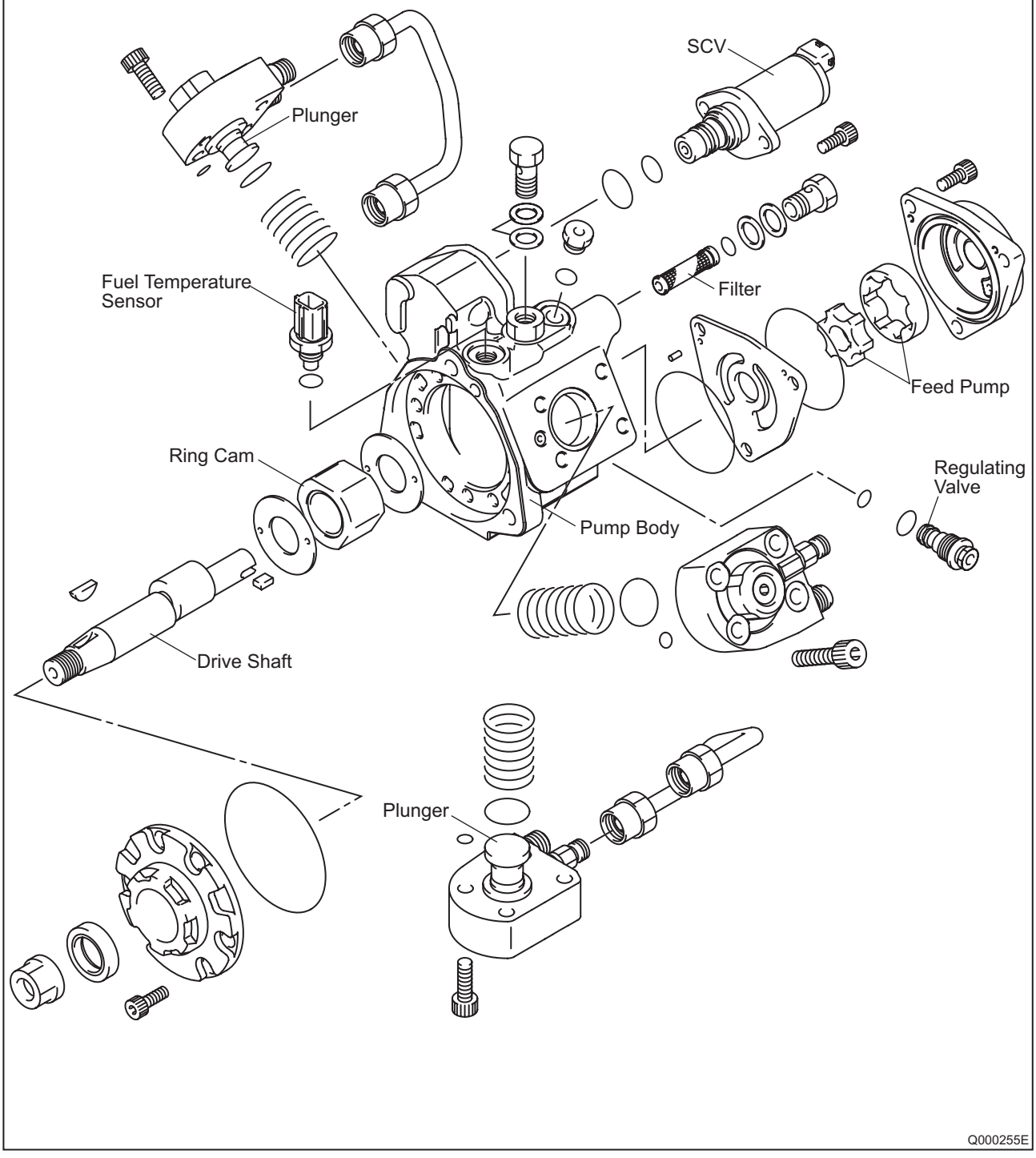





Intake Pressure
Feed Pressure
High Pressure
Return Pressure
Injector
Rail
Discharge Valve
Intake Valve
Plunger
Return Spring
Return
Fuel Overflow
SVC
Regulating Valve
Feed Pump
Filter
Camshaft
Fuel Inlet
Intake
Fuel Tank
Fuel Filter (with Priming Pump)
QD0704E

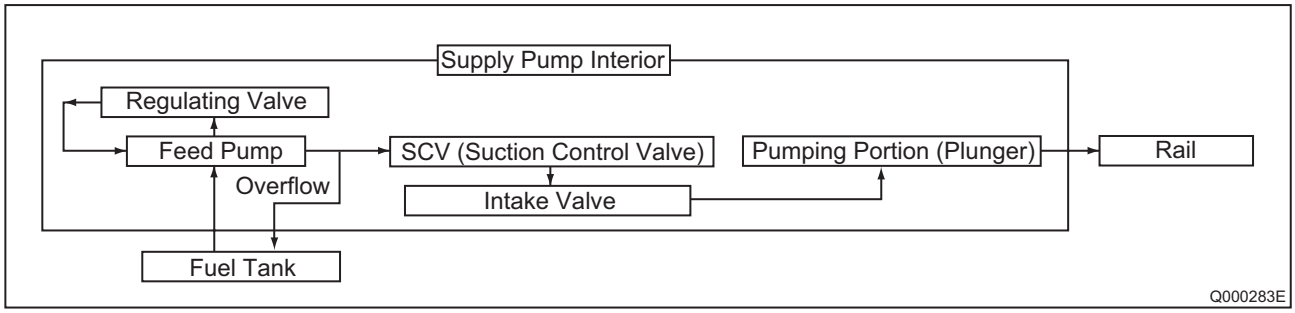

HP3
SCV
Plunger
Feed Pump
Pump Body
Fuel Temperature Sensor
Ring Cam
Regulating Valve
Drive Shaft
Filter
Plunger
Q000254E

HP4


SCV
Plunger
Fuel Temperature Sensor
Filter
Feed Pump
Ring Cam
Regulating Valve
Pump Body
Drive Shaft
Plunger
Q000255E

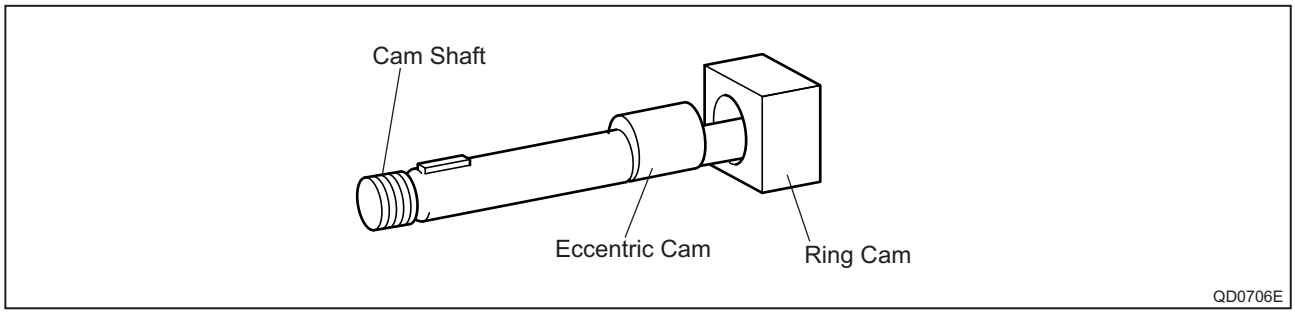
(2) Supply Pump Internal Fuel Flow

a. The fuel that is drawn from the fuel tank passes through the route in the supply pump as illustrated, and is fed into the rail.

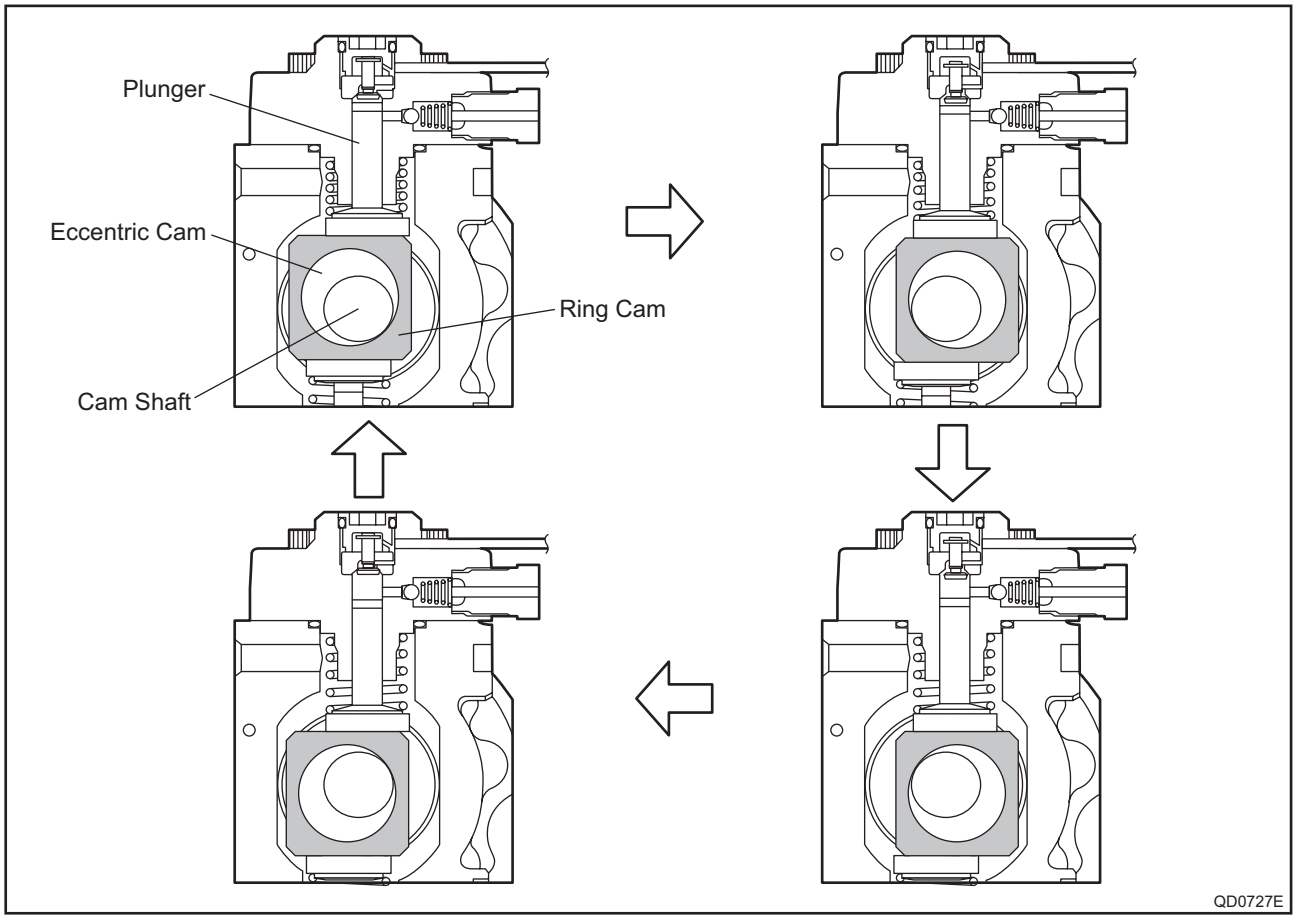


(3) Construction of Supply Pump (in case of HP3 pump)

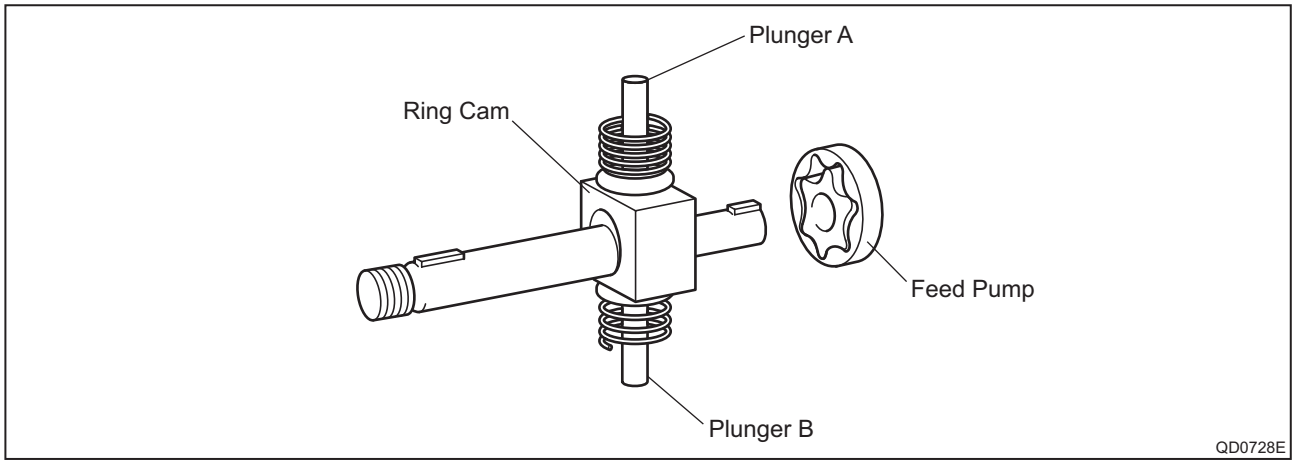
a. The eccentric cam is attached to the cam shaft. The eccentric cam is connected to the ring cam.



b. As the cam shaft rotates, the eccentric cam rotates eccentrically, and the ring cam moves up and down while rotating.

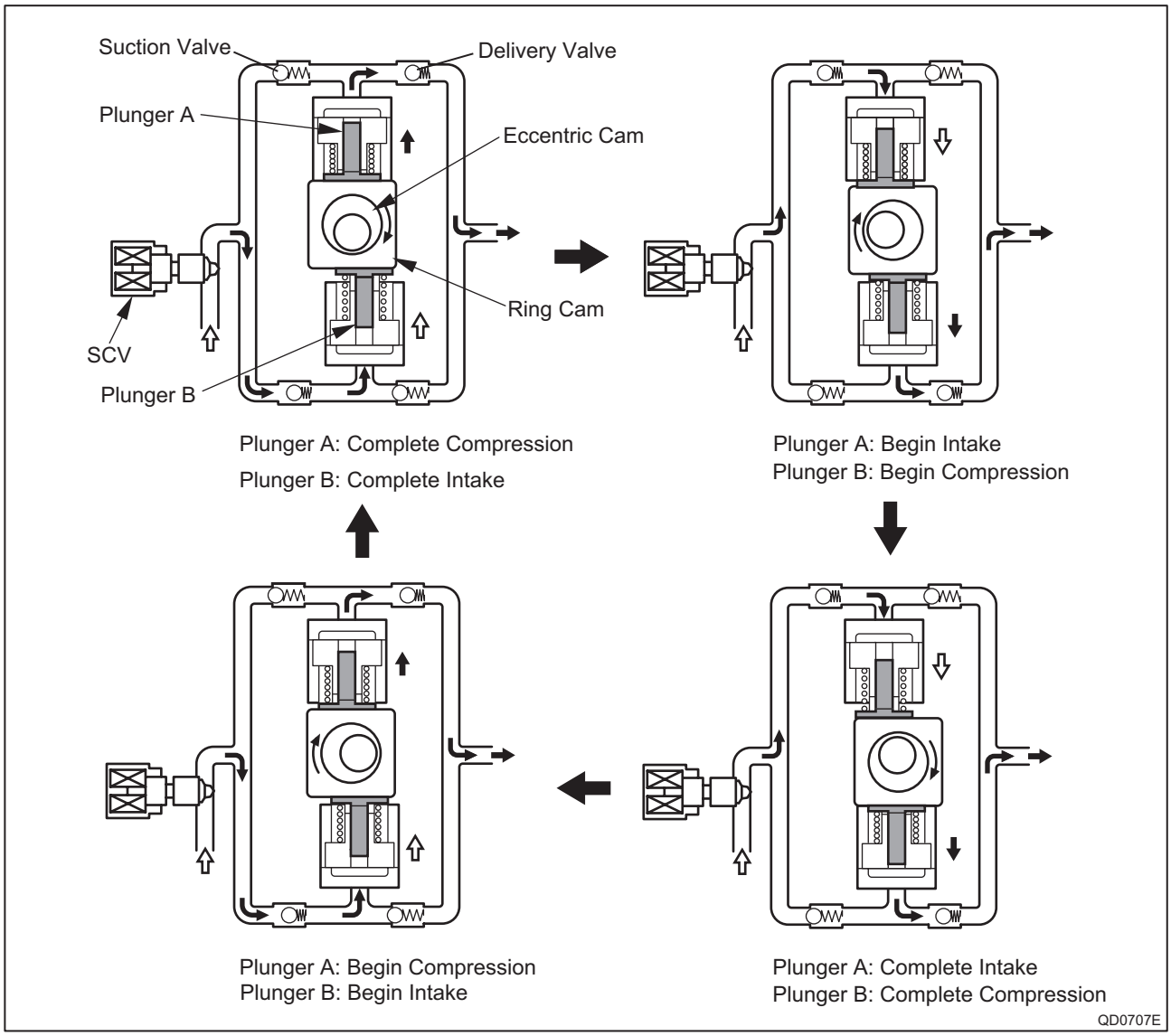


c. The plunger and the suction valve are attached to the ring cam. The feed pump is connected to the rear of the cam shaft.



(4) Operation of the Supply Pump

a. As shown in the illustration below (in case of HP3 pump), the rotation of the eccentric cam causes the ring cam to push Plunger A upwards. Due to the spring force, Plunger B is pulled in the opposite direction to Plunger A. As a result, Plunger B draws in fuel, while Plunger A pumps it to the rail. In the case of the 4-cylinder engine used with the HP3 pump, each plunger pumps fuel in a reciprocal movement during the 360° cam rotation. Conversely, in the case of the 6-cylinder engine used with the HP4 pump, 3 plungers pump fuel in a reciprocal movement for each one rotation of the cam.

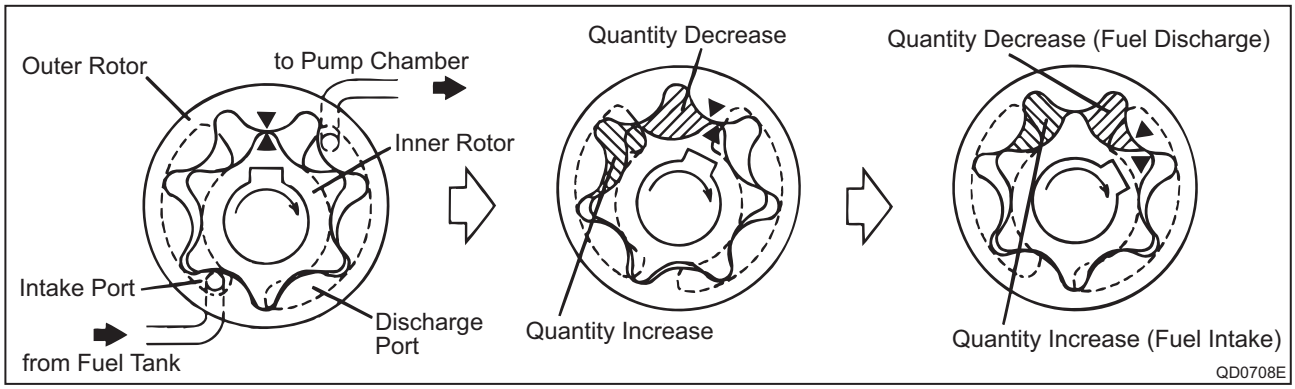


NOTE:
There are 3 plungers for the HP4.

[2] Description of Supply Pump Components

(1) Feed Pump

a. The trochoid type feed pump, which is integrated in the supply pump, draws fuel from the fuel tank and feeds it to the two plungers via the fuel filter and the SCV (Suction Control Valve). The feed pump is driven by the drive shaft. With the rotation of the inner rotor, the feed pump draws fuel from its suction port and pumps it out through the discharge port. This is done in accordance with the space that increases and decreases with the movement of the outer and inner rotors.



(2) SCV: Suction Control Valve (Normally open type)

a. A linear solenoid type valve has been adopted. The ECU controls the duty ratio (the duration in which current is applied to the SCV), in order to control the quantity of fuel that is supplied to the high-pressure plunger.

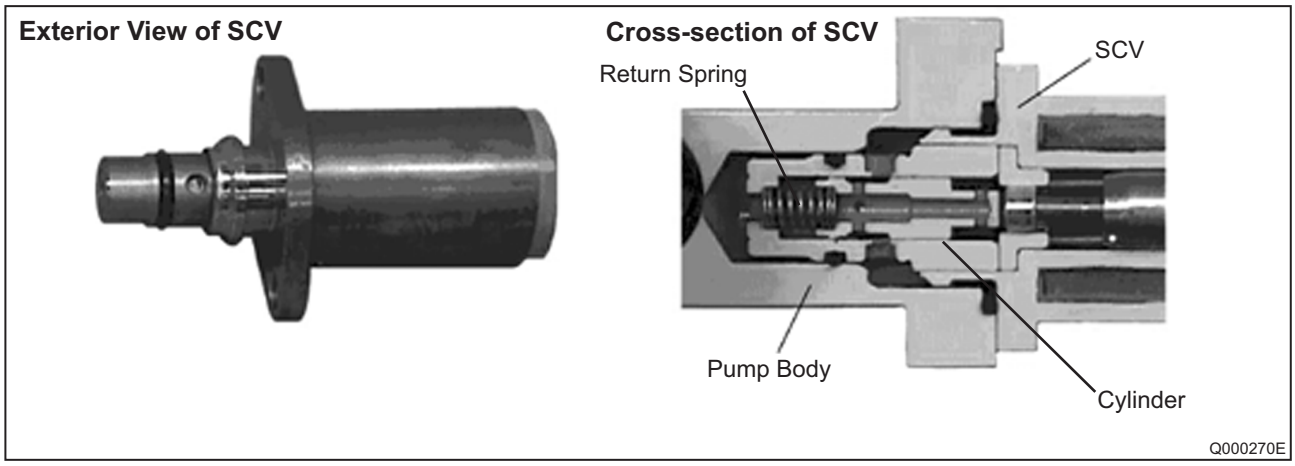
b. Because only the quantity of fuel that is required for achieving the target rail pressure is drawn in, the actuating load of the supply pump decreases.

c. When current flows to the SCV, variable electromotive force is created in accordance with the duty ratio, moving the armature to the left side. The armature moves the cylinder to the left side, changing the opening of the fuel passage and thus regulating the fuel quantity.

d. With the SCV OFF, the return spring contracts, completely opening the fuel passage and supplying fuel to the plungers. (Full quantity intake and full quantity discharge)

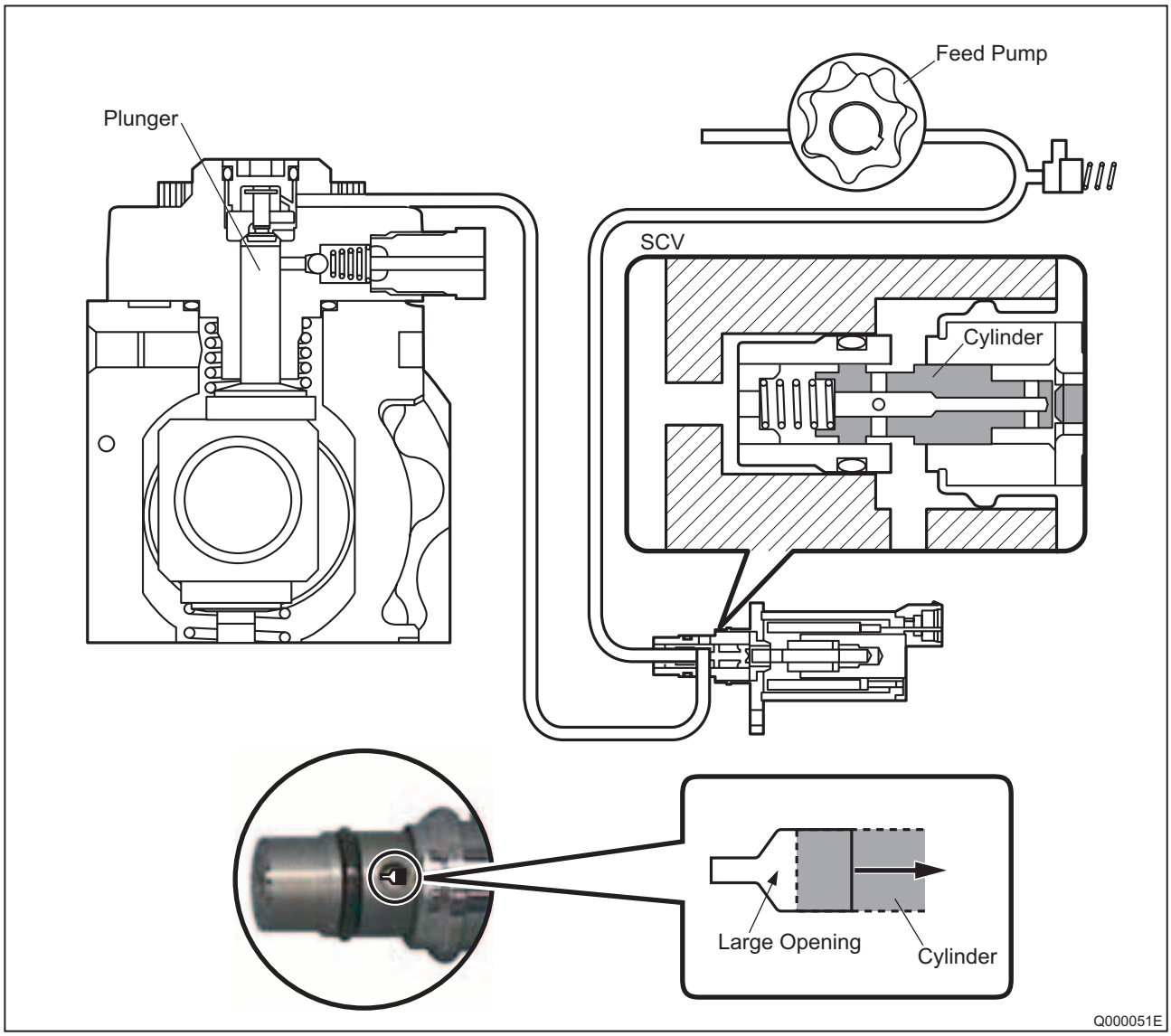
e. When the SCV is ON, the force of the return spring moves the cylinder to the right, closing the fuel passage (normally opened).

f. By turning the SCV ON/OFF, fuel is supplied in an amount corresponding to the actuation duty ratio, and fuel is discharged by the plungers.

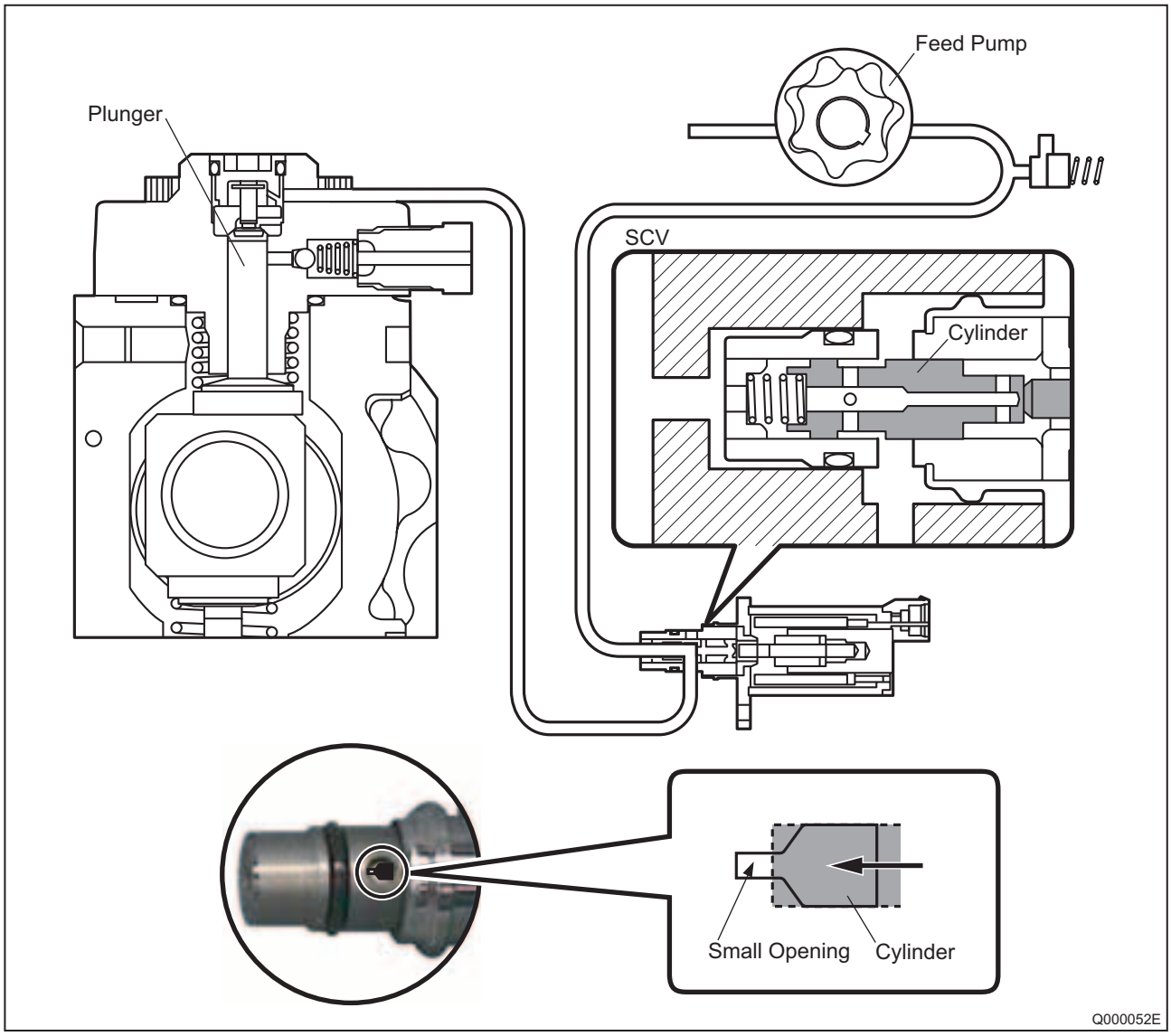


[In case of short time ON duty]

Short time ON duty → large valve opening → maximum intake quantity



[In case of long time ON duty]
Long time ON duty → small valve opening → minimum intake quantity

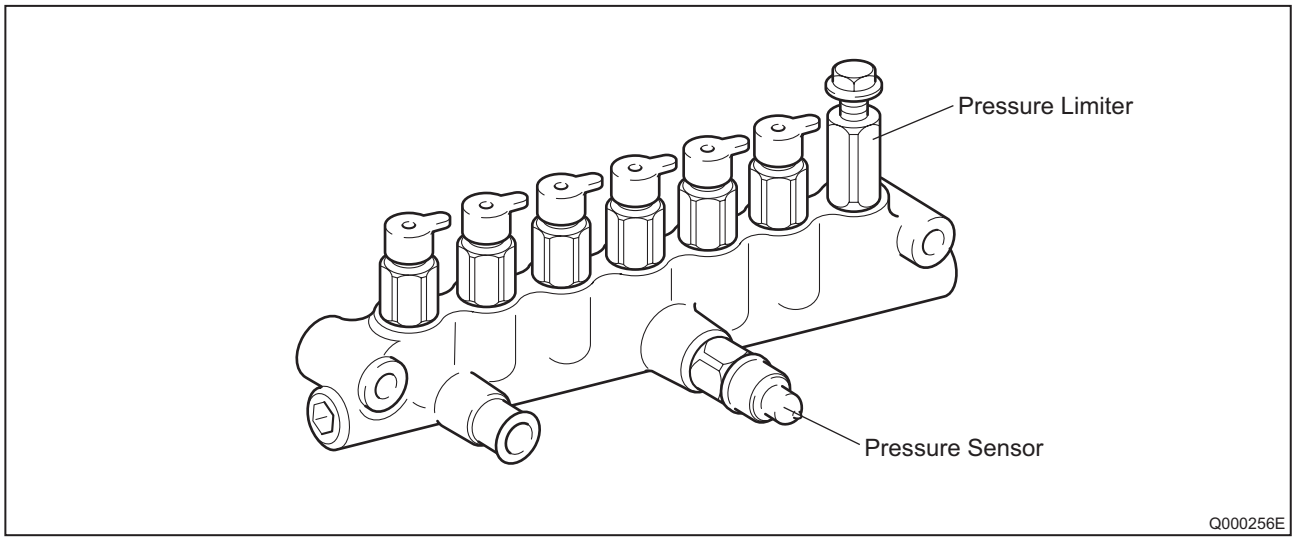


[3] Rail

(1) Outline

a. Stores pressurized fuel (0 to 150 MPa {0 to 1528.5 kg/cm^2}) that has been delivered from the supply pump and distributes the fuel to each cylinder injector. A rail pressure sensor and a pressure limiter are adopted in the rail.

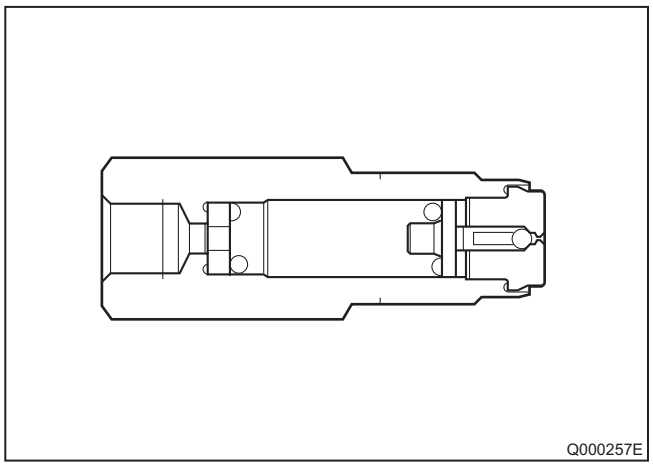
b. The rail pressure sensor (Pc sensor) detects the fuel pressure in the rail and sends a signal to the engine ECU, the pressure limiter prevents the rail pressure from being abnormally high. This ensures optimum combustion and reduces combustion noise.

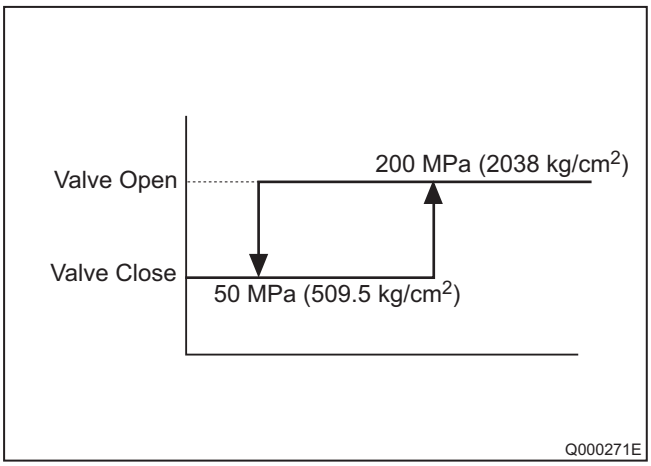


(2) Pressure Limiter

a. The pressure limiter opens to release the pressure if an abnormally high pressure is generated.

b. When the rail pressure reaches approximately 200 MPa (2038 kg/cm^2), it trips the pressure limiter (the valve opens). When the pressure drops to approximately 50 MPa (509.5 kg/cm^2), the pressure limiter returns to its normal state (the valve closes) in order to maintain the proper pressure.

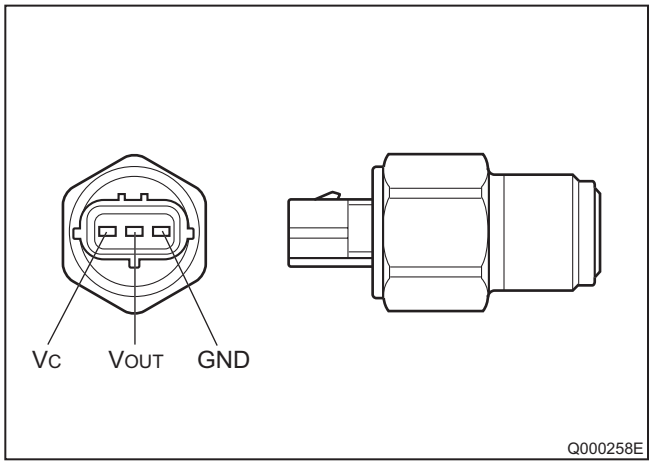


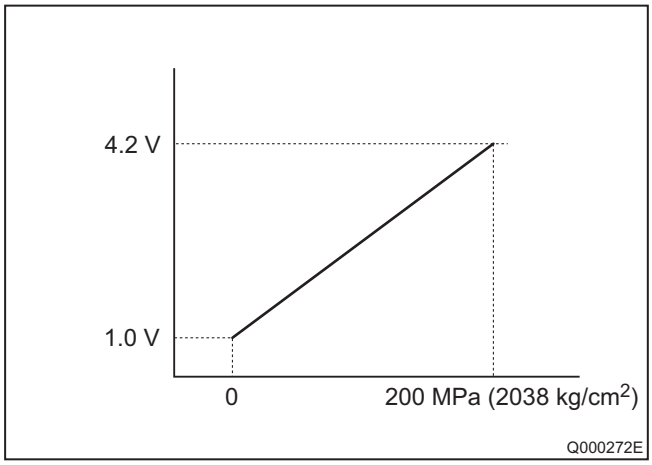


(3) Pressure Sensor

a. The rail pressure sensor (Pc sensor) is attached to the rail in order to detect the fuel pressure.

b. It is a semiconductor type pressure sensor that utilizes the characteristics of silicon, whereby the electrical resistance changes when pressure is applied to it.





REFERENCE:

It is necessary to reset the ECU default value using the Hino diagnosis tool at the time of supply pump service replacement. In addition, the ECU has a function enabling it to learn the performance of the supply pump at the time of ECU service replacement, so ensure sufficient time (several minutes) is available.

[4] Injector (G2 Type)

(1) Outline

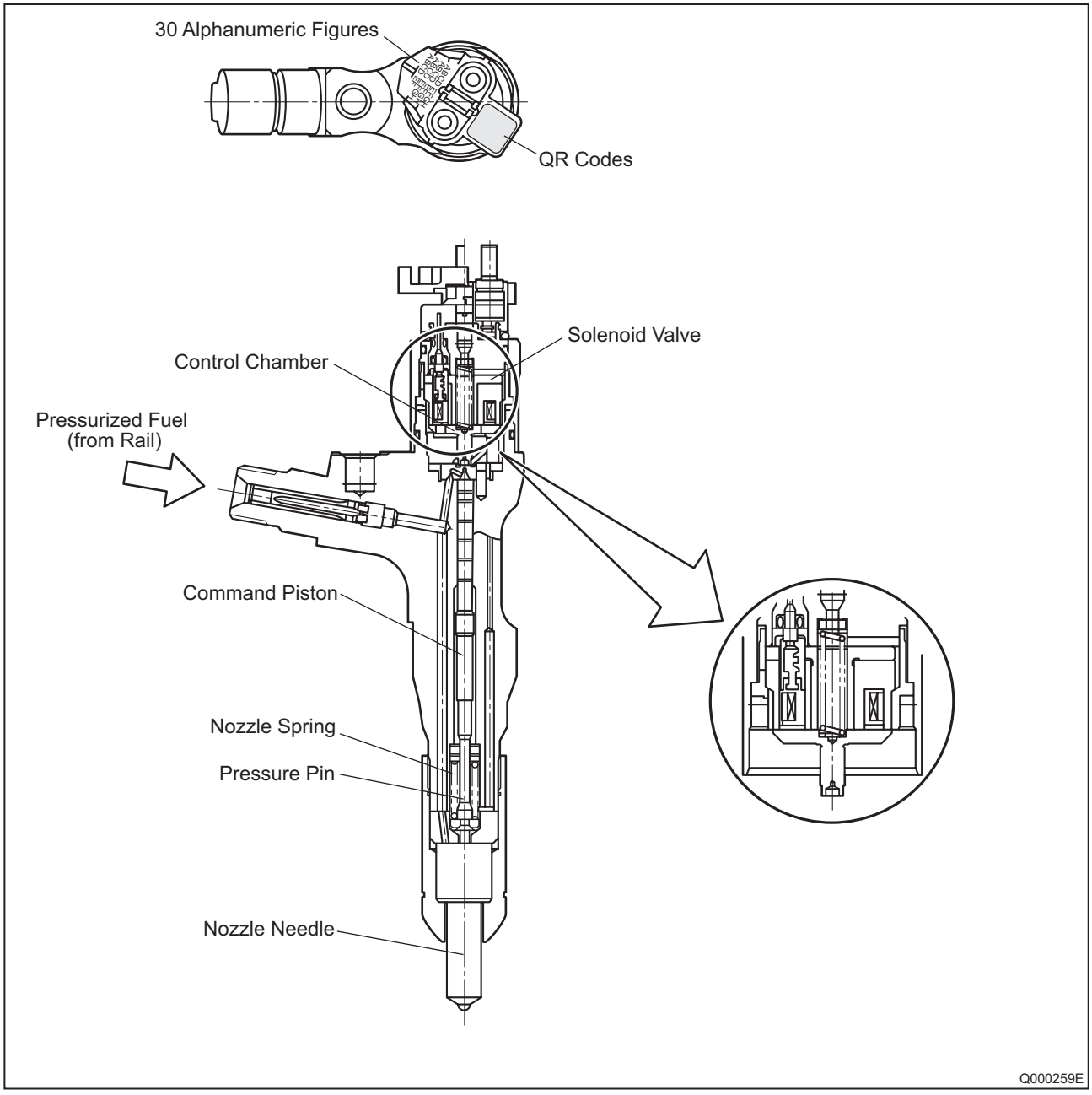
a. The injectors inject the high-pressure fuel from the rail into the combustion chambers at the optimum injection timing, rate, and spray condition, in accordance with commands received from the ECU.

(2) Characteristics

a. A compact, energy-saving solenoid-control type TWV (Two-Way Valve) injector has been adopted.

b. QR codes displaying various injector characteristics and the ID codes showing these in numeric form (30 alphanumeric figures) are engraved on the injector head. The J05/J08 engine common rail system optimizes injection volume control using this information. When an injector is newly installed in a vehicle, it is necessary to enter the ID codes in the engine ECU using the HINO Diagnostic tool.

(3) Construction



(4) Operation

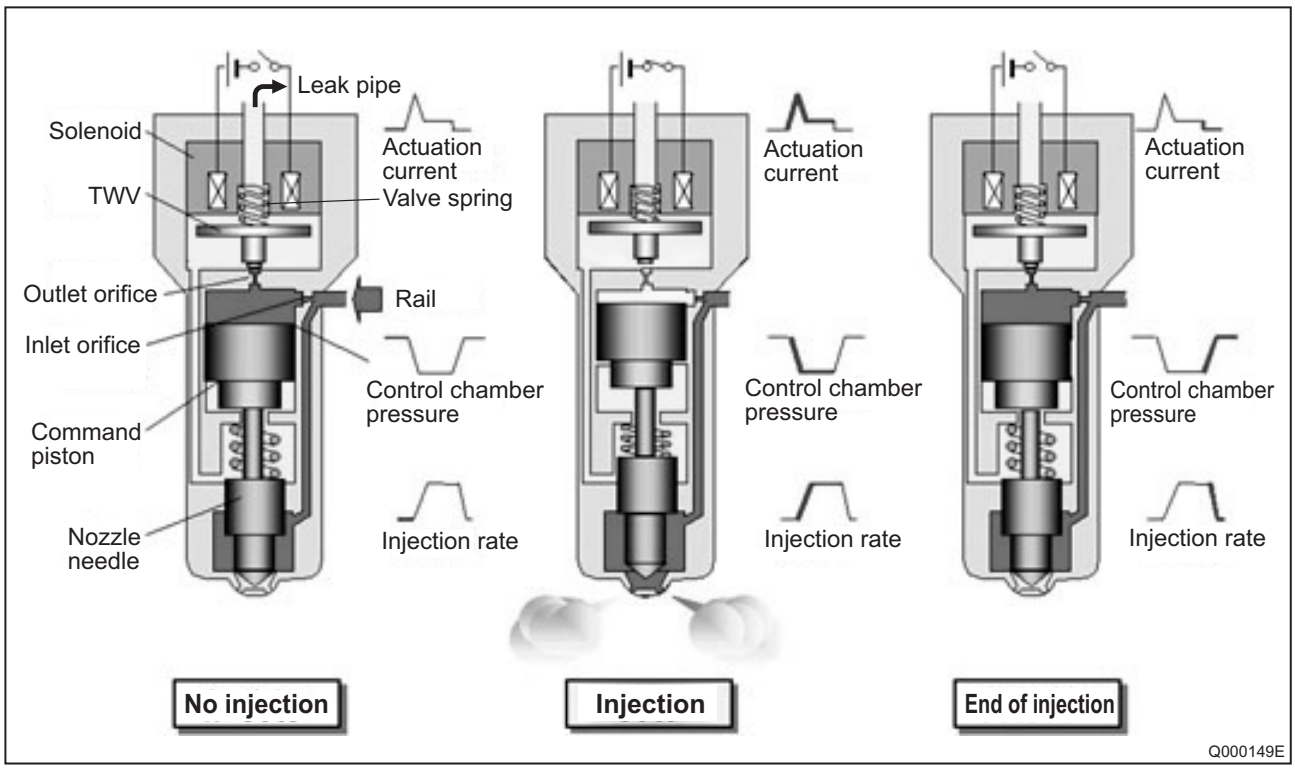
a. The TWV (Two-Way Valve) solenoid valve opens and closes the outlet orifice to control both the pressure in the control chamber, and the start and end of injection.

[No injection]

- When no current is supplied to the solenoid, the spring force is stronger than the hydraulic pressure in the control chamber. Thus, the solenoid valve is pushed downward, effectively closing the outlet orifice. For this reason, the hydraulic pressure that is applied to the command piston causes the nozzle spring to compress. This closes the nozzle needle, and as a result, fuel is not injected.

[Injection]

- When current is initially applied to the solenoid, the attraction force of the solenoid pulls the solenoid valve up, effectively opening the outlet orifice and allowing fuel to flow out of the control chamber. After the fuel flows out, the pressure in the control chamber decreases, pulling the command piston up. This causes the nozzle needle to rise and the injection to start.
- The fuel that flows past the outlet orifice flows to the leak pipe and below the command piston. The fuel that flows below the piston lifts the piston needle upward, which helps improve the nozzle's opening and closing response.
- When current continues to be applied to the solenoid, the nozzle reaches its maximum lift, where the injection rate is also at the maximum level. When current to the solenoid is turned OFF, the solenoid valve falls, causing the nozzle needle to close immediately and the injection to stop.

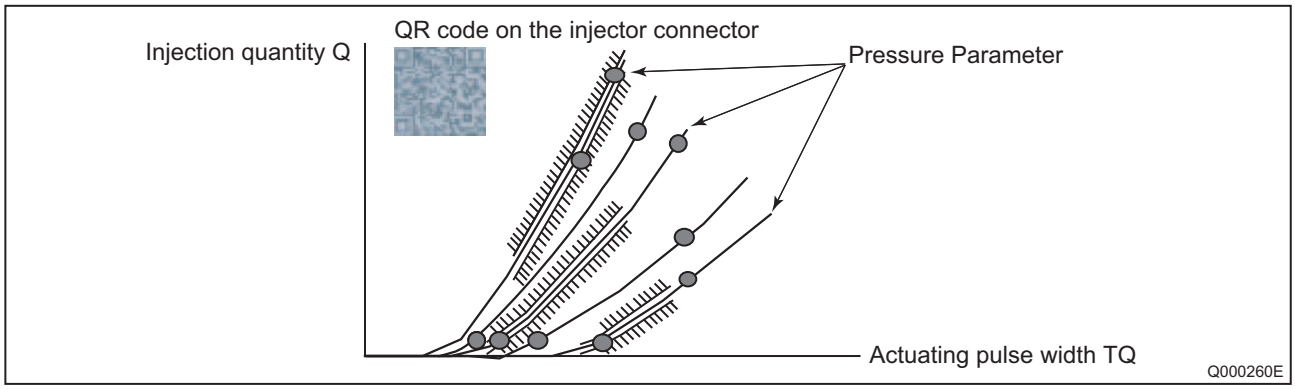


(5) QR Codes

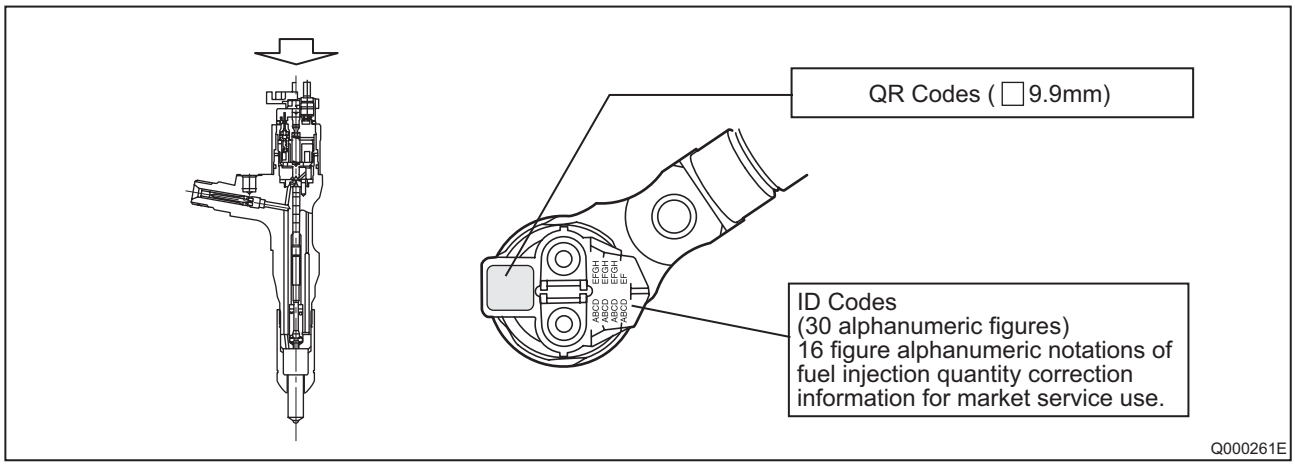
a. In order to minimize performance tolerance of injectors at replacing them, QR*1 (Quick Response) codes have been adopted to enhance correction precision.

b. Using QR codes has resulted in a substantial increase in the number of fuel injection quantity correction points, and thus the injection quantity control precision has improved. The characteristics of the engine cylinders have been further unified, contributing to improvements in combustion efficiency, reductions in exhaust gas emissions and so on.

[QR code correction points]



*1: Location of QR codes



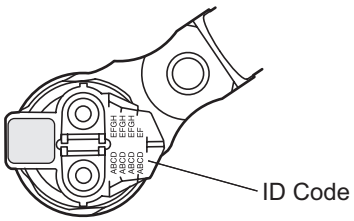
(6) Repair Procedure Changes

a. Differences in comparison with the conventional method of replacing injectors assembly are as shown below.

NOTE:
When replacing injectors with QR codes, or the engine ECU, it is necessary to record the ID codes (QR codes) in the ECU. (If the ID codes of the installed injector are not registered correctly, engine failure such as rough idling and noise will result.)

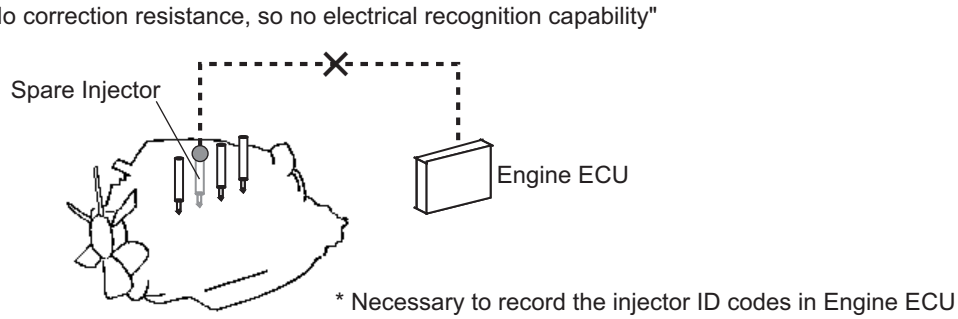
New (Injector with QR Codes)

30 alphanumeric figures-sixteen figure alphanumeric notations of fuel injection quantity correction information displaed for market service use



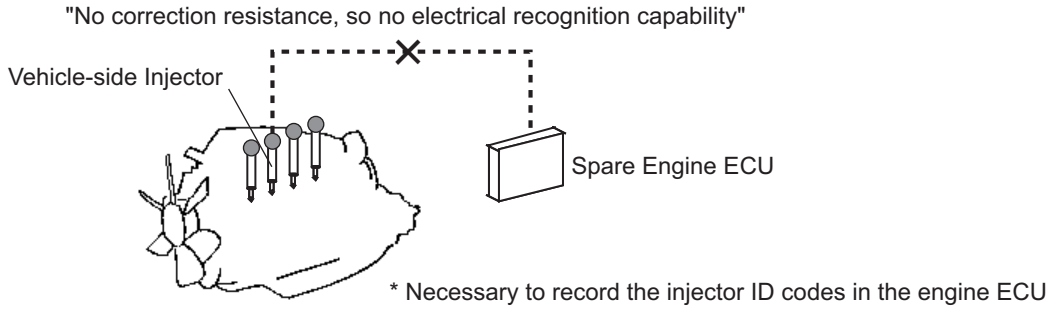
Q000284E

Replacing the Injector



QD1536E

Replacing the Engine ECU

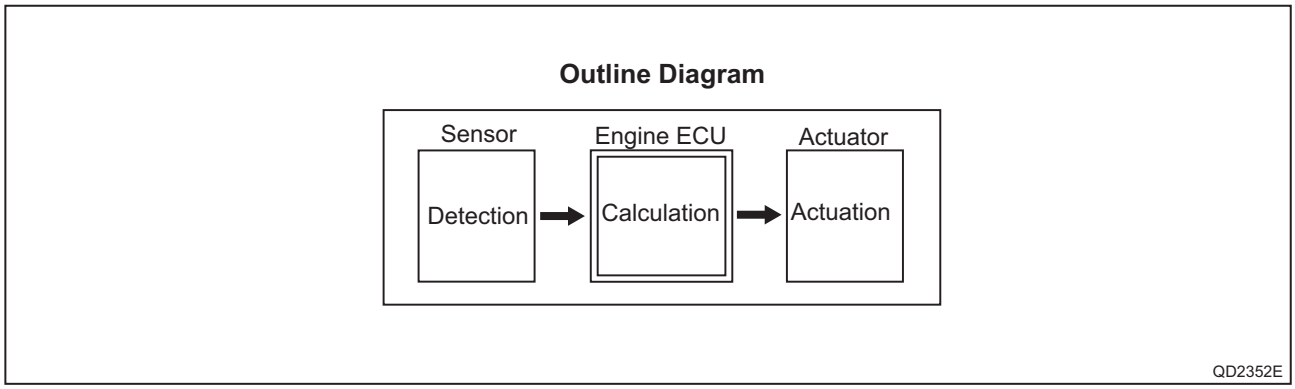


QD1537E

[5] Engine ECU (Electronic Control Unit)

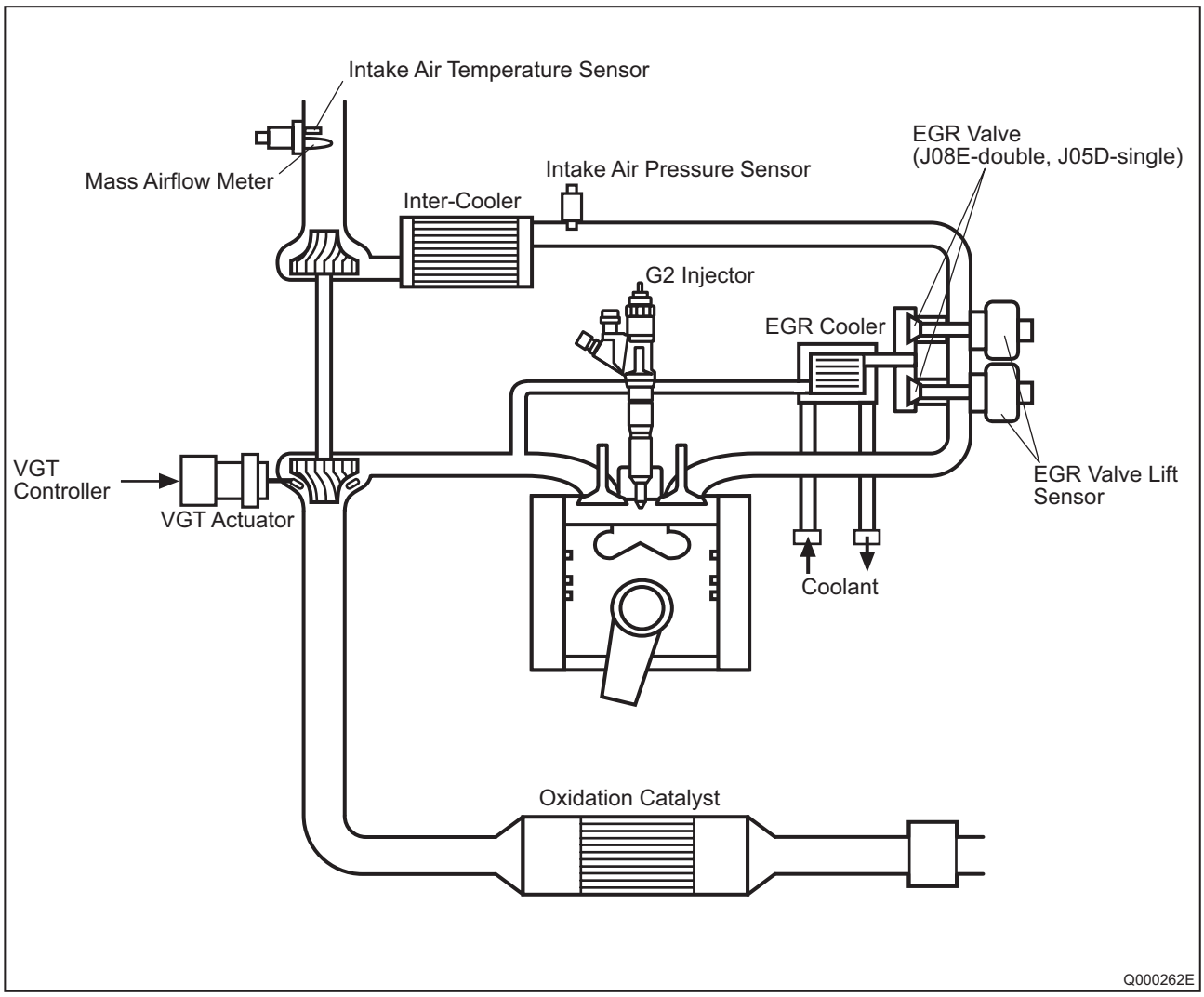
(1) Outline

a. This is the command center that controls the fuel injection system and engine operation in general.



3.2 Description of Control System Components

[1] Engine Control System Diagram



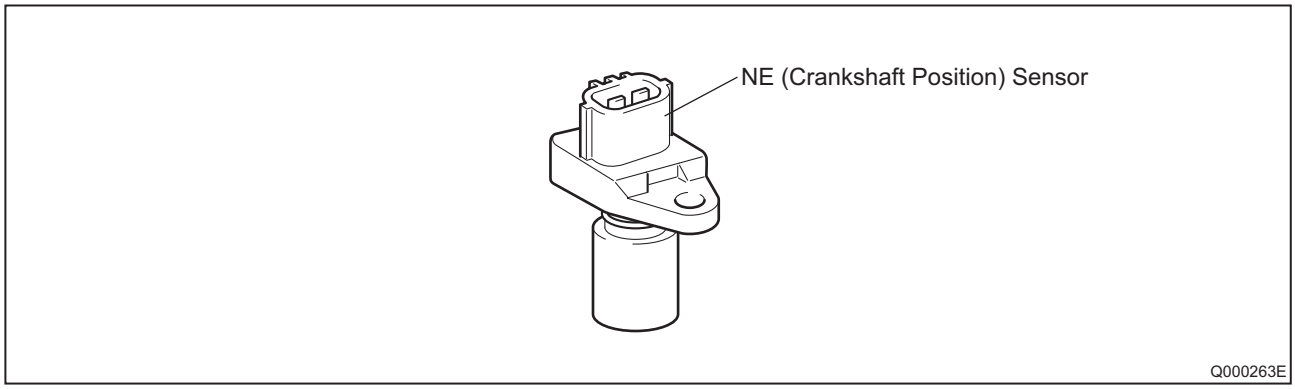
[2] Sensor and Relays

(1) NE Sensor (Crankshaft Position Sensor)

a. When the signal holes on the flywheel move past the sensor, the magnetic line of force passing through the coil changes, generating alternating voltage.

b. The signal holes are located on the flywheel at 6.5-degree intervals. There are a total of 56 holes, with holes missing in three places. Therefore, every two revolutions of the engine outputs 112 pulses.

c. This signal is used to detect the engine speed and the crankshaft position in 7.5-degree intervals.



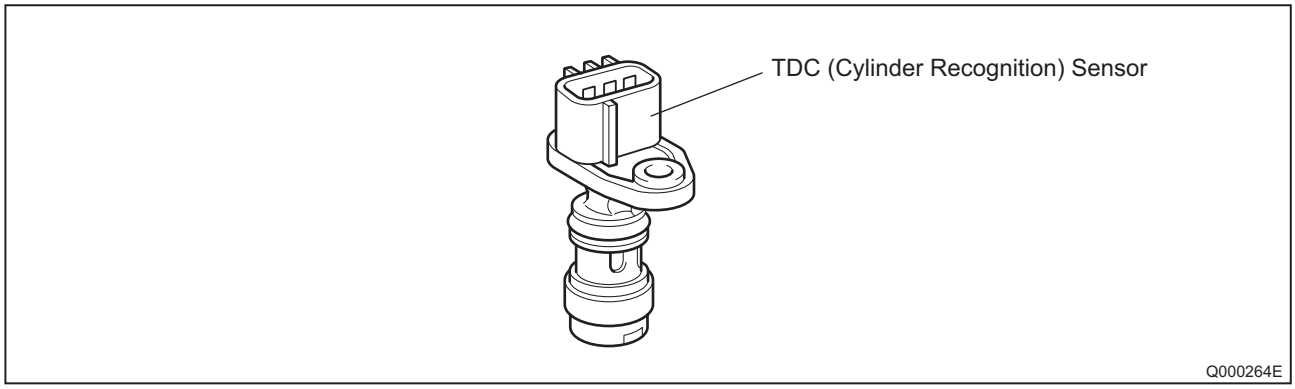
(2) TDC Sensor (Cylinder Recognition Sensor)

a. Unlike the NE sensor, the TDC sensor is an MRE (magnetic resistance element) sensor. As the pulsar near the sensor revolves, the magnetic field changes. This causes variations in the generated current, which are amplified in the internal circuits of the sensor unit before a signal is output to the engine ECU.

b. The engine camshaft gear (one revolution for every two revolutions of the engine) is used as a pulsar. The J05D and J08E use different types of gear, so the signal outputs differ as follows.

For the J05D:
In addition to four knock pins located at 90-degree intervals, there is an extra signal hole on the gear. Therefore every revolution of the gear, i.e. two revolutions of the engine, outputs 4 + 1 = 5 TDC signal pulses.

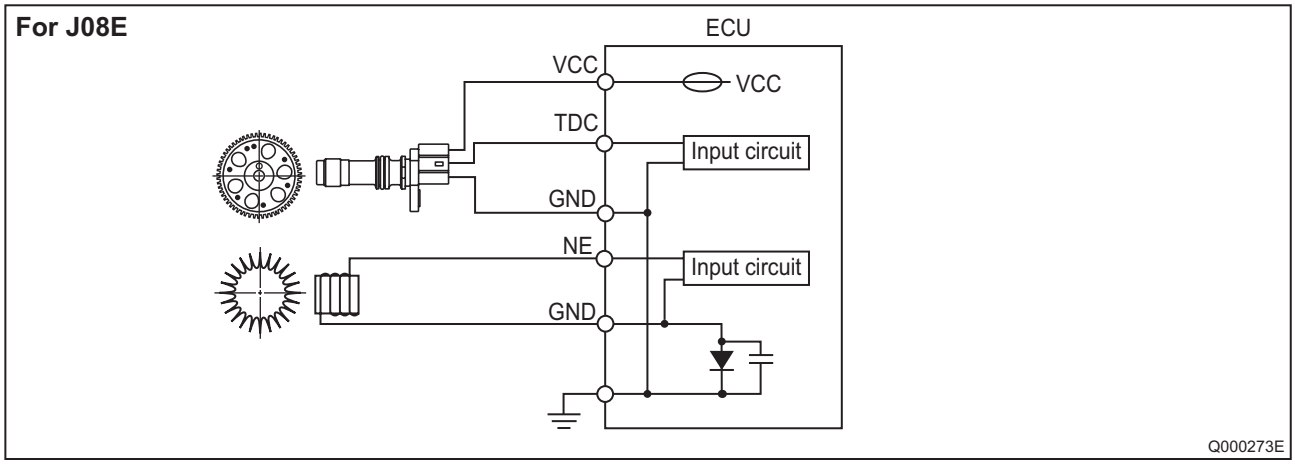
For the J08E:
In addition to six knock pins located at 60-degree intervals, there is an extra signal hole on the gear. Therefore every revolution of the gear, i.e. two revolutions of the engine, outputs 6 + 1 = 7 TDC signal pulses.



c. A combination of the NE pulse and the TDC pulses are used for the cylinder reference pulse, and the irregular pulse is used to determine the No. 1 cylinder.

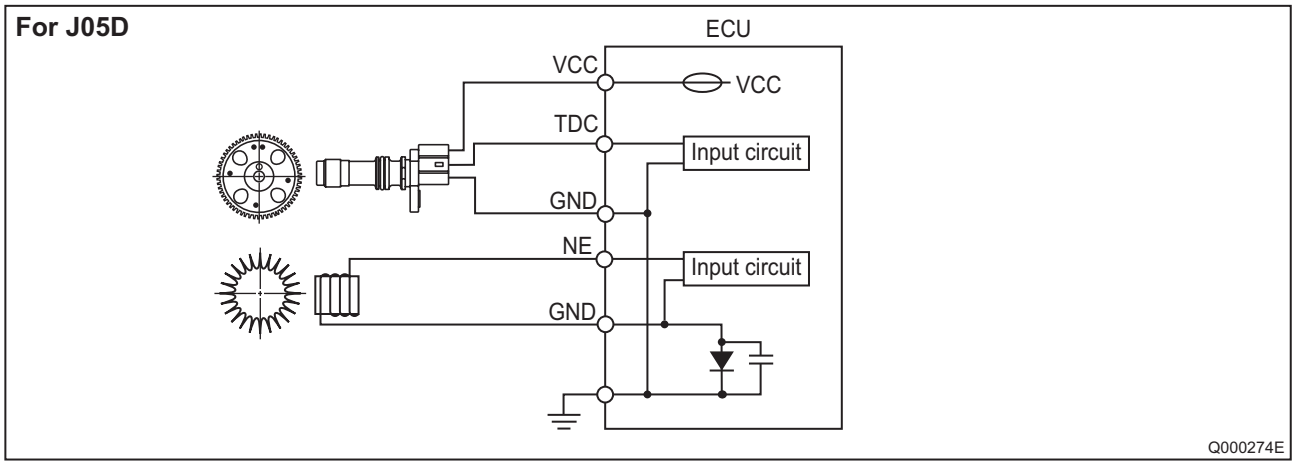
For the J08E engine

The cylinder at a rotation of 78° following the No. 1 TDC reference signal after the irregular pulse is the number one cylinder TDC (refer to the chart on the following page).

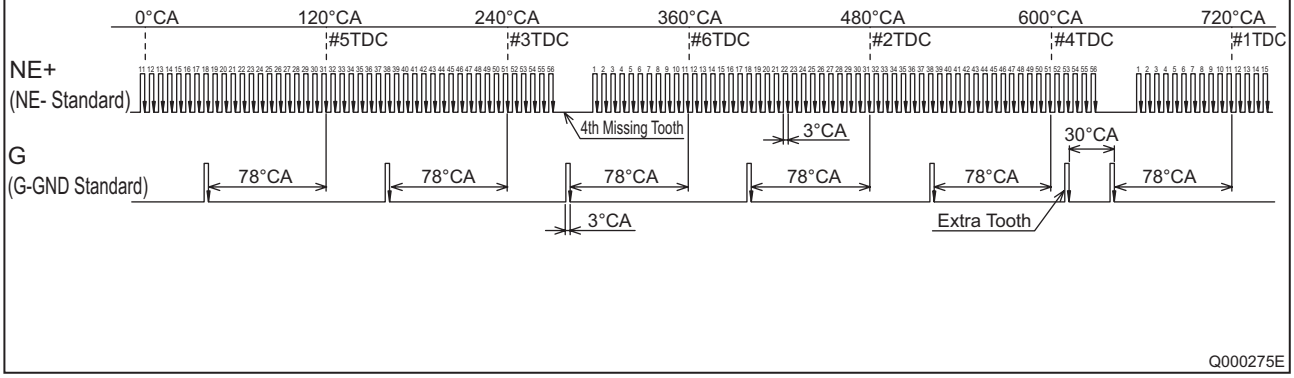


For the J05D engine

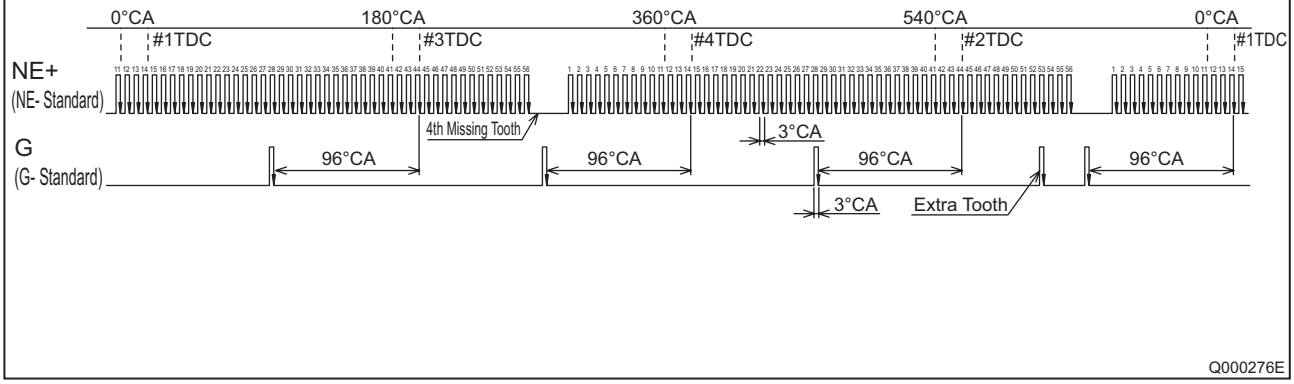
The cylinder at a rotation of 96° following the No. 1 TDC reference signal after the irregular pulse is the number one cylinder TDC (refer to the chart on the following page).



For J08E

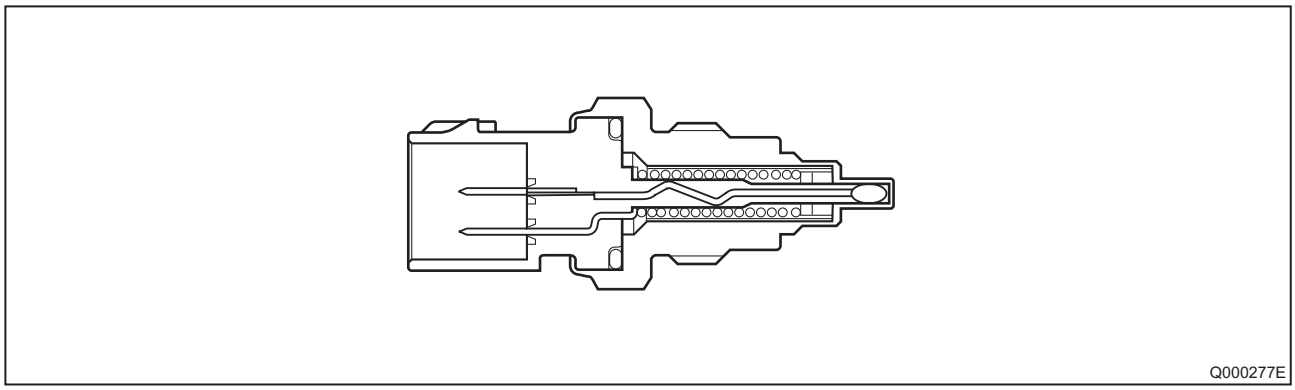


For J05D

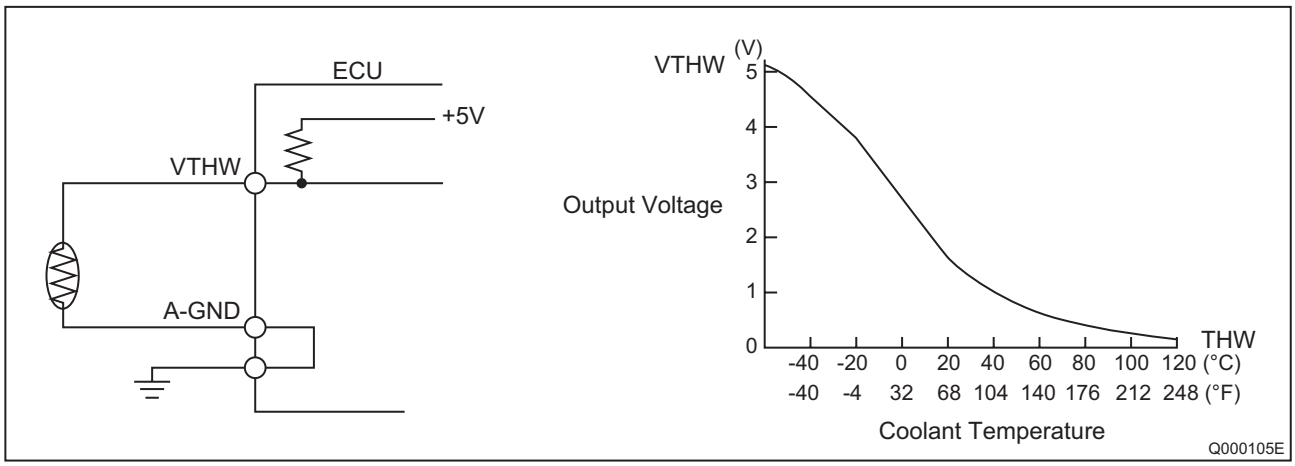


(3) Coolant Temperature Sensor

a. The coolant temperature sensor detects the temperature of the engine coolant and outputs it to the ECU.

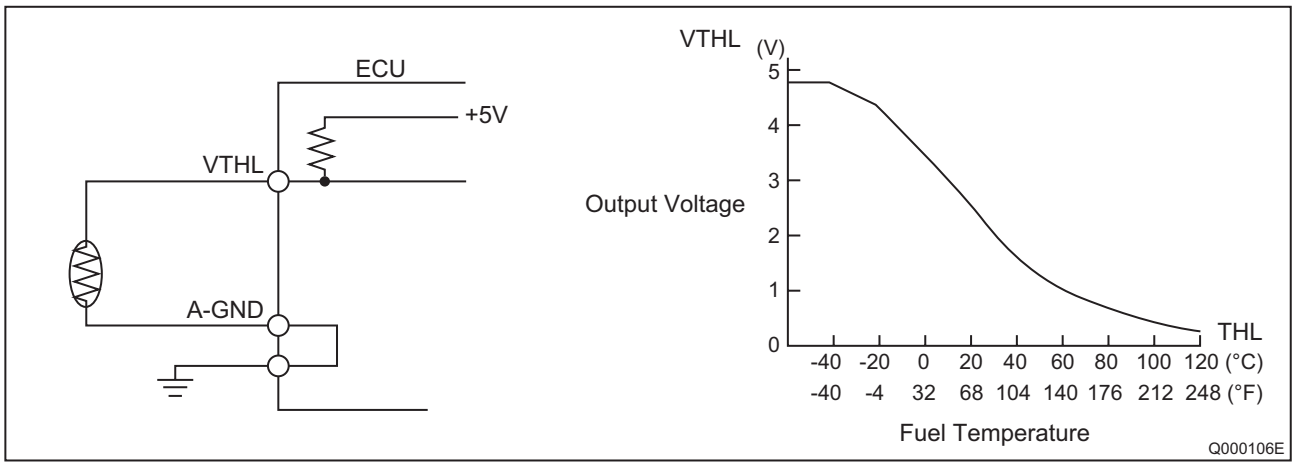


b. The sensor uses a thermistor, which varies resistance according to temperature. As the ECU applies voltage to the thermistor, it uses a voltage resulting from the division of the computer internal resistance and the thermistor resistance to detect the temperature.



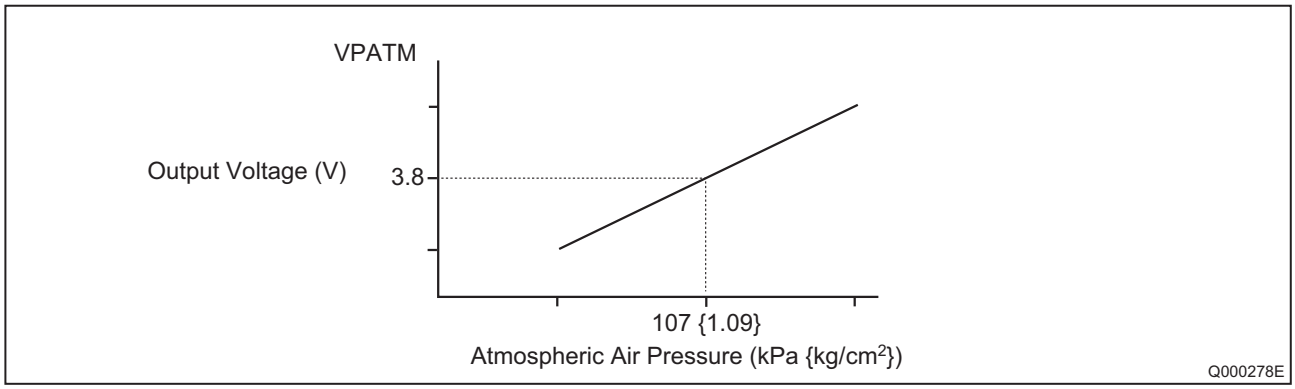
(4) Fuel Temperature Sensor (THL)

a. The fuel temperature sensor detects the fuel temperature and outputs it to the ECU. The sensor uses a thermistor, which varies resistance according to temperature. As the ECU applies voltage to the thermistor, it uses a voltage resulting from the division of the computer internal resistance and the thermistor resistance to detect the temperature.



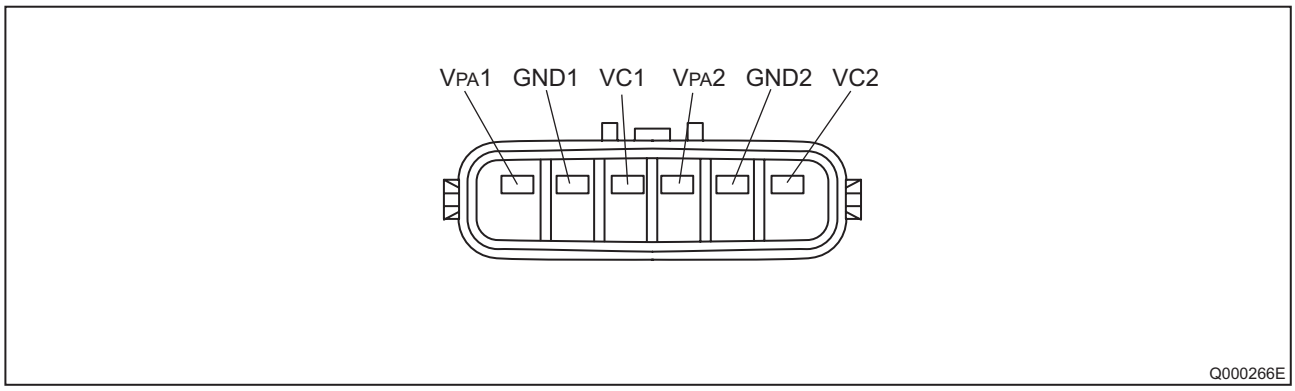
(5) Atmospheric Air Pressure Sensor (Built-in ECU)

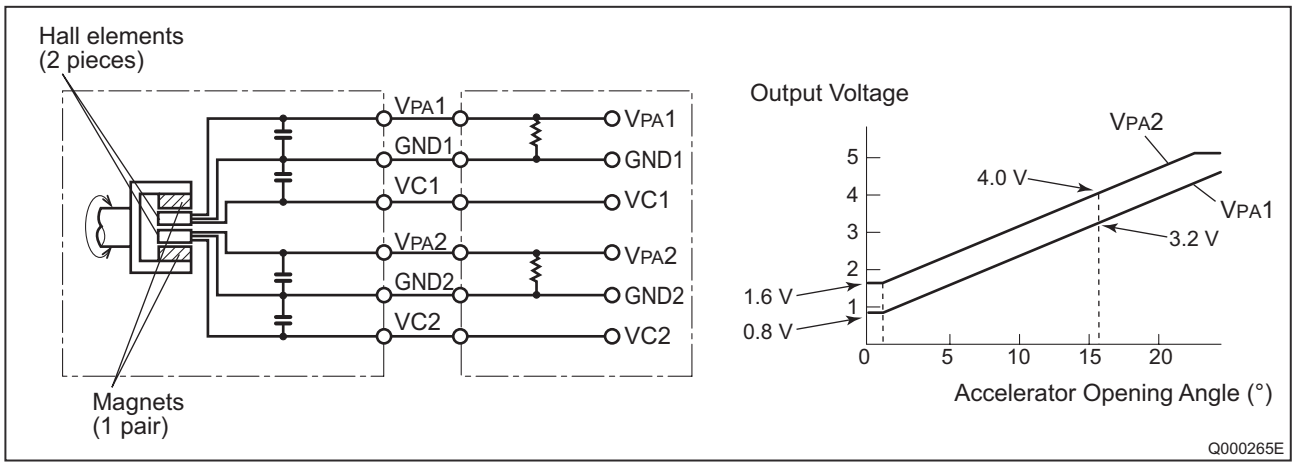
a. This sensor converts the atmospheric air pressure into an electrical signal to correct full-load injection volume.



(6) Accelerator Position Sensor

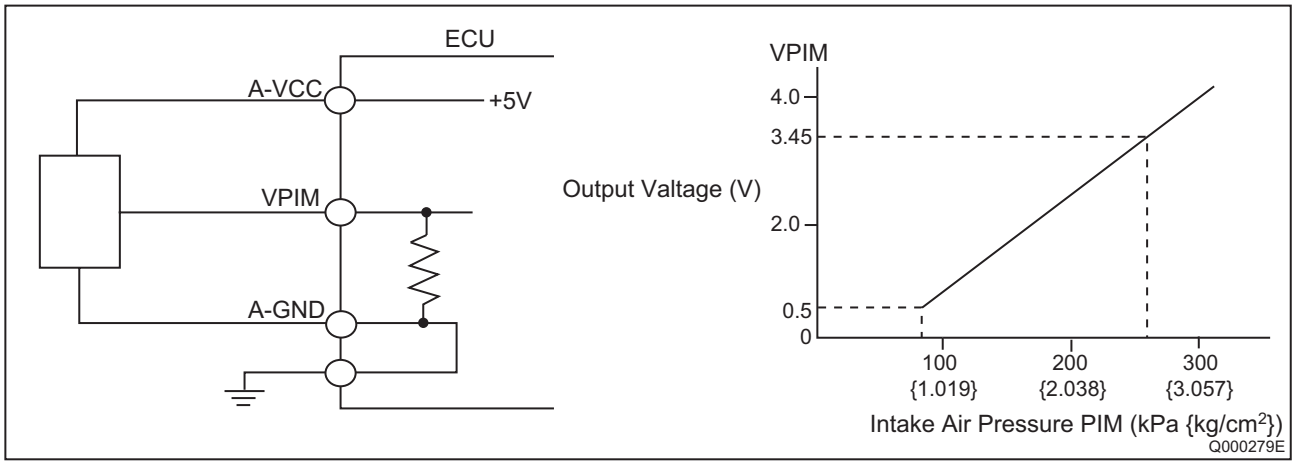
a. This sensor converts the angle of the pedal effort applied to the accelerator pedal into electrical signals and sends them to the ECU. The accelerator sensor uses hall elements. A magnet is mounted on the shaft that moves in unison with the accelerator pedal, and the magnetic field orientation changes with the rotation of the shaft. The changes in the magnetic field orientation generate voltage.





(7) Boost Pressure Sensor

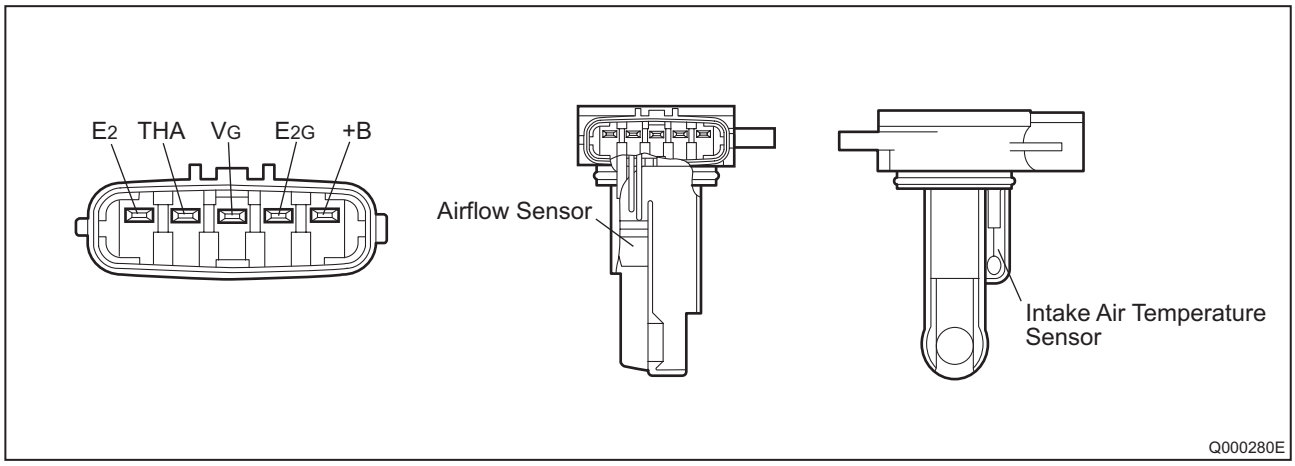
a. In order to correct the full-load injection volume, this sensor converts the intake air pressure (absolute pressure) into an electrical signal, then amplifies it into a voltage signal to the computer.



(8) Air Flow Sensor

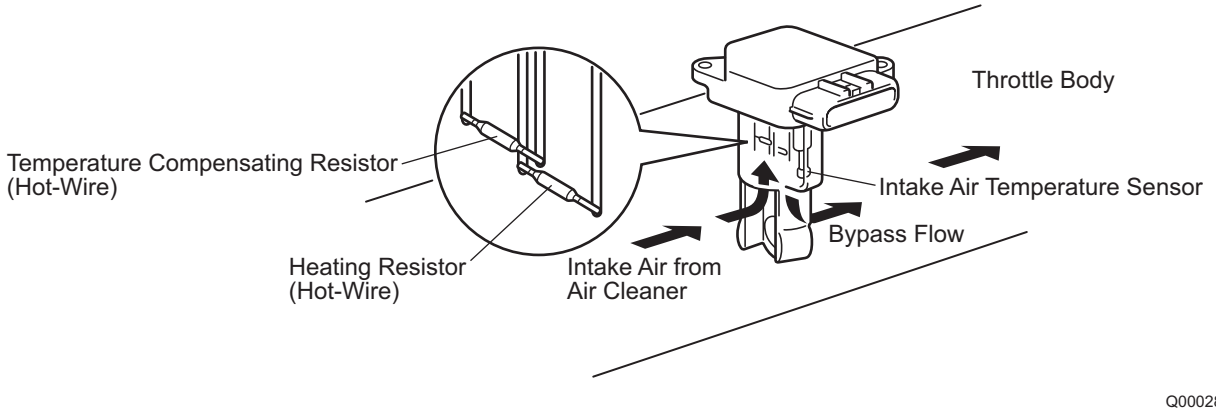
a. Detects the intake airflow (mass flow rate) in the hot-wire type airflow meter.

b. The intake airflow is converted to a voltage value and this signal is transmitted to the ECU.



c. The airflow sensor is installed to the rear of the air cleaner, and consists of a heater, thermometer, intake air temperature sensor, and control circuit (base). It diverts a portion of the intake air from the air cleaner and measures the intake airflow at the hot-wire measuring part.

Outline Diagram of Hot-Wire Type Airflow Meter



3.3 Various Types of Control

This system controls the fuel injection quantity and injection timing more optimally than the mechanical governor or timer used in conventional injection pumps.

For system control, the ECU makes the necessary calculations based on signals received from sensors located in the engine and on the vehicle in order to control the timing and duration in which current is applied to the injectors, thus realizing optimal injection timing.

(1) Fuel Injection Rate Control Function

a. The fuel injection rate control function controls the ratio of the quantity of fuel that is injected through the nozzle hole during a specified period.

(2) Fuel Injection Quantity Control Function

a. The fuel injection quantity control function, replaces the conventional governor function, and controls fuel injection to achieve an optimal injection quantity based on the engine speed and the accelerator opening.

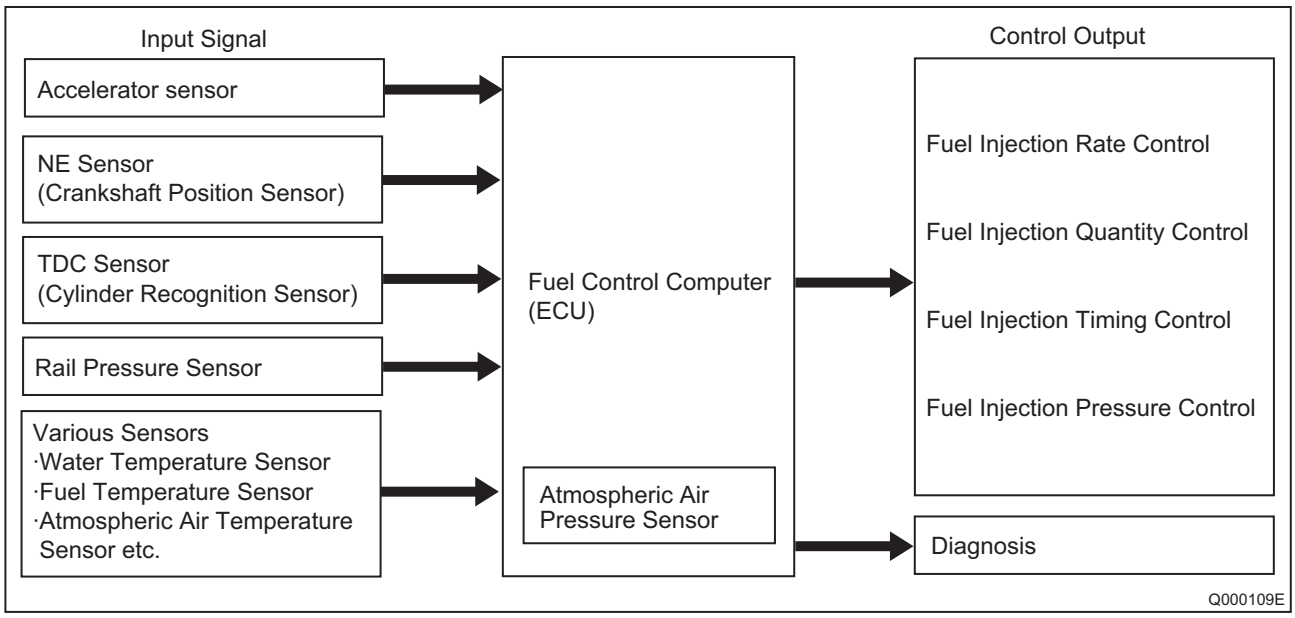
(3) Fuel Injection Timing Control Function

a. The fuel injection timing control function, replaces the conventional timer function, and controls the fuel injection to achieve an optimal injection timing according to the engine speed and the injection quantity.

(4) Fuel Injection Pressure Control Function (Rail Pressure Control Function)

a. The fuel injection pressure control function (rail pressure control function) uses a rail pressure sensor to measure fuel pressure, and feeds this data to the ECU to control the pump discharge quantity.

b. Pressure feedback control is implemented to match the optimal quantity (command quantity) set according to the engine speed and the fuel injection quantity.



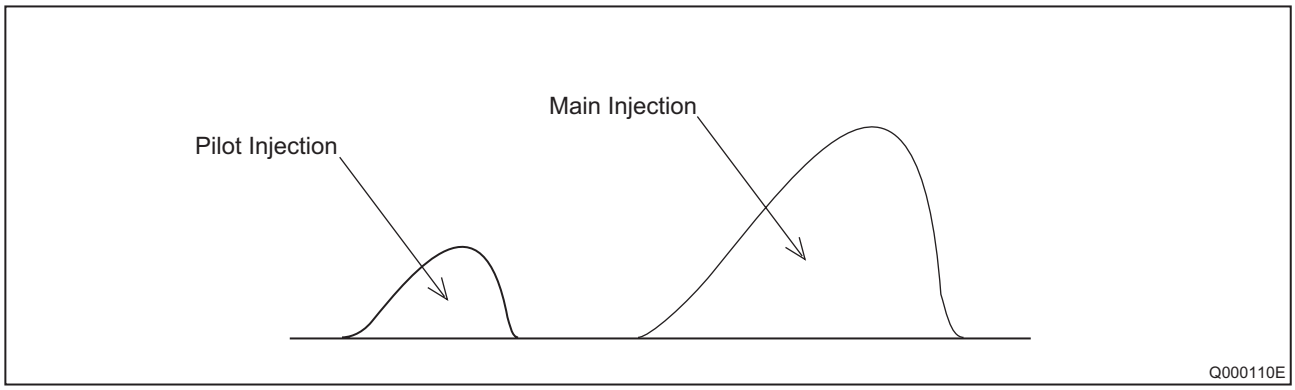
[1] Fuel Injection Rate Control

(1) Main Injection

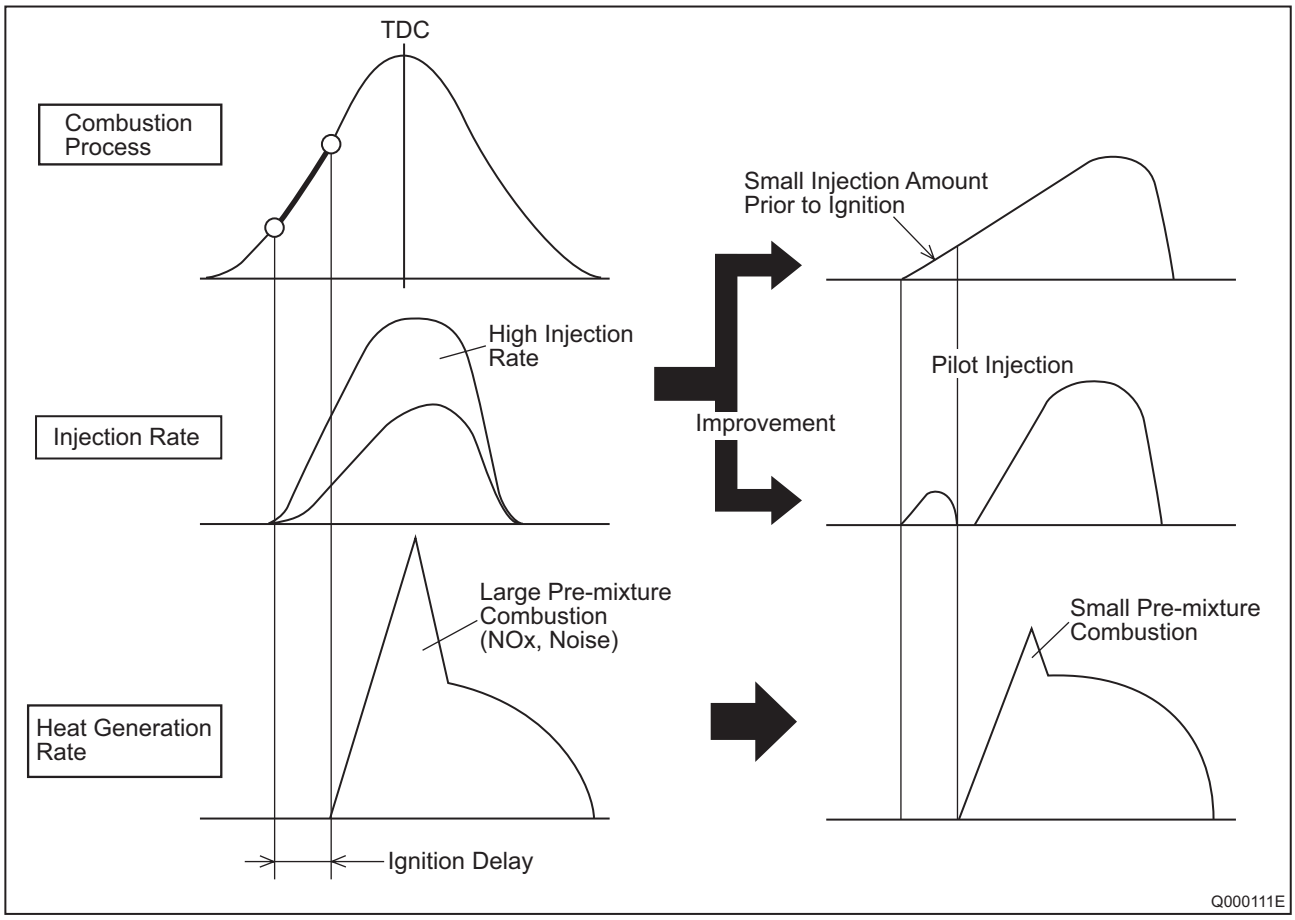
a. Same as conventional fuel injection.

(2) Pilot Injection

a. Pilot injection is the injection of a small amount of fuel prior to the main injection.

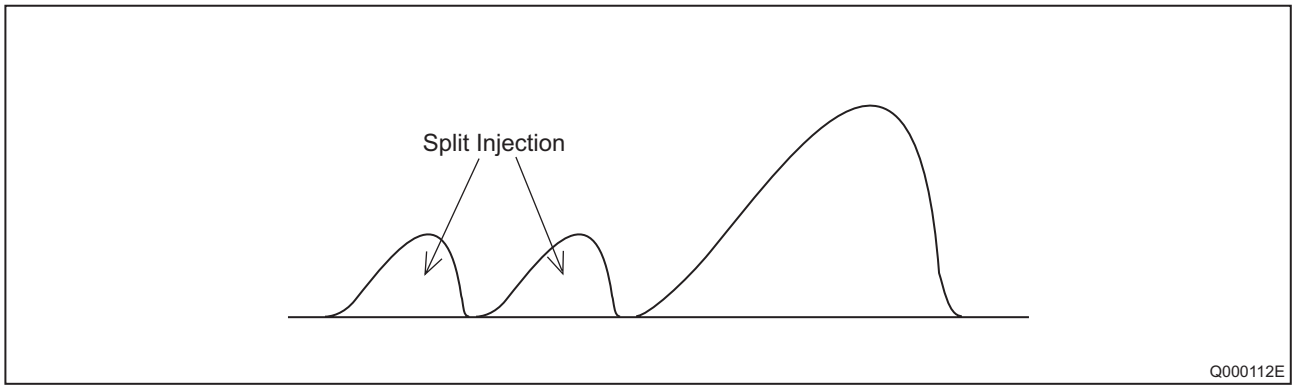


b. While the adoption of higher pressure fuel injection is associated with an increase in the injection rate, the lag (injection lag) that occurs from the time fuel is injected until combustion starts cannot be reduced below a certain value. As a result, the quantity of fuel injected before ignition increases, resulting in explosive combustion together with ignition, and an increase in the amount of NOx and noise. Therefore, by providing a pilot injection, the initial injection rate is kept to the minimum required level dampening, the explosive first-period combustion and reducing NOx emissions.



(3) Split Injection

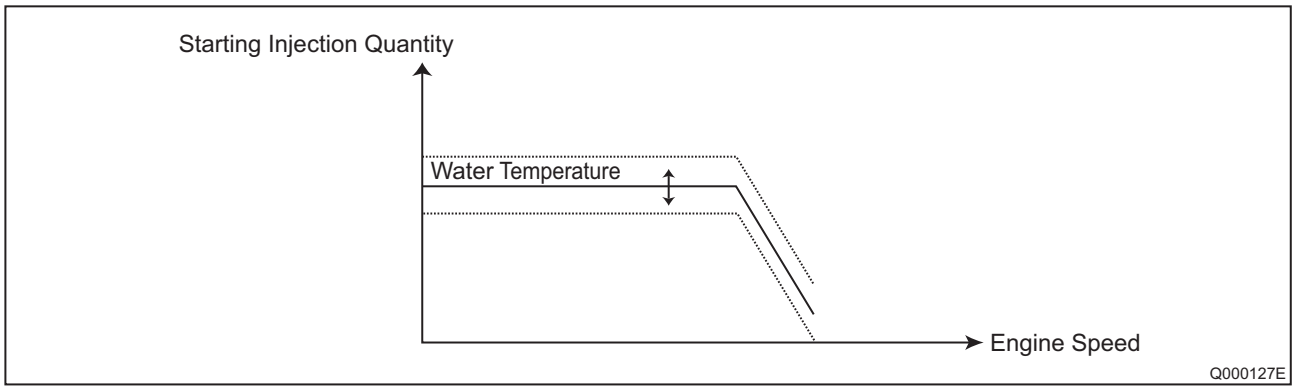
a. When the rotation is low at starting time, a small amount of fuel is injected several times prior to main injection.



[2] Fuel Injection Quantity Control

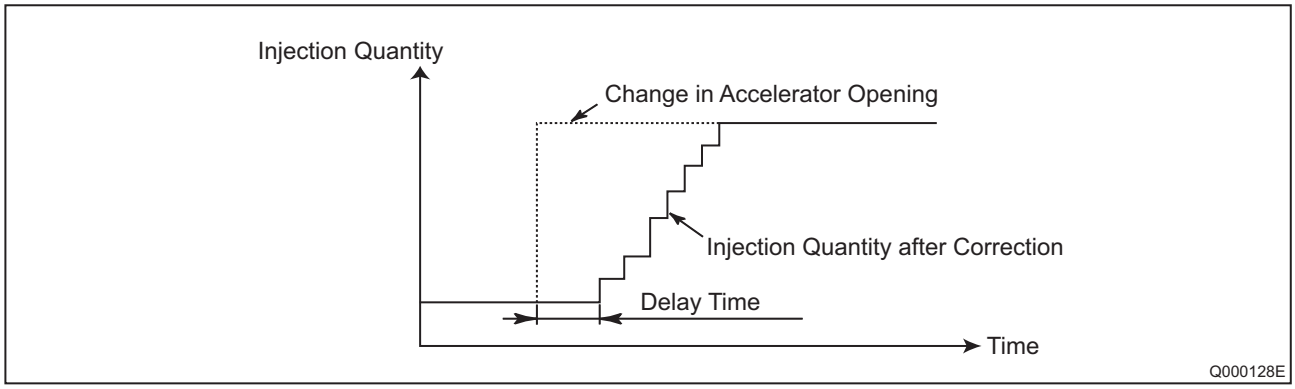
(1) Starting Injection Quantity

a. The injection quantity is determined based on the engine speed (NE) and water temperature while starting.



(2) Transient Injection Quantity Correction

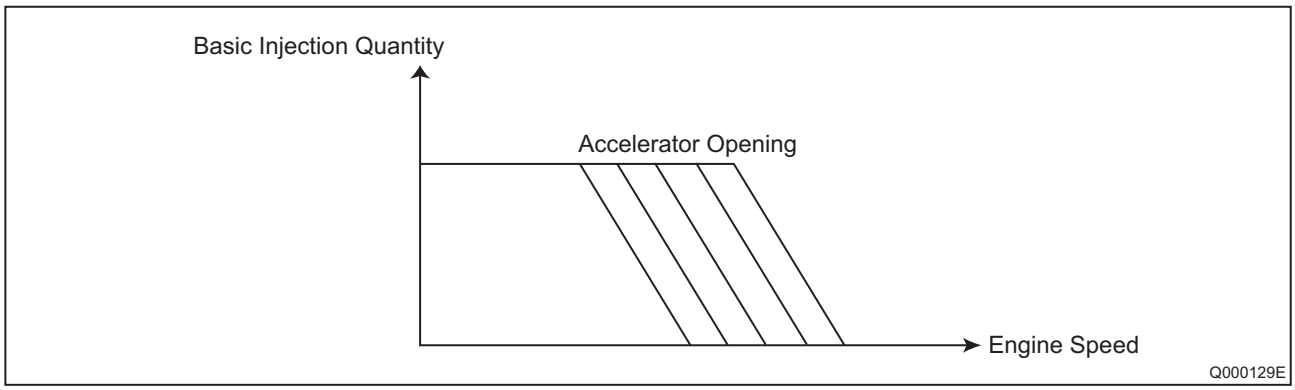
a. When the changes in the accelerator opening are great during acceleration, the increase in fuel volume is delayed to inhibit the discharge of black smoke.



(3) Basic Injection Quantity

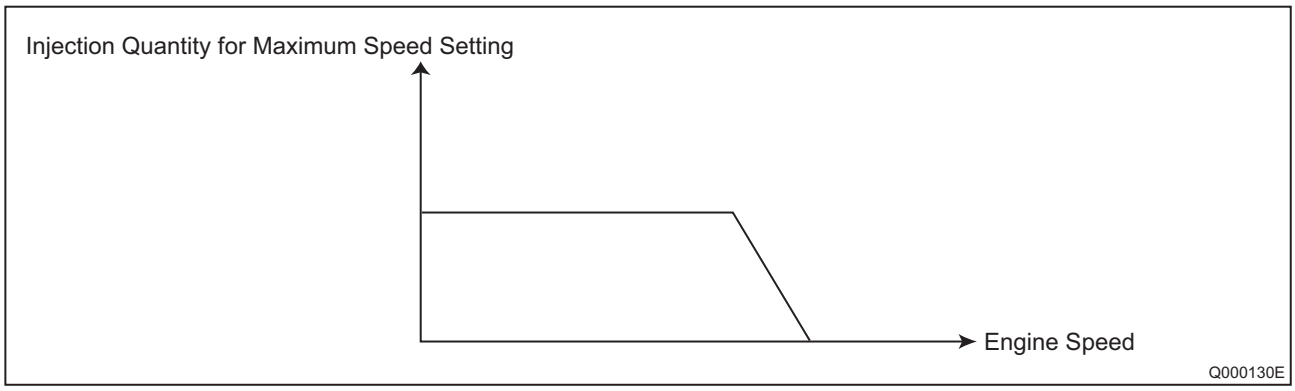
a. This quantity is determined in accordance with the engine speed (NE) and the accelerator opening.

b. Increasing the accelerator opening while the engine speed remains constant causes the injection quantity to increase.



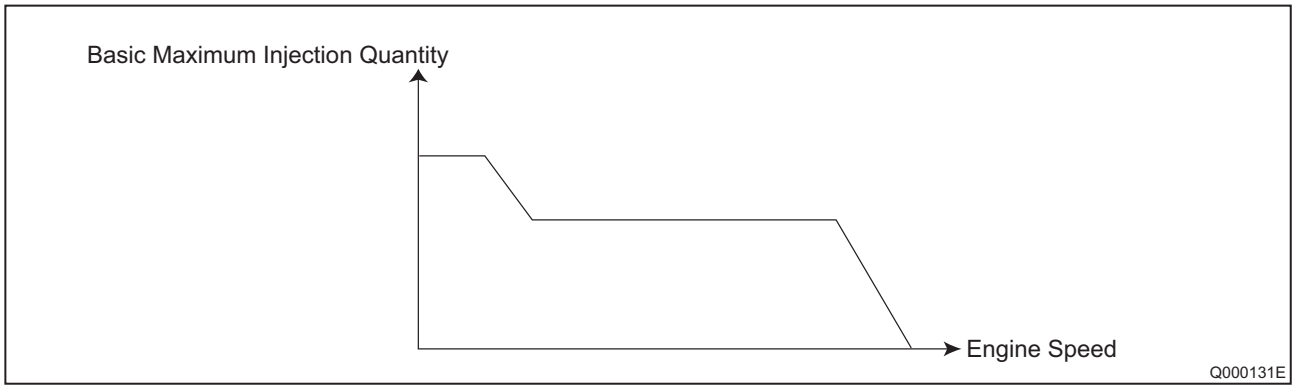
(4) Injection Quantity for Maximum Speed Setting

a. The injection quantity is regulated by a value that is determined in accordance with the engine speed.



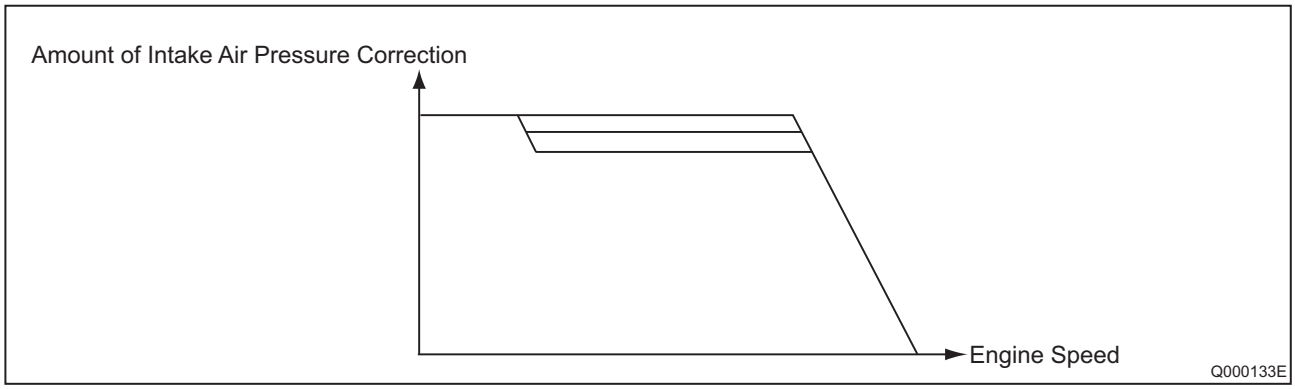
(5) Maximum Injection Quantity

a. Is determined in accordance with the engine speed and corrected by the coolant temperature signal.



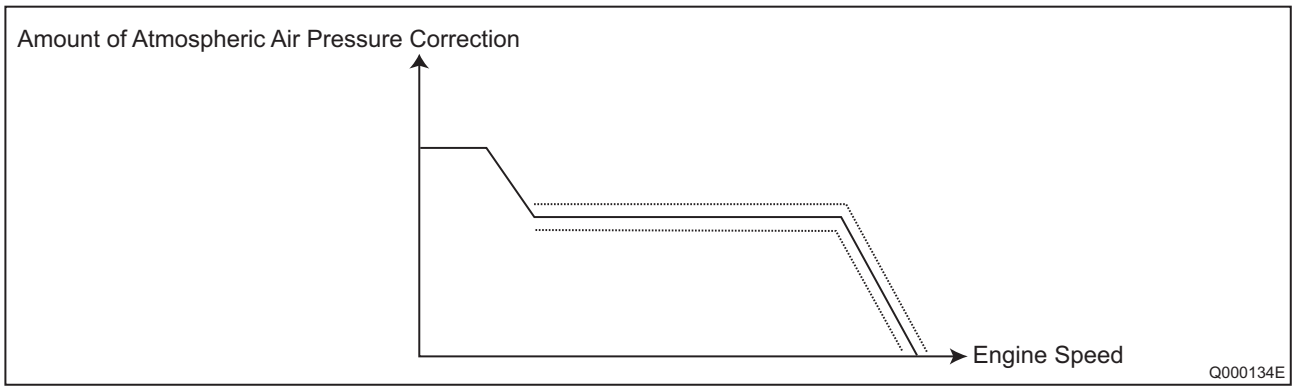
(6) Amount of Injection Quantity Intake Pressure Correction

a. Limits the maximum injection quantity in accordance with the intake pressure, in order to minimize the discharge of smoke when the intake air pressure is low.



(7) Amount of Injection Quantity by Atmospheric Air Pressure Correction

a. With using atmospheric air pressure sensor signal, the maximum injection quantity curve is corrected as shown in the right figure.

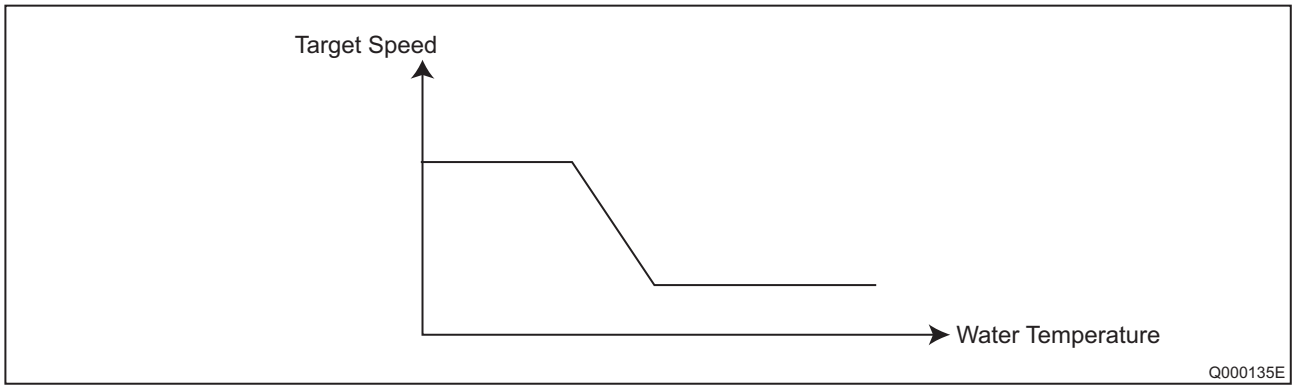


(8) Idle Speed Control System (ISC)

a. Controls the idle speed by regulating the injection quantity in order to match the target speed, which has been calculated by the computer, with the actual speed. The functions of the ISC can be broadly divided into the following two items:

• Auto ISC

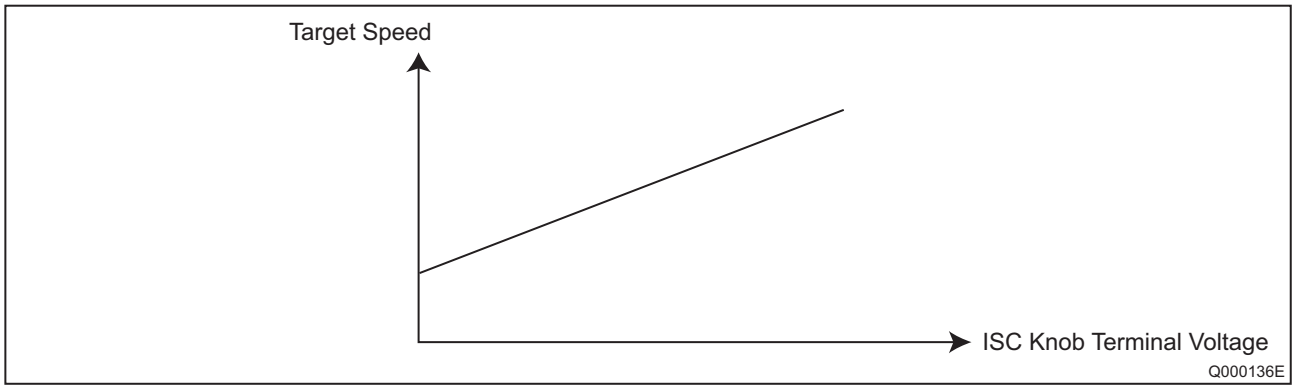
Controls the idle speed in accordance with the water temperature.



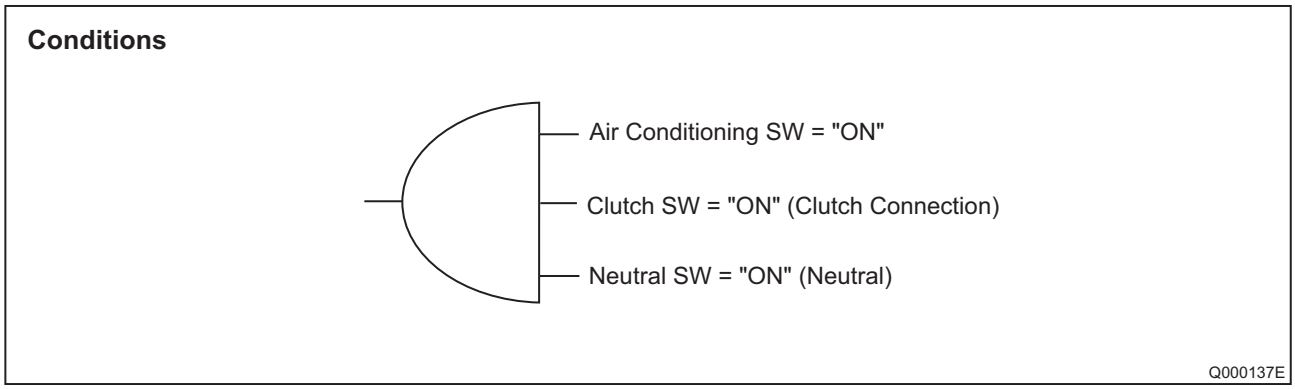
• Manual ISC

Controls the idle speed in accordance with the idle speed indicated on the manual idle setting

knob provided at the driver's seat.



• Air Conditioner Idle-up Control
When the conditions shown in the chart on the right are realized, bring the idle-up speed to constant rpm.



(9) Auto Cruise Control

a. Controls the actual vehicle speed by regulating the injection quantity in order to match the target speed that has been calculated by the computer with the actual speed.
b. The CRS ECU controls the injection quantity in accordance with signals from the cruise control computer.

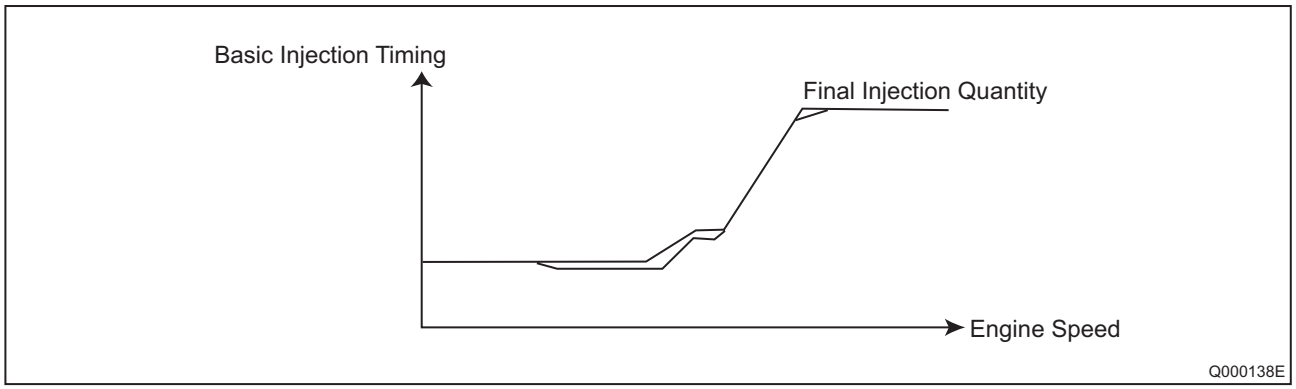
[3] Fuel Injection Timing Control

The characteristics of the fuel injection timing vary depending on whether it is the main injection or the pilot injection. Although either the NE sensor or the auxiliary NE sensor is the reference for controlling the injection timing, the NE sensor is ordinarily used for this purpose.

(1) Main Injection Timing

a. The basic injection timing is calculated in accordance with the final injection quantity, the engine speed, and the water temperature (with map correction).

b. While starting, it is calculated in accordance with the water temperature and the engine speed.

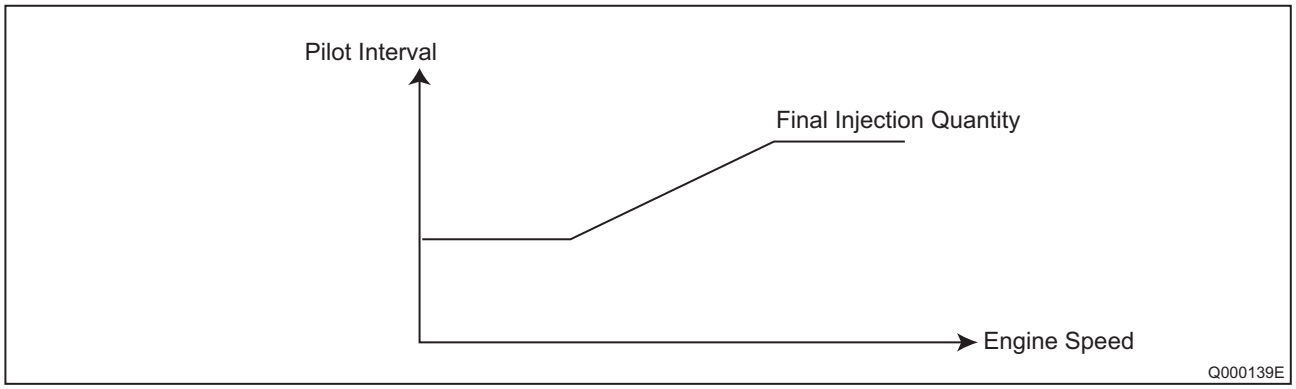


(2) Pilot Injection timing (Pilot Interval)

a. The pilot injection timing is controlled by adding the pilot interval to the main injection timing.

b. The pilot interval is calculated in accordance with the final injection quantity, the engine speed, and the water temperature (with map correction).

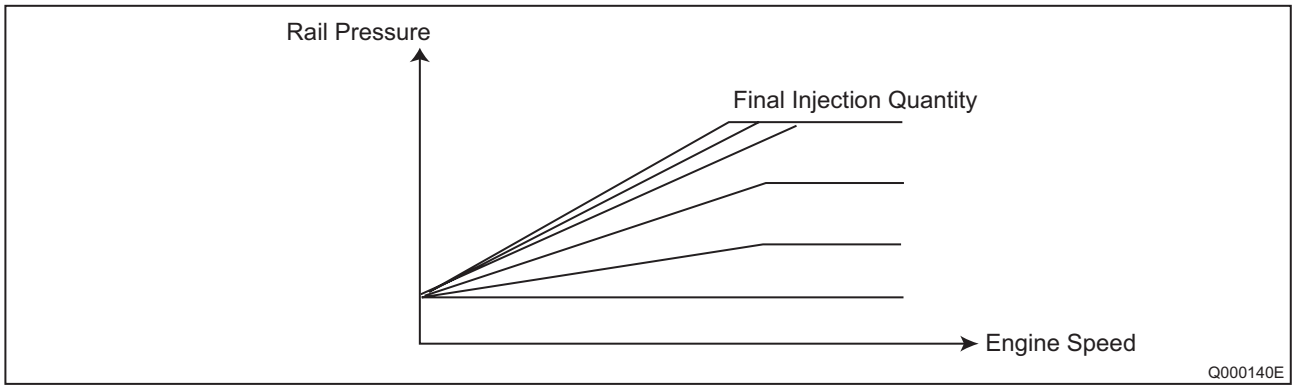
c. While starting, it is calculated in accordance with the water temperature and the engine speed.



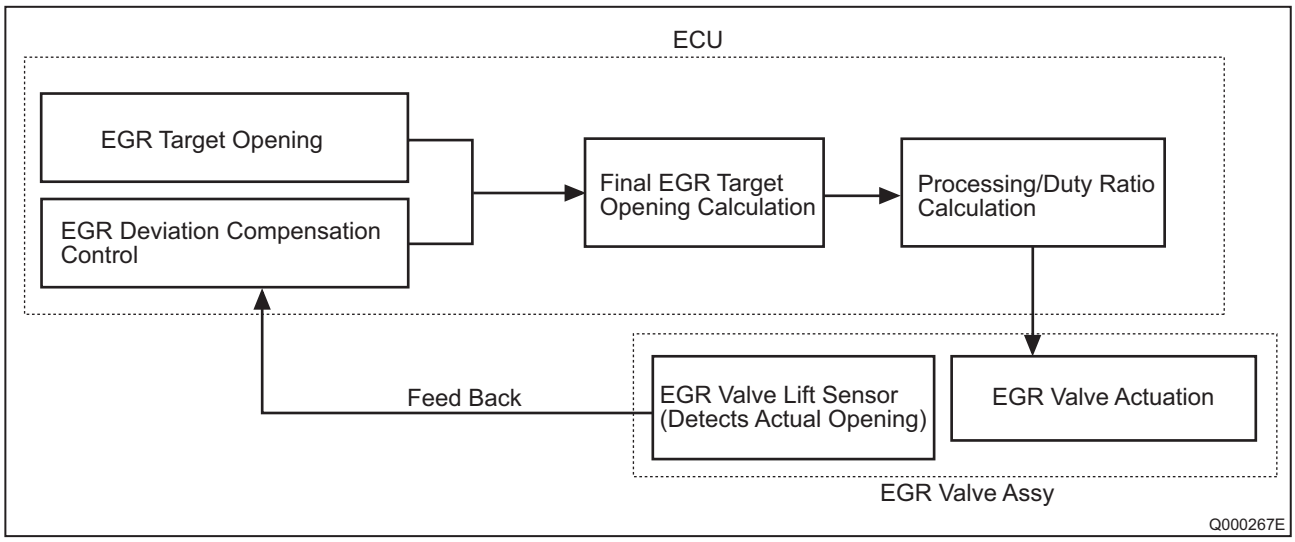
(3) Fuel Injection Pressure

a. A value is calculated as determined in accordance with the final injection quantity and the engine speed.

b. While starting, it is calculated in accordance with the water temperature and the engine speed.



3.4 Other Relevant Engine Control
[1] EGR Control
(1) Control System



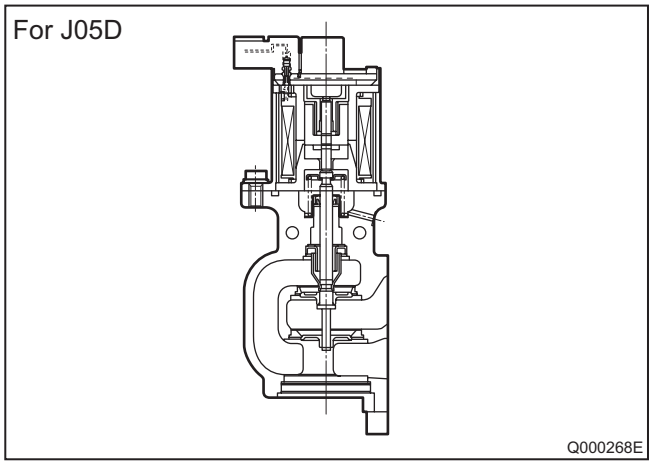
(2) Related Sensors

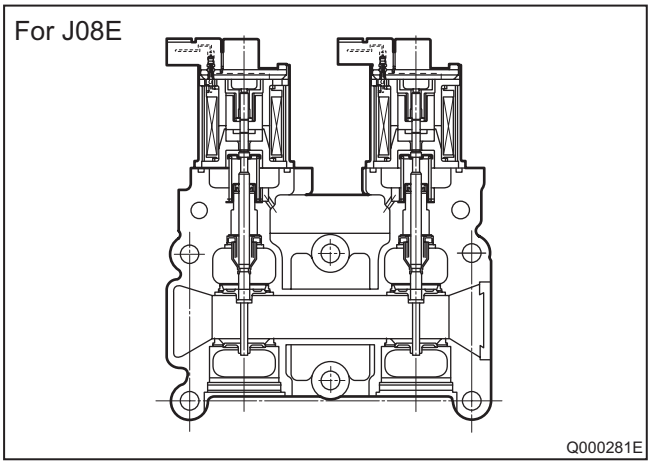
The related sensors are as follows:

- Air volume sensor: Detects the volume of air flowing into the engine.
- Coolant temperature sensor: Detects the engine coolant temperature.
- Atmospheric pressure sensor: Detects the atmospheric pressure around the engine (built into the ECU).

(3) EGR Valve

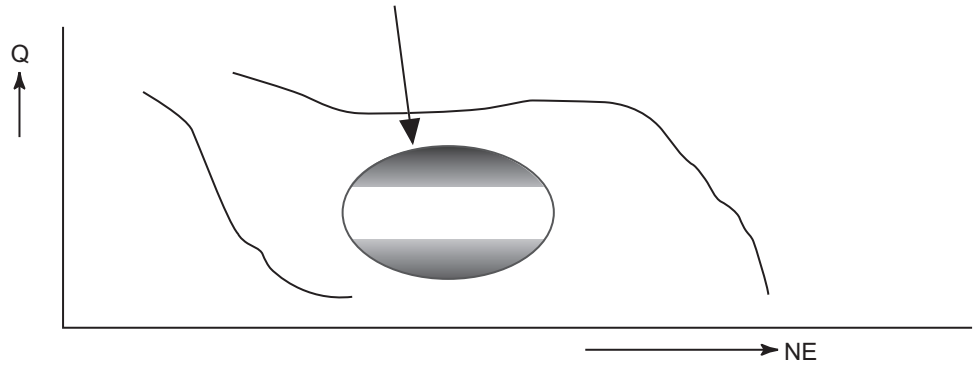
a. An EGR valve is utilized as the system actuator for the electric exhaust gas recirculation (E-EGR) system. It is constructed of an upper section and a lower section. The upper section receives output signals from the engine ECU, and contains a solenoid that generates electromagnetic force. The lower section is constructed of a nozzle that moves up and down in response to the electromagnetic force, and a valve with an opening that alters in response to the nozzle position.





(4) Control Operation

Operation Start Conditions: During engine warm-up, other than start-up, when not overheating (etc.).
EGR Operating Range: During medium engine load.



3.5 Engine ECU
[1] Diagnosis Codes

P-Code	DST-1 Display	Remarks	Description
P0045	VNT Malfunction	For the VNT.	The VNT actuator has a malfunction.
P0049	Turbo Charger Turbine Over speed	The turbine rotation sensor has been detected.	Over speed of the turbo has been detected.
P0088	Common Rail Pressure -Too high		High fuel pressure has been detected.
P0093	Fuel System Leak Detected	The pump does not work properly. (Fuel leak)	There is a possibility of the fuel leakage. Perform the fuel leakage check.
P0102	Mass Air Flow Sensor Malfunction (LO)		"The mass air flow sensor has a malfunction. There are possibilities of the sensor malfunction, open and short circuit to ground in the harness."
P0103	Mass Air Flow Sensor Malfunction (HI)		The mass air flow sensor has a malfunction. There are possibilities of the sensor malfunction and short circuit to +B in the harness.
P0108	Boost Pressure Sensor Malfunction (HI)		The boost pressure cannot be detected properly. There are possibilities of the sensor malfunction and short circuit in the harness.
P0112	Intake Air Temperature Sensor Malfunction (LO)	Integrated in the mass air flow sensor.	"The temperature cannot be detected properly. There are possibilities of the sensor malfunction, short circuit to ground in the harness."
P0113	Intake Air Temperature Sensor Malfunction (HI)	Integrated in the mass air flow sensor.	"The temperature cannot be detected properly. There are possibilities of the sensor malfunction, open and short circuit to +B in the harness."
P0117	Engine Coolant Temperature Sensor Malfunction (LO)		The temperature cannot be detected properly. There are possibilities of the sensor malfunction and short circuit to ground in the harness.
P0118	Engine Coolant Temperature Sensor Malfunction (HI)		"The temperature cannot be detected properly. There are possibilities of the sensor malfunction, open and short circuit to +B in the harness."

P-Code	DST-1 Display	Remarks	Description
P0182	Fuel Temperature Sensor Malfunction (LO)	Integrated in the supply pump.	"The temperature cannot be detected properly. There are possibilities of the sensor malfunction, short circuit to ground in the harness."
P0183	Fuel Temperature Sensor Malfunction (HI)	Integrated in the supply pump.	"The temperature cannot be detected properly. There are possibilities of the sensor malfunction, open and short circuit to +B in the harness."
P0191	Rail Pressure Sensor Malfunction	Characteristic malfunc-tion	The rail pressure cannot be detected properly. There is a possibility of the sensor malfunction.
P0192	Rail Pressure Sensor Malfunction (LO)		The rail pressure cannot be detected properly. There are possibilities of the sensor malfunction and short circuit to ground in the harness.
P0193	Rail Pressure Sensor Malfunction (HI)		"The rail pressure cannot be detected properly. There are possibilities of the sensor malfunction, open and short circuit to +B in the harness."
P0200	ECU Charge Circuit Malfunction (HI)		The voltage for the injector activation is too high. Replace the ECU.
P0201	Injector 1 Open Circuit		There is a possibility of the Injector 1 malfunction or open circuit in the harness.
P0202	Injector 2 Open Circuit		There is a possibility of the Injector 2 malfunction or open circuit in the harness.
P0203	Injector 3 Open Circuit		There is a possibility of the Injector 3 malfunction or open circuit in the harness.
P0204	Injector 4 Open Circuit		There is a possibility of the Injector 4 malfunction or open circuit in the harness.
P0205	Injector 5 Open Circuit		There is a possibility of the Injector 5 malfunction or open circuit in the harness.
P0206	Injector 6 Open Circuit		There is a possibility of the Injector 6 malfunction or open circuit in the harness.
P0217	Over Temperature Condition		The over temperature condition has been detected. Check the cooling system.
P0219	Engine Over speed Condition		The engine speed exceeded the rated value.
P0234	Turbo Charger Overboost Condition		The boost pressure is too higher than the specified value.
P0237	Boost Pressure Sensor Malfunction (LO)		"The intake air pressure cannot be detected prop-erly. There are possibilities of the sensor malfunction, open and short circuit in the harness."
P0263	Correction Error Between Cylinders #1		The rotation fluctuation in the cylinder 1 became big-ger than other cylinders. There is a possibility that the flow damper is operat-ing.
P0266	Correction Error Between Cylinders #2		The rotation fluctuation in the cylinder 2 became big-ger than other cylinders. There is a possibility that the flow damper is operat-ing.

P-Code	DST-1 Display	Remarks	Description
P0269	Correction Error Between Cylinders #3		The rotation fluctuation in the cylinder 3 became bigger than other cylinders. There is a possibility that the flow damper is operating.
P0272	Correction Error Between Cylinders #4		The rotation fluctuation in the cylinder 4 became bigger than other cylinders. There is a possibility that the flow damper is operating.
P0275	Correction Error Between Cylinders #5		The rotation fluctuation in the cylinder 5 became bigger than other cylinders. There is a possibility that the flow damper is operating.
P0278	Correction Error Between Cylinders #6		The rotation fluctuation in the cylinder 6 became bigger than other cylinders. There is a possibility that the flow damper is operating.
P0335	Crankshaft Position Sensor Malfunction	"In case that the NE and G sensor have malfunctions, this P code will be output."	The pulse from the crankshaft position sensor cannot be detected. There are possibilities of the sensor and harness malfunctions.
P0340	Engine Speed Sensor Malfunction		The pulse from the engine speed sensor cannot be detected. There are possibilities of the sensor and harness malfunctions.
P0404	EGR Valve 1 Clogged	Clogging has been detected by the lift sensor.	The EGR valve 1 is clogged in the open state.
P0405	EGR Lift Sensor 1 Malfunction (LO)		"The EGR lift sensor 1 has a malfunction. There are possibilities of the sensor malfunction, open and short circuit to ground in the harness."
P0406	EGR Lift Sensor 1 Malfunction (HI)		The EGR lift sensor 1 has a malfunction. There are possibilities of the sensor malfunction and short circuit to +B in the harness.
P0407	EGR Lift Sensor 2 Malfunction (LO)		"The EGR lift sensor 2 has a malfunction. There are possibilities of the sensor malfunction, open and short circuit to ground in the harness."
P0408	EGR Lift Sensor 2 Malfunction (HI)		The EGR lift sensor 2 has a malfunction. There are possibilities of the sensor malfunction and short circuit to +B in the harness.
P0489	EGR Solenoid Valve 1 Malfunction		"The EGR solenoid valve 1 has a malfunction. There are possibilities of the solenoid valve malfunction, open and short circuit to ground in the harness."
P0490	EGR Solenoid Valve 1 Malfunction		The EGR solenoid valve 1 has a malfunction. There are possibilities of the solenoid valve malfunction and short circuit to +B in the harness.
P0500	Vehicle Speed Sensor Malfunction (LO)	Open circuit	The pulse from the vehicle speed sensor cannot be detected . There are possibilities of the sensor and harness malfunctions.

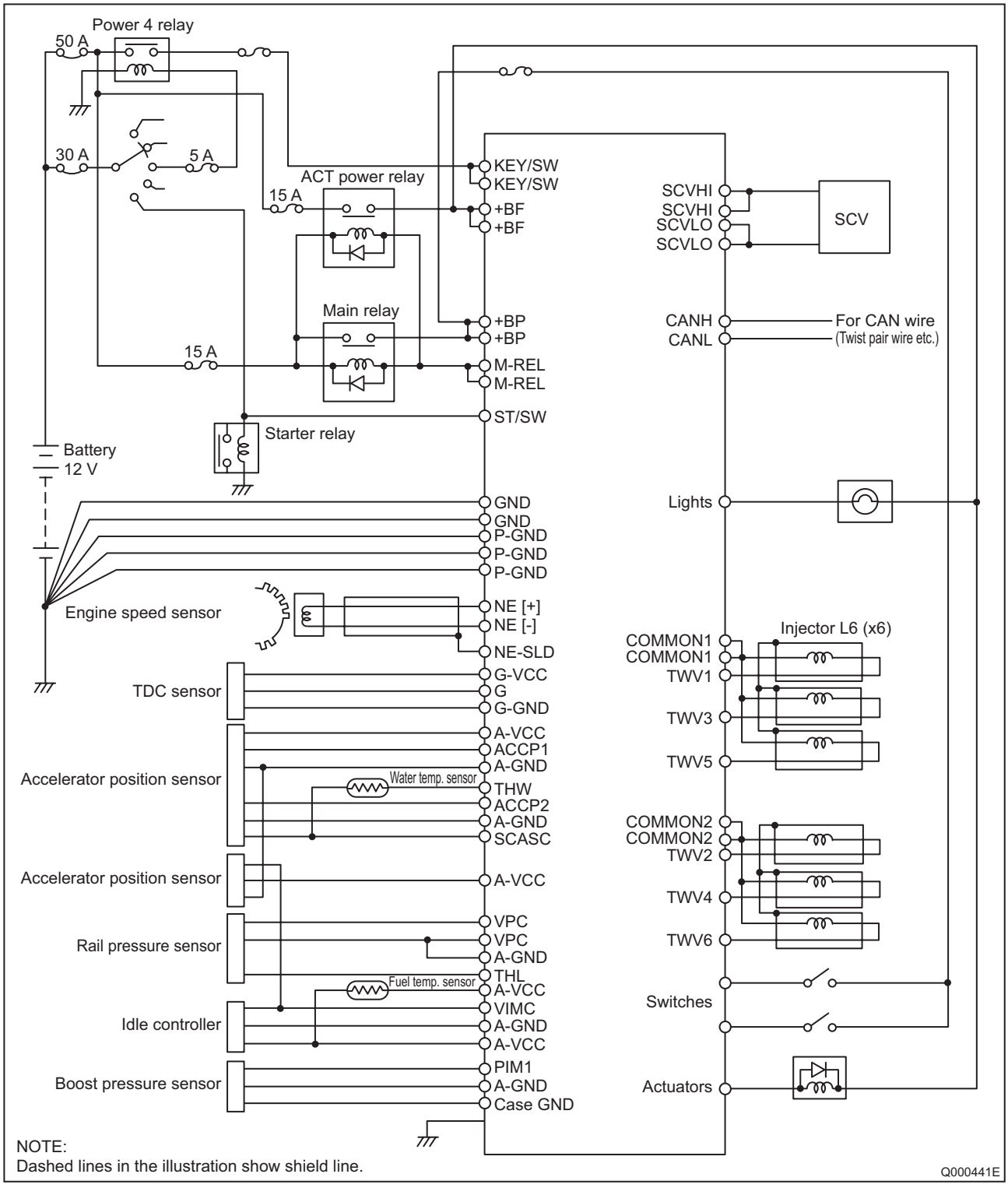
P-Code	DST-1 Display	Remarks	Description
P0501	Vehicle Speed Sensor Malfunction (HI)	Noise	The pulse from the vehicle speed sensor has an error. There are possibilities of the sensor and harness malfunctions.
P0510	Idle Switch Malfunction		The idle switch does not function properly. Monitor the state and check the ON/OFF judgment.
P0524	Engine Oil Pressure Too Low		The engine oil pressure became too low.
P1401	EGR Valve Clogged	Clogging has been detected by the lift sensor.	The EGR valve 2 system is clogged in the open state.
P0540	Preheating System Malfunction		The intake heater relay has a malfunction. There are possibilities of the relay and harness malfunctions.
P0545	Exhaust Gas Temperature Sensor 1 Malfunction (LO)		The temperature cannot be detected properly. There are possibilities of the sensor malfunction and short circuit to ground in the harness.
P0546	Exhaust Gas Temperature Sensor 1 Malfunction (HI)		"The temperature cannot be detected properly. There are possibilities of the sensor malfunction, open and short circuit to +B in the harness."
P0605	Flash ROM Malfunction		There is an internal malfunction in the ECU. Replace the ECU.
P0606	CPU Malfunction (Hardware Detected)		There is an internal malfunction in the ECU. Replace the ECU.
P0607	CPU Monitoring ID Malfunction		There is an internal malfunction in the ECU. Replace the ECU.
P0611	ECU Charge Circuit Malfunction		The voltage for the injector activation is too low. Replace the ECU.
P0617	Starter Switch Malfunction		There is a short in the starter switch circuit. Monitor the state and check the ON/OFF judgment.
P0686	Main Relay Malfunction		The main relay cannot be turned OFF. Check the relay.
P0704	Clutch Switch Malfunction		The clutch switch cannot be detected properly. Monitor the state and check the ON/OFF judgment.
P0850	Neutral Switch Malfunction		The neutral switch cannot be detected properly. Monitor the state and check the ON/OFF judgment.
P1132	Accelerator Position Sensor for Operation (LO)		The accelerator position sensor for operation cannot be detected properly. Check the sensor voltage. There are possibilities of open and short circuit to ground.
P1133	Accelerator Position Sensor for Operation (HI)		The accelerator position sensor for operation cannot be detected properly. Check the sensor voltage. There is a possibility of short circuit to +B.

P-Code	DST-1 Display	Remarks	Description
P1142	Idle Volume (LO)		The idle volume cannot be detected properly. Check the sensor voltage. There are possibilities of open and short circuit to ground.
P1143	Idle Volume (HI)		The idle volume cannot be detected properly. Check the sensor voltage. There is a possibility of short circuit to +B.
P1211	Injector Common 1 Malfunction		There is a possibility of short circuit to ground. Check the injector and wiring.
P1212	Injector Common 1 Malfunction		There is a possibility of open or short circuit to +B. Check the injector and wiring.
P1214	Injector Common 2 Malfunction		There is a possibility of short circuit to ground. Check the injector and wiring.
P1215	Injector Common 2 Malfunction		There is a possibility of open or short circuit to +B. Check the injector and wiring.
P1427	Exhaust Pressure Sensor Malfunction (LO)		"The exhaust pressure cannot be detected properly. There are possibilities of the sensor malfunction, open and short circuit to ground in the harness."
P1428	Exhaust Pressure Sensor Malfunction (HI)		The exhaust pressure cannot be detected properly. There are possibilities of the sensor malfunction and short circuit to +B in the harness.
P1472	Transmission Retarder Relay Malfunction	Transmission retarder relay linked with the cruise control system for the large- and medium-size vehicles	"The transmission retarder relay has a malfunction. There are possibilities of the relay malfunction, open and short circuit to ground in the harness."
P1473	Transmission Retarder Relay Malfunction	Transmission retarder relay linked with the cruise control system for the large- and medium-size vehicles	The transmission retarder relay has a malfunction. There are possibilities of the relay malfunction and short circuit to +B in the harness.
P1477	Cruise Control Retarder Relay Malfunction	Transmission retarder relay linked with the cruise control system for the medium-size vehicle	"The cruise control retarder relay has a malfunction. There are possibilities of the relay malfunction, open and short circuit to ground in the harness."
P1478	Cruise Control Retarder Relay Malfunction	Transmission retarder relay linked with the cruise control system for the medium-size vehicle	The cruise control retarder relay has a malfunction. There are possibilities of the relay malfunction and short circuit to +B in the harness.
P1530	Engine Stop Switch Close Malfunction		The engine stop switch has a malfunction or there is short circuit in the wiring. Monitor the state and check the ON/OFF judgment.
P1565	Cruise Control Switch Malfunction		The cruise control switch has a malfunction and remains ON. Monitor the state and check the ON/OFF judgment.
P1601	QR Code Error		The QR code has an error. Check the QR code.

P-Code	DST-1 Display	Remarks	Description
P1681	Exhaust Brake Solenoid Valve Malfunction		"The exhaust brake solenoid valve has a malfunction. There are possibilities of the solenoid valve malfunction, open and short circuit to ground in the harness."
P1682	Exhaust Brake Solenoid Valve Malfunction		The exhaust brake solenoid valve has a malfunction. There are possibilities of the solenoid valve malfunction and short circuit to +B in the harness.
P2002	DPR System Malfunction		The DPR system has a malfunction. There are possibilities of the melt down and clogging. Perform the DPR system check.
P2032	Exhaust Gas Temperature Sensor 2 Malfunction (LO)		The temperature cannot be detected properly. There are possibilities of the sensor malfunction and short circuit to ground in the harness.
P2033	Exhaust Gas Temperature Sensor 2 Malfunction (HI)		"The temperature cannot be detected properly. There are possibilities of the sensor malfunction, open and short circuit to +B in the harness."
P2120	Accelerator Position Sensor 1&2 Malfunction		Both the accelerator sensor 1 and 2 have malfunctions. There are possibilities of the sensor and harness malfunctions.
P2121	Accelerator Position Sensor 1 Malfunction		The accelerator position sensor 1 cannot be detected properly. Check the sensor voltage.
P2122	Accelerator Position Sensor 1 Malfunction (LO)		The accelerator position sensor 1 cannot be detected properly. Check the sensor voltage.
P2123	Accelerator Position Sensor 1 Malfunction (HI)		The accelerator position sensor 1 cannot be detected properly. Check the sensor voltage. There is a possibility of short circuit to +B.
P2126	Accelerator Position Sensor 2 Malfunction		The accelerator position sensor 2 cannot be detected properly. Check the sensor voltage.
P2127	Accelerator Position Sensor 2 Malfunction (LO)		The accelerator position sensor 2 cannot be detected properly. Check the sensor voltage. There are possibilities of open and short circuit to ground.
P2128	Accelerator Position Sensor 2 Malfunction (HI)		The accelerator position sensor 2 cannot be detected properly. Check the sensor voltage. There is possibility of short circuit to +B.
P2228	Atmospheric Air Pressure Sensor Malfunction (LO)		"The atmosphere pressure sensor (in ECU) has a malfunction. If the malfunction occurs frequently, it is necessary to repair or replace the ECU."
P2229	Atmospheric Air Pressure Sensor Malfunction (HI)		"The atmosphere pressure sensor (in ECU) has a malfunction. If the malfunction occurs frequently, it is necessary to repair or replace the ECU."
U0073	CAN Communication Malfunction (Engine)	For middle-sized VNT	There is a malfunction of communication with the VNT.
U0101	Lost Communication (Transmission)	Communication error between pro-shift and AT-ECU	Communication with the transmission ECU is lost.
U0104	Lost Communication (Cruise control)		Communication with the auto cruise ECU is lost.

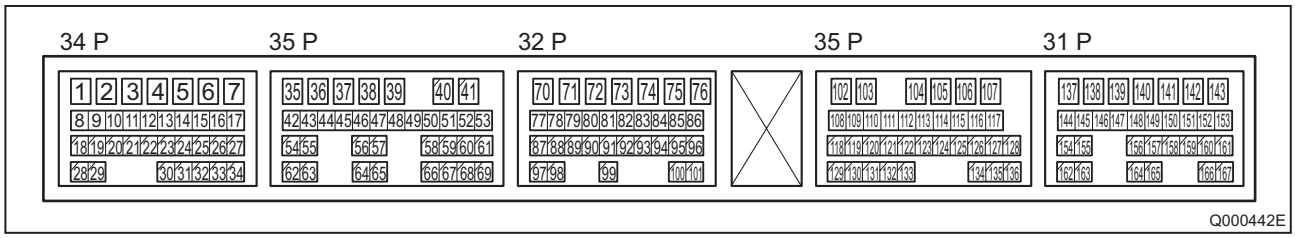
P-Code	DST-1 Display	Remarks	Description
U0121	Lost Communication (ABS)		Communication with the ABS ECU is lost.
U0132	Lost Communication (Air suspension)		Communication with the air suspension ECU is lost.
U0155	Lost Communication (Meter)		Communication with the meter ECU is lost.
U1001	CAN Communication error (Vehicle)	CAN communication bus OFF judgment	There is a malfunction of communication with other computers equipped in vehicle.
TBD	EGR Solenoid 1 Malfunction	When linear solenoid specific P code is obtained	"The EGR solenoid 1 has a malfunction. There are possibilities of solenoid valve malfunction, open and short circuit to ground in the harness."
TBD	EGR Solenoid 1 Malfunction	When linear solenoid specific P code is obtained	The EGR solenoid 1 has a malfunction. There are possibilities of solenoid valve malfunction and short circuit to +B in the harness.
TBD	EGR Solenoid 2 Malfunction	When linear solenoid specific P code is obtained	"The EGR solenoid 2 has a malfunction. There are possibilities of solenoid valve malfunction, open and short circuit to ground in the harness."
TBD	EGR Solenoid 2 Malfunction	When linear solenoid specific P code is obtained	The EGR solenoid 2 has a malfunction. There are possibilities of solenoid valve malfunction and short circuit to +B in the harness.

[2] ECU External Wiring Diagram



[3] ECU Connector Diagram

(1) ECU Connector Terminal Layout



(2) Terminal Connections

No.	Pin Symbol	Connections	No.	Pin Symbol	Connections
1	(GND)	ECU ground (spare)	18	(CASE GND)	Case ground (spare)
2	(GND)	ECU ground (spare)	19	KWP2000	ISO9141-K
3	IN3	spare	20	IN1	—
4	IN3-	spare	21	AD1	Accelerator position sensor 1
5	+B	Power	22	AD2	Accelerator position sensor 2
6	+B	Power	23	AD10	Accelerator position sensor for operation
7	+B	Power	24	AD12	spare
8	TAC1	spare	25	AD19	spare
9	TAC2	Tachometer signal (SINK)	26	AD20	spare
10	POUT1	spare	27	VS1	Vehicle speed sensor
11	POUT2	spare	28	CASE GND	Case ground
12	POUT3	spare	29	IN2	—
13	POUT4	spare	30	AD14	IMC volume
14	PIN1	spare	31	AD15	spare
15	PIN2	spare	32	AD16	Intake air temp. sensor (Build-in Airflow meter)
16	—	—	33	AD17	spare
17	(BATT)	—	34	AD18	spare
35	+BF	+BF	53	SW7	Brake switch
36	OUT5	Exhaust brake solenoid valve	54	A-GND4	Sensor ground 4
37	OUT6	spare	55	A-GND5	Sensor ground 5
38	OUT7	spare	56	SW1	Key switch
39	NE-SLD	Engine RPM shield ground	57	A-VCC4	Sensor (Power supply) 4
40	NE+	Engine RPM +	58	SW8	Accelerator pedal switch
41	NE-	Engine RPM -	59	SW10	spare
42	OUT1	spare	60	SW12	Constant-speed switch
43	OUT2	spare	61	SW17	Stop lamp switch
44	OUT3	Exhaust brake light	62	AD21	spare
45	OUT4	Glow indicator light	63	AD22	EGR valve lift sensor 2
46	SW1	Key switch	64	—	—
47	OUT8	spare	65	A-VCC5	Sensor (Power supply) 5
48	SW2	Starter switch	66	SW9	Neutral switch
49	SW3	Exhaust brake switch	67	SW11	spare
50	SW4	spare	68	SW16	Diag. switch
51	SW5	spare	69	SW18	spare
52	SW6	spare			

No.	Pin Symbol	Connections	No.	Pin Symbol	Connections
70	OUT19	Glow relay	86	—	—
71	OUT20	Glow relay	87	SW31	AT identification signal
72	GND	ECU ground	88	SW20	PTO2 switch
73	GND	ECU ground	89	SW21	PTO switch
74	OUT17	ECU main relay	90	SW25	spare
75	OUT18	ECU main relay	91	SW26	spare
76	+BF	+BF	92	SW13	Cruise switch 1
77	SW27	Clutch switch	93	SW28	Clutch stroke switch
78	SW	spare	94	SW29	spare
79	SW	Cruise switch 2	95	CANH	CAN2 HI
80	SW	Stop lamp switch 2	96	CANL	CAN2 LOW
81	SW	spare	97	SW32	Hydraulic pressure switch
82	S-OUT1	Check engine light 1	98	SW22	Warm-up switch
83	S-OUT2	spare	99	SW23	spare
84	S-OUT3	spare	100	SW30	spare
85	S-OUT4	spare	101	CAN-SLD	CAN2 Shield ground
102	P-GND	Power ground	120	G	Cam angle
103	TWV1	Injector drive signal 1	121	AD4	Rail pressure sensor 1
104	TWV3	Injector drive signal 3	122	AD11	Airflow meter
105	TWV5	Injector drive signal 5	123	A-VCC3	Sensor (Power supply) 3
106	COMMON1	Injector drive power 1	124	NE-VCC	spare
107	COMMON1	Injector drive power 1	125	A-VCC2	Sensor (Power supply) 2
108	OUT9	EGR linear solenoid drive 1	126	A-VCC1	Sensor (Power supply) 1
109	OUT10	EGR linear solenoid drive 2	127	AD13	EGR valve lift sensor 1
110	OUT11	spare	128	AD3	Boost pressure sensor
111	OUT12	spare	129	(GND)	ECU ground (spare)
112	OUT13	Cruise lamp	130	(GND)	ECU ground (spare)
113	OUT14	Constant-speed lamp	131	G-GND	CAM angle ground
114	OUT15	spare	132	AD5	Rail pressure sensor 2
115	OUT16	spare	133	G-VCC	Cam angle VCC (5V)
116	—	—	134	A-GND1	Sensor ground 1
117	—	—	135	A-GND2	Sensor ground 2
118	A-GND6	Airflow ground	136	A-GND3	Sensor ground 3
119	NE (MRE)				

No.	Pin Symbol	Connections	No.	Pin Symbol	Connections
137	TWV2	Injector drive signal 2	153	PCV1	spare
138	TWV4	Injector drive signal 4	154	AD6	spare
139	TWV6	Injector drive signal 6	155	AD7	Water temp. sensor
140	P-GND	Power ground	156	—	—
141	P-GND	Power ground	157	CAN1H	CAN1 HI
142	COMMON2	Injector drive power 2	158	CAN1L	CAN1 LOW
143	COMMON2	Injector drive power 2	159	—	—
144	SCVLO	HP 3 or 4 pump control valve drive signal	160	—	—
145	SCVLO	HP 3 or 4 pump control valve drive signal	161	(CASE GND)	Case ground (spare)
146	SCVHI	HP 3 or 4 pump control valve power	162	AD8	spare
147	SCVHI	HP 3 or 4 pump control valve power	163	AD9	Fuel temp. sensor 2
148	—	—	164	—	—
149	—	—	165	CAN1-SLD	spare
150	PCV2	spare	166	—	—
151	PCV2	spare	167	(CASE GND)	Case ground (spare)
152	PCV1	spare			
Built-in	PATM	Atmospheric air pressure sensor			