DENSO

Diesel Injection Pump

SERVICE MANUAL

Common Rail System for ISUZU 4HK1 / 6HK1 Type Engine

OPERATION

February, 2004

DENSO CORPORATION

00400056E

FORWARD

To meet the high pressurization requirements for the engine to deliver cleaner exhaust gas emissions, lower fuel consumption and reduced noise, advanced electronic control technology is being adopted in the fuel injection system.
This manual covers the electronic control model Common Rail system with HP3/HP4 pump for the ISUZU 4HK1/6HK1 type engines which are used to ELF and GM 560 series respectively. Complex theories, special functions and components made by manufacturers other than DENSO are omitted from this manual.
This manual will help the reader develop an understanding of the basic construction, operation and system configuration of the DENSO manufactured components and brief diagnostic information.

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1. Product Application

1-1. Application

Vehicle Name	Engine Model	Vehicle model	Exhaust Volume	Reference
ELF	4HK1	N series	5.2L	Direct-Injection
C560 Series	6HK1	GM 560	7.8L	Direct-Injection

1-2. System Components Parts Numbers

Parts Name	DENSO Parts Number	Car Manufacturer Parts Number	Reference
Supply Pump	294000-0260	8973288860	4HK1
	294050-0021	9876020491	6HK1
Injector	095000-5351	8976011561	6HK1
	095000-5361	8976028031	
	095000-5471	8973297031	4HK1
Rail	095440-0351	8973060632	4HK1
	095440-0470	8973230190	6HK1
Engine ECU	275800-2801	8151794773	6HK1
	275800-2812	8973750190	4HK1
	275800-2822	8973750200	

2. Outline

2-1. Outline 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.

A. 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 injection 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.

a. Injection Pressure Control

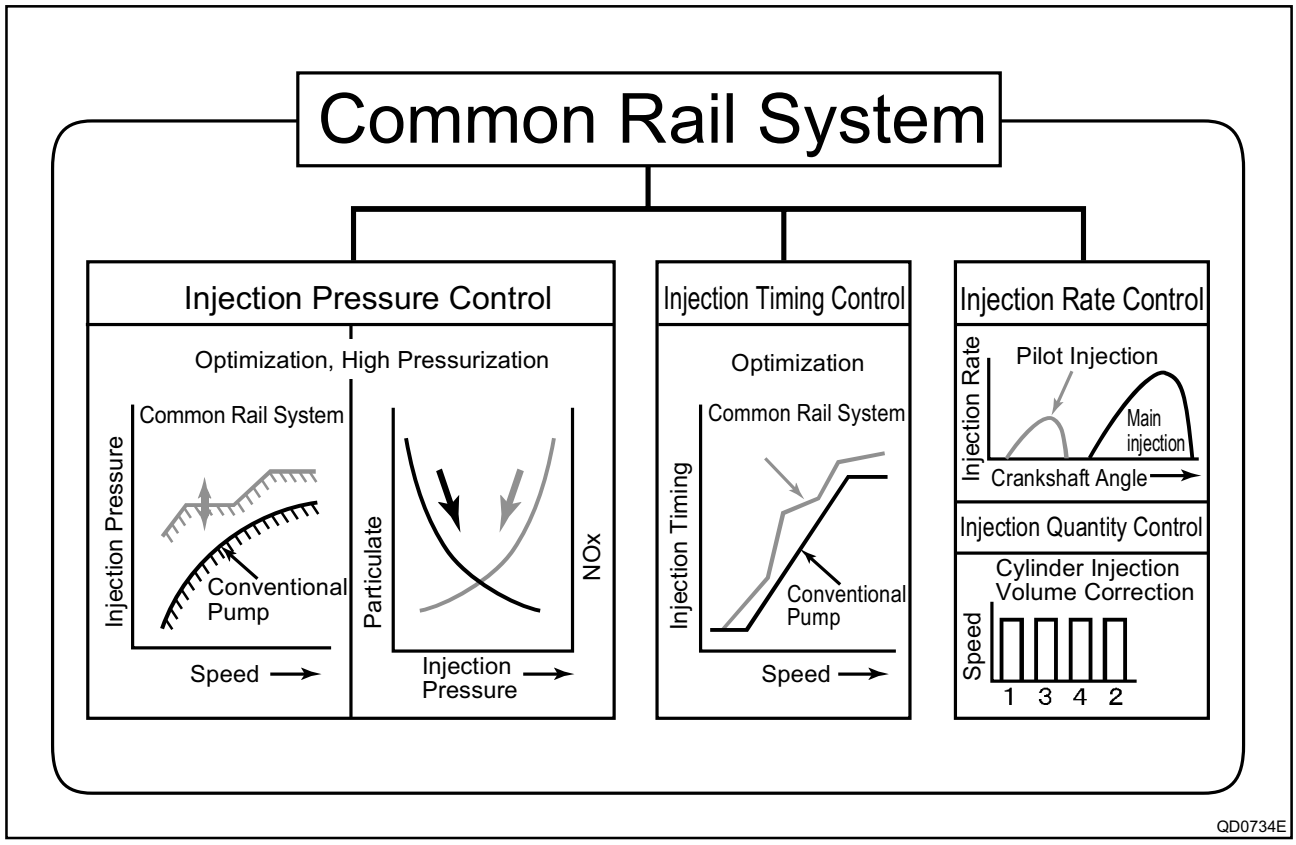
- Enables high-pressure injection even at low engine speeds.
- Optimizes control to minimize particulate matter and NOx emissions.

b. Injection Timing Control

Enables finely tuned optimized control in accordance with driving conditions.

c. Injection Rate Control

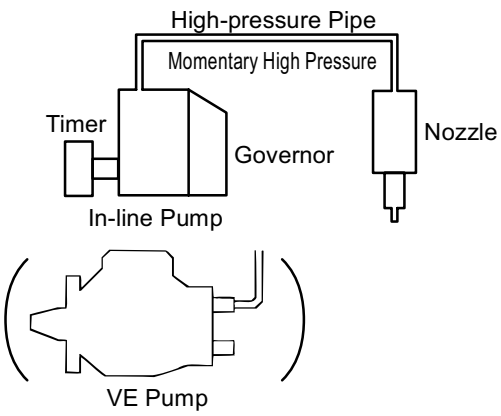
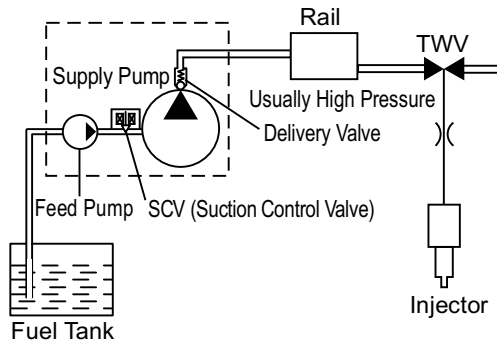
Pilot injection control sprays a small amount of fuel before the main injection.



d. EGR (Exhaust Gas Recirculation) Control

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

B. Comparison to the Conventional System

System	In-line, VE Pump	Common Rail System
	 VE Pump	
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

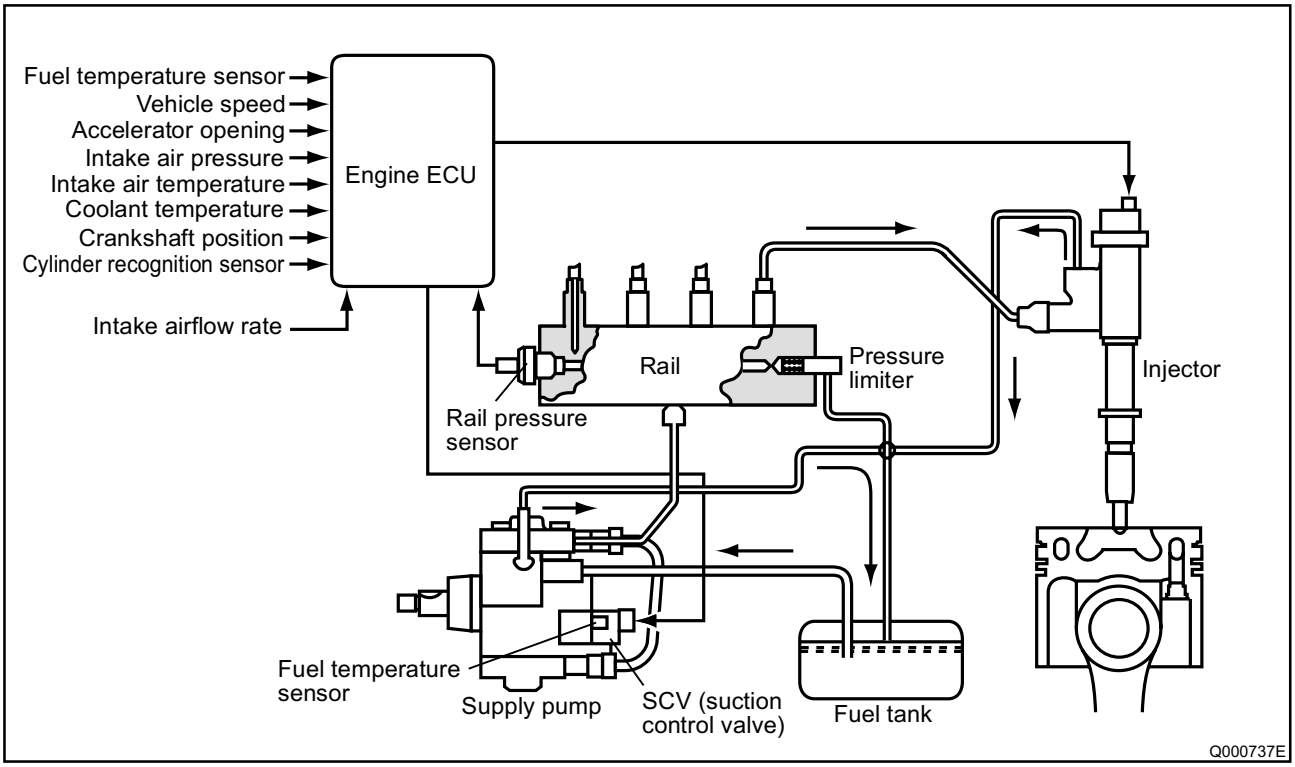
*1 TWV: Two Way Valve *2 SCV: Suction Control Valve QD2341E

2-2. Outline of System

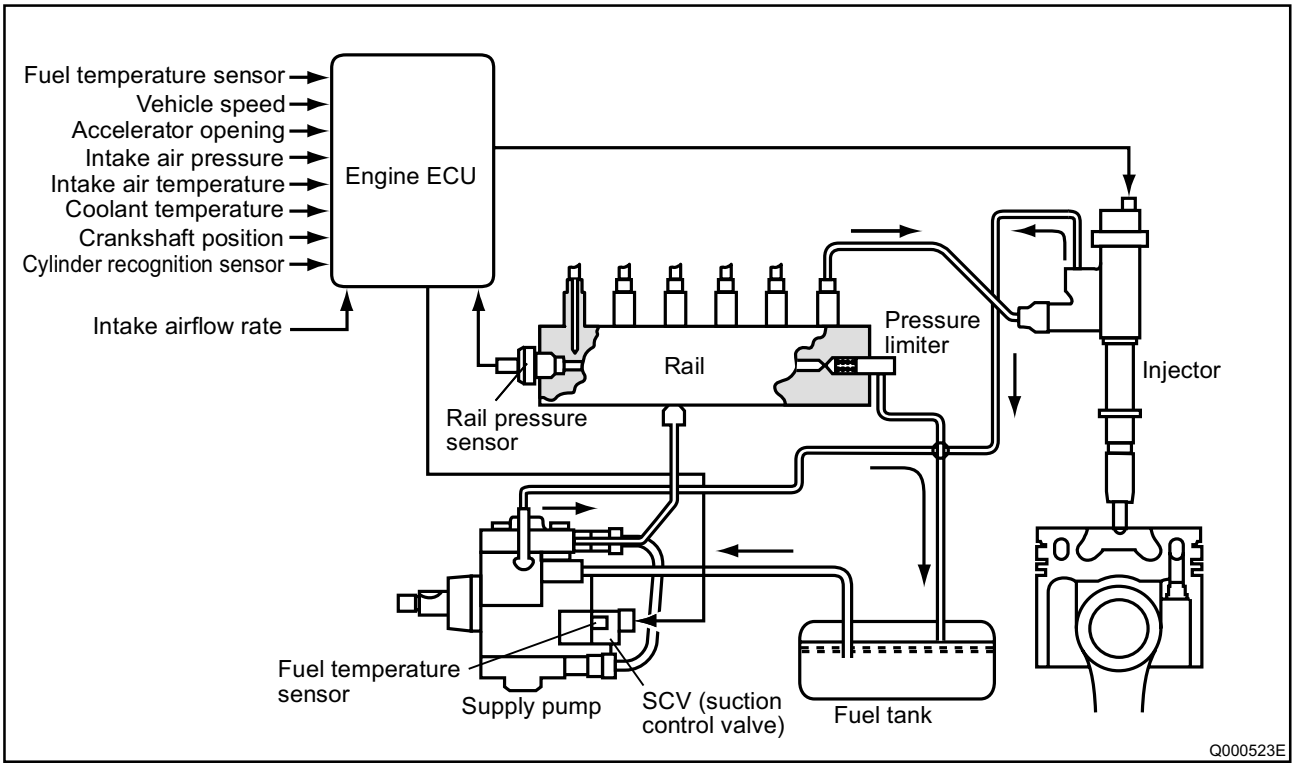
A. Composition

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

a. 4HK1



b. 6HK1



B. Operation

a. Supply pump (HP3/HP4)

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.

b. Rail

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

c. Injector (G2 type)

- 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.

d. Engine ECU

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

A. 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.

B. 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: (a.) Sensors; (b.) Engine ECU; and (c.) Actuators.

a. Sensors

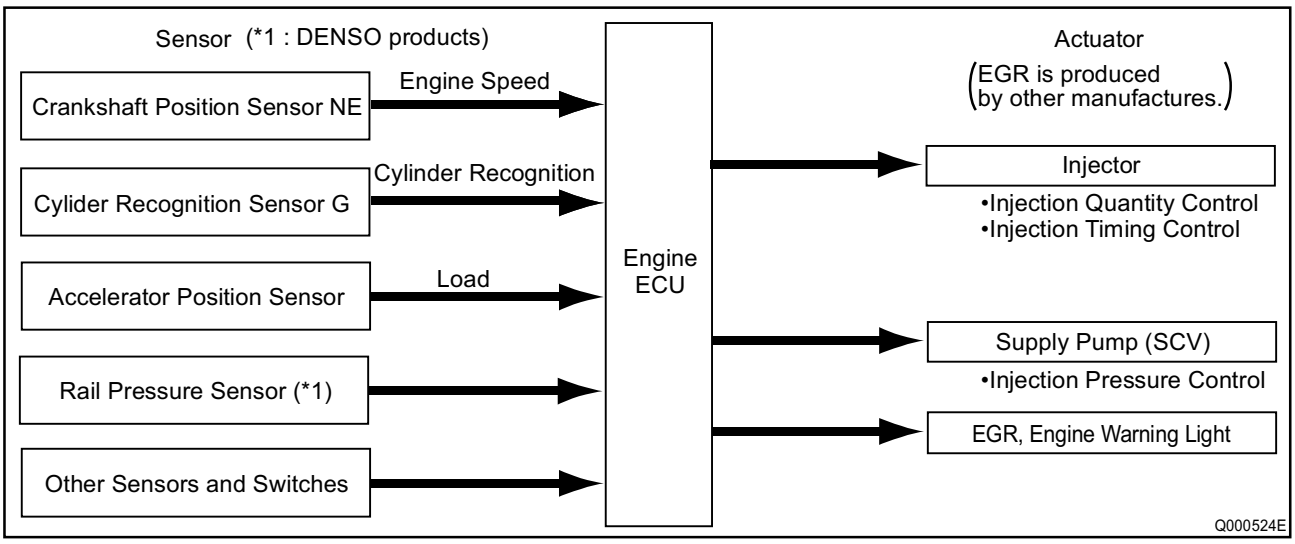
Detect the engine and driving conditions, and convert them into electrical signals.

b. Engine ECU

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

c. Actuators

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

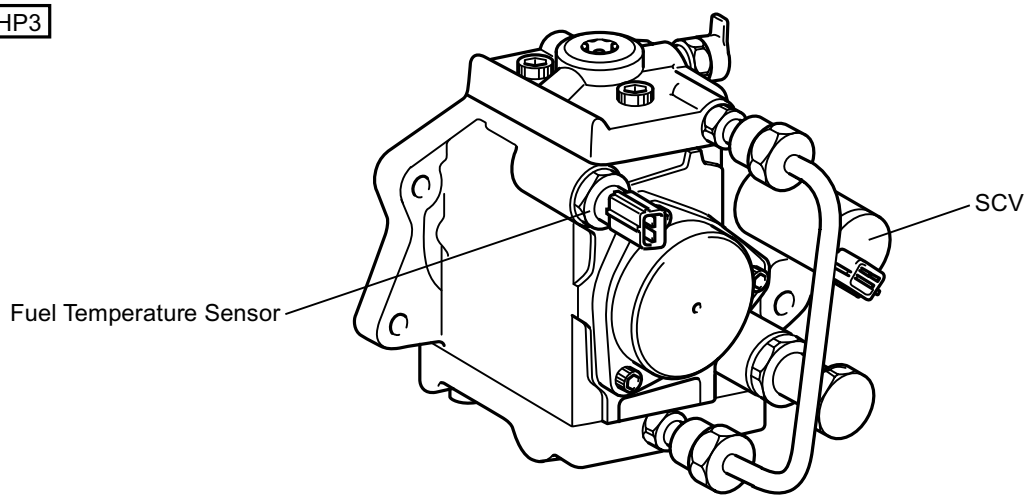
3-1. Description of Main Components

A. Supply Pump (HP3, HP4)

a. Outline

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.

HP3



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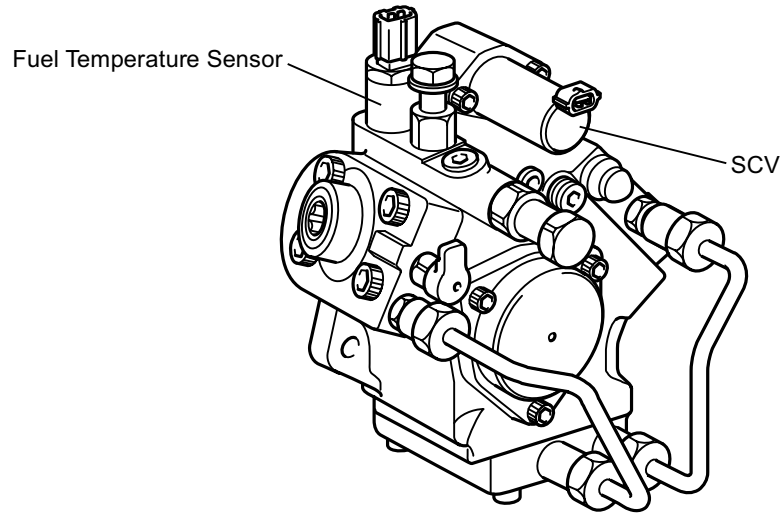
HP4



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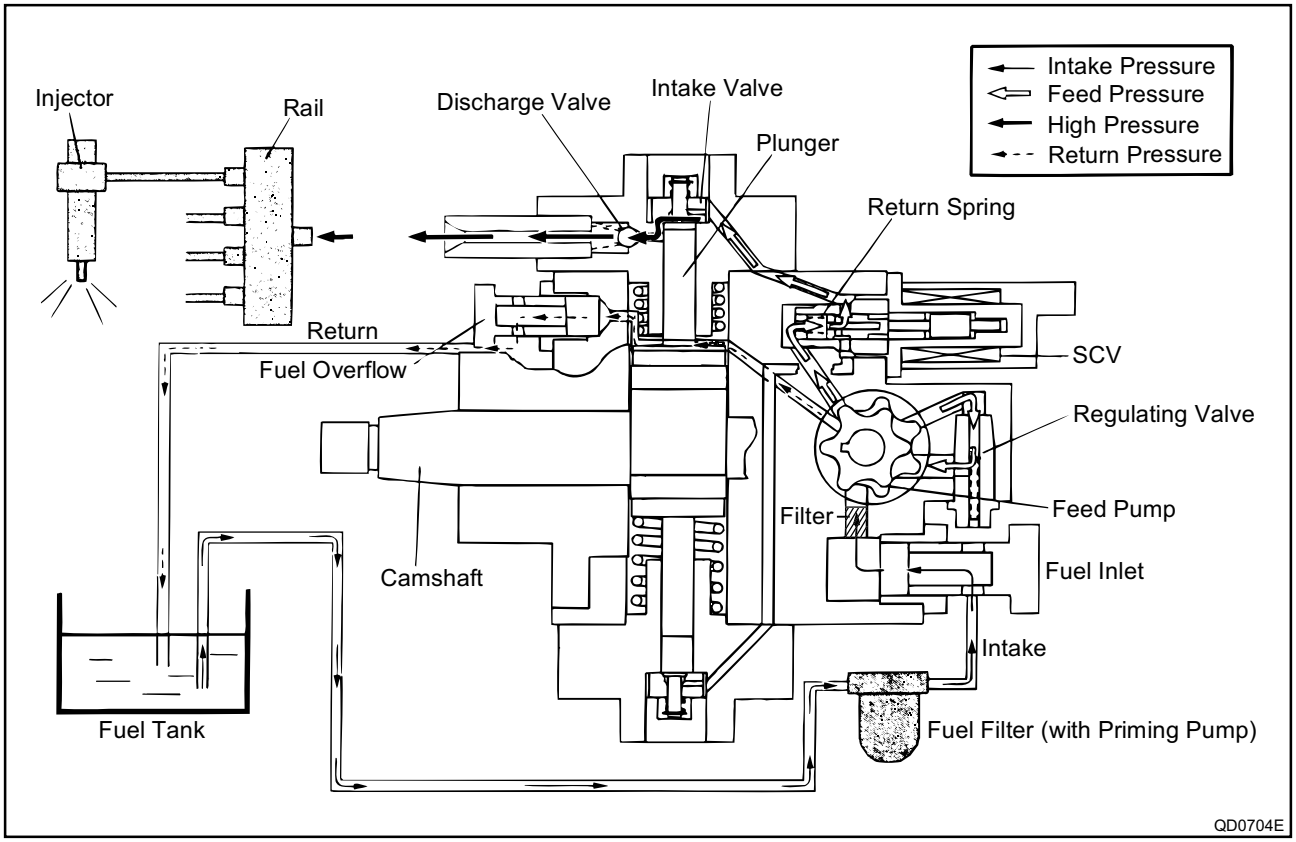
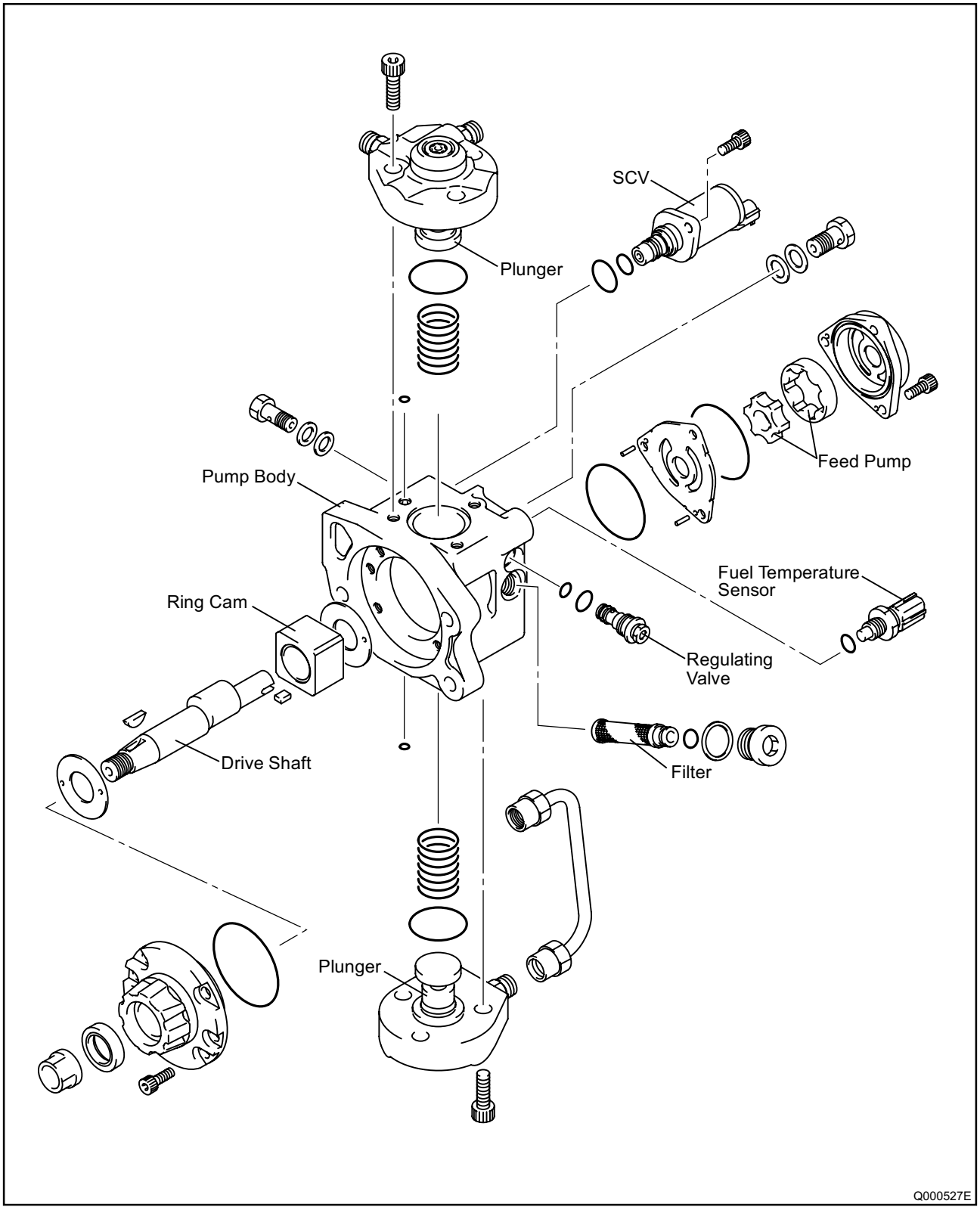
- The two plungers for HP3 or the three plungers for HP4 are positioned vertically on the outer ring cam for compactness.
- The engine drives the supply pump at a ratio of 1:1. The supply pump has a built-in feed pump (trochoid type), and draws the fuel from the fuel tank, sending it to the plunger chamber.

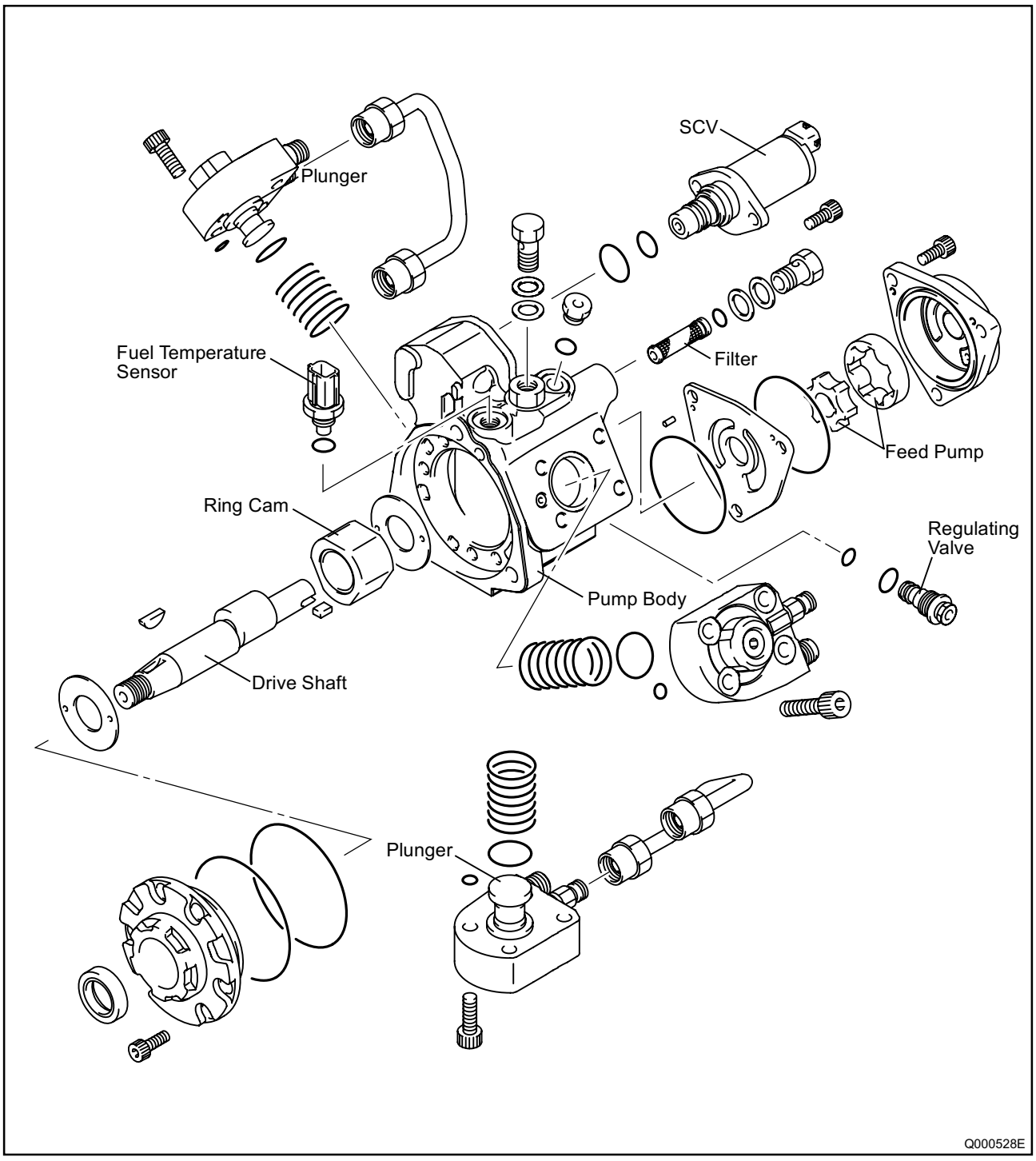
- The internal camshaft drives the two plungers, and they pressurize the fuel sent to the plunger chamber and send it to the rail. The quantity of fuel supplied to the rail is controlled by the SCV, using signals from the engine ECU. The SCV is a normally opened type (the intake valve opens during de-energization).



• Development: HP3

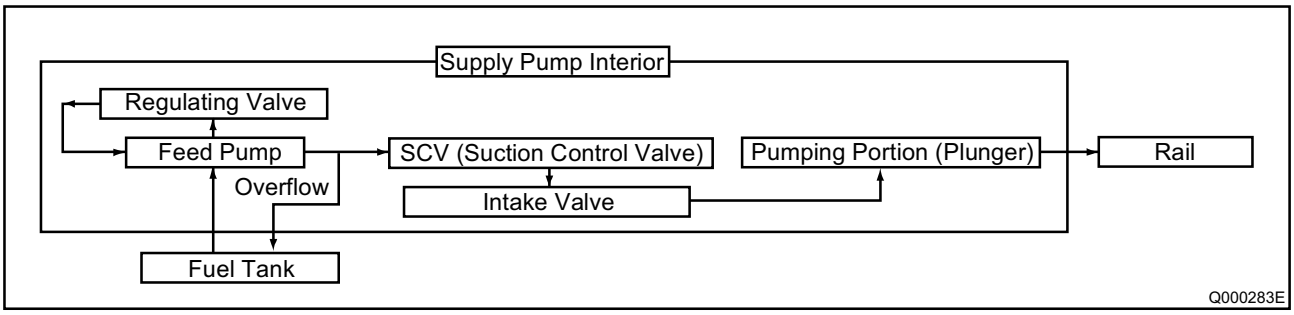


• Development: HP4



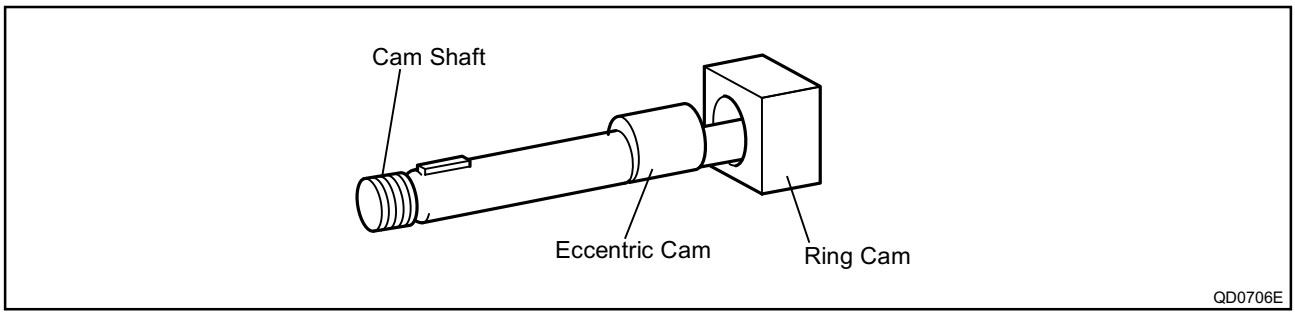
b. Supply Pump Internal Fuel Flow

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.

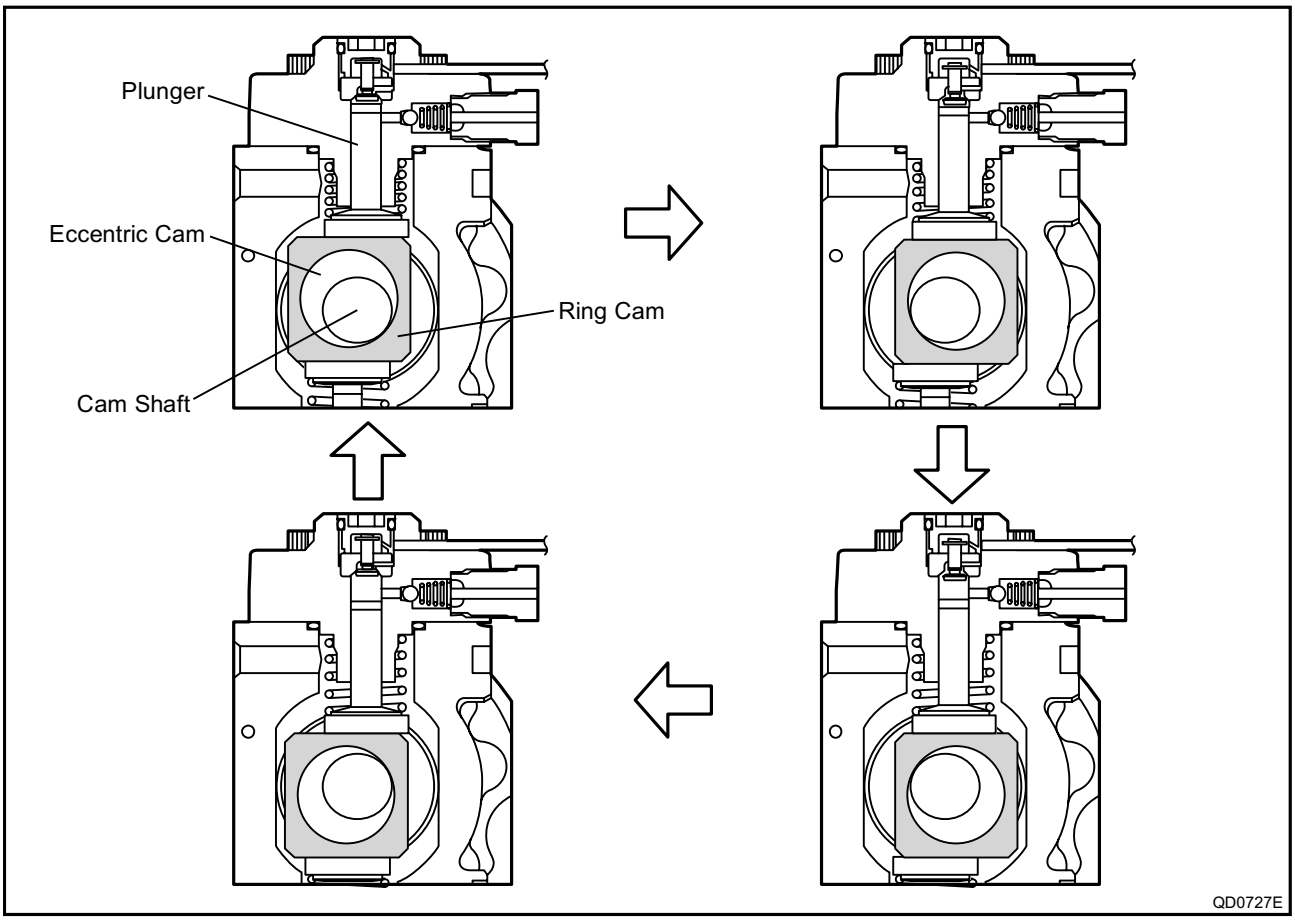


c. Construction of Supply Pump (in case of HP3 pump)

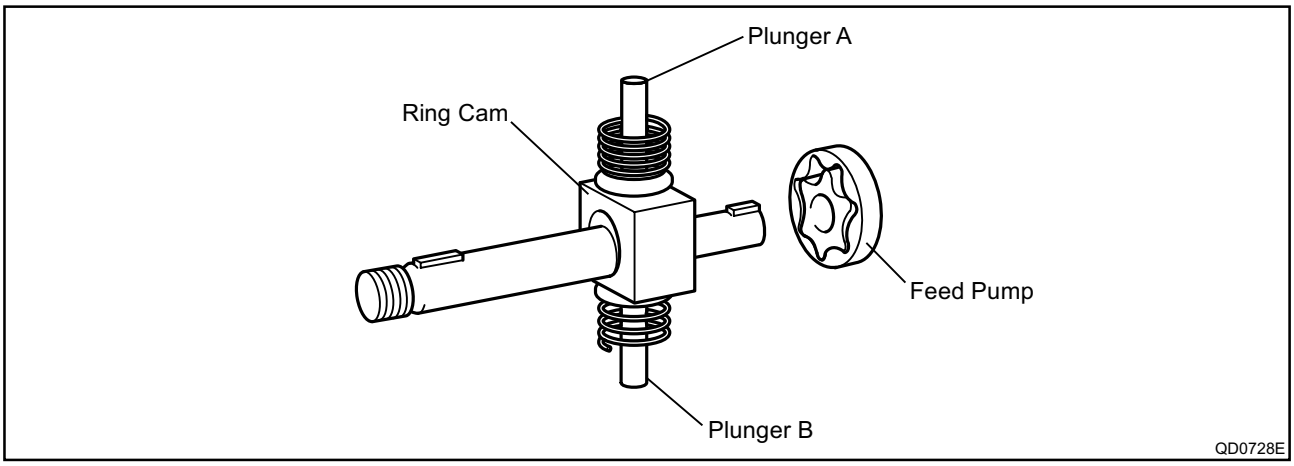
• The eccentric cam is attached to the cam shaft. The eccentric cam is connected to the ring cam.



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

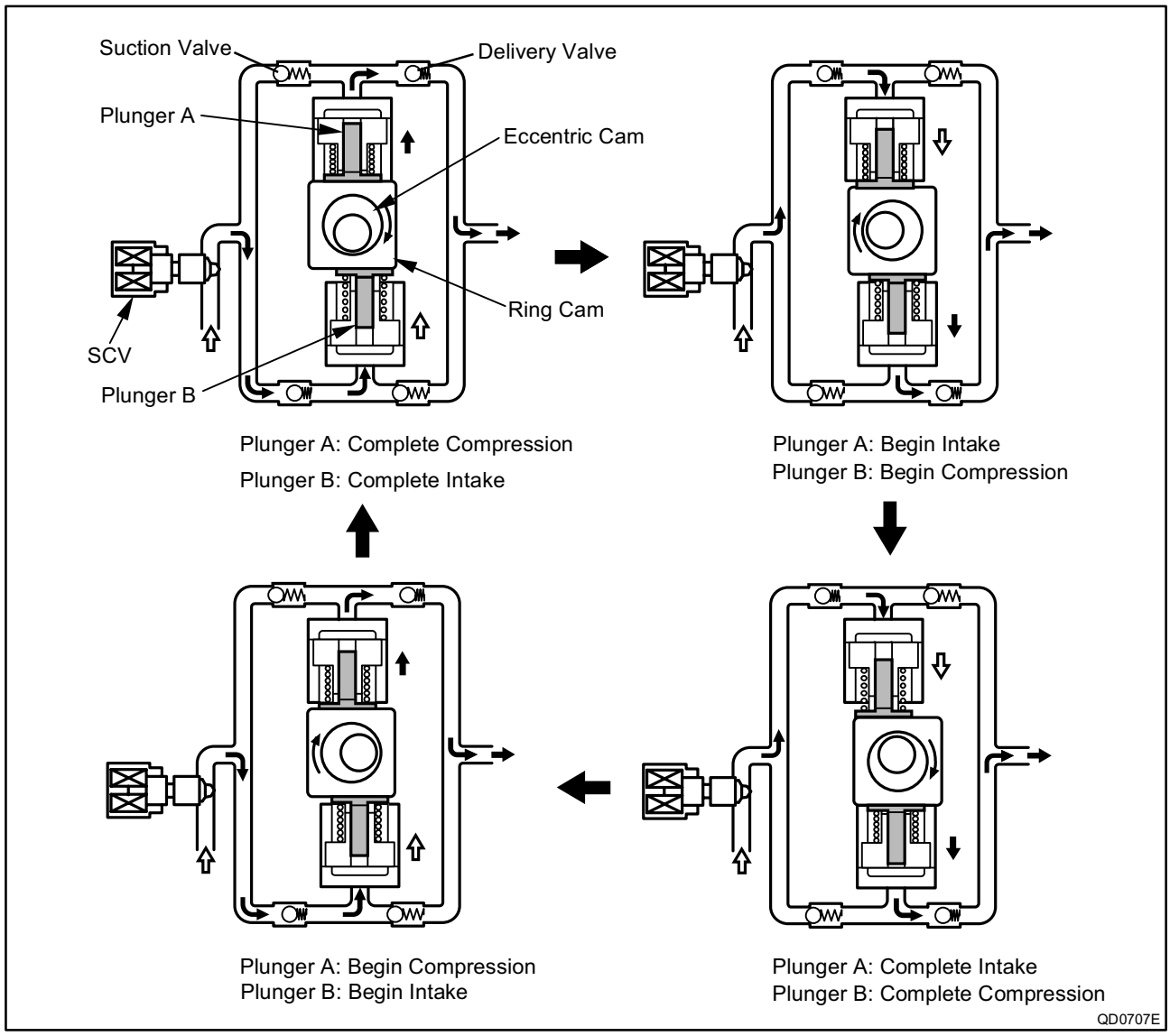


• The plunger and the suction valve are attached to the ring cam. The feed pump is connected to the rear of the cam shaft.



d. Operation of the Supply Pump

- 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.



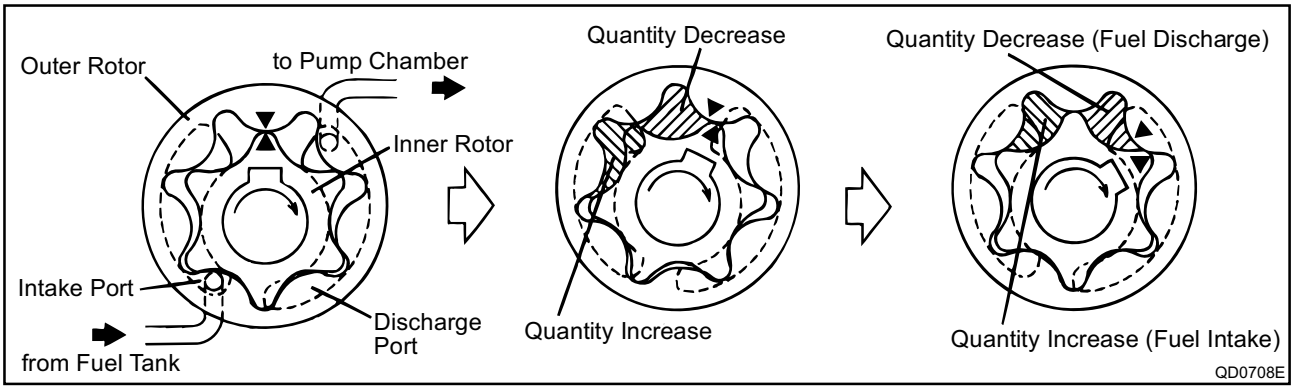
< NOTE >

- There are 3 plungers for the HP4.

B. Description of Supply Pump Components

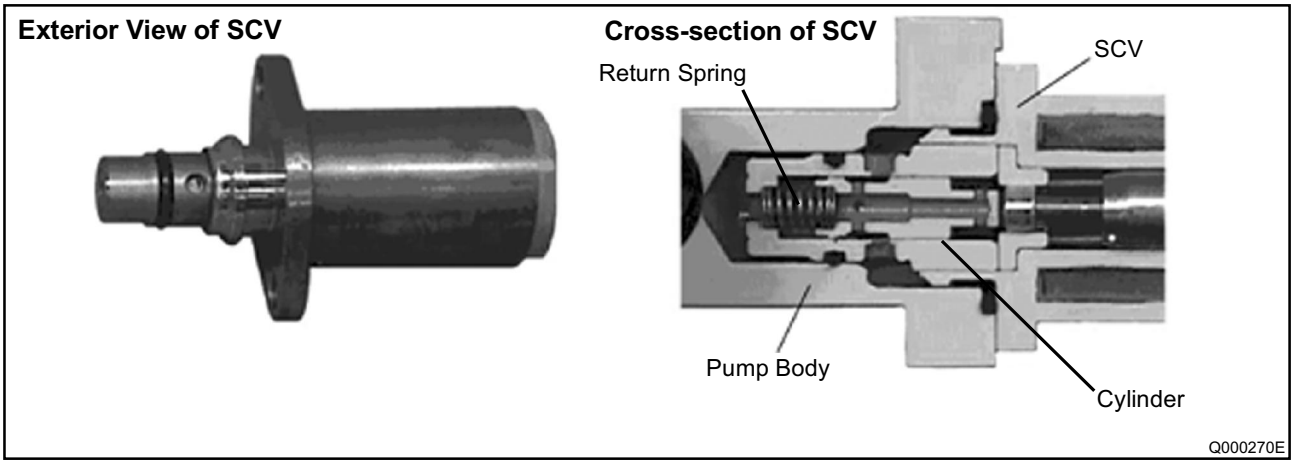
a. Feed Pump

- 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.



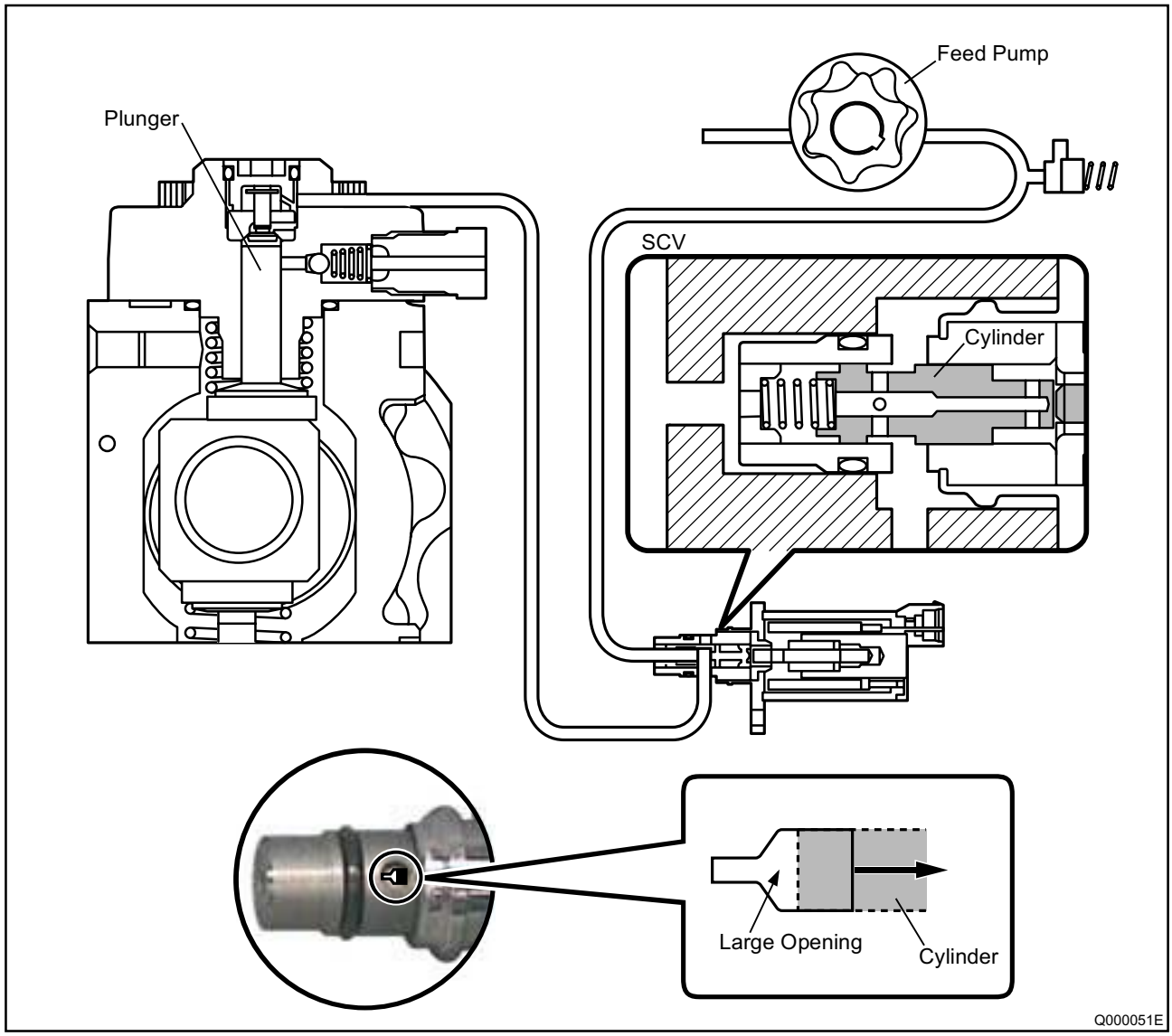
b. SCV: Suction Control Valve (Normally open type)

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



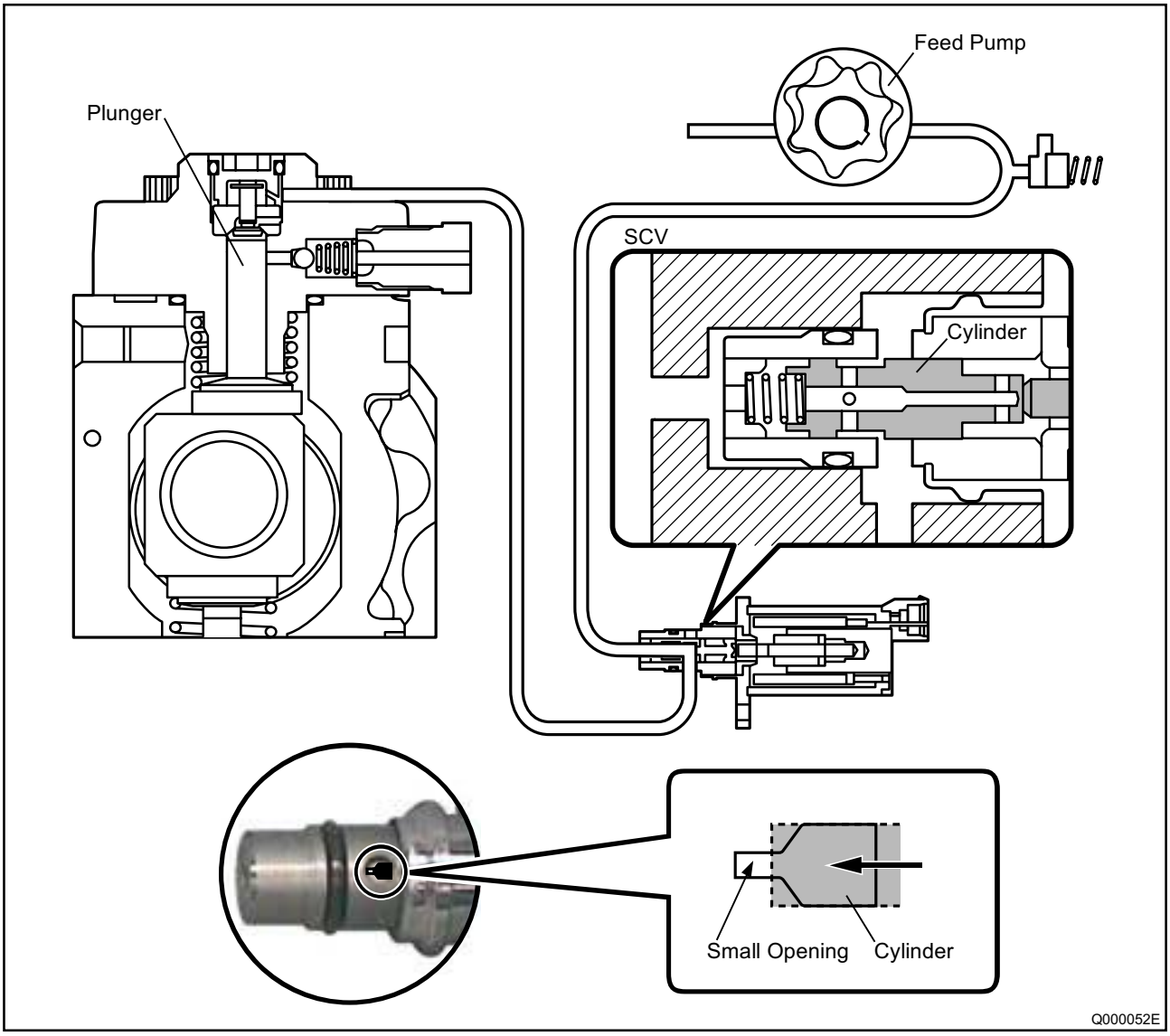
(1) In case of short time ON duty

Short time ON duty => large valve opening => maximum intake quantity



(2) In case of long time ON duty

Long time ON duty => small valve opening => minimum intake quantity

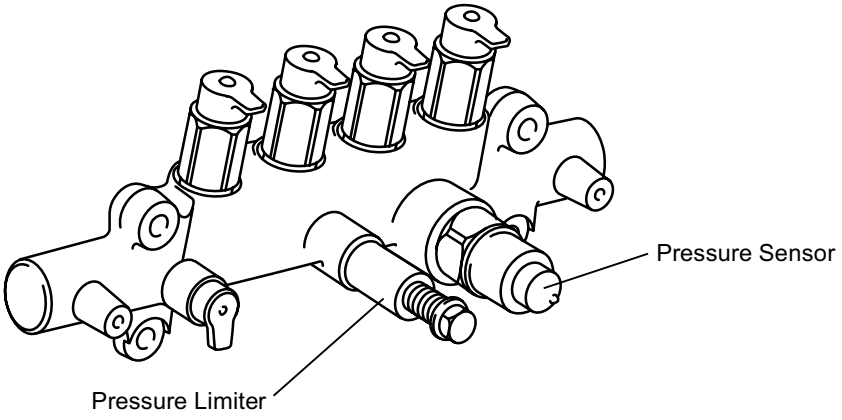


C. Rail

a. Outline

- Stores pressurized fuel (0 to 160 MPa {0 to 1631.6 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.
- 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.

For 4HK1



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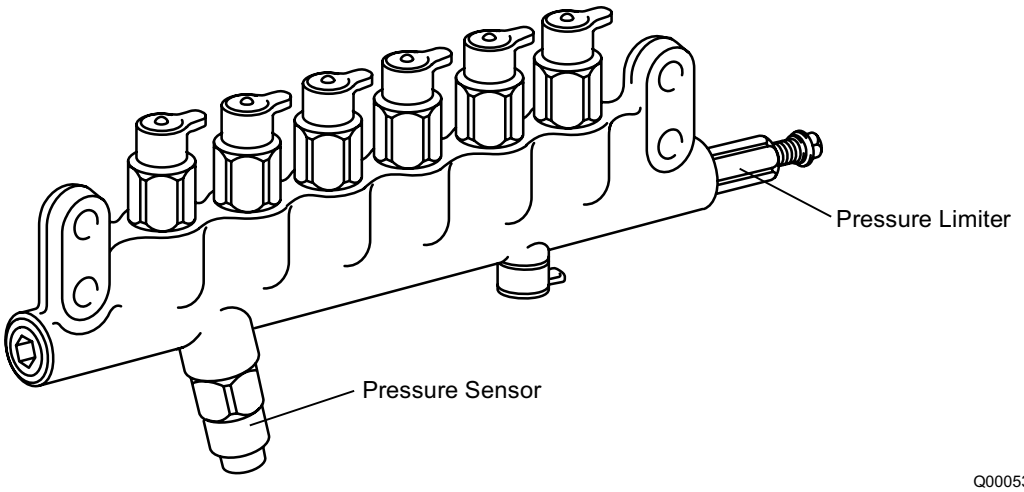
For 6HK1



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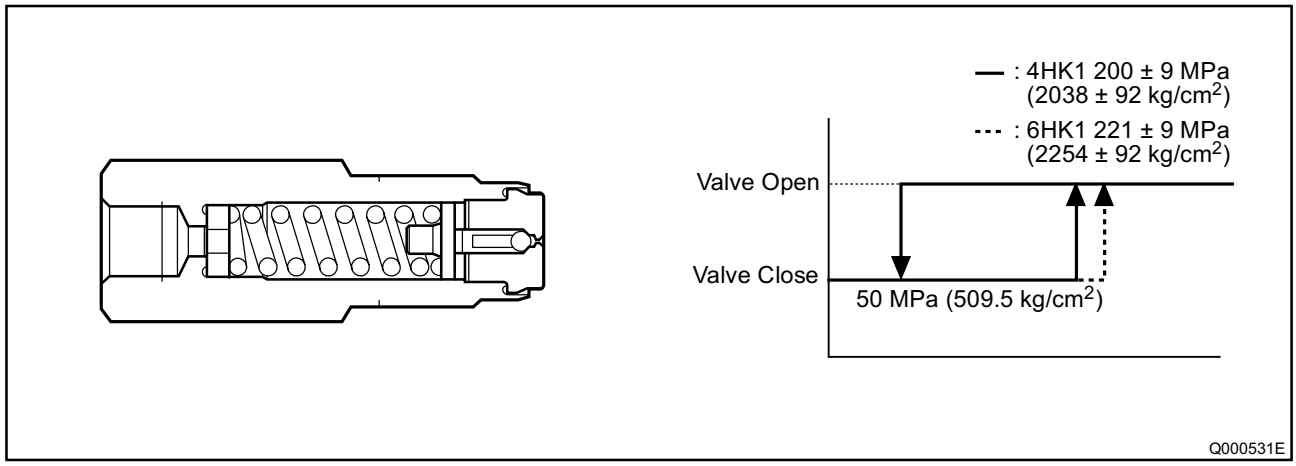
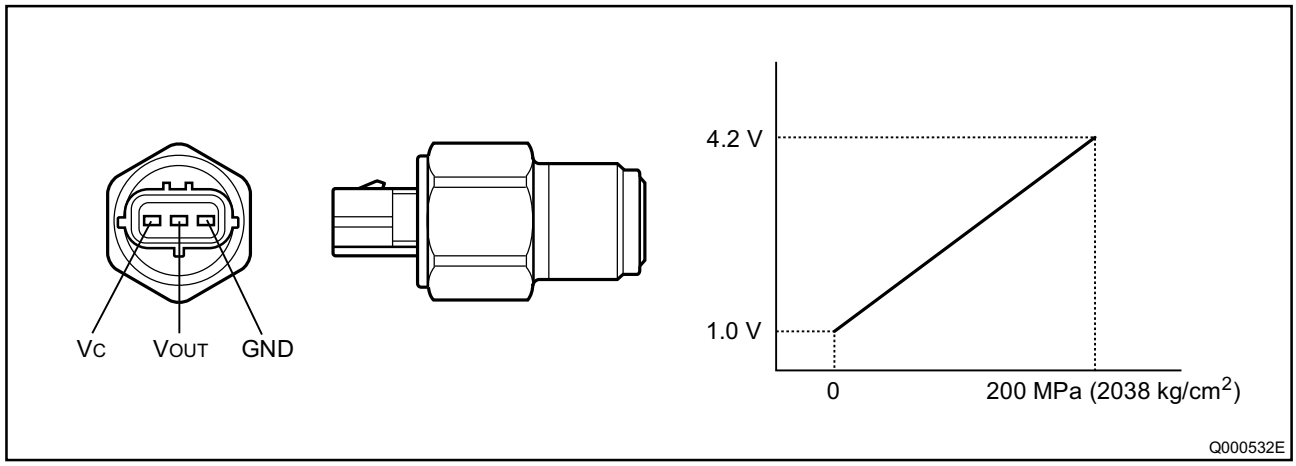
b. Pressure Limiter

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



c. Pressure Sensor

- The rail pressure sensor (Pc sensor) is attached to the rail in order to detect the fuel pressure.
- It is a semiconductor type pressure sensor that utilizes the characteristics of silicon, whereby the electrical resistance changes when pressure is applied to it.

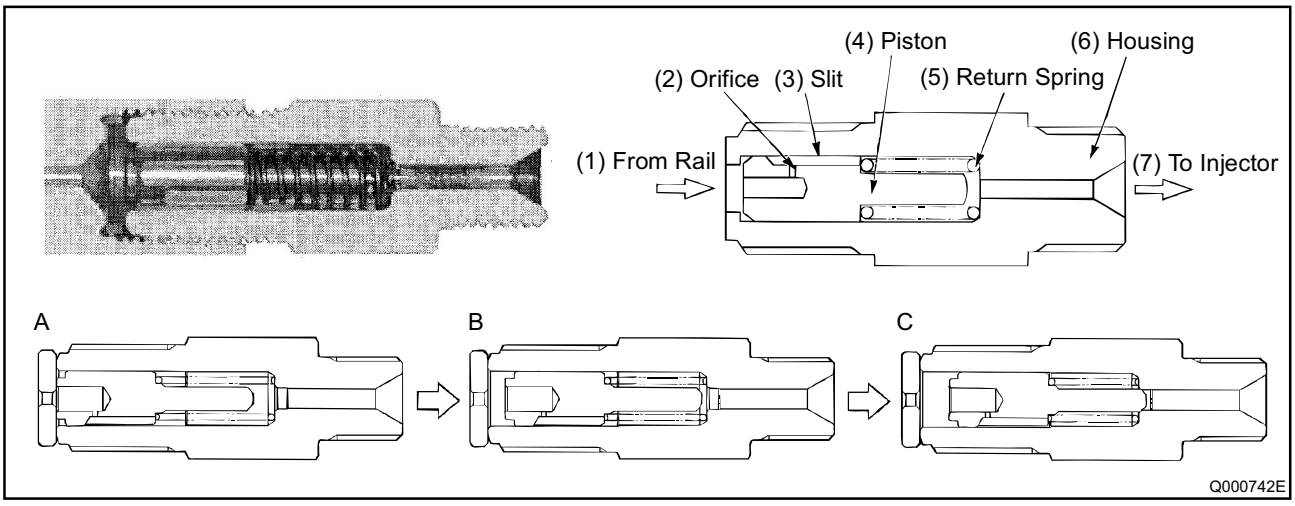


< NOTE >

- It is necessary to reset the ECU default value using the ISUZU 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.

d. Flow Damper

- The flow dampers are installed at the outlet of rail to damp a pulsation of fuel pressure inside the rail or to cut off the fuel supply when the fuel leaks in the downstream of flow damper. The fuel is supplied to the injectors through an orifice of the piston. The pressure pulsation occurring in the rail is damped by a resistive force of the return spring (5) and a passing resistance of the orifice (2), wherein the piston (4) acts as a damper. (Refer to the picture B)
- Also, the leading end of piston (4) closes an fuel supply port to cut off the fuel supply, if the fuel leak occurs in the injection pipe or injectors, and the fuel pressure on the downstream side of flow damper supplied through an orifice (2) + resistive force of return spring (5) do not balance with the fuel pressure applied on the piston (4) surface prior to the orifice (2). (Refer to the picture C)
- The piston (4) will return when the fuel pressure inside the rail less than 1.0 MPa (10.2 kgf/cm^2).



D. Injector (G2 Type)

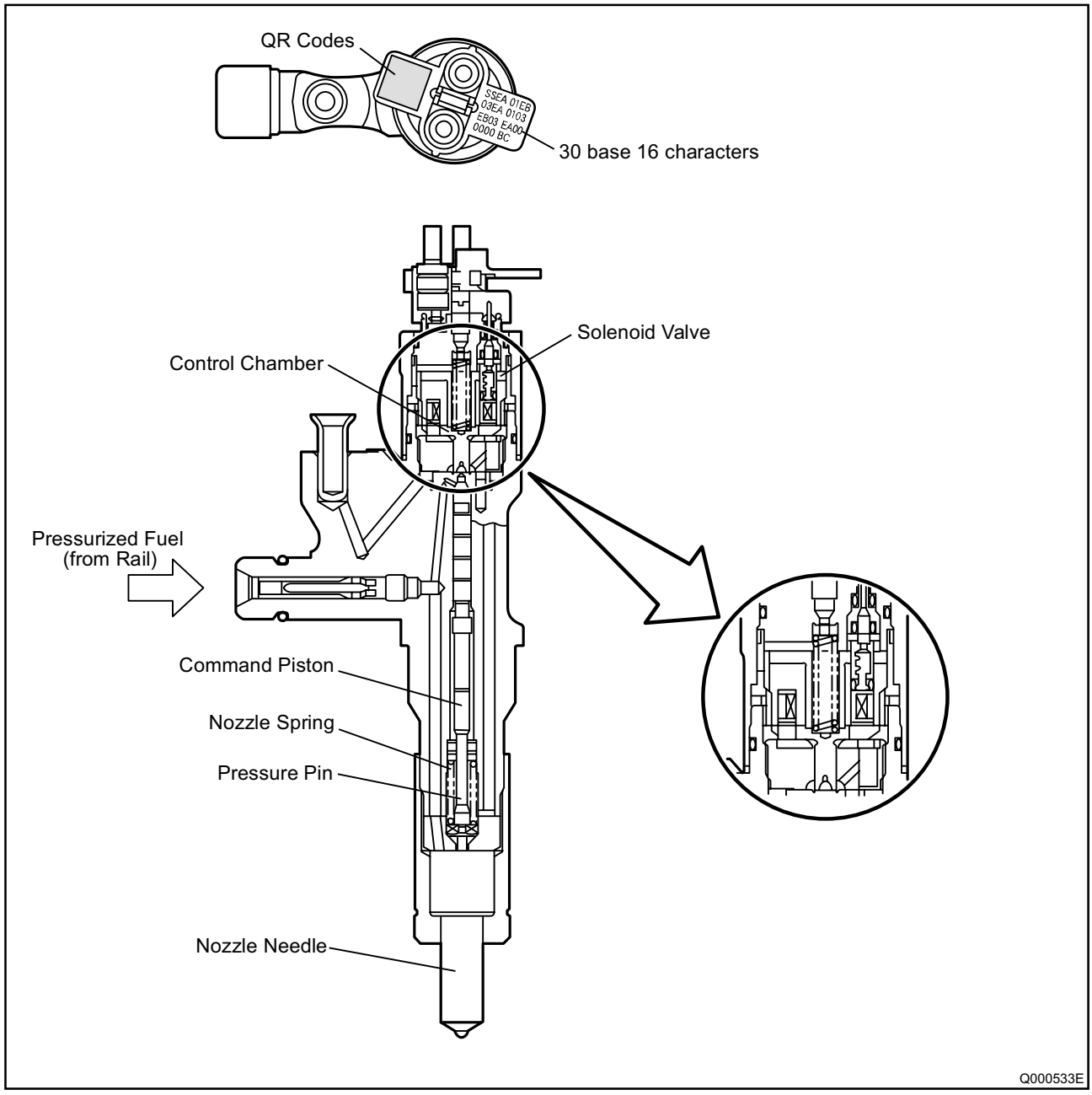
a. Outline

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.

b. Characteristics

- A compact, energy-saving solenoid-control type TWV (Two-Way Valve) injector has been adopted.
- QR codes displaying various injector characteristics and the ID codes showing these in numeric form (30 base 16 characters) are engraved on the injector head. The 4HK1/6HK1 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 ISUZU Diagnostic tool.

c. Construction

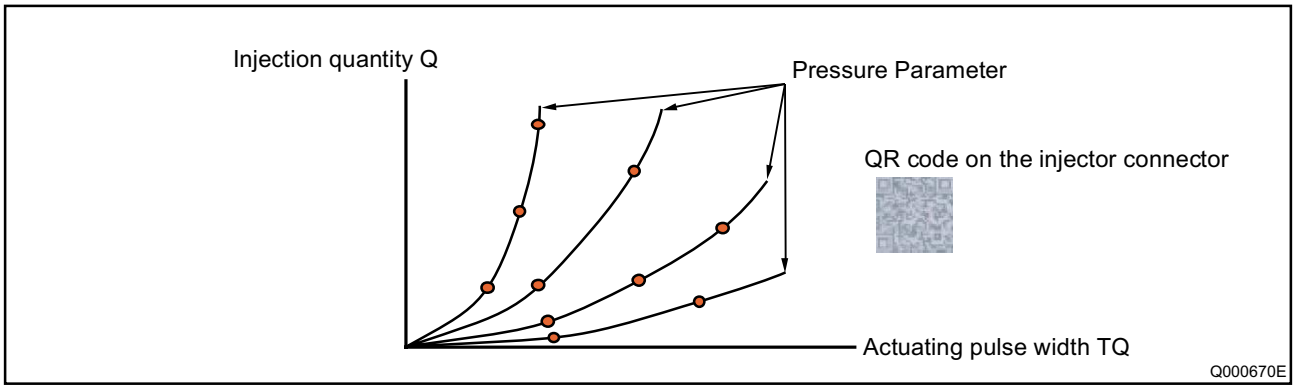


d. QR Codes

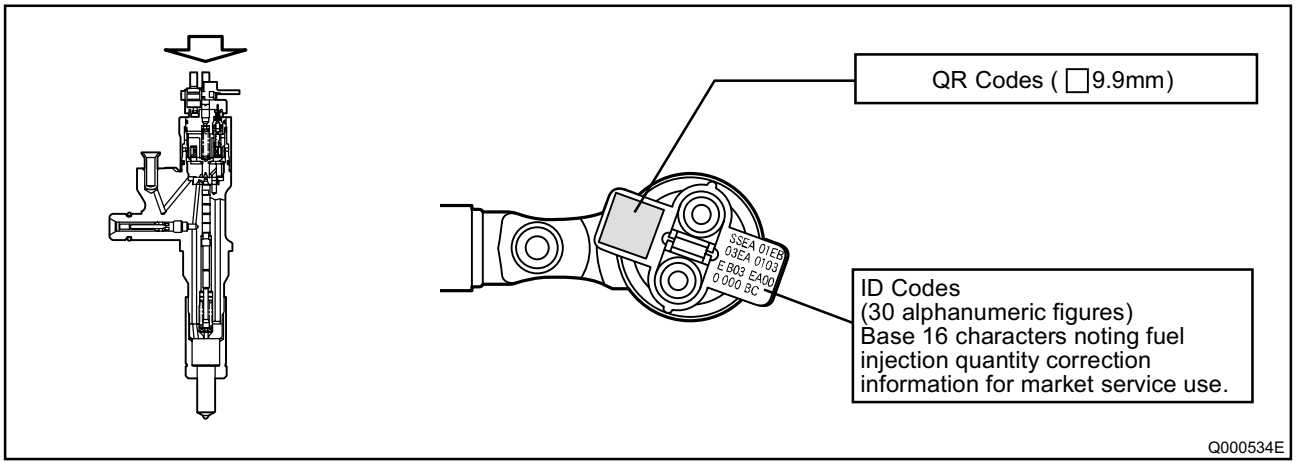
- In order to minimize performance tolerance of injectors at replacing them, QR*1 (Quick Response) codes have been adopted to enhance correction precision.
- Using QR codes has resulted in a substantial increase in the number of fuel injection quantity correction points, and thus the injection quantity 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.

< NOTE >

- QR code correction points



- Location of QR codes

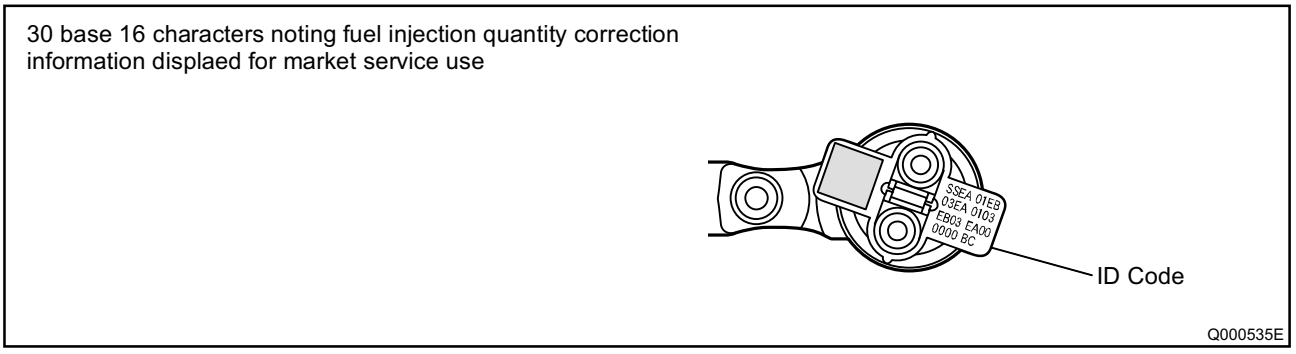


e. Repair Procedure Changes

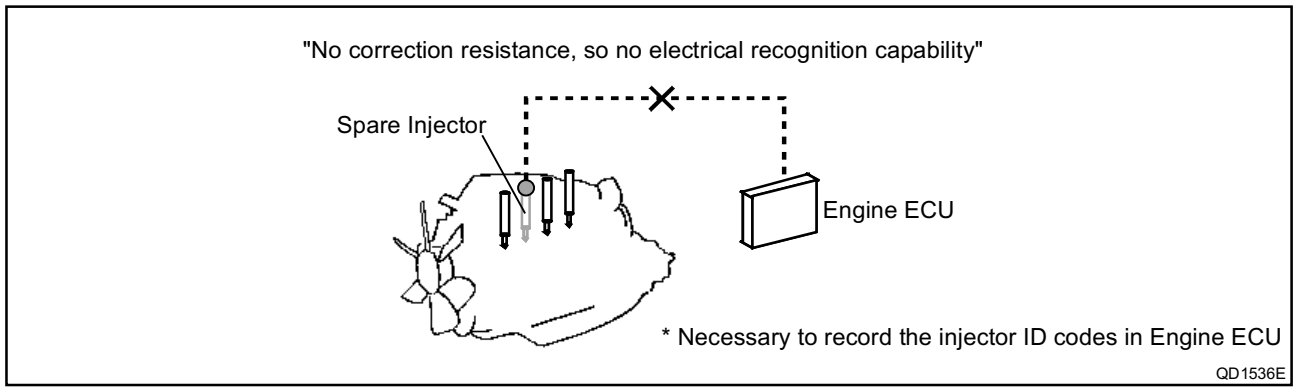
- Differences in comparison with the conventional method of replacing injectors assembly are as shown below.

< NOTE >

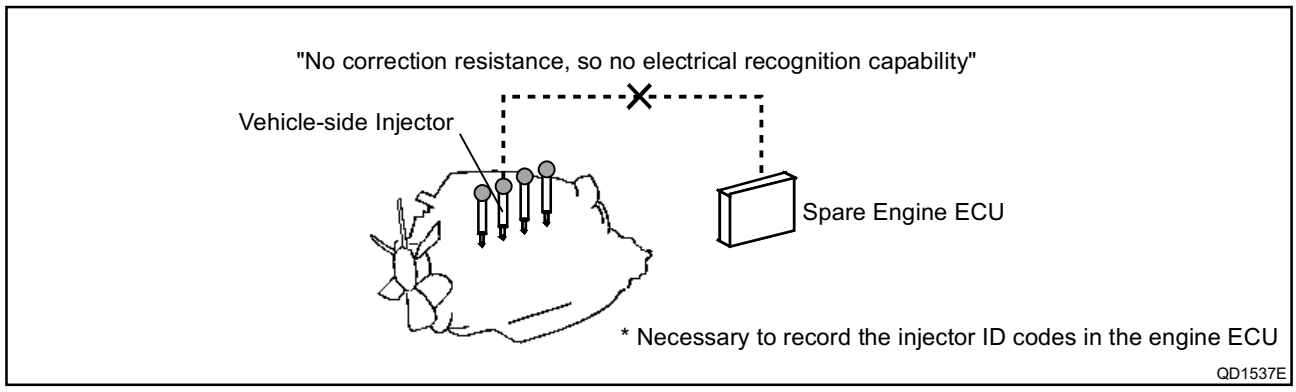
- When replacing injectors with QR codes, or the engine ECU, it is necessary to record the ID codes (QR codes) in the ECU. (If the ID codes of the installed injector are not registered correctly, engine failure such as rough idling and noise will result.)
- New (Injector with QR Codes)



• Replacing the Injector



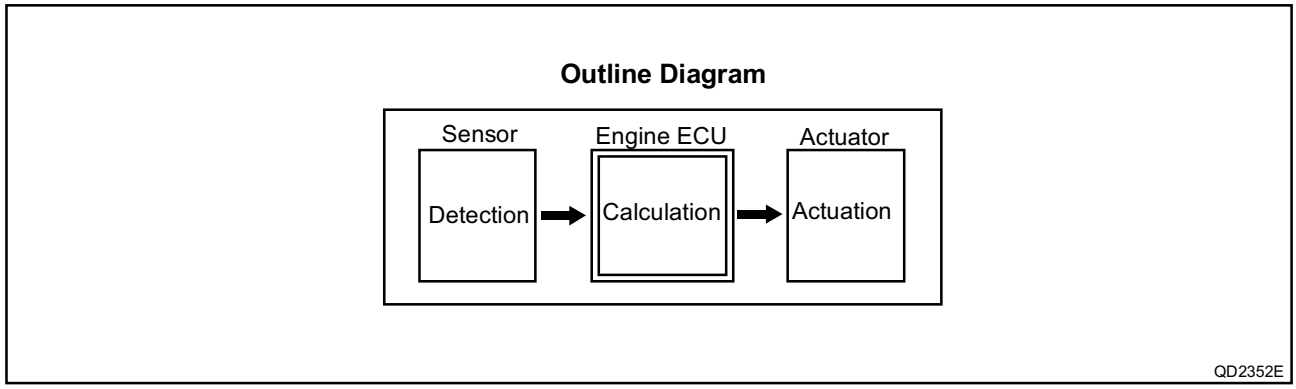
• Replacing the Engine ECU



E. Engine ECU (Electronic Control Unit)

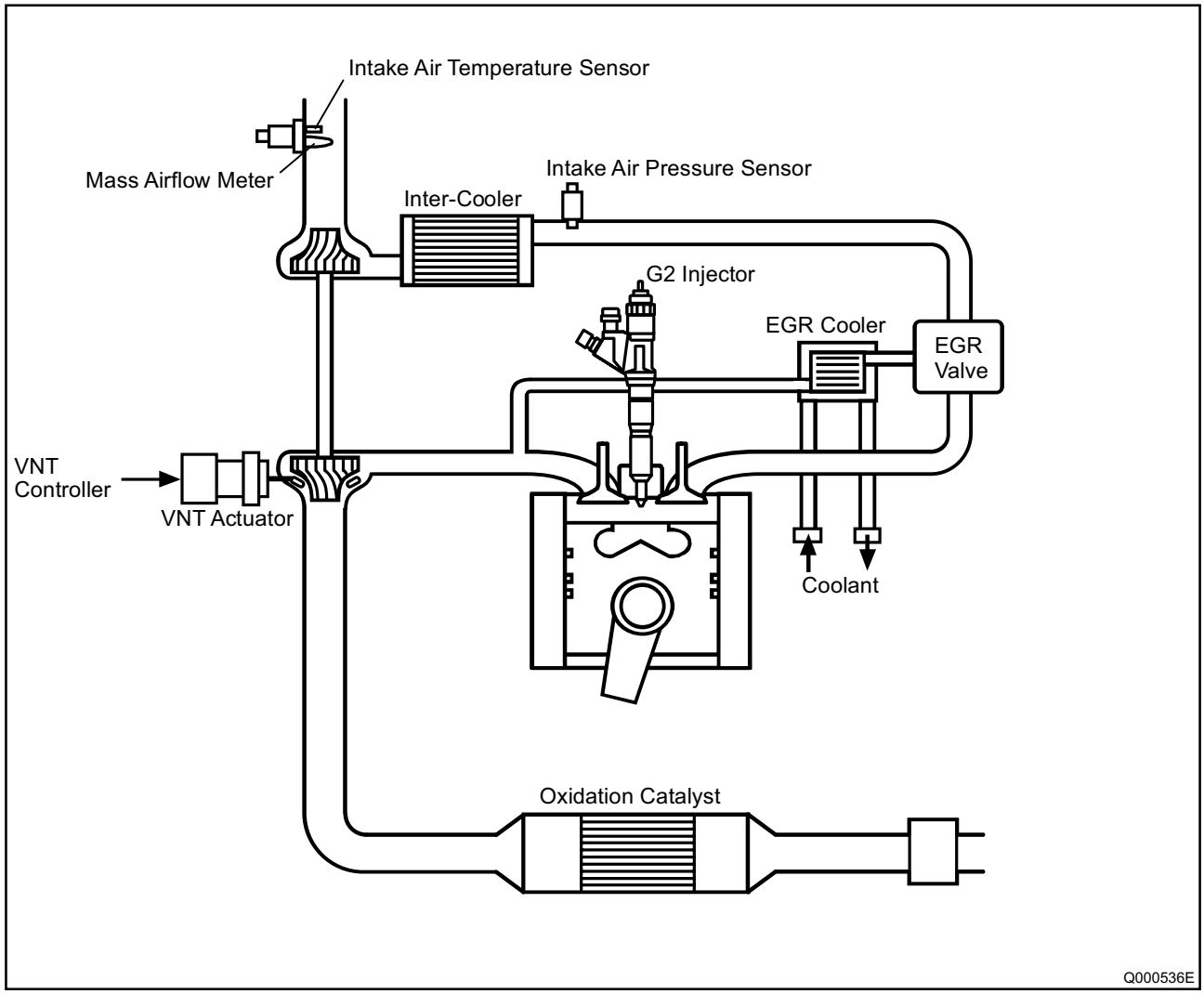
a. Outline

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



3-2. Description of Control System Components

A. Engine Control System Diagram



a. Fuel Temperature Sensor (THL)

- 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.