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

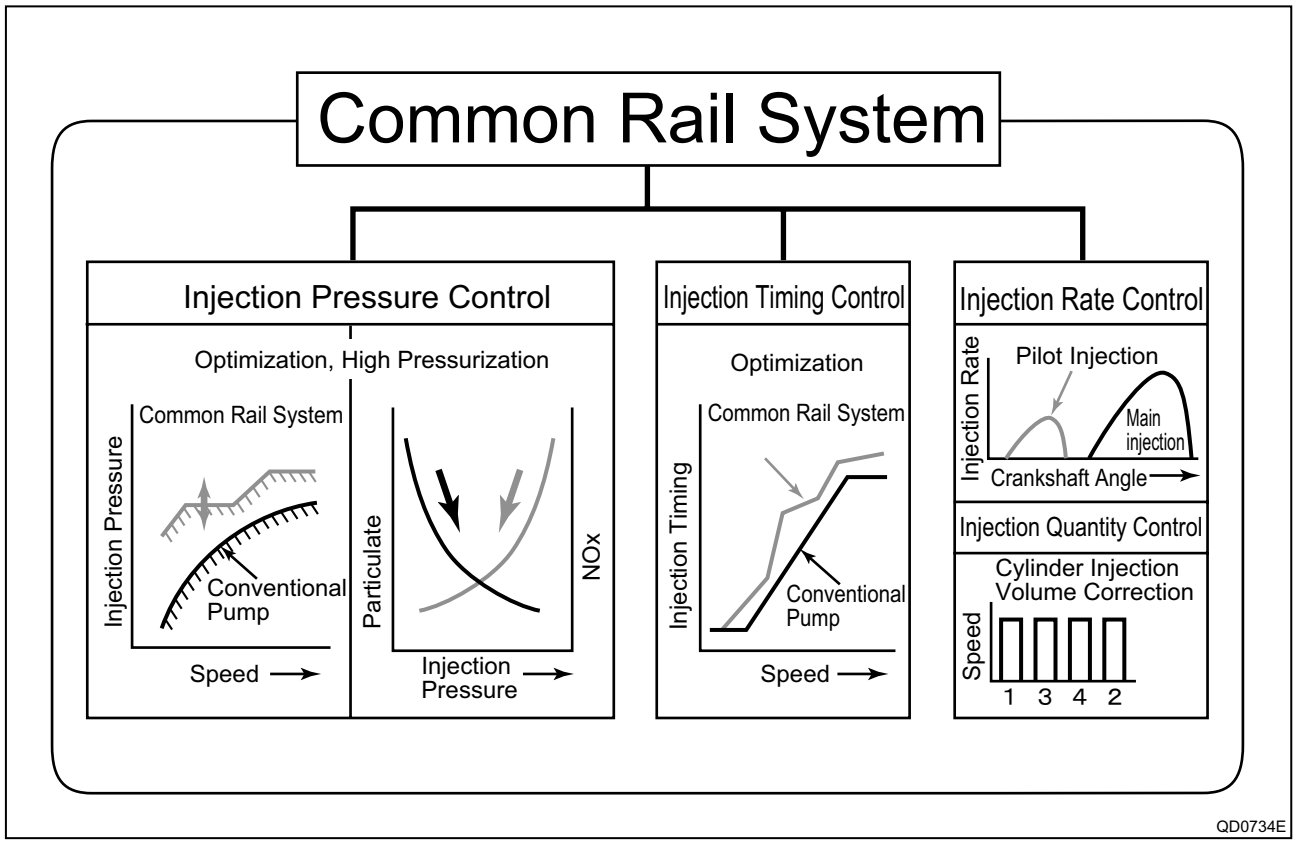
- Enables high-pressure injection even at low engine speeds.
- Optimizes control to minimize particulate matter and NOx emissions.

b. Injection Timing Control

Enables finely tuned optimized control in accordance with driving conditions.

c. Injection Rate Control

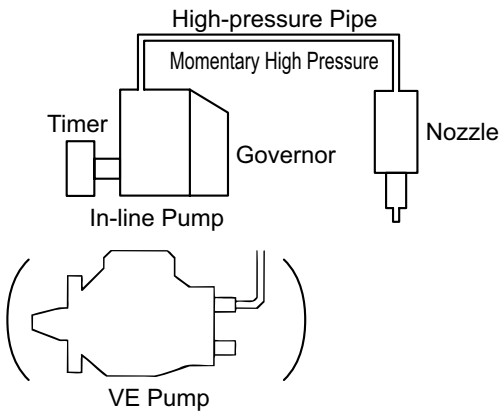
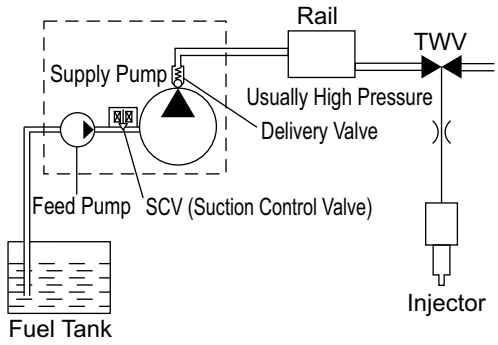
Pilot injection control sprays a small amount of fuel before the main injection.



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

	In-line, VE Pump	Common Rail System
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

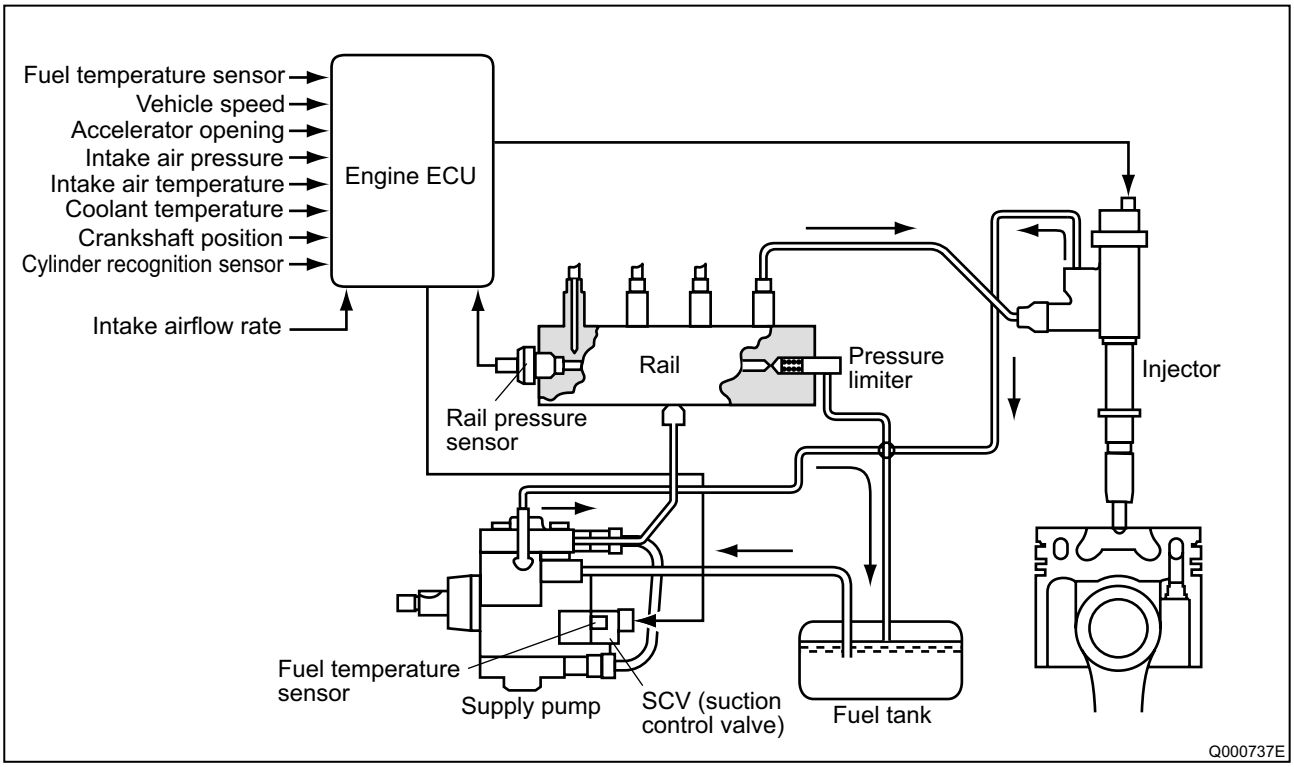
*1 TWV: Two Way Valve *2 SCV: Suction Control Valve QD2341E

2-2. Outline of System

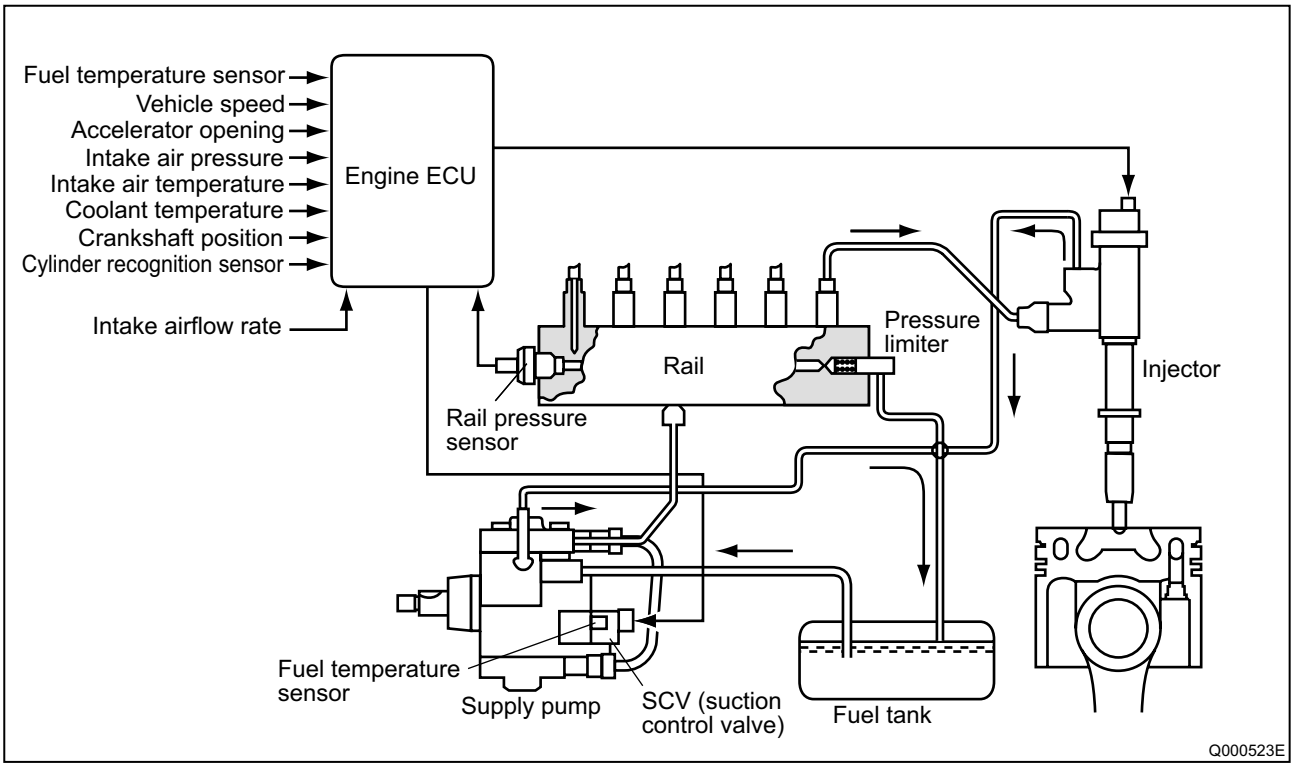
A. Composition

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

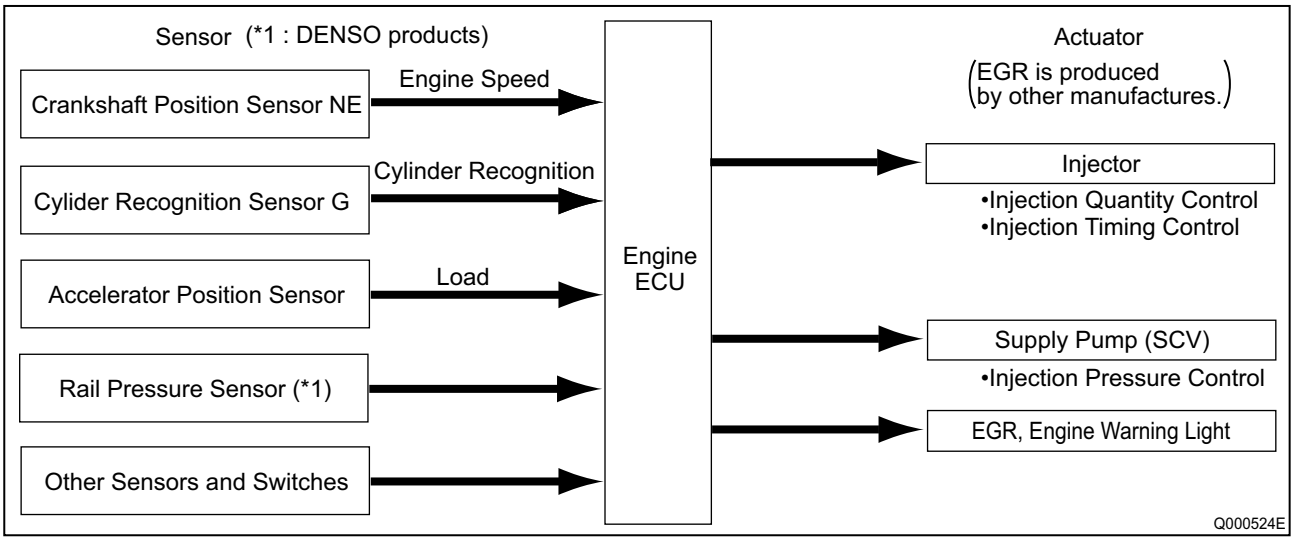
Detect the engine and driving conditions, and convert them into electrical signals.

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

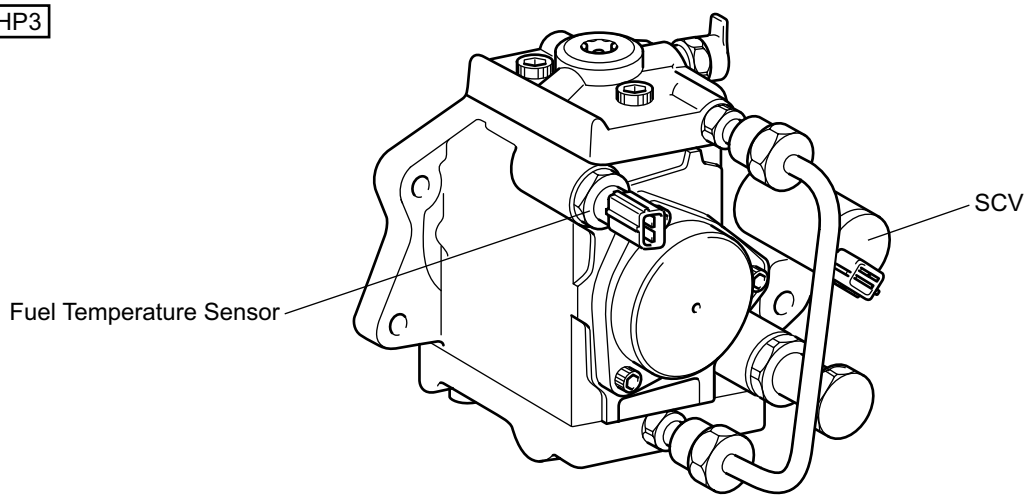
3-1. Description of Main Components

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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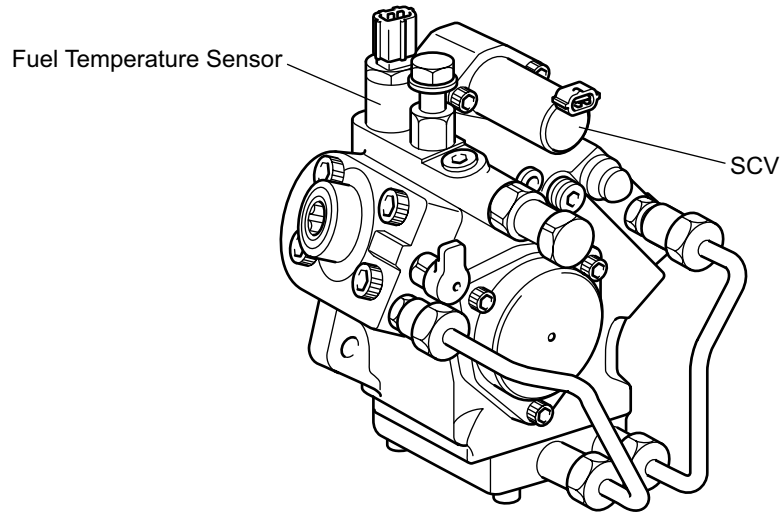
HP4



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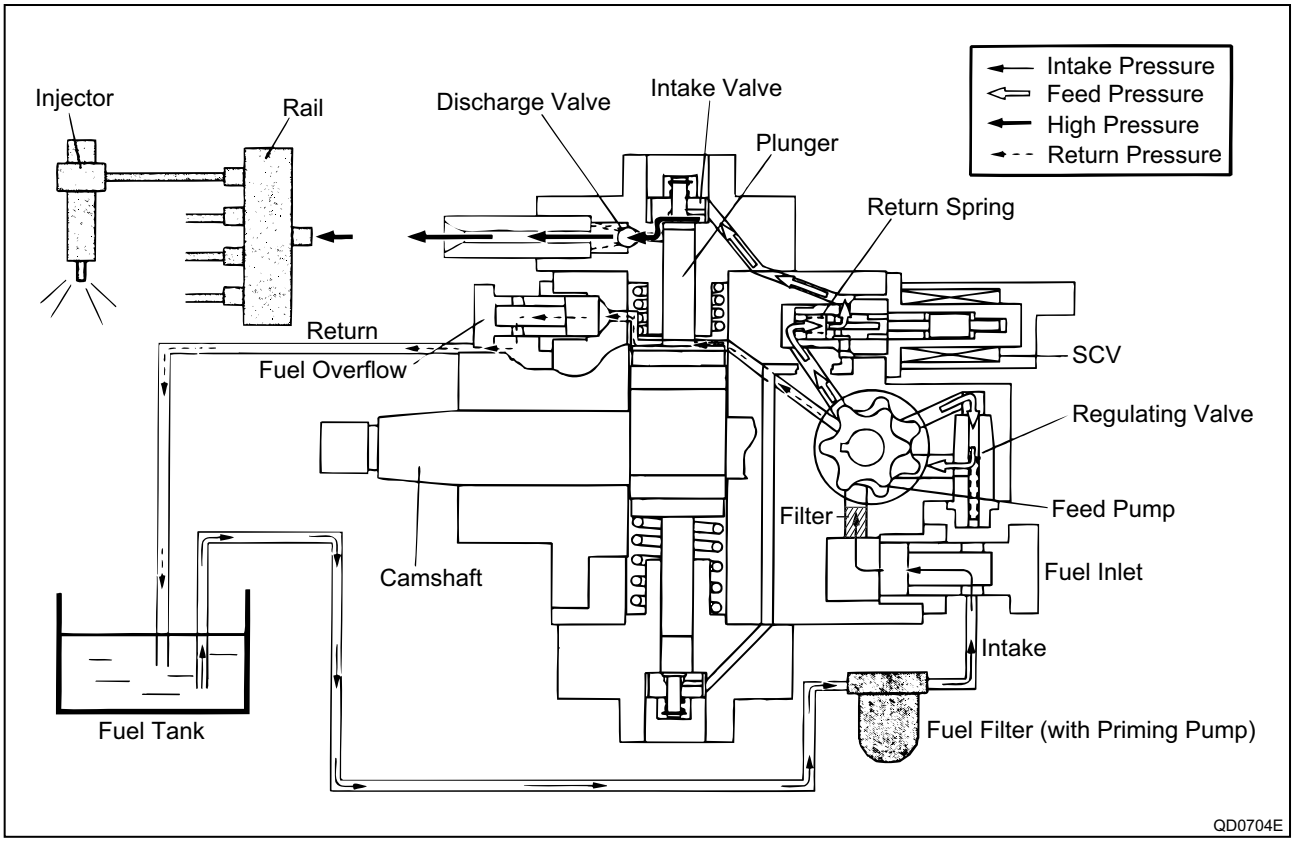
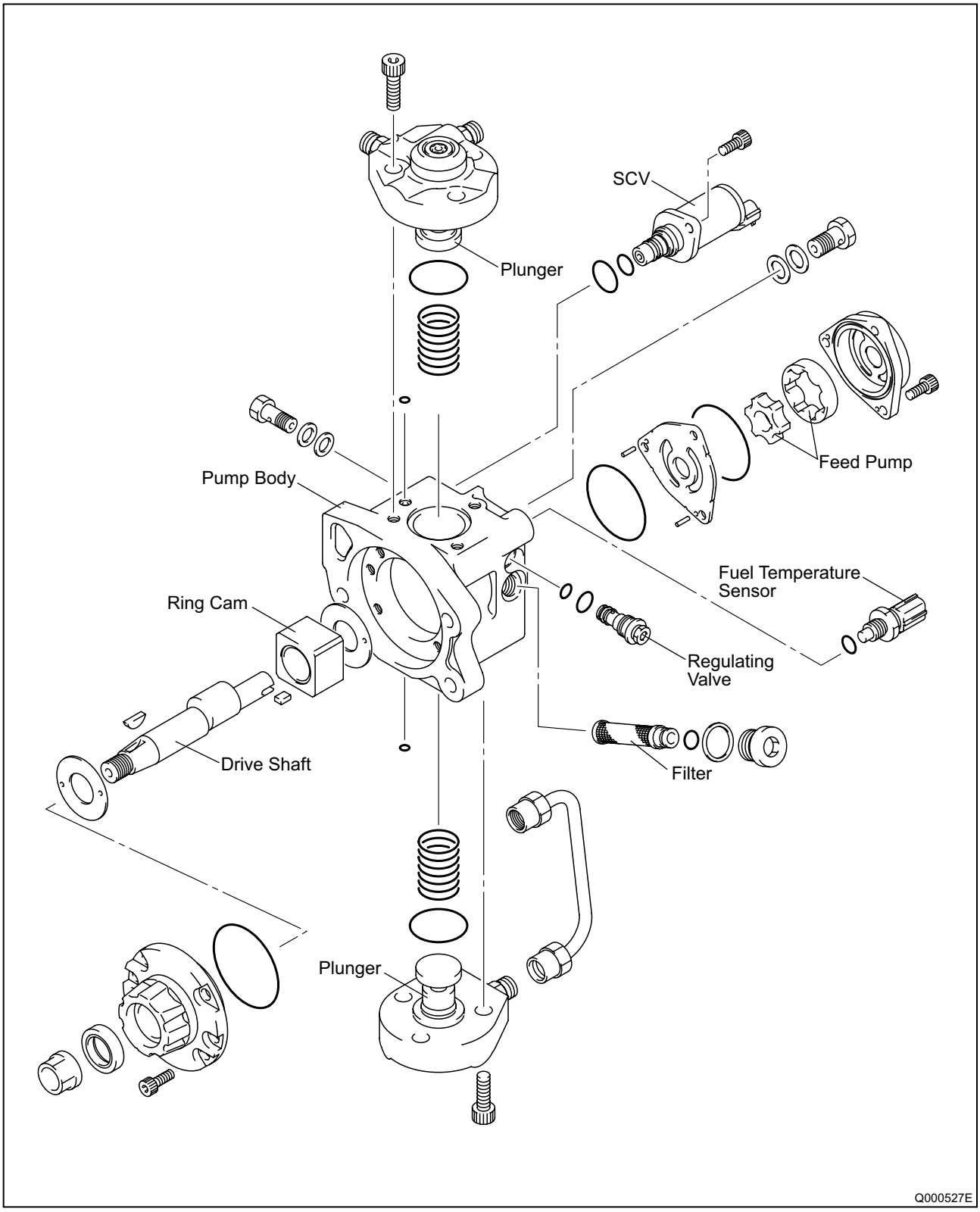
- The two plungers for HP3 or the three plungers for HP4 are positioned vertically on the outer ring cam for compactness.
- The engine drives the supply pump at a ratio of 1:1. The supply pump has a built-in feed pump (trochoid type), and draws the fuel from the fuel tank, sending it to the plunger chamber.

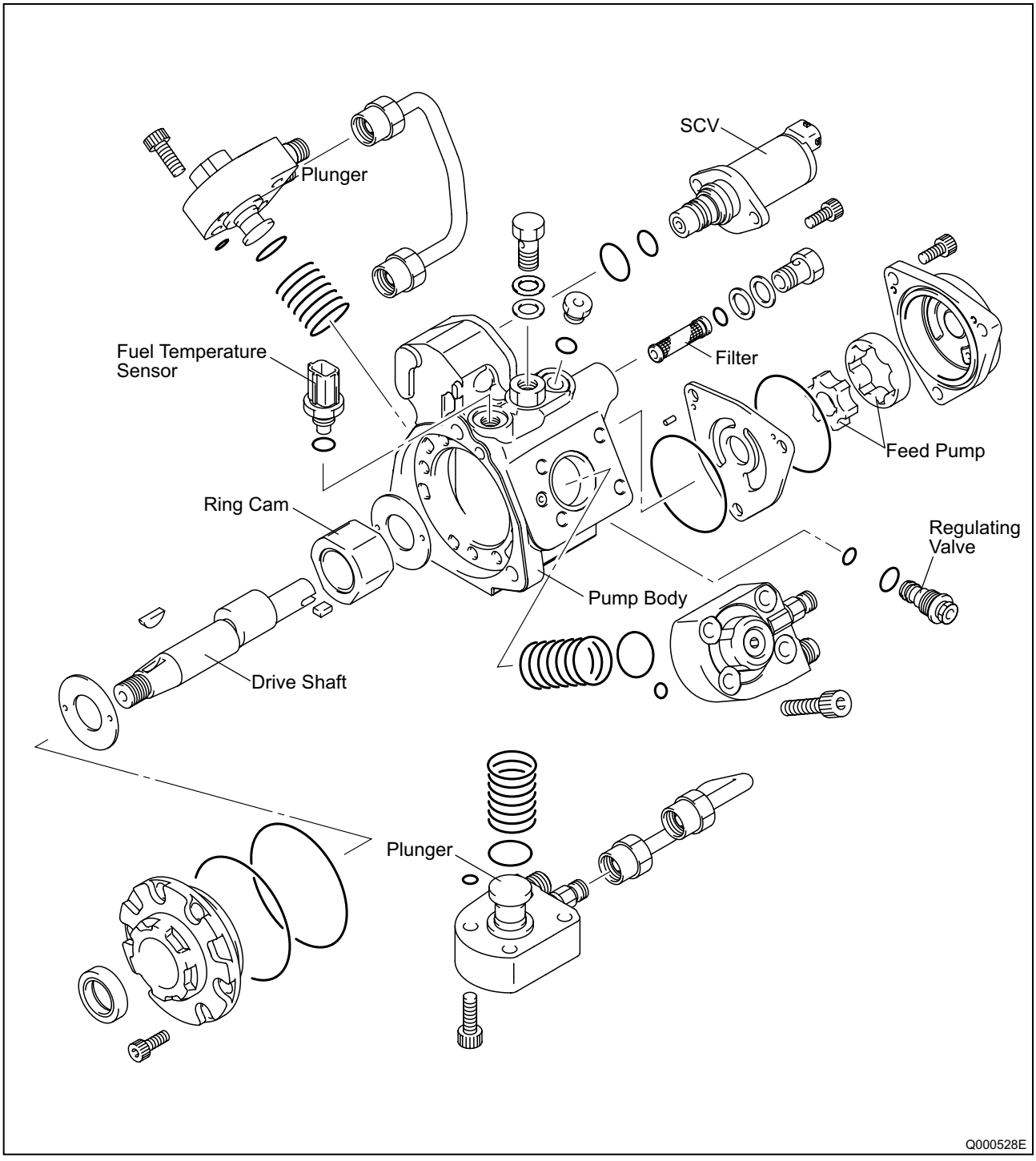
- The internal camshaft drives the two plungers, and they pressurize the fuel sent to the plunger chamber and send it to the rail. The quantity of fuel supplied to the rail is controlled by the SCV, using signals from the engine ECU. The SCV is a normally opened type (the intake valve opens during de-energization).



• Development: HP3

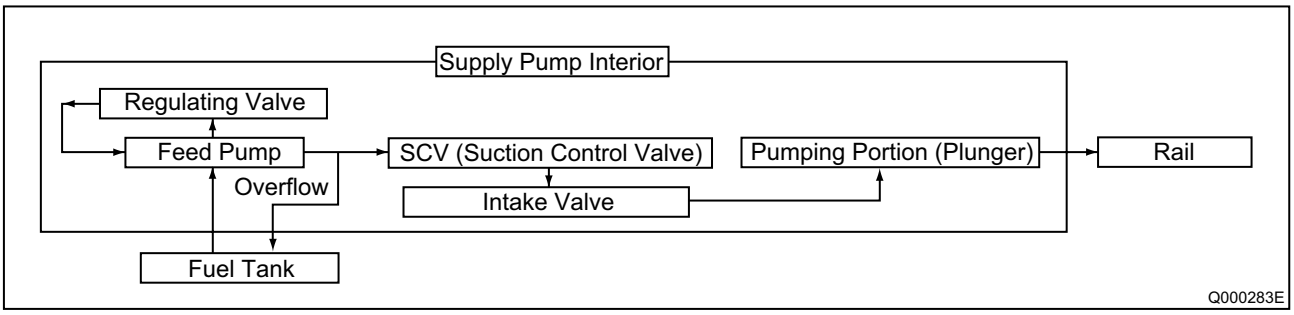


• Development: HP4



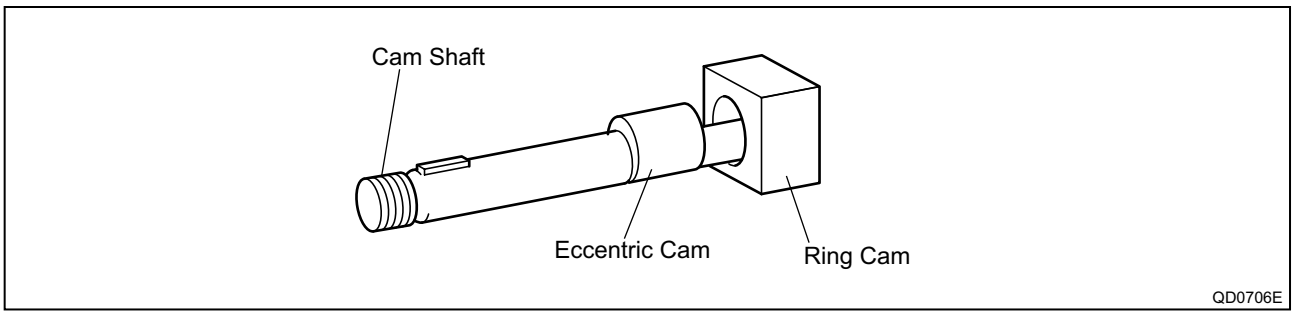
b. Supply Pump Internal Fuel Flow

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.

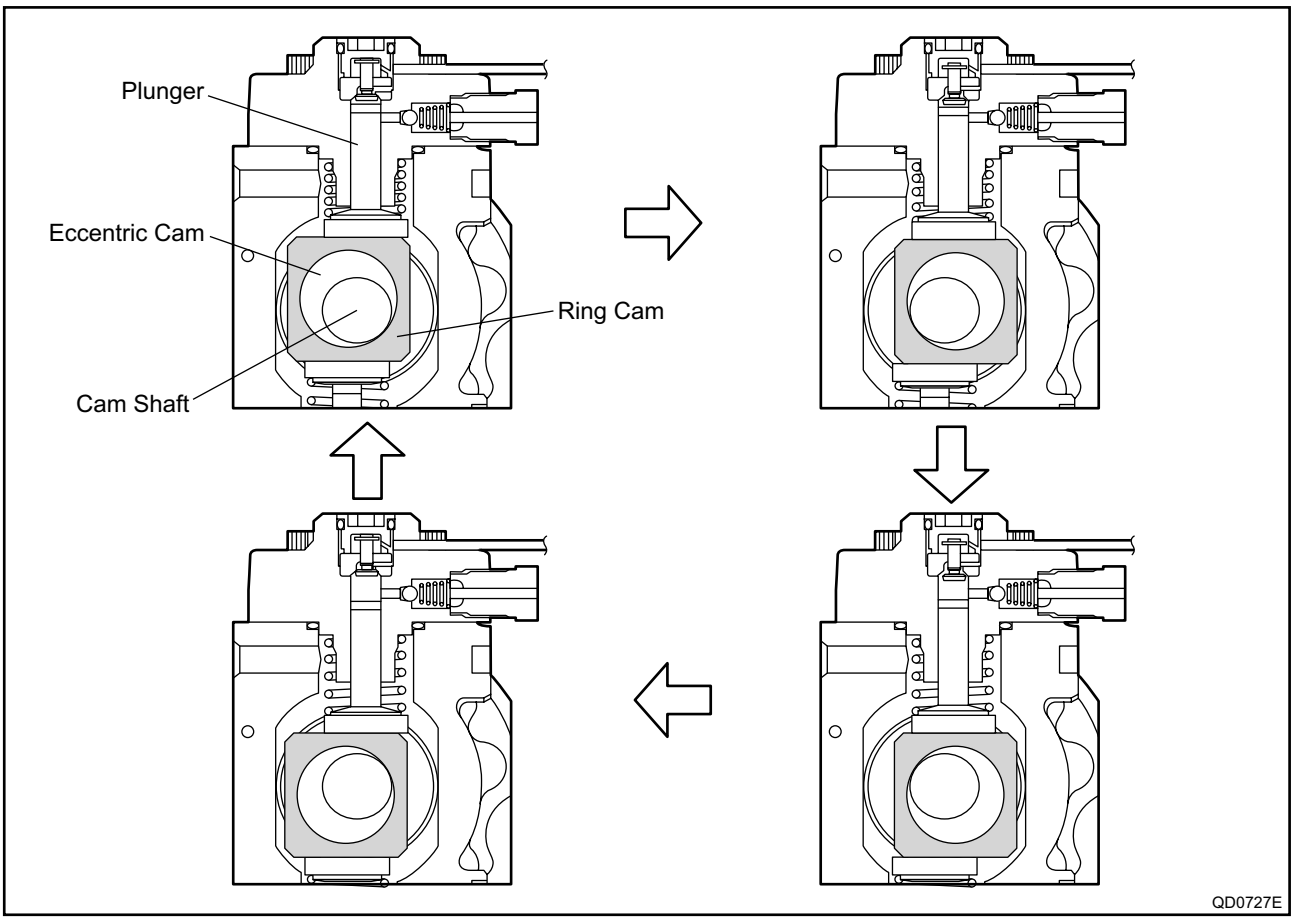


c. Construction of Supply Pump (in case of HP3 pump)

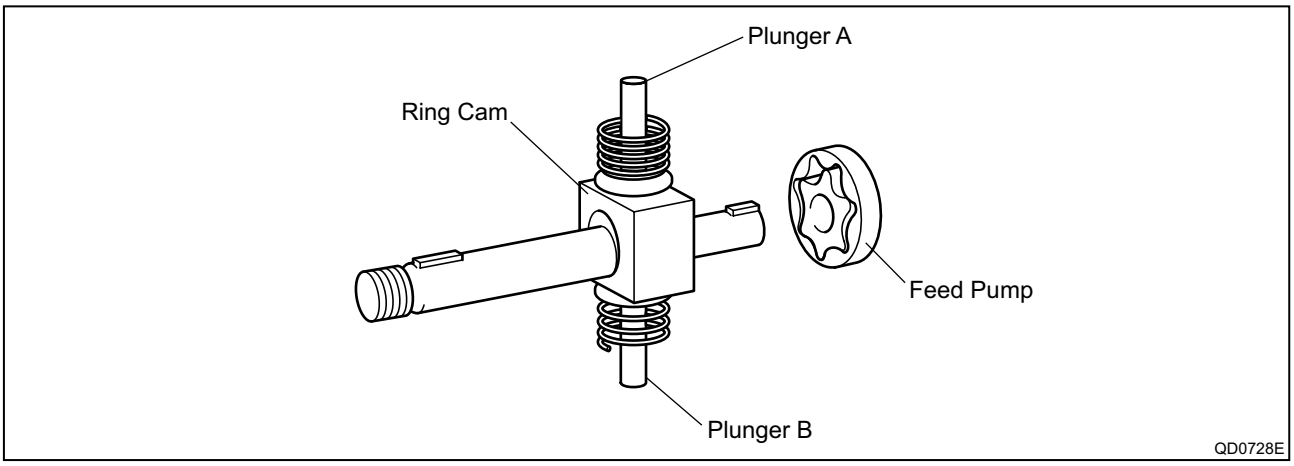
- The eccentric cam is attached to the cam shaft. The eccentric cam is connected to the ring cam.



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

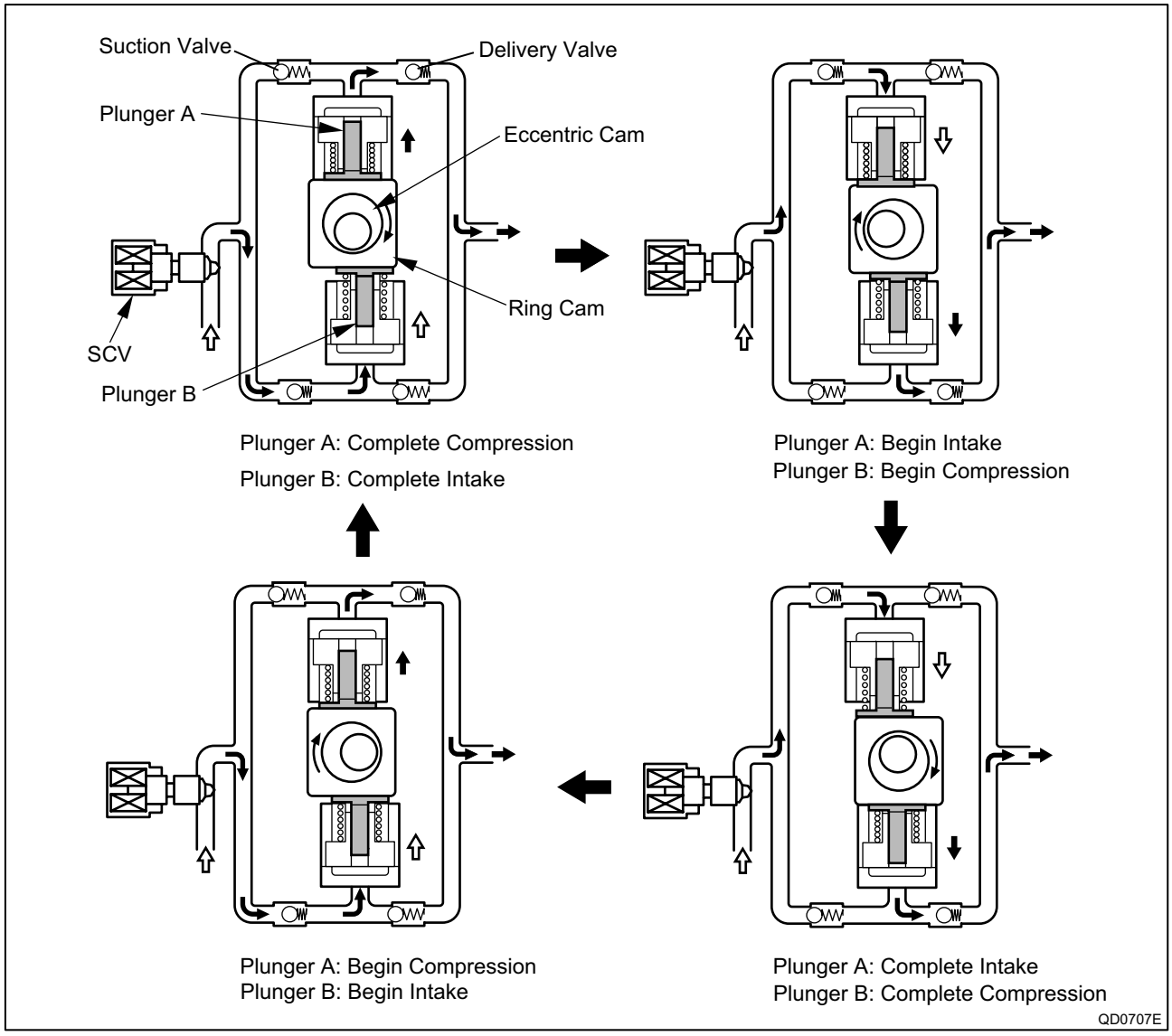


• The plunger and the suction valve are attached to the ring cam. The feed pump is connected to the rear of the cam shaft.



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.



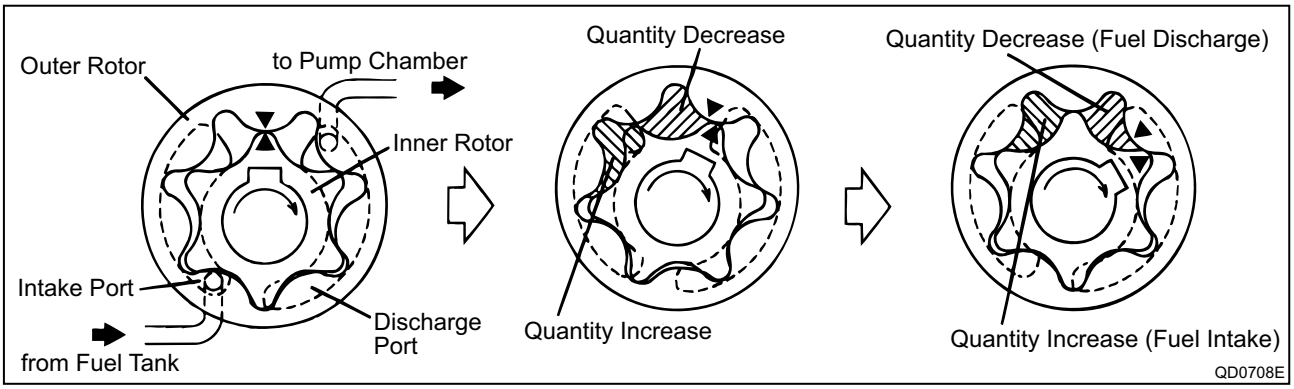
< NOTE >

- There are 3 plungers for the HP4.

B. Description of Supply Pump Components

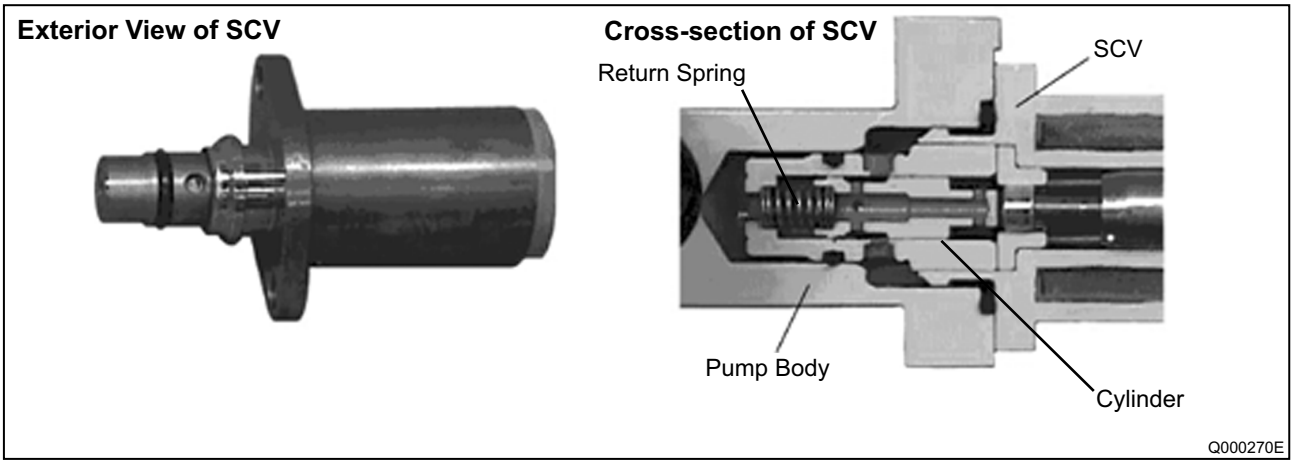
a. Feed Pump

- 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.



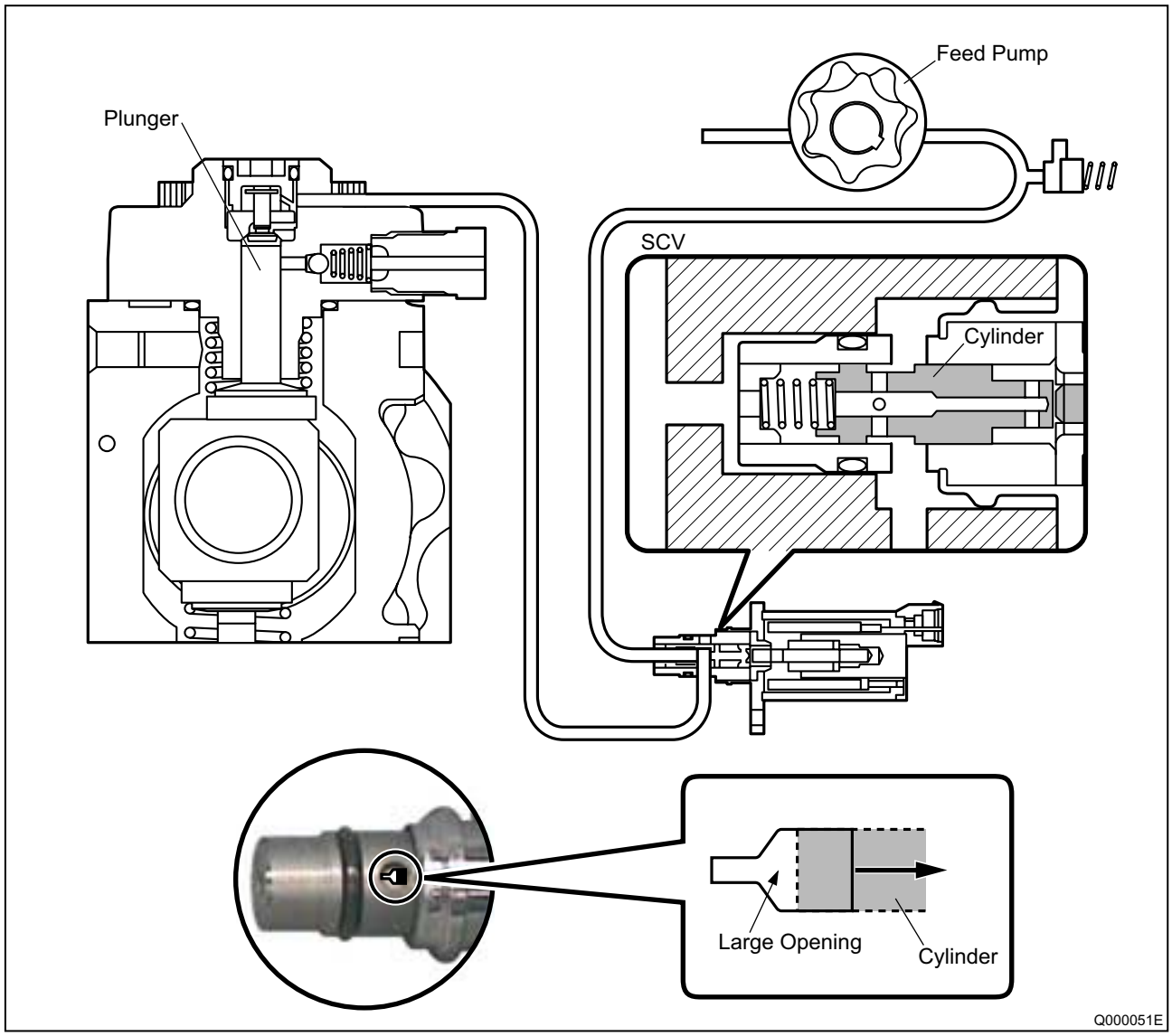
b. SCV: Suction Control Valve (Normally open type)

- 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.



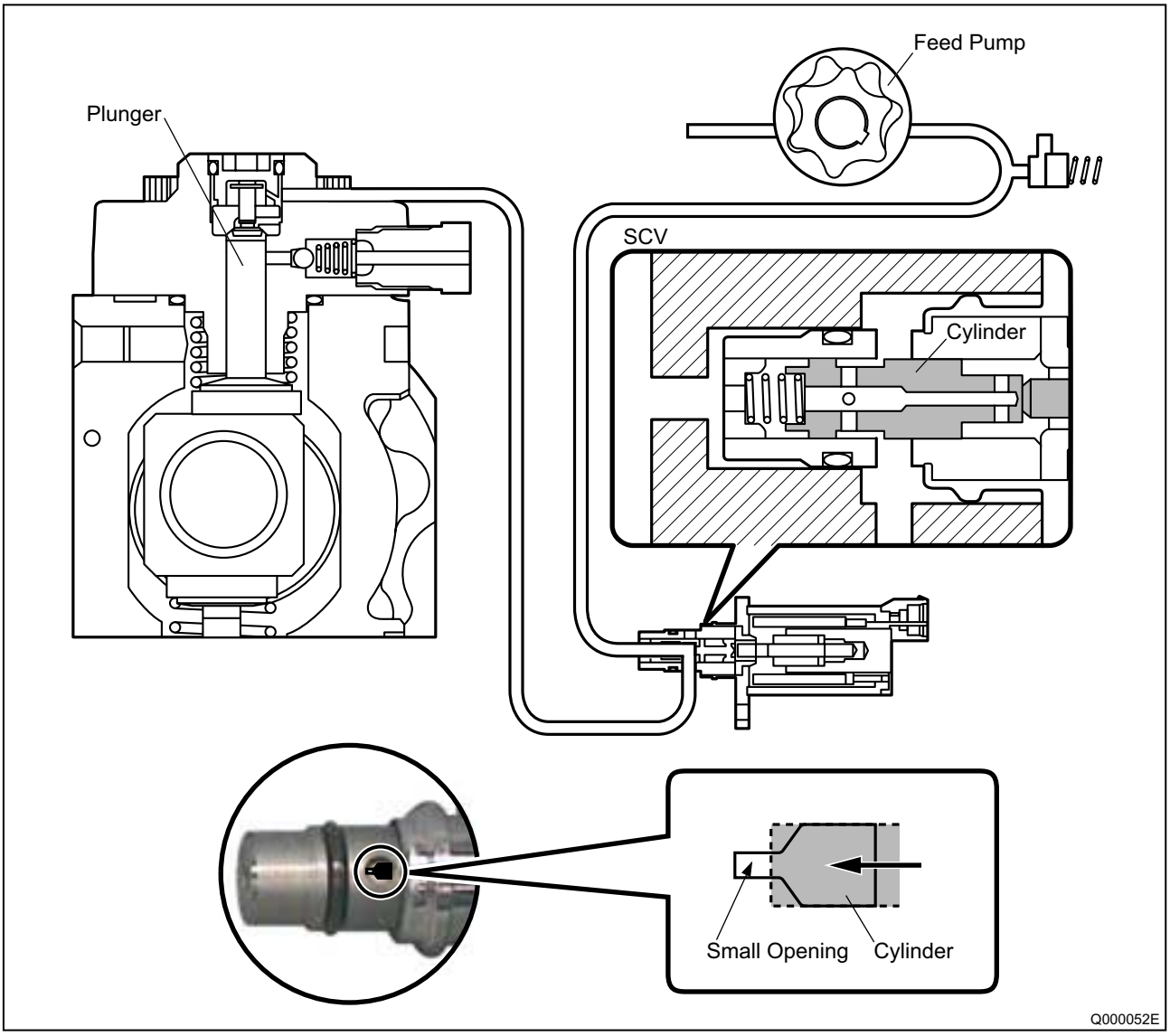
(1) In case of short time ON duty

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

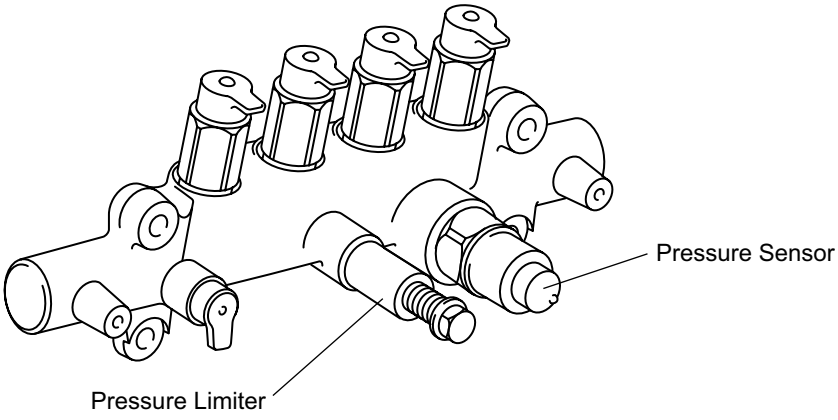


C. Rail

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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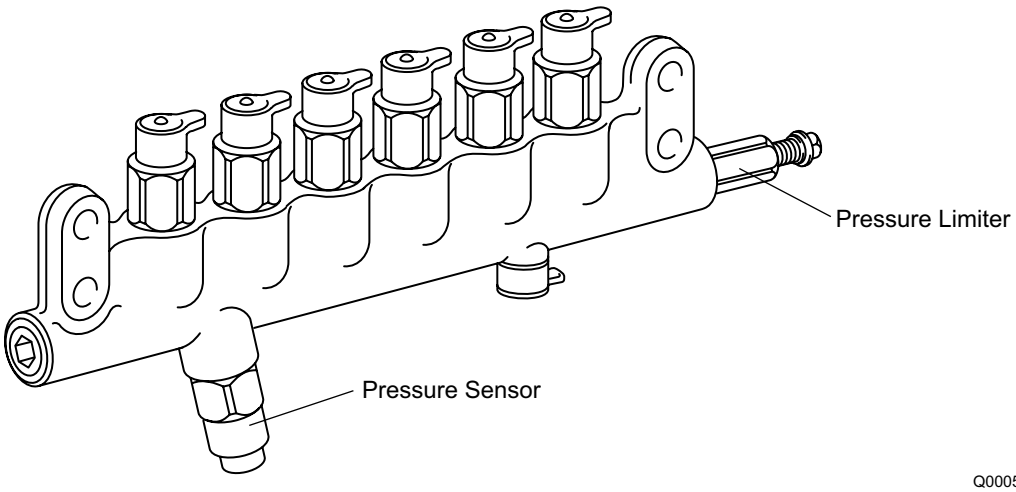
For 6HK1



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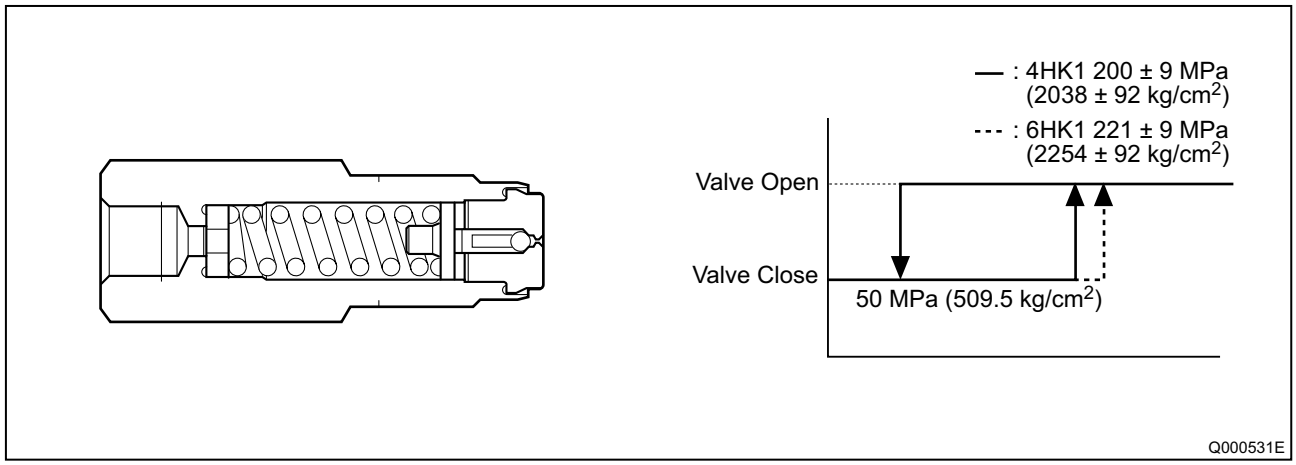
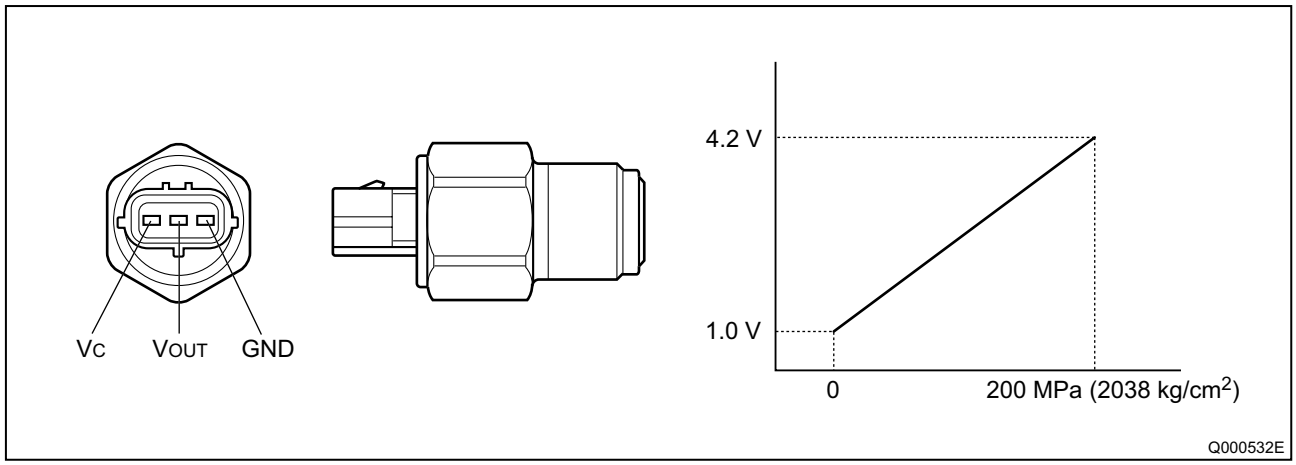
b. Pressure Limiter

- 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.

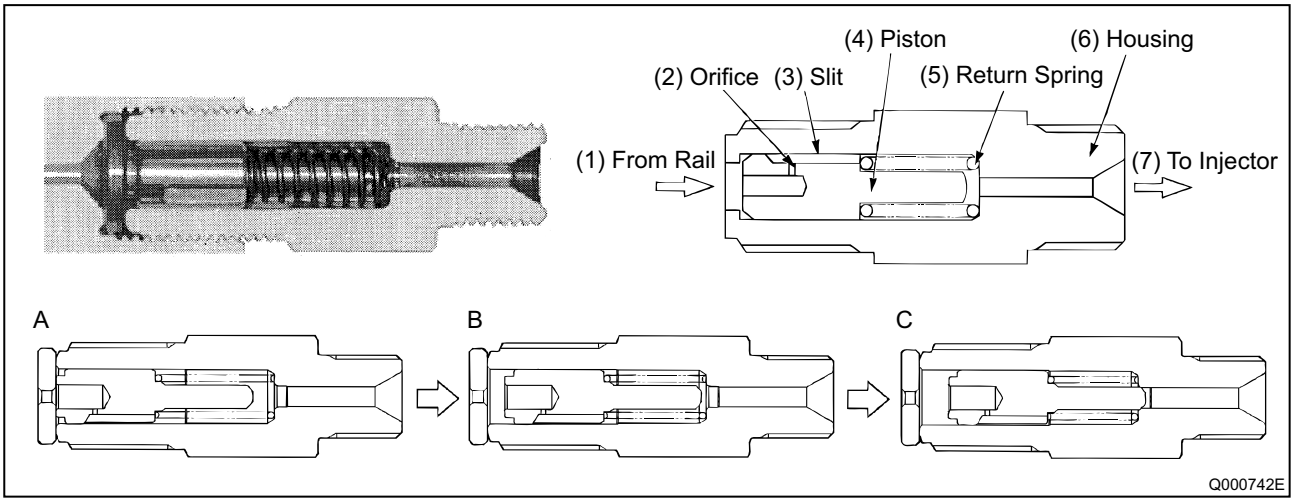


< NOTE >

- 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)

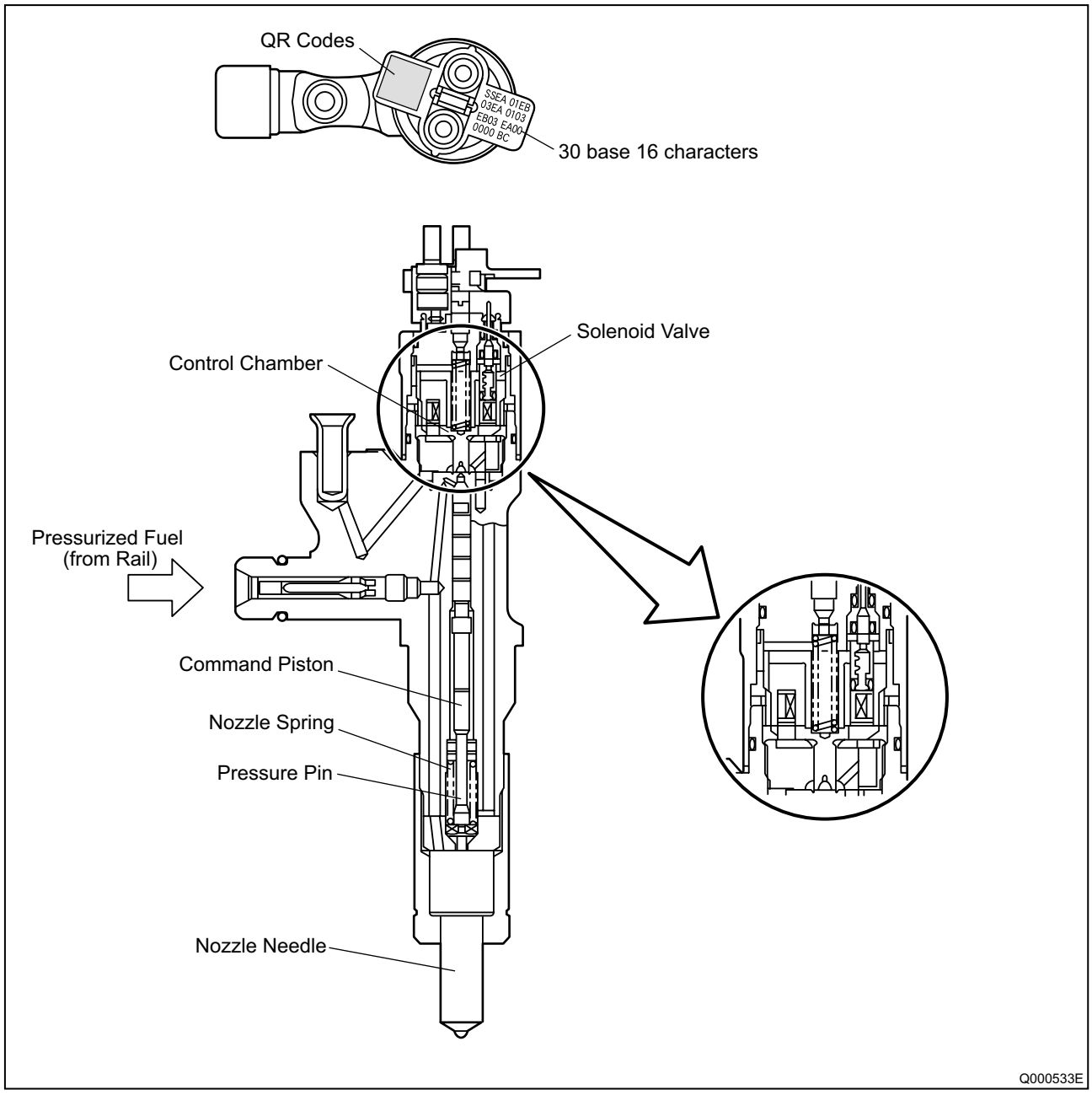
a. Outline

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

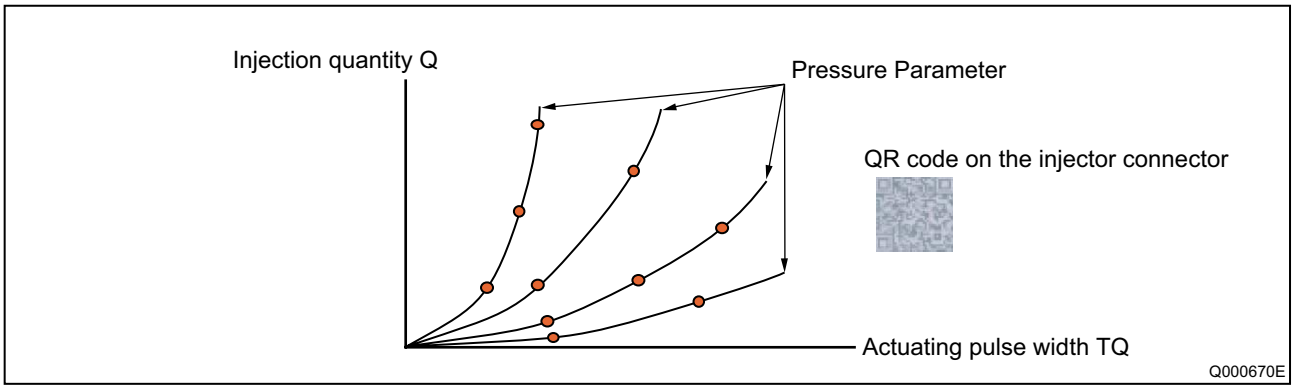


d. QR Codes

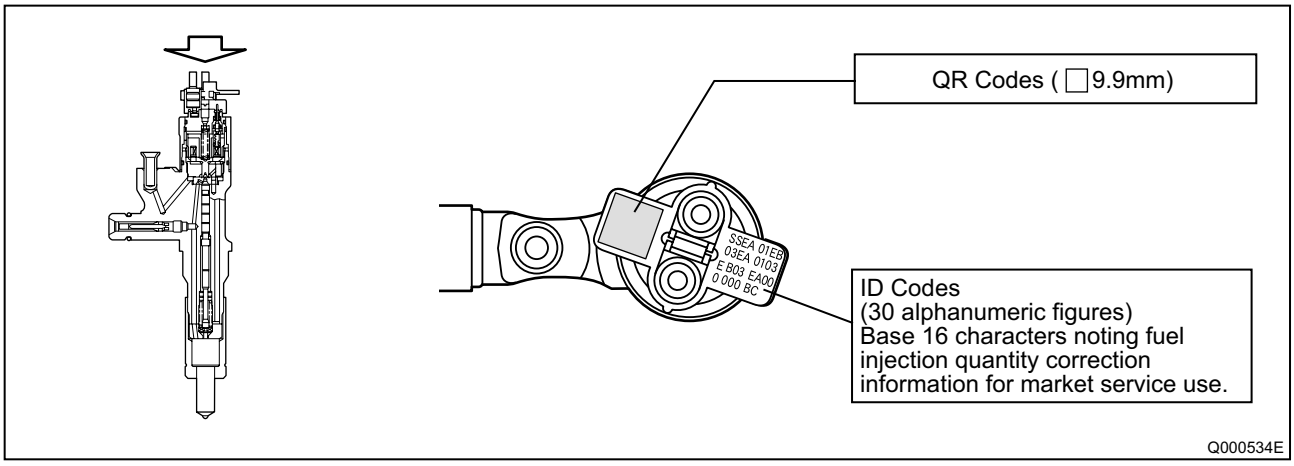
- In order to minimize performance tolerance of injectors at replacing them, QR*1 (Quick Response) codes have been adopted to enhance correction precision.
- Using QR codes has resulted in a substantial increase in the number of fuel injection quantity correction points, and thus the injection quantity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

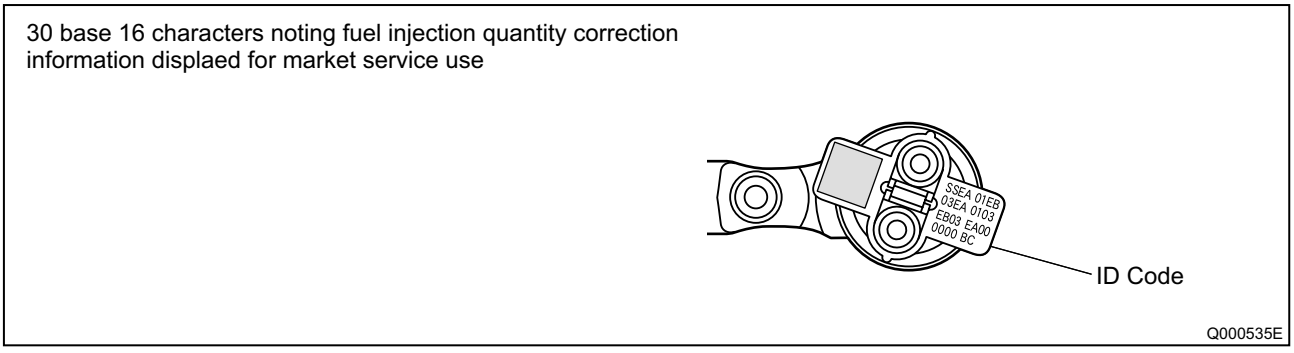


e. Repair Procedure Changes

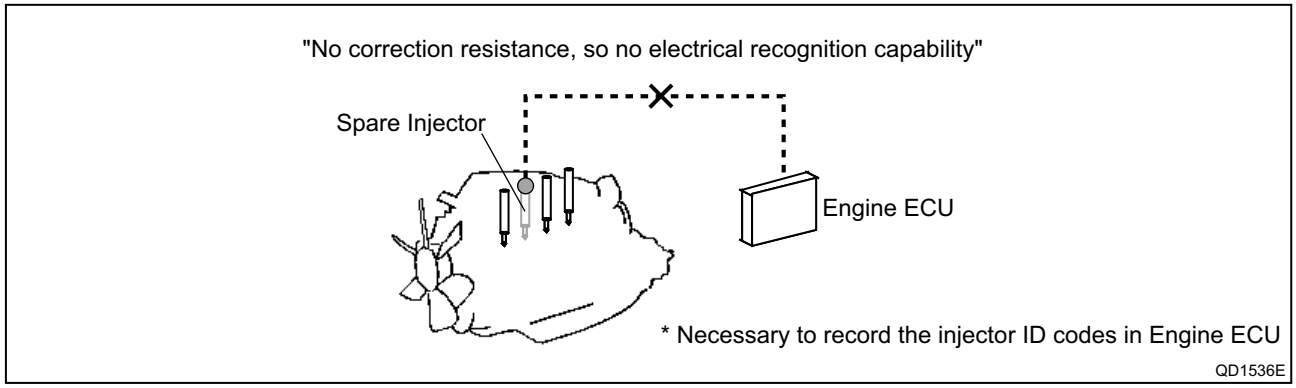
- Differences in comparison with the conventional method of replacing injectors assembly are as shown below.

< NOTE >

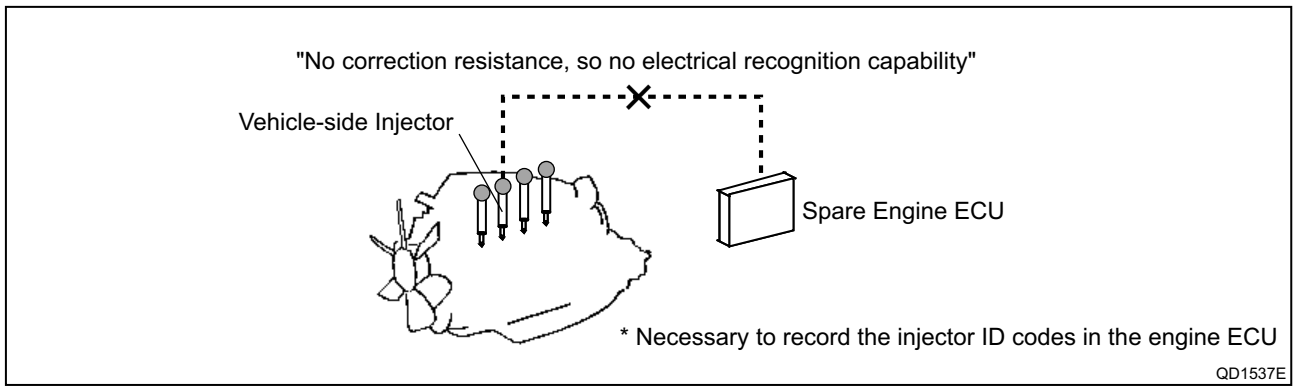
- When replacing injectors with QR codes, or the engine ECU, it is necessary to record the ID codes (QR codes) in the ECU. (If the ID codes of the installed injector are not registered correctly, engine failure such as rough idling and noise will result.)
- New (Injector with QR Codes)



• Replacing the Injector



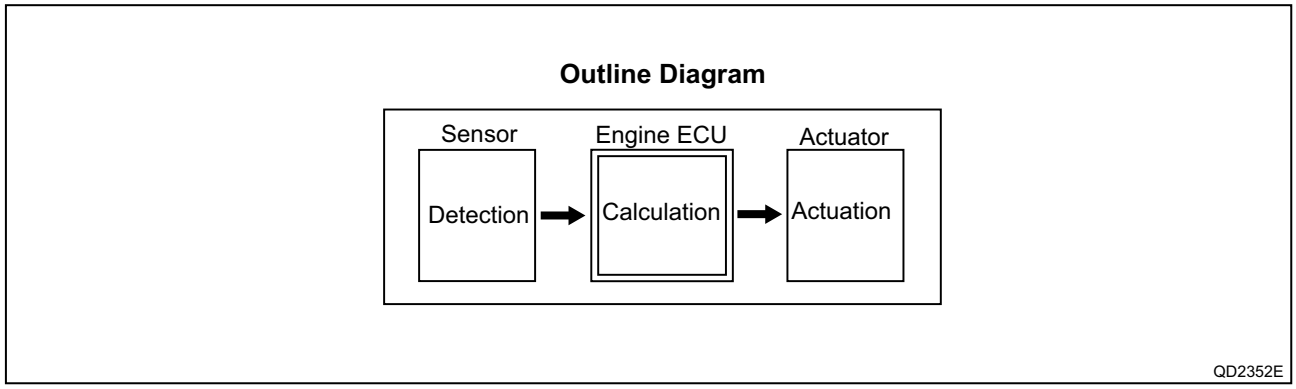
• Replacing the Engine ECU



E. Engine ECU (Electronic Control Unit)

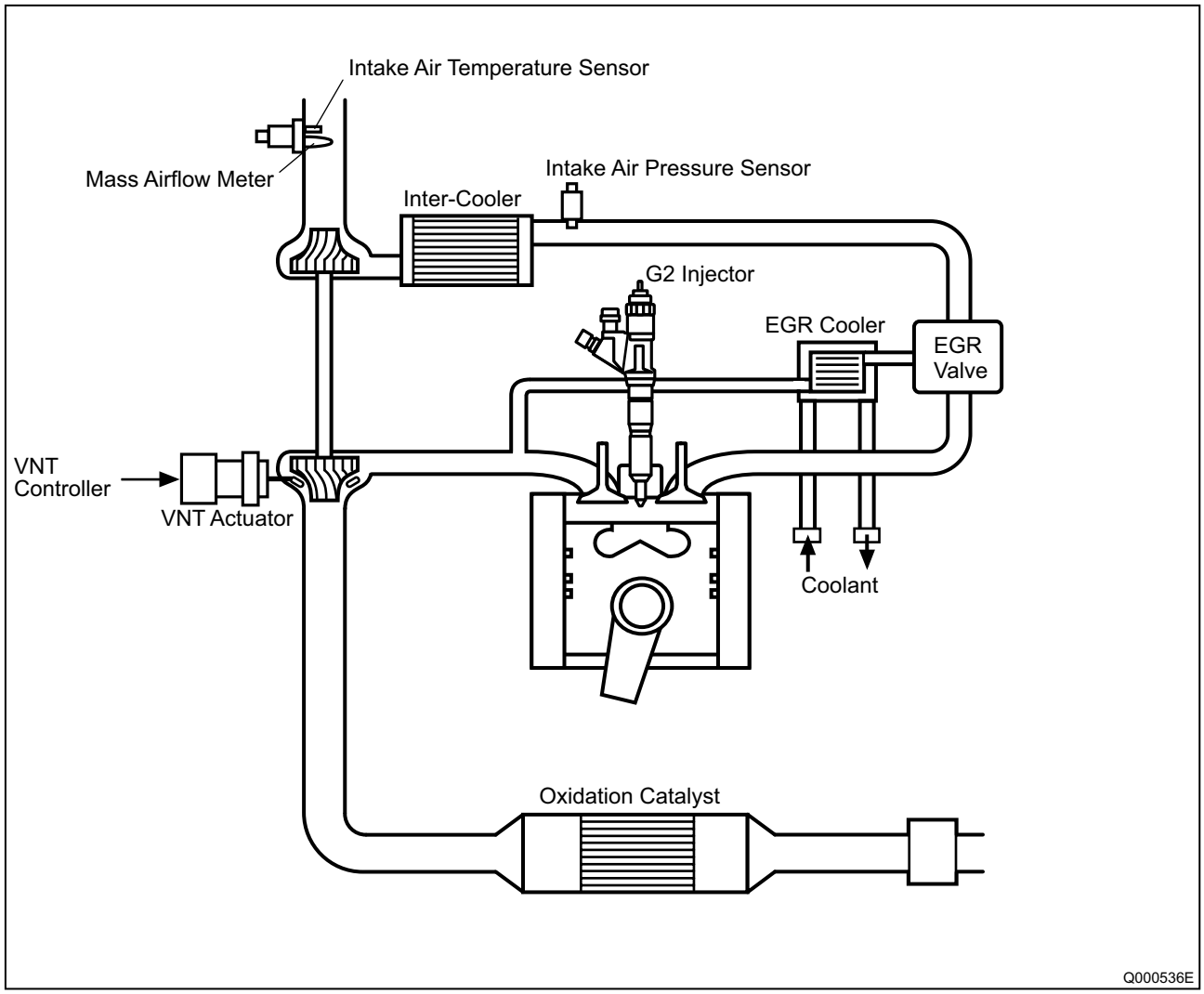
a. Outline

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



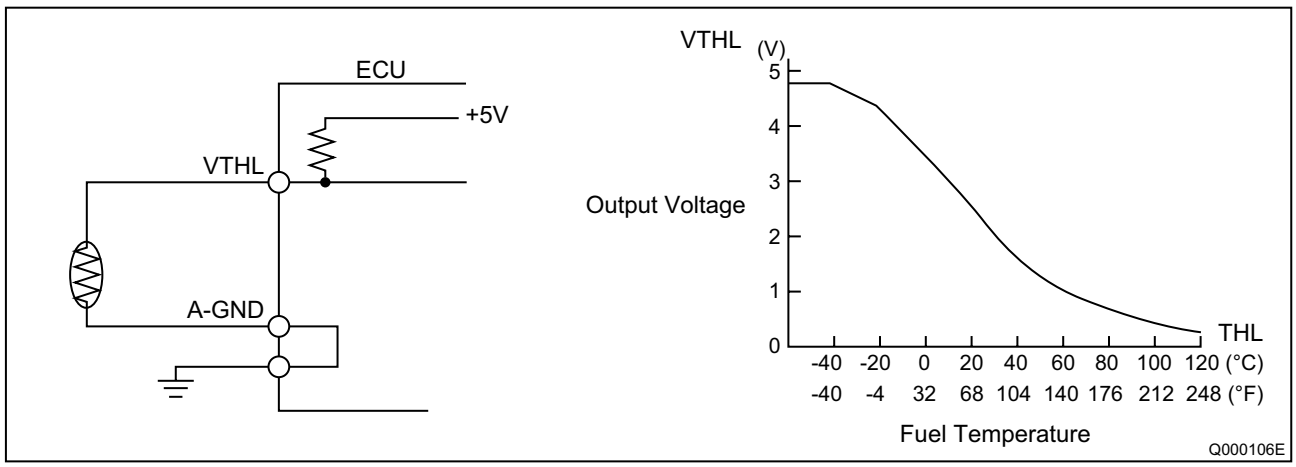
3-2. Description of Control System Components

A. Engine Control System Diagram



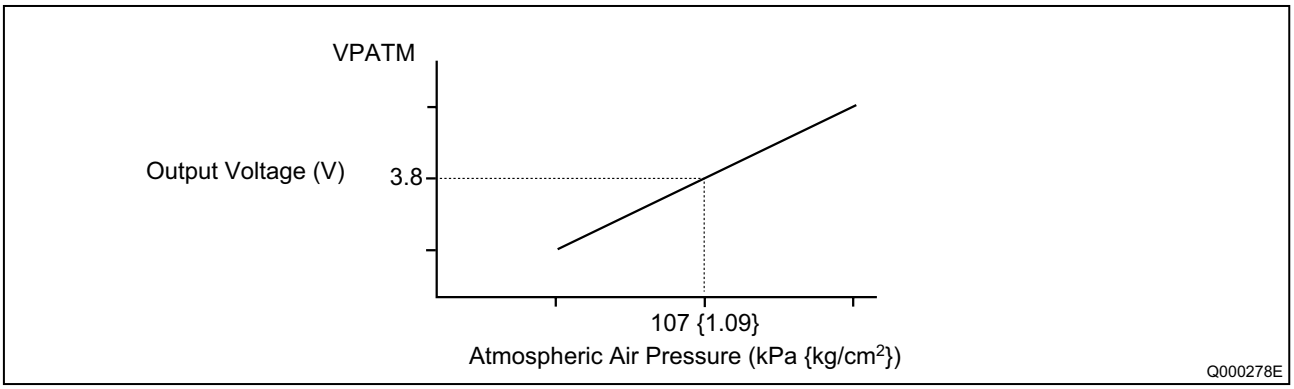
a. Fuel Temperature Sensor (THL)

- 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.



b. Atmospheric Air Pressure Sensor (Built-in ECU)

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



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.

A. Fuel Injection Rate Control Function

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.

B. Fuel Injection Quantity Control Function

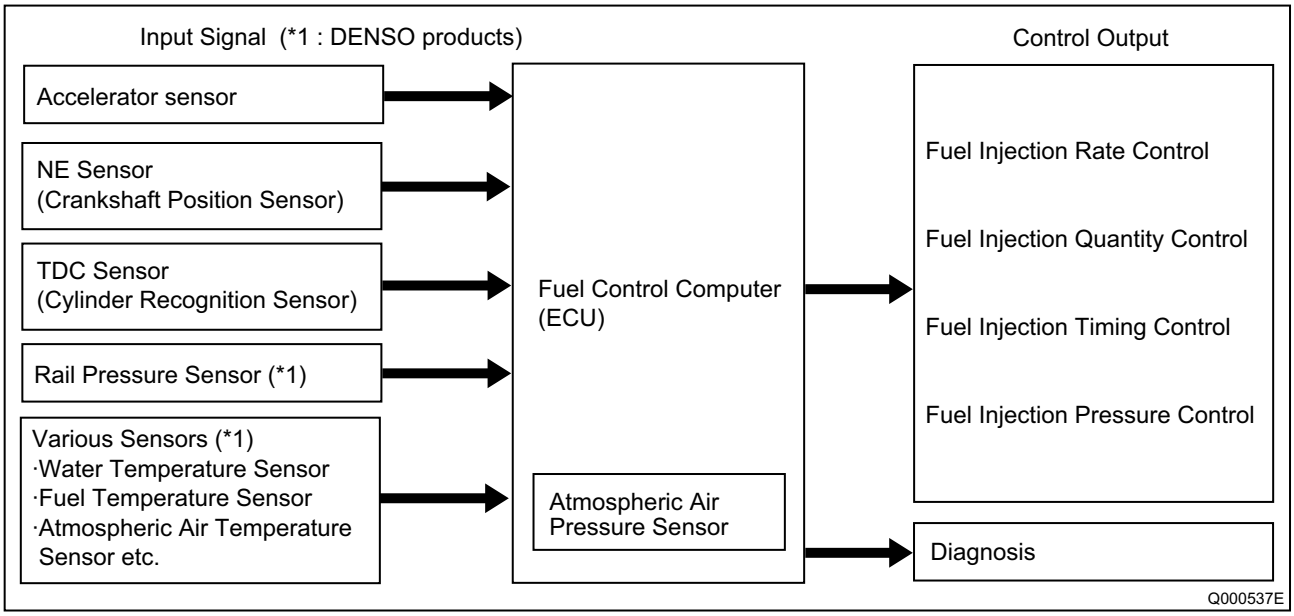
The fuel injection quantity control function, replaces the conventional governor function, and controls fuel injection to achieve an optimal injection quantity based on the engine speed and the accelerator opening.

C. Fuel Injection Timing Control Function

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.

D. Fuel Injection Pressure Control Function (Rail Pressure Control Function)

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



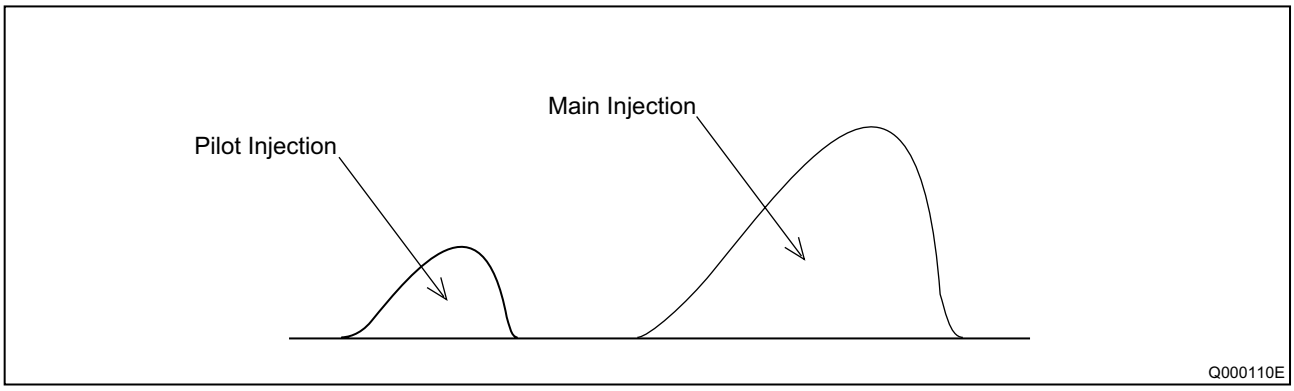
E. Fuel Injection Rate Control

a. Main Injection

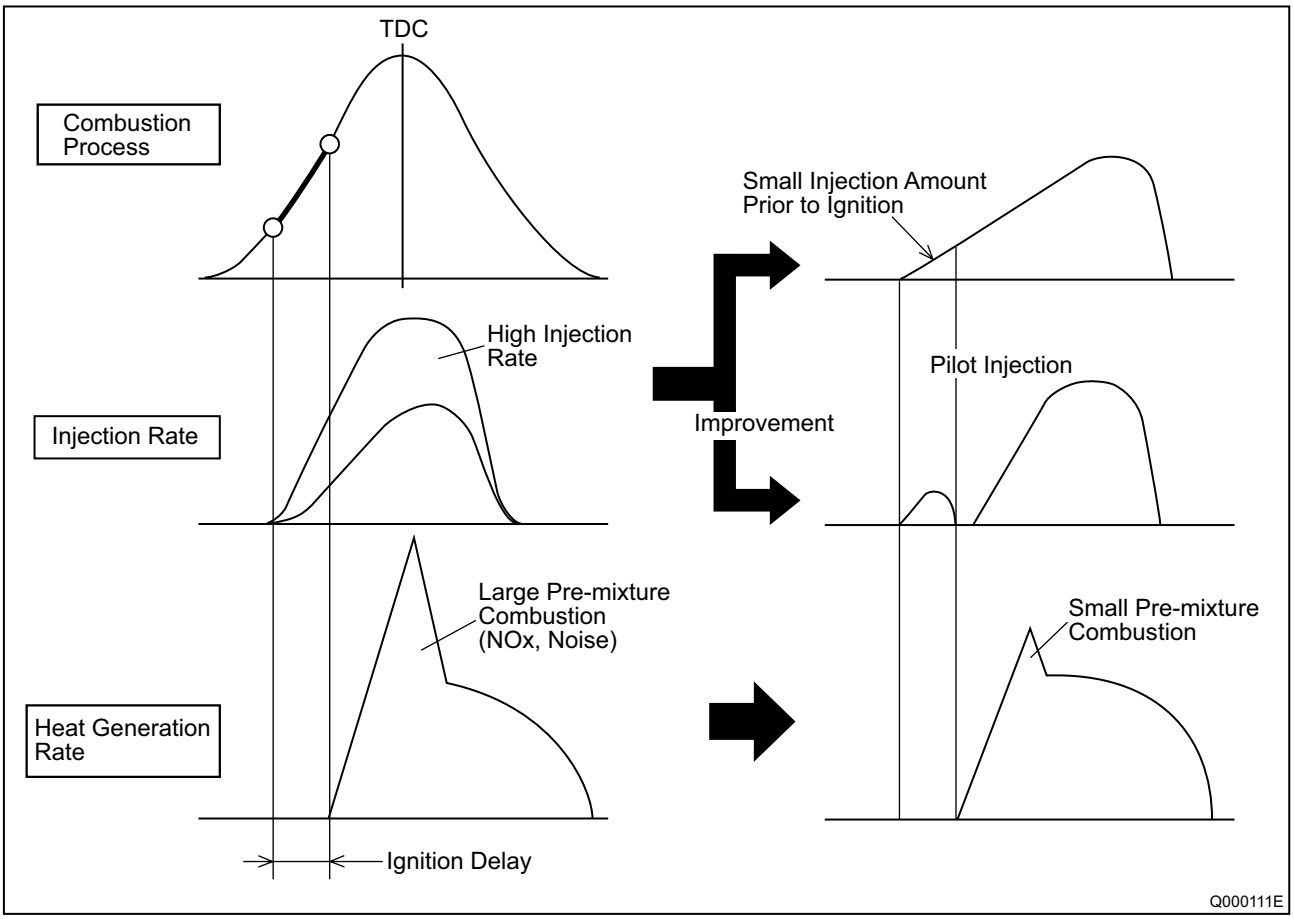
Same as conventional fuel injection.

b. Pilot Injection

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



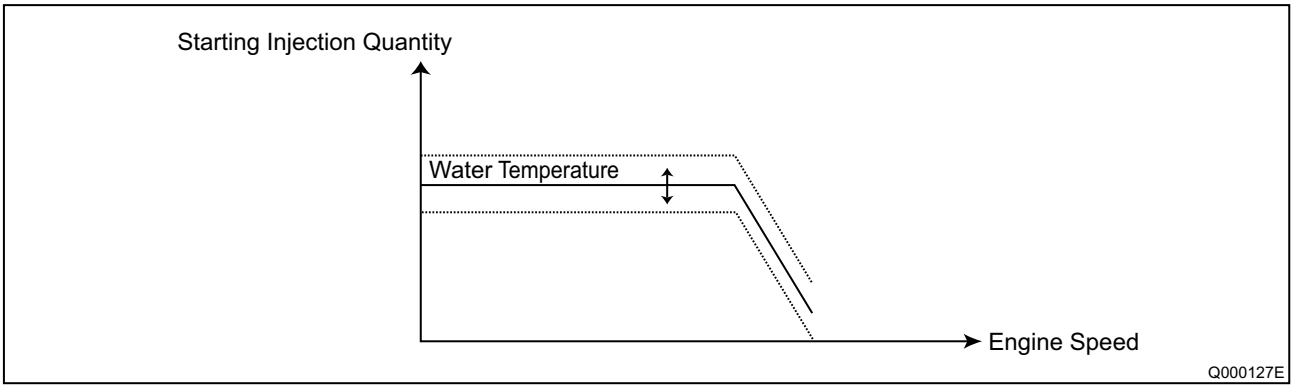
- While the adoption of higher pressure fuel injection is associated with an increase in the injection rate, the lag (injection lag) that occurs from the time fuel is injected until combustion starts cannot be reduced below a certain value. As a result, the quantity of fuel injected before ignition increases, 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.



F. Fuel Injection Quantity Control

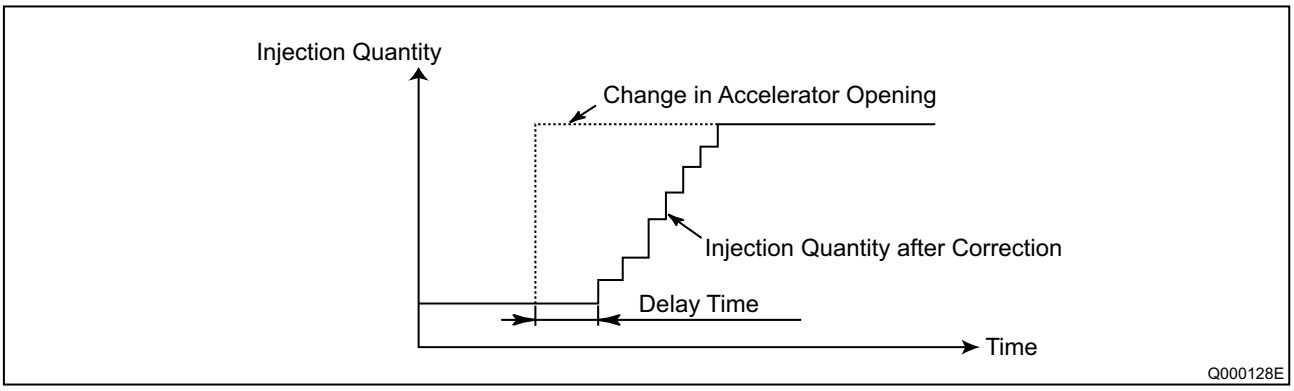
a. Starting Injection Quantity

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



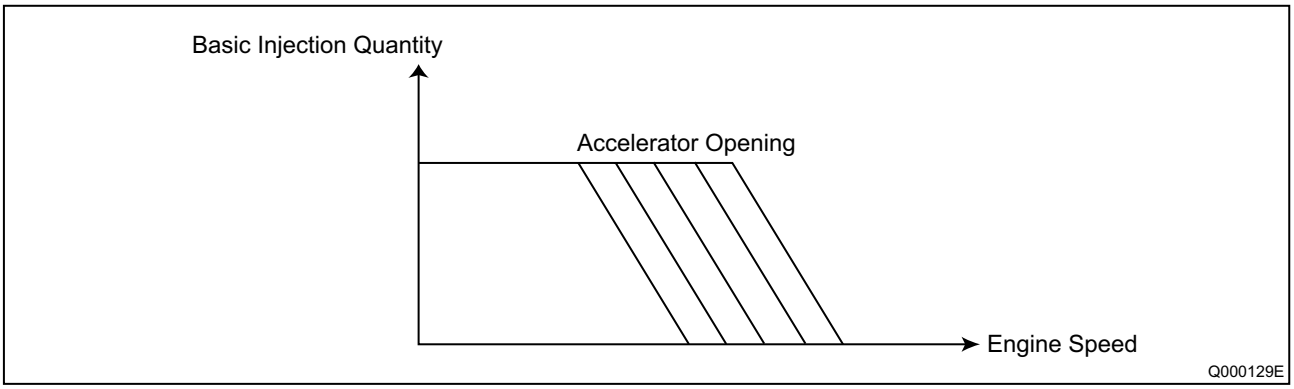
b. Transient Injection Quantity Correction

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.



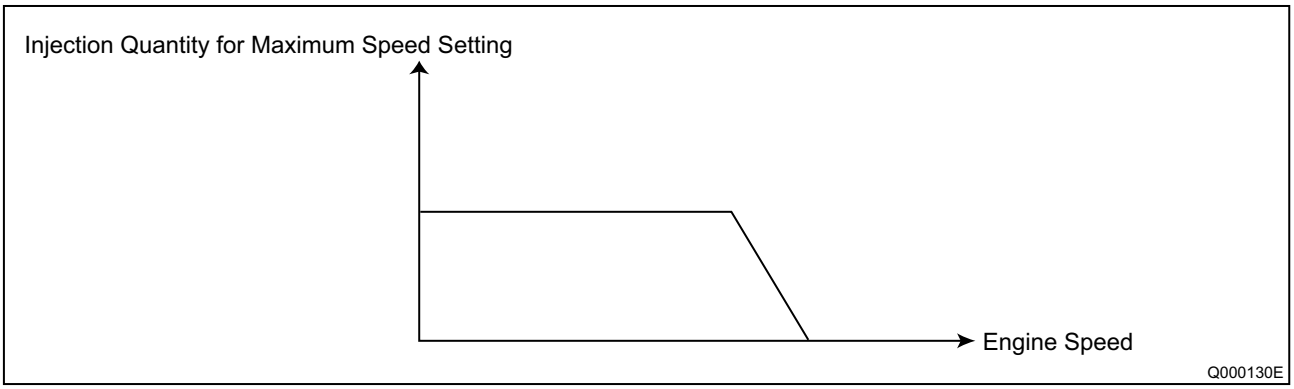
c. Basic Injection Quantity

- This quantity is determined in accordance with the engine speed (NE) and the accelerator opening.
- Increasing the accelerator opening while the engine speed remains constant causes the injection quantity to increase.



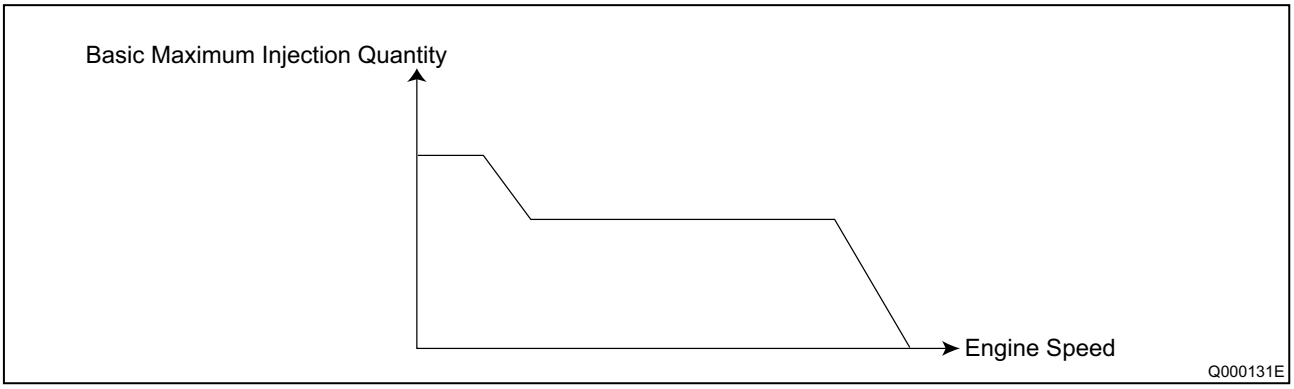
d. Injection Quantity for Maximum Speed Setting

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



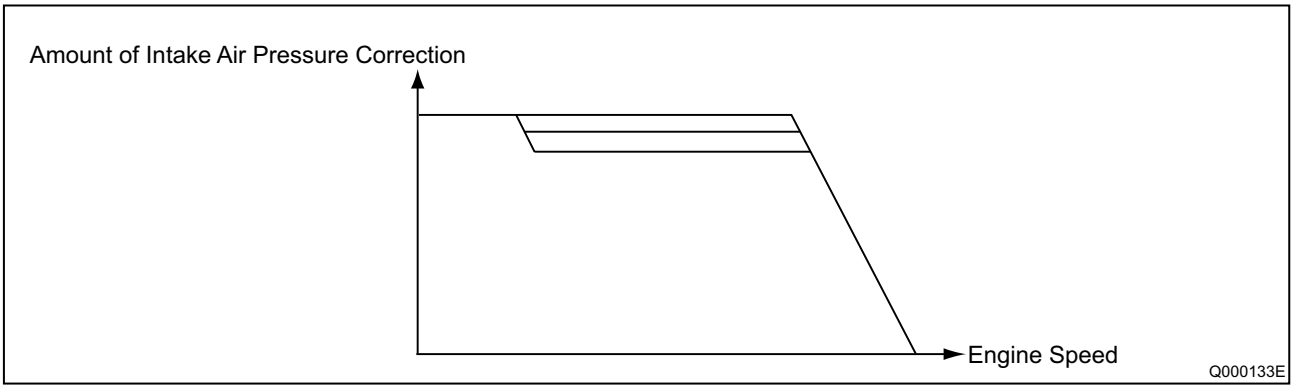
e. Maximum Injection Quantity

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



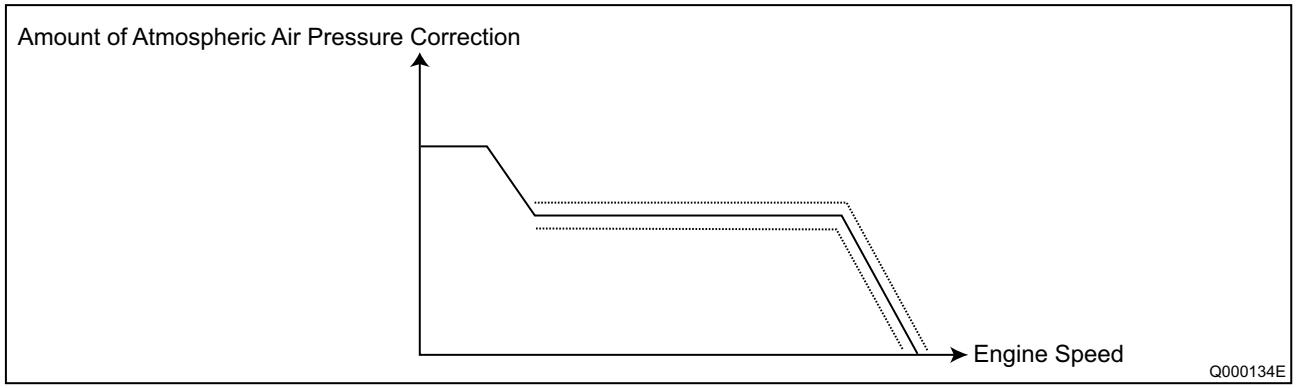
f. Amount of Injection Quantity Intake Pressure Correction

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.



g. Amount of Injection Quantity by Atmospheric Air Pressure Correction

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

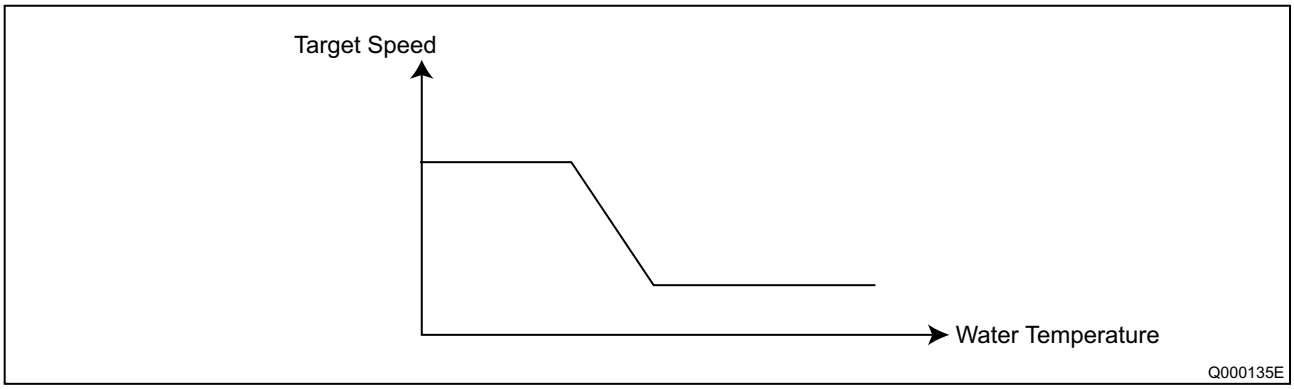


h. Idle Speed Control System (ISC)

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:

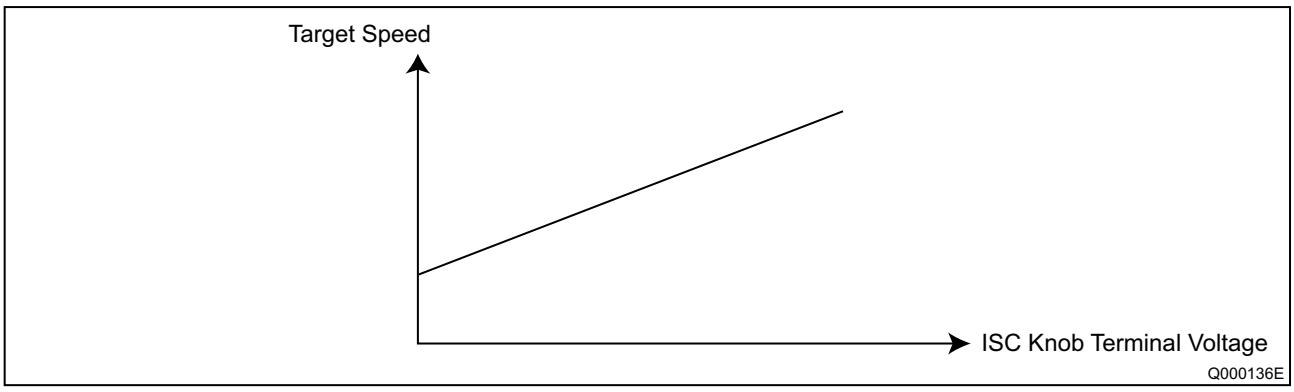
(1) Auto ISC

Controls the idle speed in accordance with the water temperature.



(2) Manual ISC

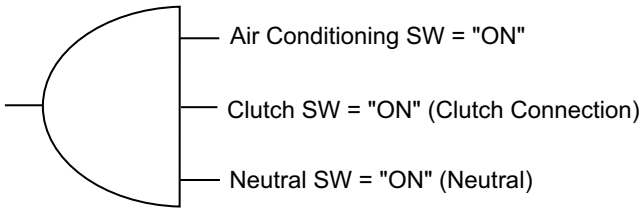
Controls the idle speed in accordance with the idle speed indicated on the manual idle setting knob provided at the driver's seat.



(3) 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.

Conditions



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i. Auto Cruise Control

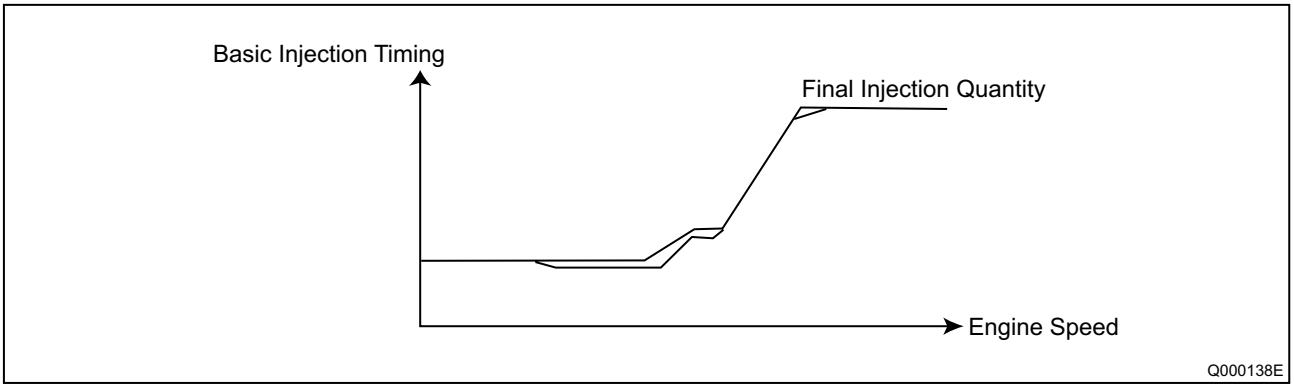
- Controls the actual vehicle speed by regulating the injection quantity in order to match the target speed that has been calculated by the computer with the actual speed.
- The CRS ECU controls the injection quantity in accordance with signals from the cruise control computer.

G. 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.

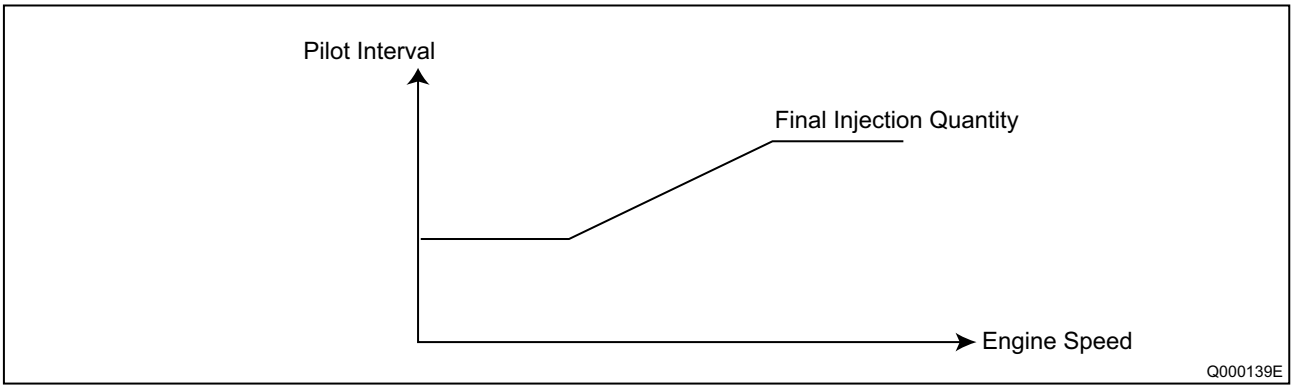
a. Main Injection Timing

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



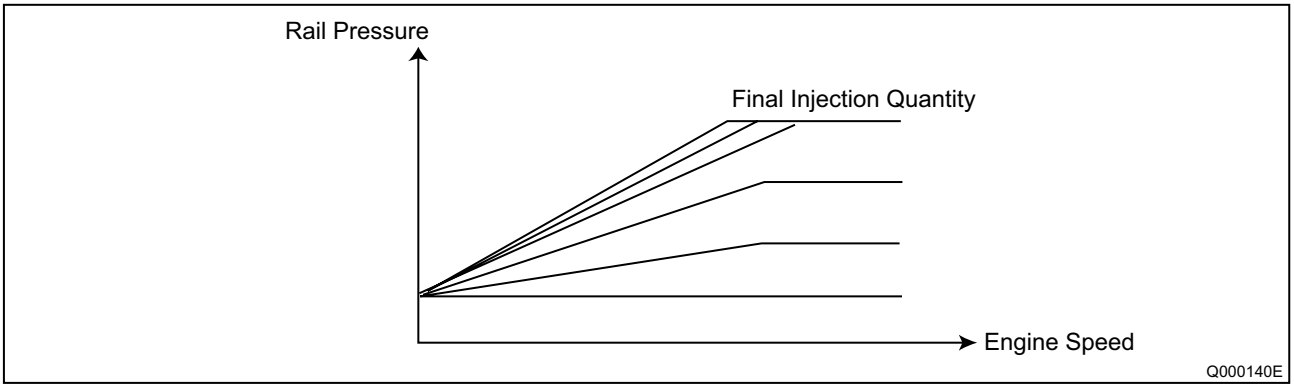
b. Pilot Injection timing (Pilot Interval)

- The pilot injection timing is controlled by adding the pilot interval to the main injection timing.
- The pilot interval is calculated in accordance with the final injection quantity, the engine speed, and the water temperature (with map correction).
- While starting, it is calculated in accordance with the water temperature and the engine speed.



c. Fuel Injection Pressure

- A value is calculated as determined in accordance with the final injection quantity and the engine speed.
- While starting, it is calculated in accordance with the water temperature and the engine speed.



3-4. Engine ECU

A. Diagnosis Codes

a. 4HK1

DTC Code	Code Description
P0643	Analog Sensor Reference Voltage Output No.1 Too High
P0642	Analog Sensor Reference Voltage Output No.1 Too Low
P0653	Analog Sensor Reference Voltage Output No.2 Too High
P0652	Analog Sensor Reference Voltage Output No.2 Too Low
P0699	Analog Sensor Reference Voltage Output No.3 Too High
P0698	Analog Sensor Reference Voltage Output No.3 Too Low
P0118	Coolant Temp. Sensor Signal Too High
P0117	Coolant Temp. Sensor Signal Too Low
P0113	Intake Air Temp. Sensor Signal Too High
P0112	Intake Air Temp. Sensor Signal Too Low
P0183	Fuel Leak Temp. Sensor Signal Too High
P0182	Fuel Leak Temp. Sensor Signal Too Low
P0113	ATM Temp. Sensor Signal Too High
P0112	ATM Temp. Sensor Signal Too Low
P0193	C/Rail Press. Sensor Signal Too High
P0192	C/Rail Press. Sensor Signal Too Low
P2229	Atom Press. Sensor Signal Too High
P2228	Atom Press. Sensor Signal Too Low
P0238	Boost Pressure Sensor Signal Too High
P0237	Boost Pressure Sensor Signal Too Low
P0563	Ignition1 Voltage Too High
P0562	Ignition1 Voltage Too Low
P0103	MAF Sensor Signal Too High
P0102	MAF Sensor Signal Too Low
P1597	PTO Accelerator Sensor Signal Too High
P1594	Idleup Signal Too High
P1593	Idleup Signal Too Low
P0406	EGR Position Signal Too High
P0405	EGR Position Signal Too Low
P0571	Cruise / Brake Switch Circuit Malfunction
P0567	Cruise Resume / Accelerator Signal
P0568	Cruise Set / Coast Signal Malfunction
P0335	Crank Sensor No Pulse
P0340	Cam Sensor No Pulse
P0092	SCV (+) output short to BATT SCV (-) output short to BATT

DTC Code	Code Description
P0091	SCV (+) output open Load / short to GND SCV (-) output open Load / short to GND SCV coil open
P1264	COM1 output short to BATT; TWV1 or 3 (or 5) output short to BATT
P1263	COM1 output short to GND; TWV1 or 3 (or 5) output short to GND
P2152	COM1 output open load; Both TWV1 or 3 (or 5) output open load
P1266	COM2 output short to BATT; TWV2 or 4 (or 6) output short to BATT
P1265	COM2 output short to GND; TWV2 or 4 (or 6) output short to GND
P2155	COM2 output open load; Both TWV2 or 4 (or 6) output open load
P0201	TWV1 output open load Injector#1 coil open
P0202	TWV2 output open load Injector#3 coil open
P0203	TWV3 output open load Injector#4 coil open
P0204	TWV4 output open load Injector#2 coil open
P1261	Capacitor charge-up circuit malfunction (insufficient charge)
P1261	Capacitor charge-up circuit malfunction (excessive charge)
P0088	Common rail pressure exceeds upper
P0088	Common rail pressure exceeds hi upper limit
P0382	Glow Controller Command Line Short to BATT
P0382	Glow Controller Command Line Open Load / Short to GND
P1094	C/Rail Press. Sensor Performance Invalid included fuel leak
P0087	P/L (pressure limiter) activated
P1404	EGR Position Error
P0400	EGR Duty Error
P0500	Vehicle Speed Sensor Malfunction
P0606	CPU fault; -Main CPU fault
P0606	CPU fault; -Watchdog IC fault
P0602	EEPROM/EERPOM Emulation via Flash EPROM Write Error
P0219	Engine overrun
P0512	Starter Switch Short to BATT

DTC Code	Code Description
P0686	Main relay diagnostics; Main relay stuck closed
P0089	Supply pump control valve (suction control valve) stuck
P0299	Boost Pressure Sensor exceeds lower limit
P0234	Boost Pressure Sensor exceeds upper limit
P2293	Supply pump protection
P2294	Supply pump exchange
P1093	Supply pump malfunction
P2122	Accelerator Pedal Position Sensor 1 Low Voltage
P2123	Accelerator Pedal Position Sensor 1 High Voltage
P2127	Accelerator Pedal Position Sensor 2 Low Voltage
P2128	Accelerator Pedal Position Sensor 2 High Voltage
P2132	Accelerator Pedal Position Sensor 3 Low Voltage
P2133	Accelerator Pedal Position Sensor 3 High Voltage
P1125	Pedal Position Sensor Circuit Intermittent
P2138	Accelerator Pedal Position Sensor 1, 2 Correlation Error
P2140	Accelerator Pedal Position Sensor 2, 3 Correlation Error
P2139	Accelerator Pedal Position Sensor 1, 3 Correlation Error
U2104	CAN Bus Error
U2106	CAN TCM SOH Diagnostic
P0602	QR Code Not Programmed
P0602	QR Code ERROR

b. 6HK1

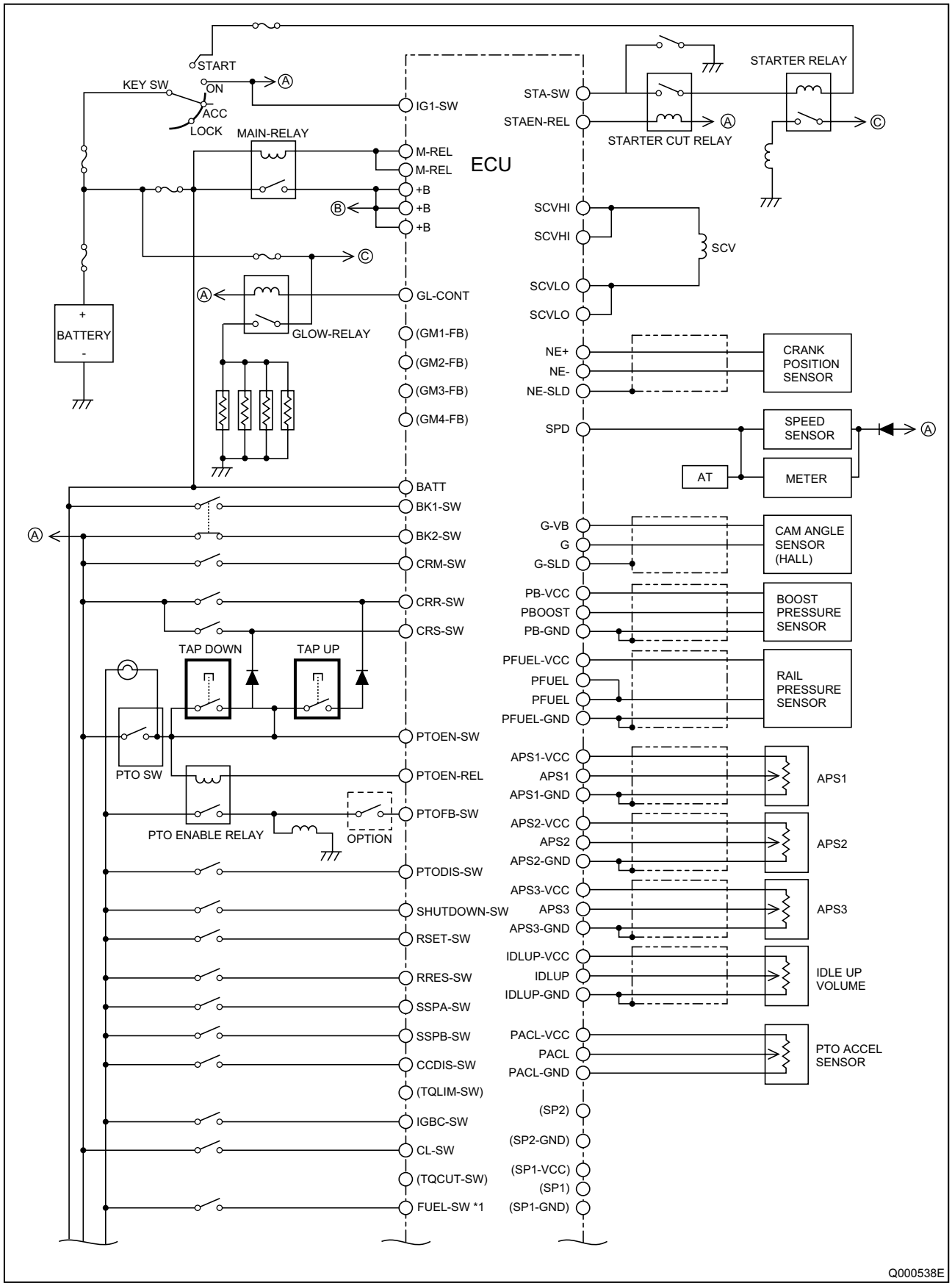
DTC Code	Code Description
P0641	Analog Sensor Reference Voltage Output No.1 Too High
P0641	Analog Sensor Reference Voltage Output No.1 Too Low
P0651	Analog Sensor Reference Voltage Output No.2 Too High
P0651	Analog Sensor Reference Voltage Output No.2 Too Low
P1646	Analog Sensor Reference Voltage Output No.3 Too High
P1646	Analog Sensor Reference Voltage Output No.3 Too Low
P0118	Coolant Temp. Sensor Signal Too High
P0117	Coolant Temp. Sensor Signal Too Low
P0113	Intake Air Temp. Sensor Signal Too High
P0112	Intake Air Temp. Sensor Signal Too Low
P0183	Fuel Leak Temp. Sensor Signal Too High
P0182	Fuel Leak Temp. Sensor Signal Too Low
P0523	Oil Press. Sensor Signal Too High
P0522	Oil Press. Sensor Signal Too Low
P0463	Fuel Level Sensor1 Signal Too High
P0462	Fuel Level Sensor1 Signal Too Low
P1433	Fuel Level Sensor2 Signal Too High
P1432	Fuel Level Sensor2 Signal Too Low
P0193	C/Rail Press. Sensor Signal Too High
P0192	C/Rail Press. Sensor Signal Too Low
P0190	C/Rail Press. Sensor Signal keeping the middle range
P0108	Atom Press. Sensor Signal Too High
P0107	Atom Press. Sensor Signal Too Low
P0238	Boost Pressure Sensor Signal Too High
P0237	Boost Pressure Sensor Signal Too Low
P0563	Ignition1 Voltage Too High
P0562	Ignition1 Voltage Too Low
P2003	MAF Sensor Signal Too High
P2004	MAF Sensor Signal Too Low
P2005	PTO Accelerator Sensor Signal Too High
P2007	VNT Current Too High
P2008	VNT Current Too Low
P0704	Clutch Pedal Switch Circuit
P0571	Cruise / Brake Switch Circuit Malfunction
P0571	Cruise / Brake Switch Circuit Malfunction
P0567	Cruise Resume / Accelerator Signal
P0568	Cruise Set / Coast Signal Malfunction
P0335	Crank Sensor No Pulse
P0385	Cam Sensor No Pulse

DTC Code	Code Description
P0092	SCV (+) output short to BATT SCV (-) output short to BATT
P0091	SCV (+) output open Load / short to GND SCV (-) output open Load / short to GND SCV coil open
P1264	COM1 output short to BATT; TWV1 or 3 (or 5) output short to BATT
P1263	COM1 output short to GND; TWV1 or 3 (or 5) output short to GND
P2011	COM1 output open load; Both TWV1 or 3 (or 5) output open load
P1266	COM2 output short to BATT; TWV2 or 4 (or 6) output short to BATT
P1265	COM2 output short to GND; TWV2 or 4 (or 6) output short to GND
P2012	COM2 output open load; Both TWV2 or 4 (or 6) output open load
P0201	TWV1 output open load Injector#1 coil open
P0202	TWV2 output open load Injector#5 coil open
P0203	TWV3 output open load Injector#3 coil open
P0204	TWV4 output open load Injector#6 coil open
P0205	TWV5 output open load Injector#2 coil open
P0206	TWV6 output open load Injector#4 coil open
P1261	Capacitor charge-up circuit malfunction (insufficient charge)
P1261	Capacitor charge-up circuit malfunction (excessive charge)
P1088	Common rail pressure exceeds hi upper limit
P0382	Glow Controller Command Line Short to BATT
P0382	Glow Controller Command Line Open Load / Short to GND
P0500	Vehicle Speed Sensor Malfunction
P0087	C/Rail Press. Sensor Performance Invalid included fuel leak
P1087	P/L (pressure limiter) activated
P2565	VNT Position Signal Too high
P2564	VNT Position Signal Too low
P2900	VNT Position Stick
P2901	EGR Brushless motor Position Sensor Signal Invalid
P2902	EGR Brushless motor Performance Error

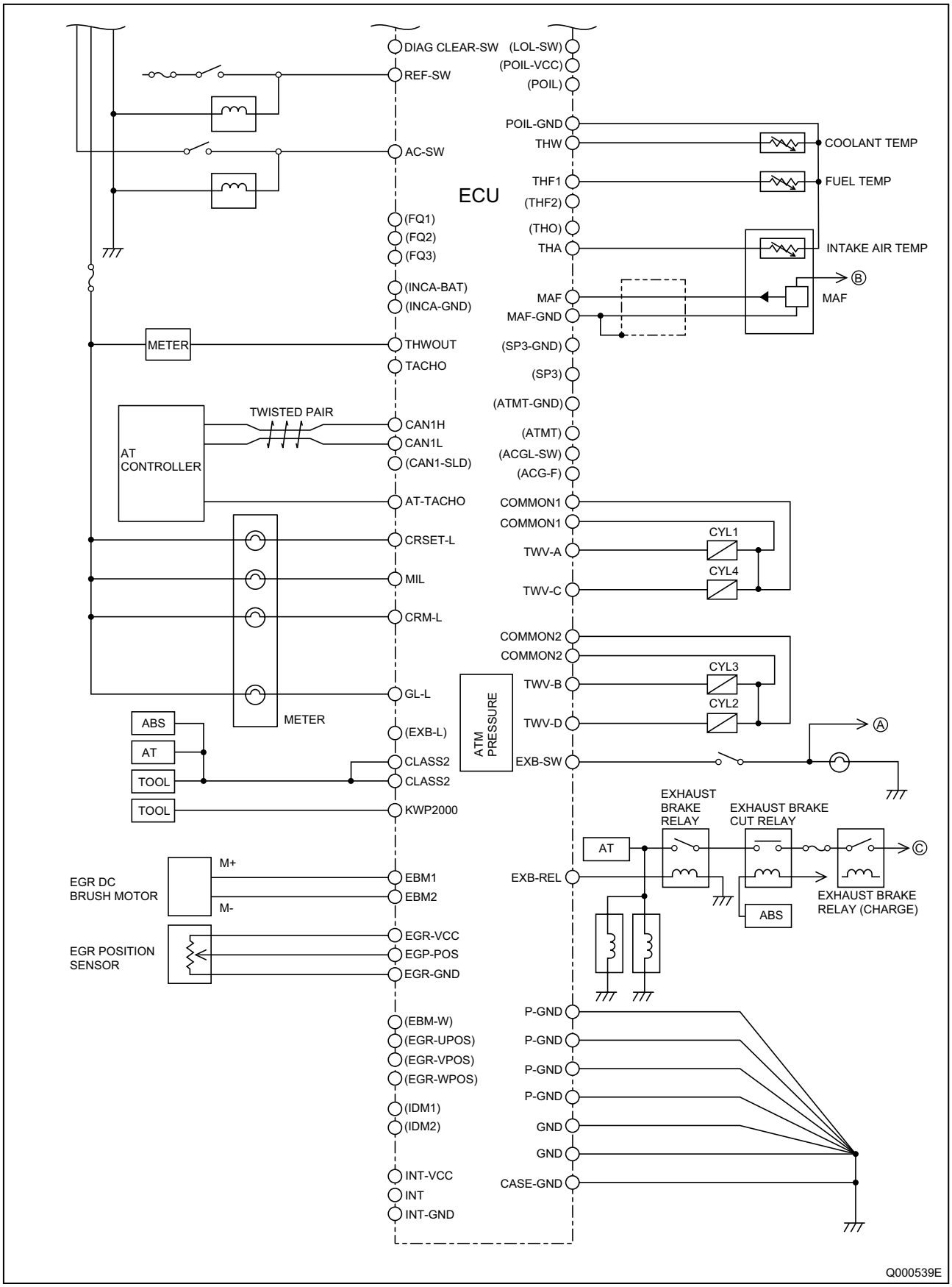
DTC Code	Code Description
P2903	EGR Valve open/Close Stick
P0606	CPU fault; -Main CPU fault
P0606	CPU fault; -Watchdog IC fault
P1621	EEPROM/EERPOM Emulation via Flash EPROM Write Error
P0219	Engine overrun
P0512	Starter Switch Short to BATT
P2920	Main relay diagnostics; Main relay stuck closed
P0088	Supply pump control valve (suction control valve) stuck
P0234	Boost Pressure Sensor exceeds upper limit
P0234	Boost Pressure Sensor exceeds upper limit (Long time)
P2921	Supply pump protection
P2922	Supply pump exchange
P2923	Supply pump malfunction
P1277	Accelerator Pedal Position Sensor 1 Low Voltage
P1278	Accelerator Pedal Position Sensor 1 High Voltage
P1282	Accelerator Pedal Position Sensor 2 Low Voltage
P1283	Accelerator Pedal Position Sensor 2 High Voltage
P1287	Accelerator Pedal Position Sensor 3 Low Voltage
P1288	Accelerator Pedal Position Sensor 3 High Voltage
P1125	Pedal Position Sensor Circuit Intermittent
P1271	Accelerator Pedal Position Sensor 1, 2 Correlation Error
P1272	Accelerator Pedal Position Sensor 2, 3 Correlation Error
P1273	Accelerator Pedal Position Sensor 1, 3 Correlation Error
U1300	Class2 Bus Short to Ground
U1301	Class2 Bus Short to Battery
U2104	CAN Bus Error
P0461	Fuel Level Sensor Circuit Performance
P0602	QR Code Not Programmed
P0602	QR Code ERROR

B. ECU External Wiring Diagram

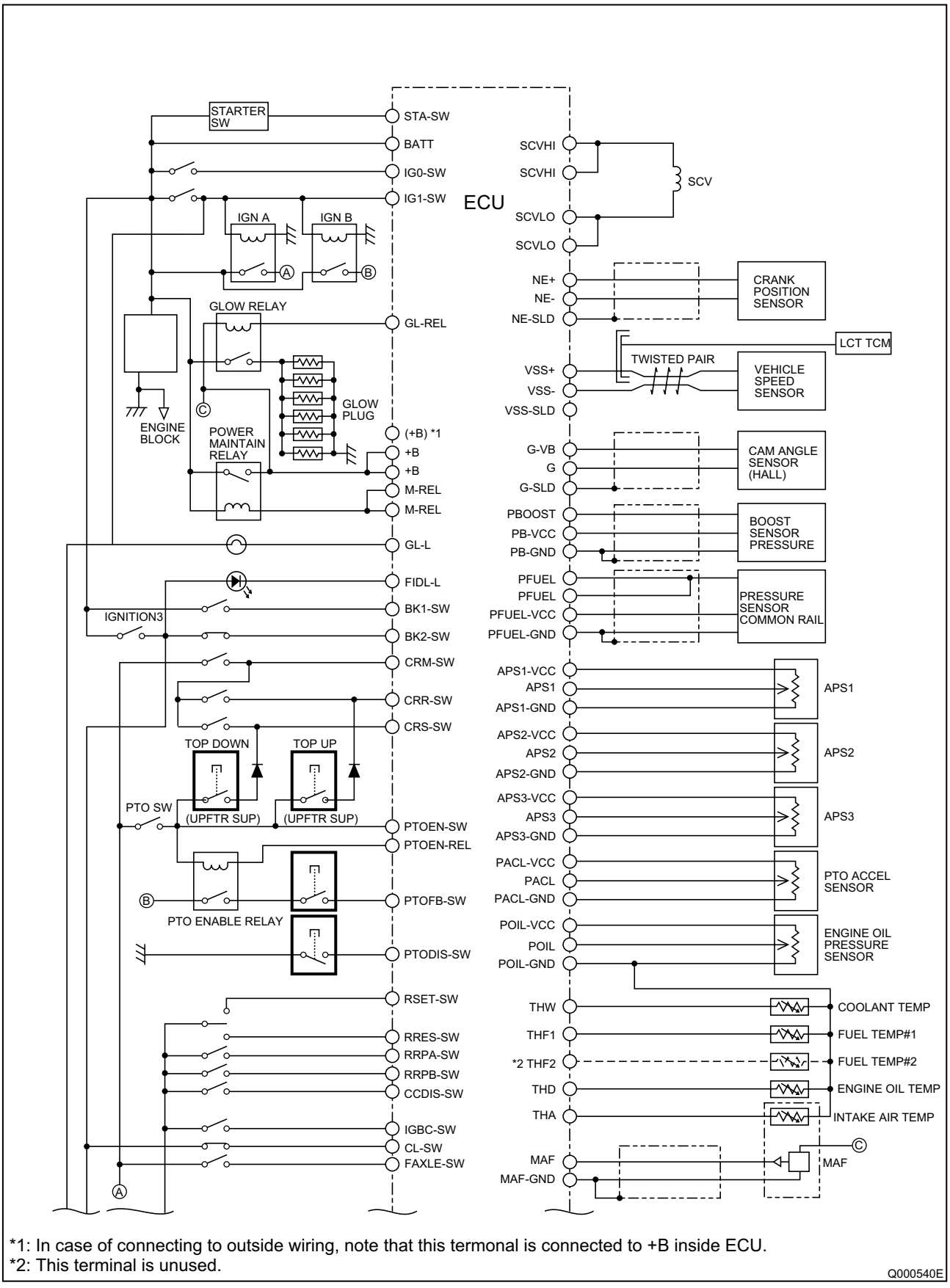
a. 4HK1 Diagram (1)



b. 4HK1 Diagram (2)

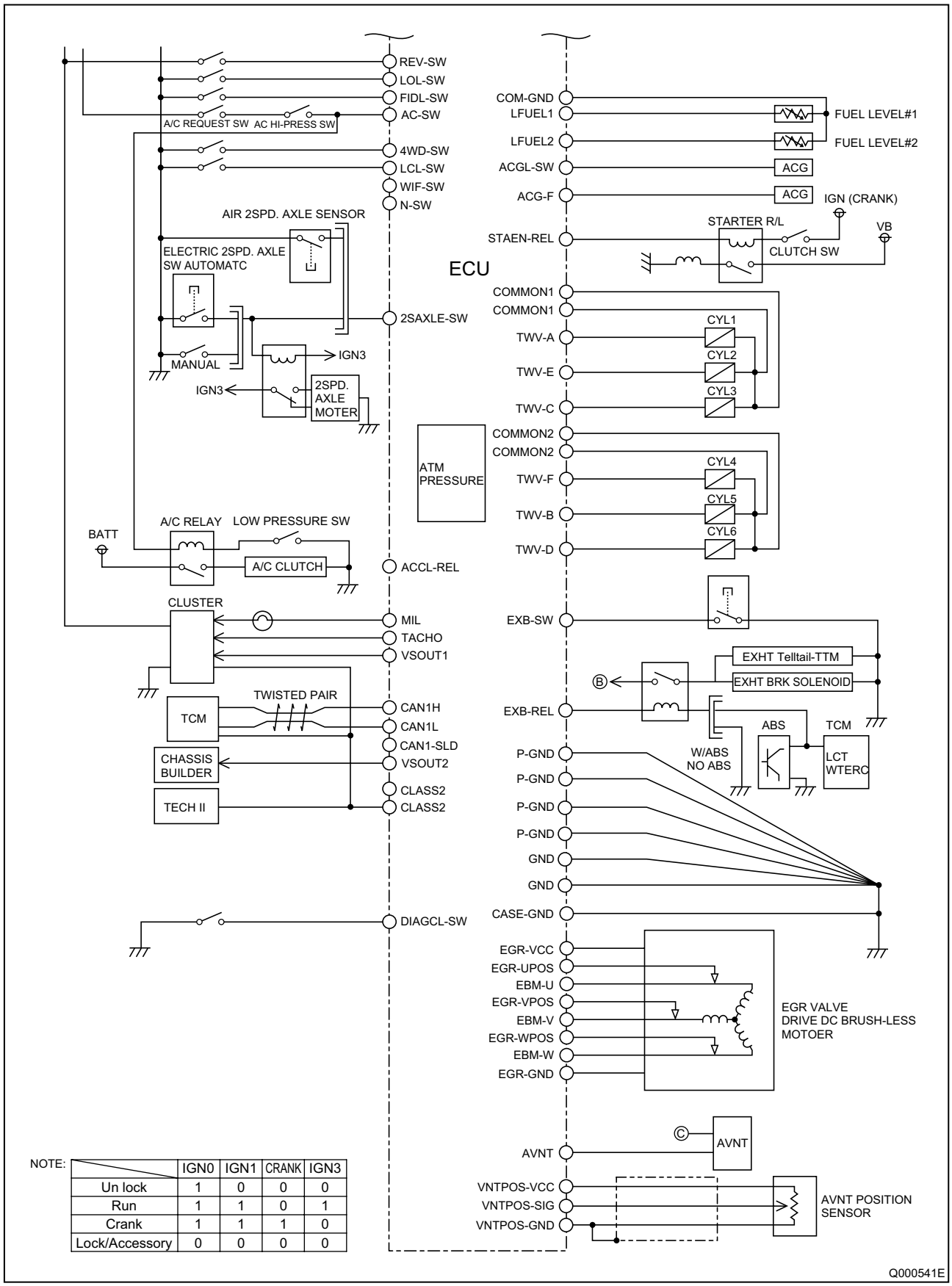


c. 6HK1 Diagram (1)



*1: In case of connecting to outside wiring, note that this termonal is connected to +B inside ECU.
*2: This terminal is unused.

d. 6HK1 Diagram (2)



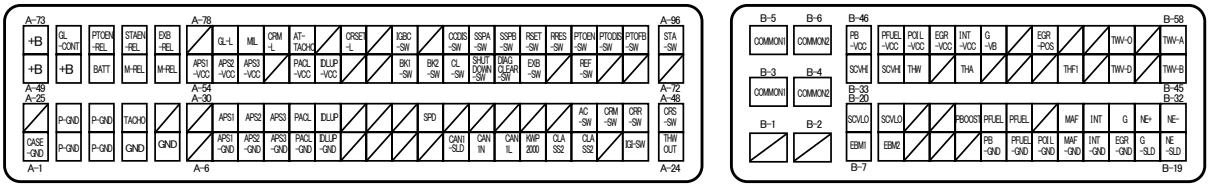
NOTE:

	IGN0	IGN1	CRANK	IGN3
Un lock	1	0	0	0
Run	1	1	0	1
Crank	1	1	1	0
Lock/Accessory	0	0	0	0

C. ECU Connector Diagram

a. 4HK1 ECU Connector Terminal Layout

ECU CONNECTOR PIN ASSIGNMENT : 154PIN



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b. 4HK1 Terminal Connections

No.	Terminal Name	Content	No.	Terminal Name	Content
A-1	CASE-GND	CASE GND	A-31	APS1	ACCEL POSITION 1 SIG
A-2	P-GND	POWER GND	A-32	APS2	ACCEL POSITION 2 SIG
A-3	P-GND	POWER GND	A-33	APS3	ACCEL POSITION 3 SIG
A-4	GND	ECU SENSOR GND	A-34	PACL	PTO ACCEL SIG
A-5	GND	ECU SENSOR GND	A-35	IDLUP	IDLE UP SIG
A-6	N/A	(Q CONTROL RESISTOR 3)	A-36	N/A	(SP1)
A-7	APS1-GND	V5RTN1	A-37	N/A	(SP2)
A-8	APS2-GND	V5RTN2	A-38	N/A	(ATM TEMP SIG)
A-9	APS3-GND	V5RTN3	A-39	SPD	SPEED INPUT
A-10	PACL-GND	PTO ACCEL GND	A-40	—	—
A-11	IDLUP-GND	IDLE UP GND	A-41	N/A	(ACG-F PULSE INPUT)
A-12	N/A	(SP3 GND)	A-42	—	—
A-13	N/A	(ATM TEMP GND)	A-43	N/A	(GLOW MONITOR2 FEEDBACK)
A-14	—	—	A-44	N/A	(GLOW MONITOR3 FEEDBACK)
A-15	N/A	(SP1-GND)	A-45	AC-SW	A/C CLUTCH REQUEST SW
A-16	CAN1-SLD	CAN1 SHIELD GND	A-46	CRM-SW	RUISE ENABLE (ON/OFF) SW
A-17	CAN1H	CAN1 HIGH	A-47	CRR-SW	CRUISE RESUME/ACCEL SW
A-18	CAN1L	CAN1 LOW	A-48	CRS-SW	CRUISE SET/COAST SW
A-19	KWP2000	ISO14230	A-49	+B	POWER
A-20	CLASS2	J1850	A-50	+B	POWER
A-21	CLASS2	J1850	A-51	BATT	BATTERY
A-22	—	—	A-52	M-REL	POWER MAINTAIN RELAY
A-23	IG1-SW	IGNITION 1	A-53	M-REL	POWER MAINTAIN RELAY
A-24	THWOUT	THW PWM OUTPUT	A-54	APS1-VCC	VBREF1
A-25	—	—	A-55	APS2-VCC	VBREF2
A-26	P-GND	POWER GND	A-56	APS3-VCC	VBREF3
A-27	P-GND	POWER GND	A-57	—	—
A-28	TACHO	TACHO	A-58	PACL-VCC	PTO ACCEL VCC
A-29	N/A	(Q CONTROL RESISTOR 1)	A-59	IDLUP-VCC	IDLE UP VCC
A-30	N/A	(Q CONTROL RESISTOR 2)	A-60	N/A	(SP1 VCC)

No.	Terminal Name	Content	No.	Terminal Name	Content
A-61	N/A	(ACG-L INPUT)	A-79	GL-L	GLOW LAMP
A-62	BK1-SW	BRAKE 1 SW	A-80	MIL	CHECK ENGINE LAMP
A-63	BK2-SW	BRAKE 2 SW	A-81	CRM-L	CRUISE MAIN LAMP
A-64	CL-SW	CLUTCH SW	A-82	AT-TACHO	AT-TACHO
A-65	SHUTDOWN-SW	ENGINE SHUTDOWN SW	A-83	N/A	(SP2 GND)
A-66	DIAG CLEAR-SW	DIAG CLEAR SW	A-84	CRSET-L	CRUISE SET LAMP
A-67	EXB-SW	EXHAUST BRAKE SW	A-85	N/A	(SP2)
A-68	—	—	A-86	IGBC-SW	IGNORE BRAKE/CLUTCH SW
A-69	REF-SW	REFRIGERATOR SW	A-87	N/A	(TORQUE LIMIT SW)
A-70	N/A	(GLOW MONITOR1 FEEDBACK)	A-88	CCDIS-SW	CAB CONTROL DISABLE SW
A-71	N/A	(TORQUE CUT SW)	A-89	SSPA-SW	SET SPEED A SW
A-72	N/A	(GLOW MONITOR4 FEEDBACK)	A-90	SSPB-SW	SET SPEED B SW
A-73	+B	POWER	A-91	RSET-SW	REMOTE SET SW
A-74	GL-CONT	GLOW CONTOROLLER	A-92	RRES-SW	REMOTE RESUME SW
A-75	PTOEN-REL	PTO ENGAGE RELAY	A-93	PTOEN-SW	PTO ENGAGE SW
A-76	STAEN-REL	STARTER ENABLE RELAY	A-94	PTODIS-SW	PTO DISABLE SW
A-77	EXB-REL	EXHAUST BRAKE RELAY	A-95	PTOFB-SW	PTO FEEDBACK SW
A-78	N/A	(EXHAUST BRAKE LAMP)	A-96	STA-SW	CRANKING REQUEST SW

No.	Terminal Name	Content	No.	Terminal Name	Content
B-1	N/A	(INTAKE DC MOTOR1)	B-22	—	—
B-2	N/A	(INTAKE DC MOTOR2)	B-23	N/A	(INCA-BAT)
B-3	COMMON1	INJECTOR POWER1	B-24	PBOOST	BOOST PRESSURE SIG.
B-4	COMMON2	INJECTOR POWER2	B-25	PFUEL	RAIL PRESSURE SIG.
B-5	COMMON1	INJECTOR POWER1	B-26	PFUEL	RAIL PRESSURE SIG.
B-6	COMMON2	INJECTOR POWER2	B-27	N/A	(OIL PRESSURE SIG.)
B-7	EBM1	EGR DC MOTOR 1	B-28	MAF	MAF SIGNAL
B-8	EBM2	EGR DC MOTOR 2	B-29	INT	INTAKE POSITION SIG.
B-9	N/A	(EGR BRUSHLESS MOTOR W)	B-30	G	CAM ANGLE
B-10	—	—	B-31	NE+	CRANK POSITION+
B-11	N/A	(INCA-GND)	B-32	NE-	CRANK POSITION-
B-12	PB-GND	BOOST PRESSURE GND	B-33	SCVHI	SCV HIGH SIDE
B-13	PFUEL-GND	RAIL PRESSURE GND	B-34	SCVHI	SCV HIGH SIDE
B-14	POIL-GND	OIL PRESSURE GND	B-35	THW	COOLANT TEMP.
B-15	MAF-GND	MAF GND	B-36	N/A	(ENGINE OIL TEMP.)
B-16	INT-GND	INTAKE POSITION GND	B-37	THA	INTAKE AIR TEMP.
B-17	EGR-GND	EGR POSITION GND	B-38	N/A	(EGR-U POSITION SIG.)
B-18	G-SLD	CAM ANGLE GND	B-39	N/A	(EGR-V POSITION SIG.)
B-19	NE-SLD	CRANK POSITION GND	B-40	N/A	(EGR-W POSITION SIG.)
B-20	SCVLO	SCV LOW SIDE	B-41	THF1	FUEL TEMP
B-21	SCVLO	SCV LOW SIDE	B-42	N/A	(FUEL TEMP. #2)

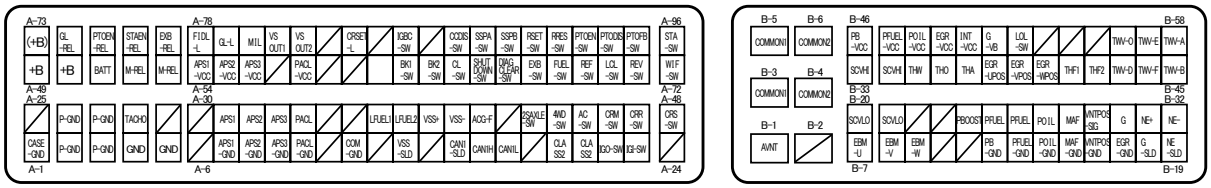
No.	Terminal Name	Content	No.	Terminal Name	Content
B-43	TWV-D	INJECTOR D(CYL2)	B-51	G-VB	CAM ANGLE VB
B-44	—	—	B-52	N/A	(LOW OIL LEVEL SW)
B-45	TWV-B	INJECTOR B(CYL3)	B-53	EGR-POS	EGR-POSITION SIG. (DC MOTOR)
B-46	PB-VCC	BOOST PRESSURE VCC	B-54	—	—
B-47	PFUEL-VCC	RAIL PRESSURE VCC	B-55	—	—
B-48	POIL-VCC	OIL PRESSURE VCC	B-56	TWV-C	INJECTOR C(CYL4)
B-49	EGR-VCC	EGR POSITION VCC	B-57	—	—
B-50	INT-VCC	INTAKE POSITION VCC	B-58	TWV-A	INJECTOR A(CYL1)

< NOTE >

- N/A: Component is not mounted (circuit pattern only). Note that the VCC and GND and pin No. A-78 for sensors are connected inside ECU.

c. 6HK1 ECU Connector Terminal Layout

ECU CONNECTOR PIN ASSIGNMENT : 154PIN



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d. 6HK1 Terminal Connections

No.	Terminal Name	Content	No.	Terminal Name	Content
A-1	CASE-GND	CASE GND	A-32	APS2	ACCEL POSITION 2 SIG
A-2	P-GND	POWER GND	A-33	APS3	ACCEL POSITION 3 SIG
A-3	P-GND	POWER GND	A-34	PACL	PTO ACCEL SIG
A-4	GND	ECU SENSOR GND	A-35	—	—
A-5	GND	ECU SENSOR GND	A-36	—	—
A-6	N/A	(Q CONTROL RESISTOR 3)	A-37	LFUEL1	FUEL LEVEL 1 SIG
A-7	APS1-GND	V5RTN1	A-38	LFUEL2	FUEL LEVEL 2 SIG (ATM TEMP)
A-8	APS2-GND	V5RTN2	A-39	VSS+	VEHICLE SPEED SENSOR+
A-9	APS3-GND	V5RTN3	A-40	VSS-	VEHICLE SPEED SENSOR-
A-10	PACL-GND	PTO ACCEL GND	A-41	ACG-F	ACG-F PULSE INPUT
A-11	—	—	A-42	—	—
A-12	COM-GND	COMMON SENSOR GND	A-43	2SAXLE-SW	2SPEED AXLE SW
A-13	—	—	A-44	4WD-SW	FOUR WHEEL DRIVE HIGH/LOW SW
A-14	VSS-SLD	VSS GND	A-45	AC-SW	A/C CLUTCH REQUEST SW
A-15	—	—	A-46	CRM-SW	CRUISE ENABLE (ON/OFF) SW
A-16	CAN1-SLD	CAN1 SHIELD GND	A-47	CRR-SW	CRUISE RESUME/ACCEL SW
A-17	CAN1H	CAN1 HIGH	A-48	CRS-SW	CRUISE SET/COAST SW
A-18	CAN1L	CAN1 LOW	A-49	+B	POWER
A-19	N/A	(ISO14230)	A-50	+B	POWER
A-20	CLASS2	J1850	A-51	BATT	BATTERY
A-21	CLASS2	J1850	A-52	M-REL	POWER MAINTAIN RELAY
A-22	IG0-SW	IGNITION 0 (KEY-SW)	A-53	M-REL	POWER MAINTAIN RELAY
A-23	IG1-SW	IGNITION 1	A-54	APS1-VCC	VBREF1
A-24	—	—	A-55	APS2-VCC	VBREF2
A-25	—	—	A-56	APS3-VCC	VBREF3
A-26	P-GND	POWER GND	A-57	—	—
A-27	P-GND	POWER GND	A-58	PACL-VCC	PTO ACCEL VCC
A-28	TACHO	TACHO	A-59	—	—
A-29	N/A	(Q CONTROL RESISTOR 1)	A-60	—	—
A-30	N/A	(Q CONTROL RESISTOR 2)	A-61	ACGL-SW	ACG-L INPUT
A-31	APS1	ACCEL POSITION 1 SIG	A-62	BK1-SW	BRAKE 1 SW

No.	Terminal Name	Content	No.	Terminal Name	Content
A-63	BK2-SW	BRAKE 2 SW	A-80	MIL	SERVICE ENGINE SOON LAMP
A-64	CL-SW	CLUTCH SW	A-81	VSOUT1	4KPPM
A-65	N-SW	NEUTRAL SW	A-82	VSOUT2	4KPPM (128KPPM)
A-66	DIAG CLEAR-SW	DIAG CLEAR SW	A-83	—	—
A-67	EXB-SW	EXHAUST BRAKE SW	A-84	ACCL-REL	A/C CLUTCH RELAY
A-68	FIDL-SW	FAST IDLE SW	A-85	—	—
A-69	FAXLE-SW	FRONT AXLE SW	A-86	IGBC-SW	IGNORE BRAKE/CLUTCH SW
A-70	LCL-SW	LOW COOLANT LEVEL SW	A-87	N/A	(TORQUE LIMIT SW)
A-71	REV-SW	REVERSE SW	A-88	CCDIS-SW	CAB CONTROL DISABLE SW
A-72	WIF-SW	WATER IN FUEL SW	A-89	SSPA-SW	SET SPEED A SW
A-73	(+B) *1	(POWER)	A-90	SSPB-SW	SET SPEED B SW
A-74	GL-REL	GLOW PLUG RELAY	A-91	RSET-SW	REMOTE SET SW
A-75	PTOEN-REL	PTO ENGAGE RELAY	A-92	RRES-SW	REMOTE RESUME SW
A-76	STAEN-REL	STARTER ENABLE RELAY	A-93	PTOEN-SW	PTO ENGAGE SW
A-77	EXB-REL	EXHAUST BRAKE RELAY	A-94	PTODIS-SW	PTO DISABLE SW
A-78	FIDL-L	FAST IDLE ENGAGE LAMP	A-95	PTOFB-SW	PTO FEEDBACK SW
A-79	GL-L	GLOW LAMP	A-96	STA-SW	CRANKING REQUEST SW

No.	Terminal Name	Content	No.	Terminal Name	Content
B-1	AVNT	AVNT DRIVE	B-23	N/A	(INCA-BAT)
B-2	—	—	B-24	PBOOST	BOOST PRESSURE SIG.
B-3	COMMON1	INJECTOR POWER1	B-25	PFUEL	RAIL PRESSURE SIG.
B-4	COMMON2	INJECTOR POWER2	B-26	PFUEL	RAIL PRESSURE SIG.
B-5	COMMON1	INJECTOR POWER1	B-27	POIL	OIL PRESSURE SIG.
B-6	COMMON2	INJECTOR POWER2	B-28	MAF	MAF SIGNAL
B-7	EBM-U	EGR BRUSHLESS MOTOR U	B-29	VNTPOS-SIG	VNT POSITION SIG.
B-8	EBM-V	EGR BRUSHLESS MOTOR V	B-30	G	CAM ANGLE
B-9	EBM-W	EGR BRUSHLESS MOTOR W	B-31	NE+	CRANK POSITION+
B-10	—	—	B-32	NE-	CRANK POSITION-
B-11	N/A	(INCA-GND)	B-33	SCVHI	SCV HIGH SIDE
B-12	PB-GND	BOOST PRESSURE GND	B-34	SCVHI	SCV HIGH SIDE
B-13	PFUEL-GND	RAIL PRESSURE GND	B-35	THW	COOLANT TEMP.
B-14	POIL-GND	OIL PRESSURE GND	B-36	THO	ENGINE OIL TEMP.
B-15	MAF-GND	MAF GND	B-37	THA	INTAKE AIR TEMP.
B-16	VNTPOS-GND	VNT POSITION GND	B-38	EGR-UPOS	EGR-U POSITION SIG.
B-17	EGR-GND	EGR POSITION GND	B-39	EGR-VPOS	EGR-V POSITION SIG.
B-18	G-SLD	CAM ANGLE SHIELD GND	B-40	EGR-WPOS	EGR-W POSITION SIG.
B-19	NE-SLD	CRANK POSITION SHIELD GND	B-41	THF1	FUEL TEMP
B-20	SCVLO	SCV LOW SIDE	B-42	THF2 *2	FUEL TEMP. #2
B-21	SCVLO	SCV LOW SIDE	B-43	TWV-D	INJECTOR D
B-22	—	—	B-44	TWV-F	INJECTOR F

No.	Terminal Name	Content	No.	Terminal Name	Content
B-45	TWV-B	INJECTOR B	B-52	LOL-SW	LOW OIL LEVEL SW
B-46	PB-VCC	BOOST PRESSURE VCC	B-53	—	—
B-47	PFUEL-VCC	RAIL PRESSURE VCC	B-54	—	—
B-48	POIL-VCC	OIL PRESSURE VCC	B-55	—	—
B-49	EGR-VCC	EGR POSITION VCC	B-56	TWV-C	INJECTOR C
B-50	VNTPOS-VCC	VNT POSITION VCC	B-57	TWV-E	INJECTOR E
B-51	G-VB	CAM ANGLE VB	B-58	TWV-A	INJECTOR A

< NOTE >

- *1: In case of connecting to outside wiring, note that this terminal is connected to +B inside ECU.
- *2: This terminal is unused.
- N/A: Component is not mounted (circuit pattern only).