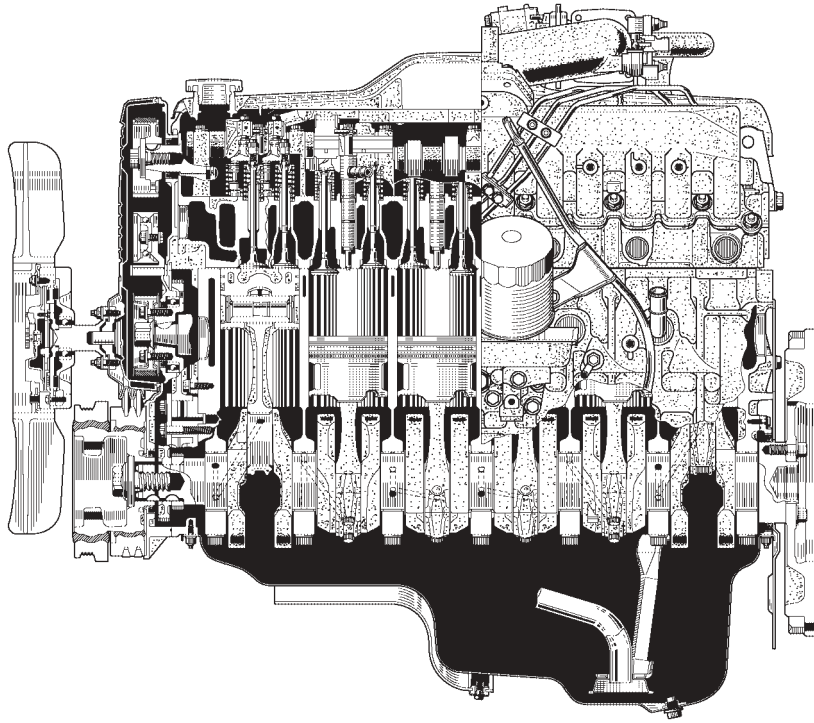


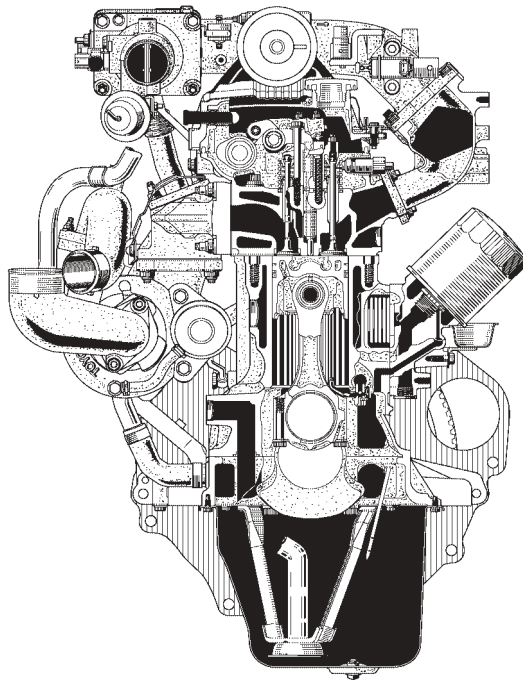
1HD-FTE ENGINE

■ DESCRIPTION

Based on the previous 1HD-FT engine, the 1HD-FTE engine has adopted an electronically controlled injection pump and an intercooler and has undergone improvements in the various areas of the engine to improve the engine performance and fuel economy while reducing exhaust emissions. At the same time, this engine contributes to the vehicle's quieter operation and improved reliability.



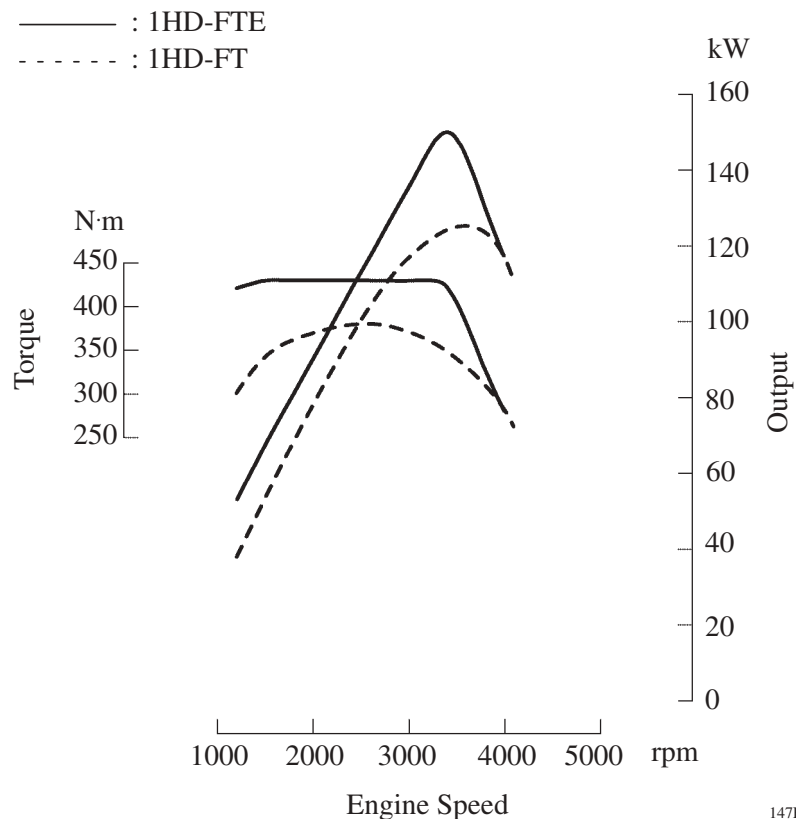
147EG28



147EG27

ENGINE SPECIFICATIONS AND PERFORMANCE CURVE

Item		Engine	1HD-FTE	1HD-FT
No. of Cyls. & Arrangement			6-Cylinder, In-Line	←
Valve Mechanism			24-Valve, OHC, Belt & Gear Drive	←
Combustion Chamber			Direct Injection Type	←
Manifolds			Cross-Flow	←
Fuel System			Distributor Type (Electronically Controlled)	Distributor Type (Mechanically Controlled)
Displacement	cm ³ (cu. in.)		4164 (254.0)	←
Bore x Stroke	mm (in.)		94.0 x 100.0 (3.70 x 3.94)	←
Compression Ratio			18.8 : 1	18.6 : 1
Max. Output		[EEC]	150 kW @ 3400 rpm	125 kW @ 3600 rpm
Max. Torque		[EEC]	430 N·m @ 1400 ~ 3200 rpm	380 N·m @ 2500 rpm
Valve Timing	Intake	Open	12° BTDC	←
		Close	24° ABDC	32° ABDC
	Exhaust	Open	54° BBDC	←
		Close	12° ATDC	←
Intercooler			With	N.A.
Fuel Cetane Number			48 or higher	←
Oil Grade			API CF-4	API CD or Better



■ MAJOR DIFFERENCES

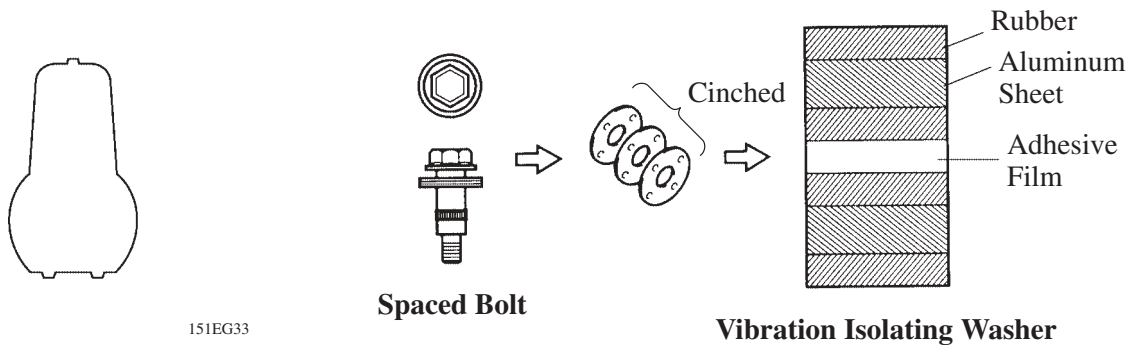
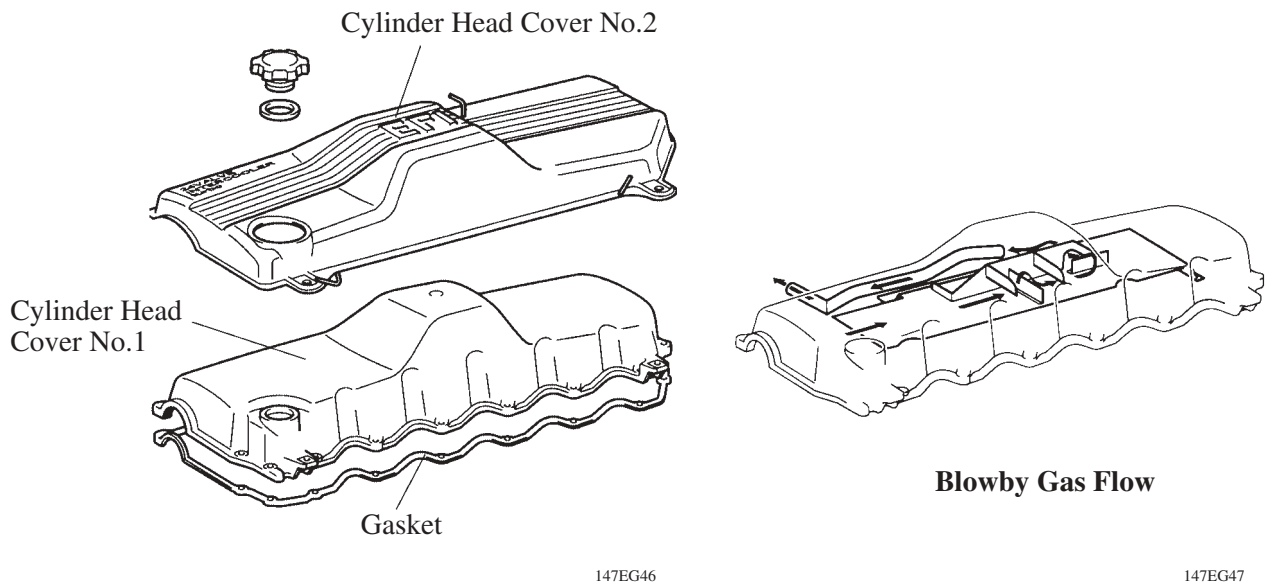
Major differences of the new 1HD-FTE engine and previous 1HD-FT engine are listed below.

Item	Features
Engine Proper	<ul style="list-style-type: none"> ● A cylinder head cover made of resin has been adopted for weight reduction and low-noise operation. ● The rigidity of the cylinder block has been improved to reduce noise and vibration. ● Newly designed pistons have been adopted to improve the engine performance and reliability. ● The crankshaft has been made highly rigid to reduce noise and vibration. ● The crankshaft bearings have been machine-bored to improve their reliability.
Cooling System	<ul style="list-style-type: none"> ● An aluminum radiator core is used for weight reduction. ● A step-up linear type temperature controlled fluid coupling has been adopted to improve cooling performance.
Lubrication System	<ul style="list-style-type: none"> ● A high-performance oil filter element has been adopted to improve the cleanliness of the engine oil. ● The oil capacity of the engine has been increased to improve its reliability. ● A drip pan is provided on the oil cooler cover to improving serviceability.
Intake and Exhaust System	<ul style="list-style-type: none"> ● A ball joint has been adopted in the front exhaust pipe to reduce noise and vibration. ● An oxidation catalytic converter has been adopted in the front exhaust pipe to reduce exhaust emissions.
Turbocharger System	<ul style="list-style-type: none"> ● A compact turbocharger has been adopted to attain a widely ranging high-efficiency region from the low- to the high-speed range. ● An intercooler has been adopted to improve engine performance.
Fuel System	<ul style="list-style-type: none"> ● A radial plunger type electronically controlled injection pump that produces a high injection pressure has been adopted to improve the engine performance while reducing exhaust emissions. ● The injection nozzles have been optimized to improve the engine performance and reduce exhaust emissions.
Starting System	<p>The 12/24 volt switchover system has been discontinued to simplify the wiring system.</p>
Engine Control System	<ul style="list-style-type: none"> ● An electronic fuel injection system has been adopted. ● M-OBD (Multiplex On-Board Diagnosis) system is adopted.

ENGINE PROPER

1. Cylinder Head Cover

- The No.1 cylinder head cover is made of resin, adopts a curved shape, and has optimally allocated ribs for weight reduction and reduced noise.
- Spaced bolts are used for fastening the cylinder head covers. In addition, vibration isolating washers containing laminated layers of rubber and aluminum sheets have been adopted to achieve a floating retaining construction that reduces noise and improves reliability.
- The blowby gas passage in the cylinder head cover has adopted a maze-like configuration to minimize the consumption of engine oil through blowby gas.
- A No.2 cylinder head cover has been adopted. The No.2 cylinder head cover, which is made of iron sheet, is completely covered with foam rubber on the inside. A vibration isolating rubber gasket is used to achieve a floating retaining construction to improve sound insulation.



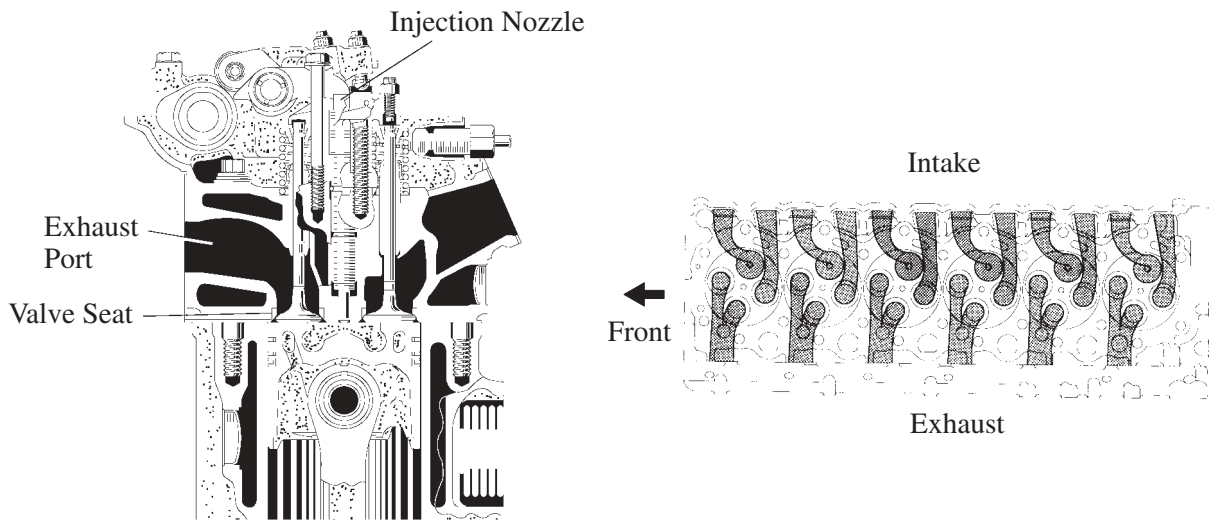
Gasket Cross Section

Vibration Isolating Washer

147EG48

2. Cylinder Head

- Similar to the previous 1HD-FT engine, the adoption of the 4-valve mechanism has made it possible to position the injection nozzle perpendicularly over the center of the cylinder bore. Together with the adoption of 2 intake ports of different shapes, this enables the generation of an optimal swirl and the introduction of an ample volume of intake air. As a result, the mixing of fuel and air has been accelerated to achieve an appropriate combustion.
- The cooling performance has been improved by enlarging the water jacket around the exhaust valves and the injection nozzles, thus improving the reliability of the engine.
- The exhaust valve seats have been changed to a type made of sintered alloy that excels in wear resistance.

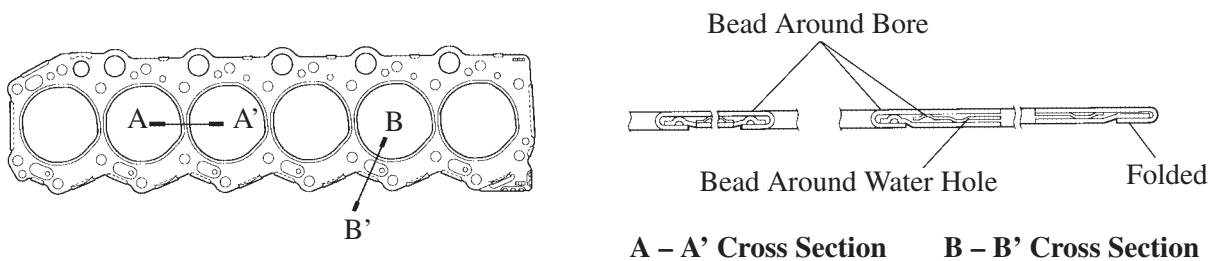


147EG102

147EG49

3. Cylinder Head Gasket

- A 3-layer steel laminate type cylinder head gasket has been adopted.
- The gasket has adopted a bead construction at its cylinder bores, water holes, and oil holes. The periphery of the gasket has been folded to accept bearing stress. This prevents unnecessary bearing stress from being applied to the sealing portions such as at the bores, thus restraining the deformation of the bores over the cylinder block.



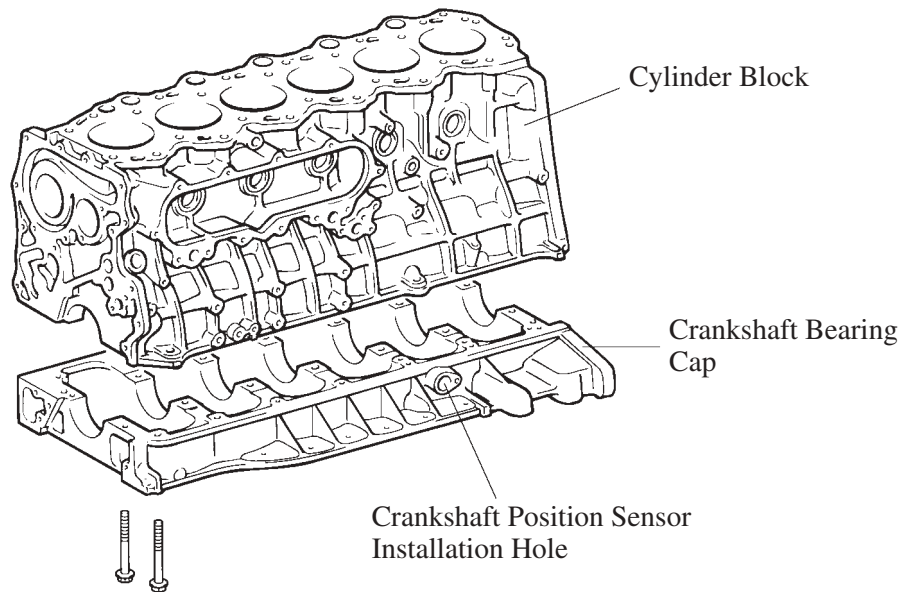
A – A' Cross Section

B – B' Cross Section

147EG50

4. Cylinder Block

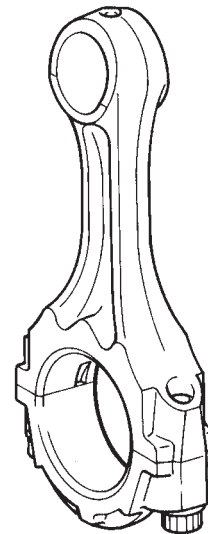
- Crankshaft bearing caps with a ladder frame construction have been adopted as in the previous model. To accommodate the high performance engine, the ladder frame has been optimally designed to improve its rigidity while restraining the increase of its weight, thus reducing noise and vibration.
- Along with the adoption of the engine control system, the hole for installing the crankshaft position sensor is provided in the crankshaft bearing cap.



147EG51

5. Connecting Rod

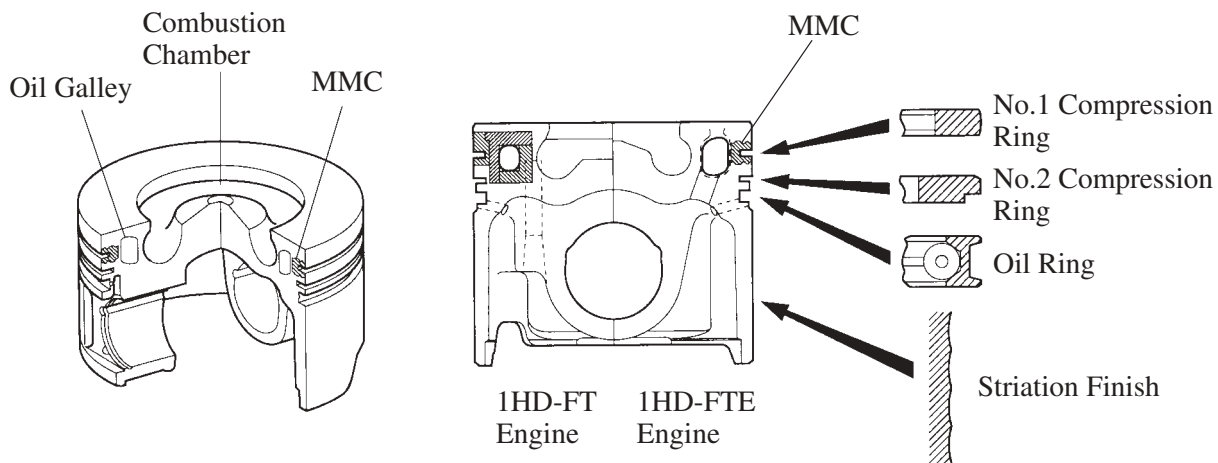
- The connecting rod is made of a lightweight carbon steel that withstand higher speed and high output operation.
- The small end of the connecting rods has been given a tapered shape to reduce weight.



147EG52

6. Piston

- The piston is made of aluminum alloy that offers high temperature strength. The top ring groove has been treated with MMC (Metal Matrix Composites) to improve its wear resistance.
- The combustion chamber has been designed with an optimal shape to improve the engine performance while reducing exhaust emissions.
- The piston skirt has been designed with an optimal shape to reduce noise and vibration.
- The cross sectional area of the oil galley in the piston has been enlarged to improve the piston's cooling performance and reduce its temperature during high power output.
- A gas nitriding process has been applied to the piston ring surface to improve its durability and reduce the piston ring tension, thus reducing the friction loss.



147EG53

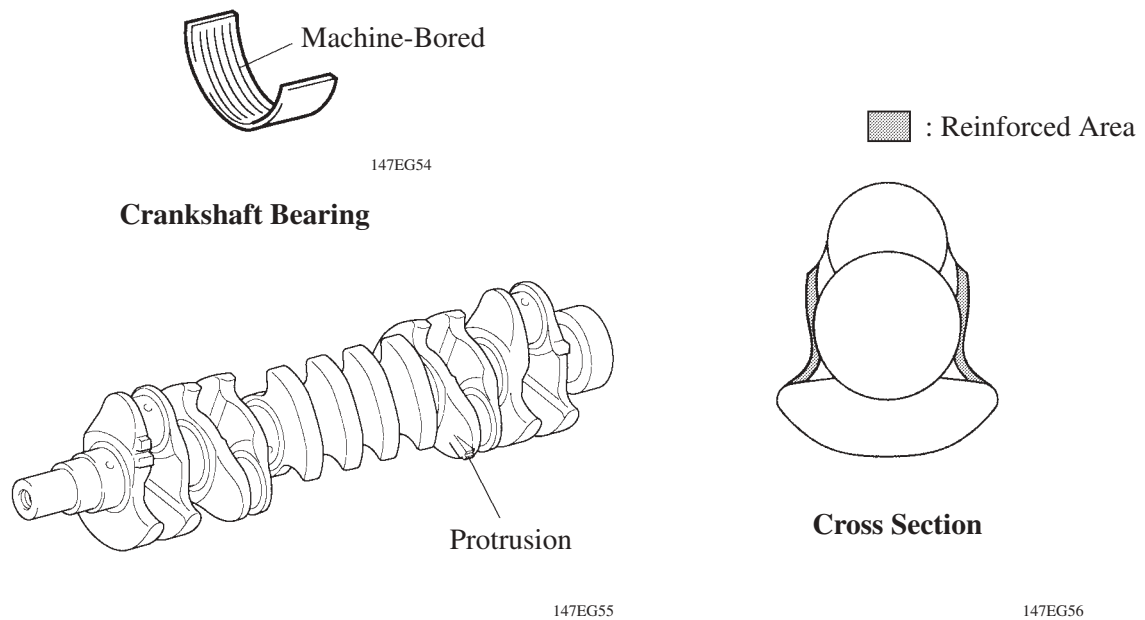
– REFERENCE –

MMC (Metal Matrix Composites)

It is a type of composite material that is made of a metal matrix for the purpose of obtaining characteristics such as high strength, high elasticity, and low thermal expansion. Because of its excellent heat transmission performance, this material helps to dissipate the piston's heat through the piston ring to the cylinder block.

7. Crankshaft

- As in the previous engine, a crankshaft with 7 forged journals and 12 balance weights has been adopted. Along with the high performance of the engine, the rigidity of its arms and the balance rate of its weights have been improved.
- Along with the adoption of the engine control system, a protrusion is provided for the crankshaft position sensor.
- The inner surface of the crankshaft bearing has been machine-bored to provide minute crests and valleys in the circumferential direction. This process helps to improve the bearing's break-in and engine oil retention, thus improving the reliability of the engine.

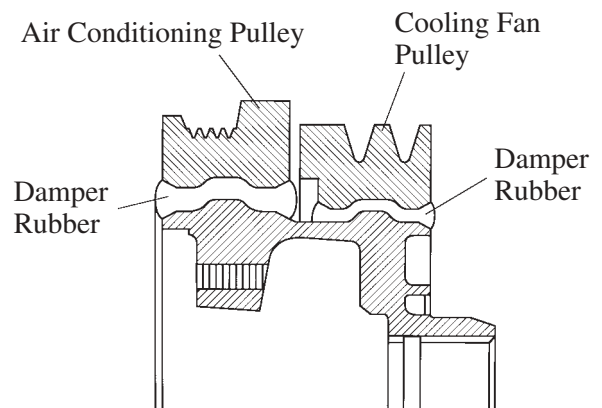


EG

8. Crankshaft Pulley

A torsional damper pulley has been adopted to reduce noise and vibration.

The pulley for air conditioning, which had previously been retrofitted, has now been integrated with the pulley for the cooling fan. At the same time, the pulley's inertial moment has been improved and a high-damping rubber damper has been adopted to further reduce noise and vibration.

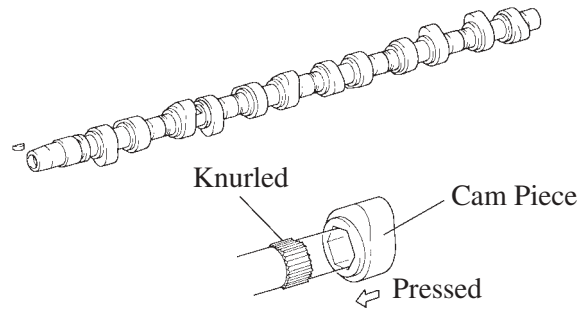


147EG57

■ VALVE MECHANISM

1. Camshaft

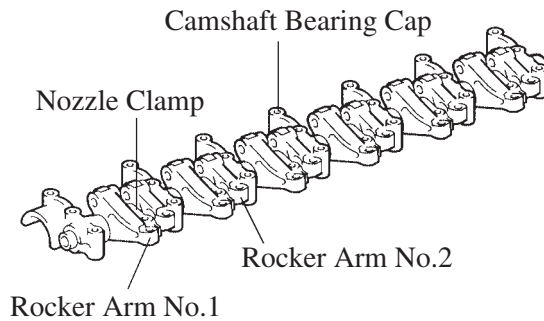
- As in the previous engine, an assembled type camshaft in which cam pieces that are pressed over the knurled shaft has been adopted.
- The shaft is made of carbon steel and is hollow for weight reduction.



147EG59

2. Rocker Arm Shaft

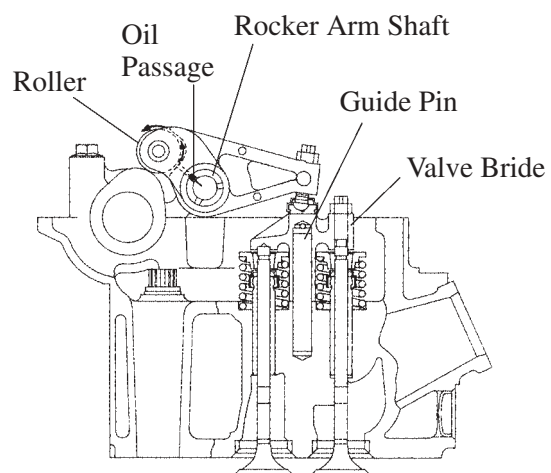
The rocker arm shaft, to which the rocker arms, nozzle clamps, and camshaft bearing caps are attached, is mounted on the cylinder head via the camshaft bearing caps.



147EG60

3. Rocker Arm and Valve

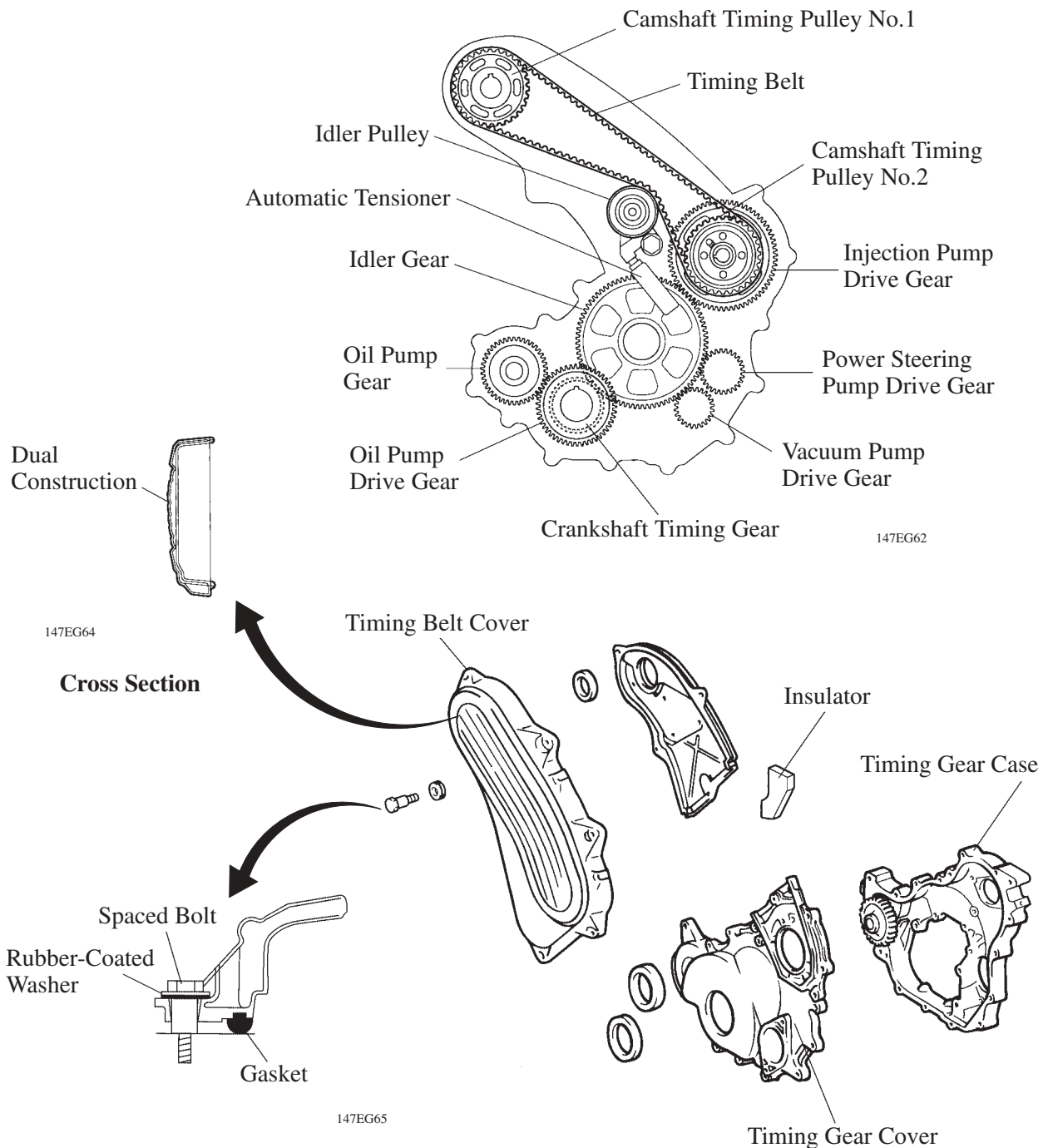
- As in the previous engine, the rocker arms are made of aluminum and use rollers to improve wear resistance and to reduce friction loss.
- The length of the exhaust valve has been extended so that the valve in its fully closed state is positioned closer to the piston in order to reduce the unnecessary amount of space in the combustion chamber. As a result, the combustion efficiency has been improved and exhaust emissions have been reduced.



147EG61

4. Timing Gear Train

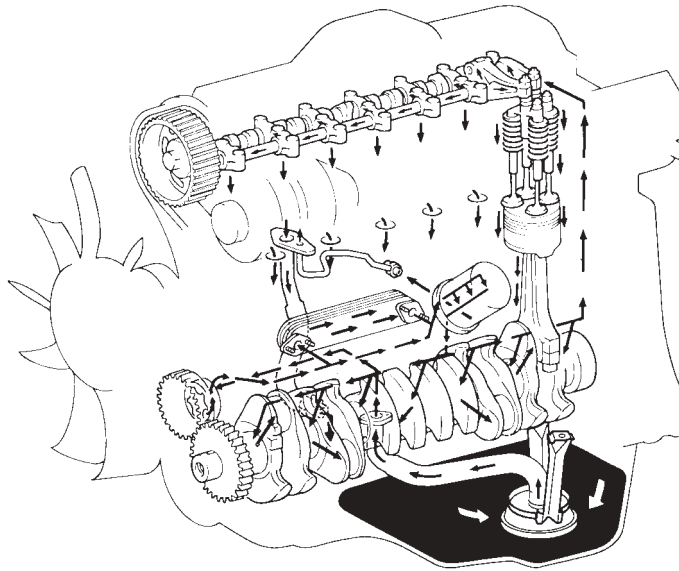
- As in the previous engine, an OHC mechanism that is driven by a belt and gears has been adopted.
- The backlash between the crankshaft timing gear, idle gear, and the injection pump drive gear has been reduced and the precision of the gear tooth flank has been improved to reduce noise.
- A bearing is used between the idle gear and the idler gear shaft to improve reliability.
- The timing belt cover has adopted a dual construction cross sectional shape containing an air layer and the portion that attaches to the engine has adopted a floating construction to reduce noise.
- The timing belt cover gasket uses foam rubber that is integrated with the cover to improve serviceability.
- A hydraulic type automatic tensioner has been adopted.



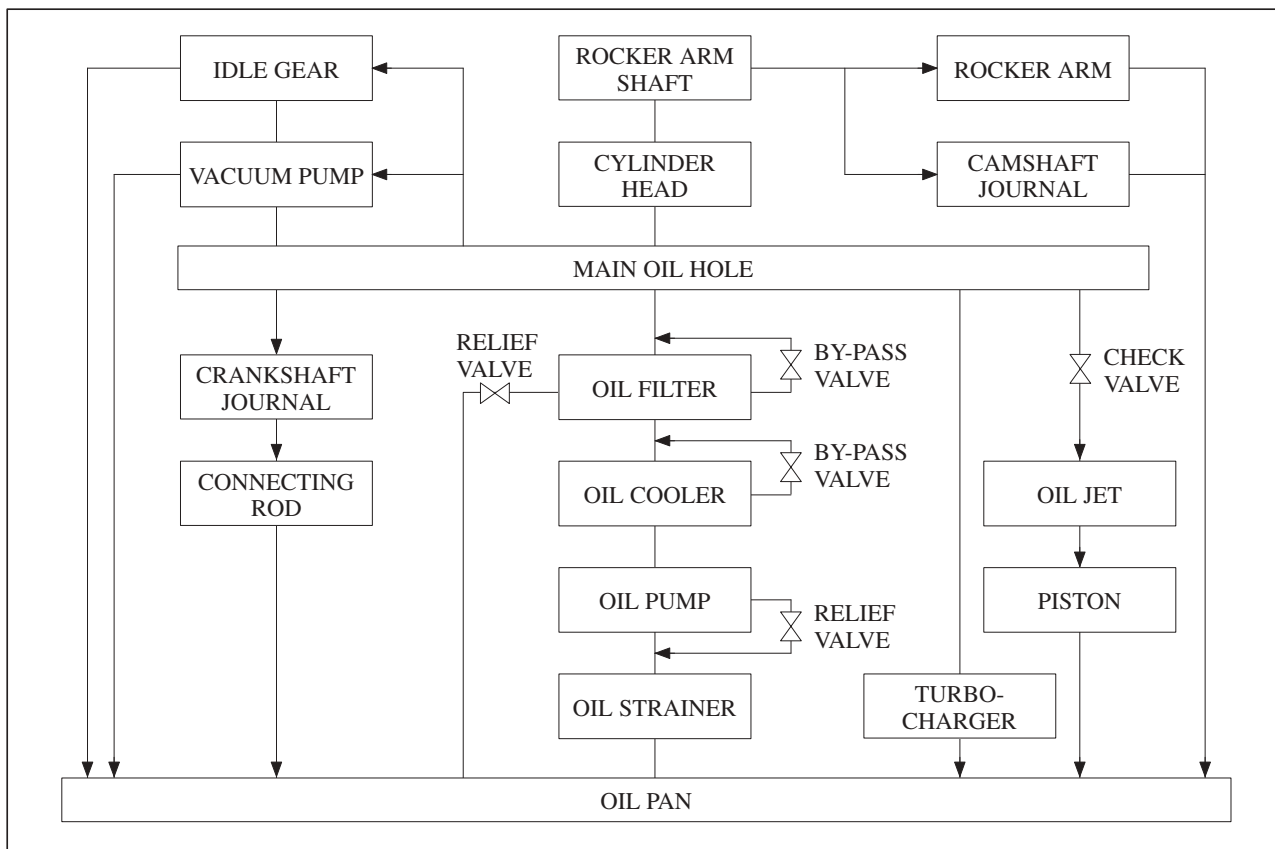
■ LUBRICATION SYSTEM

1. General

- The lubrication circuit is fully pressurized and all oil passes through an oil filter.
- A trochid gear type oil pump is directly driven by crankshaft.
- The water-cooled type engine oil cooler is used to lower the oil temperature.

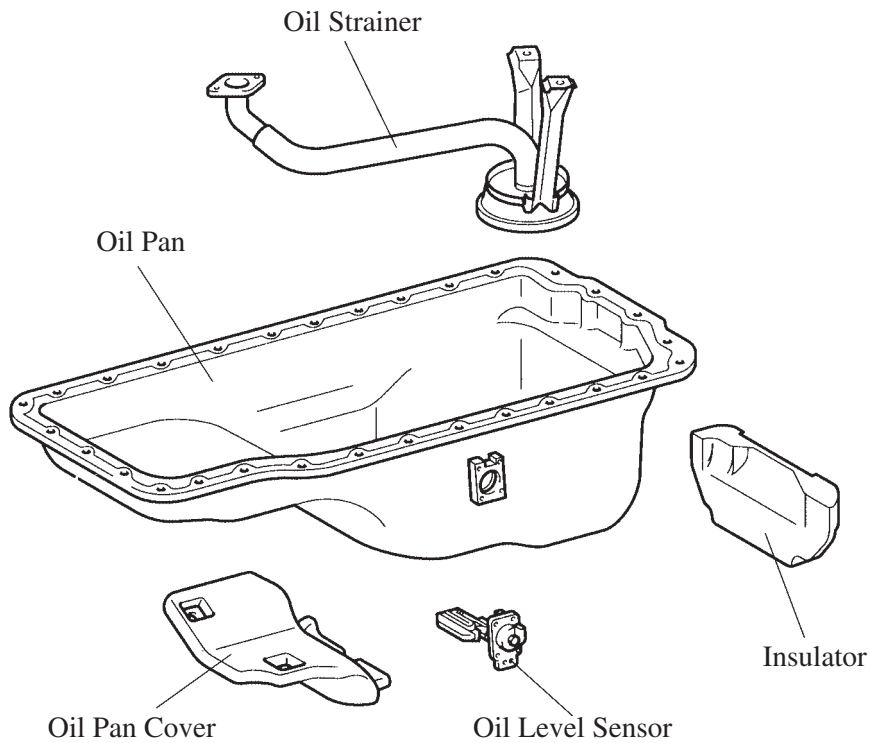


147EG66



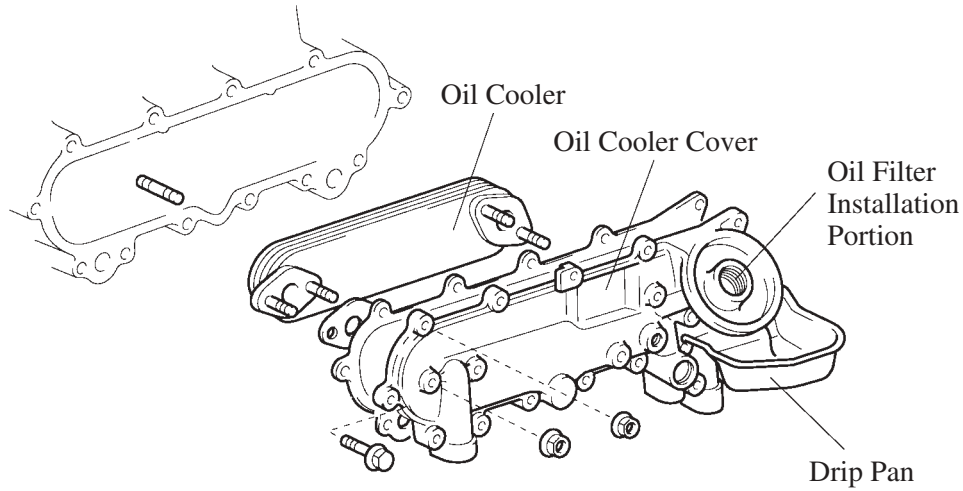
2. Oil Pan and Oil Strainer

- As in the previous engine, a vibration damping steel plate is used for the oil pan for quieter operation. In addition, an oil pan cover and an insulator have been installed for noise reduction.
- The curvature of the oil strainer pipe has been increased and the length of the pipe has been shortened to reduce the oil intake resistance, thus improving the oil pressure build-up when the engine is started.
- An oil level sensor is provided in the oil pan for efficient servicing.
When the oil level falls below the specified level, the oil level sensor causes the low engine oil level warning light inside the combination meter to light up.
- The oil capacity of the oil pan has been increased by changing the shape of the oil pan.



3. Oil Cooler

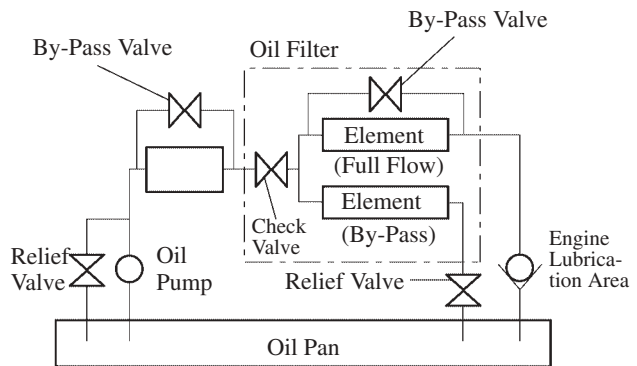
- The water-cooled oil cooler is enclosed in the cylinder block.
- A drip pan is provided in the oil cooler cover to catch the oil that could drip when the oil filter is replaced.



147EG68

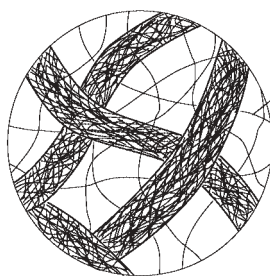
4. Oil Filter

- A twin-element type oil filter, in which a full-flow and bypass elements are combined, is used to increase the cleaning performance of the oil.
- The filter element uses newly developed filter paper to improve the filter's oil cleaning performance.



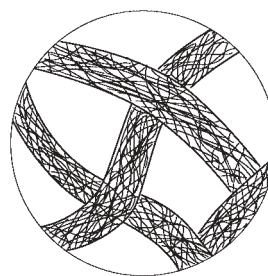
147EG42

► Oil Filter Element ◀



New

Microfilament has been added



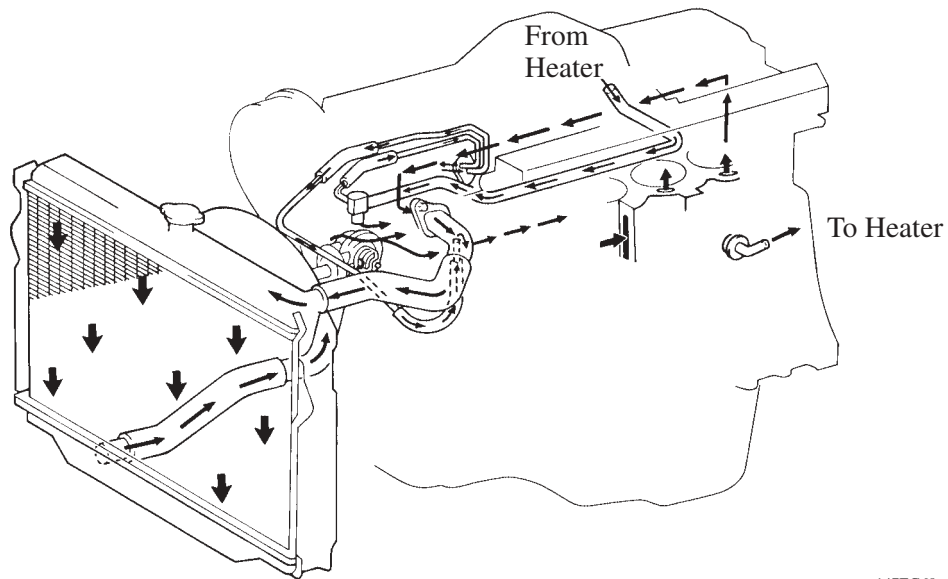
Previous

147EG41

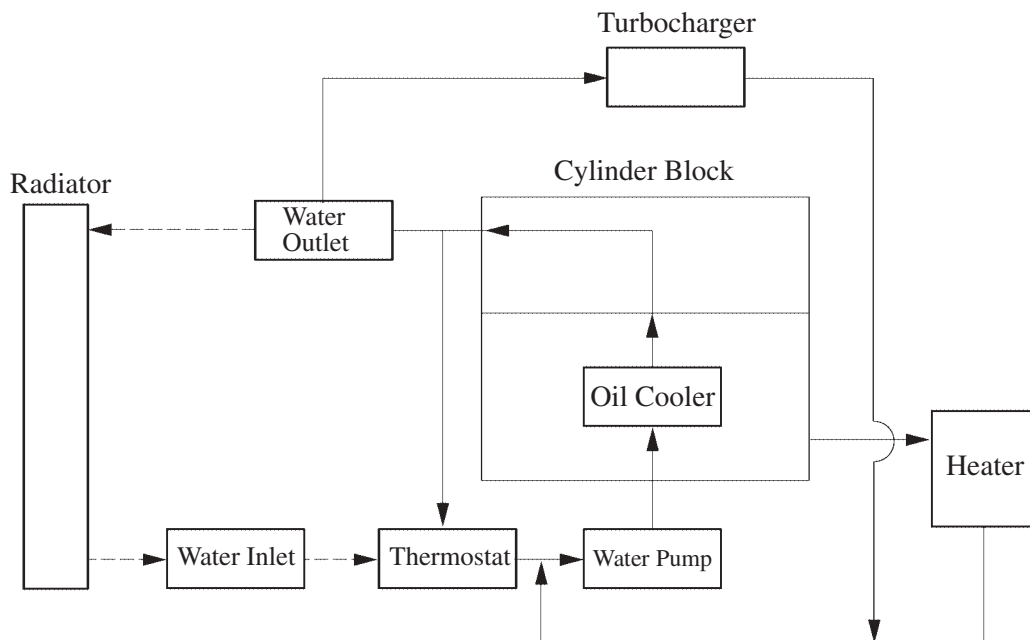
■ COOLING SYSTEM

1. General

- The cooling system is a pressurized, forced-circulation type.
- A thermostat with a bypass valve is located on the water inlet housing to maintain suitable temperature distribution in the cooling system.
- An aluminum radiator core is used for weight reduction.
- A viscous type power heater has been adopted on the cold specification model for Europe to promote the warming of the engine and to improve the heating performance of the heater during extremely cold temperatures.



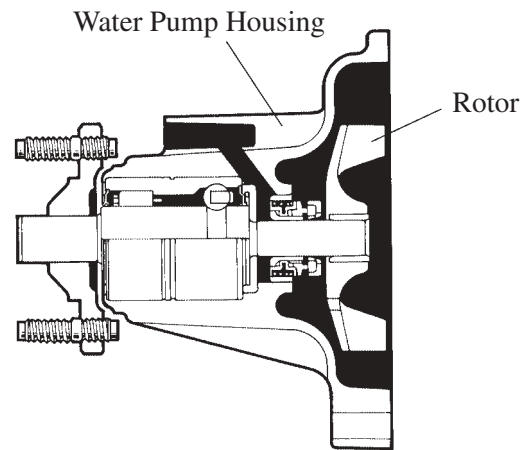
147EG69



147EG43

2. Water Pump

As in the previous engine, the water pump housing is made of aluminum and the rotor is made of resin for weight reduction. In addition, the volute chamber has been optimally designed to achieve a compact shape.

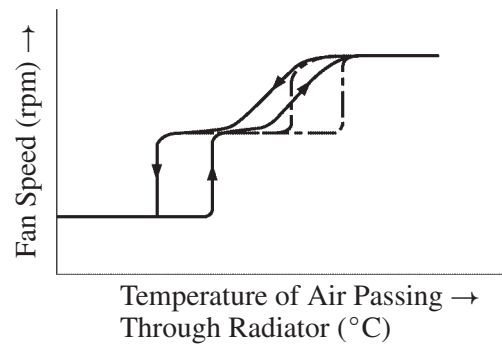


147EG70

3. Coupling Fan

A step-up linear type temperature controlled fluid coupling has been adopted to realize both cooling performance and noise reduction.

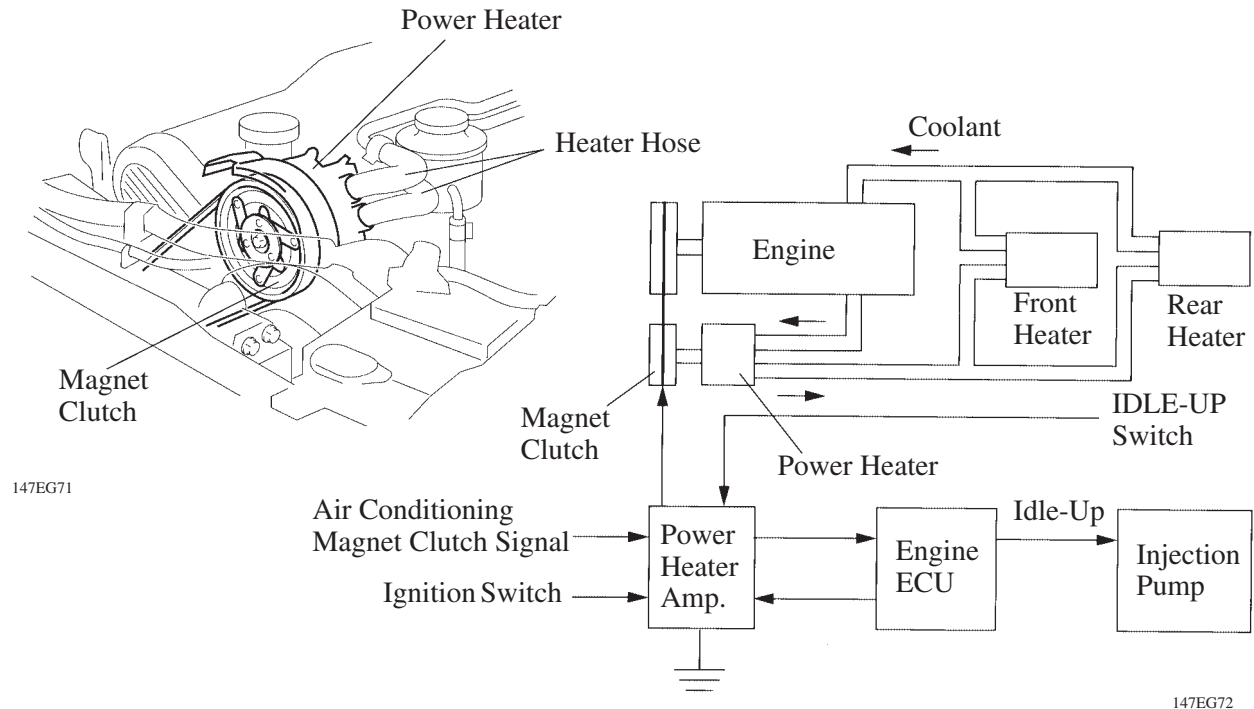
———— : Step-Up Linear Type
 - - - - : 3-Stage Type



147EG06

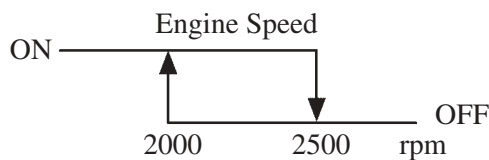
4. Power Heater

A viscous type power heater has been adopted on the cold specification model for Europe. The power heater increases the coolant temperature by utilizing the shear heat of the silicon oil and by increasing the engine load.

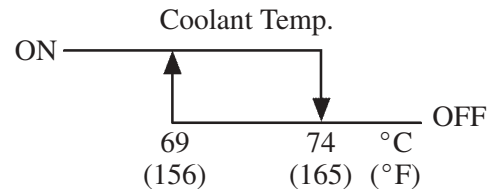


Construction and Operation

- The power heater, which is located on top of the engine, is driven by a drive belt. Pressing the Idle-Up switch provided in the instrument panel engages the magnetic clutch, causing the rotor in the power heater to rotate and the silicon oil to mix. The shear heat that is thus generated heats the coolant.
- The power heater is controlled according to engine speed and coolant temperature as described below. While the power heater is engaged, the engine idling speed increases to 1200 rpm.



147EG44-1



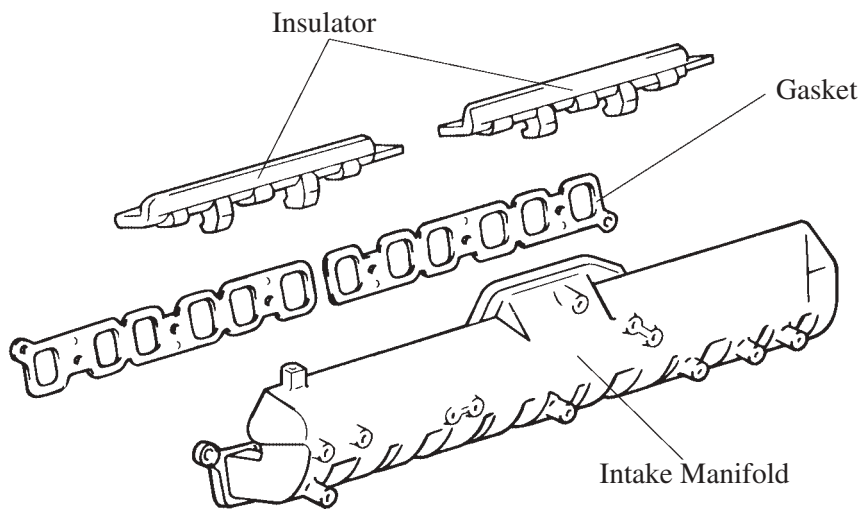
147EG44-2

However, the power heater is turned OFF when the engine is started, the air conditioning is ON, or the vehicle is accelerating (for 5 seconds while the vehicle speed is under 30 km/h (19 mph) and the throttle opening angle is more than 45%).

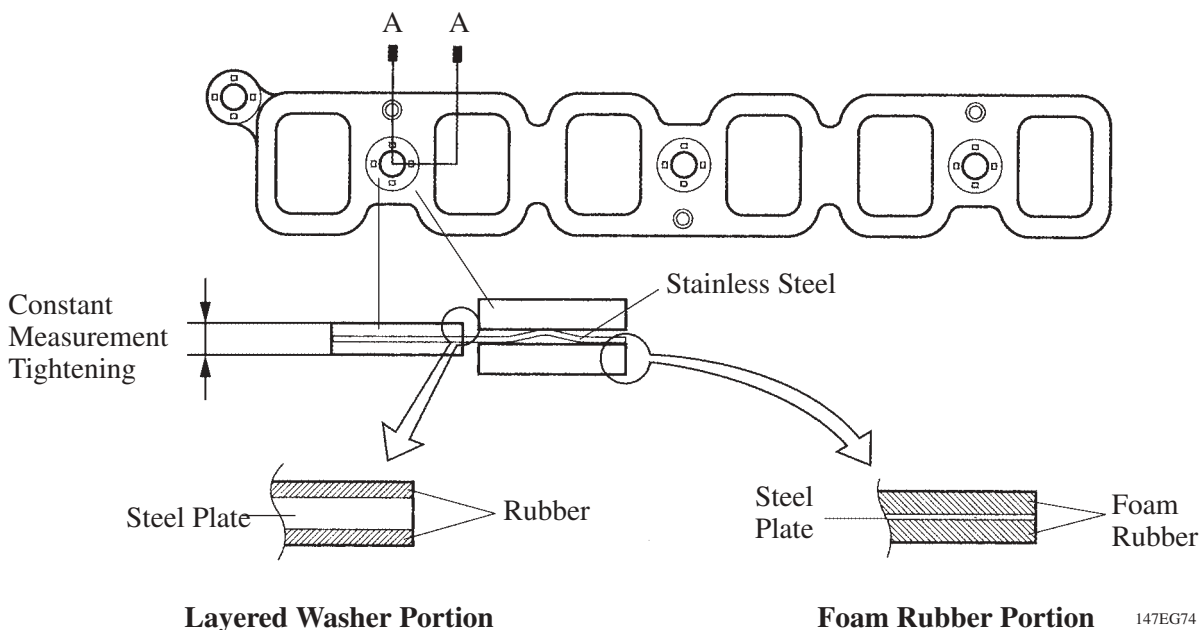
■ INTAKE AND EXHAUST SYSTEM

1. Intake Manifold

- As in the previous engine, an intake manifold made of aluminum and integrated with the intake air chamber has been adopted. In addition, a large-capacity intake air chamber and isometric intake ports have been adopted to improve the engine performance.
- Insulators are provided at the area of the intake manifold that mounts onto the cylinder head for noise reduction.
- The intake manifold gasket is constructed of steel plates that are coated with foam rubber on both sides, then riveted to the both sides of a stainless steel substrate. A composite gasket cinched with layered washers is provided for the areas that are tightened with bolts to achieve a floating retaining construction of the intake manifold for noise reduction.
- Vibration isolating washers with a layered construction have been adopted for the washers used in installing the intake manifold.



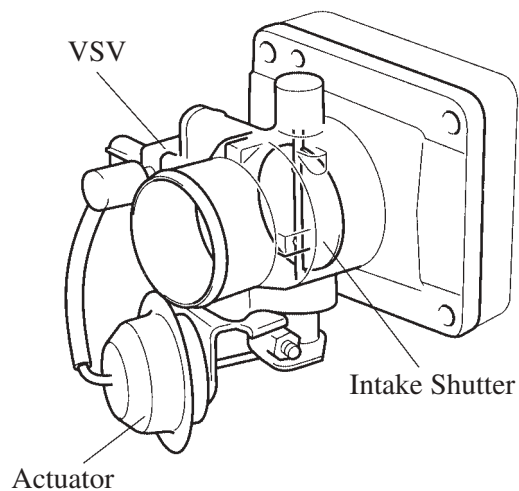
147EG73



147EG74

2. Intake Shutter

The intake manifold is provided with an intake shutter which shuts out air to reduce vibration when stopping the engine.

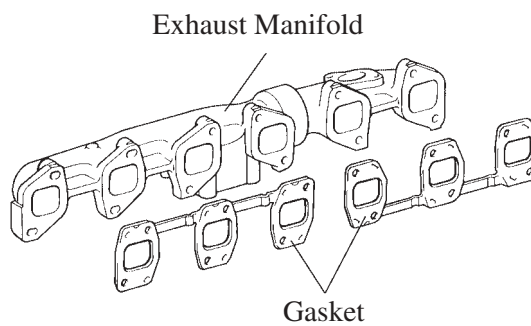


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EG

3. Exhaust Manifold

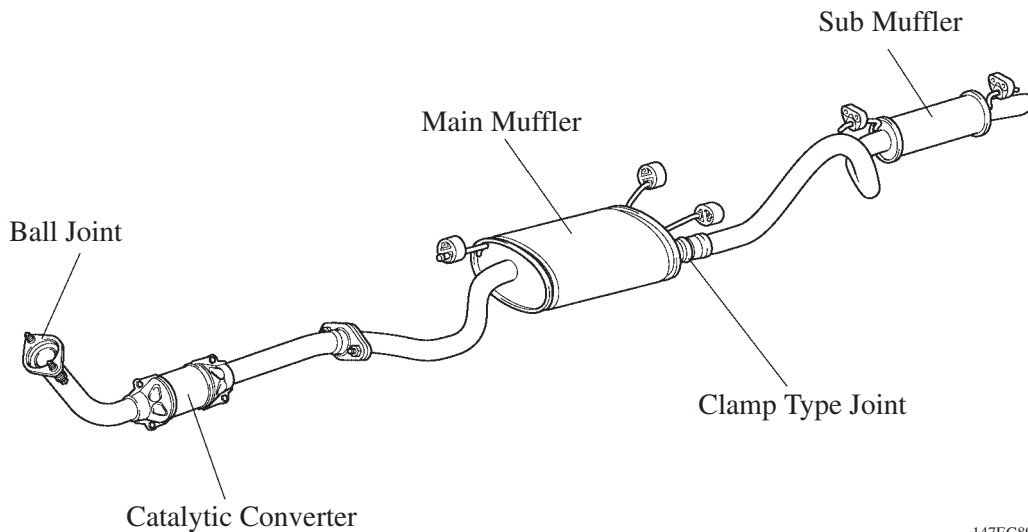
- As in the previous engine, an exhaust manifold made of cast iron has been adopted.
- A 5-layer steel laminate type exhaust manifold gasket has been adopted.



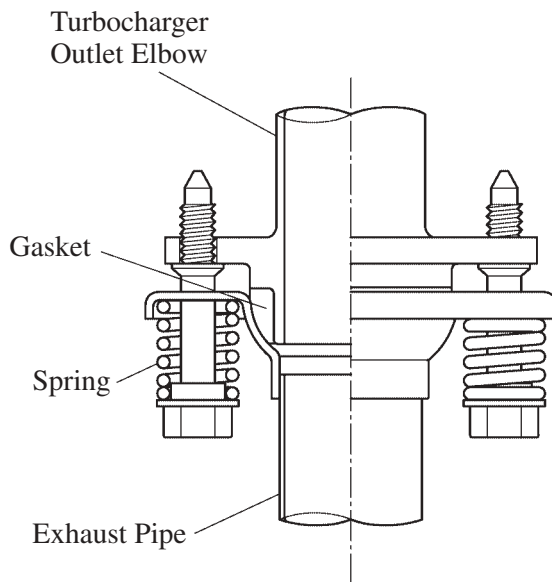
147EG76

4. Exhaust Pipe

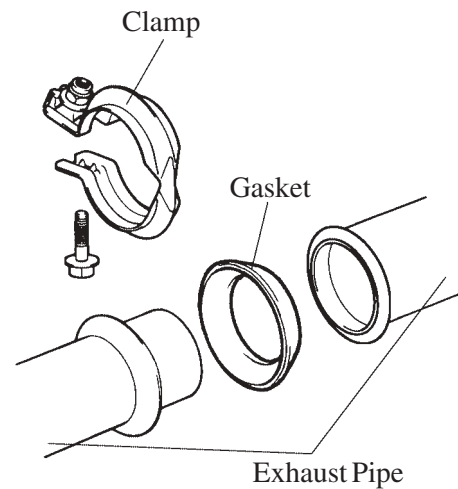
- The exhaust pipe is made of stainless steel for improved rust resistance.
- An oxidation catalytic converter has been adopted for the front exhaust pipe to reduce exhaust emissions.
- A ball joint has been adopted for joining the turbocharger and the front exhaust pipe for weight reduction and for reducing noise and vibration.
- A clamp type joint is used to join the center exhaust pipe and tail pipe to realize weight reduction.



147EG89

**Ball Joint**

147EG58

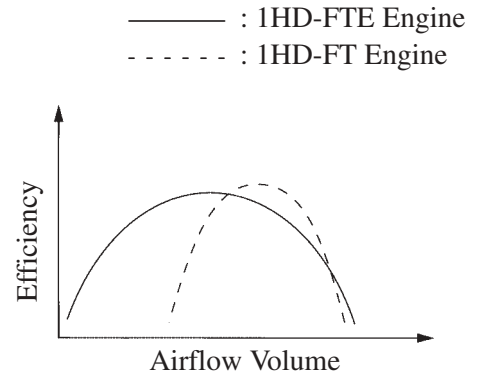
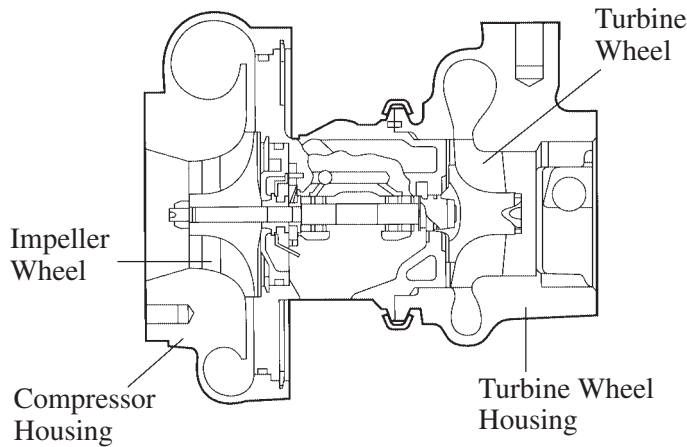
**Connecting Exhaust Pipe**

156EG06

■ TURBOCHARGER SYSTEM

1. Turbocharger

In place of the previous turbocharger, a compact and lightweight turbocharger that achieves a wide range of high-efficiency region has been adopted.



Conceptual Drawing

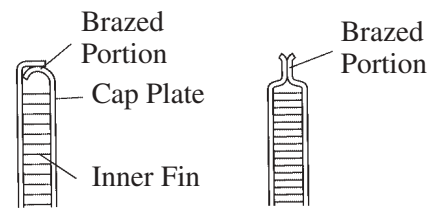
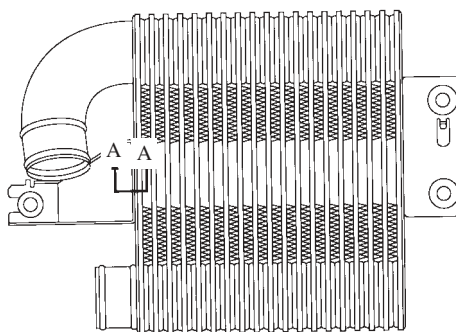
147EG77

147EG90

EG

2. Intercooler

- An air-cooled type intercooler has been adopted to lower the intake air temperature. As a result, the volumetric efficiency has been improved to enhance the engine performance and reduce exhaust emissions.
- Through the adoption of an overlap type drawn cup, a high-density core, and optimally shaped fins, the intercooler has been made more compact and lightweight while ensuring ample heat dissipating performance.



Overlap Type Drawn Cup

Ordinary Drawn Cup

A – A' Cross Section

147EG78

147EG79

– REFERENCE –

Overlap Type Drawn Cup

It is a type of cup in which the vertical surface of the cup plate is brazed in order to effectively utilize the brazed portion between the cup plates that ordinarily remains a dead space.

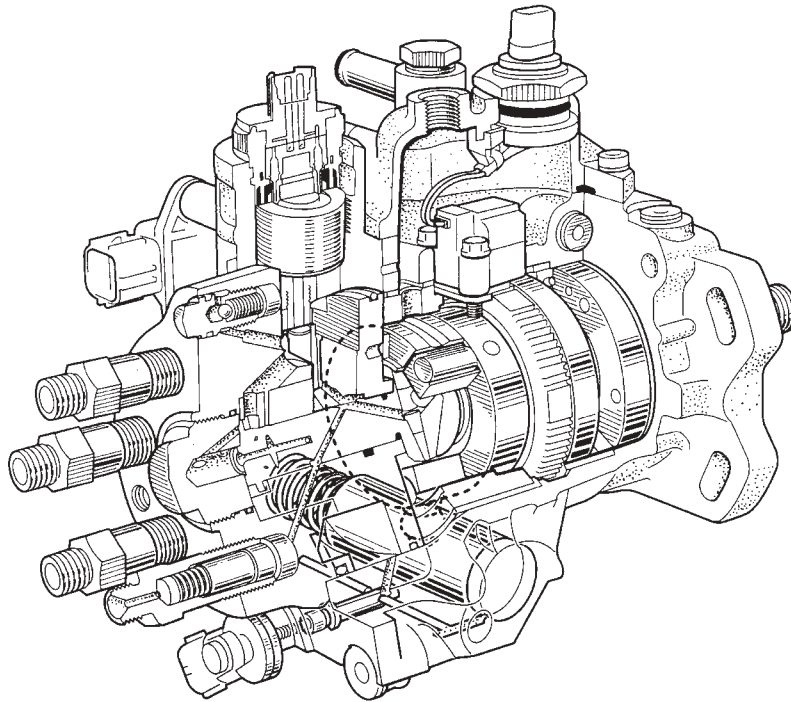
FUEL SYSTEM

1. Injection Pump

General

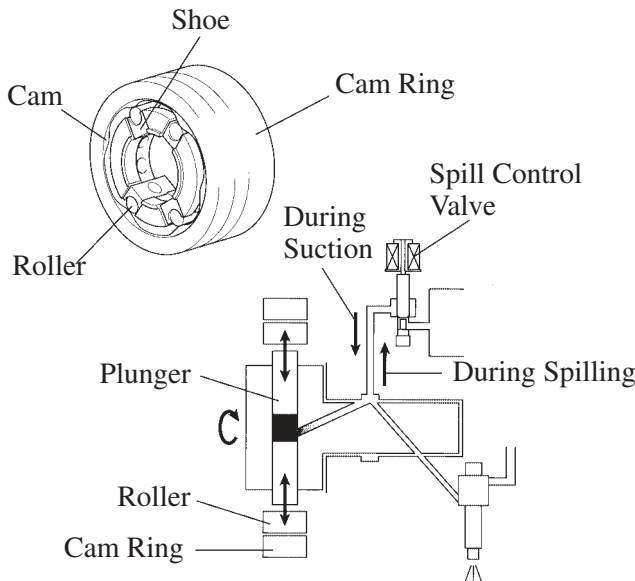
An electronically controlled distributor type injection pump has been adopted. A radial plunger type that produces a higher injection pressure than the previous axial plunger type has been adopted. As a result, it has become possible for the injected fuel to become finely atomized in order to realize both improved engine performance and reduced exhaust emissions.

In the axial plunger type pump, the rollers slip as they roll along the cam plate. Because this slippage does not occur in a radial plunger type pump, it can inject fuel at a higher pressure.



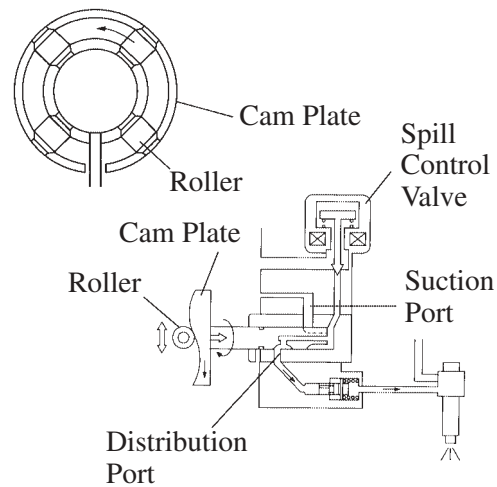
147EG80

Radial Plunger Type Injection Pump



Radial Plunger Type

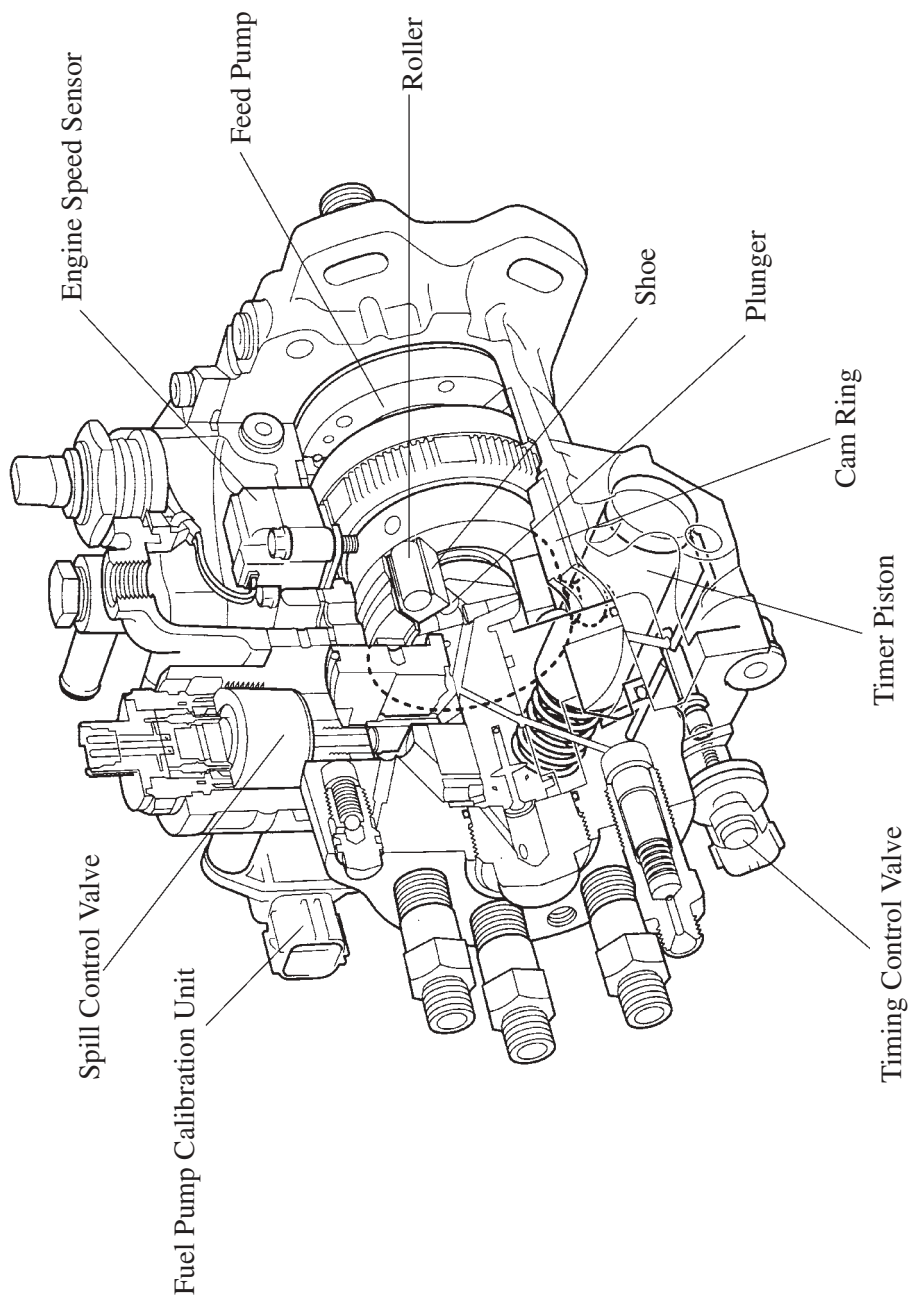
147EG92



Axial Plunger Type

147EG93

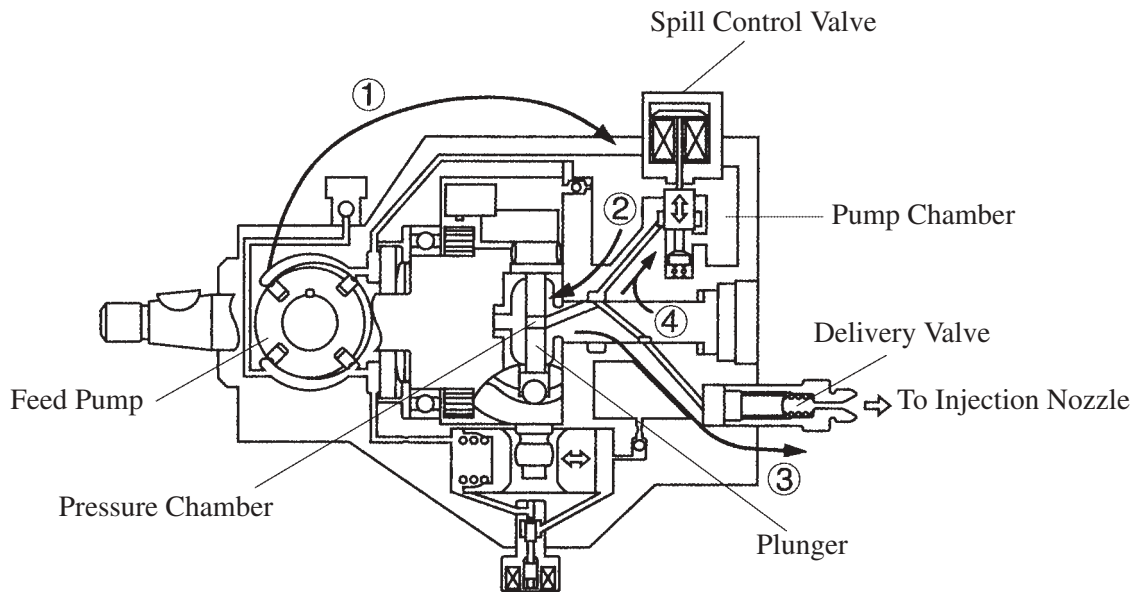
Construction and Operation



147EG81

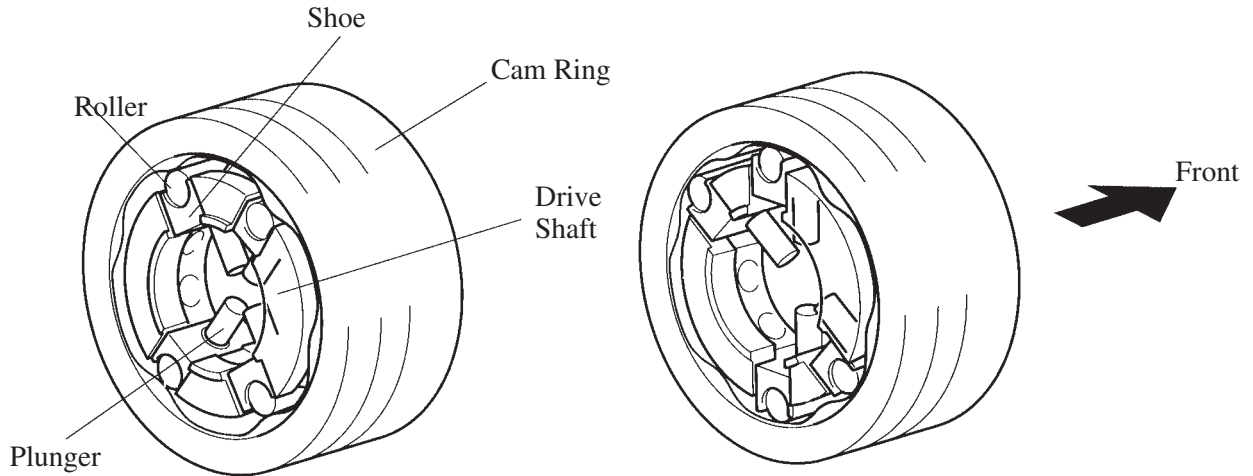
1) Operation Outline

- ①: The feed pump delivers the fuel from the fuel tank to the pump chamber and maintains its pressure between 1.5 – 2.0 MPa.
- ②: When the spill control valve opens, the fuel fills the pressure chamber.
- ③: After the spill control valve closes, the fuel that is charged in the pressure chamber is compressed by the plunger. Passing through the delivery valve and injection pipe, the pressurized fuel is pumped to the injection nozzle and injection starts.
- ④: As the spill control valve opens and the pressure in the pressure chamber drops, the injection of fuel is completed.



2) High-Pressure Generation Mechanism

This mechanism consists of a cam ring, drive shaft, rollers, shoes and plungers. As the drive shaft rotates, the shoes, rollers and the plungers that are attached to the shaft rotate along the inside of the cam ring. At that time, the protrusions on the cam ring cause the 4 rollers and plungers to move simultaneously to the center, causing the fuel pressure to increase.



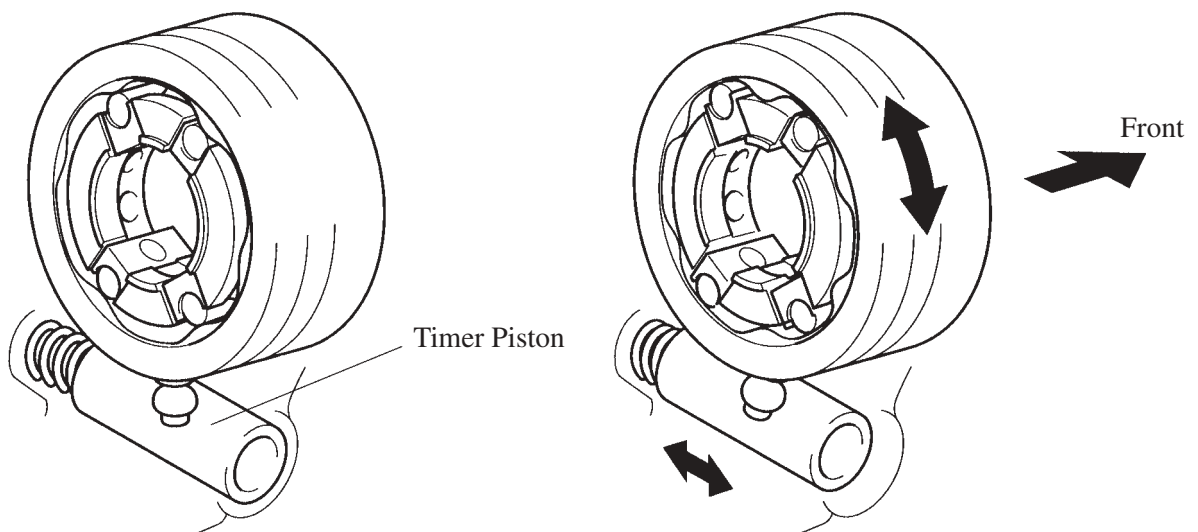
During Generation of High Pressure

During Suction

147EG83

3) Timer Mechanism

The movement of the timer piston, which is linked to the cam ring, causes the cam ring to oscillate. As a result, the relational positions of the drive shaft and the cam ring change, which causes the plunger to compress the fuel, thus changing the starting position (injection timing).



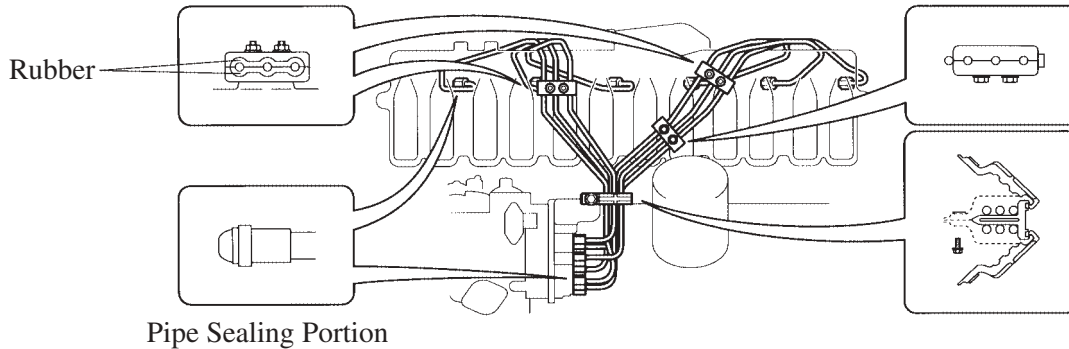
Most Retarded Timing

During Operation

147EG84

2. Injection Pipes

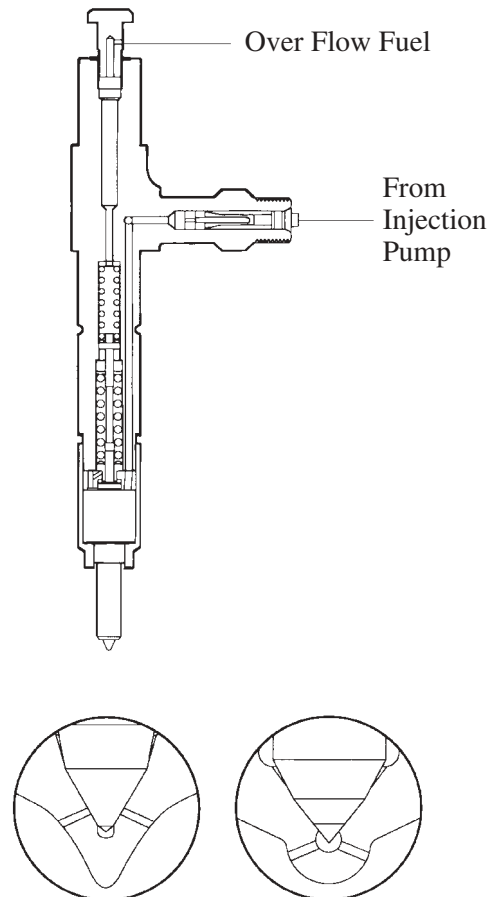
- Along with the adoption of the high-pressure injection, the seal portions at the both ends of the pipes have been spherically shaped to improve their sealing performance.
- The pipes are clamped together up in the air adjacent to the injection pump. Also, at the areas where the pipes are clamped to the intake manifold, rubber cushions are used to achieve a floating construction. As a result, improved reliability and quieter operation have been realized.



147EG85

3. Injection Nozzle

- As in the previous engine, 2-stage injection nozzles are used. For this model, the amount of pre-lift has been decreased to reduce the combustion sound.
- The VCO (Valve Covered Orifice) nozzles that provide excellent injection characteristics have been adopted to reduce white smoke and exhaust odor.
- The nozzle needle seats more gently to improve the nozzle's durability.



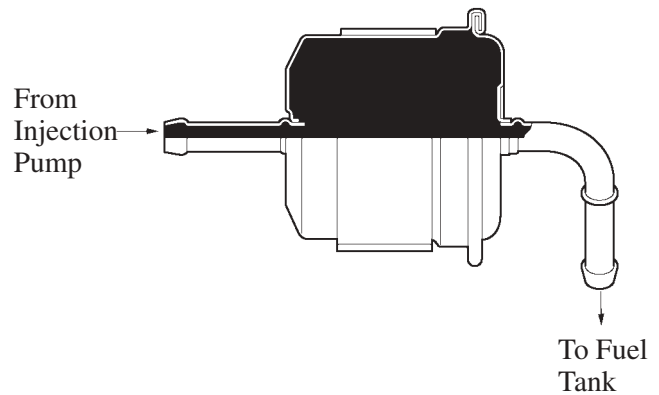
**1HD-FTE
Engine**

**1HD-FT
Engine**

147EG86

4. Fuel Damper

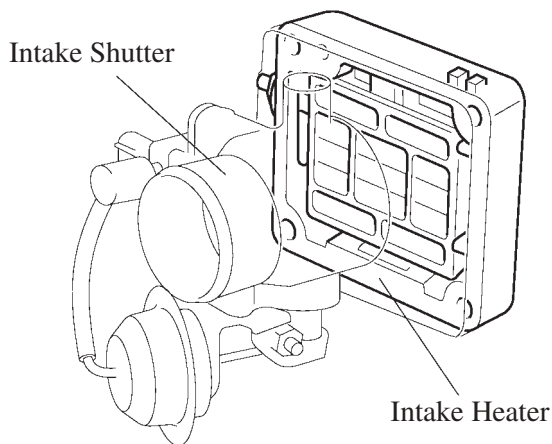
A fuel damper has been adopted to reduce the vibration of the fuel return pipe.



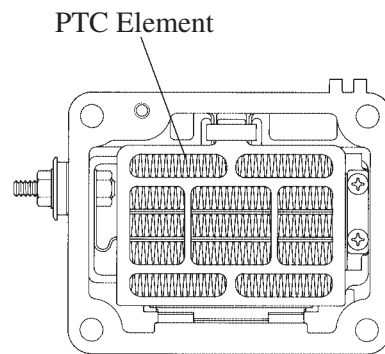
147EG128

■ INTAKE HEATER

- An intake heater has been adopted to heat the intake air at low temperature to improve the cold starting performance of the engine. The intake heater continues to operate for a prescribed length of time even after the engine has started in order to reduce the generation of diesel knocks and white smoke immediately following the starting of the engine.
- The intake heater uses a PTC (Positive Temperature Coefficient) element and is controlled by the engine ECU.



147EG87



Intake Heater

147EG88

■ STARTING SYSTEM

The previous 12/24 volt switchover system has been discontinued to simplify the system. The resistance in the wiring between the batteries and the starter is minimized by connecting the batteries in parallel in order to ensure the same level of starting performance as that of the previous model.

■ ENGINE CONTROL SYSTEM

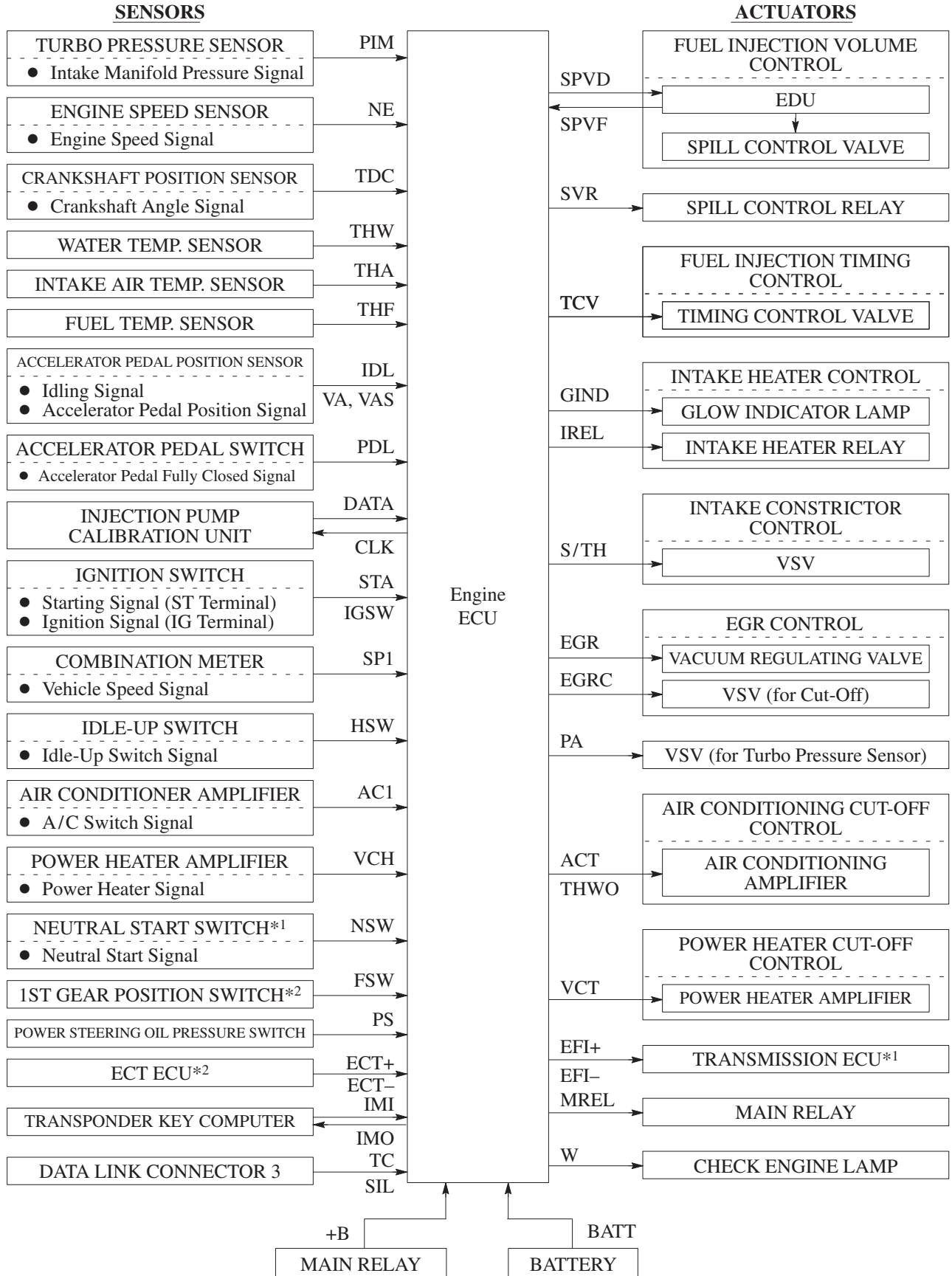
1. General

To operate the engine in an optimal condition. The engine control system of the 1HD-FTE engine has general control of the following functions: fuel injection volume control, fuel injection timing control and idle speed control. In addition, a diagnosis function has been added to improve the serviceability of the engine. Furthermore, the cruise control system has been enclosed in the engine ECU.

System	Outline
Fuel Injection Volume Control	<ul style="list-style-type: none"> ● Based on the signals received from the sensors, the engine ECU determines the fuel injection volume in accordance with the engine condition. ● In vehicles equipped with automatic transmission, torque control compensation during gear shifting is used to minimize the shift shock.
Fuel Injection Timing Control	Based on the signals received from the sensors, the engine ECU determines the fuel injection timing in accordance with the engine condition.
Idle Speed Control	The engine ECU determines the idle speed in accordance with the engine condition, and controls the fuel injection volume in order to achieve the target idle speed.
Stable Idling Control	Corrects the fuel injection volume that is directed to each cylinder during idling, thus reducing engine vibration.
Cruise Control	Controls the vehicle speed by regulating the injection volume in accordance with the instructions received from the cruise control computer that is integrated in the engine ECU.
Intake Constrictor Control	Shuts off the intake air to reduce the vibration when the engine stopped.
Intake Heater Control	Controls the length of time when the current is applied to the Intake Heater in accordance with the coolant temperature.
EGR Control	Controls the engine EGR volume in accordance with the engine condition.
Air Conditioning Cut-Off Control	<ul style="list-style-type: none"> ● By controlling the air conditioning compressor ON or OFF in accordance with the engine condition, drivability is maintained. ● Also controls the power heater on the models equipped with a power heater.
Engine Immobiliser	Prohibits fuel delivery if an attempt is made to start the engine with an invalid ignition key.
Diagnosis	<ul style="list-style-type: none"> ● When the engine ECU detects a malfunction, the engine ECU diagnoses and memorizes the failed section. ● A newly developed diagnostic system which utilizes a high speed bi-directional communication line to provide extended diagnostic capabilities and features.
Fail-Safe	When the engine ECU detects a malfunction, the engine ECU stops or controls the engine according to the data already stored in memory.

2. Construction

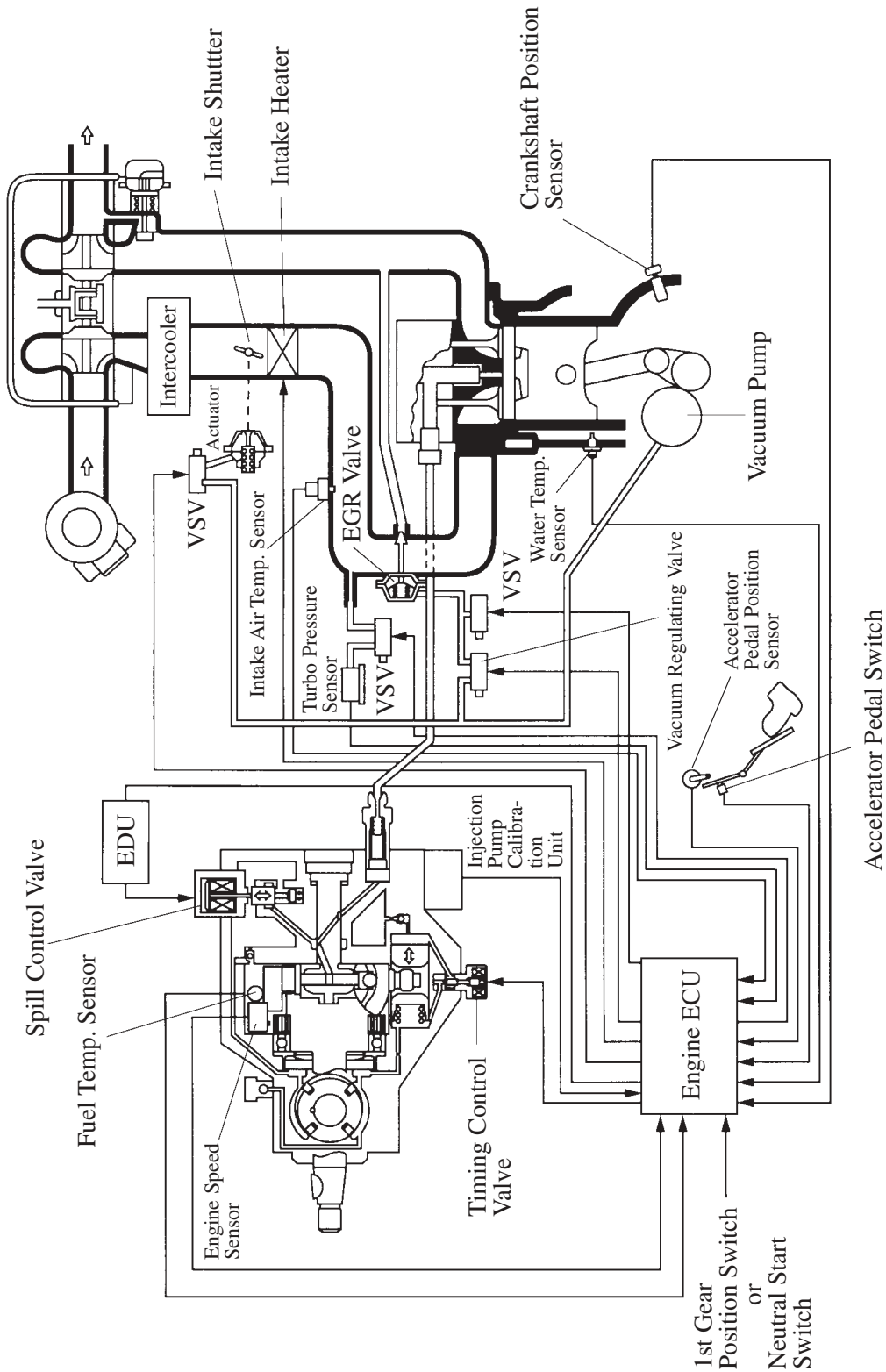
The configuration of the engine control system which can be broadly divided into three groups: the engine ECU, the sensors and the actuators, is shown in the following chart.



EG

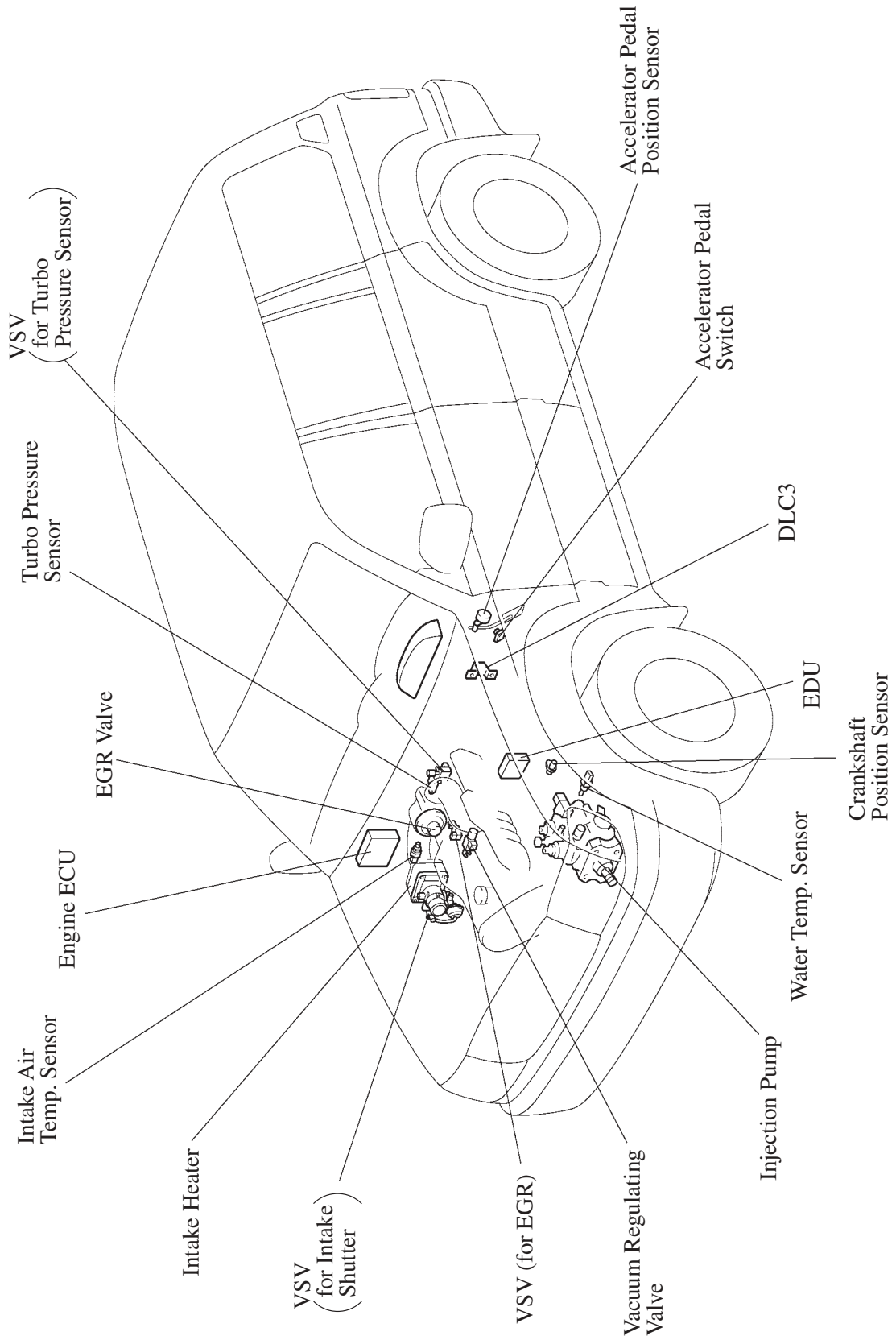
*1: Only for Automatic Transmission Model *2: Only for Manual Transmission Model

3. Engine Control System Diagram



147EG94

4. Layout of Components



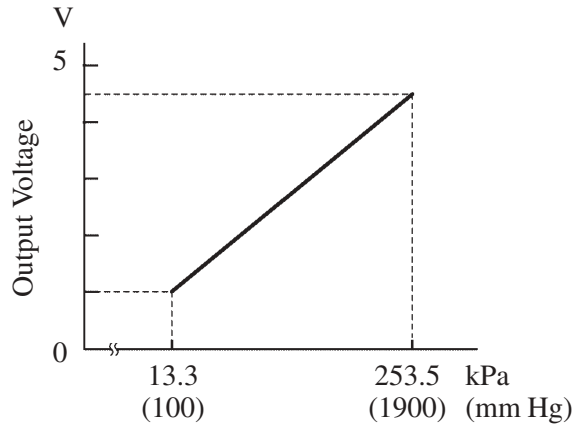
147EG101

5. Main Components of Engine Control System

Turbo Pressure Sensor

The turbo pressure sensor consists of a semiconductor which utilizes the characteristic of a silicon chip that changes its electrical resistance when pressure is applied to it. The sensor converts the intake air pressure into an electrical signal, and sends it to the engine ECU in an amplified form.

In addition, the atmospheric pressure can be detected by switching the piping passage through the operation of the VSV.

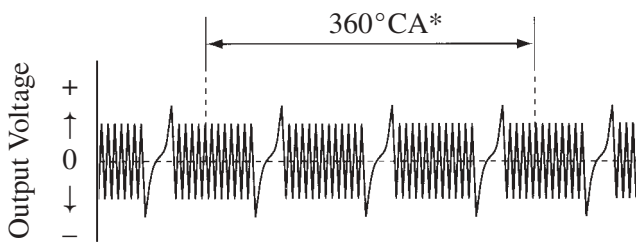


147EG103

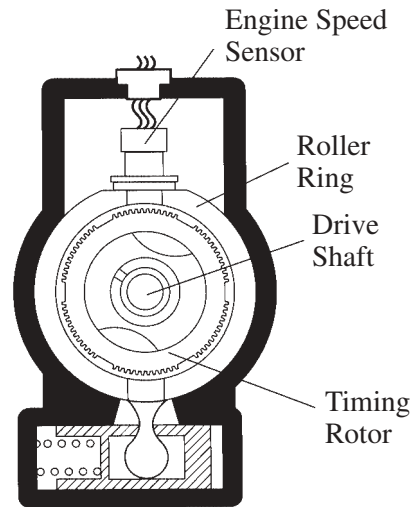
Turbo Pressure Sensor Output Characteristics

Engine Speed Sensor

The engine speed sensor is attached to the roller ring in the injection pump to detect the engine speed. The timing rotor is attached to the drive shaft. Missing 3 teeth at each of the 6 locations, the timing rotor generates a signal every 7.5° (crankshaft angle) with its 78 teeth.



147EG95

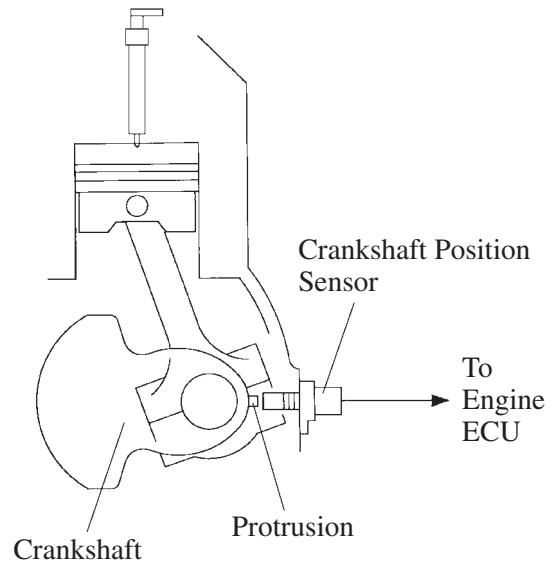


147EG98

*: CA (Crankshaft Angle)

Crankshaft Position Sensor

The crankshaft position sensor is attached to the cylinder block. Using the protrusion that is provided on the crankshaft, the sensor generates 1 signal for every revolution. This signal is then sent to the engine ECU as a crankshaft position signal.



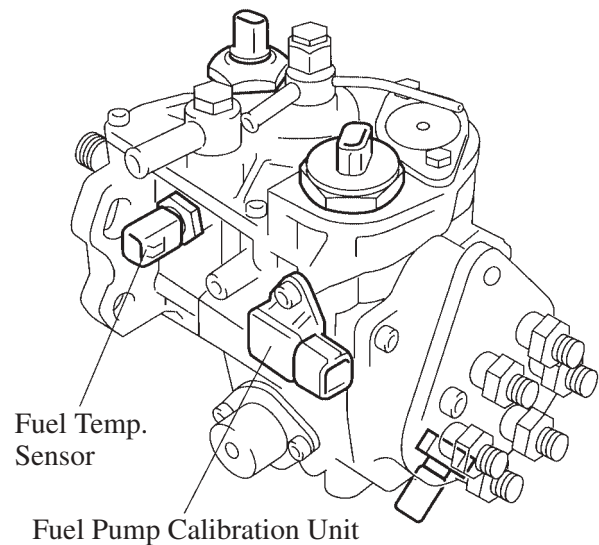
147EG91

Fuel Temperature Sensor

The fuel temperature sensor is attached to the injection pump, and uses an internal thermistor to detect the fuel temperature.

Fuel Pump Calibration Unit

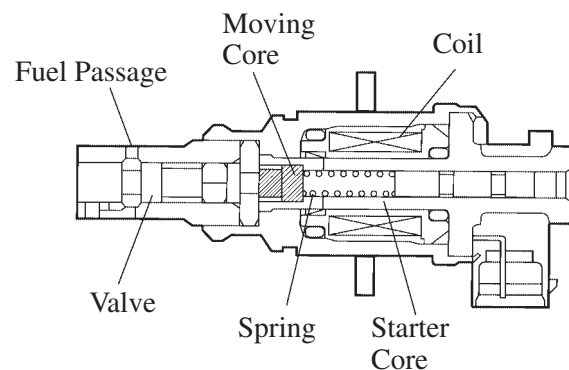
To compensate for the shift in injection volume and injection timing caused by the variances in the injection pump itself, a correction is made by using the data that is stored in the ROM in the fuel pump calibration unit.



147EG97

Timing Control Valve

The timing control valve is attached to the injection pump. In accordance with the signals from the engine ECU, it opens the valve in the fuel passage between the pump chamber and the suction side, thus controlling the injection timing. When the current flows to the coil of the timing control valve, the starter core becomes an electromagnet to push and compress the spring. This causes the moving core to retract and open the fuel passage.



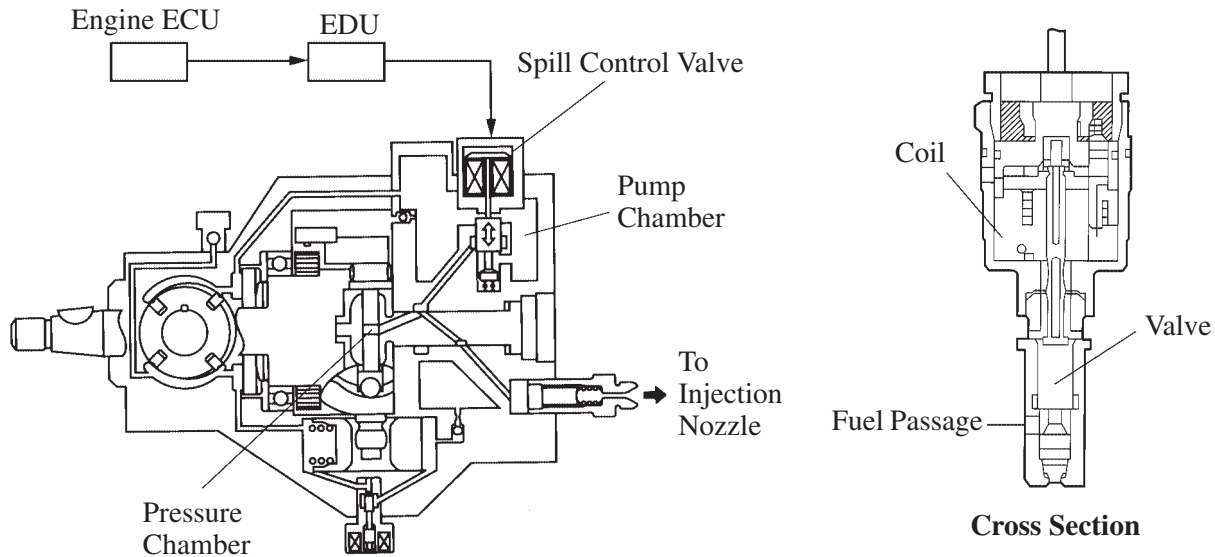
147EG99

Spill Control Valve

The spill control valve is attached to the injection pump to control the fuel injection volume in accordance with the signals received from the engine ECU.

When the spill control valve is turned OFF, the passage between the high-pressure chamber and the pump chamber opens, causing the pressure in the high-pressure chamber to drop. This completes the injection of the fuel from the injection nozzle.

The length of time till the spill control valve is turned OFF becomes the fuel injection time. Thus, the fuel injection volume is controlled by increasing or decreasing the length of time till the spill control valve is turned OFF.



Acceleration Position Sensor

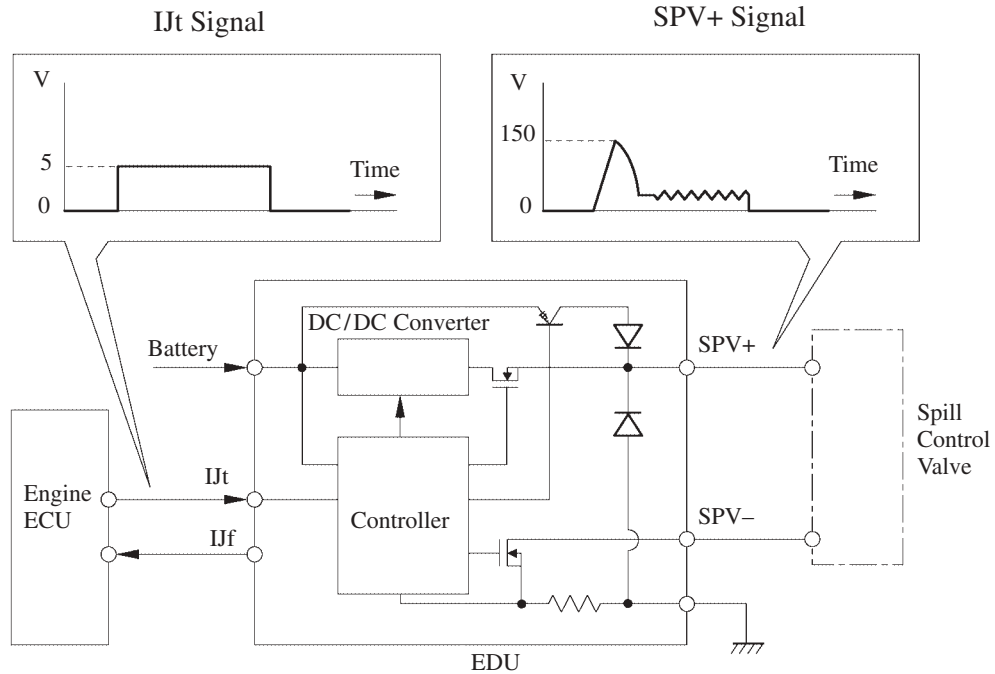
- The accelerator position sensor uses a Hall element that outputs voltage that changes linearly in relation to the amount of pedal effort that is applied to the accelerator pedal.
The accelerator position sensor uses a duplex system to ensure its reliability.
- An idle switch that detects the fully closed condition of the accelerator pedal is enclosed in the accelerator pedal position sensor.

Accelerator Pedal Switch

Attached to the accelerator pedal in addition to the accelerator pedal position sensor, the accelerator pedal switch detects the fully closed condition of the accelerator pedal.

EDU (Electronic Driving Unit)

- The EDU has been adopted to drive the spill control valve at high speeds. The EDU has realized high-speed driving under high fuel pressure conditions through the use of a DC/DC converter that provides a high-voltage, quick-charging system.
- The engine ECU constantly monitors the EDU and stops the engine in case an abnormal condition is detected.



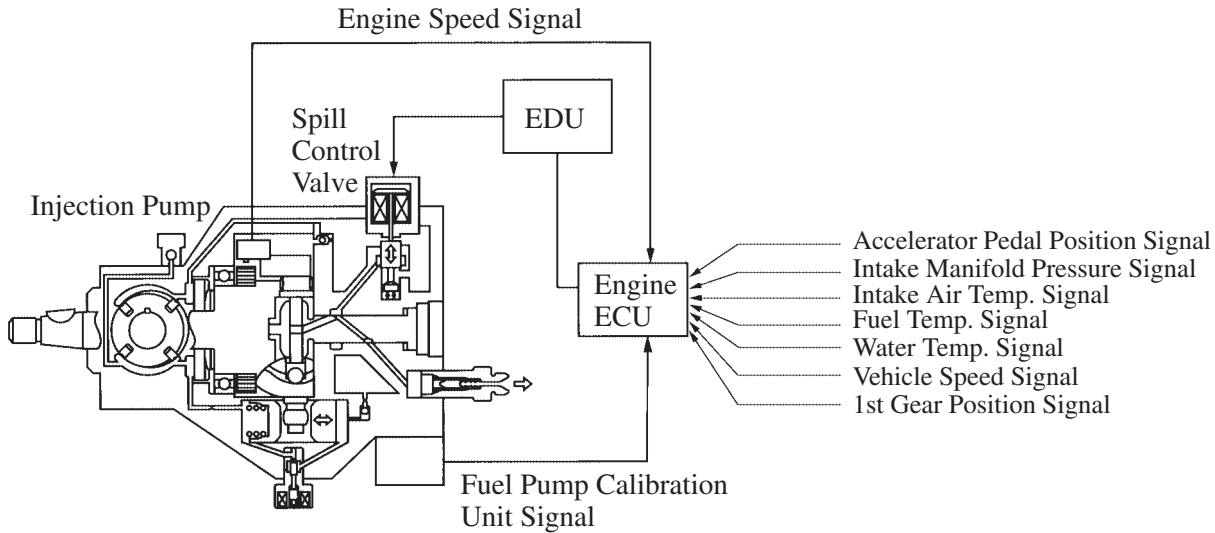
147EG126

Operation

The battery voltage is increased by the DC/DC converter. A voltage of approximately 150V is applied to the spill control valve in accordance with the IJt signal received from the engine ECU. Also at this time, the injection verification signal (IJf) is sent to the engine ECU.

6. Fuel Injection Volume Control

- Based on sensor signals, the engine ECU controls the fuel injection volume by calculating the fuel injection volume that is appropriate for the engine condition.
- On the manual transmission model, the engine's output is limited in 1st gear.



147EG106

Function of Engine ECU

The engine ECU calculates the basic injection volume based on the throttle opening and engine speed, and the maximum injection volume for the engine condition. The two injection volumes are then compared, and the lesser of the two is selected. A correction value, which is obtained via the correction resistors, is added to that injection volume, thus determining the final injection volume.

1) Basic Injection Volume

Determined in accordance with the throttle opening and the engine speed.

2) Maximum Injection Volume

Based on the signals received from the sensors, correction values are added to the theoretically required injection volume (basic maximum injection volume) to determine the maximum injection volume during engine operation.

a. Basic Maximum Injection Volume

Determined in accordance with the engine speed.

b. Intake Manifold Pressure Correction

Corrects the basic maximum injection volume in accordance with the intake manifold pressure. The higher the intake manifold pressure becomes, the larger the injection volume becomes.

c. Intake Air Temperature Correction

Corrects the variance in the air-fuel ratio that is created by the difference in the density of the intake air in accordance with the intake air temperature. The higher the intake air temperature becomes, the smaller the injection volume becomes.

d. Fuel Temperature Correction

Corrects the variance in the injection volume that is created by the difference in the density of the fuel in accordance with the fuel temperature. The higher the fuel temperature becomes, the smaller the injection volume becomes.

e. Water Temperature Correction

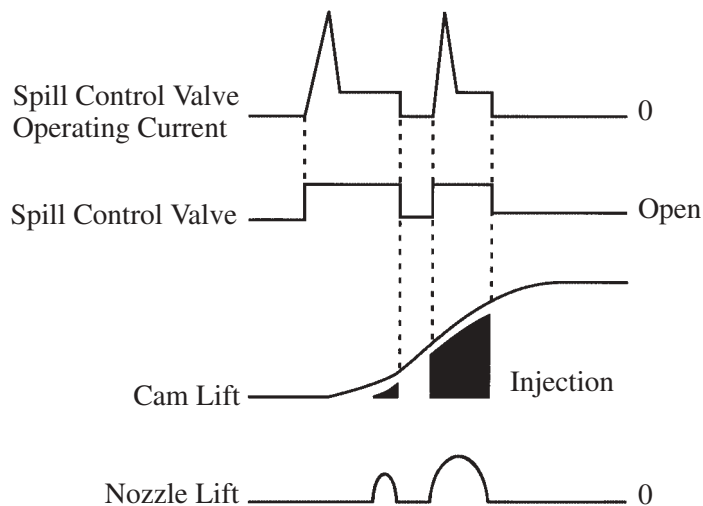
The lower the engine coolant temperature, the greater the injection volume becomes in order to ensure drivability immediately following cold-starting.

3) Starting Injection Volume Control

Determines the fuel injection volume during starting in accordance with the starting signal and the water temperature signal. When the engine is cold, the lower the coolant temperature becomes, the larger the injection volume becomes.

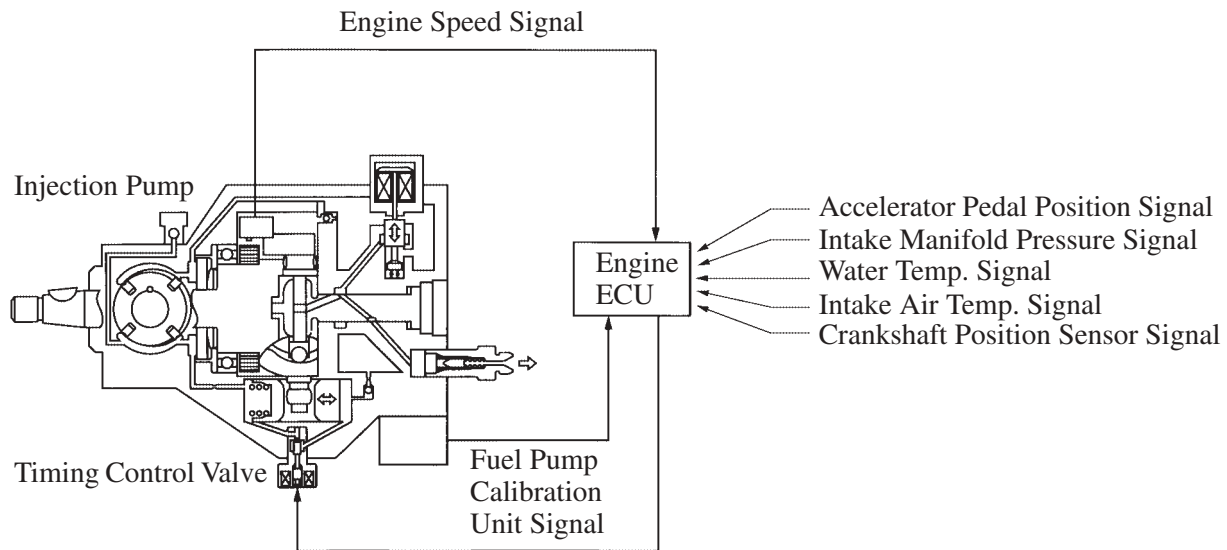
4) Split Injection Control

Split injection is performed when starting the engine at extremely low temperatures in order to improve the startability and greatly reduce the emission of white smoke and black smoke. In contrast to the ordinary injection that occurs once, fuel is injected twice during split injection.



7. Fuel Injection Timing Control

Based on the signals received from the sensors, the engine ECU calculates and controls the fuel injection timing to be optimal for the engine condition.



147EG107

Function of Engine ECU

The engine ECU adds the corrections from the sensor signals to the basic fuel injection timing to calculate the fuel injection timing that is optimal for the engine condition.

1) Basic Injection Timing

The basic injection timing is determined in accordance with the throttle opening and the engine speed.

2) Injection Timing Correction

a. Intake Manifold Pressure Correction

Corrects the basic fuel injection timing in accordance with the intake air pressure. The injection timing is advanced when the intake air pressure is low in such the case as of high altitude areas.

b. Water Temperature Control

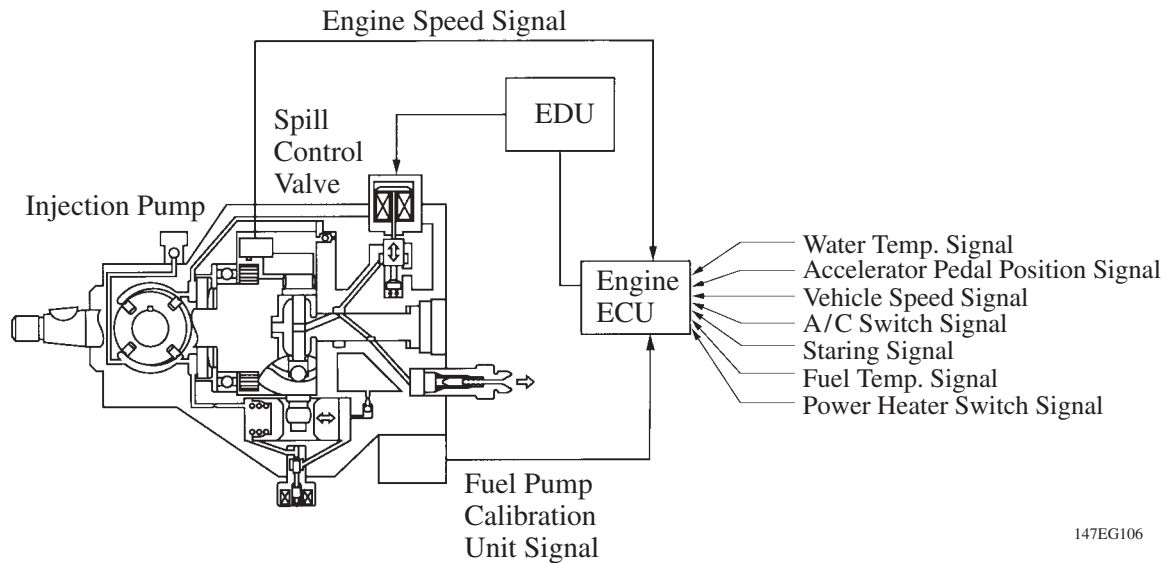
Corrects the basic fuel injection timing in accordance with the water temperature. The injection timing is advanced when the water temperature is low.

3) Starting Injection Timing Control

The starting injection timing is determined in accordance with the starting signal, water temperature signal, and engine speed. The injection timing is advanced when the engine speed is high.

8. Idle Speed Control

- In this system, the engine ECU calculates the target engine speed in accordance with the engine condition, and determines the fuel injection volume, thus controlling the idle speed rpm.
- Increases the idle speed during the operation of the power heater to improve its heating performance.



147EG106

Function of Engine ECU

1) Feedback Control

During idling, the feedback control controls the injection volume to achieve the target idle speed, if there is a difference between the target idle speed calculated by the engine ECU and the actual idle speed.

2) Warm-Up Control

Controls the injection volume during warm-up to achieve an optimal fast idle speed in accordance with water temperature.

3) Engine Speed Change Estimate Control

Immediately after the air conditioning switch is engaged, the idle speed can be affected by the change in the load that is applied to the engine. To prevent this symptom, the engine speed-change estimate control increases or decreases the injection volume before the idle speed changes.

9. Stable Idling Control

Immediately after the air conditioning switch is turned ON or OFF, the load applied to the engine changes, causing the idle speed to fluctuate. To prevent this symptom, the engine speed-change estimate control increases or decreases the injection volume before the idle speed fluctuates.

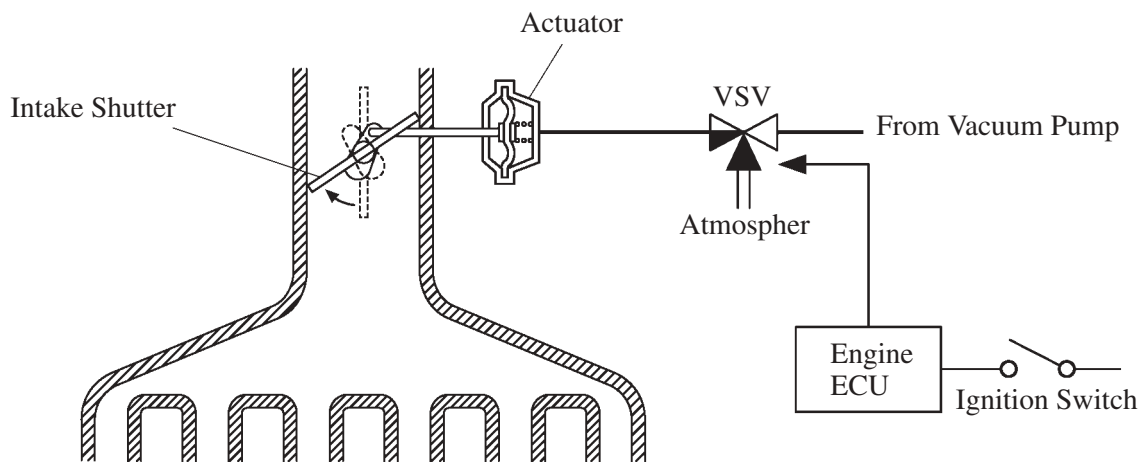
10. Cruise Control

In the previous cruise control system, the cruise control actuator moved the adjusting lever to control the vehicle speed. On this model, however, the injection volume is controlled in accordance with the instructions received from the cruise control computer that is integrated in the engine ECU in order to control the vehicle speed.

11. Intake Air Control

When the engine is stopped, the intake air control system closes the intake shutter that is provided in the intake pipe to shut off the intake air and reduce vibrations.

► System Diagram ◀



147EG104

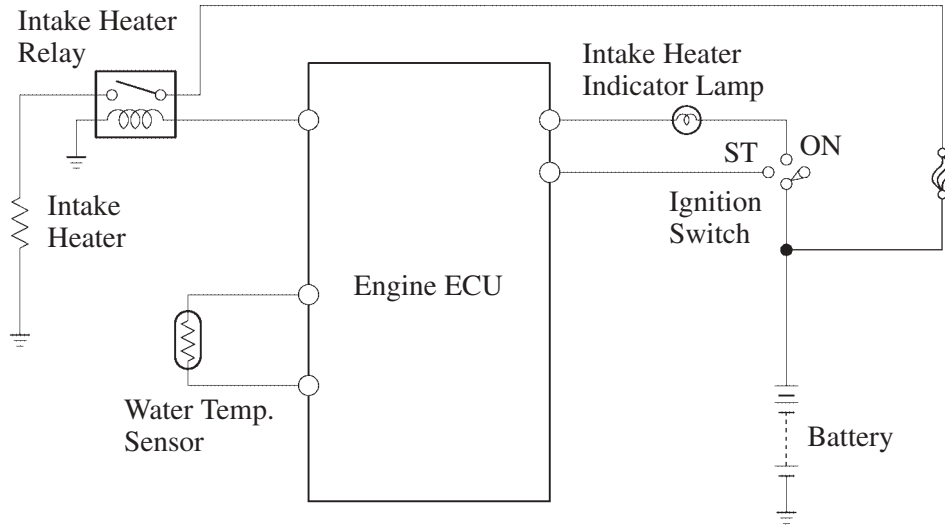
Operation

When the engine is stopped, the engine ECU turns the VSV ON to introduce air to the actuator, thus closing the intake shutter.

12. Intake Heater Control

Applies current to the intake heater during cold-starting to increase the intake air temperature and improve the engine's startability.

► System Diagram ◀



147EG109

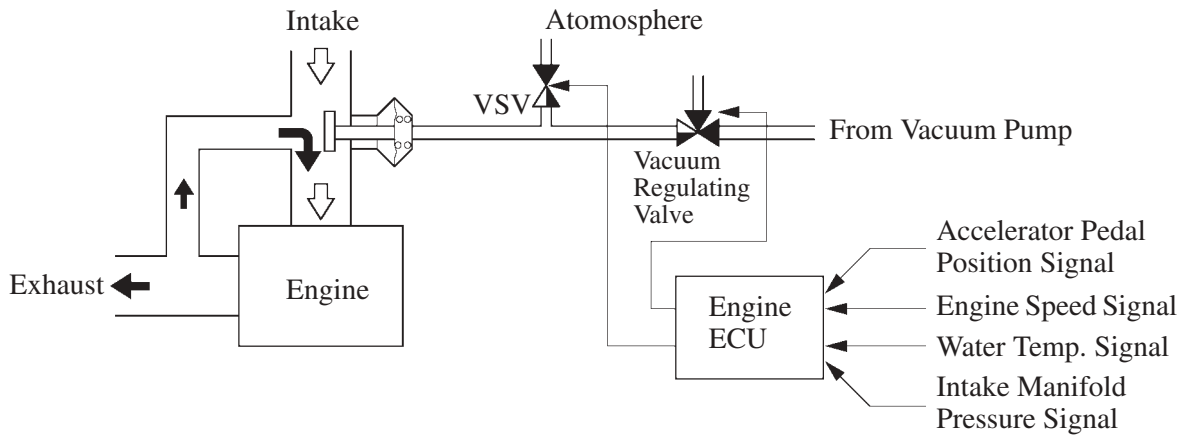
Operation

- When the engine coolant temperature is below 40°C, turning the ignition switch ON causes the intake heater relay to turn ON, allowing the intake heater to operate. The intake heater operates until the engine coolant temperature becomes higher than 40°C, or the maximum of 90 seconds.
- At the same time, the intake heater indicator lamp is illuminated in accordance with the engine coolant temperature (maximum 10 seconds).

13. EGR Control

In the EGR control system, the engine ECU controls the vacuum regulating valve to recirculate an appropriate amount of exhaust gas to the combustion chamber in accordance with the engine condition. This results in slower combustion rate, lower combustion temperature, and reduced NOx emissions.

► **System Diagram** ◀

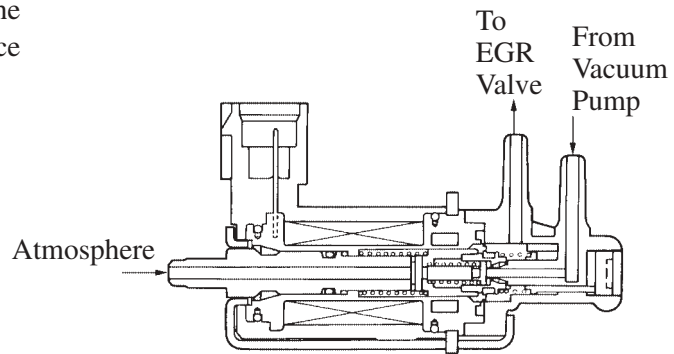


147EG110

Construction

1) Vacuum Regulating Valve

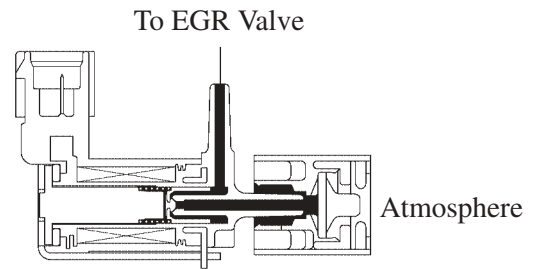
Controls the vacuum that is applied by the vacuum pump to the EGR valve in accordance with the signals from the engine ECU.



141EG51

2) VSV

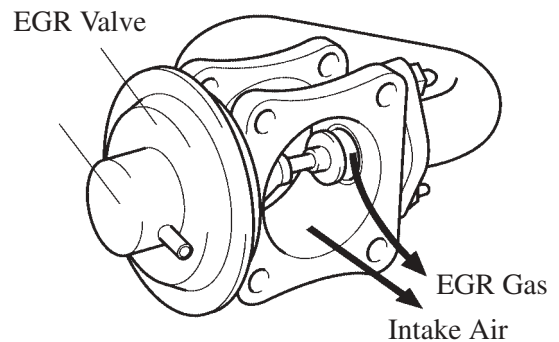
Releases the vacuum that is applied to the EGR valve when the EGR is OFF in order to improve the response when the valve is closed.



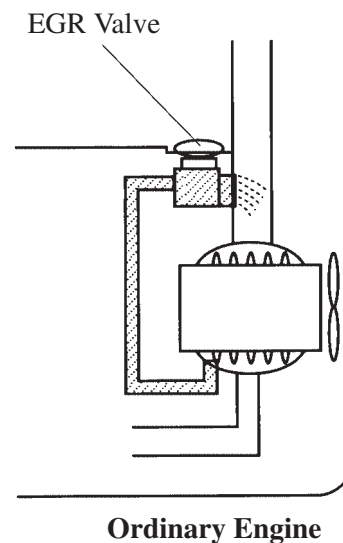
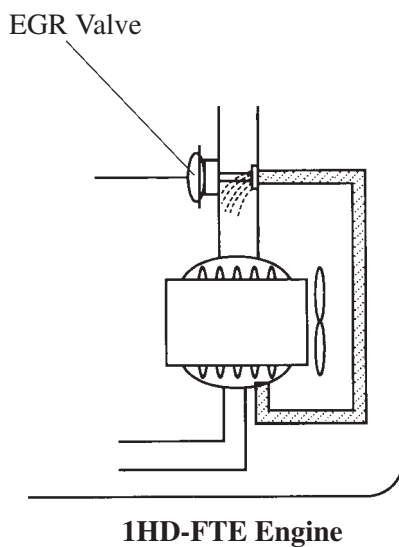
147EG115

3) EGR Valve

- Using the vacuum from the vacuum regulating valve, the EGR valve opens and closes the valve to introduce exhaust gas into the intake manifold.
- By providing the EGR valve in the intake passage, the various parts in the EGR valve are cooled by the intake air, thus enabling EGR control at higher load conditions.



147EG111



147EG112

Operation

- 1) Based on the signals from the sensors, the engine ECU applies duty control to the current that is applied to the vacuum regulating valve, thus regulating the vacuum that is applied to the EGR valve. Thus, the EGR valve opening is controlled to provide the volume of EGR gas that is appropriate for the engine condition.
- 2) The EGR function is stopped under the conditions given below to ensure drivability and to reduce diesel smoke.
 - The water temperature is low.
 - The vehicle is driven under high load condition.
 - During deceleration (The EGR operates at idle)

14. Engine Immobiliser System

The engine immobiliser system has been designed to prevent the vehicle from being stolen. This system uses a engine ECU that stores the ID code of the authorized ignition key. If an attempt is made to start the engine using an unauthorized key, the engine ECU to prohibit fuel delivery effectively in order to disable the engine. For details, [see page 277](#) in the Engine Immobiliser system section.

15. Diagnosis

- If the engine ECU detects any problem with a sensor or an electrical circuit, it turns ON the CHECK ENGINE lamp in the combination meter to inform the driver. In addition, the malfunction code will be stored in memory.
- An M-OBD (Multiplex On-Board Diagnostic) System has been adopted to improve serviceability. The operation of the M-OBD system is basically the same as the 1FZ-FE engine. For details, [see page 60](#).