

## ENGINE

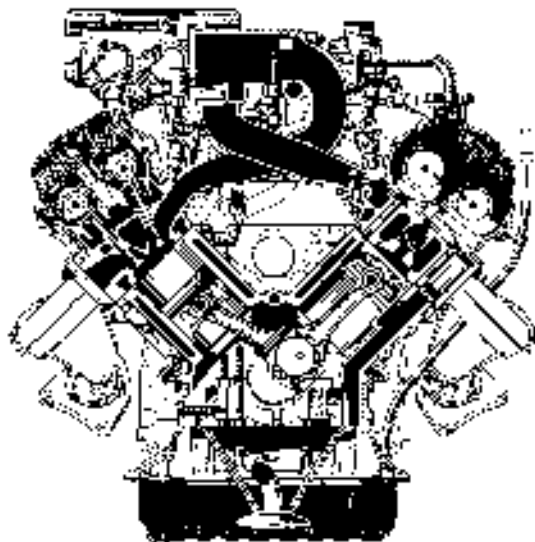
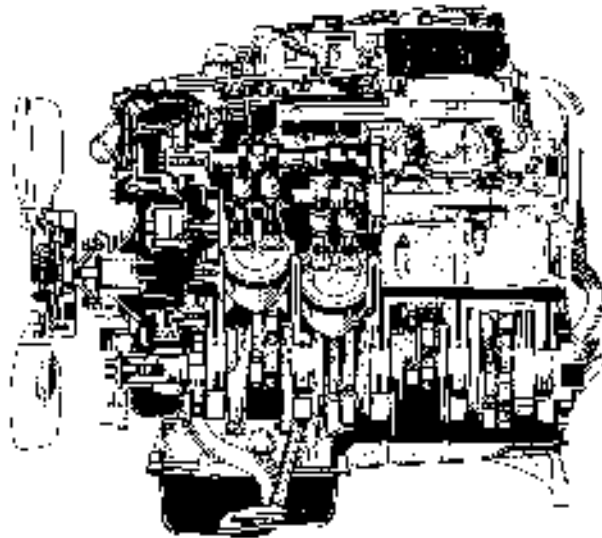
### 1UZ-FE ENGINE

#### ■ DESCRIPTION

The 1UZ-FE engine is a V-8, 4.0-liter, 32-valve DOHC engine designed exclusively for the luxury LS400 sedan.

Incorporating the state-of-the-art technology, this engine implements high-speed performance and utility at a high level providing an exciting feeling of a very smooth acceleration response to the pedal operation. With thorough analysis, design and precisely controlled manufacturing, major component parts have been improved to achieve very low vibration and noise level.

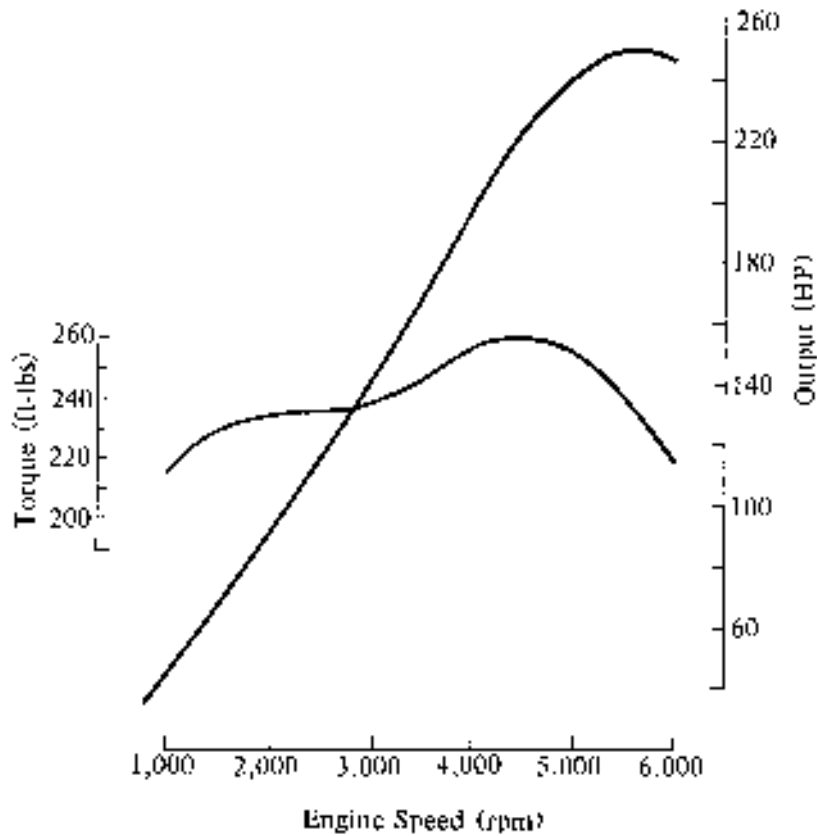
The engine operation is accurately-controlled by the ECU (Electronic Control Unit) and maintains peak performance and efficiency at all times.



## ENGINE SPECIFICATIONS AND PERFORMANCE CURVE

Engine		1UZ-FE
Item		
No. of Cyls. & Arrangement		8-Cylinder, V Type
Valve Mechanism		32-Valve, DOHC, Belt & Gear Drive
Combustion Chamber		Pentroof Type
Manifolds		Cross-flow
Displacement	cu. in. (cc)	242.1 (3,969)
Bore x Stroke	in. (mm)	3.44 x 3.25 (87.5 x 82.5)
Compression Ratio		10.0 : 1
Firing Order		1-8-4-3-6-5-7-2
Max. Output (SAE-NET)		250 HP @ 5,600 rpm
Max. Torque (SAE-NET)		260 ft-lbs @ 4,400 rpm
Fuel Octane Number (RON)		96
Oil Grade*		API SG, EC-II

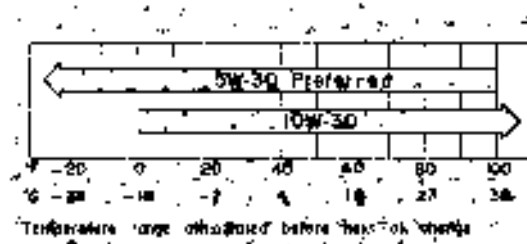
\* Refer to the next page for detail.



**\*NOTE:** Engine oil selection

Use API (American Petroleum Institute) grade SG, Energy-Conserving II multigrade engine oil.

Recommended viscosity is as follows, with SAE 5W-30 being the preferred engine oil for the 1UZ-FE engine.

**►Recommended Viscosity (SAE)◀**

A label is added to the oil filler cap and some oil containers to help you select the oil you should use.

The top portion of the label shows the oil quality by API designations such as SG. The center portion of the label shows the SAE viscosity grade, such as SAE 5W-30.

“Energy-Conserving II” shown in the lower portion, indicates that the oil has fuel-saving capabilities.

**►Oil Identification Label◀**

Oils marked “Energy-Conserving II” will have higher fuel-saving capabilities than oils marked “Energy-Conserving.”

## ■ FEATURES OF 1UZ-FE ENGINE

Features of the 1UZ-FE engine are shown in the following list:

Features	Contents
High Performance	<ul style="list-style-type: none"> <li>• Compact DOHC, 32-valve, center-firing and high compression ratio combustion chamber implements a high combustion efficiency.</li> <li>• ECU-controlled precise engine operation.</li> <li>• Reduced intake and exhaust losses resulting from large-diameter intake duct, air flow meter, dual exhaust system, etc.</li> </ul>
Lightweight and Compact Design	<ul style="list-style-type: none"> <li>• Reduced cylinder head size by the adoption of a scissors gear mechanism.</li> <li>• Cylinder block and oil pan made of aluminum alloy.</li> <li>• Compact, lightweight accessory drive system by means of serpentine, single belt and bracketless accessory installation.</li> </ul>
Low Noise and Vibration	<ul style="list-style-type: none"> <li>• Use of an aluminum oil pan having an integral stiffener.</li> <li>• Aluminum engine mount brackets and liquid-filled compound engine mounts.</li> <li>• Silent start type three-stage temperature-controlled auto-coupling fan.</li> <li>• Rigid and accurately balanced crankshaft assembly.</li> <li>• Auto tensioners for timing belt and V-ribbed belt.</li> </ul>
Serviceability	<ul style="list-style-type: none"> <li>• Outer shim type valve lifter.</li> <li>• Auto tensioners for timing belt and V-ribbed belt.</li> <li>• Engine oil level sensor.</li> </ul>
High Reliability	<ul style="list-style-type: none"> <li>• Thin cast-iron liner press-fit in aluminum cylinder block.</li> <li>• Highly durable timing belt and auto tensioner.</li> <li>• Plastic region tightening bolts in major parts (cylinder head bolts, crankshaft bearing cap bolts, connecting rod cap bolts).</li> </ul>

## ENGINE

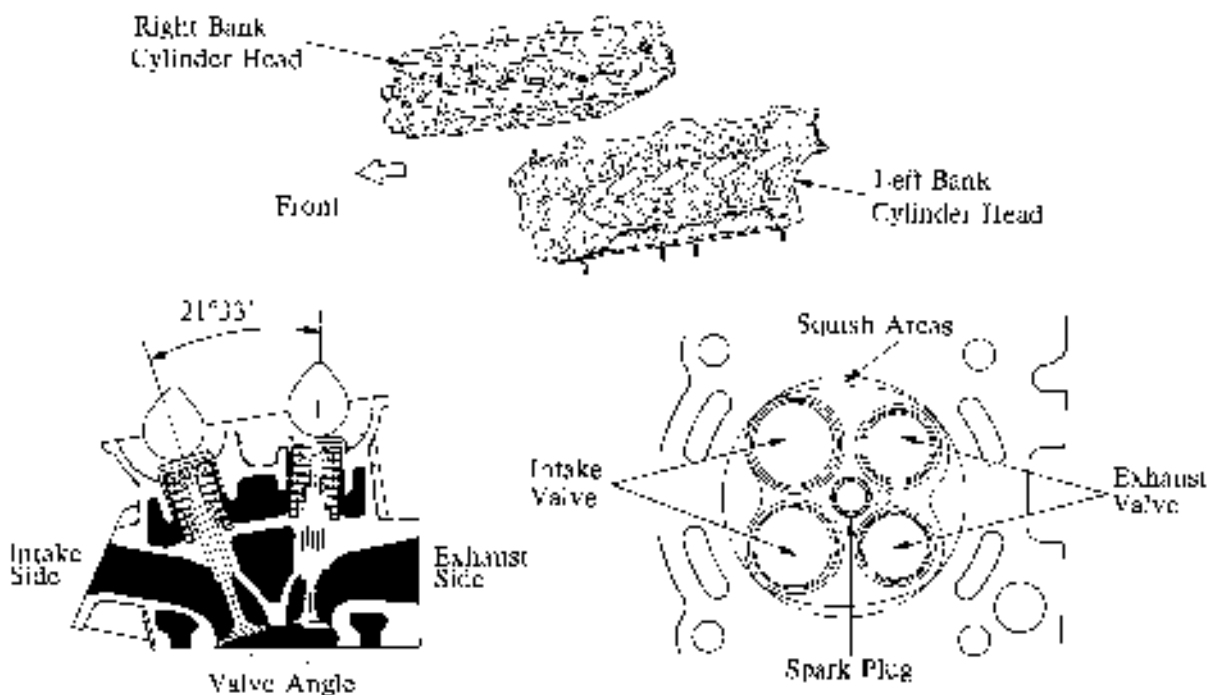
### 1. Cylinder Head

- The cylinder head is made of aluminum and has intake and exhaust ports in a cross-flow arrangement. The intake ports are on the inside and the exhaust ports on the outside of the left and right banks respectively.
- The cylinder heads are compact even for a DOHC engine. The pitch of the intake and exhaust camshafts is shortened and the valve angle is narrowed to  $21^{\circ}33'$ .
- The left and right banks of cylinder heads are common in configuration.

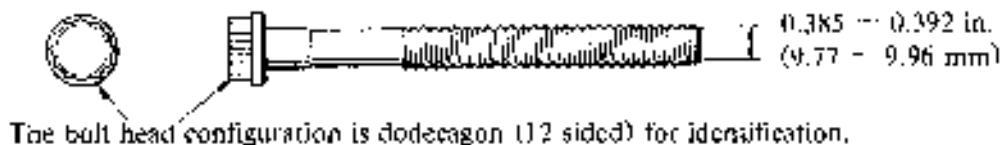
#### NOTICE

When the cylinder heads are disassembled for servicing, be sure to assemble each cylinder head to the correct right or left bank. The camshaft may seize if they are assembled incorrectly.

- Pentroof type combustion chamber with four valves is used.
- The squish area guides the air-fuel mixture to the center of the combustion chamber to increase the combustion speed and thus maintain a stable engine operation.



- Plastic region tightening bolts, having a good axial tension stability, are used for securing the cylinder heads to the block.



**NOTE:** When reusing the cylinder head bolts, make sure the diameter at the thread is not less than 0.378 in. (9.6 mm). It will be necessary to replace them with new ones if the diameter is less than specification.

## 2. Cylinder Block

- The cylinder block has a bank angle of  $90^\circ$ , a bank offset of 0.827 in. (21 mm) and a bore pitch of 4.15 in. (105.5 mm), resulting in a compact block in its length and width even for its displacement.
- Lightweight aluminum alloy is used for the cylinder block.
- A thin cast-iron liner is press-fit inside the cylinder to ensure an added reliability.

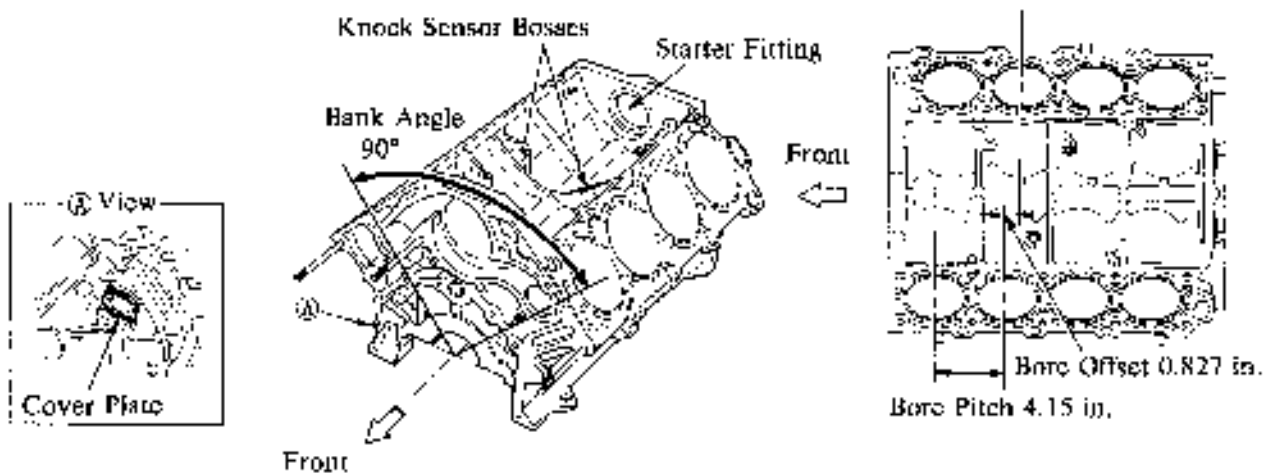
### NOTICE

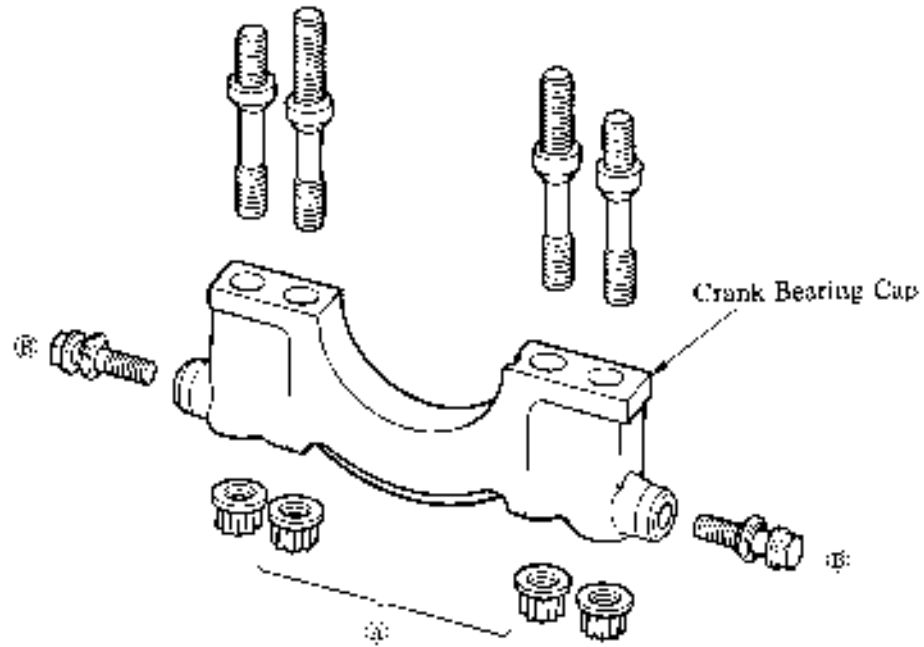
Never attempt to machine the cylinder because it has a thin 0.08 in. (2 mm) liner inside.

- Part of the volute chamber of the water pump and the water by-pass passage are incorporated into the cylinder block to shorten the engine length.
- Installation bosses of the two knock sensors are located on the inner side of left and right banks.
- The plastic region tightening bolts are used for the crankshaft bearing caps.

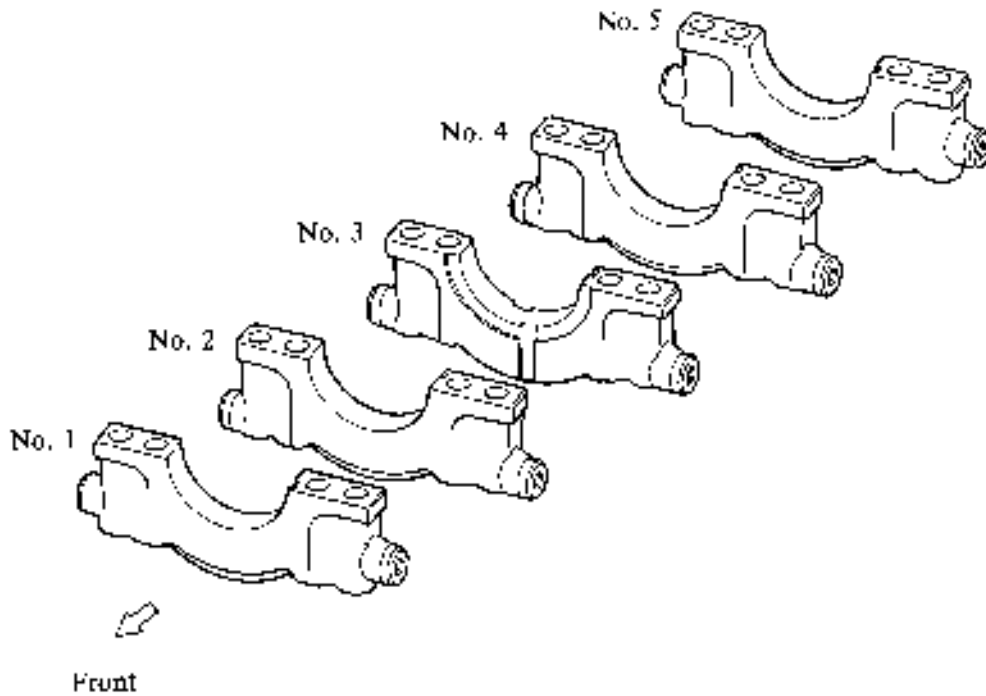
**NOTE:** When reusing the crankshaft bearing cap bolts, make sure the diameter at the thread is not less than 0.291 in. (7.4 mm). It will be necessary to replace them with new ones if the diameter is less than specification.

- The starter is located inside the V-bank.
- To install a local engine block heater, first remove the cover plate shown in the “A” view drawing below.



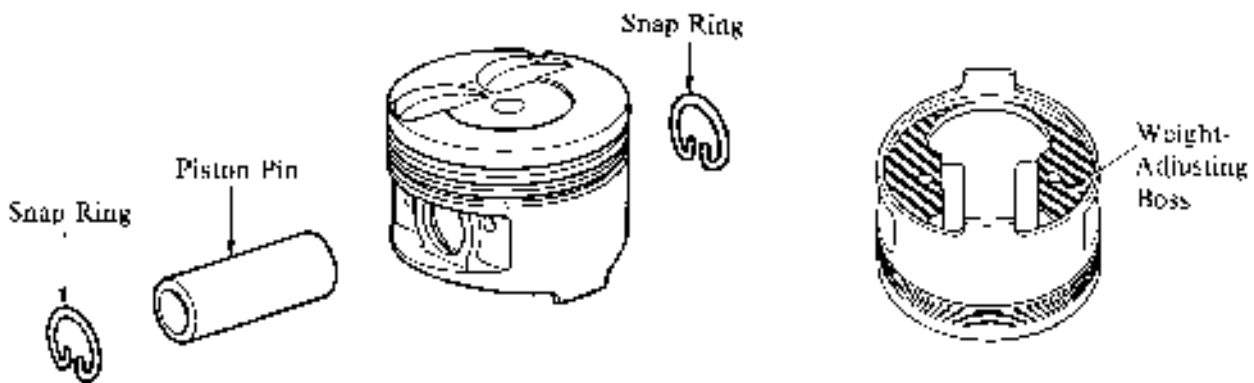
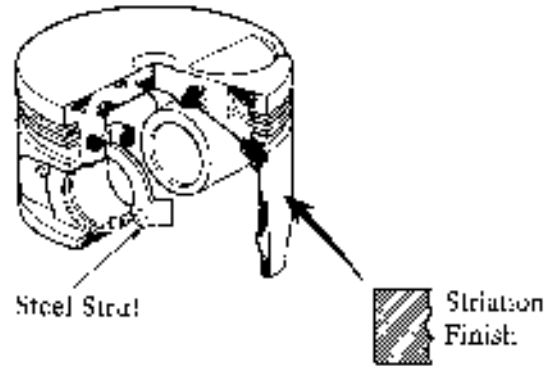
**NOTICE**

When fitting the crankshaft bearing cap, always tighten **A** first and **B** next in order to obtain roundness of the bearing.



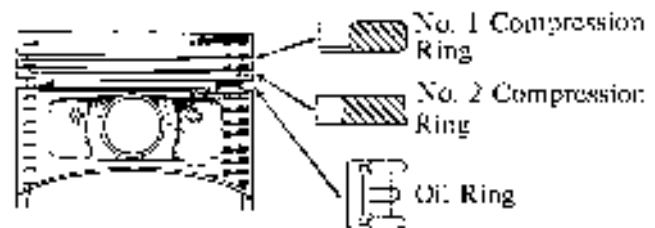
### 3. Piston

- Steel struts are used to control thermal expansion.
- The skirt of each piston is striation finished (finely grooved) for maintaining proper lubrication and reducing friction loss.
- The piston has a weight-adjusting boss to minimize fluctuation of weight among pistons and balance the engine assembly.
- Piston pins are the full-floating type and are held in place with snap rings.



### 4. Piston Ring

- Each surface of the compression ring No. 1 and the oil ring side rail is nitrified to prevent an increase of oil consumption and blow-by gas as the time elapses.

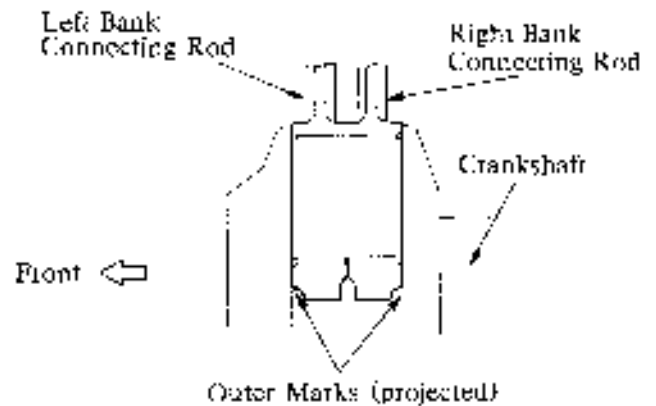
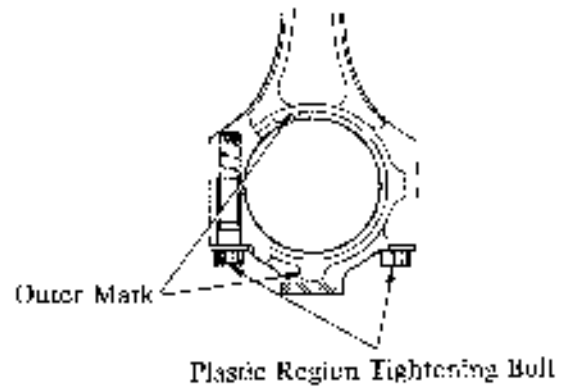
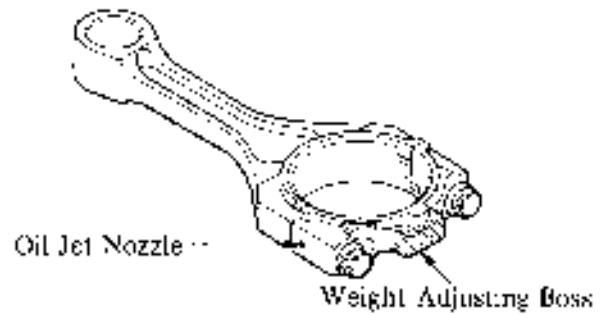


## 5. Connecting Rod

- The sintered and forged connecting rod is very rigid and has little weight fluctuation.
- A weight-adjusting boss is provided at the big end to reduce fluctuation of weight and balance the engine assembly.
- The connecting rod cap is held by plastic region tightening bolts.

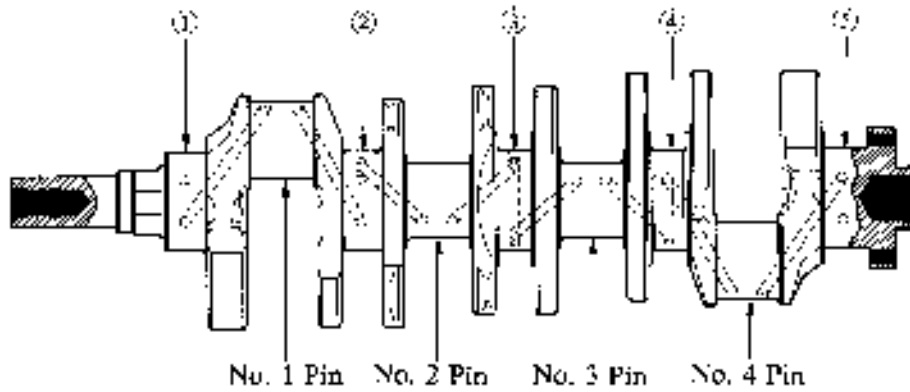
**NOTE:** When reusing the connecting rod cap bolts, if the diameter at the thread is less than 0.275 in. (7.0 mm), it is necessary to replace them with new ones.

- The connecting rods for the right and left banks are placed in opposite directions with the outer marks facing the crankshaft.

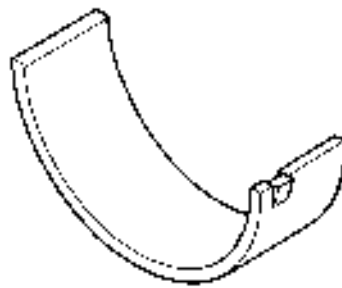


### 6. Crankshaft and Crankshaft Bearings

- A forged crankshaft with five main journals, four connecting rod pins and eight balance weights is used.
- Connecting rod pins and journals are induction-hardened to ensure an added reliability.

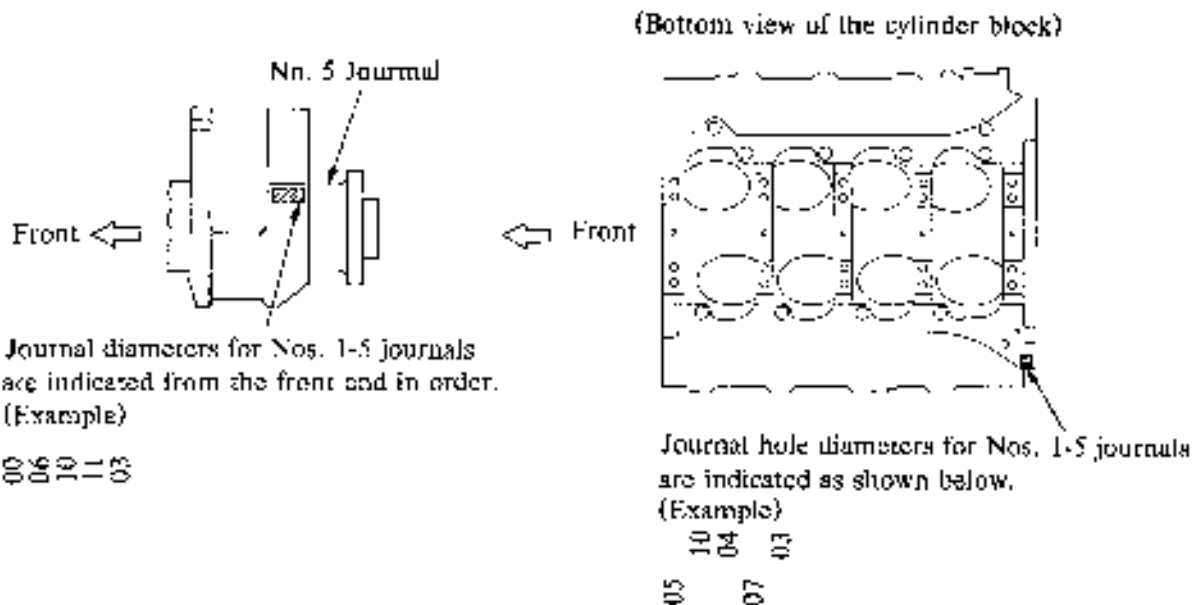


- Bearings are made of kelmet.

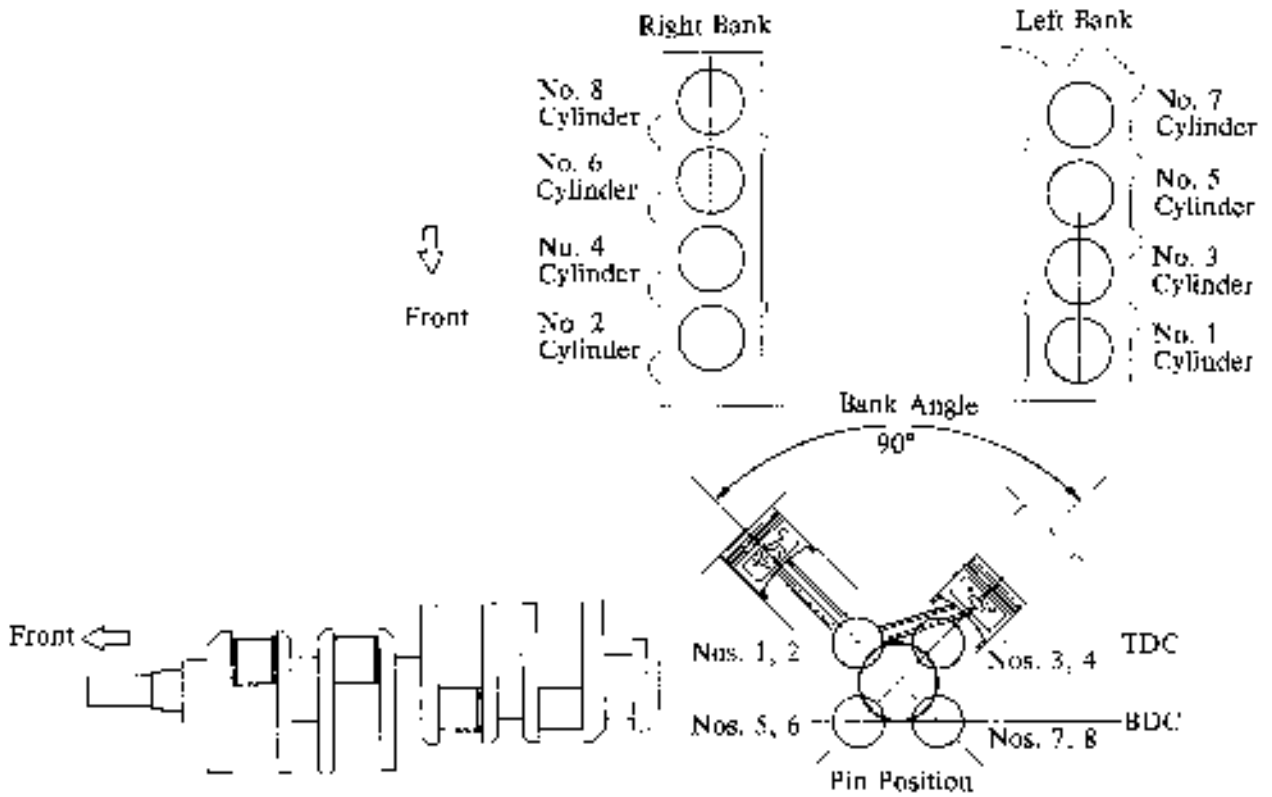


- Crankshaft bearings are selected carefully according to the measured diameters of the crank journal and cylinder block journal holes.

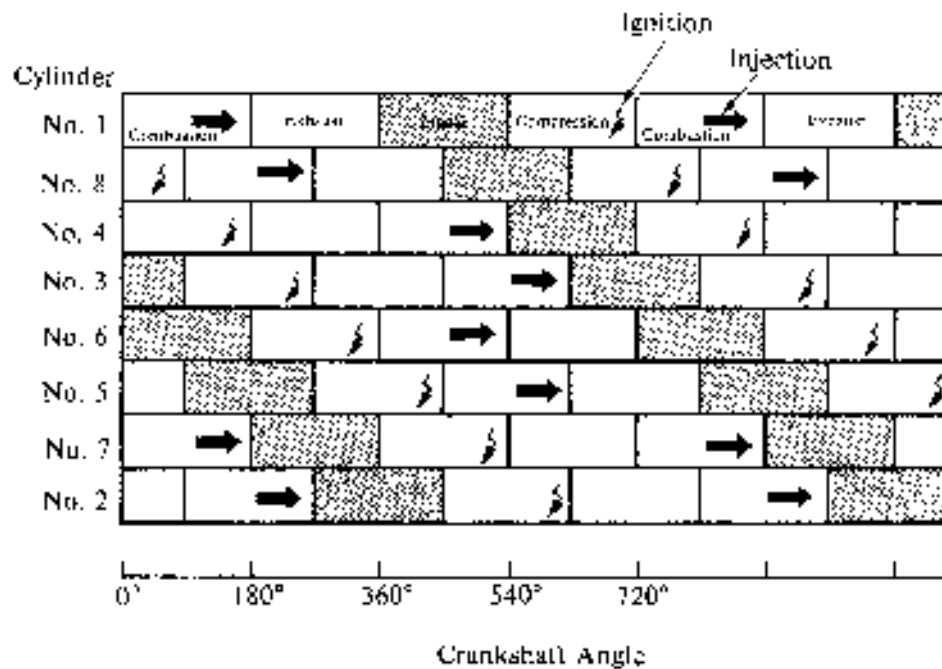
**NOTE:** The diameter of the crank journal and the cylinder block journal hole is indicated at the places shown below.



NOTE: Numbers of the crankshaft and pistons are shown on the right side.



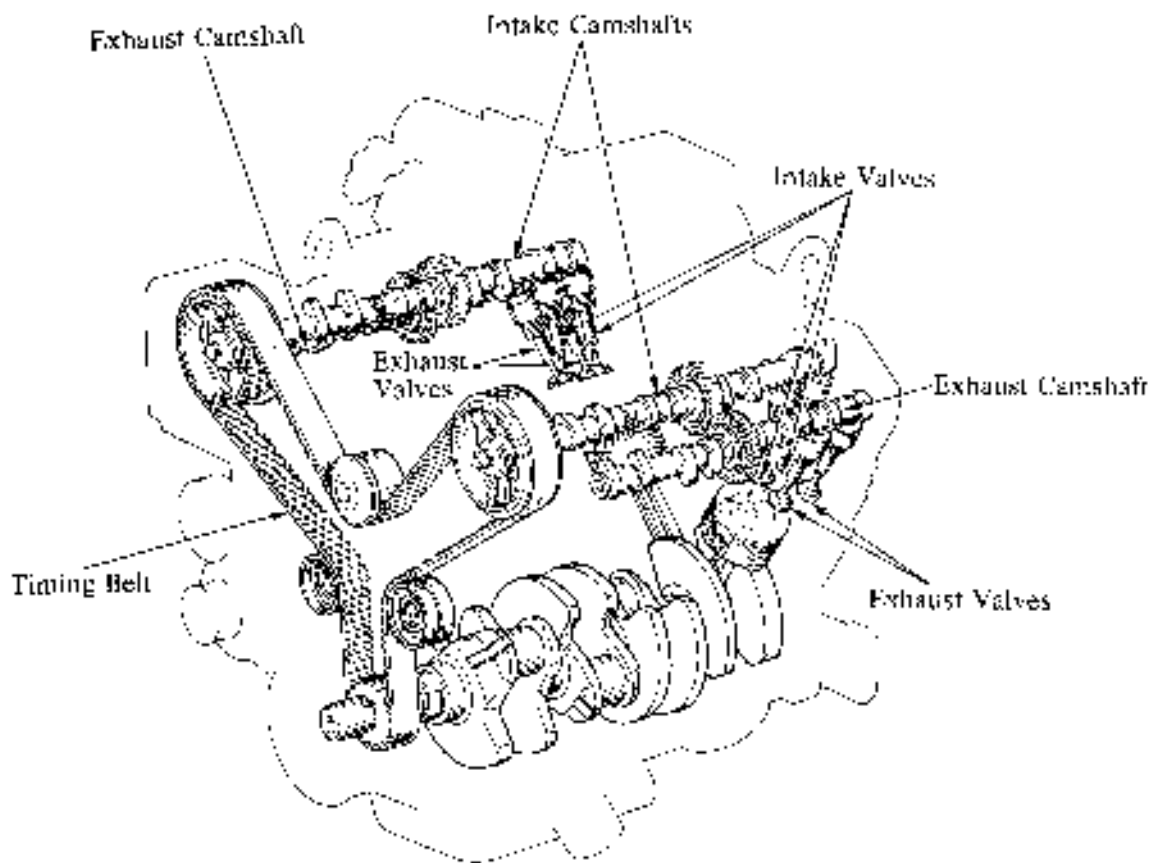
Crankshaft angles and engine strokes (intake, compression, combustion and exhaust) are shown in the table below. The firing order is 1-8-4-3-6-5-7-2.



## ■ VALVE MECHANISM

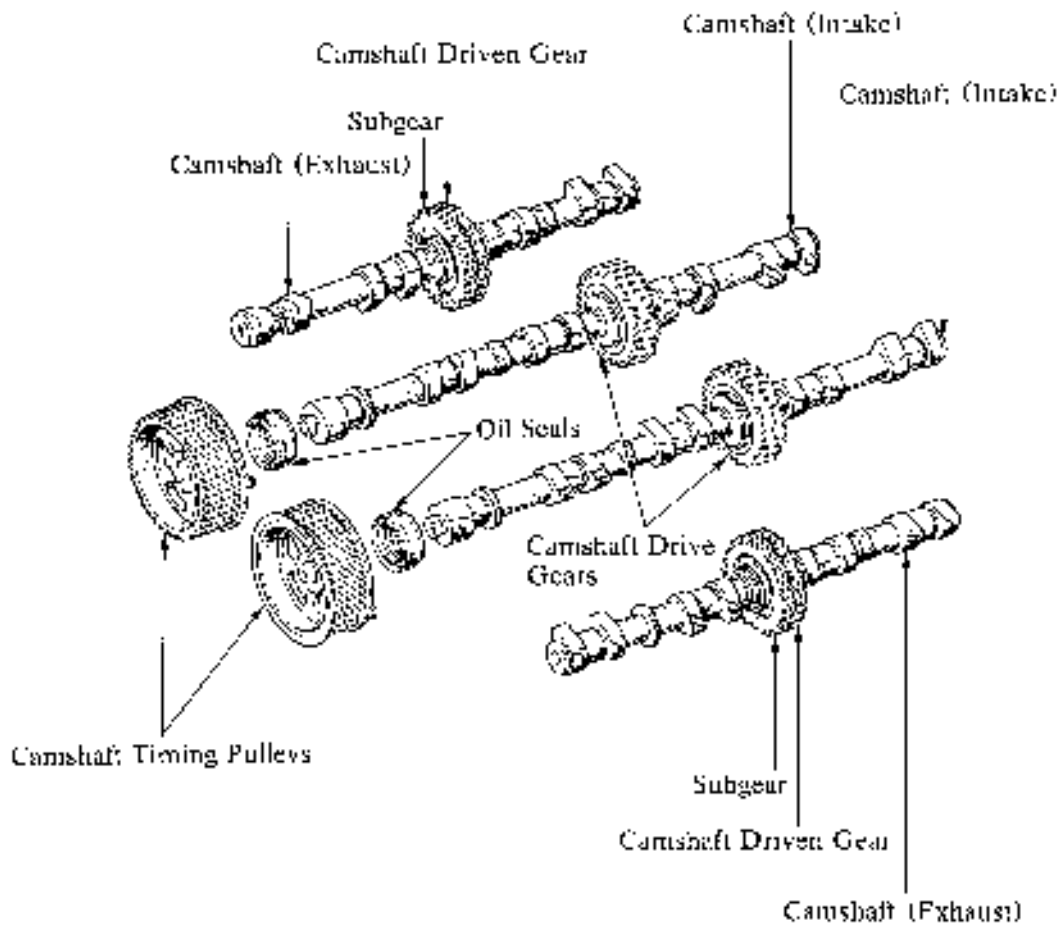
### 1. General

- Each cylinder has two intake valves and two exhaust valves.
- The valves are directly opened and closed by four camshafts.
- The intake camshafts are driven by a timing belt, while the exhaust camshafts are driven through gears on the intake camshafts.
- Use of outer shim type valve lifters makes it easy to adjust the valve clearance without removing the camshaft.



## 2. Camshafts

- The exhaust camshafts are driven by gears on the intake camshafts. The scissors gear mechanism has been used on the exhaust camshaft to control backlash and reduce gear noise.
- The camshaft journals and camshaft driven gear are lubricated by oil supplied to an oil passage in the center of the camshaft. Supply of oil from the cylinder heads to the camshafts is continuous, to prevent fluctuations in the oil pressure.
- The cast iron camshafts are used. The cam nose is chill treated.
- “T” type oil seals are used.



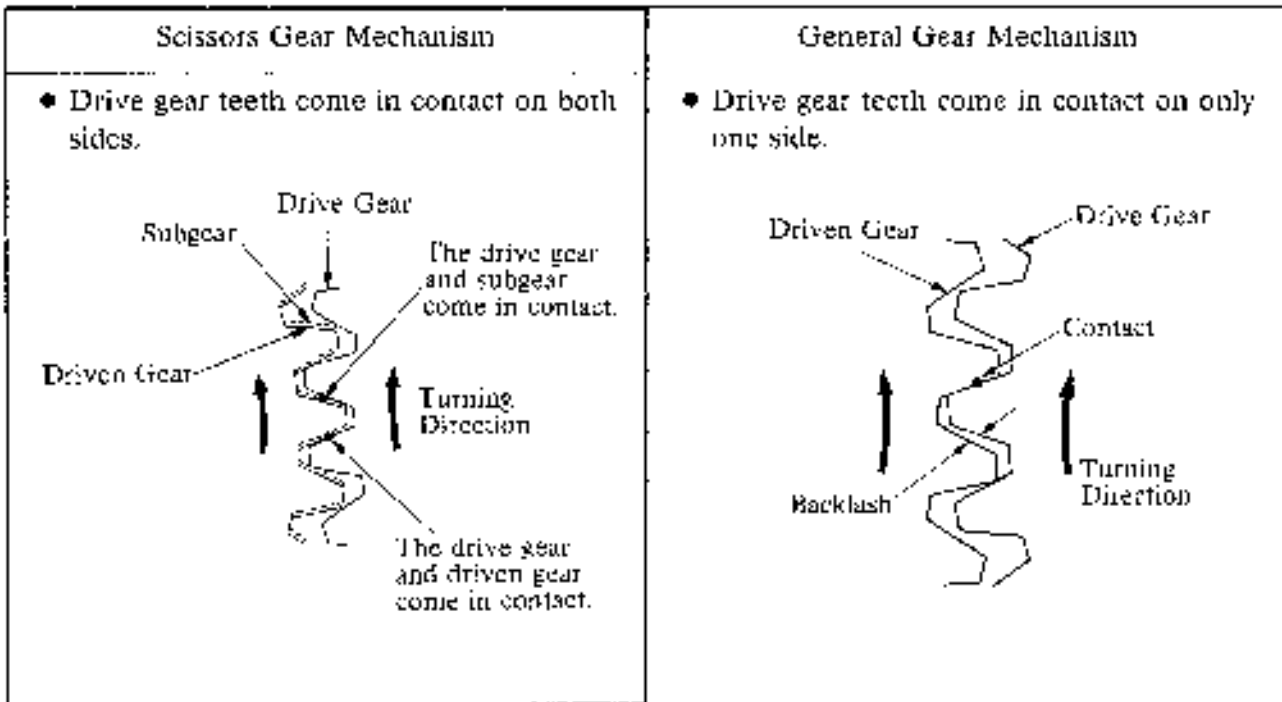
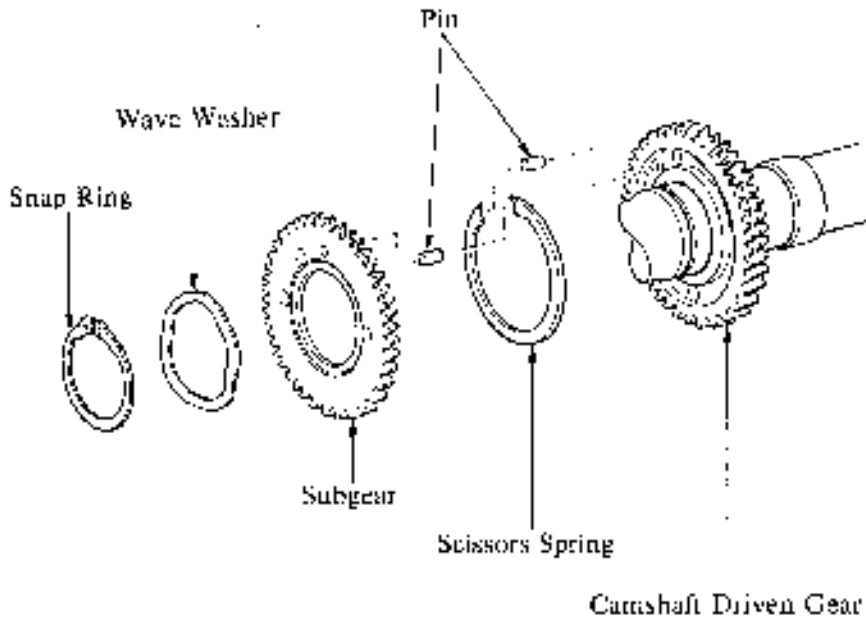
### NOTICE

Be sure to follow the disassembly and reassembling procedures as directed in the Repair Manual to avoid possibility of damaging the cylinder head or camshaft timing gears (drive, driven and subgears).

—REFERENCE—

**Scissors Gear Mechanism**

To prevent the tooth surfaces of gears from seizing or being damaged when the gears are engaged, they are designed to have backlash. However, backlash generates noise when changes in torque occur. The scissors gear mechanism is one means of preventing this noise. The scissors gear mechanism uses a subgear with the same number of teeth as the drive gear and is attached to the gear on the driven side. Through the reaction force of the scissors spring, these two gears act to pinch the drive gear, reducing backlash to zero and eliminating gear noise.

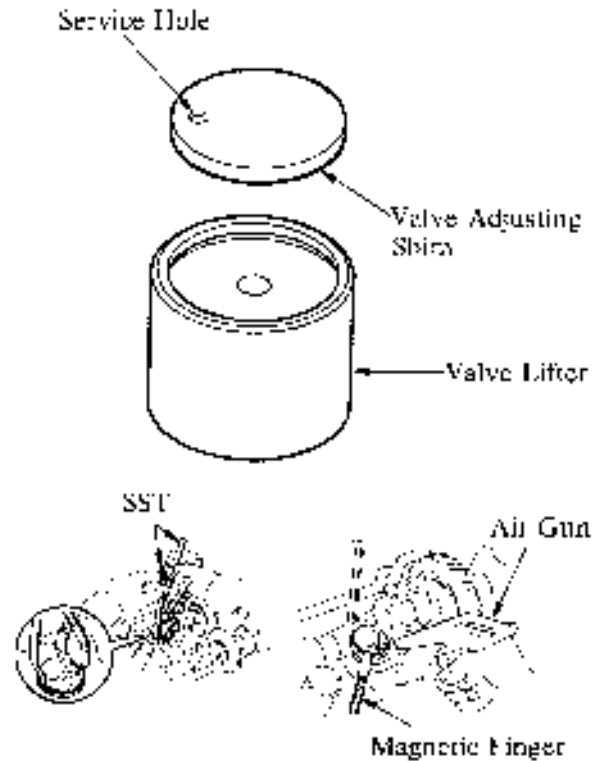


### 3. Valve Lifter and Valve Adjusting Shims

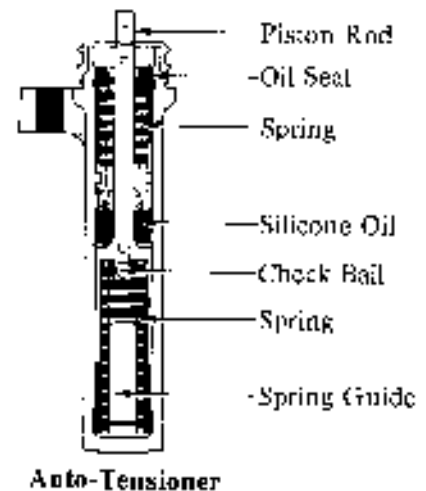
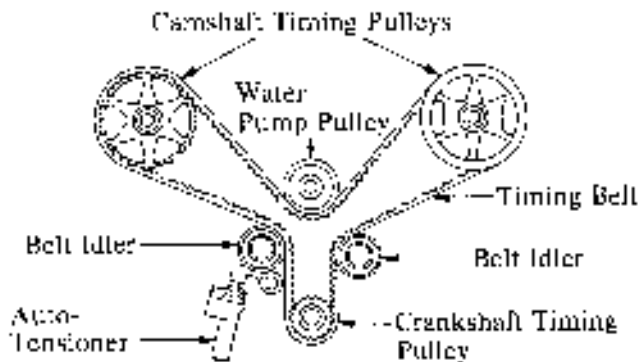
- Aluminum alloy valve lifters are used.
- The valve adjusting shims used are of the outer shim type and are located on top of the valve lifters. It is not necessary to remove the camshafts in order to replace the shims when the valve clearance is adjusted.

**NOTE:** (Method for replacing valve shims)

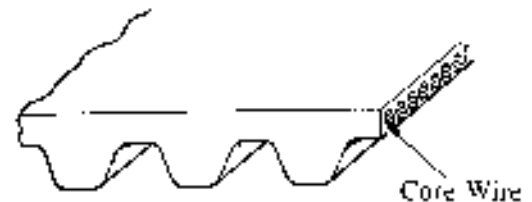
Push down the valve lifter using an SST (Special Service Tool) to make a gap between the camshaft and the valve lifter. Direct compressed air from an air gun to the service hole in the valve adjusting shim to float the shim and remove it using a magnetic finger. Be sure to direct the air gun carefully so that you do not blow the shim away.



### 4. Timing Pulleys and Belt



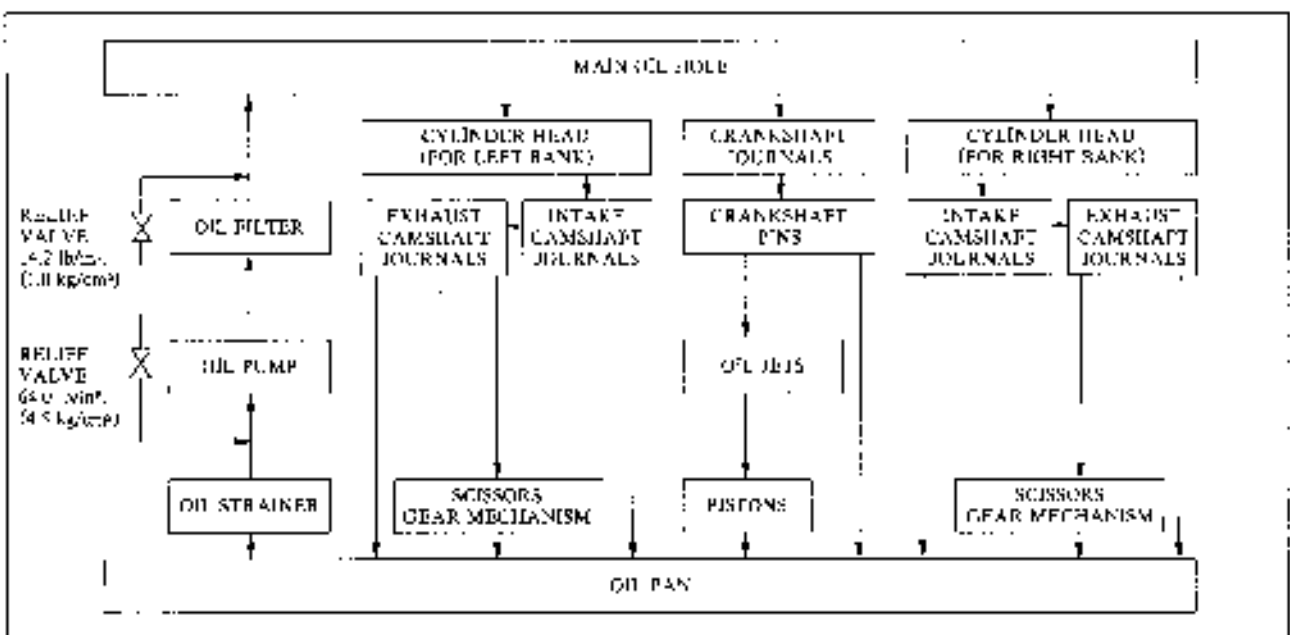
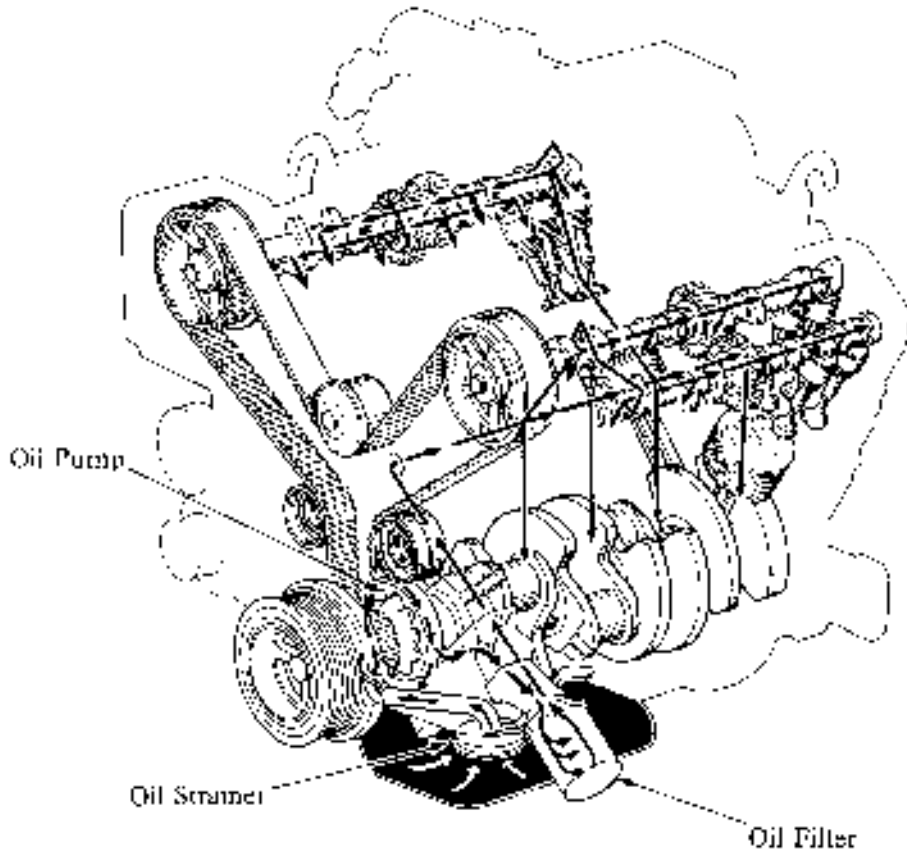
- An auto-tensioner is made up of a spring and oil damper, and maintains proper timing belt tension at all times. The auto-tensioner suppresses noise generated by the timing belt.
- The timing belt has high heat resistance and durability.
- The tooth profile of the timing belt is shown at the right. This design ensures a quiet operation and high-load transmission.



**LUBRICATION SYSTEM**

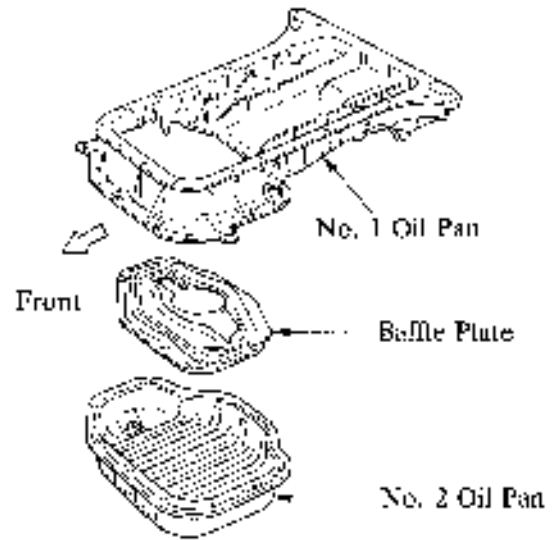
**1. General**

- The lubrication is fully pressurized and all oil passes through an oil filter.
- The oil pump is a trochoid gear type and is directly driven by the crankshaft.



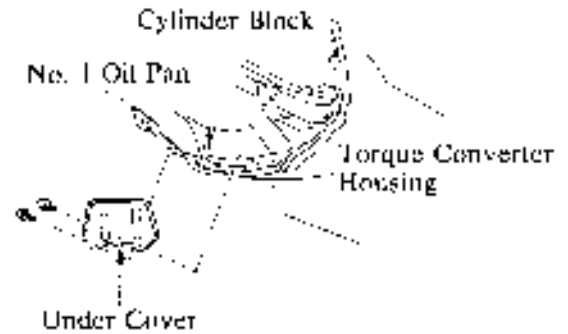
## 2. Oil Pan

- The oil pan is made up of two pieces. No. 1 oil pan is made of aluminum alloy and No. 2 oil pan is made of steel.
- The upper oil pan section is secured to the cylinder block and the torque converter housing, increasing rigidity.
- The baffle plate controls the oil flow between the two oil pans when the vehicle is turning or is running along rough roads, etc.



- An oil level sensor is provided in the oil pan for efficient servicing.

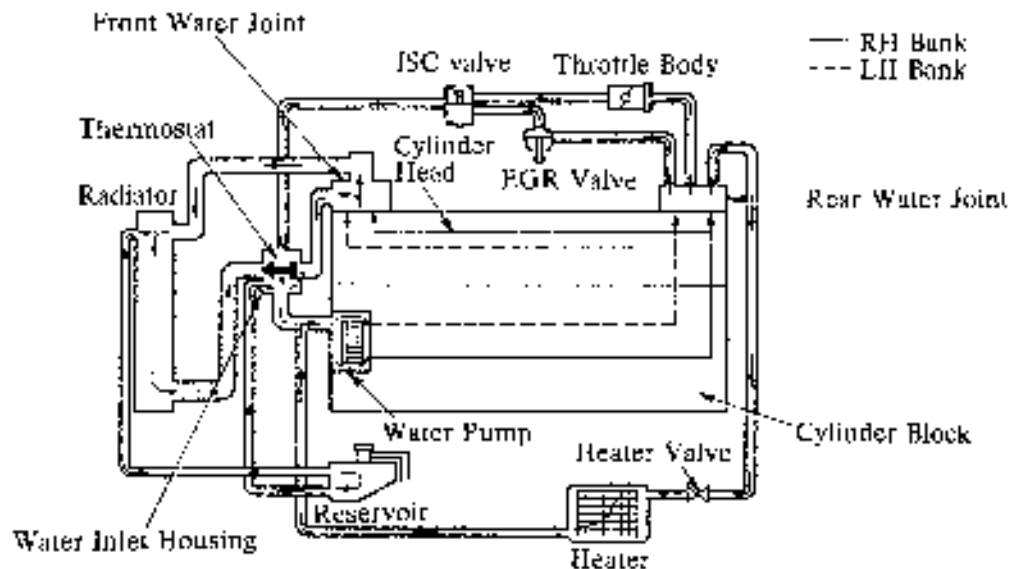
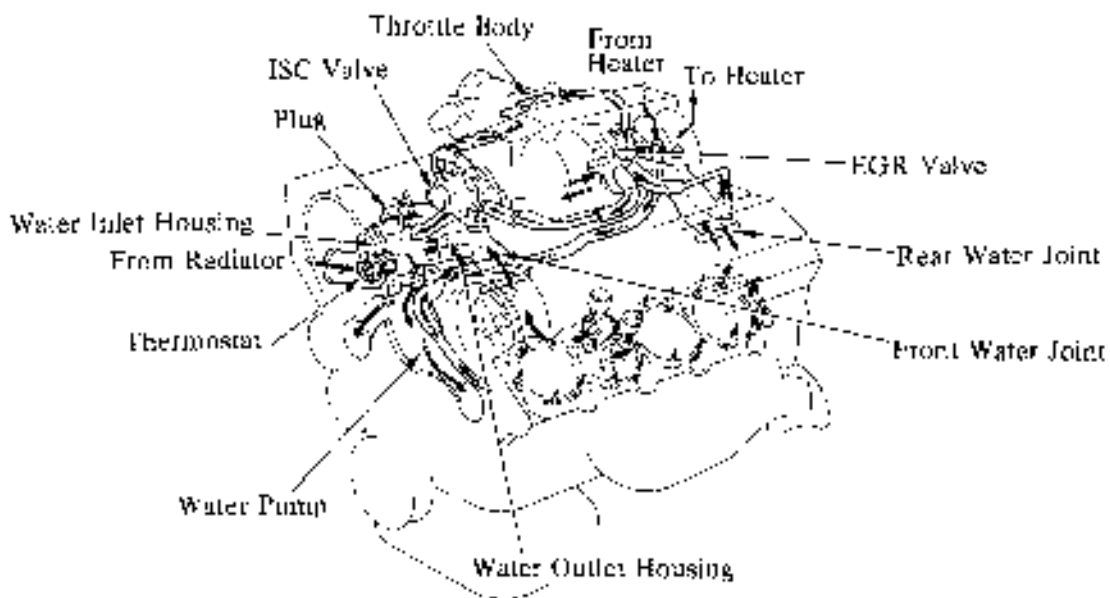
When the oil level falls below the specified level, the oil level sensor causes the low engine oil level warning light inside the combination meter to light up.



## ■ COOLING SYSTEM

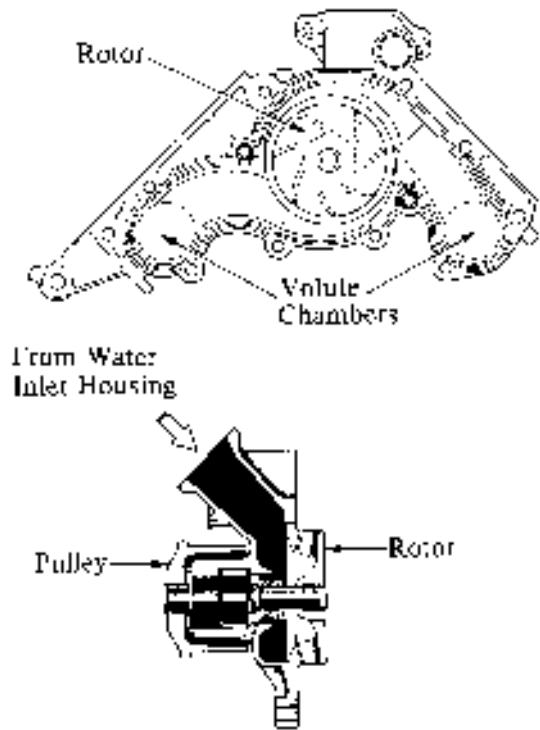
### 1. Cooling Circuit

- The cooling system is a pressurized, forced-circulation type.
- A thermostat, having a bypass valve, is located on the water pump inlet side of the cooling circuit. As the coolant temperature rises, the thermostat opens and the bypass valve closes, so the system maintains suitable temperature distribution in the cylinder head.
- A gauge coolant temperature sender, coolant temperature sensor, start injector time switch for the EFI (Electronic Fuel Injection) and BVSV (Bimetal Vacuum Switching Valve) for charcoal canister control are fitted to the front water joint.
- The rear water joint has bypass outlet ports for heating the throttle body, cooling the EGR valve and hot water for the heater.



## 2. Water Pump

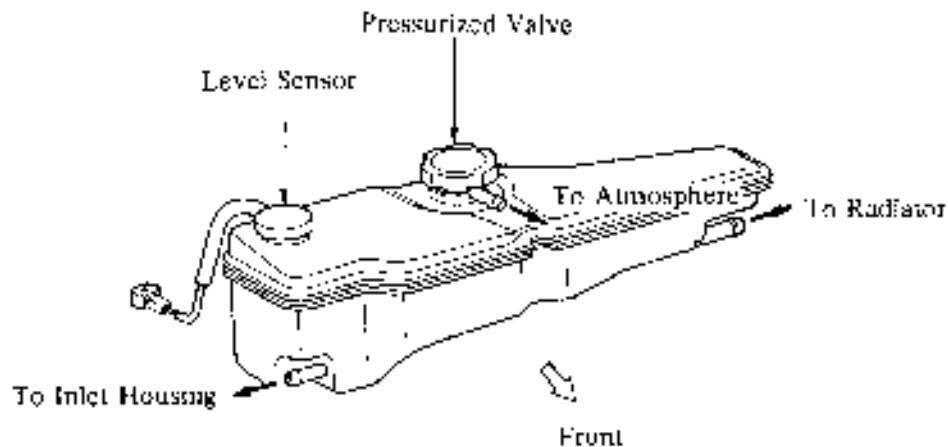
- The water pump has two volute chambers, and circulates coolant uniformly to the left and right banks of the cylinder block.
- The water pump is driven by the back of the timing belt.
- The rotor is made of resin.



## 3. Reservoir Tank

- A pressurized valve is fitted to the reservoir.
- A coolant level sensor is provided for efficient servicing.

When the coolant level falls below the specified level, the coolant level sensor causes the low engine coolant level warning light inside the combination meter to light up.



### CAUTIONS

1. Never remove the cap while it is hot because the reservoir is also pressurized.
2. Engine coolant is replenished from the reservoir. To do so, first loosen the plug at the top of the inlet housing (shown on Page 98) to bleed air out of the cooling system. Be sure that the system is filled with coolant completely.

### 4. Coupling Fan

- A three stage temperature-controlled auto coupling fan is used.

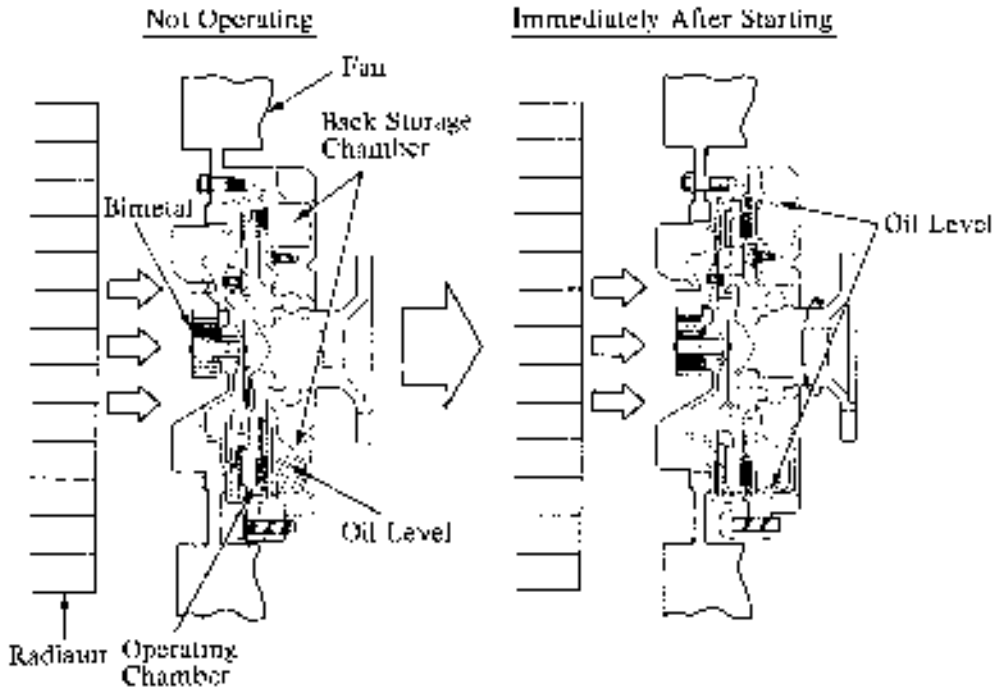
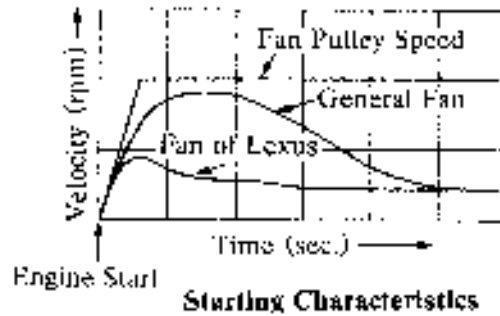
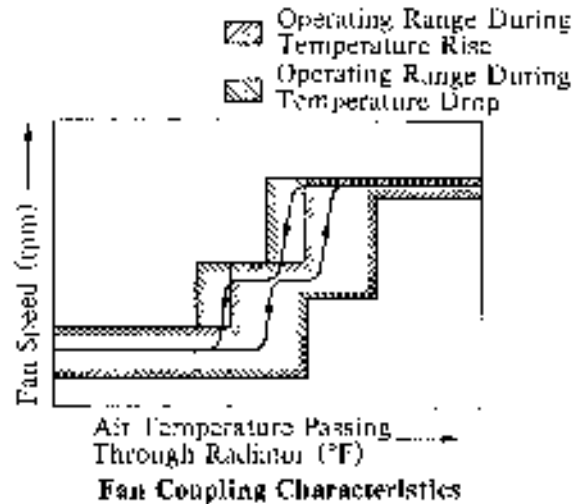
The speed of the coupling fan changes in three stages based on the temperature of the air passing through the radiator.

This keeps the fan speed low when the temperature is low, improving warm-up performance and reducing fan noise.

The fan speed is high when the engine temperature is high, improving the cooling performance.

Since part of the oil in the coupling fan is stored in the back storage chamber, the amount of oil in the operating chamber decreases at engine start. Oil resistance and the fan speed are reduced as a result immediately after engine start.

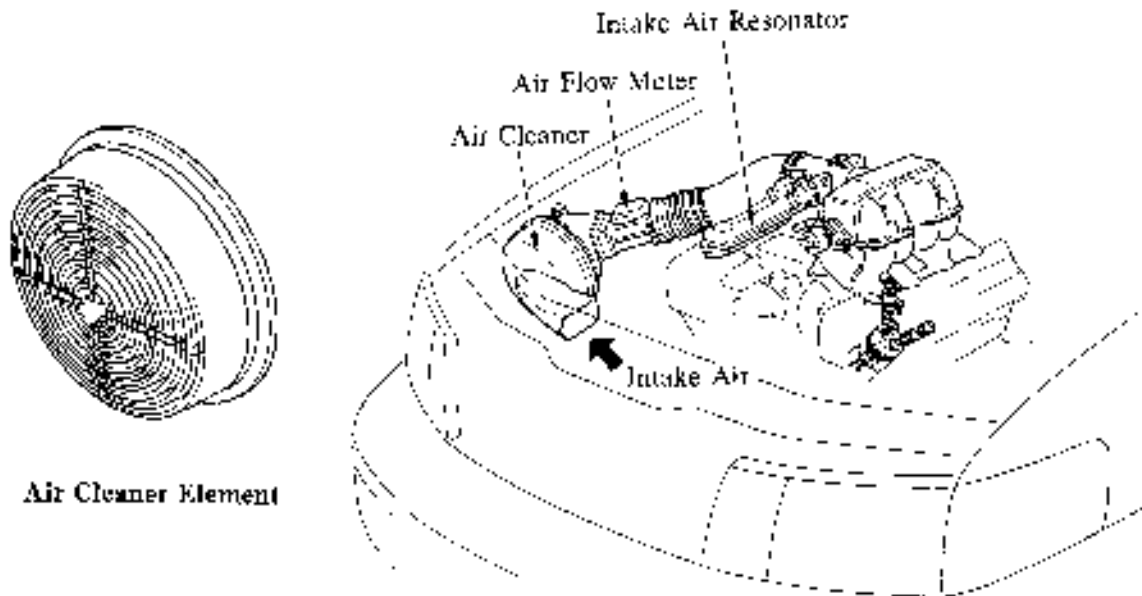
The oil stored in the back storage chamber gradually flows into the operating chamber as the coupling fan keeps revolving. It eventually flows entirely into the operating chamber.



## ■ INTAKE AND EXHAUST SYSTEM

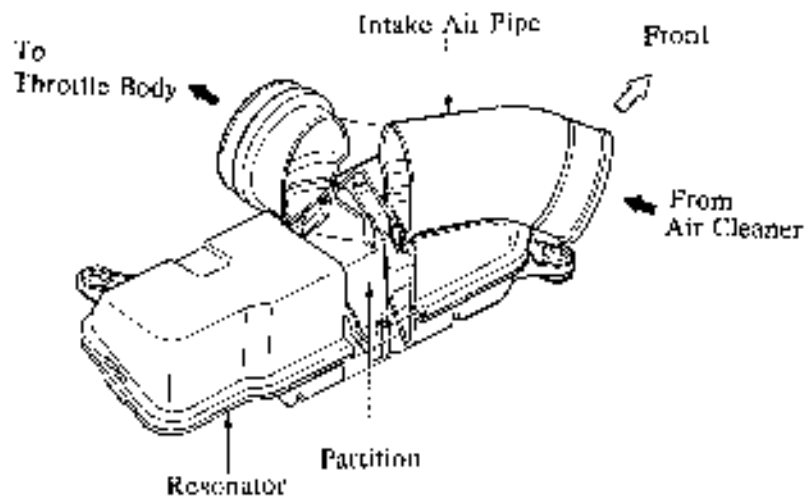
### 1. Air Cleaner

The air cleaner case and cap are made of resin and have a large filtering capacity for the large engine displacement. The air cleaner element is a low air resistance type and allows the air to pass through it very smoothly.



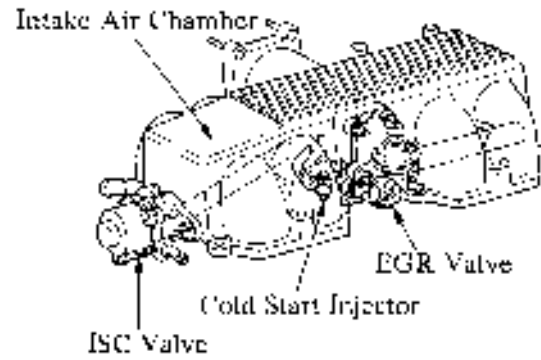
### 2. Intake Air Resonator

- A resonator is used to reduce the intake air noise.
- The resonator is made of resin. The air passage and resonator chamber are formed separately. The resonator chamber is of the dual mode type and is separated by a partition.



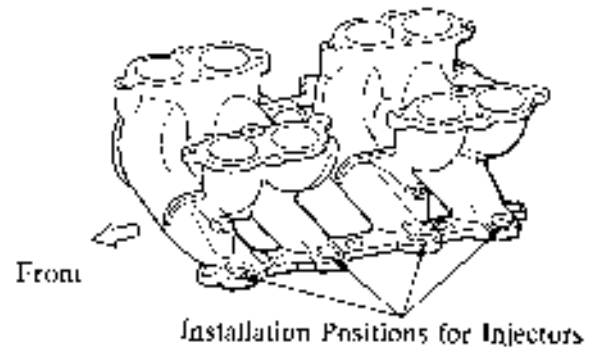
### 3. Intake Air Chamber

- The EGR and ISC (Idle Speed Control) passages are attached to the intake air chamber.
- The start injector is located at the center of the intake air chamber so that fuel is distributed evenly to all cylinders.



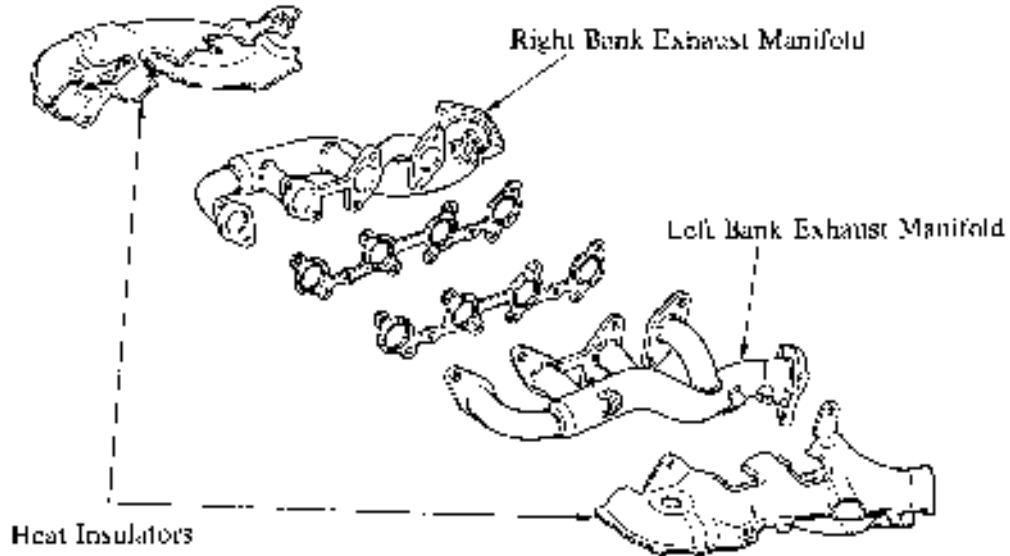
### 4. Intake Manifold

- Ports are crossed to increase the port length and inertia effects of the intake air.



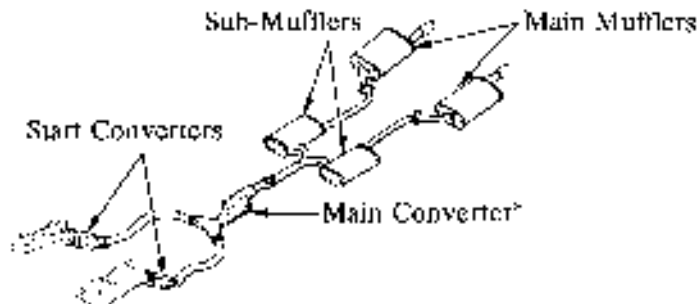
## 5. Exhaust Manifold

- Both exhaust manifolds are made of stainless steel.
- The exhaust manifolds are covered with heat insulators to protect the surrounding parts from exhaust heat.



## 6. Exhaust Pipe

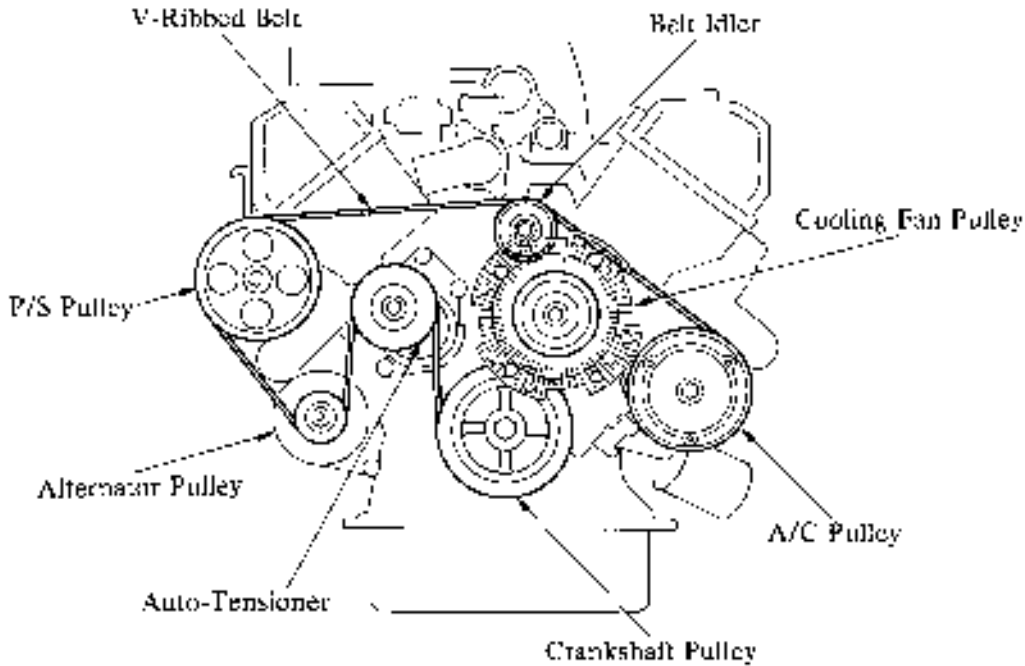
- The stainless steel exhaust pipe consists of three sections; the front, center and tail. The center section is single pipe while the front and tail are dual pipes to reduce exhaust resistance.
- The catalyst converters (start and main) are of the monolithic type three-way catalysts.
- The main catalyst converter is newly developed and has a high performance.
- Large mufflers (main and sub) effectively reduce noise and exhaust pressure from the large capacity engine.



\* Applicable only to the California specification vehicles. Refer to page 161 for detail.

## ■ SERPENTINE BELT DRIVE SYSTEM

- The serpentine belt drive system drives accessory components with a single V-ribbed belt. It reduces the overall engine length, weight and number of engine parts.
- An automatic tensioner eliminates the need for tension adjustment.



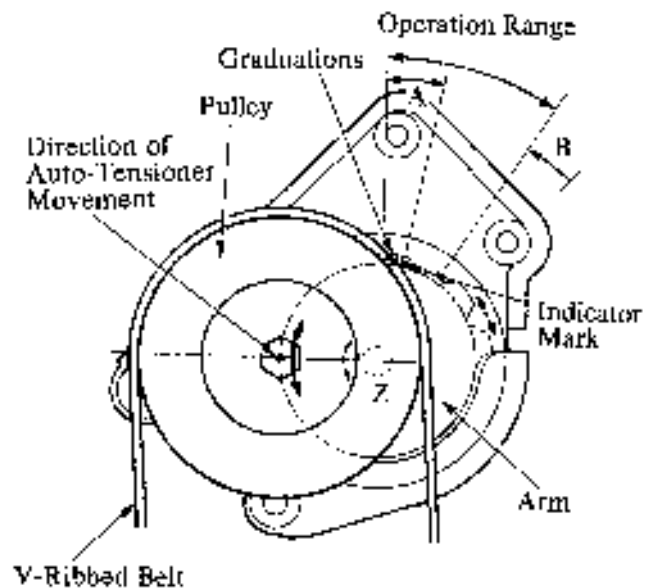
- The arm is pushed by the tension spring in a clockwise rotation direction always centering around “Z”.

The pulley’s center of rotation is bolted to the arm.

For this reason, when the belt stretches with time, the pulley center of rotation rotates to the right in an arc around “Z” with the arm. Thus the belt tension is always maintained appropriately.

### NOTICE

- Check the indicator mark. If it is outside the operation range, replace the belt.
- When a new belt is installed, the graduations must be in the area indicated by “A” in the picture.

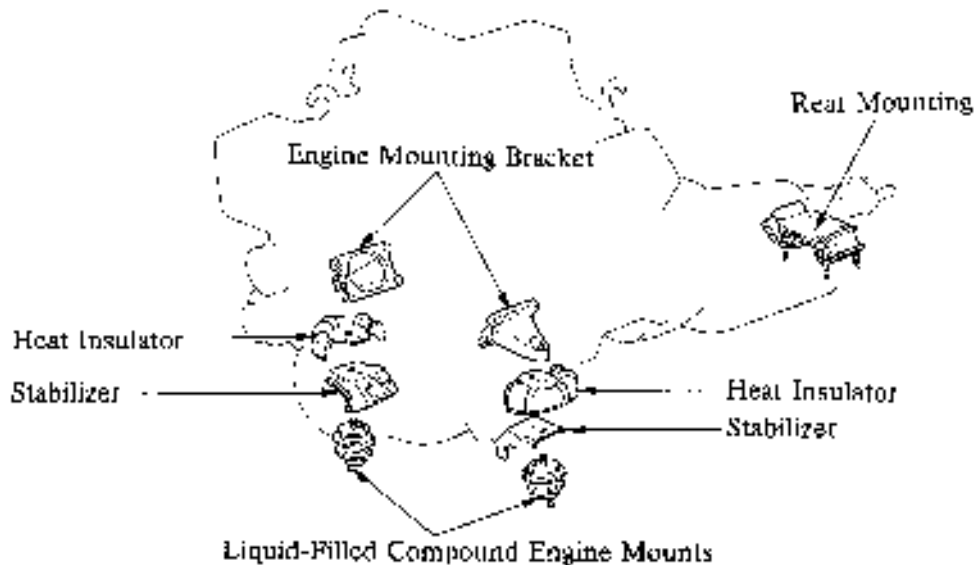


Auto-Tensioner

## ENGINE MOUNTING

### 1. General

- Liquid-filled compound engine mounts are fitted on both sides of the engine to reduce vibration and noise at all speeds.
- The aluminum engine mounting brackets reduce vibration and noise and minimize the total engine weight.

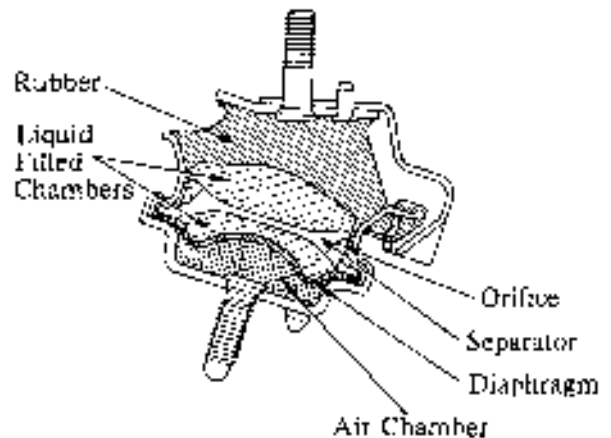


### 2. Liquid-Filled Compound Engine Mount

The engine mount combines rubber with liquid filled chambers.

The fluid flows between upper and lower chambers through an orifice.

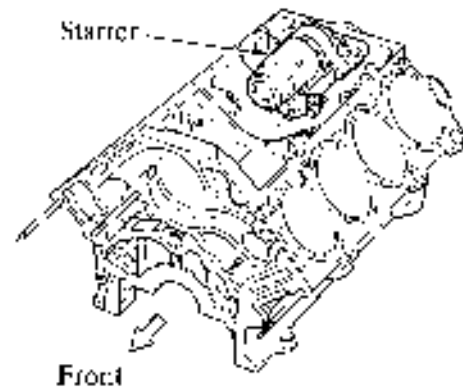
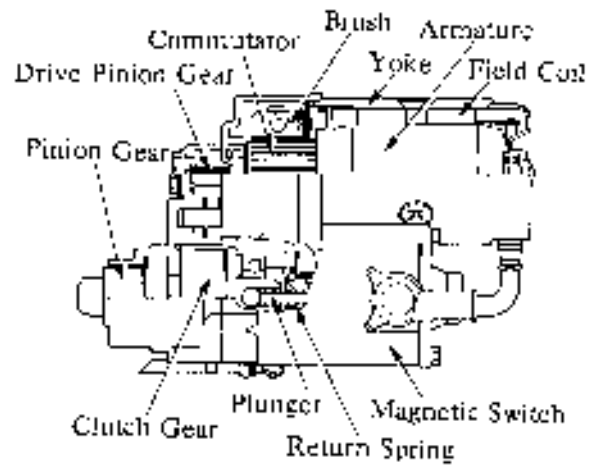
In addition to vibrations being absorbed by the rubber mounting, low frequency vibration is absorbed by the fluid flowing through the orifice. Also, by decreasing the elasticity of the rubber, the dynamic spring constant has been reduced, providing greater noise reduction in the case of high frequency vibrations.



## ■ STARTING SYSTEM

### 1. Starter

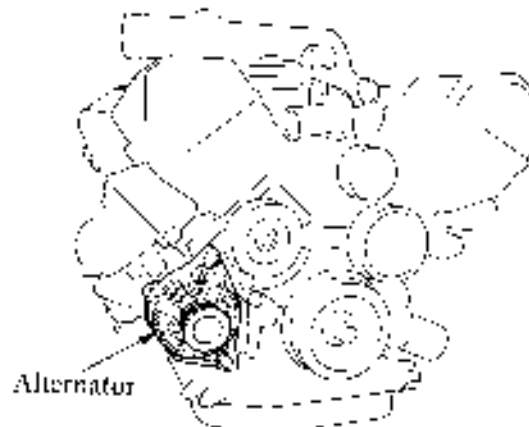
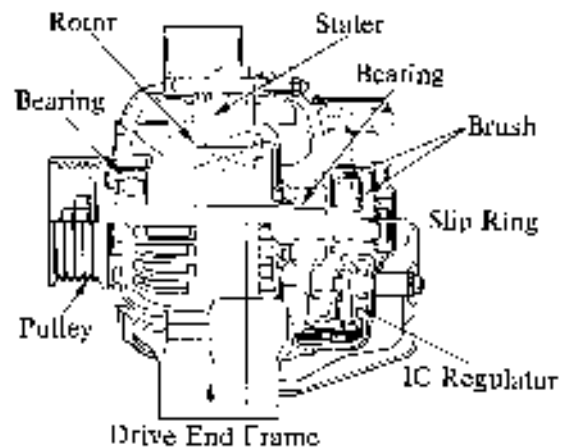
- The starter output is 2.0 KW and is located inside the V-bank of the cylinder block.



## ■ CHARGING SYSTEM

### 1. Alternator

- The IC regulated alternator has a large output of 1200 watts to produce enough electricity for the electric load.
- The alternator is fitted directly (without brackets) to the cylinder block.



## ■ ENGINE MOUNTING

### 1. General

Engine control system uses an ECU (Electronic Control Unit) with a built-in microprocessor. Stored inside the ECU is the data for fuel injection duration, ignition timing and idling speed, etc. which are matched with the various engine conditions as well as programs for calculation. The ECU utilizes these data and signals from the various sensors in the vehicle and makes calculations with the stored programs to determine fuel injection duration, ignition timing and idling speed, etc., and outputs control signals to the respective actuators which control operation.

The engine ECU and transmission ECU are integrated into one and the ECU is called the engine and transmission ECU. The engine control system for the 1UZ-FE engine has the following functions:

#### **EFI (Electronic Fuel Injection)**

The ECU determines the fuel injection duration according to intake air volume, engine speed, coolant temperature and other signals and sends control signals to the fuel injectors. Also, this fuel injection duration is the basis for deciding the fuel injection timing. The fuel injection system in the 1UZ-FE engine is a four group injection system which injects fuel simultaneously into two cylinders once every two engine revolutions.

#### **ESA (Electronic Spark Advance)**

The ECU determines the amount of ignition advance over the initial set timing of the distributor by the intake air volume, engine speed, coolant temperature and other signal and sends control signals to the igniters. Also, based on signals from the knock sensors, the ECU controls the ignition timing at the optimum in accordance with the gasoline's octane value.

#### **ISC (Idle Speed Control)**

By means of engine speed signals and coolant temperature signals, the ECU sends control signals to the ISC valve so that the actual idling speed becomes the same as the target idling speed stored in the ECU. Also, while the engine is warming up, the ECU, based on coolant temperature signals, sends controls signals to the ISC valve to control engine speed to fast idle.

#### **EGR (Exhaust Gas Recirculation) CUT CONTROL**

The ECU sends signals to the EGR VSV to cut the EGR based on coolant temperature, engine speed, neutral start switch or intake air volume signals. This system maintains drivability at low coolant temperature, under light or heavy load conditions, or at high engine speed, etc.

#### **FUEL PRESSURE CONTROL**

The ECU sends signals to the pressure regulator VSV based on coolant temperature, intake air temperature, vehicle speed and engine start signals, and increases the fuel pressure. This system maintains restartability and idling stability when the engine is hot.

#### **FUEL PUMP SPEED CONTROL**

The ECU, based on fuel injection duration, sends control signals to the fuel pump control relay to control the fuel pump speed. That is, when the engine requires a large volume of fuel, the fuel pump turns at high speeds and when only a small volume of fuel is required, the pump turns at low speeds.

**OXYGEN SENSOR HEATER CONTROL**

Based on the intake air volume, engine start and coolant temperature signals, the ECU sends control signals to the oxygen sensor heater. This system maintains the oxygen sensor at the appropriate temperature in order to improve the detecting accuracy of oxygen concentration in the exhaust gas.

**AIR CONDITIONER CONTROL**

Based on the air conditioner switch signal from the air conditioner ECU, the ECU sends control signals to the magnetic clutch of the air conditioner compressor. This system, the magnetic clutch operation, is delayed for a predetermined period after the air conditioner switch is turned on.

**DIAGNOSIS**

The ECU is constantly monitoring signals from each sensor. If a malfunction occurs with the signals, the CHECK ENGINE lamp on the combination meter lights up and informs the driver of the malfunction.

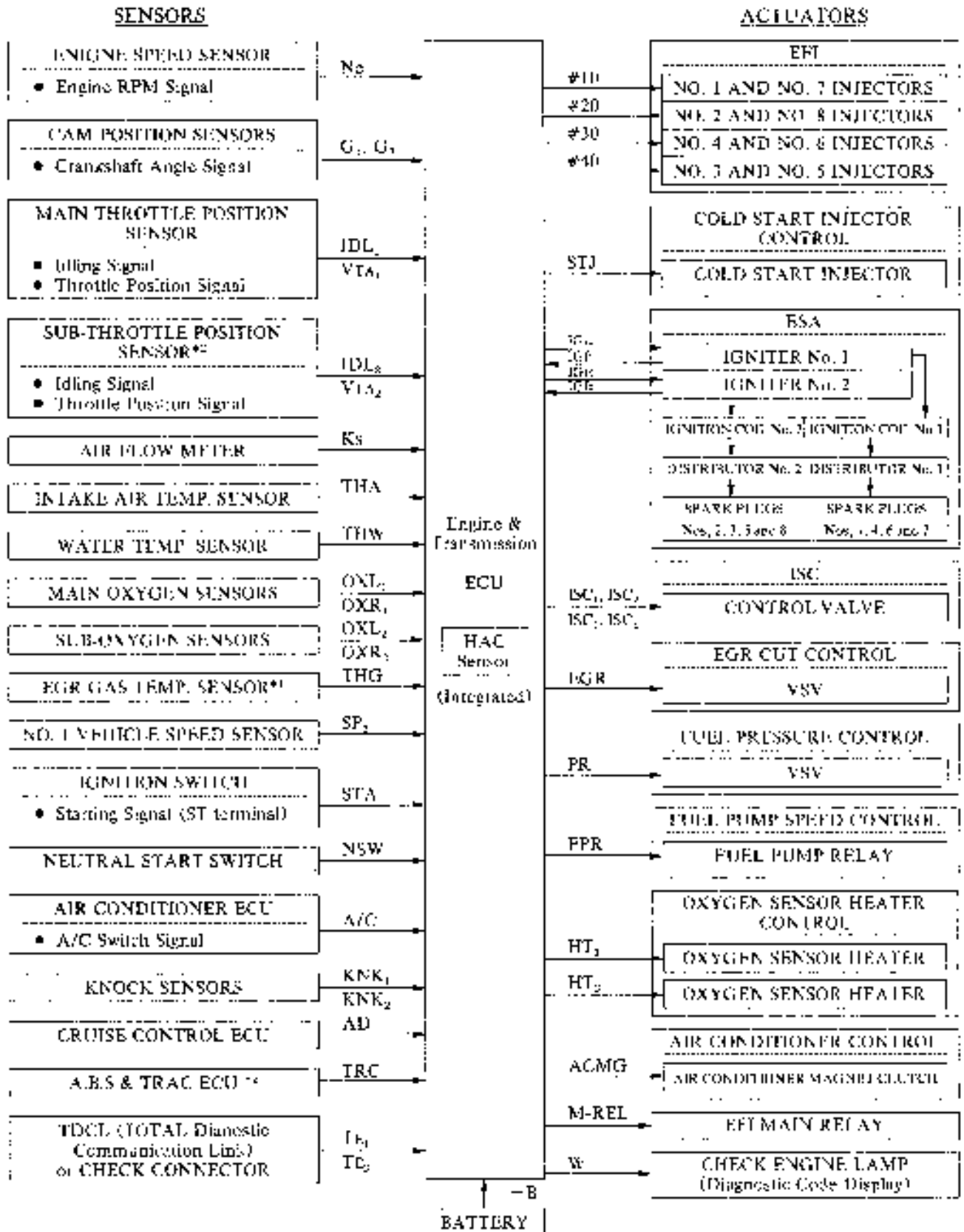
The content of the malfunction is stored in code in the ECU and when the TE<sub>1</sub> and E<sub>1</sub> terminals in the check connector or TDCL are connected, the ECU outputs the trouble code by flashing the CHECK ENGINE lamp.

**FAIL-SAFE**

If the ECU judges from the signals from each sensor that there is a malfunction, it continues the engine operation using its own data or it stops the engine.

## 2. Construction

The engine control system can be broadly divided into three groups: the ECU, the sensor and the actuators.



<sup>1</sup> Applicable only to California specification vehicles.

<sup>\*2</sup> Applicable only to vehicles equipped with the optional TRAC (Traction Control) system

### 3. Summary of Engine Control System

The following list summarizes each system and control composing engine control system of the 1UZ-FE engine and types of the related sensors, ECU and others.

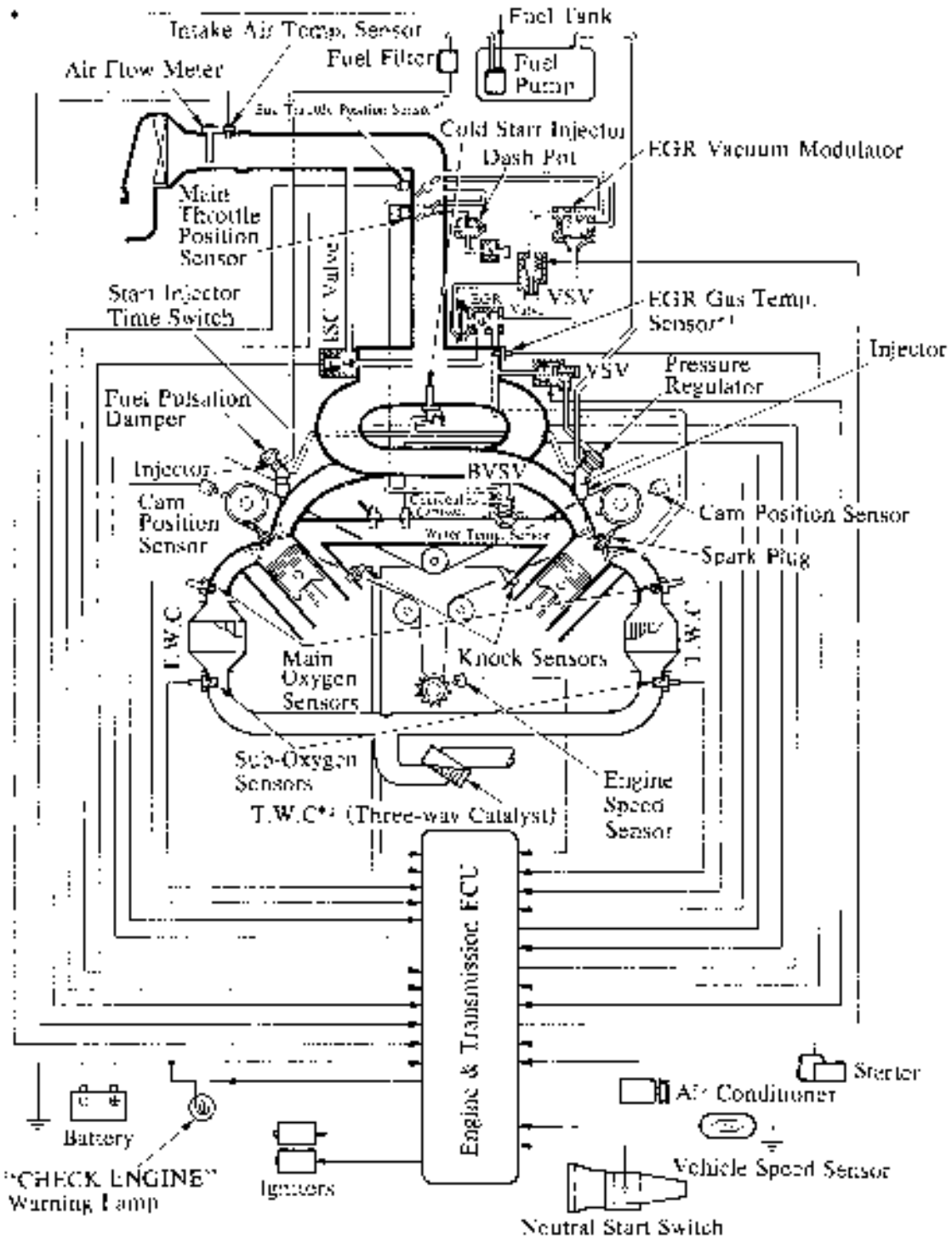
		SENSORS															ECU													
		KS	NS	G	EDW	THA	IDL1	VIA	IDL2	VIA2	SA	IGFWS	SP	OX1	OX2	OX3	THO	KNK	SNK	MSW	IP	TC	RAM	J	TRC	AD	ACC	Start Injery Time Switch		
LPI	Starting Injection Control																													
	Basic Injection Position																													
	Injection Corrections																													
	After-Start Enrichment																													
	Warm-Up Enrichment																													
	Acceleration Enrichment (Hot & Warm-Up)																													
	Power Enrichment																													
	Air-Fuel Ratio Feedback Correction																													
	Voltage Correction																													
	Fuel Cut-Off																													
MSA	Cold Start Injection Control																													
	Starting Ignition Control																													
	Basic Ignition Advance Angle Control																													
	Corrective Ignition Advance Angle Control																													
	Warm-Up Correction																													
	EGR Correction																													
	Knocking Correction																													
	Torque Control Correction																													
	Maximum and Minimum Advance Angle Control																													
	Igniter Control																													
ECU	Initial Set-Up																													
	After Start Control																													
	Warm-Up Control																													
	Feedback Control																													
	Load Speed Change Estimate Control																													
	EGR Cut-Off Control																													
	Fuel Pump Speed Control																													
	Fuel Pressure Control																													
	Oxygen Sensor Heater Control																													
	Air Conditioner Compressor Duty Control																													

\*1: Applicable only to California specification vehicles.

\*2: Applicable only to vehicles equipped with the optional TRAC (Traction Control) system

## 4. Engine Control System Diagram

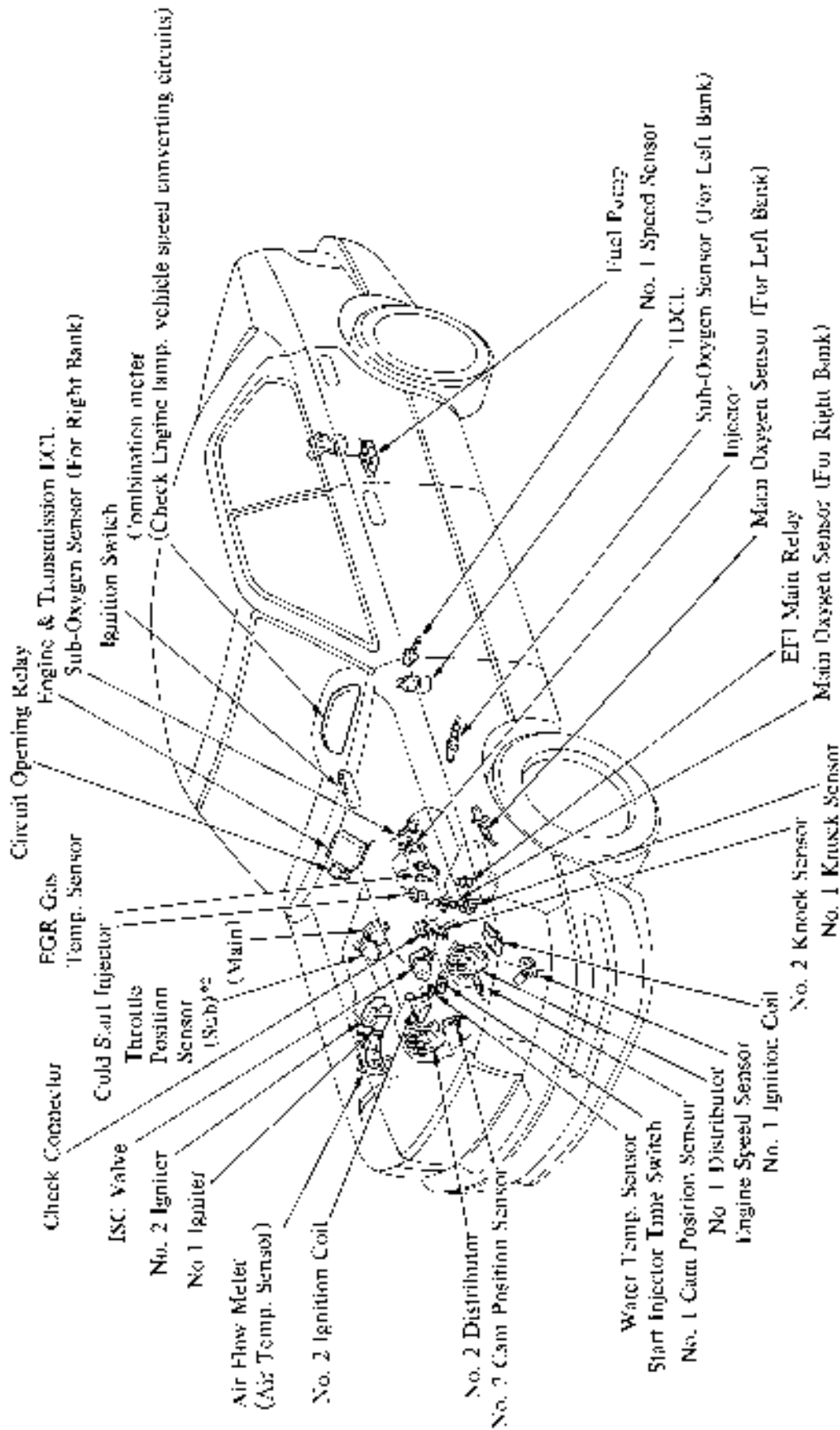
### • Ignition Switch



\*1: Applicable only to California specification vehicles.

\*2: Applicable only to vehicles equipped with the optional TRAC (Traction Control) system

5. Arrangement of Engine Control System Components



\*1 Applicable only to the California specification vehicles  
 \*2 Applicable only to the vehicles equipped with the optional TRAC (Traction Control System)

## 6. EFI (Electronic Fuel Injection)

The EFI system consists of the following three major systems:

- 1) Fuel System
- 2) Air Induction System
- 3) Electronic Control System

### Fuel System

#### 1) General

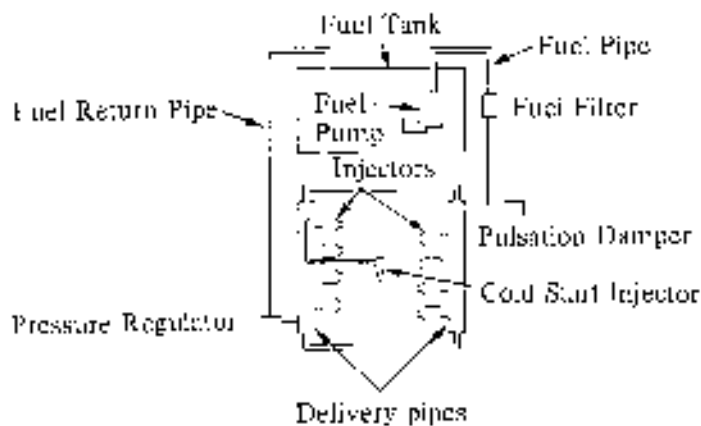
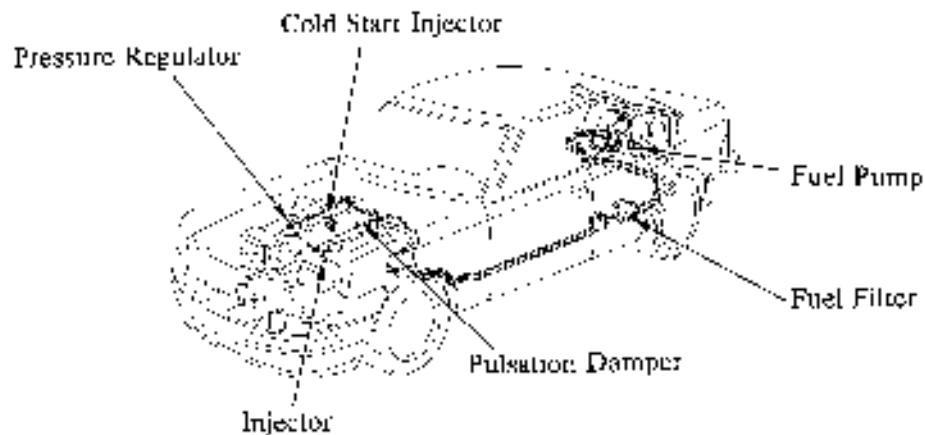
Fuel is pumped under pressure by the electric fuel pump from the fuel tank, through the fuel filter, to the injectors and the cold start injector.

The pressure regulator controls the amount of fuel being returned to the fuel tank through the return pipe, thus adjusting the pressure of fuel to the injectors.

The pulsation damper absorbs the minute fluctuations in fuel pressure due to injection of fuel.

The injectors inject fuel into the intake port in accordance with injection duration signals from the ECU.

The cold start injector injects fuel into the air intake chamber when the coolant temperature is low, improving startability in cold weather.



## 2) Fuel Pump

An in-tank type fuel pump is provided inside the fuel tank.

A turbine pump, with little discharge pulsation of the fuel in the pump, is used.

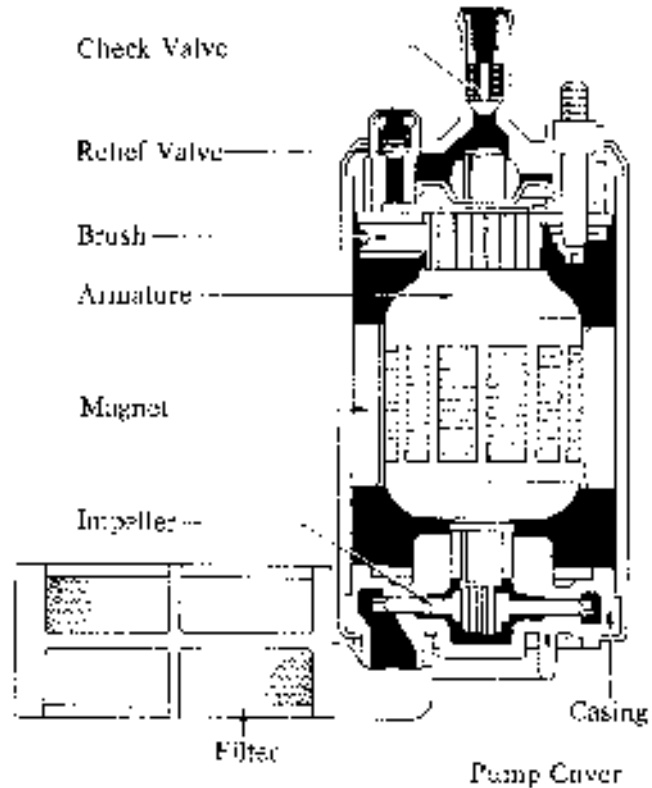
This pump consists of the motor portion and the pump portion, with a check valve, relief valve and filter also incorporated into the unit.

### a. Turbine Pump

The turbine pump consists of the impeller, which is driven by the motor, and the casing and pump cover, which compose the pump unit. When the motor turns, the impeller turn along with it.

Blades on the outer circumference of the impeller pull fuel from the inlet port to the outlet port.

Fuel discharged from the outlet port passes through the motor portion and is discharged from the pump through the check valve.



### b. Relief Valve

The relief valve open when the discharge side pressure reaches  $71.1 \sim 92.3 \text{ lb/in.}^2$  ( $5.0 \sim 6.5 \text{ kg/cm}^2$ ) and the high pressure fuel is returned directly to the fuel tank.

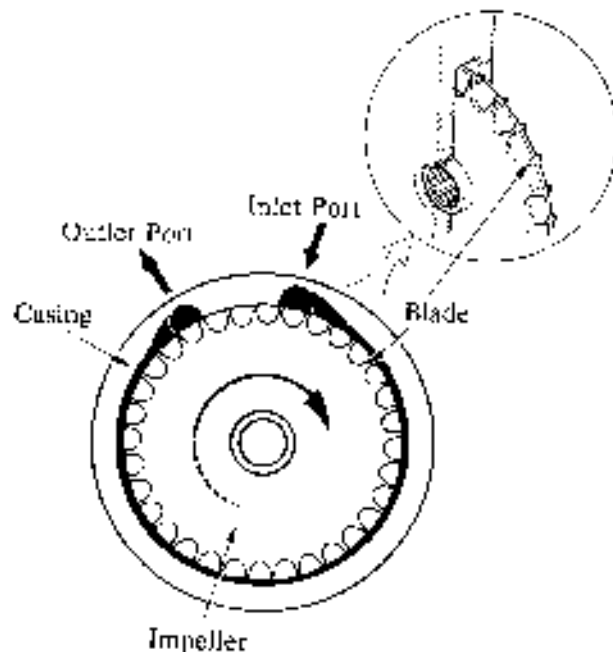
The relief valve prevents the fuel pressure from rising beyond that level.

### c. Residual Pressure Check Valve

The check valve closes when the fuel pumps stops.

The residual pressure check valve and pressure regulator both work to maintain residual pressure in the fuel line when the engine is stopped, thus easing restartability.

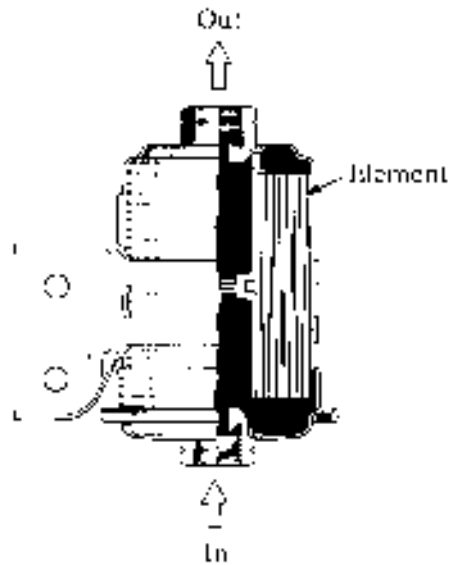
If there were no residual pressure, vapor lock could occur easily at high temperatures, making it difficult to restart the engine.



- The 1UZ-FE engine has a fuel pump speed control (ECU controlled) system which regulates the amount of electricity flowing to the fuel pump and thus the amount of fuel delivery according to the engine load. See page 149 for detail.

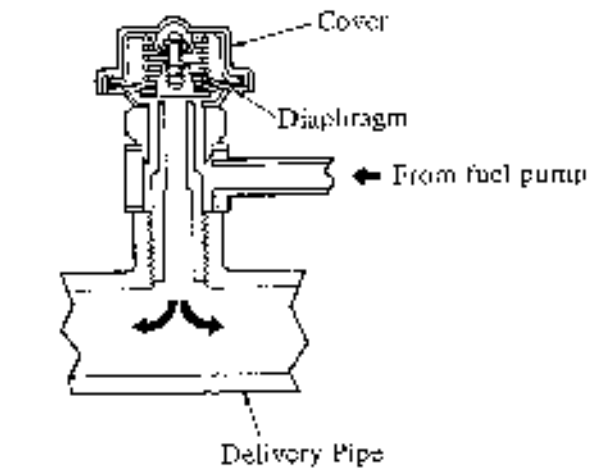
### 3) Fuel Filter

The fuel filter filters out dirt and other foreign particles from the fuel. It is installed at the high pressure side of the fuel pump.

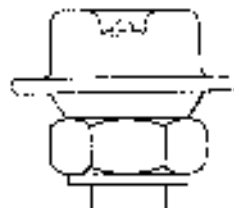


### 4) Pulsation Damper

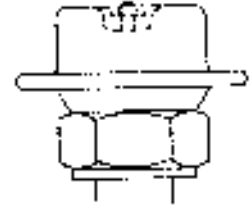
Fuel pressure is maintained at 41 lb/in.<sup>2</sup> (2.9 kg/cm<sup>2</sup>) in relation to the manifold vacuum, by the pressure regulator. However, there is a slight variation in line pressure due to injection. The pulsation damper acts to absorb this variation by means of a diaphragm.



Low Pressure



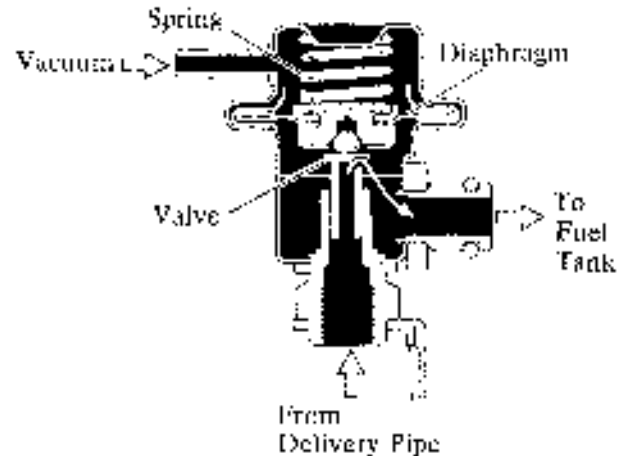
High Pressure



## 5) Pressure Regulator

### a. Function

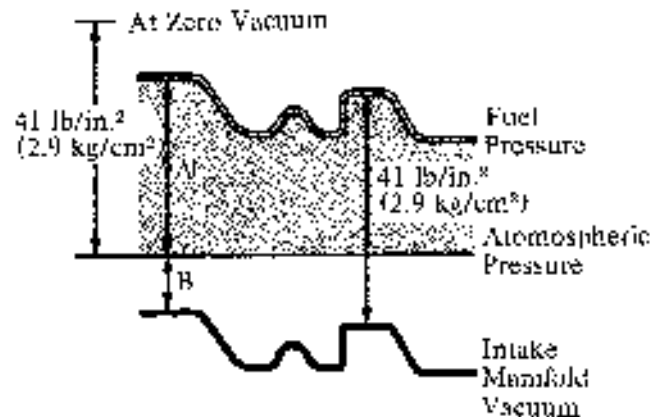
The pressure regulator regulates the fuel pressure to the injectors. Fuel injection quantity is controlled by the duration of the signal applied to the injectors, so that a constant pressure must be maintained to the injectors. However, as fuel is injected into the intake port and manifold vacuum varies, the fuel injection quantity will vary slightly even if the injection signal and fuel pressure are constant. Therefore, to acquire an accurate injection quantity, the sum of the fuel pressure A and intake manifold vacuum B must be maintained at 41 lb/in.<sup>2</sup> (2.9 kg/cm<sup>2</sup>).



### b. Operation

Pressurized fuel from the delivery pipe pushes on the diaphragm, opening the valve. Part of the fuel flows back to the fuel tank through the return pipe. The amount of fuel return depends on the extent of the diaphragm spring tension and the fuel pressure varies according to the return fuel volume.

Intake manifold vacuum is led to the chamber of the diaphragm spring side, weakening the diaphragm spring tension, increasing the volume of return fuel and lowering the fuel pressure. In short, when intake manifold vacuum rises (less pressure), fuel pressure falls only to the extent of the decrease in pressure, so that sum of the fuel pressure A and the intake manifold vacuum B is maintained at a constant.



The valve is closed by the spring when the fuel pump stops. As a result, the check valve inside the fuel pump and the valve inside the pressure regulator maintain residual pressure inside the fuel line.

- The 1UZ-FE engine has a fuel pressure control (ECU controlled) system which maintains the fuel pressure at higher levels than normal for a predetermined time when the engine is hot when started, maintaining the engine startability and the idle stability. See page 150 for detail.

**6) Fuel Injector**

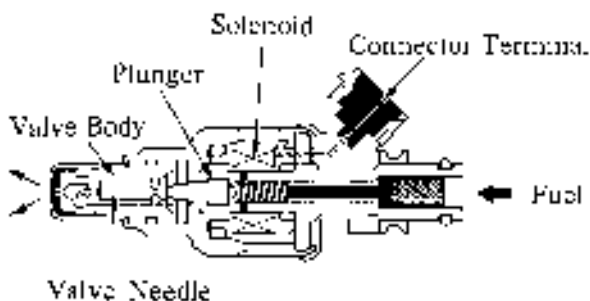
Fuel is injected into the intake port of each cylinder in accordance with injection signals from the ECU.

At the tip of the injector, there are two injection holes.

The light and small plunger permits quick response to signals from the ECU.

When a signal from the ECU is received by the solenoid coil, the plunger is pulled against spring force. Since the valve needle and plunger are a single unit, the valve needle is also pulled from its seat and fuel is injected.

Fuel volume is controlled by the duration of the signal.



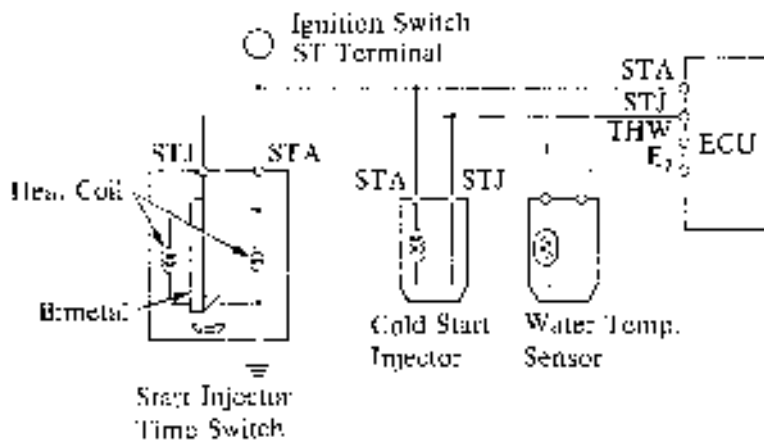
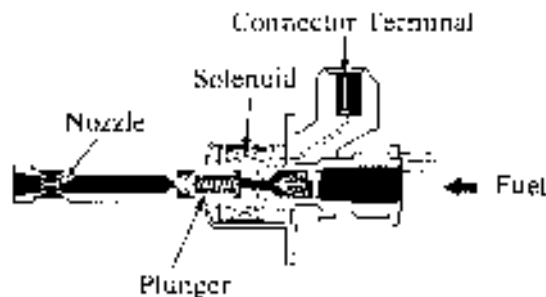
**7) Cold Start Injector**

The cold start injector injects fuel into the intake air chamber during engine cranking to improve startability.

In starting the engine when the engine coolant temperature is 71.6°F (22°C) or lower, the cold start injector's operation time is controlled by the start injector time switch.

However, starting the engine when engine coolant temperature is 140°F (60°C) or lower, the operation time of the cold start injector is controlled by the ECU.

Thus, the cold start injector is controlled by the start injector time switch and the ECU simultaneously when the coolant temperature is below 71.6°F (22°C).



## Air Induction System

### 1) General

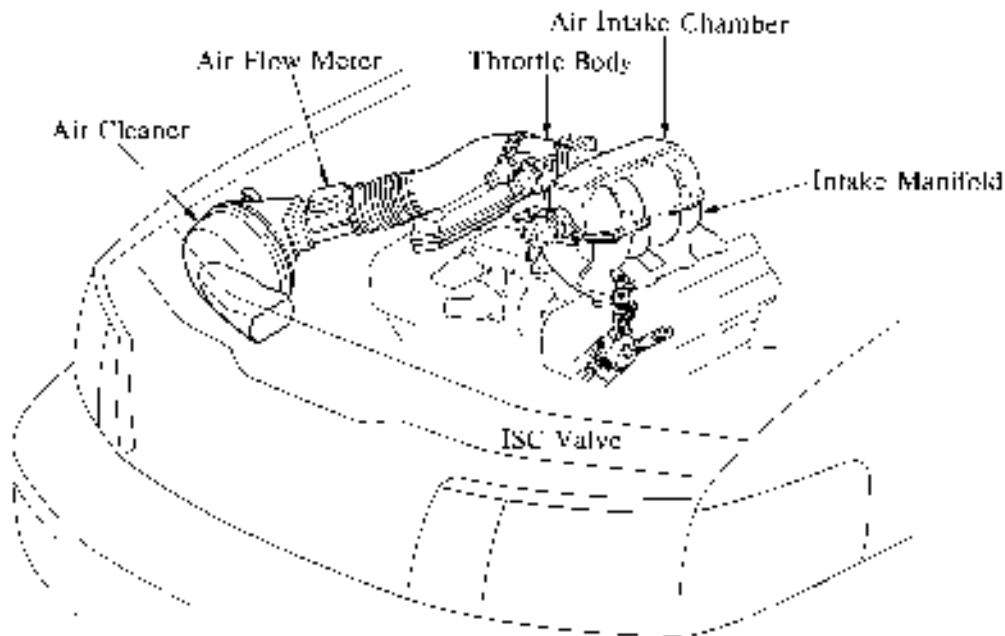
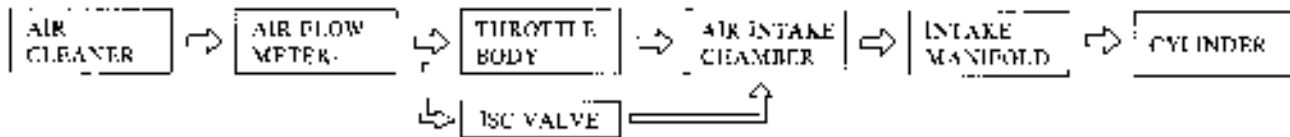
Air cleaned by the air cleaner enters the air intake chamber according to the throttle valve opening in the throttle body and the engine speed. An optical Karman–Vortex type air flow meter is provided between the air cleaner and the throttle body to optically detect the frequency of the Karman–Vortex that is generated when the air passes to measure the amount of air being taken into the engine.

A throttle valve in the throttle body controls the air volume.

The air regulated by the throttle valve enters the air intake chamber, is distributed to the intake manifold of each cylinder and enters the combustion chamber.

ISC (Idle Speed Control) valve is also provided on the throttle body and directs the intake air bypassing the throttle body to the air intake chamber. The amount of air bypassing the throttle body is determined by a signal from the ECU to control the idle speed and fast idle speed accordingly.

The air intake chamber prevents pulsation of the intake air to minimize the adverse affection to the air flow meter. This helps to increase accuracy of measurement of the intake air volume. It also prevents intake air interference in cylinders.



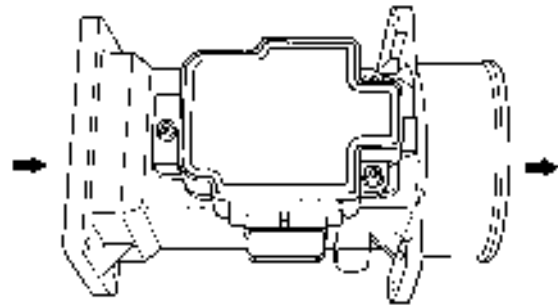
## 2) Construction and Operation of Main Components

### a. Air Flow Meter

#### • Description

An optical Karman–Vortex type air flow meter is used.

This air flow meter measures the intake air volume electrically, enabling precise detection. It is made compact and lightweight. The simplified construction of the air passage also reduces air intake resistance.



#### • Principle

##### Karman–Vortex Street

When a cylindrical object (Vortex generating body) is placed in the path of gaseous current, vortices (called Karman–Vortex) are generated in the wake of the object. If the Karman–Vortex frequency is  $f$ , the air velocity  $V$  and the diameter of the cylindrical object  $d$ , then the following equation can be made:

$$f = \frac{0.2 V}{d}$$

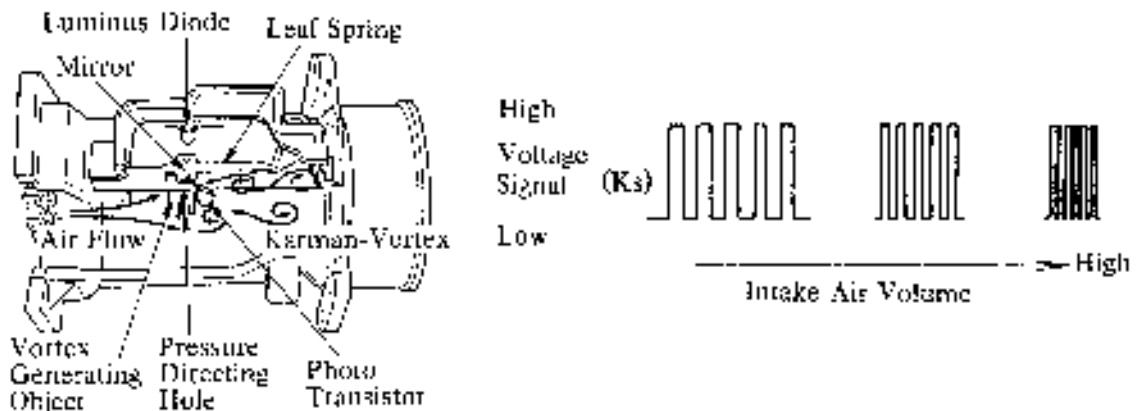
#### • Construction and Operation

Using the above principle, the air flow meter is fitted with a vortex generator. As air flows past the vortex generator, vortices are generated at a frequency proportional to the velocity of the air flow.

A calculation of the frequency can then determine the amount of air flow.

The vortices are detected by subjecting the surface of thin metal foil (mirror) to the pressure of the vortices and optically detecting the vibrations in the mirror by means of a luminous diode and a photo transistor.

The intake air volume signal ( $K_s$ ) is the pulse signal. When the intake air volume is low, this signal has a low frequency. When the intake air volume is high, it has a high frequency.



### b. Throttle Body

The throttle body contains the throttle valve that regulates the amount of intake air, the throttle position sensor that detects the throttle valve opening, and the dash pot that reduces the closing speed of the throttle valve.

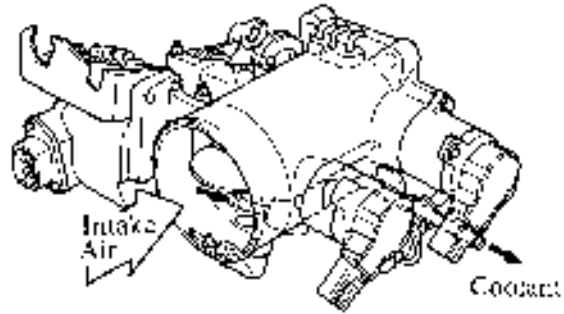
The throttle body has the following features:

- The throttle body contains a throttle valve, sufficiently large in diameter to meet the large engine displacement.
- A linear type throttle position sensor is mounted on the throttle valve shaft.

This sensor detects the throttle valve opening angle, converts it to a voltage and sends it to the engine and transmission ECU.

(Refer to the next page for detail.)

- Engine coolant passes through the throttle body to maintain warmth under cold weather conditions.
- When the optional TRAC (Traction Control) is fitted, a sub-throttle actuator, sub-throttle valve and sub-throttle position sensor are added to the throttle body.



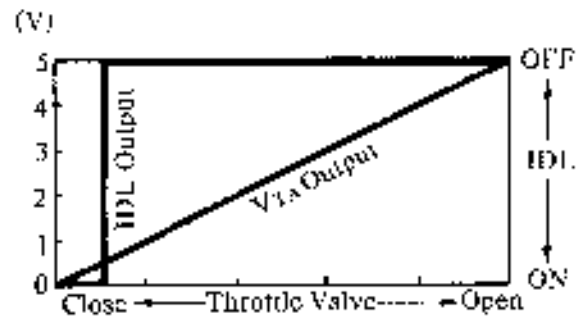
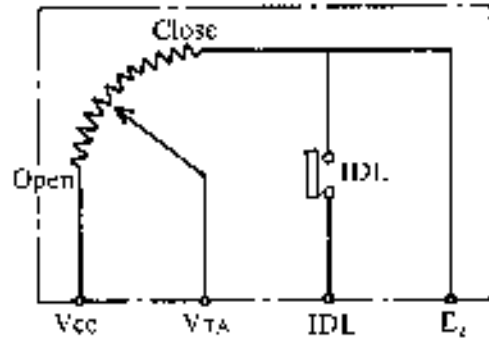
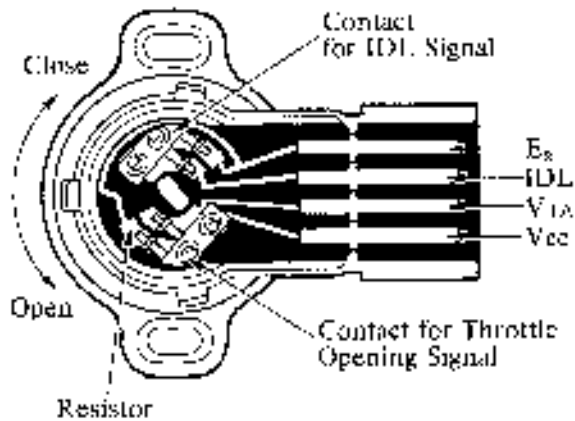
### • Throttle Position Sensor

The throttle position sensor is mounted on the throttle body. This sensor converts the throttle opening angle into a voltage and sends it to the ECU as the throttle position signal.

A constant 5V is applied to the Vcc terminal from the ECU. As the contact slides along the resistor in accordance with the throttle valve opening angle, a voltage is applied to the V<sub>TA</sub> terminal in proportion to this angle.

When the throttle valve is closed completely, the contact for the IDL signal connects between the IDL and E<sub>2</sub> terminals.

Another throttle position sensor for the sub-throttle valve is added to the vehicle with the optional TRAC (Traction Control). It is the same as the main throttle position sensor in construction and operation.



## Electronic Control System

### 1) General

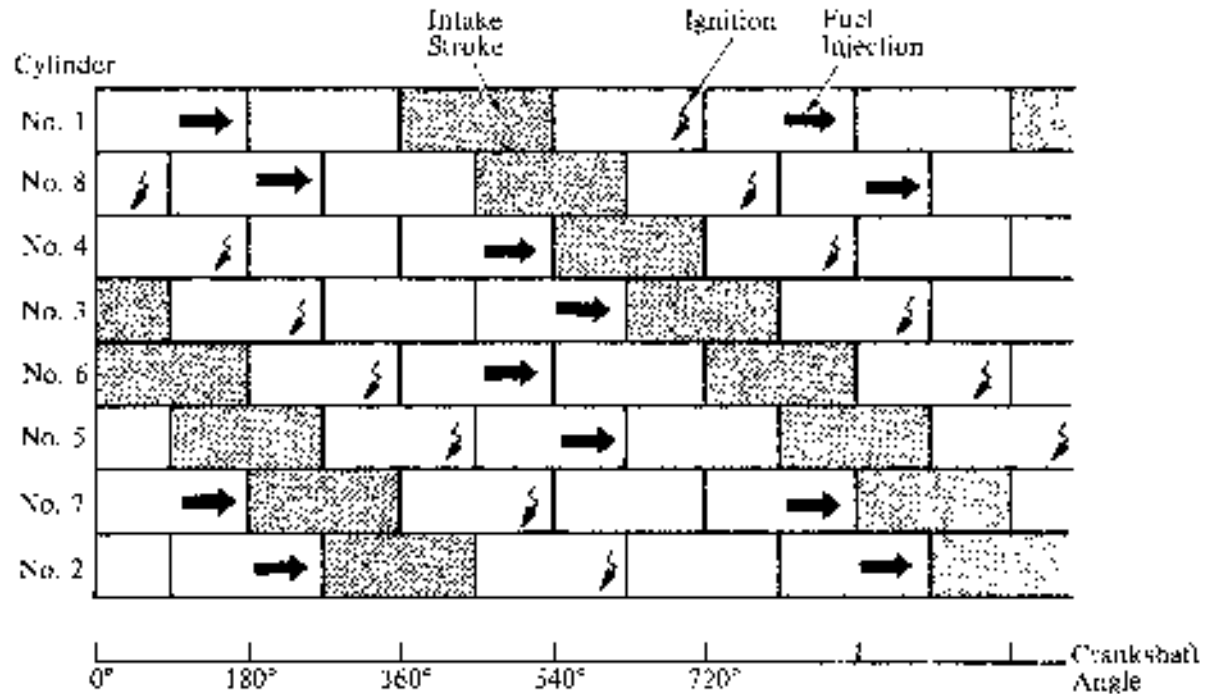
The ECU incorporates a built-in microprocessor. It controls injection duration precisely based on the data stored in its memory and signals from each sensor.

Also, the ECU, based on this injection duration, controls the ignition timing.

Further, the fuel injection system is a four group injection system.

The ECU controls to inject fuel into two cylinders simultaneously once every two engine revolutions.

### ► Fuel Injection Timing ◀

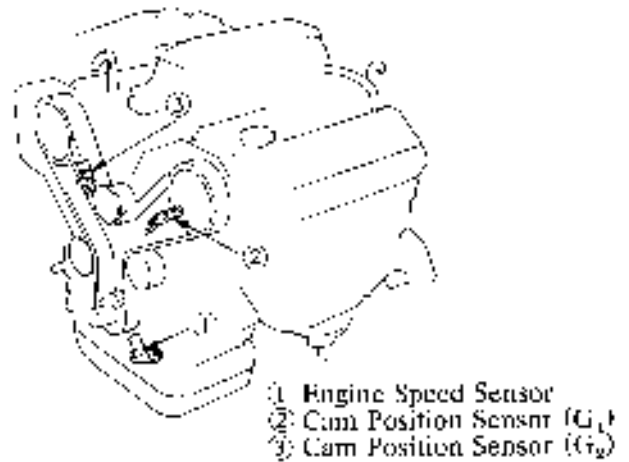


## 2) Construction and Function of Relevant Sensors

### a. Cam Position Sensors and Engine Speed Sensor

#### • General

Revolution of the G signal plate on the camshaft and Ne signal plate on the crankshaft alters the air gap between the projection of the plate and the G pickup coil (or the Ne pickup coil). The change in the gap creates an electromotive force in the pickup coil. This voltage appears as an alternating output since it reverses its direction periodically as the plate approaches and leaves the pickup coil.

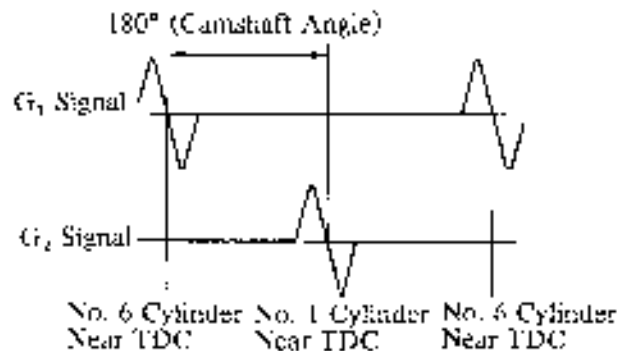
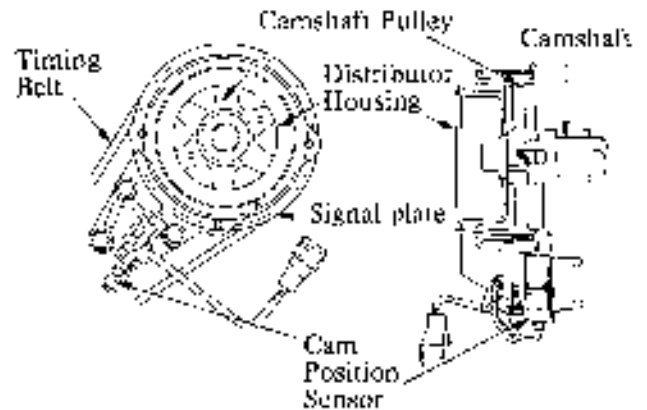


#### • Cam Position Sensors ( $G_1$ and $G_2$ signals)

The  $G_1$  signal informs the ECU of the standard crankshaft angle, which is used to determine injection timing and ignition timing in relation to TDC of No. 6 cylinder.  $G_2$  sensor conveys the same information for No. 1 cylinder.

These sensors are made up of (1) signal plate, which is fixed to the camshaft timing pulley and turn once for every two rotations of the crankshaft, and (2) the two sensors ( $G_1$  and  $G_2$  sensors), which are fitted to the distributor housing.

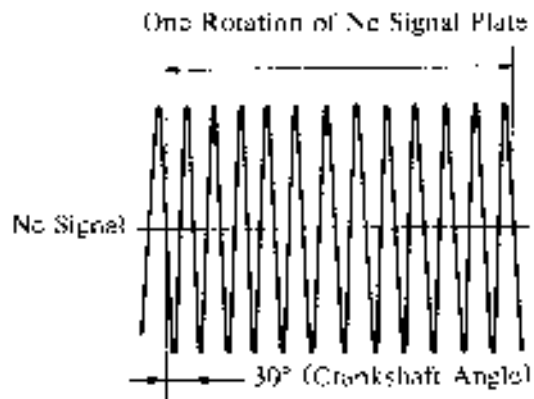
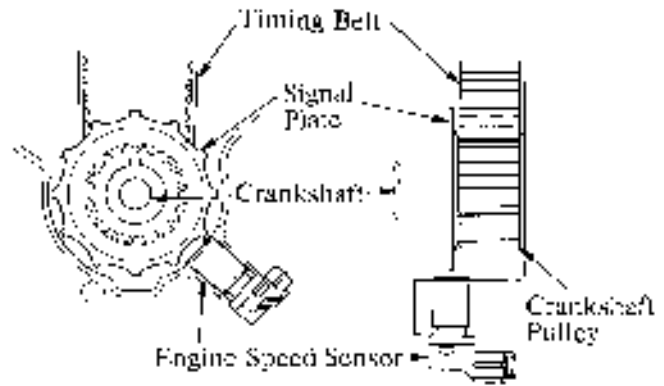
The  $G_1$ ,  $G_2$  signal plates are provided with a projection which activates the  $G_1$  and  $G_2$  sensors once for each rotation of the camshaft, generating the wave forms as shown in the chart. From these signals, the ECU detects when the No. 6 and No. 1 pistons are near their TDC.



• **Engine Speed Sensor (Ne signal)**

The Ne signal is used by the ECU to detect the actual crankshaft angle and the engine speed. The ECU determines the basic injection duration and basic ignition advance angle by these signals. Ne signals are generated in the Ne sensor by the Ne signal plate like the G<sub>1</sub> and G<sub>2</sub> signals. The only difference is that the signal plate for the Ne signal has 12 teeth. Therefore, 12 Ne signals are generated per engine rotation.

From these signals, the ECU detects the engine speed as well as each 30° change in the engine crankshaft angle.



## b. Oxygen Sensors

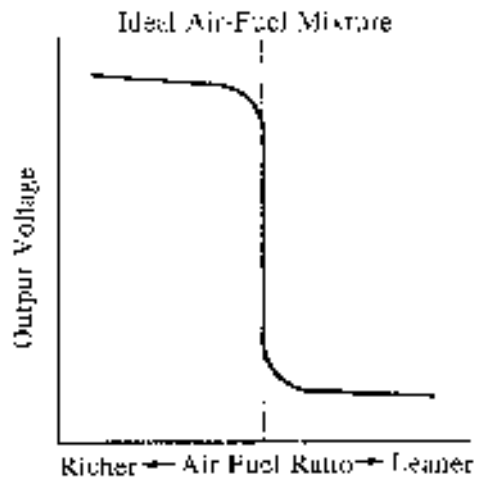
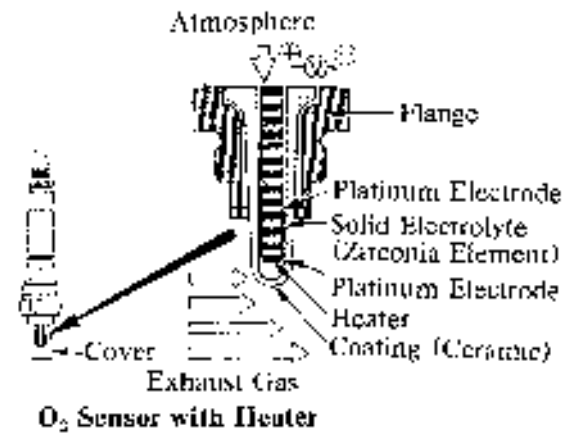
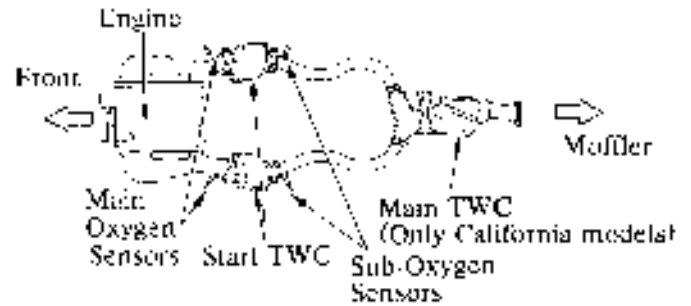
Four oxygen sensors in total are fitted, one each in front of and after the start catalyst converters. The one in front of the catalyst converter is the main oxygen sensor and after the converter is the sub-oxygen sensor. The main and sub-oxygen sensors are identical in construction and function, except for the fact that the main oxygen sensor has a heater.

The O<sub>2</sub> sensor consists of a test tube shaped zirconia element with a thin layer of platinum coated to both the inside and outside. This sensor is fitted to the exhaust manifolds and exhaust pipes on both the left and right sides to sense oxygen concentration (air-fuel ratio) in the exhaust gas. If there is a difference in the oxygen concentration on the two sides of the zirconia element, an electromotive force is generated, or if the temperature of the O<sub>2</sub> sensor becomes high, the platinum acts as a catalyst, causing the oxygen in the exhaust gas to react with the CO. This decreases the oxygen volume in the gas. The zirconia element's electromotive force changes suddenly at the boundary near the ideal air-fuel ratio.

Using these properties, exhaust gas is passed over the outer surface of the O<sub>2</sub> sensor and atmospheric air is introduced into the inside of the sensor. The sensor accurately detects whether the oxygen concentration, that is, the air-fuel ratio, is higher (rich) or lower (lean) than the ideal air-fuel ratio.

If the air-fuel is rich, the zirconia element generates high voltage (approximately 1V). This "rich" signal is sent to the ECU. Conversely, if the air-fuel ratio is lean, the electromotive force of the O<sub>2</sub> sensor is low. The ECU increases or decreases the injection volume in accordance with these signals.

A heater is provided in the sensors which are fitted to the exhaust manifolds. It heats the zirconia element. This heater is controlled by the ECU. When the intake air volume is low (the exhaust gas temperature is low), current flows to the heater, maintaining the sensor accuracy.

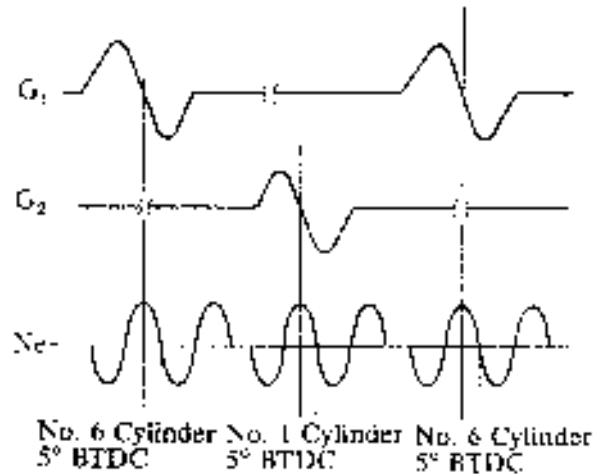


### 3) Functions of the ECU

#### a. Determination of Injection Timing

When the ECU receives the  $G_1$  signal from the cam position sensor and then the  $Ne$  signal from the engine speed sensor in this order, it determines that the crankshaft angle at No. 6 cylinder is at  $5^\circ$  BTDC position.

When the  $Ne$  signal is received immediately after the  $G_2$  signal, it judges that the crankshaft angle at No. 1 cylinder is at  $5^\circ$  BTDC. The ECU accurately calculates the crankshaft angle based on  $G_1$ ,  $G_2$  and  $Ne$  signals and determines the injection timing accordingly.



#### b. Principle of Fuel Injection Duration Control

The fuel injection duration is determined by the basic injection duration which is determined by intake air volume and the engine speed, plus any compensation based on signals from various sensors. During engine starting (cranking), it is determined differently because the amount of intake air is not stable during cranking. Once the engine is started, the ECU determines the duration of injection in the following steps:

##### Step 1: Determination of Basic Injection Duration

The ECU selects, from the data stored in its memory, an injection duration that is suitable for the intake air volume (detected by the air flow meter) and the engine rpm (detected by the engine speed sensor).

This injection duration is called the “basic injection duration.”

##### Step 2: Determination of Adjusted Duration of Injection

Under most engine condition, the engine runs smoothly at an air–fuel mixture ratio of approximately 14.7 (this is called the “ideal air–fuel ratio”). However, when the engine is still cold, or when an extra load is applied to the engine, the air–fuel ratio is reduced to below 14.7 (i.e., it becomes richer). The ECU detects these engine conditions by means of the water temp. sensor, throttle position sensor and intake air temp. sensor, etc., and corrects the basic injection duration to optimize it for the existing engine conditions.

Also, even under normal engine conditions, the injection duration is corrected by the signals from the oxygen sensors to keep the air–fuel ratio within a narrow range near 14.7. The corrected time is called the “adjusted injection duration”.

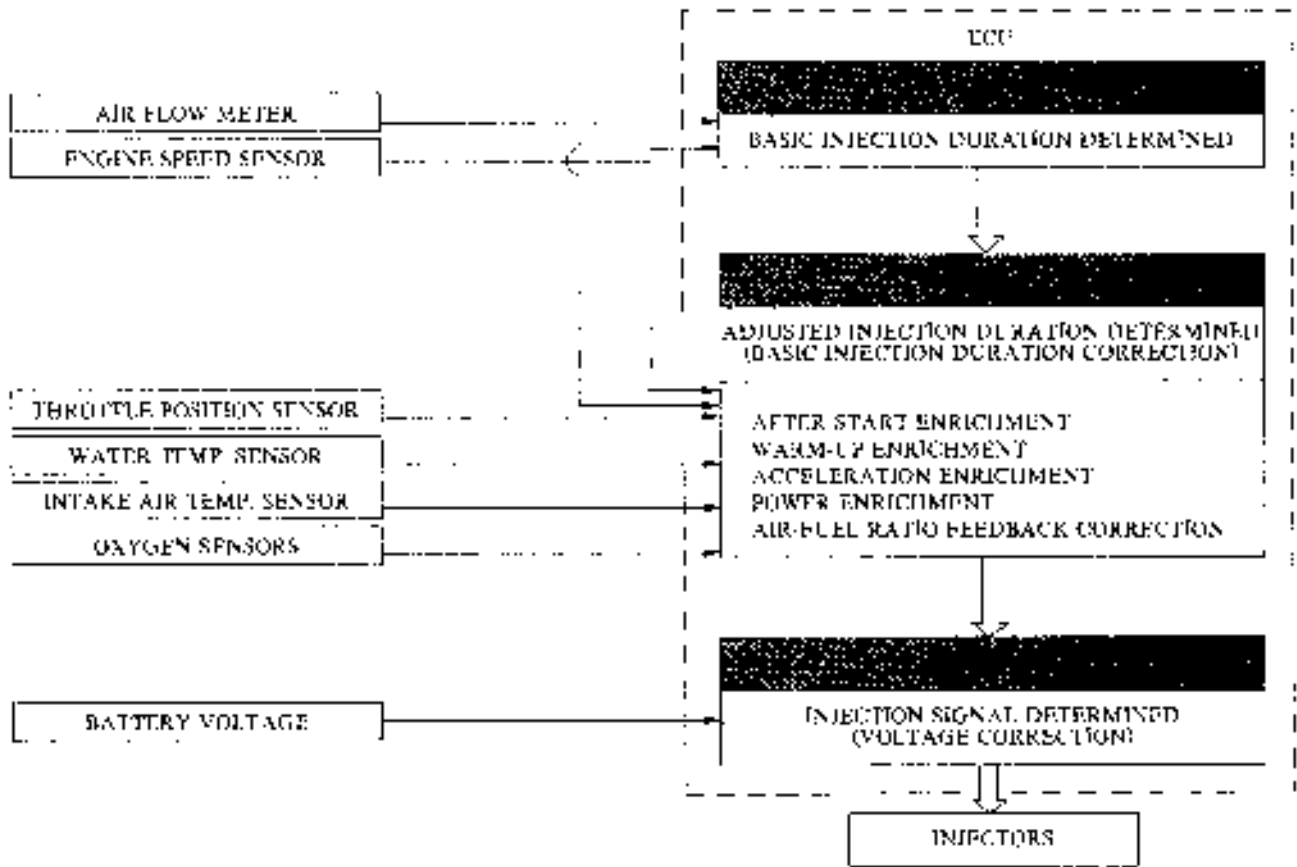
##### Step 3: Determination of Injection Signal Length

There is a slight delay between the time the ECU sends an injection signal to the injectors and the time the injectors actually open.

This delay becomes longer the more the voltage of the battery drops.

The ECU compensates for this delay by lengthening the injection signal by a period corresponding to the length of the delay.

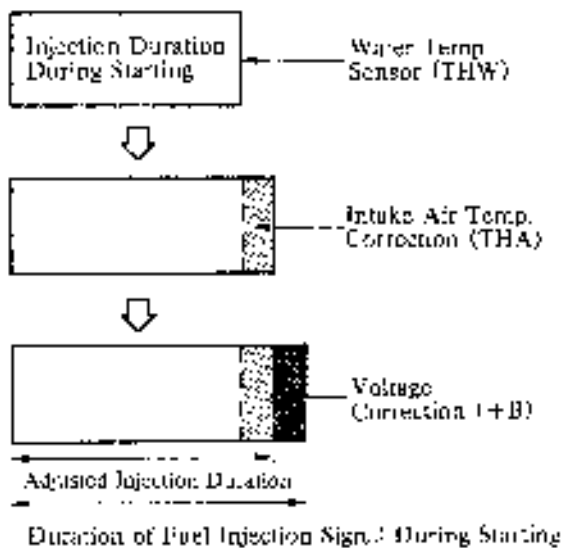
This corrects the actual injection period so that it corresponds with that calculated by the ECU.



**c. Starting Injection Control**

During engine starting, it is difficult for the air flow meter to accurately sense the amount of air being taken in due to large fluctuations in rpm.

For this reason, the ECU selects from its memory an injection duration that is suitable for the coolant temperature, regardless of intake air volume or engine rpm. It then adds to this an intake air temperature correction and a voltage correction, to obtain the injection duration.



- RELEVANT SIGNALS
- Engine speed (Ne)
  - Coolant temperature (THW)
  - Intake air temperature (THA)
  - Ignition switch (STA)
  - Battery voltage (+B)
  - Throttle position sensor (VTA<sub>1</sub>, VTA<sub>2</sub>)

CONDITIONS

Engine speed below a predetermined level, or STA on.

**d. After-Start Injection Control**

When the engine is running more or less steadily above a predetermined level rpm, the ECU determines the injection signal duration as explained below:

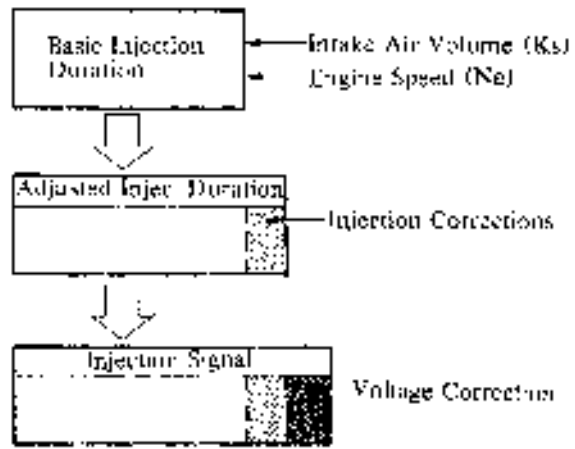
Injection Signal Duration

= Basic Injection Duration

x Injection Correction Coefficient\*

+ Voltage Correction

\* Injection correction coefficient is calculated by the sum and product of various correction coefficients.



**i) Basic Injection Duration**

This is the most basic injection duration, and is determined by the volume of air being taken in (Ks signal) and the engine speed (Ne signal). The basic injection duration can be expressed as follows:

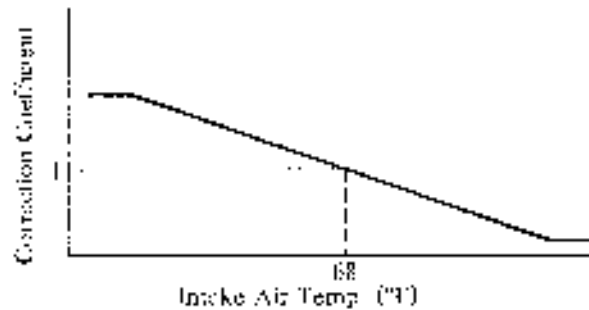
$$\text{Basic Injection Duration} = K \frac{\text{Intake Air Volume}^*}{\text{Engine Speed}} \quad \text{where K: Correction Coefficient}$$

\* The intake air volume may vary with the air density due to fluctuation of the air temperature and atmospheric pressure. The variation of air density is corrected as follows:

**• Intake Air Temperature Correction**

The density of the intake air will change depending upon its temperature. For this reason, the ECU must be kept accurately informed of both the intake air volume (by means of the air flow meter) and the intake air temperature (by means of the intake air temp. sensor) so that it can adjust the injection duration to maintain the air-fuel ratio currently required by the engine. For this purpose, the ECU considers 68°F (20°C) to be the “standard temperature” and increases or decreases the amount of fuel injected, depending upon whether intake air temperature falls below or rises above this standard.

RELEVANT SIGNAL  
Intake air temperature (THA)

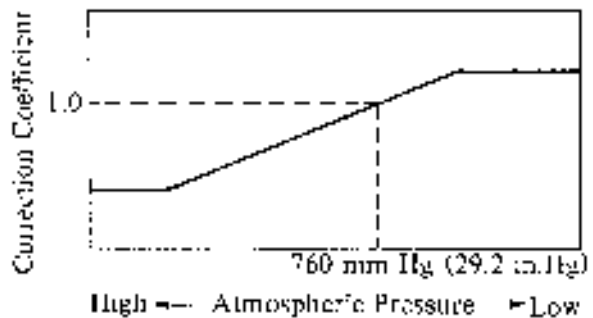


- **High Altitude Compensation**

The density of oxygen in the atmosphere is smaller at high altitudes. If the fuel is injected under the same conditions as sea level, the amount of intake air volume measured by the air flow meter for mixture with the fuel will be insufficient and the air-fuel mixture becomes too rich.

For this reason, the ECU, according to signals from the high altitude compensation sensor, adjusts signals from the air flow meter and determines the corresponding fuel injection volume.

RELEVANT SIGNAL —  
High altitude compensation (HAC)



## ii) Injection Corrections

The ECU is kept informed of the engine running conditions at each moment by means of signals from various sensors, and makes various corrections in the basic injection duration based on these signals.

- **After-Start Enrichment**

Immediately after starting (engine speed above a predetermined rpm), the ECU causes an extra amount of fuel to be supplied for a certain period to aid in stabilizing engine operation.

The initial correction value is determined by the coolant temperature, and the amount gradually decreases thereafter at a certain constant rate.

RELEVANT SIGNAL —  

- Engine speed (Ne)
- Coolant temperature (THW)

CONDITION —  
Engine speed above a predetermined rpm

- **Warm-Up Enrichment**

As fuel vaporization is poor when the engine is cold, if a richer fuel mixture is not supplied, the engine will run poorly.

For this reason, when the coolant temperature is low, the water temp. sensor informs the ECU to increase the amount of fuel injected to compensate.

As the coolant warms up, the amount of warm-up enrichment decreases, reaching zero (correction coefficient = 1.0) when the coolant reaches 140°F (60°C).

RELEVANT SIGNAL —  

- Engine speed (Ne)
- Coolant temperature (THW)

- **Acceleration Enrichment During Warm-Up**

The ECU causes an extra fuel to be supplied during acceleration when the engine is still warming up in order to aid drivability.

Through calculation of the amount of change in the intake air volume per engine revolution, the ECU detects the engine acceleration or deceleration condition. The correction value is determined according to the coolant temperature and the strength of acceleration or deceleration.

The control is performed separately for each bank.

**RELEVANT SIGNALS**

- Air flow meter (Ks)
- Engine speed (Ne)
- Coolant temperature (THW)
- Intake air temperature (THA)
- Ignition switch (STA)
- High altitude compensation (HAC)

**CONDITIONS**

Intake air volume per engine revolution changes (acceleration or deceleration) with coolant temperature below 176°F (80°C).

However, if any of the following occurs, the ECU stops calculating this change and halts the injection of extra fuel:

- Engine speed falls below a predetermined rpm
- Fuel cut-off occurs
- Intake air volume becomes smaller than a certain level

- **Power Enrichment**

When the engine is operating under heavy load conditions, the injection volume is increased in accordance with the engine load in order to ensure good engine operation.

The correction value is determined according to the intake air volume or throttle valve opening angle.

**RELEVANT SIGNALS**

- Throttle position ( $V_{TA1,2}$ )
- Air flow meter (Ks)
- Engine speed (Ne)
- Coolant temperature (THW)
- Intake air temperature (THA)
- High altitude compensation (HAC)

**CONDITIONS**

Throttle valve opening angle above 60° or intake air volume larger than a certain level.

• **Air-Fuel Ratio Feedback Correction**

The ECU corrects the ignition duration based on the signals from the main oxygen sensors to keep the air-fuel ratio within a narrow range near the ideal air-fuel ratio. (Closed loop operation)

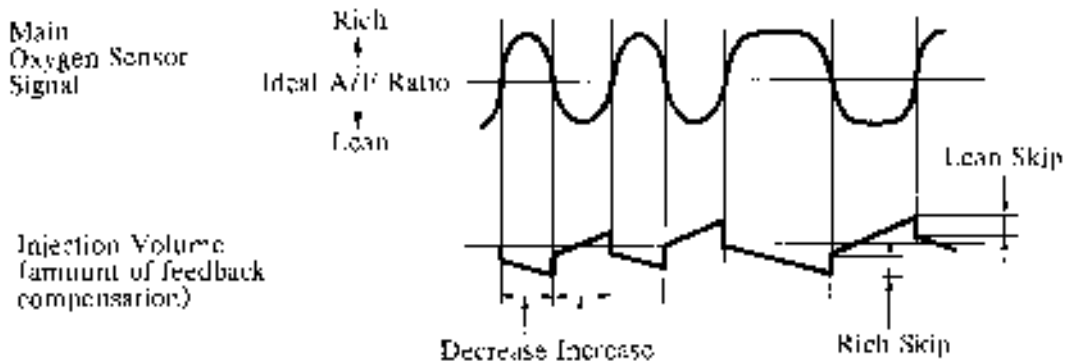
Further, in order to prevent overheating of the catalyst and assure drivability under the following conditions, the air-fuel ratio feedback operation does not work: (Open loop operation)

- During engine starting
- During after-start enrichment
- Coolant temperature below a predetermined level
- During traction control
- Fuel cut-off occurs

The ECU compares the voltage of the signals sent from the main oxygen sensors with a predetermined voltage.

As a result, if the voltage of the signal is higher, the air-fuel ratio is judged to be richer than the ideal air-fuel ratio and the amount of fuel injected is reduced at a constant rate. If the voltage of the signal is lower, it is judged that the air-fuel ratio is leaner than the ideal, so the amount of fuel injected is increased.

In addition, the ECU corrects the skip amount of “rich” or “lean” mixture based upon signals from the two sub-oxygen sensors. This implements a more accurate feedback correction.



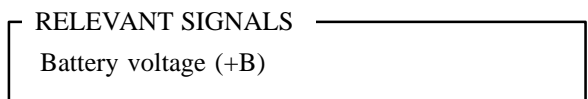
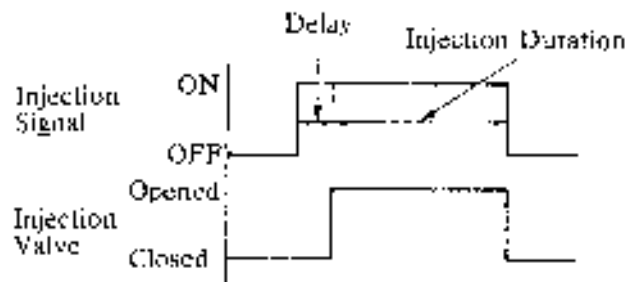
The control is performed separately for each bank.

**iii) Voltage Correction**

There is a slight delay between the time the ECU sends an injection signal to the injectors actually open. This delay becomes longer the more the voltage of the battery drops.

This means that the length of time that the injector valves remain open would become shorter than that calculated by the ECU, causing the actual air-fuel ratio to become higher (i.e., leaner) than that required by the engine, if this were not prevented by voltage correction.

In voltage correction, the ECU compensates for this delay by lengthening the injection signal by a period corresponding to the length of the delay. This corrects the actual injection period so that it corresponds with that calculated by the ECU.



### e. Fuel Cut-Off

#### • Fuel Cut-Off During Deceleration

During deceleration from a high engine speed with the throttle valve completely closed, the ECU halts injection of fuel in order to improve fuel economy and emission.

When the engine speed falls below a certain rpm or throttle valve is opened, fuel injection is resumed. These fuel cut-off and fuel injection resumption speeds are high when the coolant temperature is low.

#### RELEVANT SIGNALS

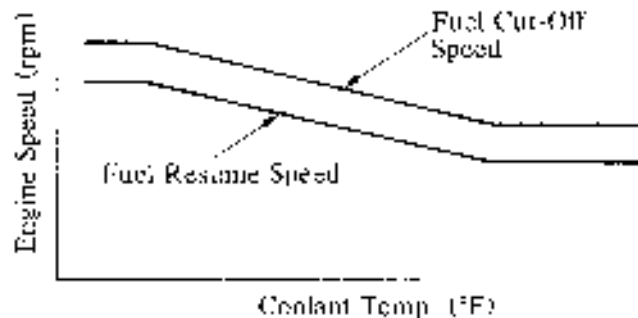
- Throttle position (IDL<sub>1</sub>)
- Engine speed (Ne)
- Coolant temperature (THW)

#### CONDITION

IDL contacts are closed with engine speed above fuel cut-off speed.

#### CONDITIONS FOR RESUMPTION OF FUEL INJECTION

Engine speed drops below fuel injection resumption speed, or IDL contacts are open.



#### • Fuel Cut-Off Due to High Engine Speed

To prevent engine over-run, fuel injection is halted if the engine speed rises above 6500 rpm. Fuel injection is resumed when the engine speed falls below this level.

### f. Cold Start Injector Control

To improve startability when the engine is cold, the injection duration of the cold start injector is controlled not only by the start injector time switch but by the ECU in accordance with the coolant temperature. Once the engine has been started, current to the cold start injector is cut off and injection is terminated.

#### RELEVANT SIGNALS

- Coolant temperature (THW)
- Ignition switch (STA, IGSW)
- Engine speed (Ne)

#### CONDITION

The engine is cranking and the coolant temperature is below 140°F (60°C).

## 7. ESA (Electronic Spark Advance)

### General

In order to maximize engine output efficiency, the air-fuel mixture must be ignited when the maximum combustion pressure occurs; that is, at about 10° after TDC. However, the time from ignition of the air-fuel mixture to the maximum combustion pressure varies depending on the engine speed and the intake air volume. Ignition must occur earlier when the engine speed is higher. In the conventional system, the timing is advanced by the governor advancer. When the intake air volume per engine revolution is small (high vacuum), ignition must also be advanced, and this is achieved by the vacuum advancer in the conventional system.

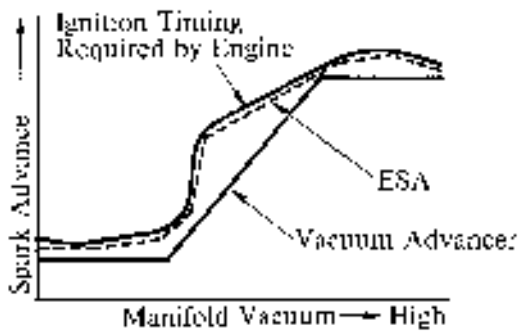
Actually, optimum ignition timing is affected by a number of other factors, such as the shape of the combustion chamber and the temperature inside the combustion chamber, etc., in addition to the engine speed and the intake air volume. Therefore, the governor and vacuum advance do not provide ideal ignition timing for the engine.

With the ESA (Electronic Spark Advance) system, the engine is provided with nearly ideal ignition timing characteristics.

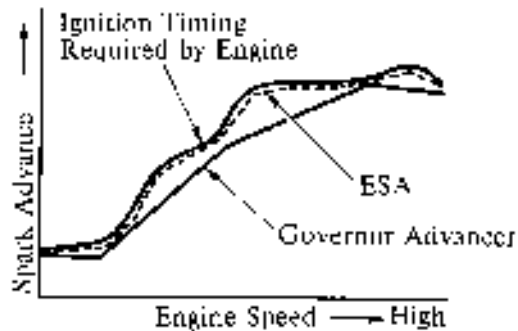
The ECU determines ignition timing from its internal memory, which contains optimum ignition timing data for each engine condition, based on signals detected by various sensors, and then sends signals to the igniter.

Since the ESA always ensures optimum ignition timing, both fuel efficiency and engine power output are maintained at optimum levels.

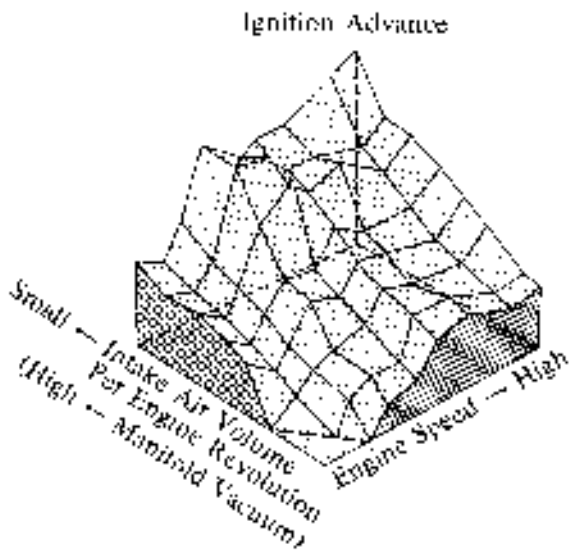
#### ► Vacuum Advancing ◀



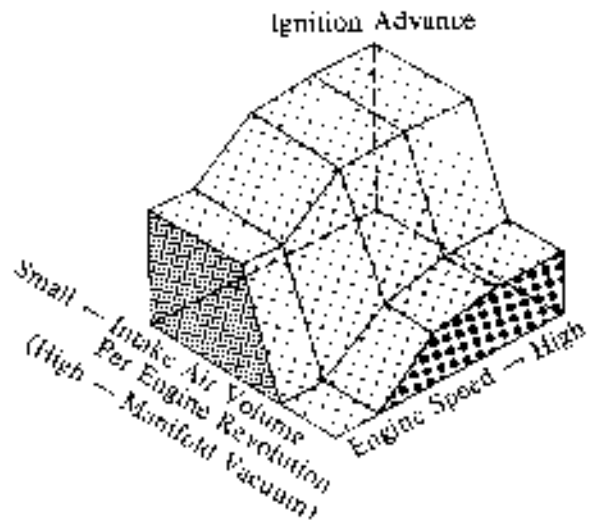
#### ► Governor Advancing ◀



#### ► ESA ◀



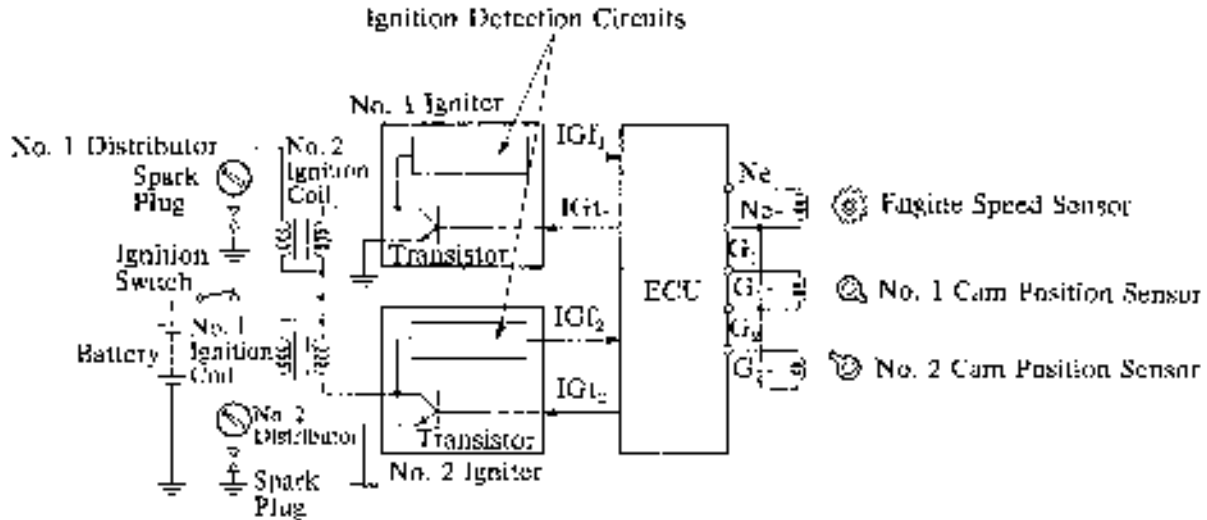
#### ► Conventional ◀



**Ignition Circuit**

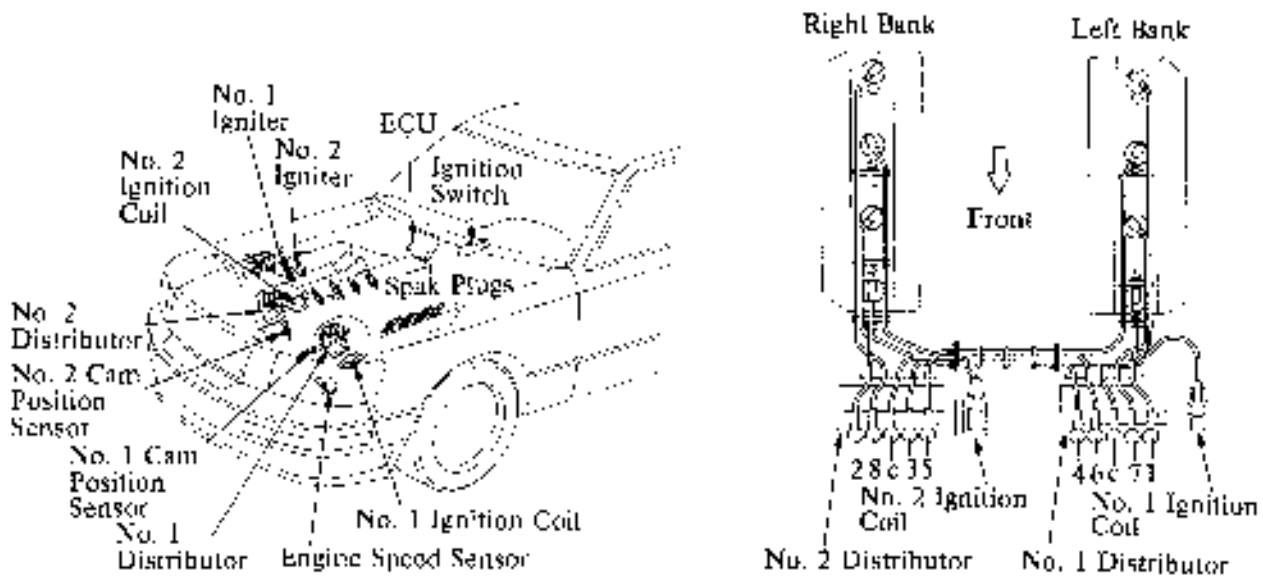
**1) Principle of Ignition**

The ignition timing is determined by the ECU based on signals ( $G_1$ ,  $G_2$ , Ne) from sensors. When it is determined, the ECU sends an IGT signal to the igniter at a predetermined timing ( $30^\circ$  crankshaft angle) before ignition. The transistor inside the igniter is turned on by this signal and primary current is supplied from the battery via the ignition switch to the ignition coil. When the crankshaft position reaches the ignition timing, the ECU stops supplying the IGT signal. The transistor inside the igniter is turned off and the primary current to the ignition coil is cut off as a result. At this time, the secondary voltage is induced in the ignition coil. The secondary voltage is distributed and causes sparks from the spark plug. The counter-electromotive force that is generated when the primary current is shut off causes an ignition confirmation signal (IGf), which is sent to the igniter.



**NOTE:** Two igniters are used in the engine, one each for four cylinders. No. 1 igniter ignites cylinders 1, 4, 6 and 7 and No. 2 igniter ignites cylinders 2, 3, 5 and 8.

**2) Layout of Components**



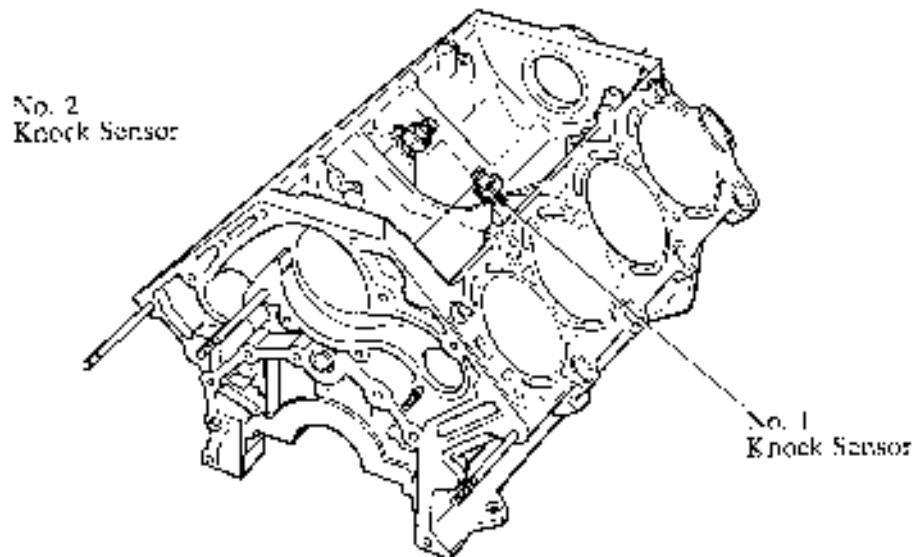
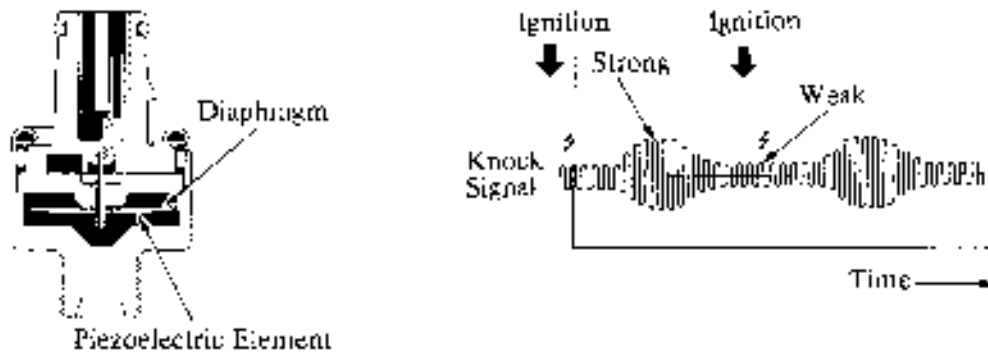
## Construction and Function of Relevant Sensor

### Knock Sensor

The knock sensor is provided on the left and right banks of the cylinder block. A piezoelectric ceramic element is incorporated into the sensor.

If knocking develops in the engine, this piezoelectric element, by resonating with the knocking vibration, generates a voltage which corresponds with the knocking strength and sends a signal to the ECU.

The ECU uses this signal to retard the ignition timing to prevent the knocking.



### —REFERENCE—

*Excessive knocking may damage the engine.*

*However, the engine operation in a marginal knocking condition is the most advantageous to the engine output and fuel economy.*

**Function of ECU**

1) The function of the ECU in the ESA control is divided into the following three items:

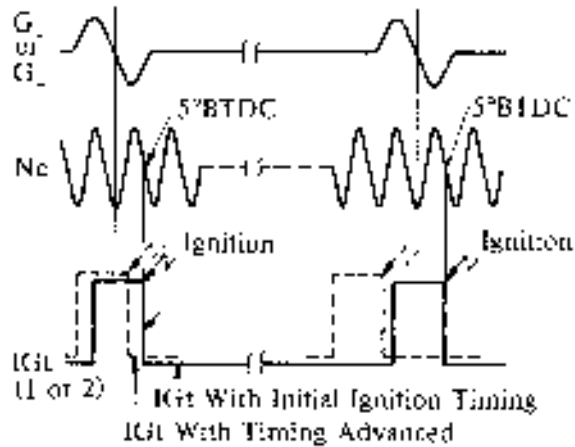
**a. Judging Crankshaft Angle**

In order to control the ignition timing, it is necessary for the ECU to know where compression top dead center is. In this engine, the ECU judges that the crankshaft has reached 5° BTDC of the compression cycle when it receives the first Ne signal following a G<sub>1</sub> (or G<sub>2</sub>) signal.

Therefore, the ECU calculates the ignition timing, and advances or retards the timing accordingly, using 5° BTDC as a reference point.

If the ignition timing is set to 10° BTDC with terminals TE<sub>1</sub> and E<sub>1</sub> shorted, the crankshaft angle will be 10° BTDC at the time of the next Ne signal after the G<sub>1</sub> (or G<sub>2</sub>) signal.

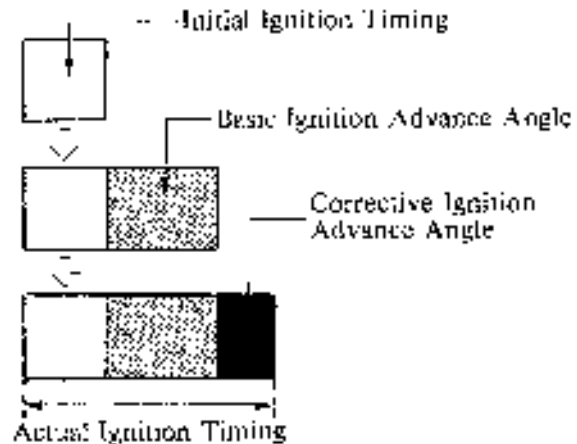
This is known as the initial ignition timing.



**b. Calculating Ignition Timing**

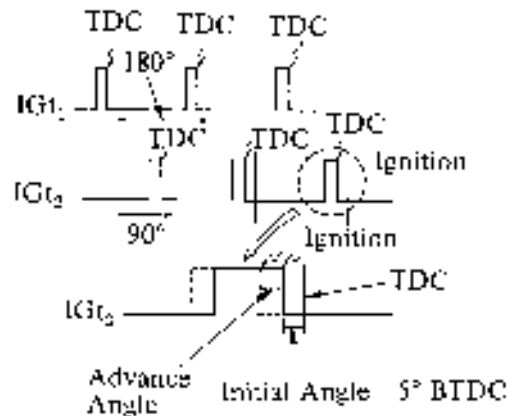
The ECU selects the basic ignition advance angle from the values stored in its memory based on the intake air volume and engine speed, then adds corrections based on signals from each sensor to determine the actual ignition timing.

$$\begin{aligned} \text{Ignition Timing} = & \text{Initial Ignition Timing} \\ & + \text{Basic Ignition Advance Angle} \\ & + \text{Corrective Ignition Advance (or Retard) Angle} \end{aligned}$$



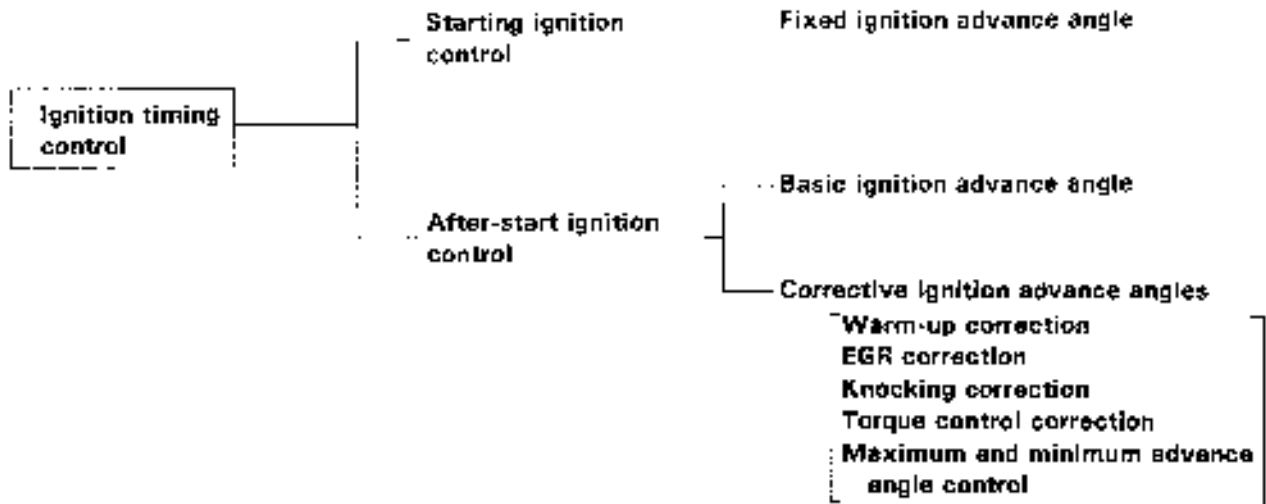
**c. Igniter Control**

The ECU sends an ignition timing signal (IGT<sub>1,2</sub>) to the igniter based on signals from each sensor so as to achieve the optimum ignition timing. This ignition timing signal goes on just before the ignition timing calculated in the ECU, then the ignition timing signal goes off. The spark plug fires at the point when this signal goes off.



## 2) Ignition Timing Control

Ignition timing control consists of two basic elements: 1) Ignition control during starting (while the engine is cranking, ignition occurs at a certain fixed crankshaft angle, regardless of engine operating conditions); and 2) After-start ignition control, in which various corrections (made by the ECU based on signals from the relevant sensors) are added to the basic advance angle, which is determined by the intake air volume signal and the engine speed signal during normal operation.



**a. Starting Ignition Control**

Since the engine speed is still below a specified rpm and unstable during and immediately after starting, the ECU cannot accurately determine the correct ignition timing. For this reason, the ignition timing is fixed at the initial ignition timing of 5° BTDC until engine operation is stabilized.

<p>RELEVANT SIGNALS</p> <ul style="list-style-type: none"> <li>• Engine speed (Ne)</li> <li>• Ignition switch (STA)</li> </ul>
<p>CONDITIONS</p> <p>Engine speed below specified rpm, or STA on.</p>

**NOTE:** At engine adjustment time, etc., with the vehicle stopped, confirm the ignition timing by connecting the TE1 and E1 terminals in the check connector or TDCL with the throttle valve fully closed.

Under the above conditions, ignition advance should not be occurring and the ignition timing should be the initial ignition timing (10° BTDC).

**b. After-Start Ignition Control**

**i) Basic Ignition Advance Angle Control**

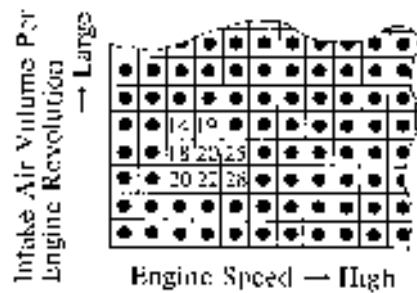
This corresponds to the vacuum advance and governor advance angles in conventional type ignition system. The memory in the ECU contains optimum advance angle data for the intake air volume and the engine speed. The ECU selects the basic ignition advance angle from memory according to the engine speed signals from the engine speed sensor and the intake air volume signals from the air flow meter.

• **IDL Contacts Open (OFF)**

When the IDL contacts open, the ECU determines the basic ignition advance angle based upon data stored in the memory. This data can be shown in the form of a table, as shown in the chart.

<p>RELEVANT SIGNALS</p> <ul style="list-style-type: none"> <li>• Air flow meter (Ks)</li> <li>• Engine speed (Ne)</li> <li>• Throttle position (IDL<sub>1</sub>)</li> <li>• Intake air temperature (THA)</li> <li>• High altitude compensation (HAC)</li> </ul>
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► Basic Ignition Advance Angle Data ◀



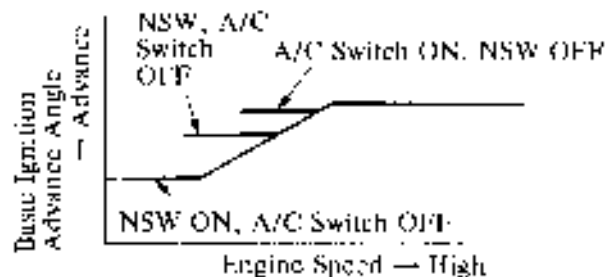
—REFERENCE—

Since the capacity of the ECU's memory is limited, it cannot hold all possible advance angle data. For this reason, the ECU selects the value that is the closest to the required value for each particular combination of engine speed and intake air volume. It then carries out proportional calculations to find the optimum ignition timing for the given engine speed and the intake air volume.

• **IDL Contacts Closed (ON)**

When the IDL contacts close, the ignition timing is advanced as shown, in accordance with the engine speed, whether the air conditioner is on or off, and whether neutral start switch is on or off.

<p>RELEVANT SIGNALS</p> <ul style="list-style-type: none"> <li>• Throttle position (IDL<sub>1</sub>)</li> <li>• A/C switch (A/C)</li> <li>• Engine speed (Ne)</li> <li>• Neutral start switch (NSW)</li> <li>• Vehicle speed (SP<sub>1</sub>)</li> </ul>
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**ii) Corrective Ignition Advance Angle Control****• Warm-Up Correction**

When the coolant temperature is low, the ignition timing is advanced according to it to improve drivability.

**RELEVANT SIGNALS**

- Coolant temperature (THW)
- Intake air volume (Ks)
- Engine speed (Ne)
- Intake air temperature (THA)
- High altitude compensation (HAC)

**• EGR Correction**

When the EGR is operating and the IDL contacts are turned off, the ignition timing is advanced according to the amount of intake air and the engine rpm to improve drivability.

**RELEVANT SIGNALS**

- Intake air volume (Ks)
- Engine speed (Ne)
- Intake air temperature (THA)
- Throttle position (IDL<sub>1</sub>, V<sub>TA1</sub>, V<sub>TA2</sub>)
- High altitude compensation (HAC)
- Coolant temperature (THW)
- Neutral start switch (NSW)
- Traction control (TRC)\*

\* Models with optional TRAC system

- **Knocking Correction**

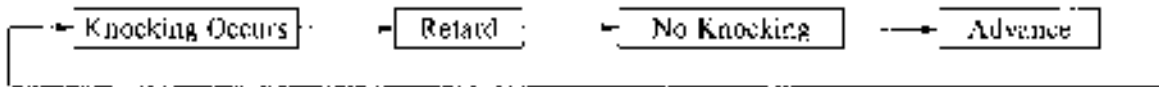
The ignition timing at which engine knocking occurs differs according to the fuel octane value. The ECU controls the ignition timing at the optimum timing to correspond to the fuel octane value.

If engine knocking occurs, the knock sensor converts the vibration from the knocking into voltage signals and sends them to the ECU. The ECU judges whether the knocking strength is at one of three levels; strong, medium or weak, according to the strength of the knock signals and changes the corrective ignition retard angle. That is, if knocking is strong, the ignition timing is retarded a lot, and if it is weak, it is retarded a little.

When engine knocking stops, the ECU stops retarding the ignition timing and advances it by fixed angles a little at a time.

If ignition timing advance continues and engine knocking recurs, ignition timing is again retarded.

The ECU feeds back signals from the knock sensor to correct ignition timing as shown below.



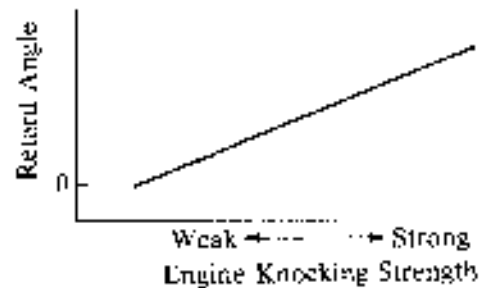
- \* The knocking is judged for each cylinder at the time of ignition. But knocking correction is performed for all cylinders at one time.

#### RELEVANT SIGNALS

- Engine speed (Ne)
- Intake air volume (Ks)
- Coolant temperature (THW)
- Engine knocking (KNK<sub>1</sub>) (KNK<sub>2</sub>)

#### CONDITIONS

- Intake air volume per engine revolution is larger than a certain level.
- Ignition timing is not retarded at coolant temperature below 140°F (60°C).



### • Torque Control Correction

Each clutch and brake of the planetary gear unit in the transmission generates shock more or less during shifting. In the 1UZ-FE engine of the Lexus, this shock is minimized by momentarily retarding the ignition timing when gears are shifted up or down in the automatic transmission.

When the ECU judges a gear shift timing according to signals from various sensors, it activates the shift control solenoid valves to perform gear shifting. When the gear shifting starts, the ECU retards the engine ignition timing to reduce the engine torque.

As a result, engagement force of the clutches and brakes of the planetary gear unit is weakened and the gear shift change is performed smoothly.

#### RELEVANT SIGNALS

- Vehicle speed (SP<sub>2</sub>)
- OD direct clutch speed (Nco)
- Throttle position (V<sub>TA</sub>)
- Gear shift position (S<sub>1</sub>, S<sub>2</sub>)
- Coolant temperature (THW)
- Battery voltage (+B)

### iii) Maximum and Minimum Advance Angle Control

If the actual ignition timing (initial ignition timing + basic ignition advance angle + corrective ignition advance or retard angle) becomes abnormal, the engine will be adversely affected. To prevent this, the ECU controls the actual ignition timing so that the sum of the basic ignition and corrective ignition advance or retard angle cannot be greater or less than certain values.

Maximum advance angle: 55° BTDC

Minimum advance angle: 4° BTDC

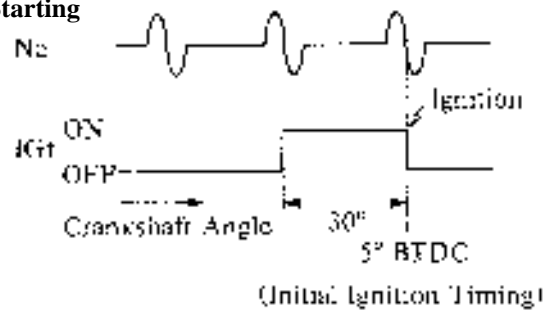
### 3) Igniter Control

#### a. During Engine Starting and Immediately After Starting

During engine starting and immediately after starting, the ECU begins sending the IGt<sub>1, 2</sub> signal to the igniter at 30° crankshaft angle before the initial ignition timing angle (5° BTDC).

#### CONDITION

- STA on or engine speed below 400 rpm.



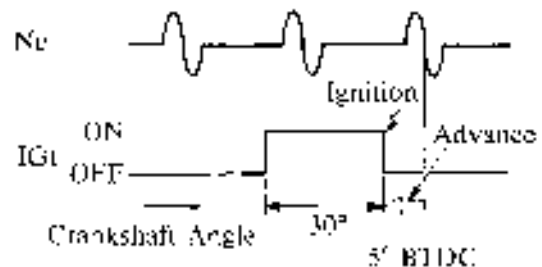
**NOTE:** The ignition timing is fixed at 10° BTDC when the IDL is on and the T<sub>E1</sub> and E<sub>1</sub> terminals in the check connector or TDCL are connected.

#### b. During Engine Running

During engine running, the ECU begins sending the IGt<sub>1, 2</sub> signal to the igniter at 30° crank angle before the ignition point that it has just calculated.

#### CONDITION

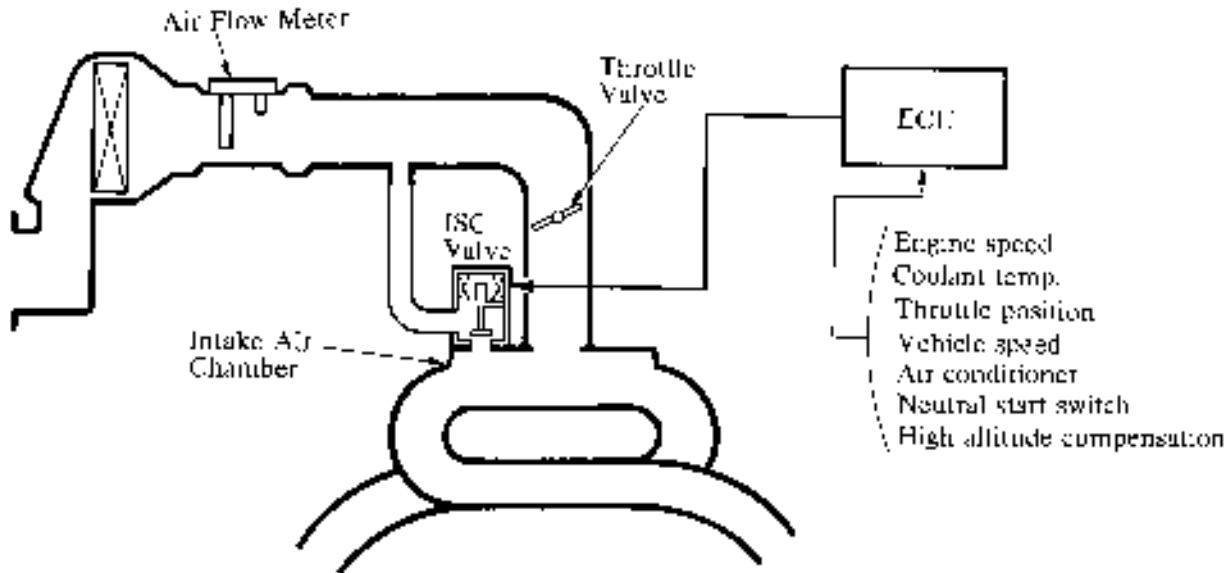
- Engine speed above 400 rpm.



## 8. ISC (Idle Speed Control)

### General

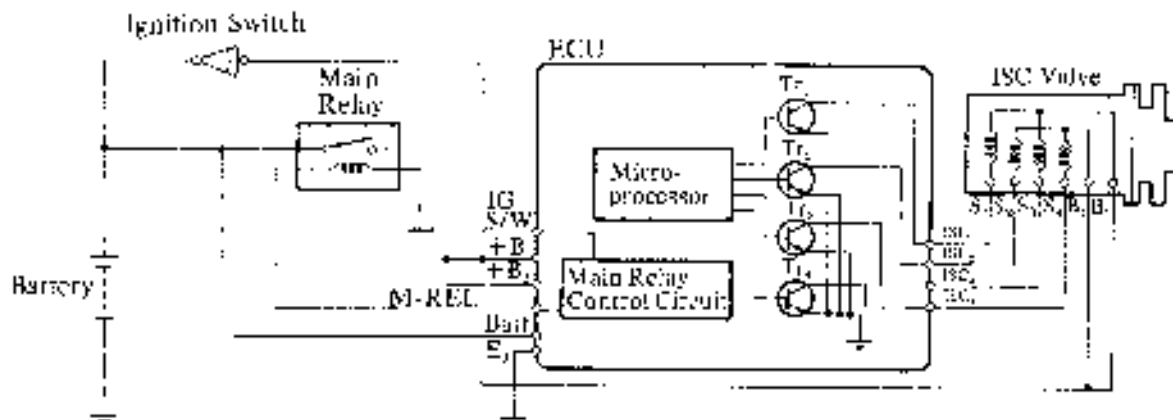
The step motor type ISC valve is used, which controls the idle speed at a target speed based on the signals from the ECU by adjusting the volume of air by passing the throttle valve. Also, when the engine is cold, the ISC valve is opened widely corresponding to the coolant temperature and the engine speed is increased, causing fast idle.



### System Diagram

This type of ISC valve is connected to the ECU as shown in the following diagram. Target speeds for each coolant temperature, air conditioner operating state and neutral start switch signal are stored in the ECU's memory.

When the ECU judges from the throttle valve opening angle and vehicle speed signals that the engine is idling, it switches on Tr<sub>1</sub> to Tr<sub>4</sub> in order, in accordance with the output of those signals, sending current to the ISC valve coil, until the target speed is reached.



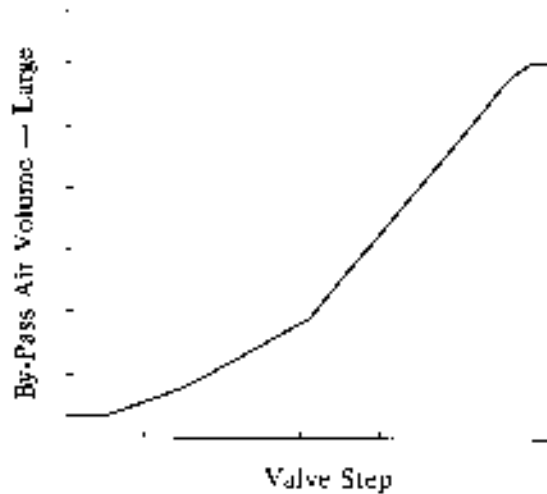
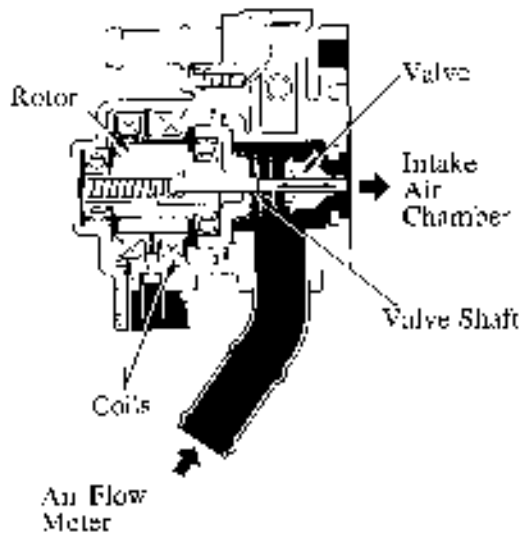
## ISC Valve

The ISC valve is provided on the intake air chamber and intake air bypassing the throttle valve is directed to the ISC valve through a hose.

A step motor is built into the ISC valve. It consists of four coils, the magnetic rotor, valve shaft and valve.

When current flows to the coils due to signals from the ECU, the rotor turns and moves the valve shaft forward or backward, changing the clearance between the valve and the valve seat. In this way the intake air volume bypassing the throttle valve is regulated, controlling the engine speed.

There are 125 possible positions to which the valve can be opened.

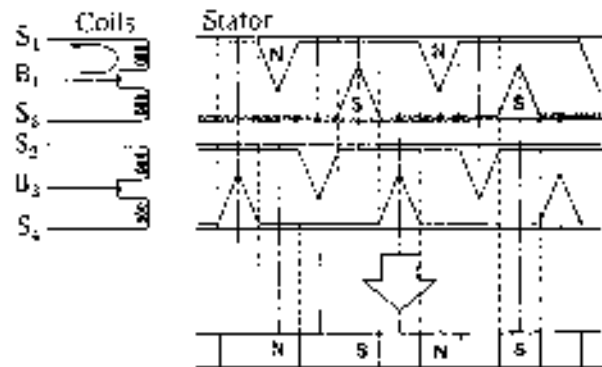


- Rotor—Constructed of a 16-pole permanent magnet.
- Stator—Two sets of 16-pole cores, each of which is staggered by half a pitch in relation to the other; two coils are wound around each core, each coil being wound in opposing directions.



## Movement of Valve

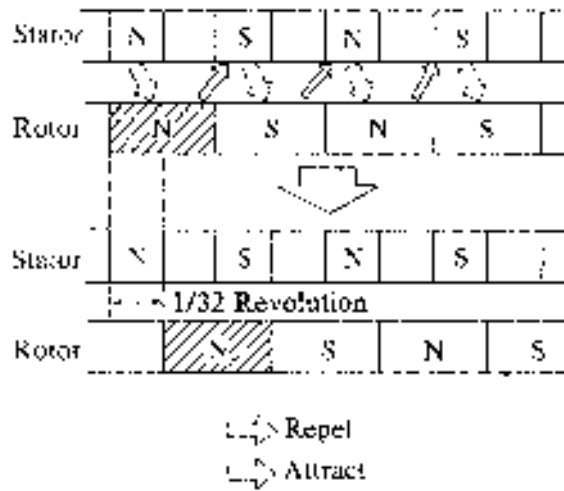
The valve shaft is screwed into the rotor. It is prevented from turning by means of a stopper plate so it moves in and out as the rotor rotates. This causes the distance between the valve and valve seat to decrease or increase, thus regulating the amount of air allowed through the bypass.



**Rotation of Rotor**

The direction of rotation of the motor is reversed by changing the order in which current is allowed to pass through the four coils. The rotor rotates about 11° (1/32 of a revolution) each time electric current passes through the coils.

When the rotor rotates one step, the positional relationship shown in the figure develops, and the stator coil is excited. Since the N poles tend to be attracted to the S poles in the stator and rotor, and since like poles in the stator and rotor tend to repel each other, the rotor moves one step.



**Function of ECU**

**1) Initial Set-Up**

When the engine is stopped, the ISC valve is fully opened to the 125th step to improve startability when the engine is restarted.

RELEVANT SIGNAL	_____
• Engine speed (Ne)	

• **Main Relay (ISC Valve Initial Set-Up) Control**

The supply of power to the ECU and ISC valve must be continued, even after the ignition switch is turned off, in order to allow the ISC valve to be set-up (fully opened) for the next engine start-up.

Current to Main Relay	Conditions
ON	Ignition switch on
OFF	Ignition switch off, ISC valve set-up complete

Therefore, the ECU outputs 12V from the M-REL terminal until the ISC valve is set-up in order to keep the main relay on. Once set-up is complete, it cuts off the flow of current to the main relay coil.

## 2) After-Start Control

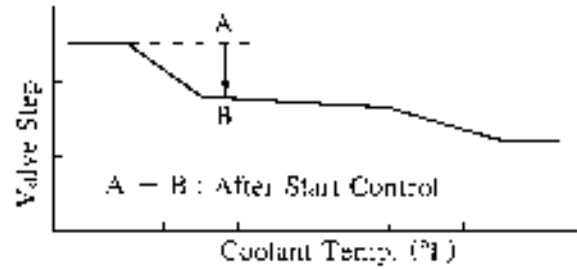
If the engine is started and the ISC valve were kept fully open, the engine speed will rise too high. Therefore, immediately after the engine is started, the ISC valve is adjusted to a position which corresponds to the coolant temperature. This makes the engine speed drop.

### RELEVANT SIGNALS

- Engine speed (Ne)
- Coolant temperature (THW)
- Ignition switch (STA)
- Battery voltage (IGSW)
- Intake air temperature (THA)
- High altitude compensation (HAC)
- Neutral start switch (NSW)
- Air conditioner (A/C)

### CONDITIONS

When the engine speed rises to a certain level. (The lower the coolant temperature, the higher this level becomes.)



## 3) Warm-Up (Fast-Idle) Control

As the coolant warms up, ISC valve continues to gradually close from B to C.

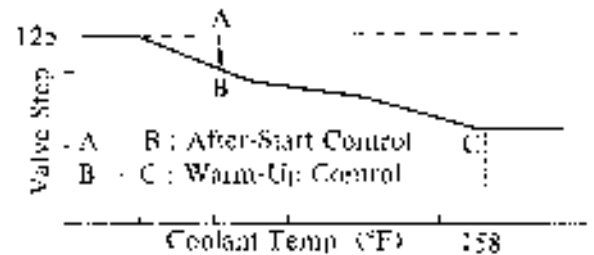
When the coolant temperature reaches 158°F (70°C), fast-idle control by the ISC valve ends.

### RELEVANT SIGNALS

- Engine speed (Ne)
- Coolant temperature (THW)
- Intake air temperature (THA)
- High altitude compensation (HAC)

### CONDITIONS

Engine speed above 300 rpm.



#### 4) Feedback Control

If there is a difference between the actual engine speed and the target speed stored in the memory of the ECU, then the ECU sends a signal to the ISC valve and increases or decreases the volume of the air bypass so that the actual engine speed will match the target speed.

The target speeds differ depending on engine conditions such as neutral start switch on or off, and air conditioner switch on or off.

##### RELEVANT SIGNALS

- Throttle position (IDL<sub>1</sub>)
- Vehicle speed (SP<sub>1</sub>)
- Engine speed (Ne)
- Coolant temperature (THW)
- Intake air temperature (THA)
- Air conditioner (A/C)
- Neutral start switch (NSW)

##### CONDITIONS

IDL contacts close, vehicle speed is below a certain speed, engine speed is above 300 rpm and coolant temperature above 163.4°F (73°C).

#### ►Target Idling Speed◄

Air Conditioner Switch	Neutral Start Switch	Engine Speed
ON	ON	900 rpm
	OFF	750 rpm
OFF	ON	650 rpm
	OFF	580 rpm

#### 5) Engine Speed Change Estimate Control

Immediately after the air conditioner switch or automatic transmission shift position is changed, the engine load also changes.

To prevent the engine speed from changing the ECU sends signals to the ISC valve to open or close it to a fixed amount before changes in the engine speed occur.

##### RELEVANT SIGNALS

- Engine speed (Ne)
- Air conditioner (A/C)
- Neutral start switch (NSW)
- Coolant temperature (THW)
- Vehicle speed (SP<sub>1</sub>)

##### CONDITIONS

When air conditioner switch or neutral start switch is turned on or off with engine speed above 300 rpm.

## 9. EGR (Exhaust Gas Recirculation) Cut-Off Control

This system actuates the VSV (Vacuum Switching Valve) to cut the intake manifold vacuum acting on the EGR valve and thus shut off the EGR to maintain drivability.

### 1) Purpose of the EGR System

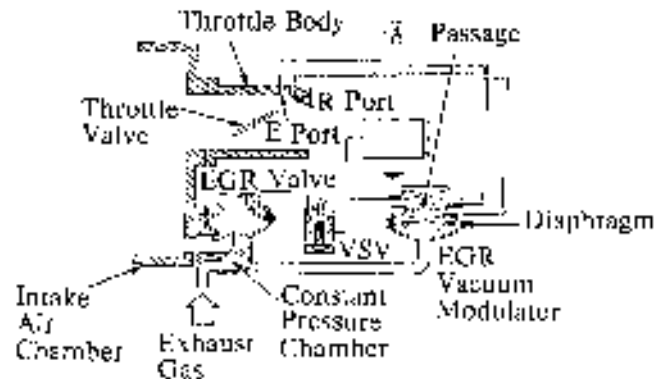
The EGR system is designed to recirculate the exhaust gas, properly controlled according to the driving condition, back into the intake air–fuel mixture. It helps to slow down combustion in the cylinder and thus lower the combustion temperature which, in turn, reduces the amount of NOx emission. The amount of EGR is regulated by the EGR vacuum modulator according to the engine load.

### 2) Operation of the EGR System

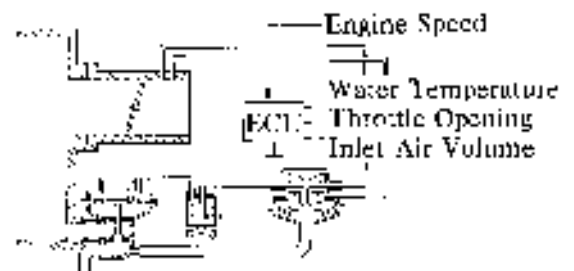
The exhaust gas pressure increases in proportion to the amount of intake air. As the throttle valve opens more and the amount of intake air increases, a higher exhaust gas pressure applies to the constant pressure chamber of the EGR valve. It pushes the diaphragm of the EGR vacuum modulator upward to narrow the “E” passage. Since intake vacuum acts then on E and R ports of the throttle body, the vacuum regulated by the “E” passage determined by the EGR vacuum modulator acts on the EGR vacuum chamber via the VSV. It opens the EGR valve which, in turn, leads exhaust gas into the intake air chamber. This also causes the gas pressure inside the constant pressure chamber to go down which, in turn, lowers the EGR vacuum modulator diaphragm.

The EGR valve is now under less vacuum and the valve moves until the vacuum balances with the spring tension. The amount of EGR gas is regulated as a result. As explained above, the EGR system controls the amount of EGR properly according to the exhaust gas pressure and the intake vacuum.

#### ►EGR Operating (VSV OFF)◄



#### ►EGR Cut-Off (VSV ON)◄



### 3) EGR Cut-Off Operation

When the VSV is turned on by a signal from the ECU, atmospheric air is led to the EGR valve, the EGR valve closes and shuts off the exhaust gas. This operation (EGR cut-off) is implemented when the following conditions exist:

- 1) Coolant temperature below 134.6°F (57°C)
- 2) During deceleration (throttle valve closed)
- 3) Light engine load (amount of intake air very small)
- 4) Engine speed over 4000 rpm
- 5) Engine racing (neutral start switch turned on)

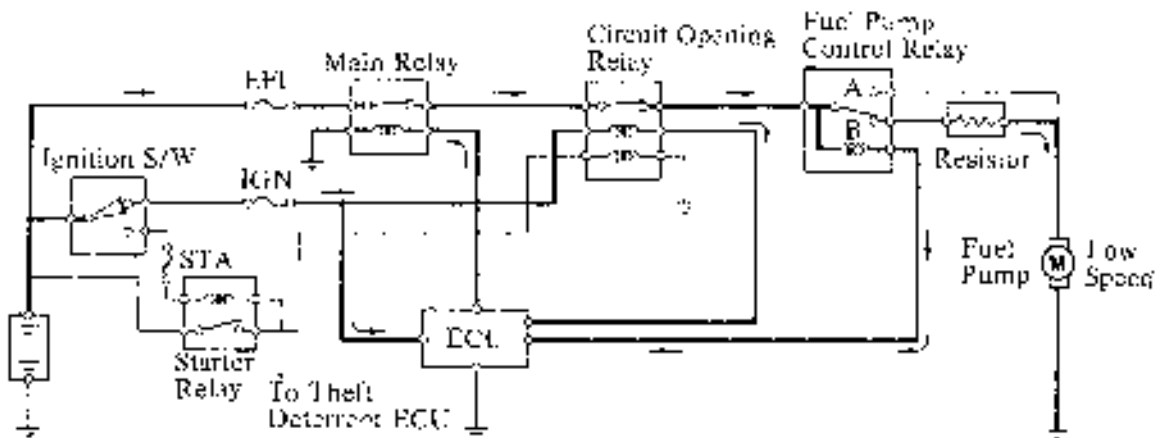
## 10. Fuel Pump Speed Control

This control system increases the fuel pump output by switching the fuel pump speed to high if a large amount of fuel is required by the engine. In normal operations where the engine speeds are low, the fuel pump rotates at low speed to reduce unnecessary consumption of electric power and to maintain fuel pump durability.

### Operation

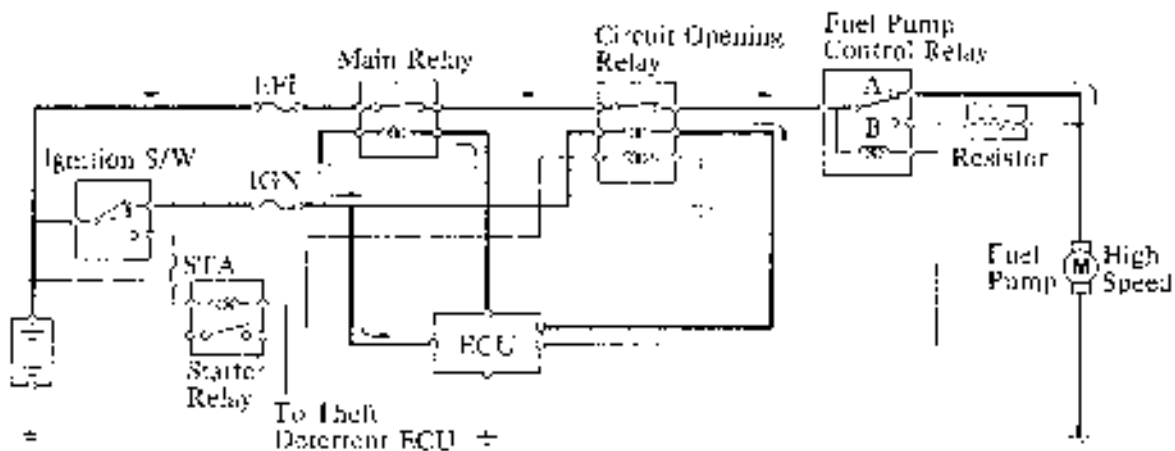
#### 1) During Engine Idling or Cruising

The ECU is constantly calculating the fuel injection duration per fixed period of time. When the engine is idling, or under normal driving conditions, that is, when the fuel injection duration per fixed period of time is shorter than the reference value, the ECU turns on the fuel pump control relay coil. When the control relay coil is turned on, the point contacts side B and the current to the fuel pump flows through a resistor, causing the fuel pump to run at low speed.



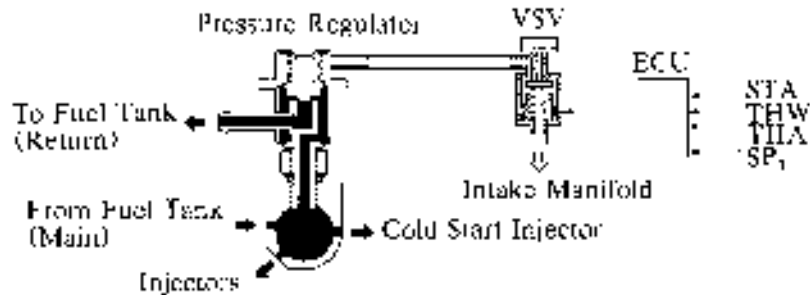
#### 2) During High Engine Speed and High Load Operation

When the engine is operated at high speeds or under heavy loads, the fuel pump control relay coil is turned off. The point contacts with side A and the current to the fuel pump flows directly to the pump without passing through a resistor, causing the fuel pump to run at high speed.



## 11. Fuel Pressure Control

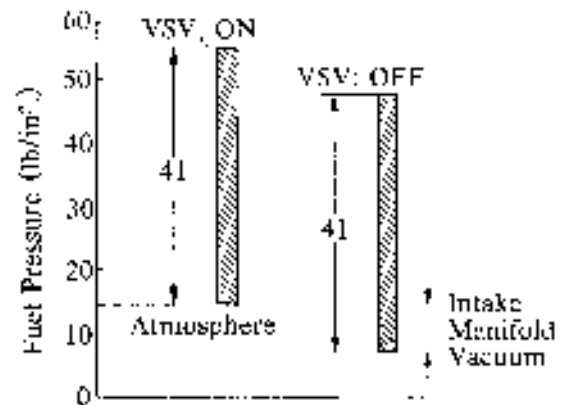
When starting engine at high temperature, the ECU turns on a VSV to draw atmospheric pressure into the diaphragm chamber of the pressure regulator. Thereby, the fuel pressure is increased to prevent fuel vapor lock in order to help engine start.



### Operation

When the coolant temperature is 185°F (85°C) or higher and the intake air temperature is above a predetermined level, if the engine is cranked, the ECU turns on the VSV. As the VSV goes on, atmospheric air is introduced into the diaphragm chamber of the pressure regulator and the fuel pressure becomes higher by the amount of the intake manifold vacuum than the fuel pressure under normal engine operating conditions.

Even after the engine is started, the VSV remains on for about 100 seconds.



## 12. Oxygen Sensor Heater Control

The ECU controls the operation of the oxygen sensor heater according to intake air volume and engine speed. When the engine load is small and the exhaust gas temperature is low, the heater is operated to maintain sensor efficiency. Also, when the engine load becomes large and exhaust gas temperature becomes high, heater operation is stopped to prevent deterioration of the sensor.

This system controls both left and right banks simultaneously.

### RELEVANT SIGNALS

- Coolant temperature (THW)
- Engine speed (Ne)
- Intake air volume (Ks)
- Intake air temperature (THA)
- Battery voltage (+B)
- High altitude compensation (HAC)

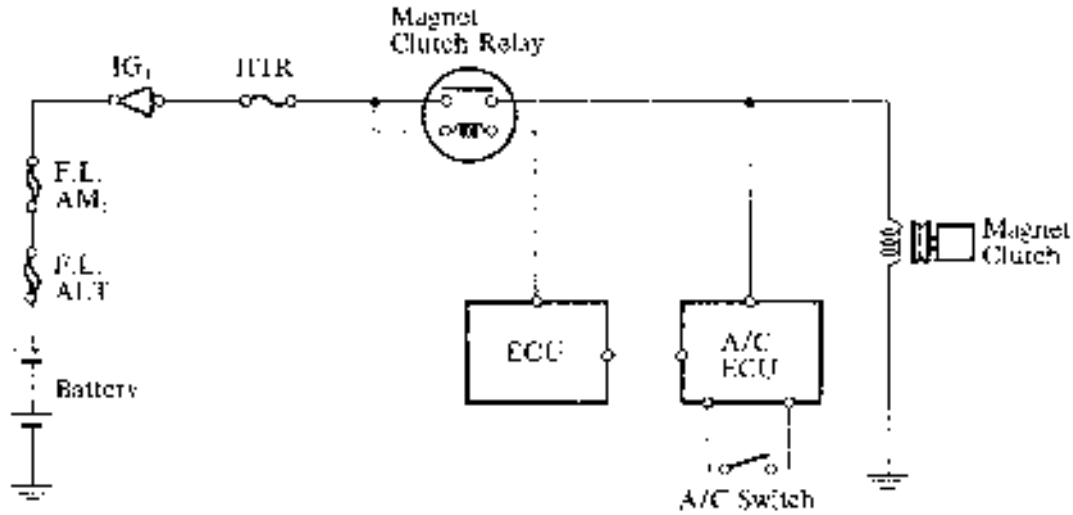
### 13. Air Conditioner Compressor Delay Control

When the air conditioner compressor is operated during idling, engine load fluctuates and the engine rpm drops momentarily. The delay control is designed to prevent the engine rpm drop.

#### Operation

When the ECU detects a signal (A/C) from the air conditioner ECU that the air conditioner switch is turned on, the ECU output a magnet clutch signal (ACMG) to the magnet clutch relay and turns it on.

The compressor magnetic clutch operation is delayed about 0.5 seconds after the air conditioner switch is turned on. During this time, the ECU opens ISC (Idle Speed Control) valve to offset the drop in the engine rpm due to the operation of the air conditioner compressor. This prevents the idle speed from dropping.



---

## 14. Diagnosis

### General

The ECU contains a built-in self-diagnostic system. The ECU, which is constantly monitoring all sensors, and lights the "CHECK ENGINE" lamp when it detects a problem in the sensors or their circuitry. At the same time, the ECU registers the system containing the malfunction into its memory. This information is retained in memory even after the ignition switch is turned off, even after the malfunction has been corrected. When the vehicle is brought into the workshop for service because of the problem in the system, the contents of the memory may be checked to identify the malfunction.

After the problem is repaired, the diagnostic system is cleared by removing the EFI fuse for more than 10 seconds.

The contents of the diagnostic memory can be checked by connecting terminals in the check connector or in the TDCL and counting the number of times the CHECK ENGINE lamp blinks.

This self-diagnostic system has two types of malfunction detection mode; normal mode and test mode.

In the normal mode, it detects a malfunction if a problem, shown in the diagnostic items on page 154, occurs in the sensors or circuitry a specified number of times or continues for more than a specified period of time. The ECU lights the "CHECK ENGINE" lamp.

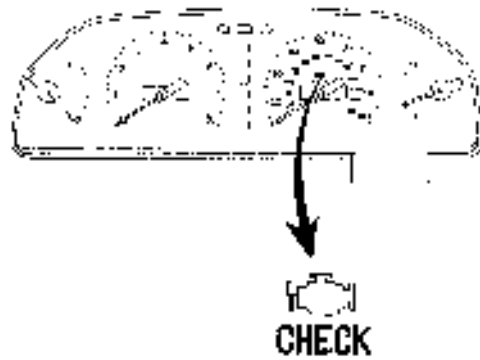
In the test mode, it has a more sensitive detection accuracy than the normal mode and detects a malfunction even if it occurs only once.

Thereby, it detects a poor contact between terminals of the connector or momentary disconnection of the wire, which is difficult to detect in the normal mode. The diagnostic items in the test mode are also shown on page 154.

**“CHECK ENGINE” Lamp**

**1) Operation**

- When the ignition switch is turned from OFF to ON, the “CHECK ENGINE” lamp goes on. After the engine is started, the lamp goes out. This is to inform the driver that the “CHECK ENGINE” lamp circuitry is operating normally.



- The lamp lights immediately if a problem occurs in engine control system while the engine is operating (both in normal mode and test mode).
- If the problem is corrected, the lamp goes out five seconds after the problem has been corrected in the normal mode.  
In the test mode, the lamp is kept lit until the ignition switch is turned off or T<sub>E1</sub> and E<sub>1</sub> terminals are disconnected.
- In the normal mode, if the problem no longer exists at the time of repair (for example, if it is an intermittent problem), the “CHECK ENGINE” lamp will not light, even if the malfunction has been recorded in the memory of the ECU.

**Diagnostic Mode and Output of “CHECK ENGINE” Lamp**

The diagnostic mode (normal or test) and the output of the “CHECK ENGINE” lamp can be selected by changing the connections of the T<sub>E1</sub>, T<sub>E2</sub> and E<sub>1</sub> terminals in the TDCL (Total Diagnostic Communication Link) or check connector as shown in the table below.

T <sub>E1</sub> and E <sub>1</sub> Terminals	T <sub>E2</sub> and E <sub>1</sub> Terminals	Diagnostic Mode	Output of “CHECK ENGINE” Lamp
Open	Open	Normal	Warning to driver of malfunction.
	Connected	Normal	Output of diagnostic results (content of malfunction) in normal mode, indicated by number of times lamp blinks.
Connected	Open	Test	Warning to technician of malfunction.
	Connected	Test	Output of diagnostic results (content of malfunction) in test mode, indicated by number of times lamp blinks.

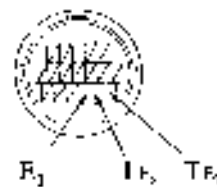
**Diagnostic Procedure**

**1) Normal Mode**

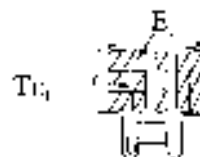
The diagnostic codes are displayed, by the procedure listed below, in order from the smallest to the largest code with the number of times the lamp blinks indicating the code number.

- ① Turn the ignition switch ON.
- ② Connect terminals T<sub>E1</sub> and E<sub>1</sub>.
- ③ IDL contacts ON (throttle valve fully closed).

**►TDCL◄**



**►Check Connector◄**



\* Terminal T<sub>E2</sub> is not provided in the check connector.

## 2) Test Mode

- ① First, connect terminals T<sub>E2</sub> and E<sub>1</sub>, then turn the ignition switch on to begin the diagnosis in the test mode.
- ② Start the engine.
- ③ Simulate the conditions of the malfunction described by the customer.
- ④ When a malfunction occurs and the “CHECK ENGINE” lamp lights up, terminals T<sub>E1</sub> and E<sub>1</sub> should be connected for outputting the malfunction code. Lighting up of the “CHECK ENGINE” lamp and retention of the malfunction in the ECU memory continues until T<sub>E2</sub> and E<sub>1</sub> terminals are disconnected or the ignition switch is turned to OFF.
- ⑤ End the test mode by disconnecting the terminals T<sub>E2</sub> and E<sub>1</sub> or turn the ignition switch OFF.

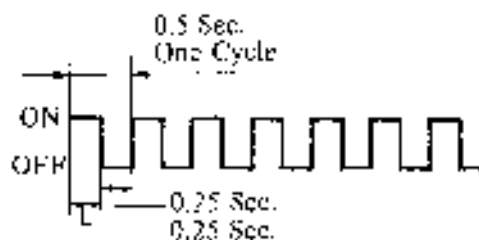
**NOTE:** The test mode will not start if terminals T<sub>E2</sub> and E<sub>1</sub> are connected after the ignition switch is turned on or terminals T<sub>E1</sub> and E<sub>1</sub> are connected before the ignition switch is turned on.

## Diagnostic Code Display

In both normal and test modes, the diagnostic results are displayed in two-digit codes.

### 1) Normal

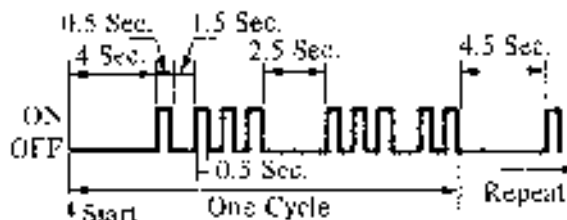
The “CHECK ENGINE” lamp will blink about two times per second as shown in the chart.



### 2) Malfunction

The appropriate diagnostic code(s) will be displayed.

In this case, codes 13 and 32 are indicated.



**NOTE:** If two or more malfunctions are present at the same time, the lowest-numbered diagnostic code will be displayed first.

## Diagnostic Items

Code No.	Item	"CHECK ENGINE" Lamp*1		Diagnosis	Trouble Area	Memory*2
		Normal Mode	Test Mode			
12	RPM Signal	ON	N.A.	No "Ne" or "G" signal to ECU within 2 seconds after engine is cranked.	<ul style="list-style-type: none"> <li>• Ne, G sensor circuit</li> <li>• Starter signal circuit</li> <li>• Ne, G sensor</li> <li>• ECU</li> </ul>	○
13	RPM Signal	ON	ON	<ul style="list-style-type: none"> <li>• No "Ne" signal to ECU when the engine speed is above 1000 rpm.</li> <li>• The phase of the G<sub>1</sub> or G<sub>2</sub> signal and the Ne signal is shifted more than the standard value.</li> </ul>	<ul style="list-style-type: none"> <li>• Ne sensor circuit</li> <li>• Ne sensor</li> <li>• ECU</li> </ul>	○
14*6	Ignition No. 1 Signal	ON	N.A.	No "IGf <sub>1</sub> " signal to ECU 8–11 times in succession.	<ul style="list-style-type: none"> <li>• Igniter circuit</li> <li>• Igniter</li> <li>• ECU</li> </ul>	○
15*6	Ignition No. 2 Signal	ON	N.A.	No "IGf <sub>2</sub> " signal to ECU 8–11 times in succession.	<ul style="list-style-type: none"> <li>• Igniter circuit</li> <li>• Igniter</li> <li>• ECU</li> </ul>	○
16	ECT Control Signal	ON	N.A.	ECT control program faulty.	<ul style="list-style-type: none"> <li>• ECU</li> </ul>	X
17	Cam Position Sensor No. 1 Signal	N.A.	OFF	Open circuit in G <sub>1</sub> sensor signal (G <sub>1</sub> ).	<ul style="list-style-type: none"> <li>• G<sub>1</sub> sensor circuit</li> <li>• G<sub>1</sub> sensor</li> <li>• ECU</li> </ul>	X
18	Cam Position Sensor No. 2 Signal	N.A.	OFF	Open circuit in G <sub>2</sub> sensor signal (G <sub>2</sub> ).	<ul style="list-style-type: none"> <li>• G<sub>2</sub> sensor circuit</li> <li>• G<sub>2</sub> sensor</li> <li>• ECU</li> </ul>	X
21	Main Oxygen Sensor Signal (for left bank)	ON	ON	During air–fuel ratio feedback correction, output voltage of main oxygen sensor remains between 0.35V and 0.7V continuously for a certain period (OXL <sub>1</sub> ).	<ul style="list-style-type: none"> <li>• Main oxygen sensor circuit</li> <li>• Main oxygen sensor</li> </ul>	○
				Open circuit in oxygen sensor heater signal (HT <sub>1</sub> ).	<ul style="list-style-type: none"> <li>• Oxygen sensor heater circuit</li> <li>• Oxygen sensor heater</li> <li>• ECU</li> </ul>	○
22	Water Temp. Sensor Signal	ON	ON	Open or short circuit in water temp. sensor signal (THW).	<ul style="list-style-type: none"> <li>• Water temp. sensor circuit</li> <li>• Water temp. sensor</li> <li>• ECU</li> </ul>	○
24	Intake Air Temp. Signal	ON*3	ON	Open or short circuit in intake air temp. sensor signal (THA).	<ul style="list-style-type: none"> <li>• Intake air temp. sensor circuit</li> <li>• Intake air temp. sensor</li> <li>• ECU</li> </ul>	○
25*4	Air–Fuel Ratio Lean Malfunction	ON	ON	<ul style="list-style-type: none"> <li>• When air–fuel ratio feedback correction value continues at the upper (lean) limit for a certain period of time or adaptive control value is not renewed for a certain period of time.</li> <li>• When air–fuel ratio feedback compensation value or adaptive control value feedback frequency is abnormally high during idle switch on and feedback condition.</li> <li>• When the difference of air–fuel ratio feedback compensation value between right and left banks is more than a certain percentage.</li> </ul>	<ul style="list-style-type: none"> <li>• Injector circuit</li> <li>• Injector</li> <li>• Ignition system</li> <li>• Fuel line pressure</li> <li>• Oxygen sensor circuit</li> <li>• Oxygen sensor</li> <li>• Air flow meter</li> <li>• Water temp. sensor</li> <li>• ECU</li> </ul>	○
26*4	Air–Fuel Ratio Rich Malfunction				<ul style="list-style-type: none"> <li>• Injector circuit</li> <li>• Injector</li> <li>• Fuel line pressure</li> <li>• Cold start injector</li> <li>• Air flow meter</li> <li>• Water temp. sensor</li> <li>• ECU</li> </ul>	
27	Sub–Oxygen Sensor Signal (for left bank)	ON	ON	Open circuit in sub–oxygen sensor signal (OXL <sub>2</sub> ).	<ul style="list-style-type: none"> <li>• Sub–oxygen sensor circuit</li> <li>• Sub–oxygen sensor</li> <li>• ECU</li> </ul>	○

Code No.	Item	“CHECK ENGINE” Lamp*1		Diagnosis	Trouble Area	Memory*2
		Normal Mode	Test Mode			
28	Main Oxygen Sensor Signal (for right bank)	ON	ON	During air–fuel ratio feedback correction, output voltage of main oxygen sensor remains between 0.35V and 0.7V continuously for a certain period (OXR <sub>1</sub> ).	<ul style="list-style-type: none"> <li>● Main oxygen sensor circuit</li> <li>● Main oxygen sensor</li> </ul>	○
				Open circuit in oxygen sensor heater signal (HT <sub>2</sub> ).	<ul style="list-style-type: none"> <li>● Oxygen sensor heater circuit</li> <li>● Oxygen sensor heater</li> <li>● ECU</li> </ul>	○
29	Sub-Oxygen Sensor Signal (for right bank)	ON	ON	Open circuit in sub–oxygen sensor signal (OXR <sub>2</sub> ).	<ul style="list-style-type: none"> <li>● Sub–oxygen sensor circuit</li> <li>● Sub–oxygen sensor</li> <li>● ECU</li> </ul>	○
31	Air Flow Meter Signal	ON	ON	No “Ks” signal to ECU when the engine speed is above 300 rpm.	<ul style="list-style-type: none"> <li>● Air flow meter circuit</li> <li>● Air flow meter</li> <li>● ECU</li> </ul>	○
35	HAC Sensor Signal	ON	ON	Open circuit in altitude HAC sensor signal.	<ul style="list-style-type: none"> <li>● ECU</li> </ul>	○
41	Throttle Position Sensor Signal	ON*3	ON	Open or short circuit in throttle position sensor signal (VTA <sub>1</sub> ).	<ul style="list-style-type: none"> <li>● Throttle position sensor circuit</li> <li>● Throttle position sensor</li> <li>● ECU</li> </ul>	○
43	Starter Signal	N.A.	OFF	No “STA” signal to ECU until engine speed reaches 400 rpm with vehicle not moving.	<ul style="list-style-type: none"> <li>● Starter signal circuit</li> <li>● Ignition switch, main relay circuit</li> <li>● ECU</li> </ul>	X
47	Sub-Throttle Position Sensor Signal	ON*3	ON	Open or short circuit in throttle position sensor signal (VTA <sub>2</sub> ).	<ul style="list-style-type: none"> <li>● Sub–throttle position sensor</li> <li>● Sub–throttle position sensor circuit</li> <li>● ECU</li> </ul>	○
52	Knock Sensor Signal 1	ON	N.A.	Open or short circuit in knock sensor signal (KNK <sub>1</sub> ).	<ul style="list-style-type: none"> <li>● Knock sensor circuit</li> <li>● Knock sensor</li> <li>● ECU</li> </ul>	○
53	Knock Control Signal	ON	N.A.	Knock control program faulty.	<ul style="list-style-type: none"> <li>● ECU</li> </ul>	X
55	Knock Sensor Signal 2	ON	N.A.	Open or short circuit in knock sensor signal (KNK <sub>2</sub> ).	<ul style="list-style-type: none"> <li>● Knock sensor circuit</li> <li>● Knock sensor</li> <li>● ECU</li> </ul>	○
71*5	EGR System Malfunction	ON	ON	EGR gas temp. below a predetermined level during EGR operation.	<ul style="list-style-type: none"> <li>● EGR system components</li> <li>● EGR gas temp. sensor circuit</li> <li>● EGR gas temp. sensor</li> <li>● ECU</li> </ul>	○
51	Switch Condition Signal	N.A.	OFF	No “IDL” signal or No “NSW” signal or “A/C” signal to ECU during diagnosis check for test mode.	<ul style="list-style-type: none"> <li>● A/C amplifier</li> <li>● A/C switch circuit</li> <li>● Neutral start switch circuit</li> <li>● Neutral start switch</li> <li>● Throttle position sensor circuit</li> <li>● Throttle position sensor</li> <li>● Accelerator pedal and cable</li> <li>● ECU</li> </ul>	X

\*1: ON in the diagnostic mode column indicates that the “CHECK ENGINE” lamp will light up when a diagnosis is conducted and a malfunction is detected. OFF indicates that the lamp will not light even if a malfunction is detected during a diagnosis. N.A. indicates that diagnosis is not performed for that item.

\*2: ○ mark in the memory column indicates that the code for a malfunction is stored in the ECU memory if that malfunction occurs once. X mark indicates that the code is not stored in the memory even if that malfunction occurs. For this reason, lamp indication of the malfunction code is limited to those times when the diagnostic results are output in accordance with the normal or test mode procedures.

\*3: In the normal mode, when a malfunction occurs in code Nos. 24, 41 and 47, the “CHECK ENGINE” lamp will light up only in California specification vehicles.

\*4: If the circuit of the main oxygen sensor is open or shorted in California specification vehicles, only code No. 25 is stored in the ECU memory. If malfunctions occur with items other than the main oxygen sensor, code Nos. 25 and 26 are stored simultaneously in memory for all items.

\*5: Code No. 71 is used only for California specification vehicles.

\*6: If diagnostic code “14” is displayed, check No. 1 igniter connected with harness wrapped with yellow tape. If diagnostic code “15” is displayed, check No. 2 igniter connected with harness not wrapped with yellow tape.

## 15. Fail-Safe

### Fail-Safe Function

When a malfunction is detected by any of the sensors, there is a possibility of an engine or other malfunction occurring if the ECU were to continue to control the engine control system in the normal way. To prevent such a problem, the fail-safe function of the ECU either relies on the data stored in memory to allow the engine control system to continue operating, or stops the engine if a hazard is anticipated.

The following table describes the problems which can occur when trouble occurs in the various circuits, and the responses of the fail-safe function:

Circuit with Abnormal Signals	Necessity of Fail-Safe Function	Fail-Safe Function
Ignition Confirmation Signal (IGf <sub>1,2</sub> ) Circuit	If trouble occurs in the ignition system and ignition cannot take place (the ignition confirmation signal (IGf <sub>1,2</sub> ) is not input to the ECU), the catalyst could overheat due to misfiring.	Fuel injection is stopped.
<ul style="list-style-type: none"> <li>Water Temp. Sensor Signal (THW) Circuit</li> <li>Intake Air Temp. Sensor Signal (THA) Circuit</li> </ul>	If an open or short circuit occurs in the water temperature or intake air temperature signal circuit, the ECU senses that the temperature is below $-58^{\circ}\text{F}$ ( $-50^{\circ}\text{C}$ ) or higher than $274.2^{\circ}\text{F}$ ( $139^{\circ}\text{C}$ ). This results in the air-fuel ratio becoming too rich or too lean, which leads to engine stall or rough engine running.	Fixed values (standard values) are used, standard values are $176^{\circ}\text{F}$ ( $80^{\circ}\text{C}$ ) for coolant temperature and $68^{\circ}\text{F}$ ( $20^{\circ}\text{C}$ ) for intake air temperature.
Transmission Control Signal	If trouble occurs in the transmission control program in the ECU, transmission does not operate properly.	Torque control correction by the ESA is prohibited.
Air Flow Meter Signal (Ks) Circuit	If an open or short circuit occurs in the air flow meter signal circuit, it becomes impossible to detect the intake air volume and calculation if the basic injection duration cannot be done. This results in engine stalling or inability to start the engine.	Fixed (standard) values determined by the STA signal and IDL contacts conditions are used for the fuel injection duration and the ignition timing ( $10^{\circ}$ BTDC), making engine operation possible.
High Altitude Compensation Sensor Signal (HAC) Circuit	If an open or short circuit occurs in the HAC sensor signal circuit, the atmospheric pressure corrective value is either the maximum or the minimum value.  This causes the engine to run rough or reduces drivability.	A fixed value of 760 mmHg is used.
Main and Sub-Throttle Position Sensor Signal (VTA <sub>1,2</sub> ) Circuit	When an open or short circuit occurs in the throttle position sensor signal circuit, the ECU detects the throttle valve as being either fully open or fully closed to prevent engine stall.	A fixed value of $0^{\circ}$ throttle valve opening angle is used.
<ul style="list-style-type: none"> <li>Knock Sensor Signal (KNK<sub>1,2</sub>) Circuit</li> <li>Knock Control System</li> </ul>	If an open or short circuit occurs in the knock signal circuit, or if trouble occurs in the knock control system inside the ECU, whether knocking occurs or not, ignition timing retard control will not be carried out by the knock control system, which could lead to damage to the engine.	The corrective retard angle value is set to the maximum value.

**Back-Up Function**

If there is trouble with the program in the ECU and the ignition signals (IGt) are not output, the ECU controls fuel injection and ignition timing at predetermined levels as a back-up function to make it possible to continue to operate the vehicle.

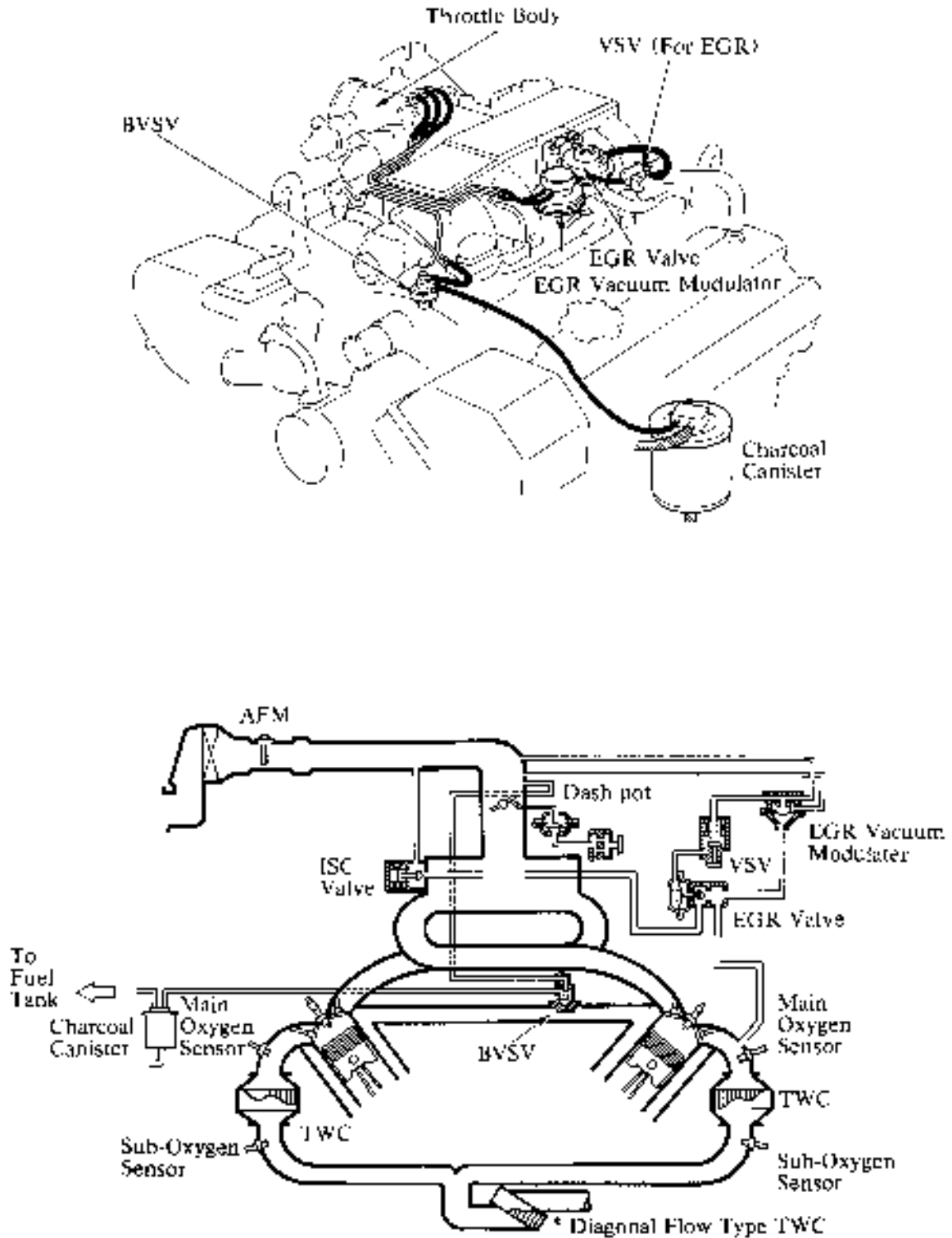
Furthermore, the injection duration is calculated from the starting signal (STA) and the throttle position signal (IDL). Also, the ignition timing is fixed at the initial ignition timing, 5° BTDC, without relation to the engine speed.

**NOTE:** If the engine is controlled by the back-up function, the “CHECK ENGINE” lamp lights up to warn the driver of the malfunction but the diagnostic code is not output.

**■ EMISSION CONTROL SYSTEM****1. System Purpose**

System	Abbreviation	Purpose
Positive crankcase ventilation	PCV	Reduces HC by eliminating blow-by gas
Exhaust gas recirculation	EGR	Reduces NO <sub>x</sub>
Three-way catalyst	TWC	Reduces HC, CO and NO <sub>x</sub>
Evaporative emission control	EVAP	Reduces evaporative HC
Air-fuel ratio feedback control	A/F	Reduces HC, CO and NO <sub>x</sub>
Electronic fuel injection	EFI	Regulates all engine conditions for reduction of exhaust emissions.
High altitude compensator	HAC	Reduces HC and CO

## 2. Component Layout and Schematic Drawing

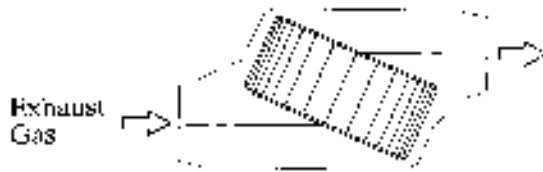


\* Applicable only to the California specification vehicles.

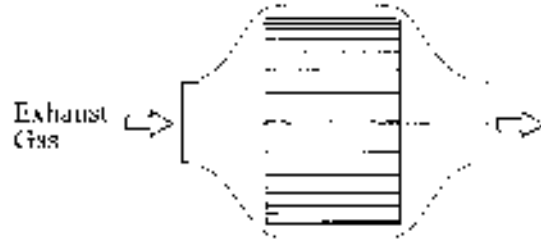
### 3. Diagonal Flow Type Three-Way Catalyst (TWC)

A new type of high-performance catalyst converter developed by improving the shape and container construction is used.

It has monolithic catalysts and is diagonally arranged in relation to the flow of exhaust gas reducing the length and the exhaust resistance with wider cross section area.



**Diagonal Flow Type TWC**



**Conventional Type TWC**