

**SERVICE MANUAL**

**MITSUBISHI  
DIESEL ENGINES  
S4Q, S4Q2**

**October 2006**



# INTRODUCTION

This service manual describes the specifications of the Mitsubishi Diesel Engine and the maintenance and adjustment procedures.

To maintain the performance of the engine for many years and to ensure safe operation, it is important to use the engine correctly and conduct regular inspection and maintenance, and also to take necessary measures which involves the disassembly, inspection, repair and reassembly of the engine and engine parts.

Read this manual carefully and understand the work procedures fully before reassembling, inspecting, repairing or reassembling the engine.

The contents of the manual are based on the engine models that are being produced at the time of publication.

Due to improvements made thereafter, the actual engine that you work on may differ partially from the one described in this manual.

## How to Use This Manual

In this service manual, the Mitsubishi Diesel Engine (standard model for land use) specifications, maintenance standards and adjustment procedure as well as service procedures such as disassembly, inspection, repair and reassembly are arranged in groups for quick reference.

There are separate manuals for the fuel injection pump, governor and turbocharger.

A short summary of each Group is given in the General Contents, and there is also a table of contents at the beginning of each Group.

Regarding engine operation and periodical maintenance, refer to the Operation & Maintenance Manual. For component parts and ordering of service parts, refer to the Parts Catalogue. Structure and function of the engine are described in various training manuals.

### 1. Methods of Indication

- (1) Parts shown in illustrations and described in text are numbered to correspond with the sequence of disassembly.
- (2) Inspections to be conducted during disassembly are indicated in a box  in disassembled views.
- (3) Maintenance standards for inspection and repair are described in text where they are relevant, are also listed in Group 1 in the General Contents.
- (4) The sequence in which parts are to be assembled is summarized below each assembled view.  
Such as: ⑤→④→③→②→①.
- (5) The following marks are used in this manual to emphasize important safety cautions.



.....Indicates a highly hazardous situation which, if not avoided, can result in death or serious injury.



.....Indicates a potentially hazardous situation which, if not avoided, can result in death or serious injury.



.....Indicates a potentially hazardous situation which, if not avoided, can result in minor or moderate injury.

**CAUTION**

.....Indicates a potentially hazardous situation which, if not avoided, can result in property damage.

**Note:**

.....Indicates important information or information which is useful for engine operation or maintenance.

- (6) Tightening torque under wet conditions is indicated as "[Wet]." When so indicated, apply engine oil to the threaded portion of the fastener. Unless indicated as such, the tightening torque is to be assumed in the dry condition.

## 2. Terms Used in This Manual

Nominal value ..... Indicates the standard dimension of a part to be measured.

Standard ..... Indicates the dimension of a part, the clearance between parts, or the standard performance. Since the value is indicated in a range needed for inspection, it is different from the design value.

Limit ..... A part must be repaired or replaced with a new part when it reaches the limit value.

## 3. Abbreviations, Standards, Etc.

- BTDC = Before Top Dead Center
- ATDC = After Top Dead Center
- BBDC = Before Bottom Dead Center
- ABDC = After Bottom Dead Center
- TIR = Total Indicated Reading
- API = American Petroleum Institute
- ASTM = American Society for Testing and Materials
- JIS = Japanese Industrial Standards
- LLC = Long Life Coolant
- MIL = Military Specifications and Standards (U.S.)
- MSDS = Material Safety Data Sheet
- SAE = Society of Automotive Engineers (U.S.)

## 4. Units of Measurement

Measurements are based on the International System of Units (SI), and their converted metric values are indicated in parentheses ( ). For metric conversion, the following rates are used.

- Pressure: 1 MPa = 10.197 kgf/cm<sup>2</sup>
- Torque: 1 N·m = 0.10197 kgf·m
- Force: 1 N = 0.10197 kgf
- Horsepower: 1 kW = 1.341 HP = 1.3596 PS
- Meter of mercury: 1 kPa = 0.7 cmHg
- Meter of water: 1 kPa = 10.197 cmH<sub>2</sub>O (cmAq)
- Rotational speed: 1 min<sup>-1</sup> = 1 rpm

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**Supplement**

Engine inspection record sheet

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## **WARNING** Danger of Fire and Explosion

### ● **Keep flames away**

Do not use flames or smoke at a site where fuel or engine oil is handled or cleaning solvent is used for washing parts.

Flames can ignite such materials and result in a dangerous situation.

Spilled fuel and oil should be wiped immediately and thoroughly. Spilled fuel and oil can ignite and cause fire.

When storing fuel or engine oil, make sure that the storage area is well ventilated and the caps of containers are tightly closed.



### ● **Keep surrounding area neat and clean**

Do not leave combustible or explosive materials, such as fuel and engine oil, near the engine. They can cause fire or explosion.

Remove dust, dirt and other foreign materials accumulated on or near the engine. They can cause fire or engine overheating. Be sure to remove dust from the top side of the battery after maintenance. Dust can cause a short-circuit.

The engine must be positioned at least 1 m [3.28 ft] away from buildings and other equipment to prevent possible fire caused by engine heat.

### ● **Do not open crankcase until engine cools**

After the engine stops operation, let the engine cool for at least 10 minutes before opening the side cover of the crankcase.

Inflow of fresh air into the crankcase of a hot engine can cause oil mist to ignite and explode.

### ● **Check for fuel and oil leaks**

When fuel or oil leaks are found, repair the leakage immediately.

Fuel or engine oil spilled on a hot surface of the engine can cause fire and result in personal injury or equipment damage.

### ● **Use shatterproof light**

Use a shatterproof light when inspecting the fuel system, lubrication system, cooling system or battery fluid level.

A non-shatterproof light may catch fire and explode.

### ● **Do not short-circuit electrical wires**

Do not inspect or repair the electrical system with the battery cables connected to the battery, since it can cause accidental short-circuiting and lead to fire. Be sure to disconnect the negative (-) battery cable from the battery before conducting work.

Loose terminals and damaged cables/wires can result in a short-circuit and cause fire. Inspect the terminals, cables and wires before servicing, and repair or replace when damage is found.

### ● **Keep fire extinguishers and first aid kit nearby**

Always keep fire extinguishers nearby, and be familiarized with their usage.

Keep a first aid kit at a designated place, and make sure it is easily accessible whenever needed.

Also, establish emergency response procedures to follow in the event of a fire or accident, and post emergency contact locations and contact methods.



## **WARNING** Danger of Entanglement

### ● Install protective covers on rotating parts

Make sure the protective covers of the engine are installed correctly at rotating parts.

If protective covers are loose or damaged, repair.

Never remove the covers guarding rotating parts, such as the camshaft cover and rocker covers, when the engine is operating.

When the engine is coupled to other equipment or connected to a radiator, be sure to install covers on the exposed connecting belt and coupling.

Never remove protective covers.



### ● Check surrounding area for safety before starting engine

Before starting the engine, check to make sure no one is near the generator and tools are not left on or near the engine. Always verbally notify people within the immediate area when starting the engine.

When the starter switch is posted with a sign that prohibits startup operation, do not operate the engine.

### ● Stay clear of rotating parts while engine is in operation

Do not approach rotating parts while the engine is in operation.

Keep items that can be easily entangled away from rotating parts.

Rotating parts can entangle a persons' body or tools to cause serious.



### ● Lock out and tag out

Be sure to lock out and tag out before starting inspection and maintenance.

Lockout and tagout are effective methods of cutting off machines and equipment from energy sources.

To lock out and tag out, pull out the key from the starter switch, turn off the battery switch, and post a "Do Not Operate" tag or a similar sign on the starter switch.

The starter switch key should be kept by the person performing the inspection and maintenance.

If the engine is installed with an air starter system, close the main valve of the air tank, and post a "Do Not Open" tag on the main valve.

### ● Always stop engine before inspection and maintenance

Before inspection and maintenance, be sure to stop the engine. Never attempt to adjust the belt tension while the engine is operating. Operating belt can entangle your body and result in serious injury.

### ● Always return turning tools to original position after use

Be sure to remove all turning tools used in inspection and maintenance. Return the turning gear in the original position before starting the engine.

Starting the engine with the turning tools inserted or turning gears engaged may not only cause engine damage but personal injury as well.



## WARNING Danger of Burns

- Do not touch engine in operation or immediately after operation

Do not touch any part of the engine while the engine is operating or immediately after it stops operation.

Touching the engine in operation or immediately after operation can cause burns.

When conducting inspection and maintenance, check the water temperature gage to make sure the engine has cooled sufficiently.



- Open radiator filler cap carefully

Never open the radiator filler cap while the engine is operating or immediately after it stops operation. Open the cap only after the engine stops and the coolant temperature drops sufficiently.

When opening the cap, slowly turn the cap to release internal pressure. To prevent burns caused by spurting steam, wear thick rubber gloves or cover the cap with a cloth.

When closing the cap, make sure to tighten it securely. If the radiator filler cap is opened when the coolant is at operating temperature, steam and hot coolant may blow out, causing skin burns as a result.

- Add coolant after coolant temperature drops sufficiently

Do not add coolant immediately after the engine stops, wait until the coolant temperature drops sufficiently. Otherwise, it will result to burns.

- Do not remove heat shields

The exhaust system, which becomes extremely hot while the engine is operating, is installed with heat shields. Never remove these heat shields. If they must be removed for inspection and maintenance, be sure to reinstall the heat shields after inspection and maintenance.

## WARNING Beware of Exhaust Gas Poisoning

- Operate engine in well-ventilated area

If the engine is installed in an enclosed area and an exhaust duct is used to discharge the exhaust gas to the outside, inspect the duct joints to make sure there is no exhaust gas leak from duct joints.



When the engine is used as a movable generator, do not use the engine in an enclosed area (inside a warehouse, tunnel, etc.) or at a site where all sides are blocked for poor ventilation. If the engine must be operated in an enclosed area, discharge the exhaust gas to the outside and provide adequate ventilation. Make sure the exhaust gas does not blow in the direction of plants or animals.

Exhaust gas from the engine contains carbon monoxide and other harmful substances. Operating the engine in an ill-ventilated area can cause gas poisoning.

## WARNING Danger of Hearing Problems

- Wear ear plugs

Always wear ear plugs when entering the machine room (engine room).

Combustion sound and mechanical noise generated by the engine can cause hearing problems.



## **WARNING Beware of Falling Equipment**

### ● Lift engine carefully

When lifting the engine, use wire ropes capable of supporting the entire weight of the engine.

Attach appropriate slings to the hangers provided on the engine to lift the engine.

Keep the engine balanced during lifting by considering center of gravity of the engine.

Keep the angle formed by wire ropes within 60°. If the angle exceeds this limit, excessive load is applied on the hangers and may damage the hangers.

If wire ropes contact the engine directly, place a cloth or other soft padding to prevent damage to the engine and wire ropes.



### ● Do not climb onto engine

Do not climb onto the engine, or set a foot on any part located on the side of the engine.

To work on parts located on the upper section, use a ladder, stand, etc., and be careful not to fall.

Climbing on the engine can damage engine parts, and a person may fall and get injured.

### ● Watch footing when conducting maintenance

When working on the upper part of the engine and other hard-to-reach places, use a stable work platform.

Standing on a decrepit stand or parts box may result in personal injury.

Do not place any item on a work platform.



## **CAUTION Cautions Regarding Engine Oil and LLC**

### ● Use only specified fuel, engine oil and coolant

Use fuel, engine oil and coolant specified in this manual, and handle them carefully.

Use of other fuel, oil or coolant, and improper handling may cause various engine problems and malfunctions.

Obtain the MSDSs (Material Safety Data Sheets) issued by the fuel, oil and coolant manufacturers, and follow the directions on the MSDSs for proper handling.

### ● Handle LLC (long life coolant) carefully

LLC contains strong alkali. Do not swallow or allow it to contact eyes.

Since drained coolant (containing LLC) is harmful, do not dispose of it into conventional sewage. Abide by the applicable law and regulations when discarding drained coolant.

### ● Properly disposed of drained oil and coolant

Do not disposed of drained engine oil or coolant into conventional sewage.

Laws and regulations prohibit disposal of oil and coolant into ordinary sewage systems.

When disposing oil waste, coolant and other environmentally hazardous waste, abide by the law and regulations.

## CAUTION Cautions Regarding Battery

### ● Handle battery carefully

- Never use flames or allow sparks near the battery. The battery releases flammable hydrogen gas and oxygen gas. These gases can be ignited by flames and cause an explosion.
- Do not use the battery when the fluid surface is lower than the minimum level. Using a battery with a low electrolytic level can result in an explosion.
- Do not short the battery terminals with a tool or other metal object.
- When disconnecting battery cables, always remove the cable from the negative (-) terminal first. When reconnecting cables, attach the cable to the positive (+) terminal first.
- Charge the battery in a well-ventilated area, with all filling hole plugs removed.
- Make sure the cable clamps are securely installed on the battery terminals. A loose cable clamp can cause sparks that may result in an explosion.
- Before servicing electrical components or conducting electric welding, set the battery switch to the [Open/OFF] position or disconnect the cable from the negative (-) battery terminal to cut off the electrical current.
- Electrolyte (battery fluid) contains dilute sulfuric acid. Careless handling of the battery can lead to the loss of sight and/or skin burns. Also, do not swallow electrolyte.
- Wear protective goggles and rubber gloves when maintaining and inspecting the battery (when adding water, charging, etc.).
- If electrolyte is spilled onto the skin or clothes, immediately wash with lots of water and thoroughly clean with soap.
- If electrolyte gets into eyes, immediately flush with lots of clean fresh water, and seek immediate medical attention.
- Should accidentally swallow electrolyte, gargle with plenty of water, then drink lots of water, and seek immediate medical attention.



## CAUTION Response to Abnormalities

### ● If engine overheats, conduct heating operation before stopping engine

If the engine overheats, do not stop the engine immediately. Abruptly stopping an overheated engine may cause the coolant temperature to rise, resulting in seizing of the engine. If the engine overheats, operate the engine at low idling speed (cooling operation), and stop the engine after the coolant temperature lowers sufficiently.

Do not add coolant immediately after stopping the engine. Adding coolant to a hot engine may cause damage to the cylinder heads due to sudden change in temperature. Add coolant after the engine cools to room temperature.

### ● If engine stops due to abnormality, exercise caution when restarting

If the engine stops due to an abnormality, do not restart the engine immediately. If the engine stops with an alarm, check and correct the cause of the problem before restarting. Operating the engine without correcting the problem may result in serious engine problems.

### ● If oil pressure drops, stop engine immediately

If the engine oil pressure decreases, stop the engine immediately, and inspect the lubrication system. Operating the engine with low oil pressure may cause seizing of the bearings and other parts.

### ● If fan belt breaks, stop engine immediately

If the fan belt breaks, stop the engine immediately. Continued operation of the engine without the fan belt causes coolant to change into steam and blow out from the reservoir and radiator, thus resulting in burns.

## CAUTION Other Cautions

### ● Never modify engine

Unauthorized modification of the engine will void the manufacturer's warranty.

Modification of the engine may not only cause engine damage but also result in personal injury.

### ● Never break seals

To ensure proper engine operation, the fuel control link is attached with seals that prevent change of the fuel injection volume and rotation speed settings. Operating the engine without these seals in place can result in the following problems, and also invalidates the warranty.

- Rapid wear of moving and rotating parts
- Engine malfunctions including engine damage and seizing of engine parts
- Increased consumption of fuel and lubricating oil
- Degradation of engine performance due to improper balance between fuel injection volume and governor operation

### ● Always perform specified pre-operation inspections and periodic inspections

Conduct the pre-operation inspections and periodic inspections as described in this manual.

Failure to conduct the specified pre-operation inspections or periodic inspections may cause various engine problems and damage to parts, as well as serious accidents.

### ● Break in new engine

Break in a new engine by operating it with a light load during the first 50 hours of operation. Operating a new engine under high load or severe condition during the break-in period can shorten the service life of the engine.

### ● Conduct warm-up operation

After the engine starts, let it idle at low speed for 5 to 10 minutes before using the engine for work.

Warm-up operation circulates lubricants in the engine, thus prolonging the service life and contributing to high-performance and economical operation.

Do not conduct warm-up operation for an extended period of time. Prolonged warm-up operation causes carbon build-up in the cylinders that leads to incomplete combustion.

### ● Never operate engine under overload condition

Do not operate the engine if the exhaust smoke is black.

Overloading the engine (indicated by black smoke) causes not only high fuel consumption but also excessive carbon deposits inside the engine that leads to engine problems and shortens the service life of the engine.

### ● Conduct cooling operation before stopping engine

Before stopping the engine, conduct cooling operation (operating at low speed) for 5 to 6 minutes.

Abruptly stopping the engine immediately after high-load operation can cause partial overheating and shorten the service life of the engine.

During cooling operation, check the engine for abnormalities.

### ● Do not splash water on engine

Do not allow rain water to enter the engine through the air inlet or exhaust openings.

Do not wash the engine while it is operating. Cleaning fluid (water) can be sucked into the engine.

If water enters the combustion chambers of the engine, starting the engine can cause water hammer action, and may result in internal engine damage and serious accidents.

### ● **Conduct proper maintenance of air cleaner**

The major cause of abnormal wear on engine parts is dust entering with intake air. Worn parts result in many problems such as an increase of oil consumption, decrease of output, and starting difficulties. For effective removal of dust from intake air, conduct maintenance of the air cleaner according to the following directions.

- Do not conduct maintenance of the air cleaner while the engine is operating.
- When removing the air cleaner, do not allow dust attached on the air clear to fall into the outlet side of the air cleaner.
- If equipped with a dust indicator, conduct maintenance only when the clog warning sign appears. Unnecessary maintenance may cause dust to enter the engine when removing the filter element, or result in element damage or deformation.

### ● **Observe safety rules at workplace**

Observe the safety rules established at workplace when operating and maintaining the engine.

When feeling ill, do not operate the engine, and inform supervisor of condition.

Operation of the engine with reduced awareness may cause operation errors that may result in accidents.

When working in a group, use specified hand signals to communicate among the workers.

### ● **Wear proper work clothes and protective gear**

Wear a hardhat, face shield, safety shoes, dust mask and other protective gear, as needed.

When handling compressed air, wear safety goggles, hardhat, gloves and other necessary protective gear.

Conducting work without proper protective gear may result in serious injury.

### ● **Use appropriate tools for maintenance work**

To conduct maintenance work, use tools appropriate for the type of work to be performed, and use them correctly.

If tools are damaged, replace with new tools.

### ● **Do not operate starter for prolonged time**

Do not operate the starter for more than 10 seconds at a time if the engine does not start and wait for at least 30 seconds before cranking again.

Continuous operation of the starter will drain the battery power and cause seizing of the starter.

### ● **Do not turn off battery switch while engine is operating**

Do not turn off the batter switch while the engine is in operation.

Turning off the battery switch while the engine is in operation not only stops the instrument operations but also damages the diodes and transistors inside the alternator.

### ● **Cautions in transporting engine**

When transporting the engine on a truck, consider the generator weight, width and height to ensure safety, and also abide by the traffic law, road trucking vehicle law, vehicle restriction ordinance and other pertinent laws.

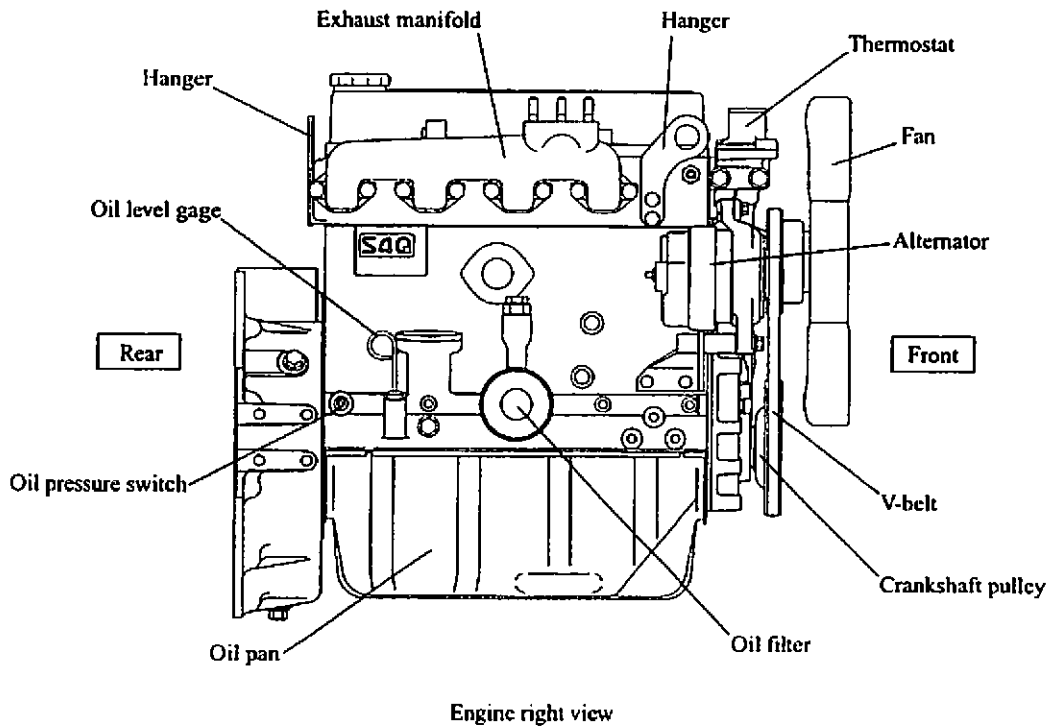
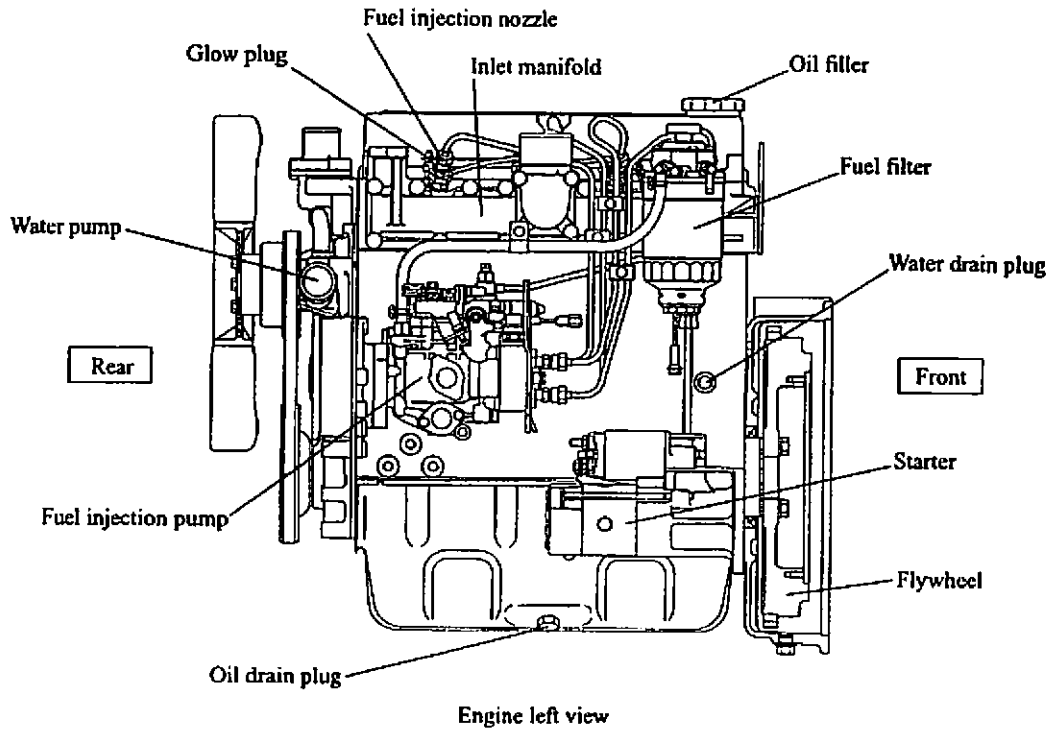
# GENERAL

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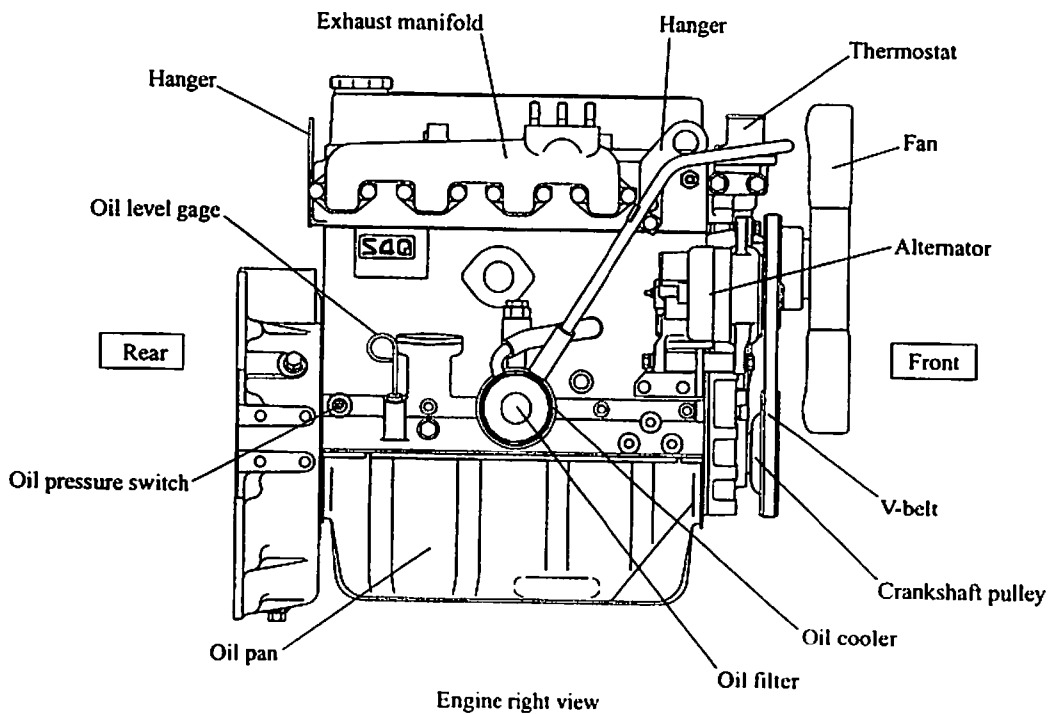
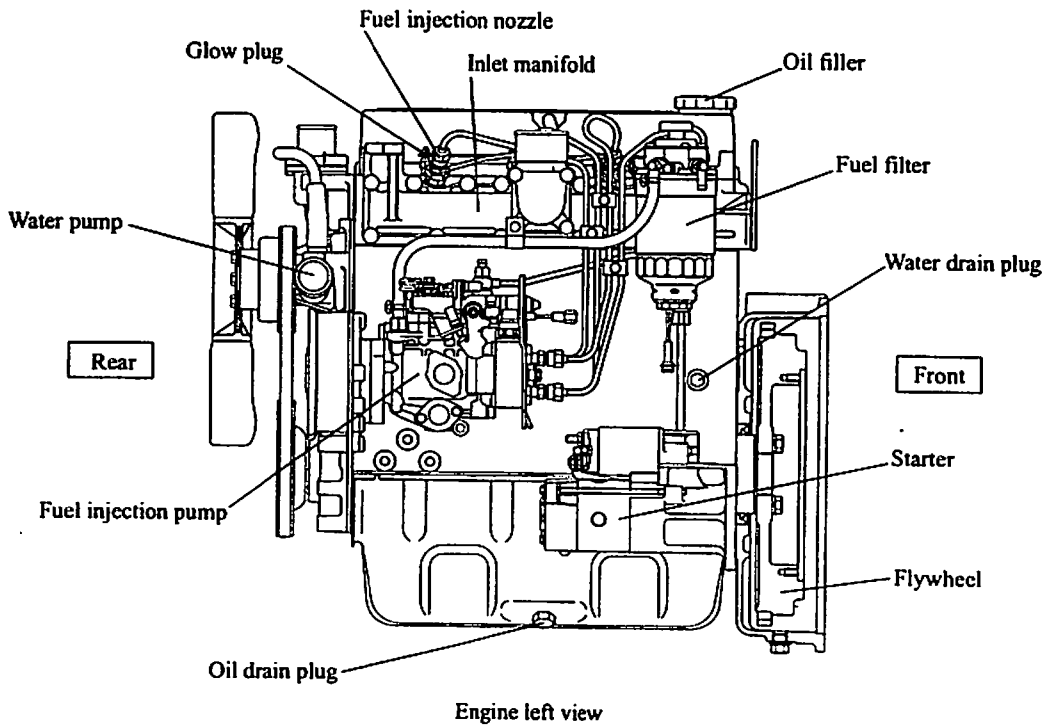
1. Outline

1.1 External View

For Power Unit

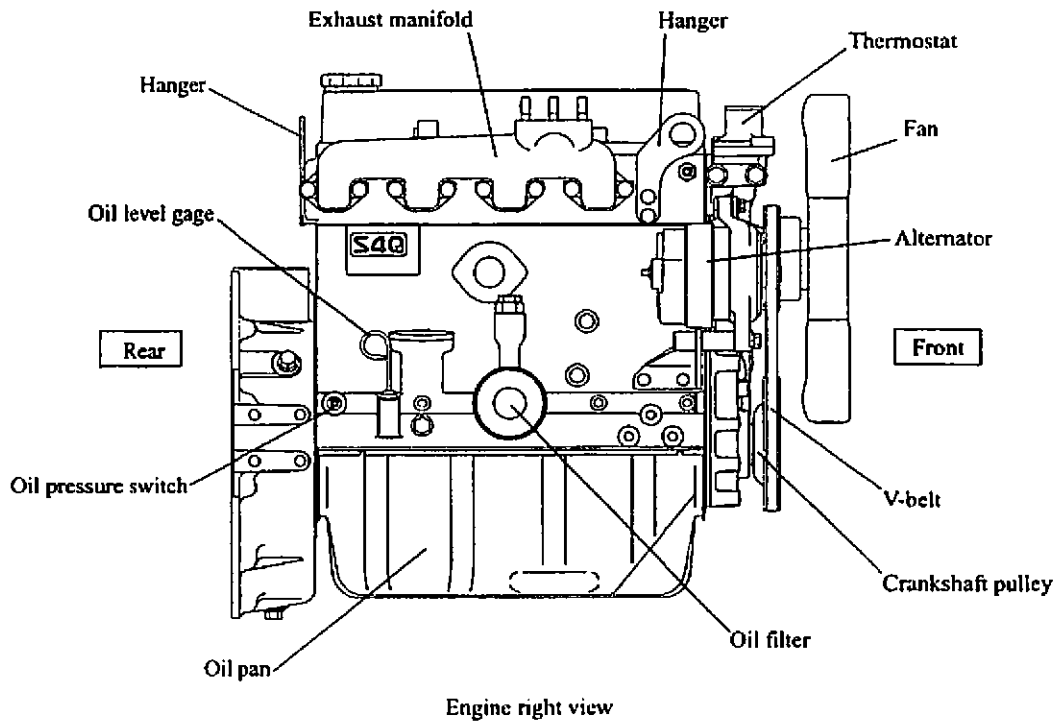
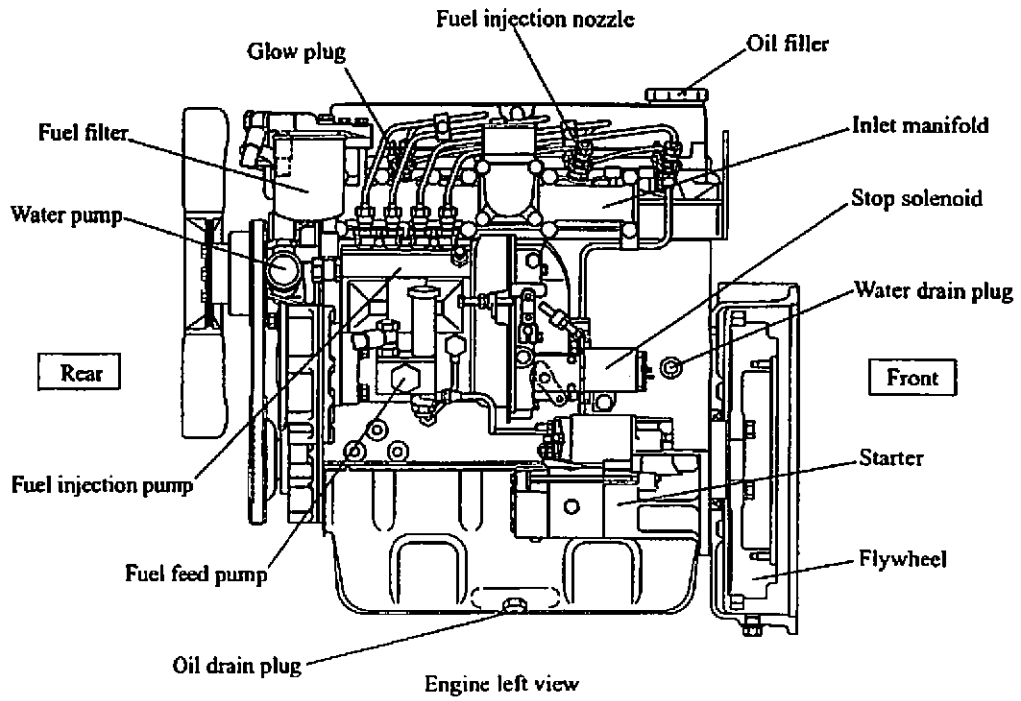


For Power Unit (High Speed Specification)

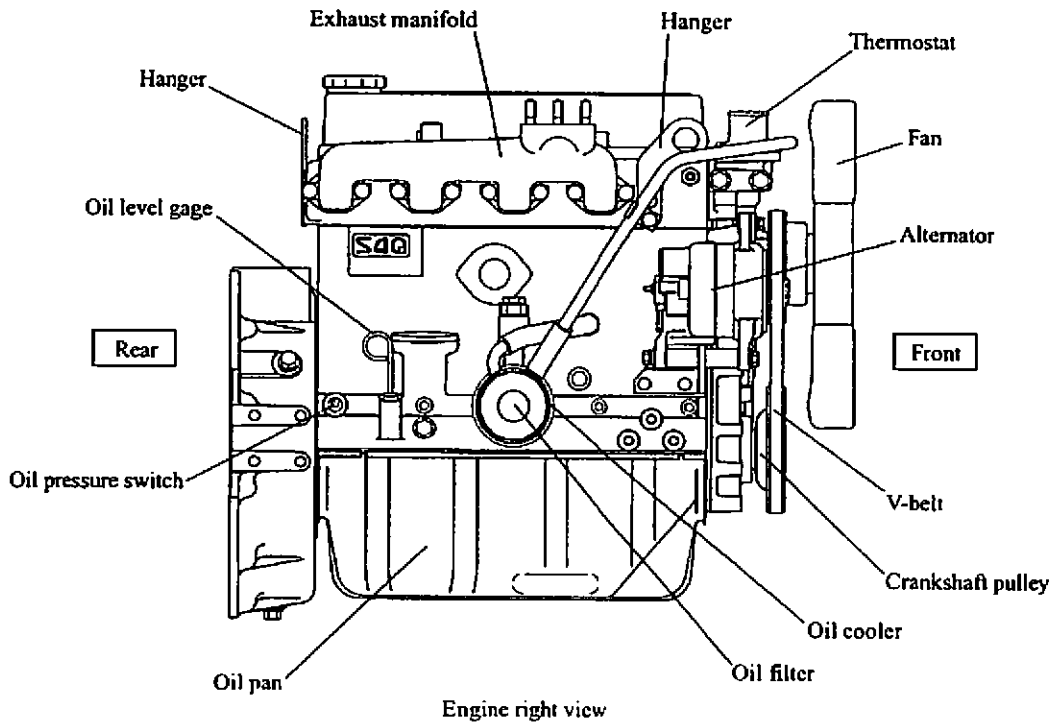
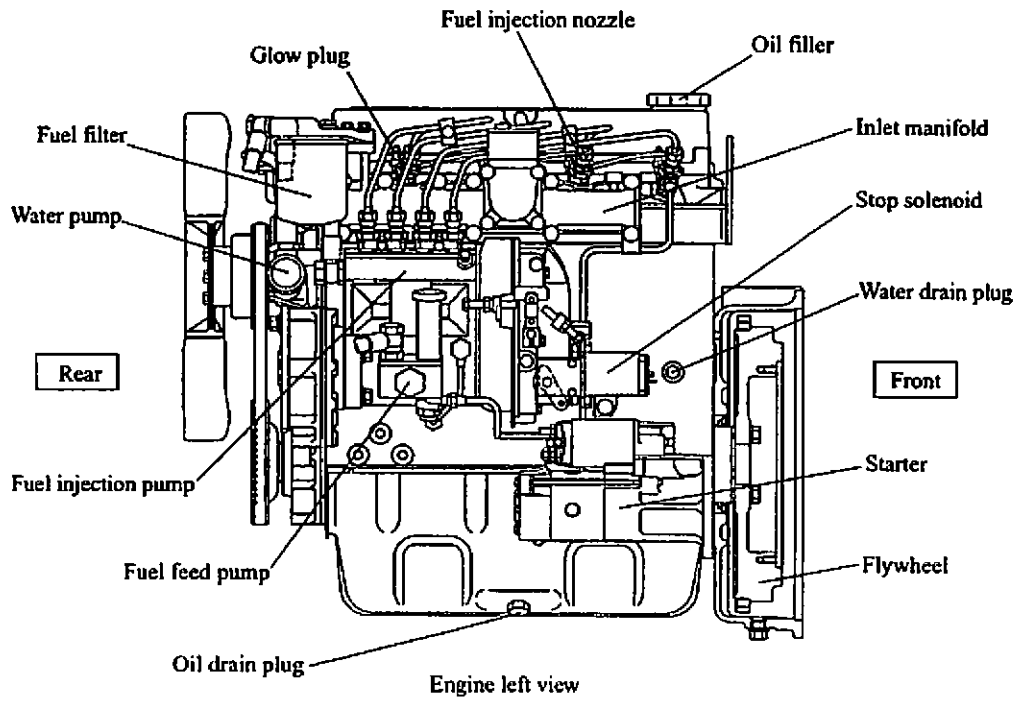




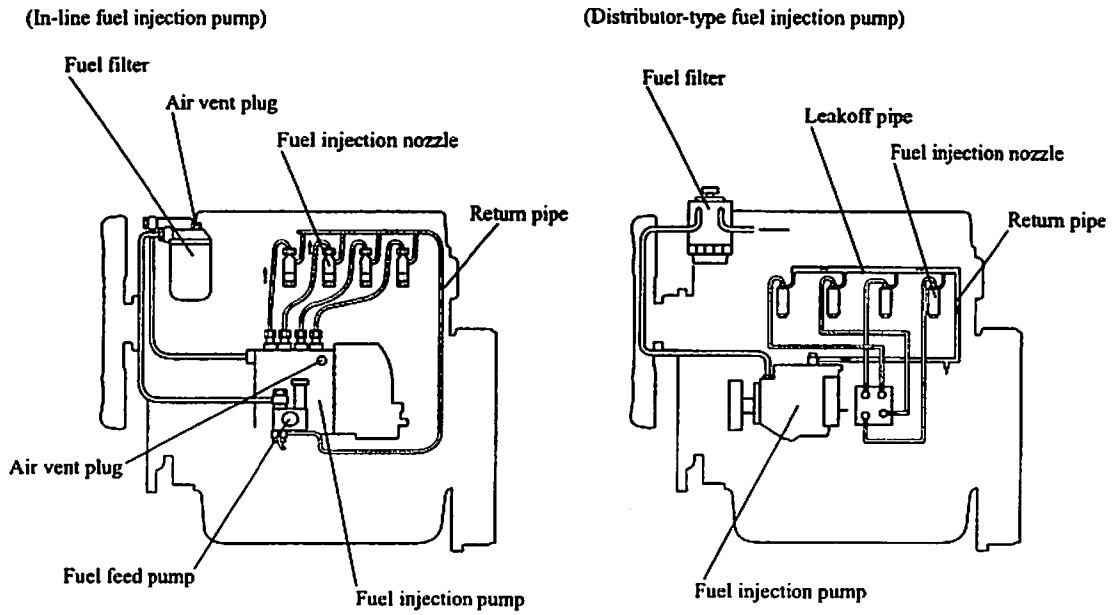
For Generator



For Generator (High Speed Specification)

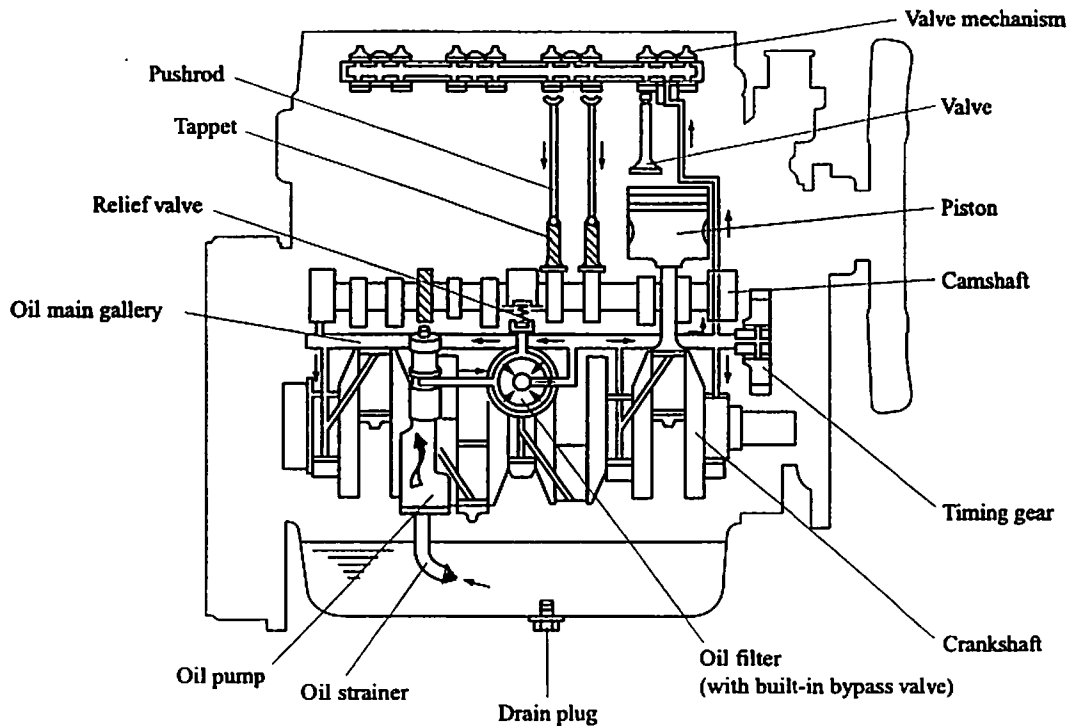


1.2 Outline of Fuel System



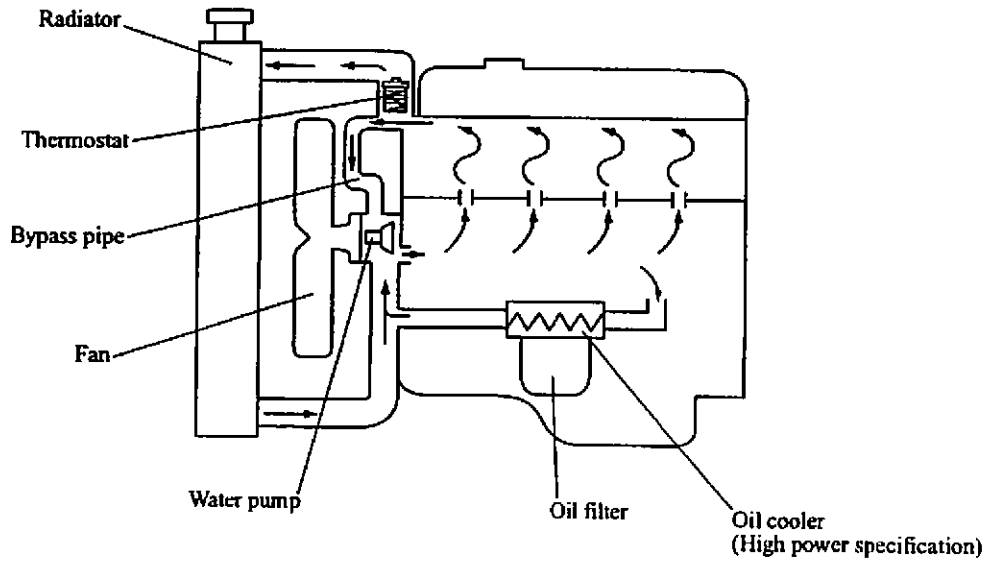
Outline of fuel system

1.3 Outline of Lubrication System



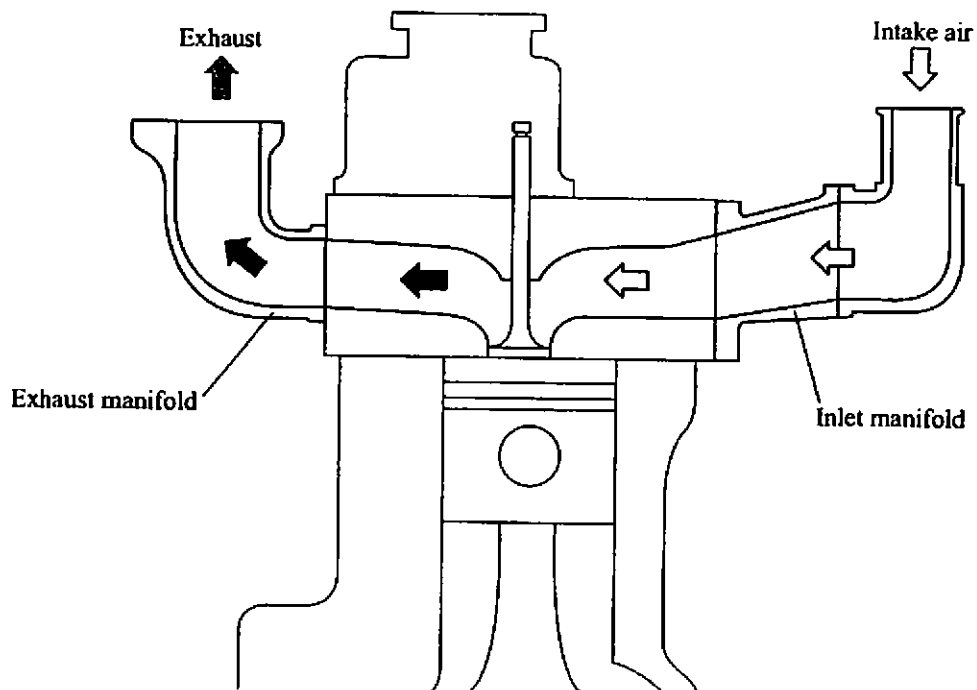
Outline of lubrication system

## 1.4 Outline of Cooling System



Outline of cooling system

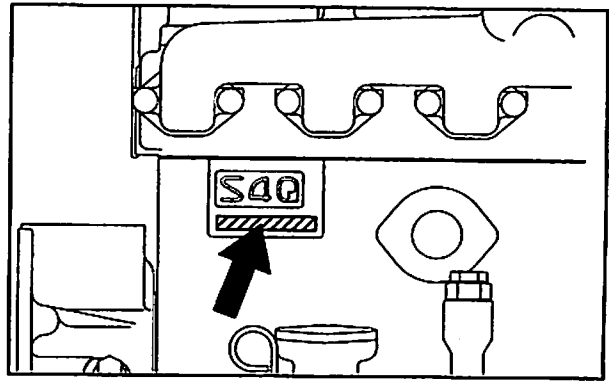
## 1.5 Outline of Inlet and Exhaust Systems



Outline of inlet and exhaust system

1.6 Engine Serial Number

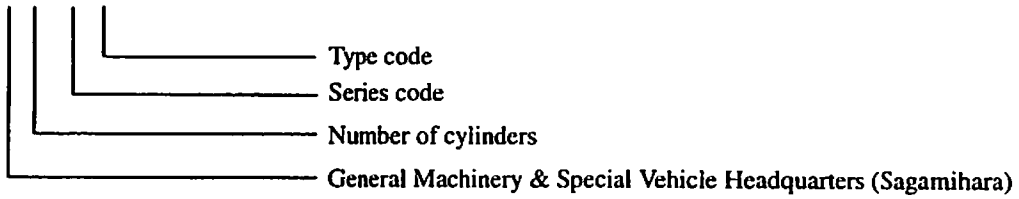
The engine serial number is stamped on the side of the crankcase



Nameplate location

1.7 Engine Model and Application Code

**S 4 Q 2**



## 2. Specifications

For Power Unit and Power Unit (High Speed Specification)

Item		Model	S4Q	S4Q2
Name	Type		Water-cooled vertical-type 4-cycle diesel engine	
	Firing order		1-3-4-2	
	Compression ratio		22	
	Combustion chamber		Swirl chamber system	
	Weight (dry)	kg [lb]	195 [430]	
Cylinder	No. of cylinders		4	
	Bore × Stroke	mm [in.]	88×95 [3.47×3.74]	88×103 [3.47×4.06]
	Total displacement	ℓ [U.S.gal]	2.311 [0.611]	2.505 [0.662]
Inclination	Longitudinal/traverse inclination (lower-limit oil)		15°	
Fuel system	Injection pump model		NP-VE4	
	Nozzle		DN0PD21, throttle type	
	Fuel		11.77 MPa (120 kgf/cm <sup>2</sup> ) [1707 psi] Diesel fuel (JIS K2204)	
Lubrication system	Lubrication system		Forced circulation type (oil pump pressure feed type)	
	Filtration system		Paper-element filter system	
	Oil capacity	ℓ [U.S.gal]	Oil pan: approx. 5.5 [1.45] (high level) Filters: approx. 1 [0.26]	
Cooling system	Cooling type		Forced circulation	
	Coolant capacity (engine water jacket)	ℓ [U.S.gal]	4 [1.06]	
Electrical system	Starter	V-kW	12-2.0	
	Alternator	V-A	12-50	

## For Generator and Generator (High Speed Specification)

Item		Model	S4Q	S4Q2
Name	Type		Water-cooled vertical-type 4-cycle diesel engine	
	Firing order		1-3-4-2	
	Compression ratio		22	
	Combustion chamber		Swirl chamber system	
	Weight (dry)	kg [lb]	195 [430]	
Cylinder	No. of cylinders		4	
	Bore × Stroke	mm [in.]	88×95 [3.47×3.74]	88×103 [3.47×4.06]
	Total displacement	ℓ [U.S.gal]	2.311 [0.611]	2.505 [0.662]
Inclination	Longitudinal/traverse inclination (lower-limit oil)		15°	
Fuel system	Injection pump model		PES4A65B(Bosch A)	
	Nozzle		DN15PD6, throttle type 13.73 MPa (140 kgf/cm <sup>2</sup> ) [1991 psi]	
	Fuel		Diesel fuel (JIS K2204)	
Lubrication system	Lubrication system		Forced circulation type (oil pump pressure feed type)	
	Filtration system		Paper-element filter system	
	Oil capacity	ℓ [U.S.gal]	Oil pan: approx. 5.5 [1.45] (high level) Filters: approx. 1 [0.26]	
Cooling system	Cooling type		Forced circulation	
	Coolant capacity (engine water jacket)	ℓ [U.S.gal]	4 [1.06]	
Electrical system	Starter	V-kW	12-2.0	
	Alternator	V-A	12-50	

# MAINTENANCE STANDARDS

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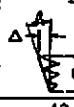
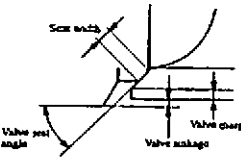


1. Maintenance Standards Table

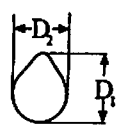
Unit mm [in.]

Group		Inspection point	Nominal value	Standard	Limit	Remarks	
General		Maximum speed (under no load) (min <sup>-1</sup> )	Varies depending on specifications.			Use governor for adjustment.	
		Minimum speed (under no load) (min <sup>-1</sup> )	Varies depending on specifications.				
		Compression pressure	2.94 MPa (30 kgf/cm <sup>2</sup> ) [427 psi] (150 to 200 min <sup>-1</sup> )		2.55 MPa (26 kgf/cm <sup>2</sup> ) [370 psi]	Oil and coolant temperatures at 20 to 30 °C [68 to 86 °F]	
		Lubricating oil pressure	0.29 to 0.49 MPa (3 to 5 kgf/cm <sup>2</sup> ) [43 to 71 psi] (at 1500 min <sup>-1</sup> )		0.15 MPa (1.5 kgf/cm <sup>2</sup> ) [21 psi]	Oil temperature at 70 to 90 °C [158 to 194 °F]	
			0.1 MPa (1 kgf/cm <sup>2</sup> ) [14 psi] or more (at 750 min <sup>-1</sup> )		0.05 MPa (0.5 kgf/cm <sup>2</sup> ) [7.1 psi]		
	Valve timing	Inlet valve open Inlet valve closed Exhaust valve open Exhaust valve closed	BTDC 30° ABDC 50° BTDC 74° ATDC 30° ±3° (crank angle)				
		Valve clearance (in cold engine)		0.25 [0.0098]		Both inlet and exhaust valves	
		Fuel injection timing	BTDC 20° B.T.D.C				This indicates standard injection start timing. Be sure to check specifications since your engine's injection start timing may be different.
		Fan belt deflection (crankshaft pulley -alternator pulley)		Approx. 13 [0.51]		Amount of belt deflection when pushed with thumb 98 N (10 kgf) [22 lbf].	
	Engine main parts	Cylinder head	Bottom surface distortion		0.05 [0.0020] or less	0.20 [0.0080]	Slight refacing permissible
Compressed gasket thickness			1.3 [0.0512]	1.27 to 1.35 [0.050 to 0.053]			
Rocker arm		Rocker bushing inside diameter	φ19 [0.7490]	19.010 to 19.030 [0.7490 to 0.7500]			
		Rocker bushing outside diameter	φ19 [0.7490]	18.980 to 19.000 [0.7480 to 0.7490]			
	Clearance between rocker bushing and shaft		0.010 to 0.050 [0.0004 to 0.0020]	0.070 [0.0028]			

Unit mm [in.]

OU	Inspection point		Nominal value	Standard	Limit	Remarks	
Engine main parts	Valve spring	Free length		48.85 [1.925]	47.60 [1.875]		
		Squareness		$\theta=1.5$ or less $\Delta=1.3$ or less [0.051] $L_f=48.85$ [1.925] 	$\Delta=1.5$ [0.060] Across the entire length		
		Set length/ Set force mm(in.)/N(kgf)[lbf]		43.0 [1.694]/ 176 to 196 (18 to 20) [40.00 to 44.10]	43.0 [1.694]/ 147 (15) [33.0]		
	Pushrod	Deflection		0.3 [0.012] or less		Measure runout (dial gage reading) with pushrod supported at centers of spherical sections on both ends	
	Valve and valve guide	Valve stem diameter	Inlet	$\phi 8$ [0.3152]	7.940 to 7.955 [0.3128 to 0.3134]	7.900 [0.3112]	
			Exhaust		7.920 to 7.940 [0.3120 to 0.3128]	7.850 [0.3093]	
		Clearance between valve stem and valve guide	Inlet		0.065 to 0.095 [0.0026 to 0.0037]	0.150 [0.0059]	
			Exhaust		0.080 to 0.115 [0.0032 to 0.0045]	0.200 [0.0079]	
	Valve guide installation length		15.5 [0.6110]	15.1 to 15.6 [0.5950 to 0.6150]			
	Valve seat	Valve seat angle		30°			
		Valve sinkage	0.8 [0.0315]	0.7 to 0.9 [0.0276 to 0.0355]	1.3 [0.0512]		
		Seat width	1.18 [0.0465]	1.04 to 1.32 [0.0410 to 0.0520]	1.6 [0.0630]		
		Valve margin	1.70 [0.0670]		Refacing permissible up to 1.20 [0.0473]		
	Flywheel	Flatness		0.10 [0.0039] or less	0.50 [0.0197]		
		Runout		0.10 [0.0039] or less	0.50 [0.0197]		
Idler gear	Clearance between idler gear and shaft		0.025 to 0.075 [0.0010 to 0.0030]	0.100 [0.0039]	Replace bushing.		
	End play		0.05 to 0.20 [0.0020 to 0.0079]	0.35 [0.0138]	Replace thrust plate.		
	Interference between shaft and crankcase bore		-0.039 to -0.076 [-0.0015 to -0.0030]				
Timing gear backlash	Crankshaft gear - Idler gear		0.03 to 0.16 [0.0012 to 0.0063]	0.25 [0.0099]	Replace gears.		
	Idler gear - Camshaft gear		0.04 to 0.17 [0.0016 to 0.0067]	0.25 [0.0099]			
	Idler gear - Injection pump gear		0.03 to 0.18 [0.0012 to 0.0071]	0.25 [0.0099]			

Unit mm [in.]

Group	Inspection point		Nominal value	Standard	Limit	Remarks	
Engine main parts	Deflection			0.02 [0.0008] or less	0.05 [0.0020]	Correct deflection or replace	
	Cam lift	Inlet	$D_1$ 46.916 $^{+0.1}_{-0.3}$ [1.848 $^{+0.004}_{-0.012}$ ]	$D_1 - D_2$ 6.684 [0.2633]	$D_1 - D_2$ 6.184 [0.2436]		
		Exhaust	$D_1$ 45.944 $^{+0.1}_{-0.3}$ [1.810 $^{+0.004}_{-0.012}$ ]	$D_1 - D_2$ 7.344 [0.2894]	$D_1 - D_2$ 6.844 [0.2697]		
	Journal diameter	No. 1, 2	$\phi 54$ [2.1276]	53.94 to 53.96 [2.1252 to 2.1260]		53.90 [2.1237]	
				No. 3	$\phi 53$ [2.0882]		52.94 to 52.96 [2.0858 to 2.0866]
		Circularity				0.02 [0.0008] or less	
		Cylindricity				0.02 [0.0008] or less	
	End play		5 [0.1970]	0.10 to 0.25 [0.0040 to 0.0100]	0.30 [0.0120]	Replace thrust plate.	
	Camshaft bore	Inside diameter	No. 1, 2	$\phi 54$ [2.1276]	54.030 to 54.050 [2.1288 to 2.1296]	53.90 [2.1237]	
			No. 3	$\phi 53$ [2.0882]	53.030 to 53.050 [2.0893 to 2.0901]	52.90 [2.0843]	
		Circularity				0.02 [0.0008] or less	
		Concentricity				0.05 [0.0020] or less	
	Clearance from camshaft journal				0.07 to 0.11 [0.0028 to 0.0043]	0.15 [0.0059]	
	Piston	Outside diameter (at skirt)	S.T.D	87.970 [3.4660]	87.955 to 87.985 [3.4654 to 3.4666]	87.770 [3.4581]	Measure diameter in direction perpendicular to piston pin at 14 mm [0.55 in.] from bottom edge.
			0.25 [0.01] O.S	88.220 [3.4759]	88.205 to 88.235 [3.4753 to 3.4765]	88.020 [3.4680]	
			0.50 [0.02] O.S	88.470 [3.4857]	88.455 to 88.485 [3.4851 to 3.4863]	88.270 [3.4778]	
			Amount of protrusion from crankcase			0.13 to 0.60 [0.005 to 0.024]	
		Weight difference in one engine				5 g [0.2 oz.] or less	
	Piston ring	Clearance from ring groove	Ring No. 1	0.060 to 0.100 [0.0024 to 0.0039]		0.200 [0.0079]	Replace rings when within limit value. If limit value is exceeded, replace piston.
			Ring No. 2	0.045 to 0.080 [0.0018 to 0.0032]		0.150 [0.0059]	
Oil ring			0.025 to 0.065 [0.0010 to 0.0026]		0.150 [0.0059]		
End gap		Ring No. 1	0.25 to 0.40 [0.0100 to 0.0158]		1.50 [0.0591]		
		Ring No. 2	0.30 to 0.50 [0.0118 to 0.0197]		1.50 [0.0591]		

Unit mm [in.]

Group	Inspection point	Nominal value	Standard	Limit	Remarks	
Engine main parts	Piston pin	Bore diameter	φ28 [1.1032]	28.000 to 28.010 [1.1032 to 1.1036]		
		Outside diameter	φ28 [1.1032]	27.994 to 28.000 [1.1030 to 1.1032]		
		Clearance between piston pin bore and piston pin		0.000 to 0.016 [0.000 to 0.0006]	0.050 [0.0020]	Replace piston pin when within limit value. If limit value is exceeded, replace piston.
		Clearance from connecting rod bushing		0.020 to 0.051 [0.0008 to 0.0020]	0.080 [0.0032]	Replace piston pin or bushing. (ream if necessary)
	Connecting rod	Bushing inside diameter	φ28 [1.1032]	28.020 to 28.045 [1.1040 to 1.1050]		
		Connecting rod bend and twist		0.05/100 [0.002/3.940] or less	0.15/100 [0.006/3.940]	
		Bearing inside diameter	φ58 [2.2852]	58.000 to 58.045 [2.2852 to 2.2870]		
		Clearance between crankpin and connecting rod bearing (oil clearance)		0.030 to 0.090 [0.0012 to 0.0035]	0.20 [0.0079]	Replace bearing when within limit value. If limit value is exceeded, regrind crankpin and install undersized bearing.
		End play		0.15 to 0.35 [0.0059 to 0.0138]	0.50 [0.0197]	Replace connecting rod.
	Crankshaft	Deflection		0.02 [0.0008] or less	0.05 [0.0020]	
		Crankshaft journal diameter	φ65 [2.5561]	64.965 to 64.985 [2.5596 to 2.5604]		
		Crankpin outside diameter	φ58 [2.2852]	57.955 to 57.970 [2.2834 to 2.2840]		
		Center-to-center distance between journal and crankpin	51.5 [2.0291]	51.46 to 51.54 [2.0275 to 2.0307]		
		Crankpin journal parallelism		Maximum crankpin runout 0.01 [0.0004] or less		
		Crankpin journal circularity		0.01 [0.0004] or less	0.03 [0.0012]	
		Crankpin journal cylindricity		0.01 [0.0004] or less	0.03 [0.0012]	
		Crankpin journal fillet radius	3R [0.1181]	±0.2 [0.0079]		
	End play		0.100 to 0.204 [0.0039 to 0.0080]	0.300 [0.0118]		

Unit mm [in.]

Group	Inspection point		Nominal value	Standard	Limit	Remarks	
Engine main parts	Main bearing	Crankcase bore (main bearing lower half)	Inside diameter	φ69 [2.72]	φ69 <sup>+0.019</sup> <sub>0</sub> [2.72 <sup>+0.0007</sup> ]		With main bearing cap tightened.
			Circularity		0.02 [0.0008] or less		
			Concentricity		0.05 [0.0020] or less		
		Clearance from crankshaft journal (oil clearance)			0.035 to 0.085 [0.0014 to 0.0033]	0.200 [0.0079]	
		Thrust bearing journal (cap width)		23 [0.9062]	22.979 to 23.000 [0.9054 to 0.9062]	Standard+0.2 [+0.0079]	
	Cylinder	Bore diameter		φ88 [3.46]	φ88 <sup>+0.03</sup> [3.46 <sup>+0.011</sup> ]	Standard+0.2 [+0.0079]	Regrind to +0.25 [+0.01] or +0.50 [+0.02] overnominal value for installation of oversized pistons and piston rings.
		Circularity			0.01 [0.00039] or less		
		Cylindricity			0.015 [0.00059] or less		
	Crankcase	Upper surface distortion			0.05[0.0020] or less	0.20[0.0079]	Slight refacing permissible
	Tappet guide bore	Inside diameter		φ14 [0.5516]	14.000 to 14.018 [0.5516 to 0.5523]	14.100 [0.5555]	
Clearance from tappet bore			0.016 to 0.052 [0.0006 to 0.0020]	0.080 [0.0032]			
Fuel system	Injection nozzle	Valve opening pressure	ND0PD21	11.77 MPa (120 kgf/cm <sup>2</sup> ) [1707 psi]	11.77 to 12.75 MPa (120 to 130 kgf/cm <sup>2</sup> ) [1707 to 1850 psi]		Varies depending on specifications.
			ND15PD6	13.73 MPa (140 kgf/cm <sup>2</sup> ) [1991 psi]	13.73 to 14.71 MPa (140 to 150 kgf/cm <sup>2</sup> ) [1991 to 2134 psi]		Varies depending on specifications.
	Spray cone angle	ND0PD21	0°			Use hand-operated tester for inspection (diesel fuel at about 20 °C [68 °F]). If angle is still defective after cleaning with clean diesel fuel, replace nozzle tip.	
		ND15PD6	15°				
	Needle valve seat oil sealing performance		There must be no leak when fuel is applied at pressure which is 1.96 MPa (20 kgf/cm <sup>2</sup> ) [284 psi] lower than valve opening pressure for 10 seconds				Clean or replace nozzle tip

Unit mm [in.]

Group	Inspection point	Nominal value	Standard	Limit	Remarks		
Lubrication system	Oil pump	Rotor and case end play		0.04 to 0.09 [0.0016 to 0.0035]	0.15 [0.0059]		
		Clearance between outer rotor and inner rotor		0.13 to 0.15 [0.0051 to 0.0059]	0.20 [0.0079]		
		Clearance between outer rotor and case		0.200 to 0.280 [0.0079 to 0.0110]	0.500 [0.0197]		
		Shaft diameter	φ13 [0.5122]	12.985 to 13.000 [0.5116 to 0.5122]			
		Clearance between shaft and case		0.032 to 0.074 [0.0013 to 0.0029]			
Relief valve	Valve opening pressure	0.34 MPa (3.5 kgf/cm <sup>2</sup> ) [49.31 psi]	0.29 to 0.39 MPa (3.0 to 4.0 kgf/cm <sup>2</sup> ) [42.06 to 56.56 psi]				
Cooling system	Water pump	Interference between case and bearing unit		-0.026 to -0.064 [-0.0010 to -0.0025]			
	Thermostat	Valve opening temperature		76.5±1.5 °C [169.7±2.7 °F]			
		Temperature at which valve lift is 8 mm [0.3 in.]		90 °C [194 °F]			
Electrical system	Starter	Commutator outside diameter	φ32 [1.26]		31.4 [1.24]		
		Commutator runout			0.10 [0.0039]		
		Depth of undercut between segments		0.4 to 0.6 [0.0158 to 0.0236]	0.2 [0.0079]		
		Brush	Length		18 [0.7]	11 [0.4]	
			Spring pressure	31 N (3.2 kgf) [7.0 lbf]	26 to 36 N (2.7 to 3.7 kgf) [5.8 to 8.1 lbf]	15 N (1.5 kgf) [3.4 lbf]	
		Pinion shaft thrust gap		0.5 [0.02] or less		0 or lower not permissible	
		Pinion gap		0.5 to 2.0 [0.02 to 0.08]			
	Alternator	Slip ring	Under no load			Magnetic switch operating voltage	
			Voltage (V)	Current (A)	Rotation speed (min <sup>-1</sup> )	Must be 8 V or lower when pinion tip is constrained at location 2 mm [0.08 in.] from pinion stationary position	
			11 Characteristic	130 or lower	3600 or higher		
Alternator	Slip ring	Brush spring tension		4.8 to 6.0 N (490 to 610 gf) [1.1 to 1.3 lbf]	2.2 N (220 gf) [0.5 lbf]		
		Brush length		18.5 [0.730]	5.0 [0.200]		
		Slip ring resistance	2.8 Ω	2.6 to 3.0 Ω		At 20 °C [68 °F]	
		Slip ring outside diameter		φ22.7 [0.90]	22.1 [0.87]		

2. Tightening Torque Table

2.1 Important Bolts and Nuts

Description	Threads Diameter x Pitch mm	Torque			Remark
		N·m	kgf·m	lbf·ft	
<b>Engine main parts</b>					
Cylinder head bolt	M12x1.75	113 to 123	11.5 to 12.5	83.3 to 90.7	
Cylinder plug	M16x1.5	39.2 to 49.0	4.0 to 5.0	28.9 to 36.1	
Rocker cover	M8x1.25	10.8 to 12.7	1.1 to 1.3	8.0 to 9.4	
Rocker shaft bracket (long)	M8x1.25	12.7 to 16.7	1.3 to 1.7	9.4 to 12.3	
Main bearing cap	M12x1.75	78.5 to 88.3	8.0 to 9.0	57.9 to 65.1	
Connecting rod cap	M10x1.0	49.0 to 58.8	5.0 to 6.0	36.1 to 43.4	
Flywheel	M12x1.25	78.5 to 88.3	8.0 to 9.0	57.9 to 65.1	
Camshaft thrust plate	M8x1.25	10.8 to 12.7	1.1 to 1.3	8.0 to 9.4	
Front plate	M8x1.25	10.8 to 12.7	1.1 to 1.3	8.0 to 9.4	
Timing gear case cover	M8x1.25	10.8 to 12.7	1.1 to 1.3	8.0 to 9.4	
Crankshaft pulley	M24x1.5	382 to 402	39 to 41	281.7 to 296.5	
Rear plate stud	M10x1.25	21.6 to 25.5	2.2 to 2.6	15.9 to 18.8	
Exhaust manifold	M8x1.25	27.5 to 33.3	2.8 to 3.4	20.3 to 24.6	
<b>Fuel system</b>					
Fuel injection nozzle	M20x1.5	53.0 to 64.7	5.4 to 6.6	39.1 to 47.7	
Fuel injection nozzle retaining nut	M16x0.75	34.3 to 39.2	3.5 to 4.0	25.3 to 28.9	
Fuel leak-off pipe mounting nuts	M12x1.5	20.6 to 24.5	2.1 to 2.5	15.2 to 18.1	
Fuel injection pump gear	In-line type	M12x1.75	59 to 69	6.0 to 7.0	43.5 to 50.9
	Distributor type	M12x1.75	59 to 69	6.0 to 7.0	43.5 to 50.9
Fuel pipe nut	M12x1.5	26.5 to 32.4	2.7 to 3.3	19.5 to 23.9	
Fuel return pipe nut	M10x1.25	17.7 to 21.6	1.8 to 2.2	13.1 to 15.9	
Fuel filter element (Distributor type)	M20x1.5	12.0 to 18.0	1.2 to 1.8	8.70 to 13.0	
Fuel filter level sensor (Distributor type)	M20x1.5	4.0 to 6.0	0.4 to 0.6	2.90 to 4.33	
<b>Lubrication system</b>					
Oil pan	Cast oil pan	M8x1.25	27.5 to 33.4	2.8 to 3.4	20.3 to 24.6
	Extruded oil pan	M8x1.25	6.87 to 8.83	0.7 to 0.9	5.06 to 6.51
Oil pan drain plug	M14x1.5	35.3 to 43.1	3.6 to 4.4	26.0 to 31.8	
Oil cooler connector	M20x1.5	58.8 to 78.5	6.0 to 8.0	43.4 to 57.9	
Oil relief valve	M22x1.5	44.1 to 53.9	4.5 to 5.5	32.5 to 39.8	
Oil pump set bolt	M12x1.75	30.4 to 38.2	3.1 to 3.9	22.4 to 28.2	
Oil filter	M20x1.5	10.8 to 12.7	1.1 to 1.3	8.0 to 9.4	
<b>Cooling system</b>					
Coolant drain plug	1/4-18 NPTF	35.3 to 43.1	3.6 to 4.4	26.0 to 31.8	
Thermo switch	M16x1.5	20.6 to 24.5	2.1 to 2.5	15.2 to 18.1	
Thermostat case	M8x1.25	17.0 to 20.0	1.7 to 2.0	12.3 to 14.5	
<b>Electrical system</b>					
B terminal of starter	M8x1.25	9.81 to 11.8	1.0 to 1.2	7.2 to 8.7	
Glow plug	(Body)	M10x1.25	15.7 to 19.6	1.6 to 2.0	11.6 to 14.5
	(Terminal)	M4x0.7	1.08 to 1.47	0.11 to 0.15	0.80 to 1.08

2.2 Standard Bolts and Nuts

Threads Diameter X pitch (mm)	Strength classification					
	4T			7T		
	N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft
M6 X 1.0	2.94 to 4.90	0.3 to 0.5	2.2 to 3.6	7.85 to 9.80	0.8 to 1.0	5.8 to 7.2
M8 X 1.25	9.80 to 12.7	1.0 to 1.3	7.2 to 9.4	14.7 to 21.6	1.5 to 2.2	10.8 to 15.9
M10 X 1.25	17.7 to 24.5	1.8 to 2.5	13.0 to 18.1	29.4 to 41.2	3.0 to 4.2	21.7 to 30.4
M12 X 1.25	29.4 to 41.2	3.0 to 4.2	21.7 to 30.4	53.9 to 73.5	5.5 to 7.5	39.8 to 54.2

- (a) The above table shows the tightening torque for standard bolts and nuts.
- (b) The values in the table apply when tightened together with spring washers.
- (c) The above table shows standard values, for which a tolerance of 10% is allowed.
- (d) Unless otherwise specified, standard bolts and nuts should be tightened to the torque in the table.
- (e) Do not apply oil to threaded portions (Tighten under dry conditions).

2.3 Standard Eyebolts

Threads Diameter X pitch (mm)	Width across flats mm [in.]	Strength classification		
		4T		
		N·m	kgf·m	lbf·ft
M8 X 1.25	12 [0.47]	8 ± 1	0.8 ± 0.1	5.8 ± 0.7
M10 X 1.25	14 [0.55]	15 ± 2	1.5 ± 0.2	10.8 ± 1.4
M12 X 1.25	17 [0.67]	25 ± 3	2.5 ± 0.3	18.1 ± 2.2
M14 X 1.5	22 [0.87]	34 ± 4	3.5 ± 0.4	25.3 ± 2.9
M16 X 1.5	24 [0.95]	44 ± 5	4.5 ± 0.5	32.5 ± 3.6
M18 X 1.5	27 [1.06]	74 ± 5	7.5 ± 0.5	54.2 ± 3.6
M20 X 1.5	30 [1.18]	98 ± 10	10.0 ± 1.0	72.3 ± 7.2
M24 X 1.5	36 [1.42]	147 ± 15	15.0 ± 1.5	108.5 ± 10.8
M27 X 1.5	41 [1.61]	226 ± 20	23.0 ± 2.0	166.4 ± 14.5

(Dry conditions)

2.4 Standard Union Nuts

Nominal diameter	Cap nut size M (mm)	Width across flats mm [in.]	N·m	kgf·m	lbf·ft
63	14 X 1.5	19 [0.75]	39	4	28.9
80	16 X 1.5	22 [0.87]	49	5	36.2
100	20 X 1.5	27 [1.06]	78	8	57.9
120	22 X 1.5	30 [1.18]	98	10	72.3
150	27 X 1.5	32 [1.26]	157	16	115.7
180	30 X 1.5	36 [1.42]	196	20	144.7
200	30 X 1.5	36 [1.42]	196	20	144.7
220	33 X 1.5	41 [1.61]	245	25	180.8
254	36 X 1.5	41 [1.61]	294	30	217.0

(Tolerance is ±10%, dry conditions)

2.5 Taper Bolts

Size	Tightening into aluminum			Tightening into iron		
	N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft
NPTF1/16	4.90 to 7.85	0.5 to 0.8	3.6 to 5.8	7.85 to 11.8	0.8 to 1.2	5.8 to 8.7
PT1/8	7.85 to 11.8	0.8 to 1.2	5.8 to 8.7	14.7 to 21.6	1.5 to 2.2	10.8 to 15.9
PT1/4, NPTF1/4	19.6 to 29.4	2.0 to 3.0	14.5 to 21.7	34.3 to 44.1	3.5 to 4.5	25.3 to 32.5
PT3/8	—	—	—	53.9 to 73.5	5.5 to 7.5	39.8 to 54.2



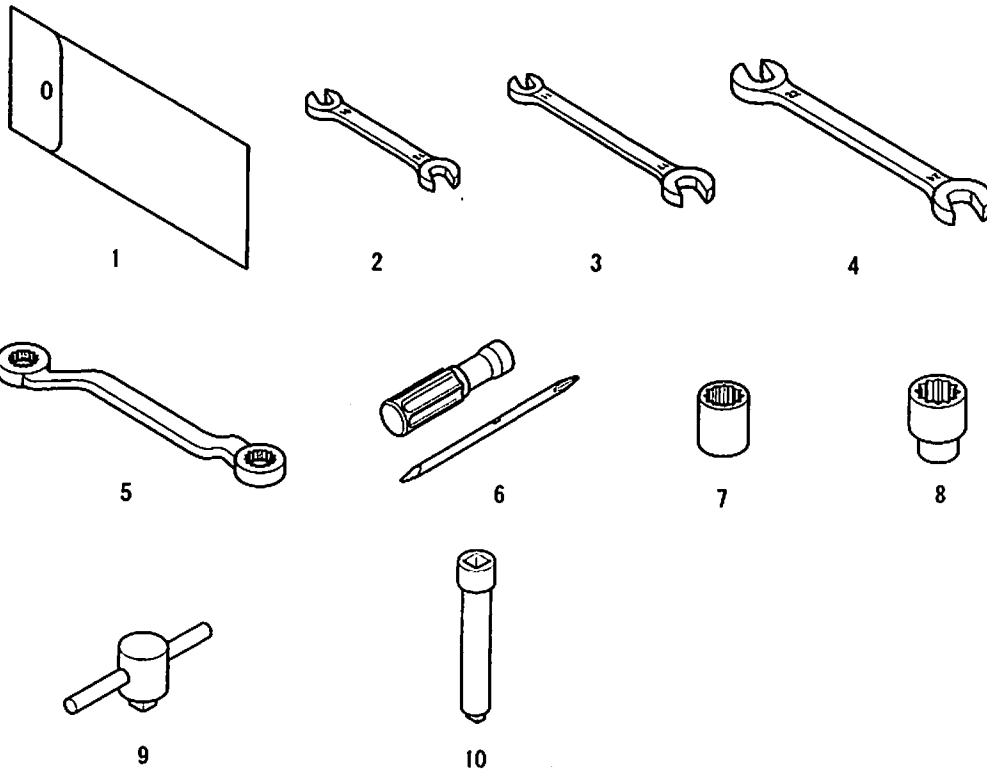
**3. Sealants Table**

<b>Application point</b>	<b>Counterpart</b>	<b>Sealant</b>	<b>How to use</b>
Cylinder head water hole plug	Cylinder head	ThreeBond 1386D	Coat hole, and drive sealing plug into hole.
Crankcase water hole plug	Crankcase	ThreeBond 1386D	Coat hole, and drive sealing plug into hole.
Crankcase oil gallery hole plug	Crankcase	ThreeBond 1386D	Coat hole, and drive sealing plug into hole.
Crankcase oil return pipe	Crankcase	ThreeBond 1334	Coat pipe, and tighten.
Crankcase, grooves on bearing caps No. 1, 5	Oil pan gasket	ThreeBond 1207C or 1211	
Starter mounting stud	Flywheel housing	ThreeBond 1344	Coat threads, and tighten.
Injection pump mounting stud	Flange plate	ThreeBond 1344	Coat threads, and tighten.

# BASIC AND SPECIAL TOOLS

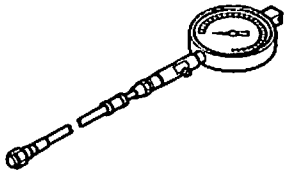
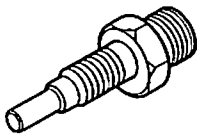
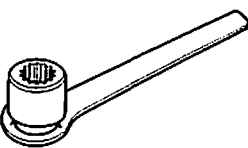
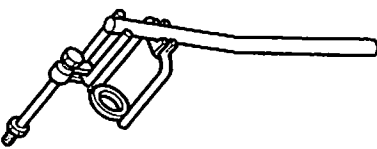
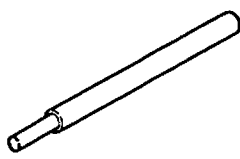
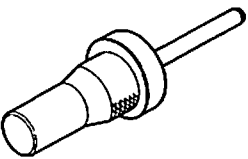
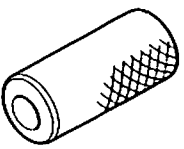
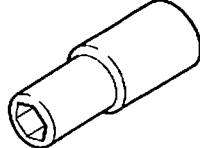
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2. Special Tools.....	1-23

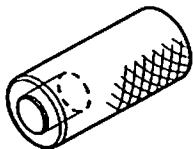
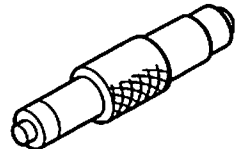
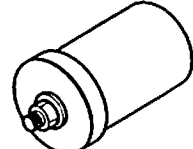
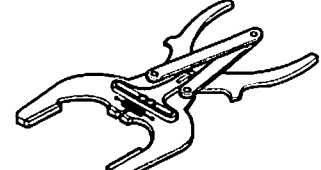
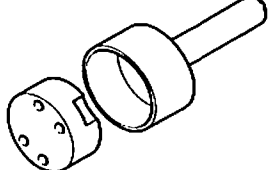
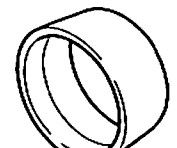
1. Basic Tools



No.	Tool name	Part No.	Remarks
-	Tool set	32A91-00010	Includes parts No. 1 through No. 10
1	Tool bag	34491-01102	
2	Open-end wrench	F9600-10012	Width across flats: 10 mm [0.39 in.], 12 mm [0.47 in.]
3	Open-end wrench	F9600-14017	Width across flats: 14 mm [0.55 in.], 17 mm [0.67 in.]
4	Open-end wrench	F9600-22024	Width across flats: 22 mm [0.87 in.], 24 mm [0.95 in.]
5	Box wrench	F9612-12014	Width across flats: 12 mm [0.47 in.], 14 mm [0.55 in.]
6	Screwdriver	91267-00201	Cross-headed tip, flat tip
7	Socket	F9614-17000	Width across flats: 17 mm [0.67 in.]
8	Socket	F9614-19000	Width across flats: 19 mm [0.75 in.]
9	Slide handle	F9618-25000	
10	Extension bar	F9615-15000	

2. Special Tools

Application	Tool name/Part No.	Shape	Use
Inspection for overhaul need And testing	Compression gage 33391-02100		Compression pressure Measurement: 0 to 7MPa (0 to 71 kgf/cm <sup>2</sup> [0 to 1010 psi])
	Gage adpter 30691-21100		Compression pressure Measurement
Engine main parts Cylinder head valve mechanism	Turning handle 30691-21800		Rotation of engine
	Valve spring pusher 30691-04500		Valve spring removal/installation
	Valve guide remover 32A91-00300		Valve guide removal
	Valve seat insertion/caulking tool Inlet 30691-02700 Exhaust 30691-02800		Valve seat installation
	Stem seal installer 32C91-10400		Stem seal installation
	Socket 34491-00300		Camshaft, thrust plate and Rocker bracket installation

Application	Tool name/Part No.	Shape	Use	
Engine main parts	Cylinder head valve mechanism	Valve guide installer 32C91-00300		Valve guide installation
	Timing gear	Idler bushing installer 30691-51900		Idler bushing removal/installation
		Idler shaft puller MH061077		Idler shaft removal
	Piston, crankshaft	Piston ring pliers 31391-12900		Piston ring removal/installation
		Crankcase oil seal sleeve installer set 30691-13010		Crankshaft rear oil seal sleeve installation
		Piston guide (installer) 30691-58100		Piston insertion

# OVERHAUL INSTRUCTIONS

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2. Measurement of Compression Pressure .....	1 -27
2.1 Preparation for Inspection .....	1 -27
2.2 Inspection .....	1 -27

## 1. Determination of Overhaul Timing

Generally, the engine needs an overhaul when the compression pressure of the engine becomes low, and the amounts of engine oil consumption and blow-by gas increase.

Reduced power output, increased fuel consumption, low oil pressure, difficult in starting, and increased operating noise are also signs that suggest the need for an overhaul; however, since these problems can be caused by various factors, they do not serve as reliable criteria for determining the need for an overhaul.

Reduced compression pressure manifests a variety of symptoms, thus making it difficult to accurately determine when the engine needs an overhaul. The following shows typical problems caused by reduced compression pressure.

- (1) Decreased output power
- (2) Increased fuel consumption
- (3) Increased engine oil consumption
- (4) Increased blow-by gas from breather due to leakage of combustion gas through worn cylinder liners and piston rings

- (5) Increased gas leakage due to poor seating of inlet and exhaust valves
- (6) Difficulty in starting
- (7) Increased noise from engine parts
- (8) Abnormal exhaust color after warm-up operation

The engine can exhibit these conditions in various combinations.

Some of these problems are directly caused by worn engine parts, while others are not.

Phenomena described in (2) and (6) can also result from improper fuel injection volume, incorrect fuel injection timing, worn plungers, defective nozzles, and faulty conditions of electrical devices such as battery, starter and alternator.

The most valid reason to overhaul an engine is a decrease in the compression pressure due to worn cylinder liners and pistons, as described in (4), and once this is determined, other symptoms should be taken into consideration in order to make the final judgment of whether the engine needs an overhaul.

## 2. Measurement of Compression Pressure

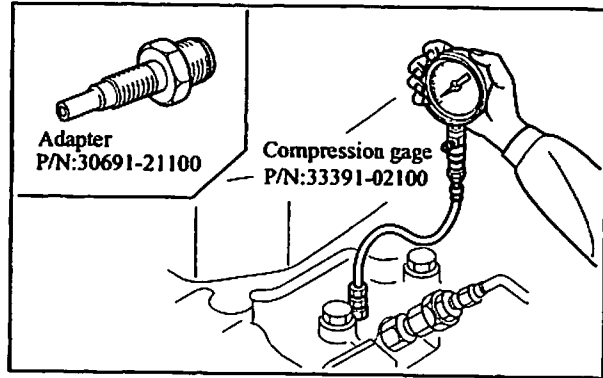
### 2.1 Preparation for Inspection

Check the following before inspection.

- (1) Make sure that the engine oil, air cleaner, starter, battery, etc. are in normal operating condition.

### 2.2 Inspection

- (1) Move the control lever to the Stop position.
- (2) Remove the glow plugs from all cylinders, and attach the gage adapter and compression gage to the cylinder to be tested.
- (3) Crank the engine with the starter, and read the compression gage indication when the indication stabilizes.
- (4) If the measured compression pressure is lower than the limit, consider overhauling the engine.



Measurement of compression pressure

### ⚠ CAUTION

- (a) Measure the compression pressure in all cylinders.
- (b) As compression pressure varies with the engine speed, measure the engine speed at the same time.

	Unit MPa (kgf/cm <sup>2</sup> ) [psi]	
	Nominal value	Limit
Compression pressure	2.94 (30) [427]	2.55 (26) [370]

Note : Measure the compression pressure while the engine is running at 150 to 200 min<sup>-1</sup>. The oil and coolant temperatures should be between 20 and 30 °C [68 and 86 °F].

### ⚠ CAUTION

It is important to regularly check the compression pressure so that you can tell the difference.

- New or overhauled engines have slightly higher compression pressure.
- The compression pressure settles to the standard value as the piston rings and valve seats fit in.
- As wear progresses further, the compression pressure drops.



# PREPARATION FOR DISASSEMBLY

1. Preparation .....	1 -30
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1.2 Draining Coolant.....	1 -30
1.3 Draining Engine Oil .....	1 -30

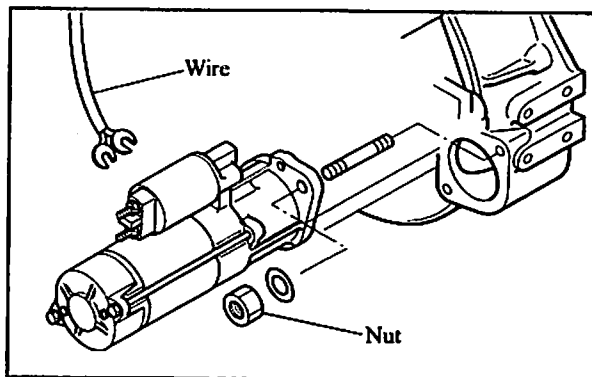
## 1. Preparation

### 1.1 Removing Electrical Wiring

Disconnect harnesses and wires from the following devices.

Before disconnecting, attach tags or other indications on the terminals to facilitate reconnection.

- Starter
- Switches



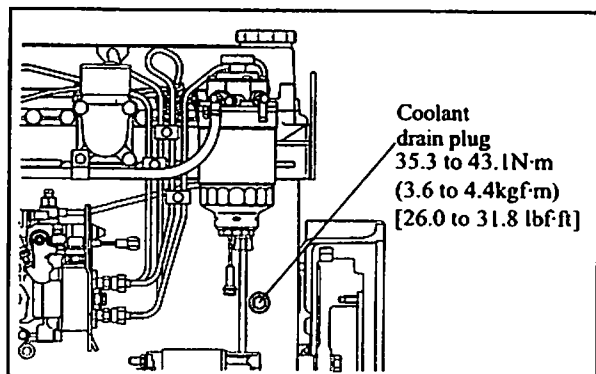
Removing electrical wiring

### 1.2 Draining Coolant

Loosen the coolant drain plug on the right-hand side of the cylinder block to drain coolant.

After draining coolant, reinstall the drain plug and tighten to the specified torque.

Coolant	S4Q	Engine: 4ℓ [1.06 U.S. gal] Radiator: 3ℓ [0.79 U.S. gal]
	S4Q2	Engine: 4ℓ [1.06 U.S. gal] Radiator: 4ℓ [1.06 U.S. gal]



Draining coolant

### 1.3 Draining Engine Oil

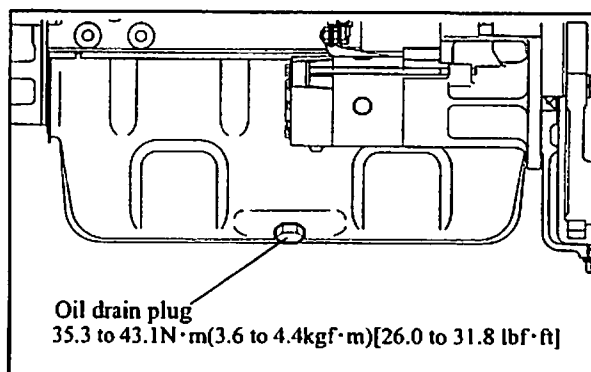
Remove the drain plug from the oil pan to drain engine oil.

After draining engine oil, reinstall the drain plug and tighten to the specified torque.

(Oil pan capacity: 5.5 ℓ [1.45 U.S. gal])

#### **⚠ CAUTION**

Do not touch hot drained engine oil since it can be hot and cause burns.

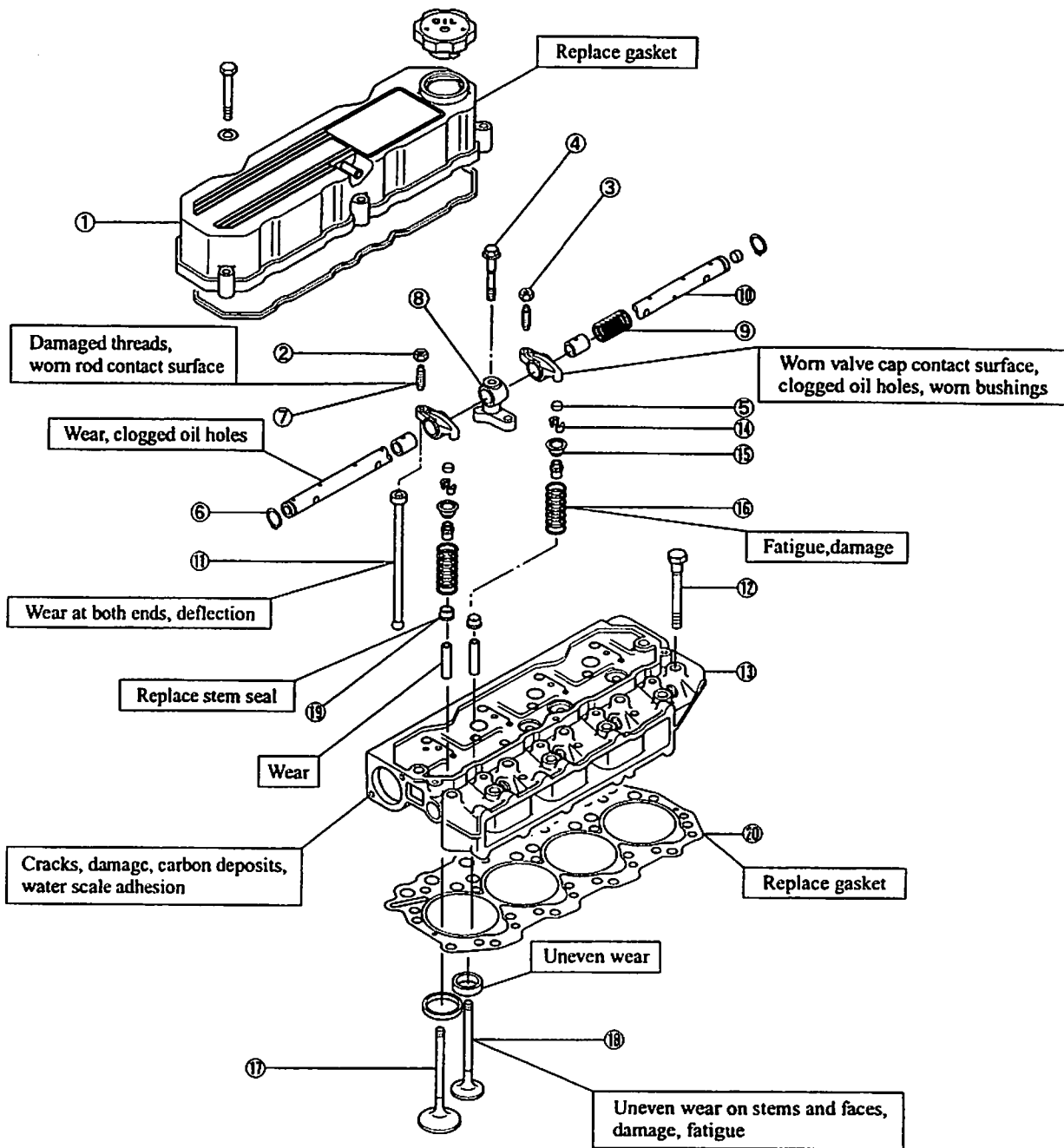


Oil pan drain plug

# DISASSEMBLY OF ENGINE MAIN PARTS

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1. Cylinder Head and Valve Mechanisms



Disassembly and inspection of cylinder head and valve mechanism

< Disassembly sequence >

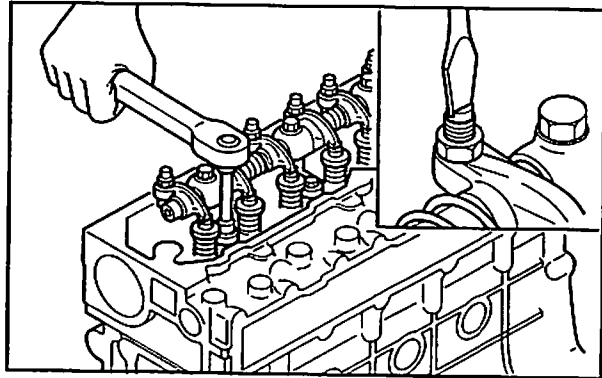
- |                   |                        |                        |
|-------------------|------------------------|------------------------|
| ① Rocker cover    | ⑧ Rocker shaft bracket | ⑮ Valve retainer       |
| ② Adjusting screw | ⑨ Rocker shaft spring  | ⑯ Valve spring         |
| ③ Short bolt      | ⑩ Rocker shaft         | ⑰ Inlet valve          |
| ④ Long bolt       | ⑪ Pushrod              | ⑱ Exhaust valve        |
| ⑤ Valve cap       | ⑫ Cylinder head bolt   | ⑲ Valve stem seal      |
| ⑥ Snap ring       | ⑬ Cylinder head        | ⑳ Cylinder head gasket |
| ⑦ Rocker arm      | ⑭ Valve cotter         |                        |

### 1.1 Removal of Rocker Shaft Assembly

- (1) Loosen the adjusting screws on the rockers by rotating each screw about one turn.
- (2) Loosen the short bolts on the rocker shaft brackets first, then loosen the long bolts to remove the rocker shaft assembly from the cylinder head.

#### **CAUTION**

Incorrect bolt loosening sequence can result in the damage to the rocker shaft brackets.



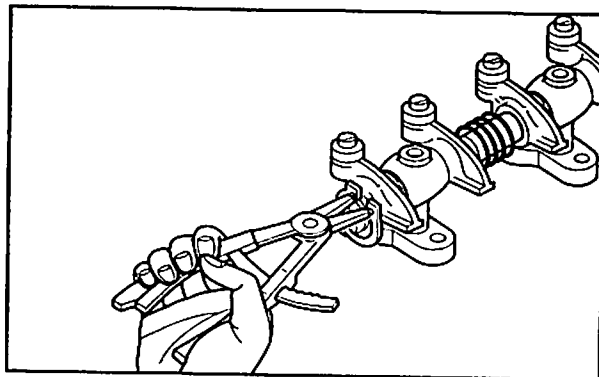
Removal of rocker shaft assembly

- (3) Remove the pushrods.

### 1.2 Disassembly of Rocker Shaft Assembly

Arrange the disassembled rockers in the order of removal, so that the rockers can be reinstalled exactly in the opposite sequence.

This ensures the same rocker shaft clearances as before.

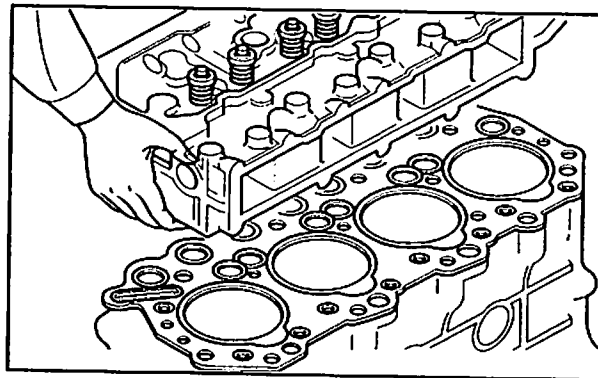


Disassembly of rocker shaft assembly

### 1.3 Removal of Cylinder Head Bolts

Remove the cylinder head bolts from the cylinder head, and lift the cylinder head vertically to detach it from the crankcase.

**Note :** If there is any problem in the cylinder head, before removing the bolts, examine the cylinder head bolt tightening condition by checking the bolt tightening torque with a torque wrench.

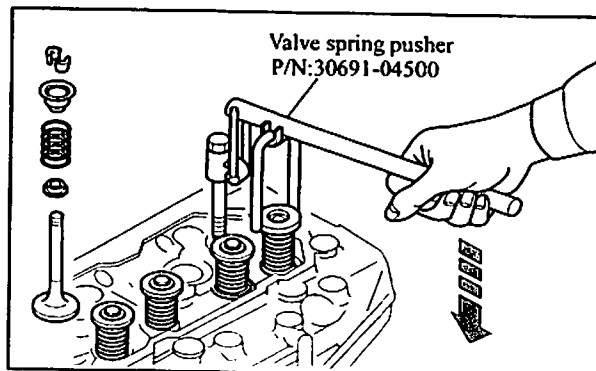


Removal of cylinder head bolt

### 1.4 Removal of Valves and Valve Springs

Using the valve spring pusher, compress the valve spring squarely, then remove the valve cotter.

**Note :** If the valves are to be reused, mark them to indicate their original installation positions.

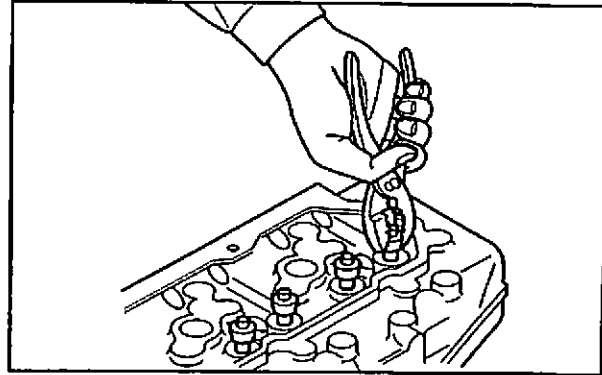


Removal of valve and valve spring

**1.5 Removal of Valve Stem Seals**

To remove steam seals, pull with pliers.

Note : Do not reuse the removed steam seals.

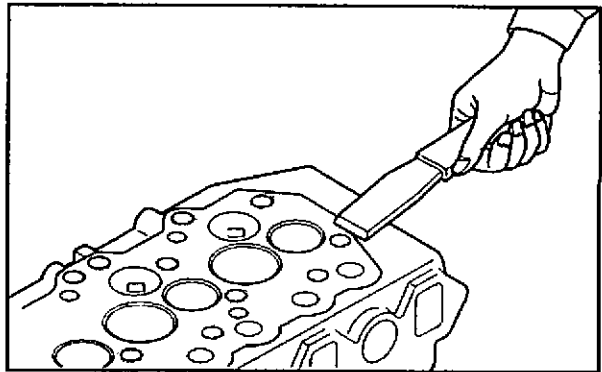


Removal of valve stem seal

**1.6 Cleaning of Cylinder Head Bottom Surface**

Remove adhered gasket pieces from the bottom surface of the cylinder head, making sure not to scratch the surface.

Note : Use a scraper to remove large pieces first, then remove remaining small pieces by using an oilstone dampened with engine oil.



Cleaning of cylinder head bottom surface

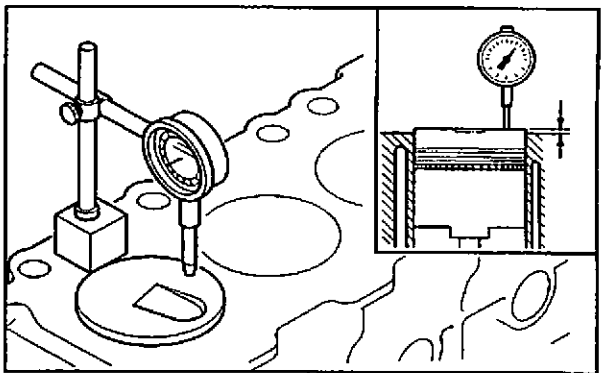
**1.7 Measurement of Piston Protrusions**

Determine the amount of the protrusion of the piston. If the amount of piston protrusion does not conform to the standard, be sure to inspect and repair each bearing.

- (1) Determine the top dead center of the piston with a dial gage.
- (2) Attach a dial gage on the top surface of the crankcase, and set the indicator to zero (0).
- (3) Check the piston protrusion at three locations on the top surface of the piston, and obtain the average value. Subtract the amount of piston protrusion from the compressed thickness of the gasket to determine the clearance between the piston top and cylinder head.

Unit mm [in.]

	Standard
Amount of piston protrusion from crankcase	0.13 to 0.60 [0.005 to 0.024]
Compressed thickness of gasket	1.27 to 1.35 [0.050 to 0.053]

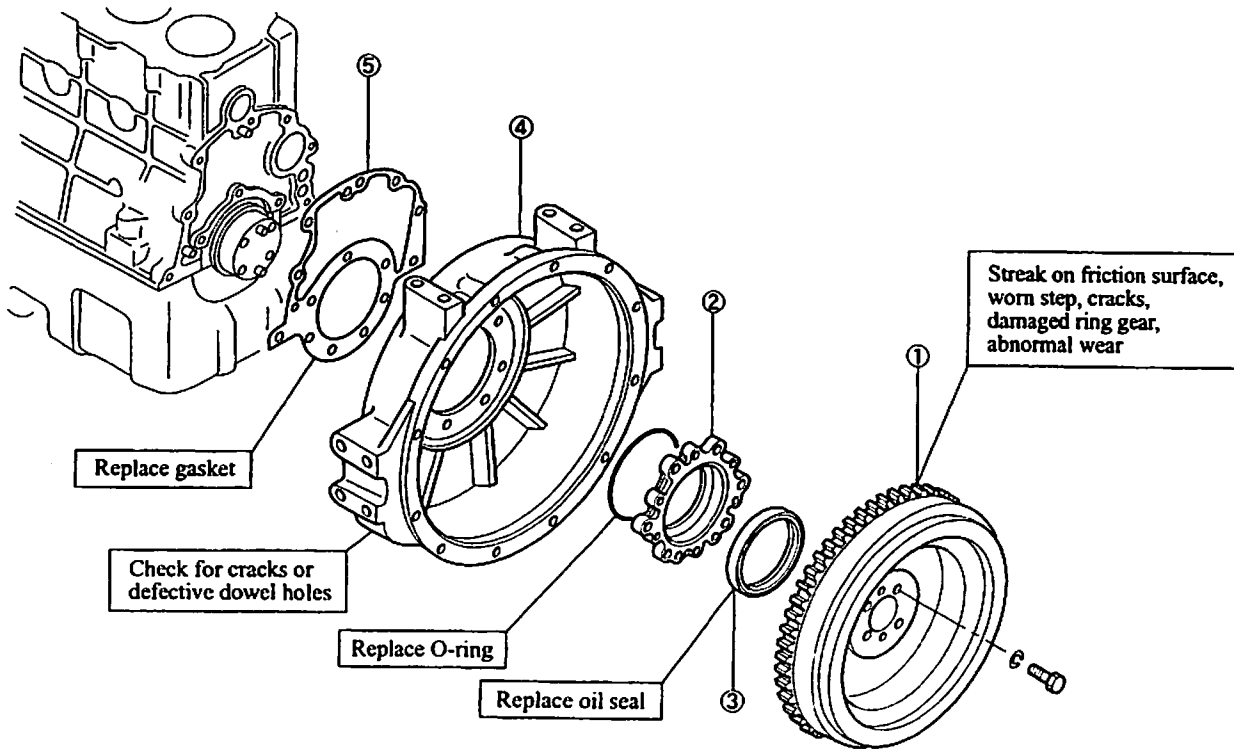


Measurement of piston protrusion

**⚠ CAUTION**

Piston protrusions must comply with the standard to ensure proper engine performance and prevent the interference between the valves and pistons.

2. Flywheel



Disassembly and inspection of flywheel

< Disassembly sequence >

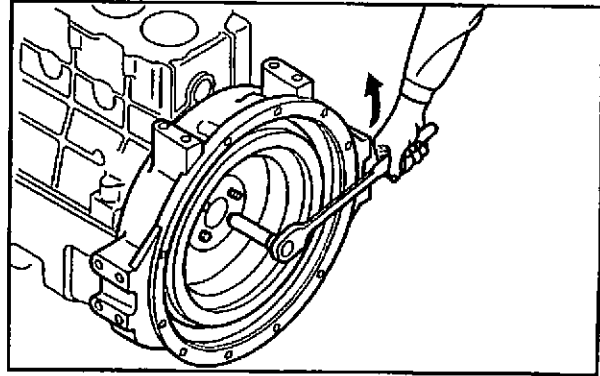
- ① Flywheel
- ② Oil seal case (option)
- ③ Oil seal
- ④ Flywheel housing
- ⑤ Gasket

## 2.1 Removal of Flywheel

- (1) To prevent the flywheel from rotating, have someone hold the crankshaft pulley with a wrench.
- (2) Remove one of the flywheel mounting bolts.

### **⚠ CAUTION**

The person holding the flywheel in place should exercise utmost caution, and communicate with the person removing the flywheel during the removal process to ensure safety.



Removal of flywheel

- (3) Screw a safety bar (M12×1.25 mm) in the threaded hole from which the bolt was removed in the above step, then remove the remaining bolts.
- (4) Hold the flywheel securely with both hands, jiggle it back and forth, and pull it straight out.

### **⚠ CAUTION**

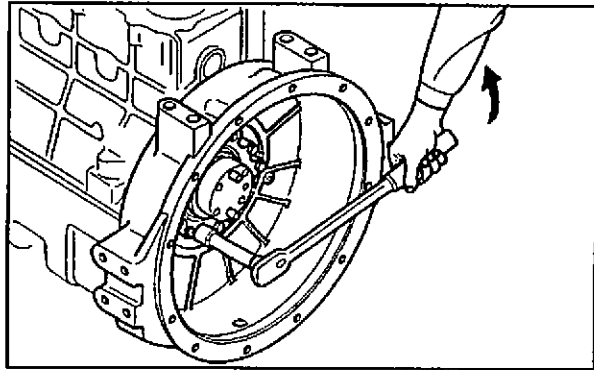
When removing the flywheel, be careful not to cut your hands with the ring gear.

## 2.2 Removal of Oil Seal Case (Option)

Remove the oil seal case mounting bolts, and remove the oil seal case together with the oil seal.

### **⚠ CAUTION**

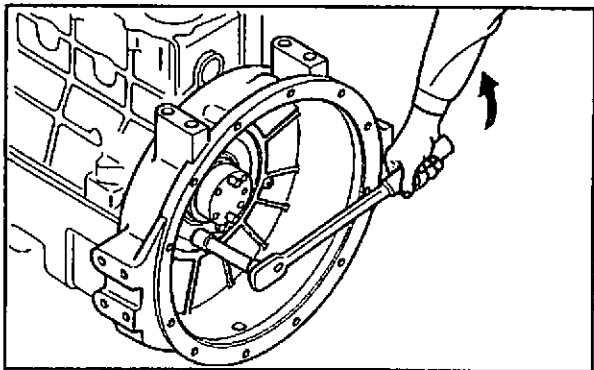
Be careful not to damage the surface of the oil seal.



Removal of oil seal case (option)

## 2.3 Removal of Flywheel Housing

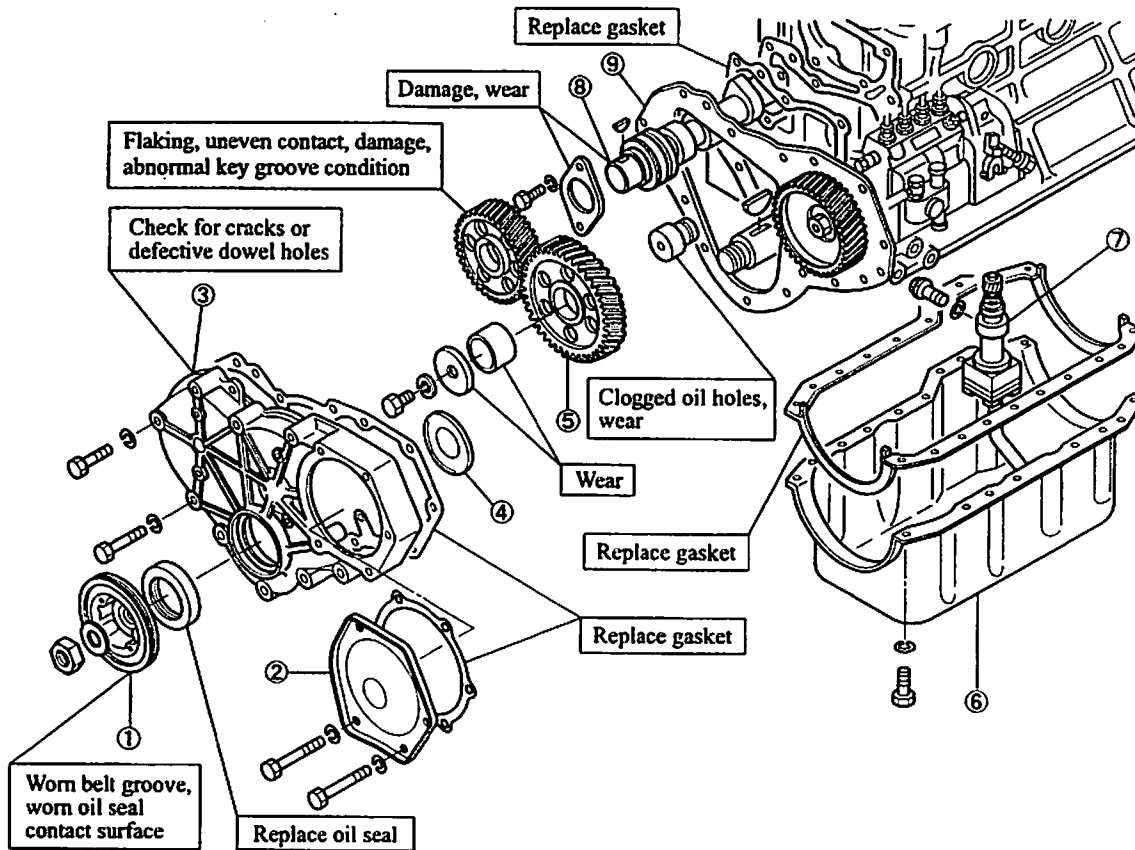
Remove the flywheel housing mounting bolts, and remove the flywheel housing.



Removal of flywheel housing



3. Timing Gears, Camshaft and Oil Pan



Disassembly and inspection of timing gears, camshaft and oil pan

< Disassembly sequence >

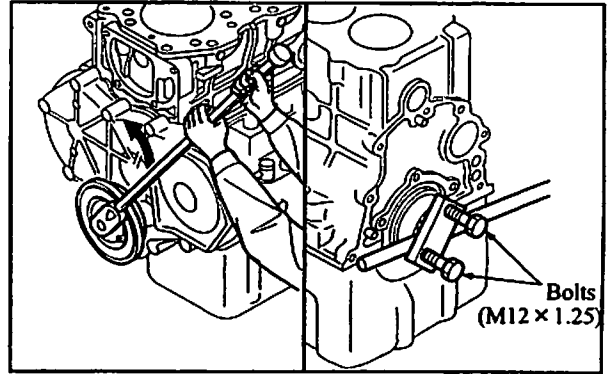
- |                     |                |               |
|---------------------|----------------|---------------|
| ① Crankshaft pulley | ④ Baffle plate | ⑦ Oil pump    |
| ② Cover             | ⑤ Idler gear   | ⑧ Camshaft    |
| ③ Timing gear case  | ⑥ Oil pan      | ⑨ Front plate |

**3.1 Removal of Crankshaft Pulley**

- (1) Screw two bolts (M12x1.25 mm) into the threaded holes on the back-end of the crankshaft, and put a bar between the bolts to prevent the crankshaft from rotating.
- (2) Remove the crankshaft pulley.

**⚠ CAUTION**

Pay attention to safety. The bar may disengage from the bolts.



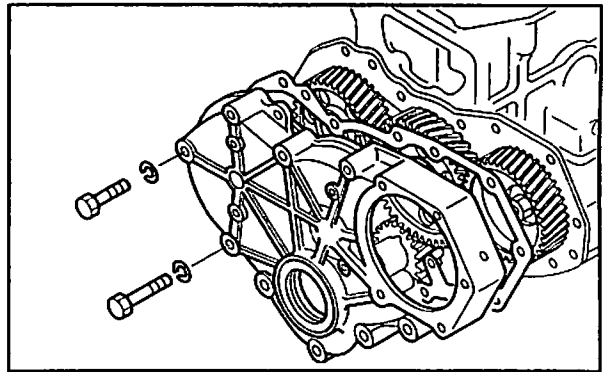
Removal of crankshaft pulley

**3.2 Removal of Timing Gear Case**

Pull the timing gear case straight out to remove it because it is held in place by right and left dowel pins.

**⚠ CAUTION**

Since the front plate is bolted inside the gear case, do not attempt to remove it together with the gear case by tapping it.



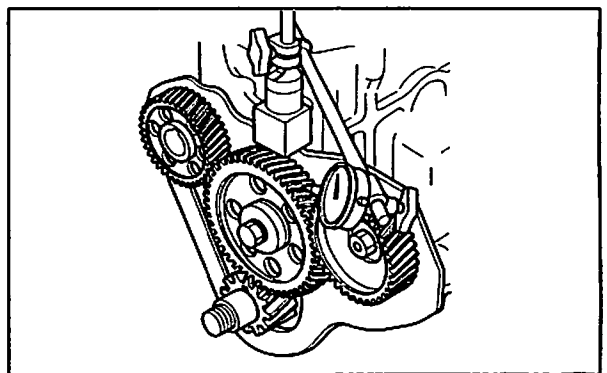
Removal of timing gear case

**3.3 Measurement of Backlashes**

Measure the backlash of each gear, and use it as a reference in reinstallation.

If the measured value exceeds the limit value, all gears should be replaced as a general rule.

Backlash	Unit mm [in.]	
	Standard	Limit
Crankshaft gear	0.03 to 0.16	0.25
- idler gear	[0.0012 to 0.0063]	[0.0099]
Idler gear	0.04 to 0.17	0.25
- camshaft gear	[0.0016 to 0.0067]	[0.0099]
Injection pump gear	0.03 to 0.18	0.25
- idler gear	[0.0012 to 0.0071]	[0.0099]



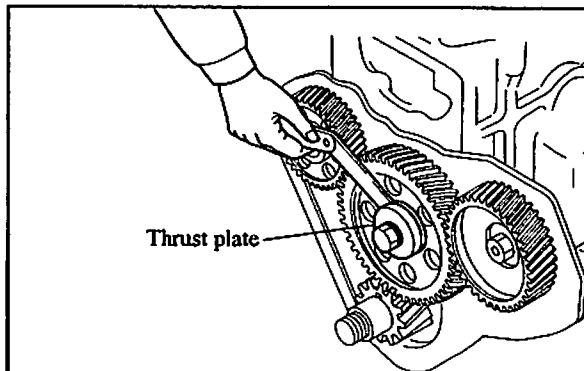
Measurement of idler gear backlash

**3.4 Measurement of Idler Gear End Play**

Measure the end play with feeler gages or a dial gage, if the limit value is exceeded, replace the thrust plate.

Unit mm [in.]

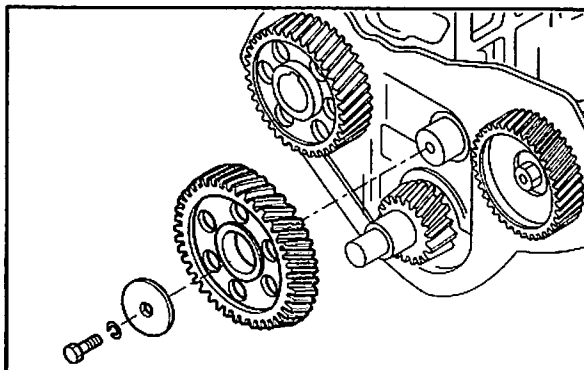
	Standard	Limit
Idler gear end play	0.05 to 0.20 [0.0020 to 0.0079]	0.35 [0.0138]



Measurement of idler gear end play

**3.5 Removal of Idler Gear**

Remove the idler gear by turning in the direction of the gear tooth slant.



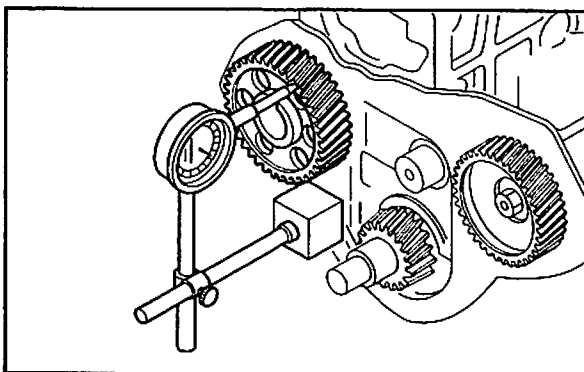
Removal of idler gear

**3.6 Camshaft End Play**

Measure the camshaft end play, and, if the limit value is exceeded, replace the thrust plate.

Unit mm [in.]

	Standard	Limit
Camshaft end play	0.10 to 0.25 [0.0040 to 0.0100]	0.30 [0.0120]



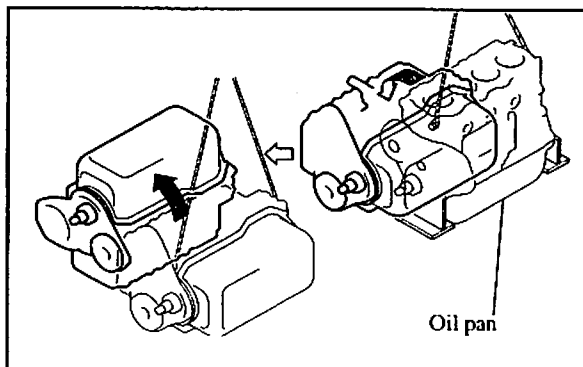
Measurement of camshaft end play

**3.7 Reversal of Crankcase**

Gently lay the crankcase on its side, then turn the crankcase upside down.

**⚠ CAUTION**

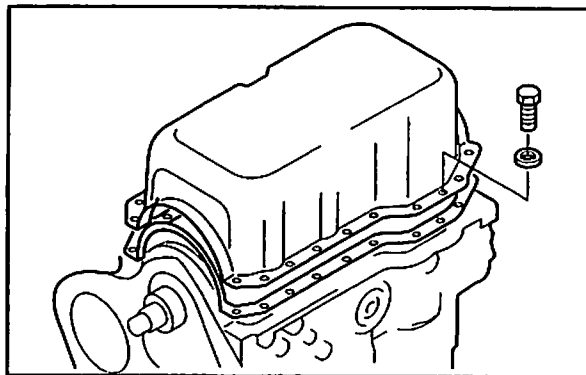
Resting the crankcase with the oil pan on the bottom can cause the oil pan to crack.



Reversal of crankcase

### 3.8 Removal of Oil Pan and Oil Pan Gasket

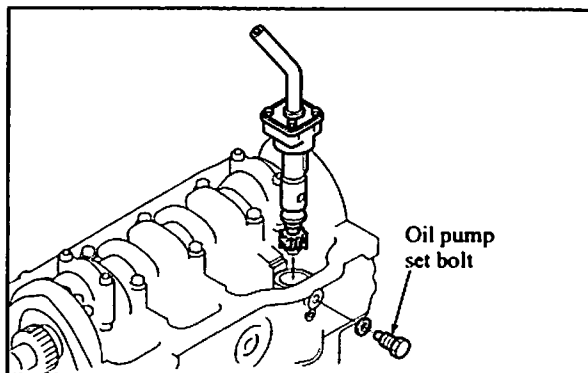
- (1) Unscrew the oil pan mounting bolts, and detach the oil pan.
- (2) Remove the oil pan gasket.



Removal of oil pan and oil gasket

### 3.9 Removal of Oil Pump

Unscrew the oil pump set bolt, and pull out the oil pump.



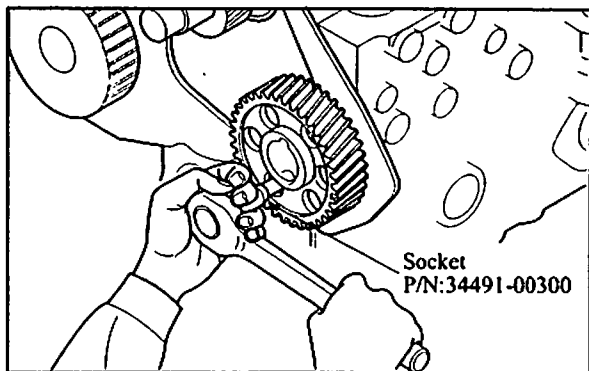
Removal of oil pump

### 3.10 Removal of Camshaft

- (1) Position the camshaft gear so that the two lightening holes are on the top and bottom, then remove the thrust plate mounting bolts using the socket.
- (2) Pull out the camshaft from the crankcase.

#### **⚠ CAUTION**

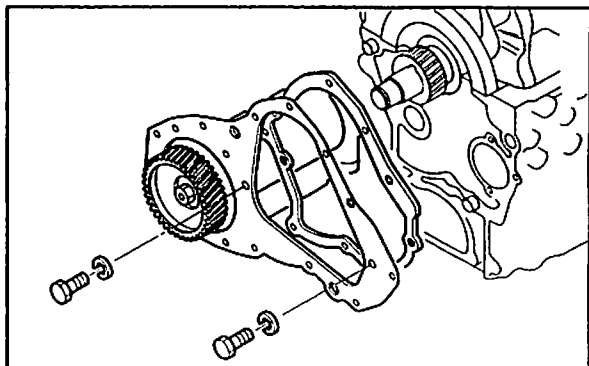
Be careful not to damage the cams and bearing sections on the camshaft.



Removal of camshaft

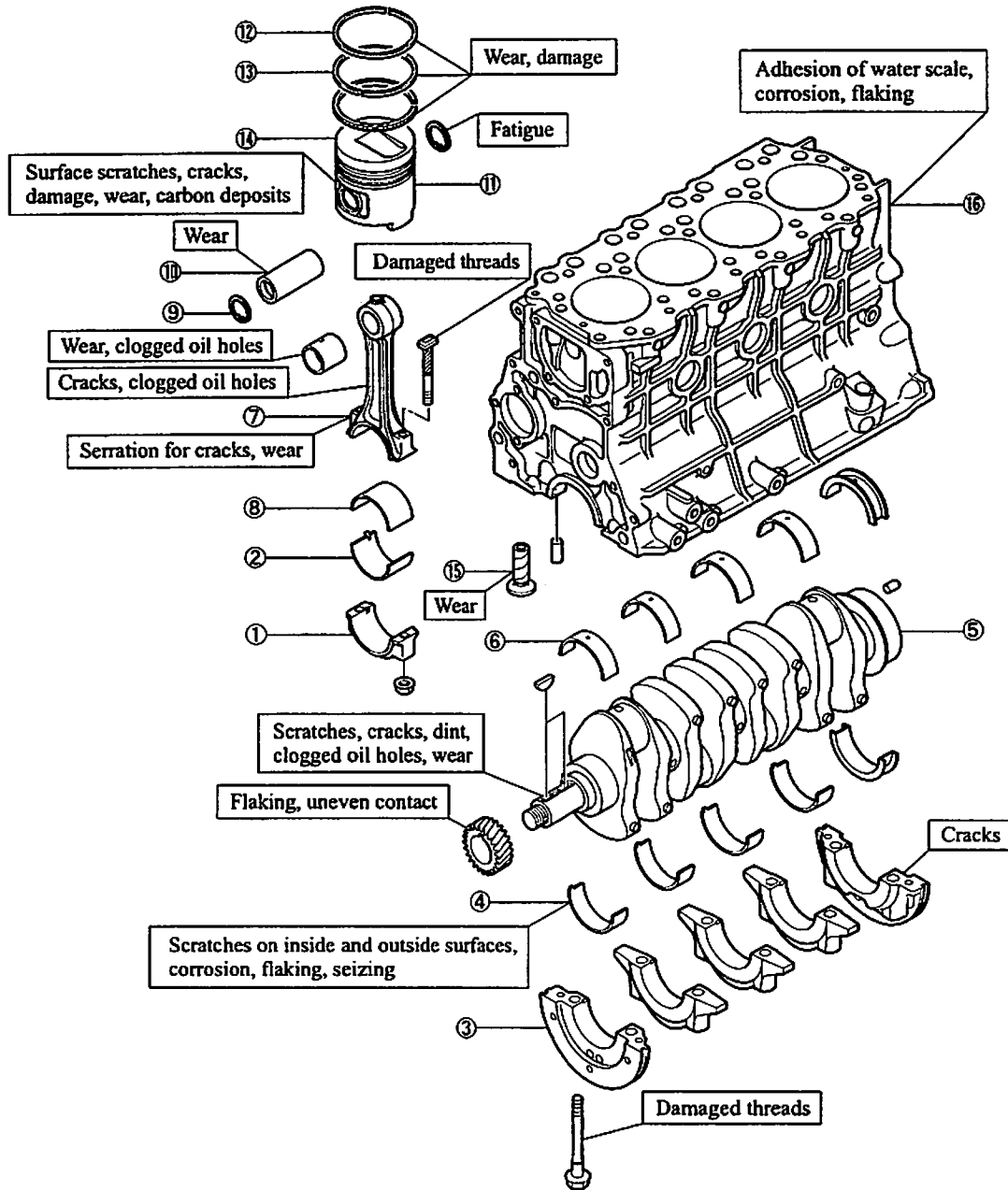
### 3.11 Removal of Front Plate

Unscrew the front plate mounting bolts, and dismount the front plate (together with the injection pump) from the crankcase.



Removal of front plate

4. Pistons, Connecting Rods, Crankshaft and Crankcase



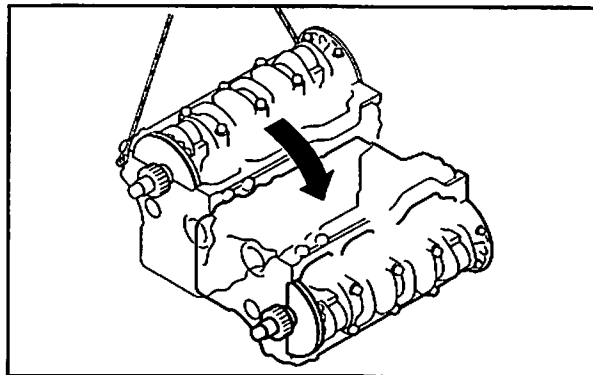
Disassembly and inspection of pistons, connecting rods, crankshaft and crankcase

< Disassembly sequence >

- |                                       |                                       |                     |
|---------------------------------------|---------------------------------------|---------------------|
| ① Connecting rod cap                  | ⑦ Connecting rod                      | ⑫ Piston ring No. 1 |
| ② Connecting rod bearing (lower half) | ⑧ Connecting rod bearing (upper half) | ⑬ Piston ring No. 2 |
| ③ Main bearing cap                    | ⑨ Snap ring                           | ⑭ Oil ring          |
| ④ Main bearing (lower half)           | ⑩ Piston pin                          | ⑮ Tappet            |
| ⑤ Crankshaft                          | ⑪ Piston                              | ⑯ Crankcase         |
| ⑥ Main bearing (upper half)           |                                       |                     |

Note : When replacing the crankcase, remove all accessories (relief valve and others) carefully from the crankcase, and reinstall them on a new crankcase.

**4.1 Laying Crankcase on Its Side**  
Gently lay the crankcase on its side.

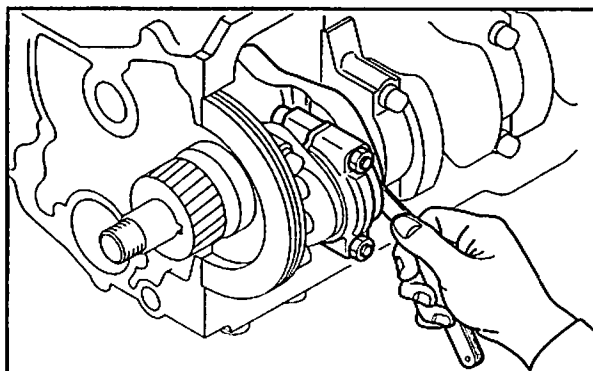


Laying crankcase on its side

**4.2 Measurement of Connecting Rod End Play**

- (1) Measure the clearance between the big-end of each connecting rod and the crankshaft (end play) with feeler gages.
- (2) If the measured clearance exceeds the limit value, replace the connecting rod.

	Unit mm [in.]	
	Standard	Limit
Connecting rod end play	0.15 to 0.35 [0.0059 to 0.0138]	0.50 [0.0197]

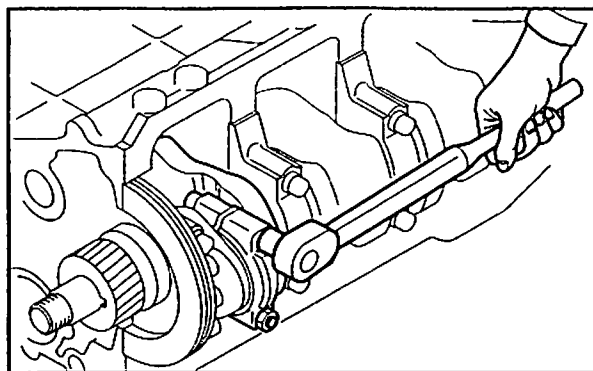


Measurement of connecting rod End Play

**4.3 Removal of Connecting Rod Caps**

- (1) On each connecting rod and cap, put a mark indicating its cylinder No.
- (2) Remove the connecting rod caps.
- (3) For each removed connecting rod bearing (lower half), indicate the piston No. from which it was removed and the upper/lower identification.

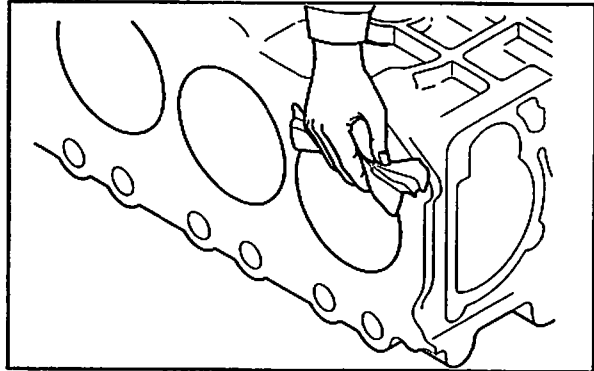
**Note :** Be careful not to damage the bearings. Arrange the removed bearings in such a way that they can be reinstalled in their original positions during reassembly.



Removal of connecting rod cap

**4.4 Preparation for Removal of Pistons**

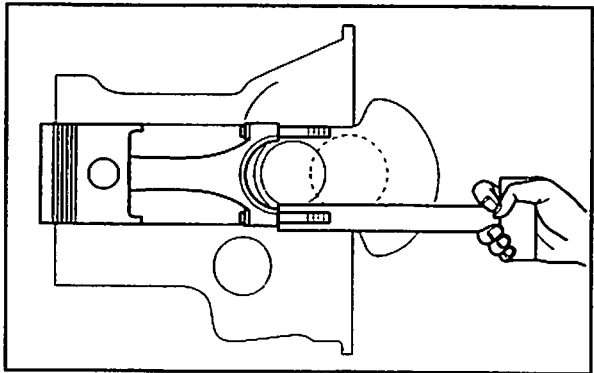
If carbon deposits are present at the upper sections of the cylinders, remove the carbon deposits with sandpaper and a cloth to facilitate piston removal.



Preparation for removal of piston

**4.5 Removal of Pistons**

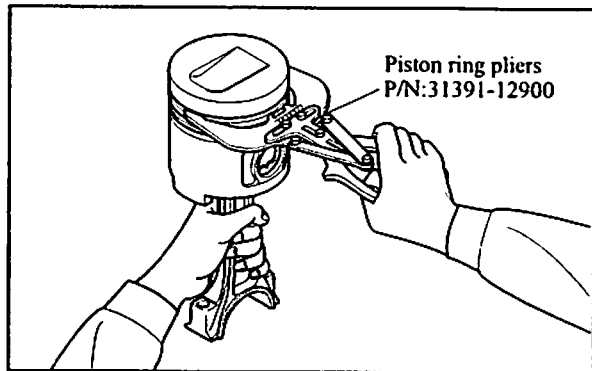
- (1) Turn the crankshaft to bring the piston to be removed to the top dead center.
- (2) Using the wooden handle of a hammer, push the connecting rod on the cap contacting surface to remove the piston and connecting rod assembly from the top side of the cylinder.



Removal of piston

**4.6 Removal of Piston Ring**

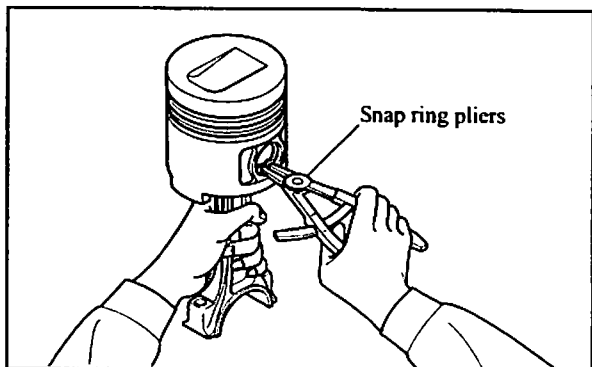
Using the piston ring pliers, remove the piston rings.



Removal of piston ring

**4.7 Removal of Piston Pins**

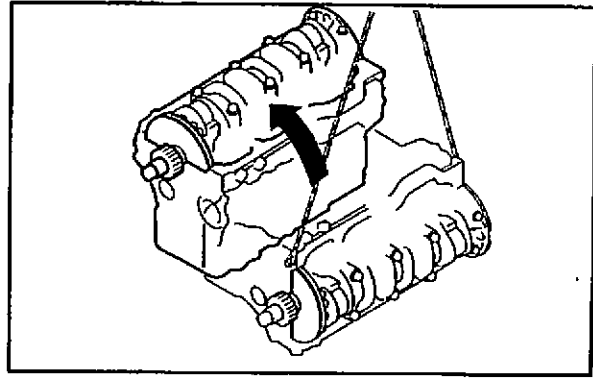
- (1) Using the snap ring pliers, remove the snap rings.
- (2) Pull out the piston pin, and separate the piston from the connecting rod.
- (3) If the piston pin cannot be removed easily, heat the piston with a piston heater or in hot water.



Removal of piston pin

**4.8 Reversal of Crankcase**

Gently stand the crankcase so that the oil pan mounting side faces up.

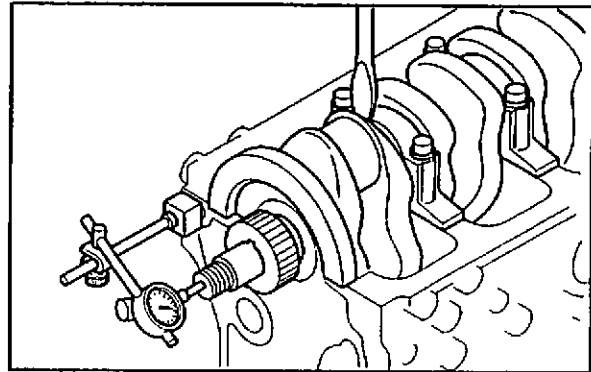


Reversal of crankcase

**4.9 Measurement of Crankshaft End Play**

- (1) With a dial gage positioned at the end of the crankshaft, measure the end play.
- (2) If the limit value is exceeded, replace the flanged bearing.

	Unit mm [in.]	
	Standard	Limit
Crankshaft end play	0.100 to 0.204 [0.0039 to 0.0080]	0.300 [0.0118]

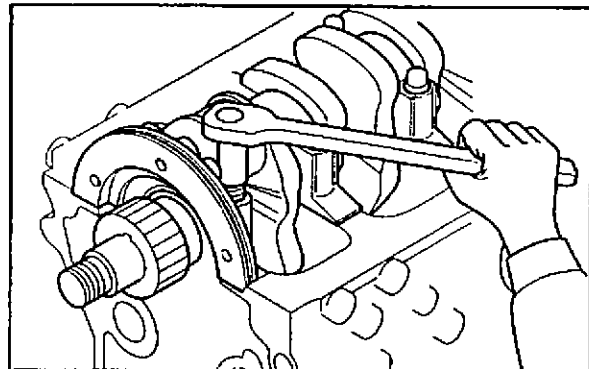


Measurement of crankshaft end play

**4.10 Removal of Main Bearing Caps**

Unscrew the main bearing cap mounting bolts, and remove the main bearing caps together with the bearings.

**Note :** Be careful not to damage the bearings. Arrange the removed bearings so that they can be reinstalled in the original positions during reassembly.

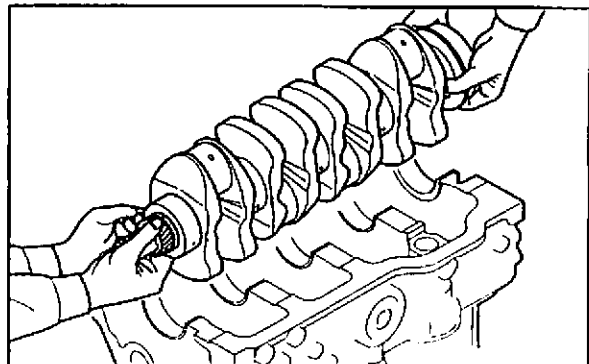


Removal of main bearing cap

**4.11 Removal of Crankshaft**

Gently lift the crankshaft to remove it from the crankcase.

**⚠ CAUTION**  
Be careful not to damage the bearings during the removal of the crankshaft.



Removal of crankshaft

**4.12 Arrangement of Bearings**

Be sure to arrange the removed bearings so that they can be reinstalled in their original positions and combined with their matching halves.



# INSPECTION AND REPAIR OF ENGINE MAIN PARTS

<p><b>1. Cylinder Head and Valve Mechanisms..... 2 -16</b></p> <p>1.1 Measurement of Distortion of Cylinder Head Bottom Surface..... 2 -16</p> <p>1.2 Measurement Rocker Arm Inside Diameter and Rocker Shaft Diameter ..... 2 -16</p> <p>1.3 Measurement of Valve Spring Perpendicularity and Free Length ..... 2 -16</p> <p>1.4 Measurement of Pushrod Deflection ..... 2 -17</p> <p>1.5 Measurement of Valve Stem Diameter ..... 2 -17</p> <p>1.6 Measurement of Clearance between Valve Stem and Valve Guide ..... 2 -17</p> <p>1.7 Replacement of Valve Guides ..... 2 -18</p> <p>1.8 Inspection of Valve Faces..... 2 -18</p> <p>1.9 Replacement of Valve Seats ..... 2 -19</p> <p>1.10 Refacing Valve Faces..... 2 -20</p> <p>1.11 Regrinding Valve Seats ..... 2 -20</p> <p>1.12 Lapping Valves against Valve Seats..... 2 -20</p> <p>1.13 Replacement of Combustion Jets ..... 2 -21</p> <p><b>2. Flywheel..... 2 -22</b></p> <p>2.1 Measurement of Flywheel Flatness ..... 2 -22</p> <p>2.2 Replacement of Ring Gear ..... 2 -22</p> <p><b>3. Timing Gears, Camshaft and Oil Pan..... 2 -23</b></p> <p>3.1 Inspection of V-Belt Groove for Wear ..... 2 -23</p> <p>3.2 Inspection of Oil Seal Contact Surface ..... 2 -23</p> <p>3.3 Measurement of Clearance between Idler Gear Bore and Shaft... 2 -23</p> <p>3.4 Replacement of Idler Bushing ..... 2 -23</p> <p>3.5 Replacement of Idler Shaft ..... 2 -24</p> <p>3.6 Measurement of Cam Lift ..... 2 -24</p> <p>3.7 Measurement of Camshaft Journal Diameter and Journal Bore Diameter ..... 2 -24</p> <p>3.8 Measurement of Camshaft Deflection ..... 2 -25</p> <p>3.9 Removal of Camshaft Gear..... 2 -25</p> <p>3.10 Installation of Camshaft Gear and Thrust Plate ..... 2 -25</p>	<p><b>4. Pistons, Connecting Rods, Crankshaft and Crankcase..... 2 -26</b></p> <p>4.1 Measurement of Piston Outside Diameter ..... 2 -26</p> <p>4.2 Inspection of Pistons and Piston Rings ..... 2 -26</p> <p>4.3 Measurement of Piston Ring End Gap..... 2 -27</p> <p>4.4 Measurement of Piston Pin Bore and Piston Pin ..... 2 -27</p> <p>4.5 Measurement of Clearance between Connecting Rod Bushing and Piston..... 2 -27</p> <p>4.6 Replacement of Connecting Rod Bushings ..... 2 -28</p> <p>4.7 Inspection of Connecting Rods for Bend and Twist..... 2 -28</p> <p>4.8 Inspection of Oil Clearance of Connecting Rod Bearing ..... 2 -29</p> <p>4.9 Inspection of Oil Clearance of Main Bearing ..... 2 -30</p> <p>4.10 Inspection of Oil Seal Contact Surface ..... 2 -31</p> <p>4.11 Measurement of Crankshaft Deflection ..... 2 -32</p> <p>4.12 Removal of Crankshaft Gear..... 2 -32</p> <p>4.13 Installation of Crankcase Gear..... 2 -32</p> <p>4.14 Measurement of Cylinder Bore ..... 2 -33</p> <p>4.15 Measurement of Distortion of Crankcase Upper Surface..... 2 -34</p> <p>4.16 Inspection of Cam Contacting Surfaces of Tappets ..... 2 -34</p> <p>4.17 Measurement of Clearance between Tappet and Tappet Guide Bore..... 2 -34</p>
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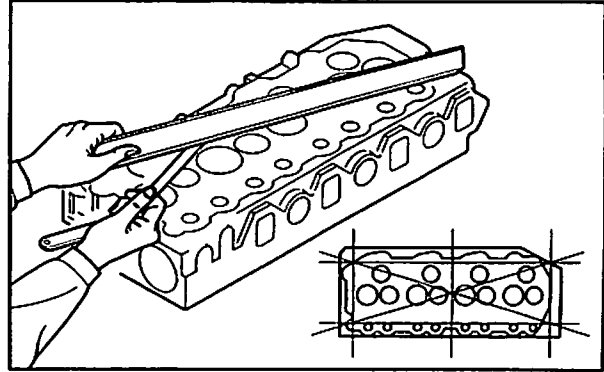
1. Cylinder Head and Valve Mechanisms

1.1 Measurement of Distortion of Cylinder Head Bottom Surface

Place a straight edge on the bottom surface of the cylinder head, measure the amount of surface distortion using feeler gages, and, if the limit value is exceeded, reface the surface with a surface grinder.

Unit mm [in.]

	Standard	Limit
Distortion of cylinder head bottom surface	0.05 [0.0020] or less	0.20 [0.0080]



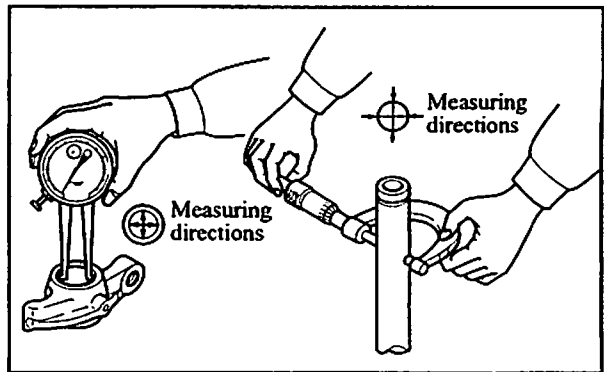
Measurement of distortion of cylinder head bottom surface

1.2 Measurement of Rocker Arm Inside Diameter and Rocker Shaft Diameter

Measure the inside diameter of the rocker arm (bushing) and the diameter of the rocker shaft to calculate the clearance between the rocker arm and shaft, and replace the rocker arm if the clearance is within the limit value. If the limit value is exceeded, replace the rocker arm and shaft.

Unit mm [in.]

	Nominal value	Standard	Limit
Rocker arm (bushing) inside diameter	$\phi 19$ [0.7490]	19.010 to 19.030 [0.7490 to 0.7500]	—
Rocker shaft diameter	$\phi 19$ [0.7490]	18.980 to 19.000 [0.7480 to 0.7490]	—
Clearance between rocker arm (bushing) and shaft	—	0.010 to 0.050 [0.0004 to 0.0020]	0.070 [0.0028]



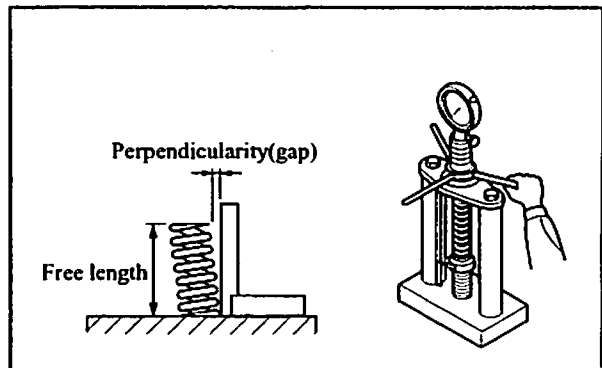
Measurement of rocker arm inside diameter and shaft diameter

1.3 Measurement of Valve Spring Perpendicularity and Free Length

Inspect each valve spring for perpendicularity and free length, and, if the limit value is exceeded, replace the valve.

Unit mm [in.]

	Standard	Limit
Free length	48.85 [1.925]	47.60 [1.875]
Squareness	$\theta = 1.5^\circ$ or less $\Delta(\text{gap}) = 1.3[0.051]$ or less $L_f = 48.85[1.925]$	$\Delta = 1.5$ [0.060] across entire length
Installed length/load mm[in.]/N(kgf)(lbf)	43.0[1.694]/ 176 to 196 (18.0 to 20.0) [40.00 to 44.10]	43.0[1.694] /147 (15.0) [33.0]



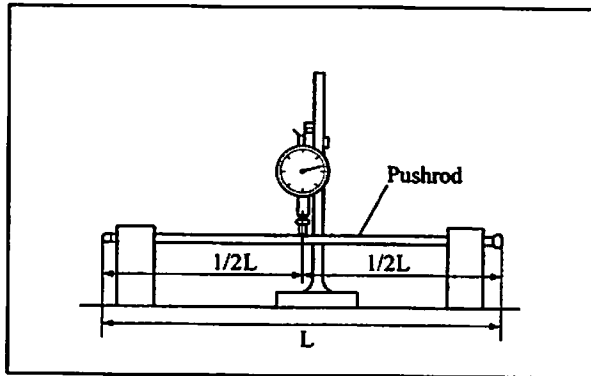
Measurement of spring perpendicularity and free length

**1.4 Measurement of Pushrod Deflection**

If the pushrod deflection exceeds the standard value, replace the pushrod.

		Unit mm [in.]
		Standard
Pushrod deflection		0.3 [0.012] or less

Note: The standard value above is based on dial gage reading.



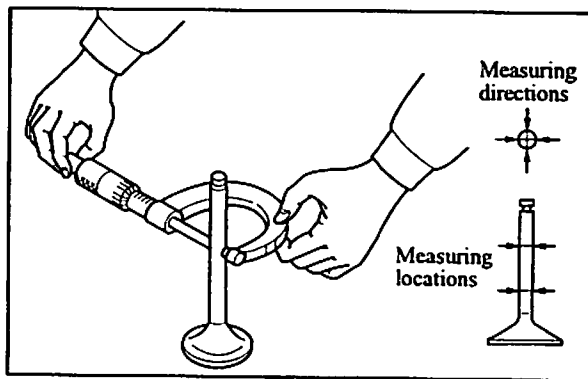
Measurement of pushrod deflection

**1.5 Measurement of Valve Stem Diameter**

If the valve stem diameter exceeds the limit value, replace the valve stem.

Also replace the valve stem if it is unevenly worn.

		Unit mm [in.]		
		Nominal value	Standard	Limit
Valve stem diameter	Inlet	φ8 [0.3152]	7.940 to 7.955 [0.3128 to 0.3134]	7.900 [0.3112]
	Exhaust	φ8 [0.3152]	7.920 to 7.940 [0.3120 to 0.3128]	7.850 [0.3093]



Measurement of valve stem diameter

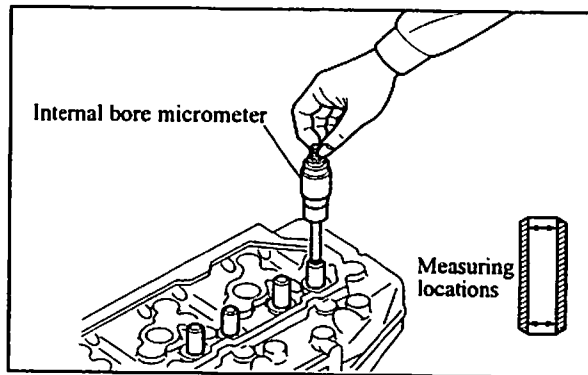
**1.6 Measurement of Clearance between Valve Stem and Valve Guide**

Measure the valve guide bore with an internal bore micrometer.

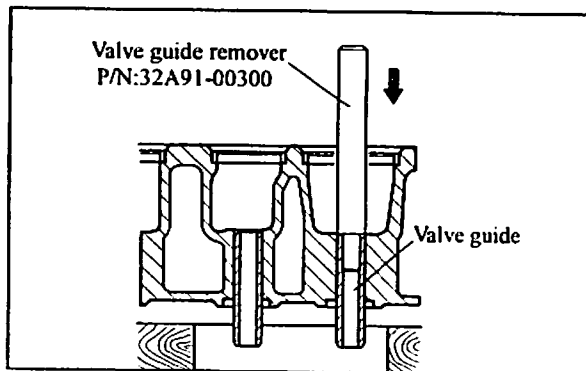
Because the valve guide wears more rapidly at the upper and lower ends, measure the diameter at both ends in two crossing directions. If the limit is exceeded, replace worn parts.

		Unit mm [in.]		
		Nominal value	Standard	Limit
Clearance between valve stem and valve guide	Inlet	-	0.065 to 0.095 [0.0026 to 0.0037]	0.150 [0.0059]
	Exhaust	-	0.080 to 0.115 [0.0032 to 0.0045]	0.200 [0.0079]
Valve guide installation length		15.5 [0.6110]	15.1 to 15.6 [0.5950 to 0.6150]	-

Note: Remove carbon deposits from the valve and valve guide before measuring the clearance.



Measurement of valve guide inside diameter



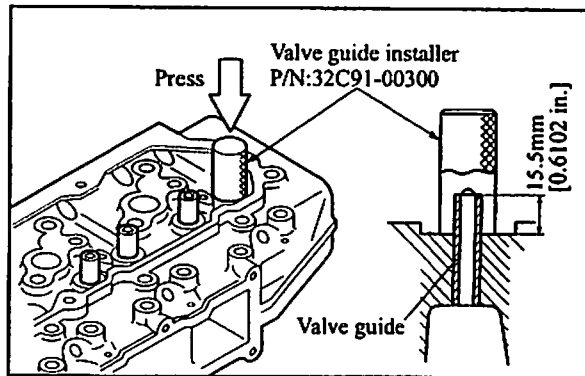
Removal of valve guide

1.7 Replacement of Valve Guides

- (1) To remove the valve guides, use the valve guide remover.
- (2) To press-fit the valve guides, use the valve guide installer and a press.

**⚠ CAUTION**

Be sure to use the valve guide installer in order to drive the valve guide to the prescribed depth.

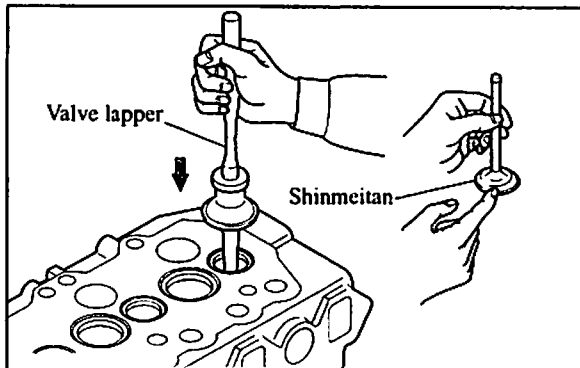


Installation of valve guide

- (3) After installing the valve guide, insert a new valve and check the smoothness of the movement.
- (4) When the valve guide is replaced, check the contact of the valve with the valve seat.

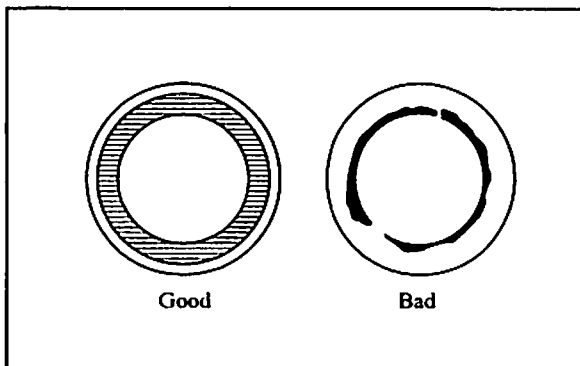
1.8 Inspection of Valve Faces

Coat the valve face lightly with shinmeitan, and use the valve lapper to inspect the valve contact with the valve seat. If the contact is not uniform and the valve is defective, or if the limit is exceeded, correct or replace the valve and valve seat.



Inspection of valve face

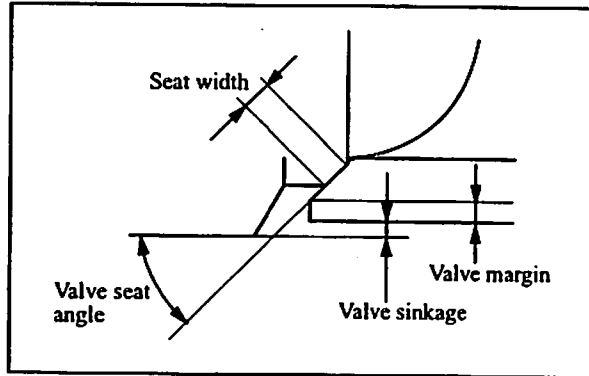
- Note:
- (a) Inspect the valve face after the valve guide is inspected or replaced.
  - (b) When pressing the valve coated with shinmeitan against the valve seat, do not rotate the valve.
  - (c) After the valve or valve seat is corrected or replaced, lap the valve against the valve seat.



Valve seat contact with seat

Unit mm [in.]

		Nominal value	Standard	Limit
Valve seat	Valve seat angle	30°		
	Seat width	1.18 [0.0465]	1.04 to 1.32 [0.0410 to 0.0520]	1.6 [0.0630]
	Valve sinkage	0.8 [0.0315]	0.7 to 0.9 [0.0276 to 0.0355]	1.3 [0.0512]
Valve margin		1.70 [0.0670]		Refacing permissible up to 1.20 [0.0473]



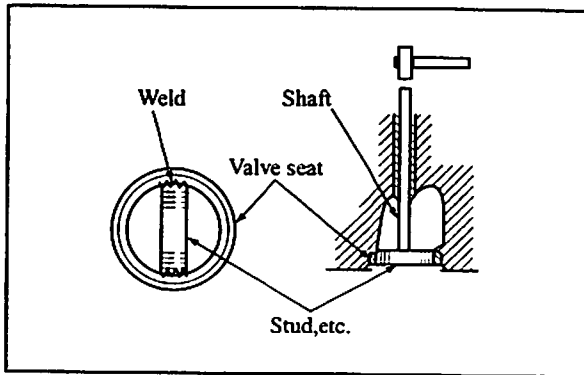
Valve contact with seat

### 1.9 Replacement of Valve Seats

#### (1) Removal of valve seat

Weld a stud or bar to the valve seat, insert a shaft into the valve guide bore from the top of the cylinder head, and drive the seat off the cylinder head.

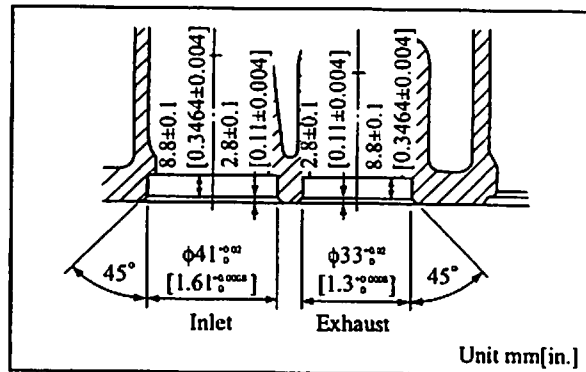
Note: When welding the stud, do not allow spatter to adhere on the machined surfaces of the cylinder.



Removal of valve seat

#### (2) Installation of valve seat

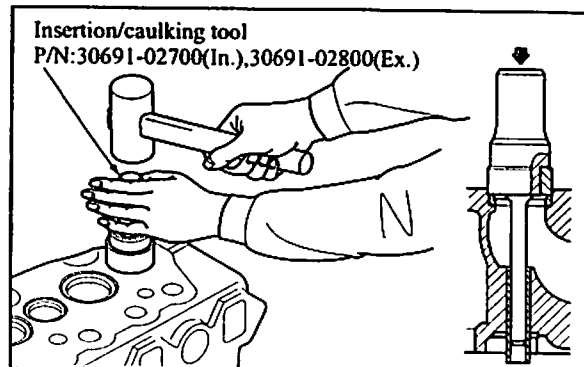
(a) Before inserting a new valve seat, measure the cylinder head bore to which the valve seat is installed to make sure the dimension conforms to the standard.



Valve seat installation dimension

(b) When installing a valve seat, keep the cylinder head at room temperature and cool the valve seat in liquid nitrogen (approx. -170°C [-274 °F]) for more than 4 minutes, or heat the cylinder head to 80 to 100 °C [176 to 212 °F] and keep the valve seat chilled in either ether or alcohol containing dry ice.

(c) Using the insertion/caulking tool, drive the valve seat into place.

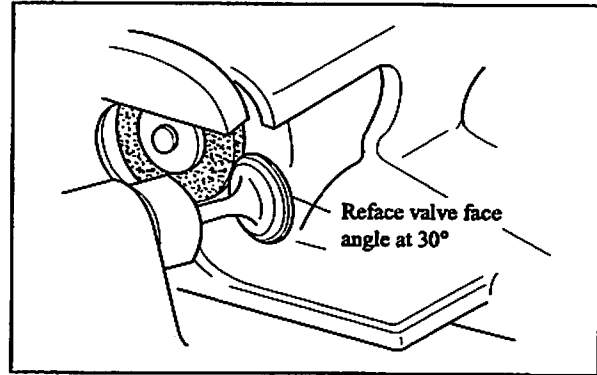


Installation of valve seat

### 1.10 Refacing Valve Faces

If the valve face is excessively worn, reface it with a valve refacer.

- Note:** (a) Reface the valve face to an angle of 30°.  
 (b) Be sure to ensure the valve margin limit. If the grinding does not result in the conformity of the dimension, replace the valve.

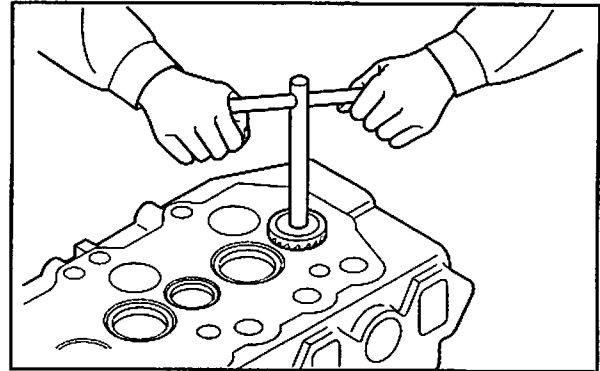


Refacing valve face

### 1.11 Regrinding Valve Seats

Use the valve seat cutter or valve seat grinder to reface the valve seat. After refacing, grind the seat lightly by inserting #400-grade sandpaper between the cutter and valve seat.

- Note:** (a) Grind the valve seat as little as possible.  
 (b) If the seat width exceeds the limit due to wear or as a result of grinding, replace the valve seat.



Regrinding valve seat

### 1.12 Lapping Valves against Valve Seats

Be sure to lap each valve in its valve seat after the valve or seat has been refaced or replaced.

- (1) Coat the seat contact surface of the valve face lightly and evenly with a lapping compound.

**Note:** (a) Do not allow the compound to adhere on the valve stem.

- (b) Use a compound of medium coarseness (120 to 150 mesh) for initial lapping, and use a finer compound (200 mesh or finer) for finishing.

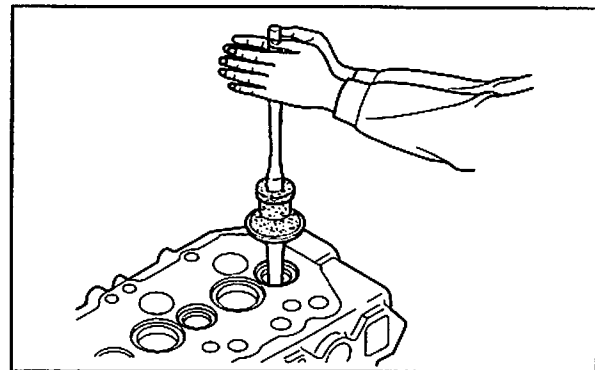
- (c) Mix a small amount of engine oil with the compound for smooth and even application.

- (2) Use the valve lapper to lap the valve in the seat. To lap, strike the valve against the valve seat while rotating the valve a little at a time.

- (3) Wash off the compound with diesel fuel.

- (4) Coat the seat contact surface of the valve face with engine oil, then lap the valve again.

- (5) Inspect the valve face for contact.

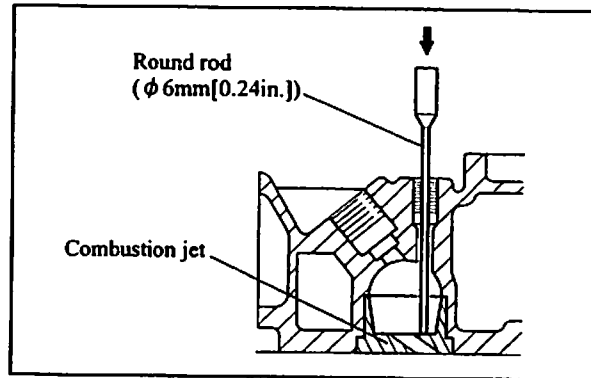


Lapping valve against valve seat

### 1.13 Replacement of Combustion Jets

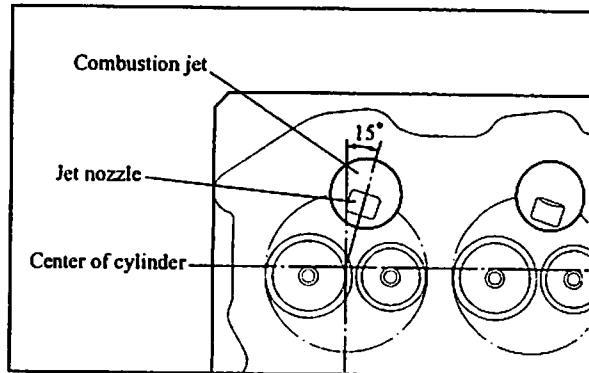
Replace the combustion jets only when cracks or other abnormal conditions are found.

- (1) To remove the combustion jet, insert a round rod measuring about  $\phi 6$  mm [0.24 in.] in diameter into the glow plug mounting hole, and lightly tap the inside surface of the jet at the perimeter.



Removal of combustion jet

- (2) To reinstall the combustion jet, point the jet nozzle toward the center of the cylinder, and strike with a plastic hammer.



Installation of combustion jet

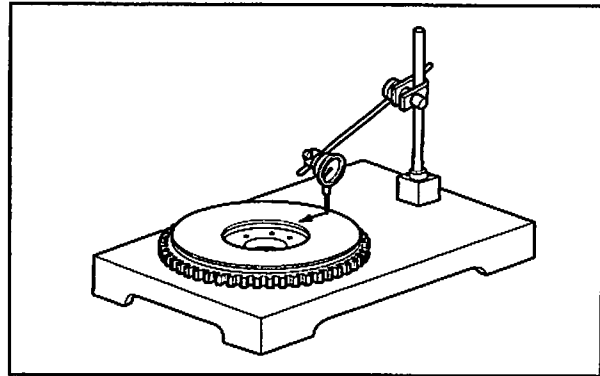
2. Flywheel

2.1 Measurement of Flywheel Flatness

Place the flywheel on a surface plate, and run a dial gage on the friction face of the flywheel to measure the flatness.

If the limit value is exceeded, refinish the friction surface.

	Unit mm [in.]	
	Standard	Limit
Flywheel flatness	0.10 [0.0039] or less	0.50 [0.0197]



Measurement of flywheel flatness

2.2 Replacement of Ring Gear

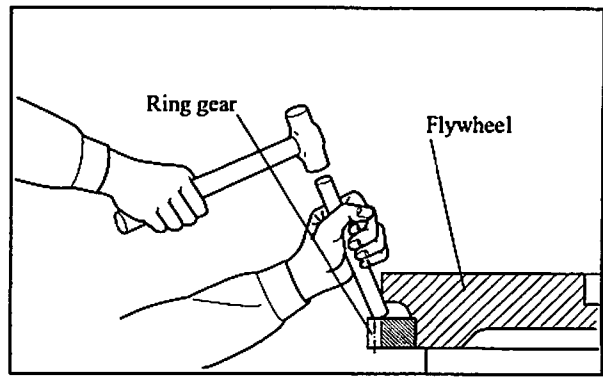
Inspect the ring gear, and, if missing teeth or abnormally worn tooth faces are found, replace the ring gear by following the procedure described below.

(1) Removal of ring gear

- (a) Heat the ring gear uniformly using an acetylene torch.
- (b) To remove the ring gear, tap the entire perimeter of the ring gear evenly using a rod and a hammer.

(2) Reinstallation of ring gear

Heat the ring gear using a piston heater (to a temperature lower than 150 °C [302 °F]), and install the ring gear with the non-chamfered side facing the flywheel.



Removal of ring gear



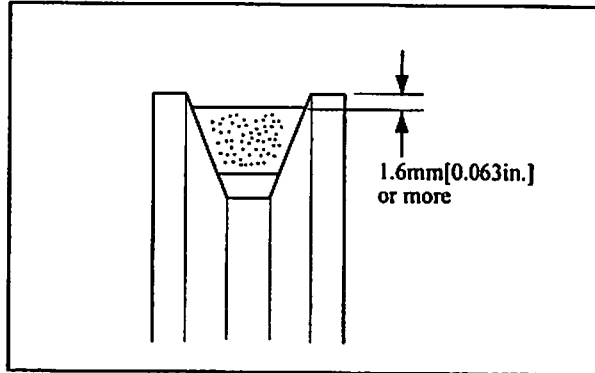
### 3. Timing Gears, Camshaft and Oil Pan

#### 3.1 Inspection of V-Belt Groove for Wear

Inspect the V-belt groove on the pulley for wear. To judge the amount of wear, wrap a new V-belt around the pulley, and check whether the outside surface of the belt is higher or lower than the edges of the pulley groove.

If the outside surface of the belt extends from the edges of the groove, the pulley can be still used.

If the outside surface of the belt is lower than the edges by more than 1.6 mm [0.063 in.], the pulley is excessively worn and must be replaced.



Inspection of V-belt groove for wear

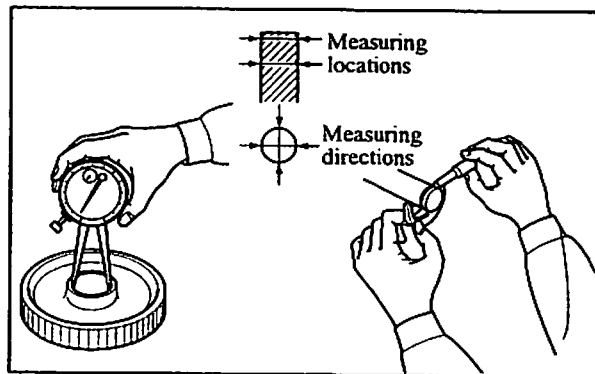
#### 3.2 Inspection of Oil Seal Contact Surface

Inspect the oil seal contact face of the pulley, and, if the pulley face has been excessively worn by the oil seal, replace the pulley.

#### 3.3 Measurement of Clearance between Idler Gear Bore and Shaft

Measure the idler gear inside diameter and the shaft diameter to determine the clearance, and, if the limit value is exceeded, replace the idler gear or shaft.

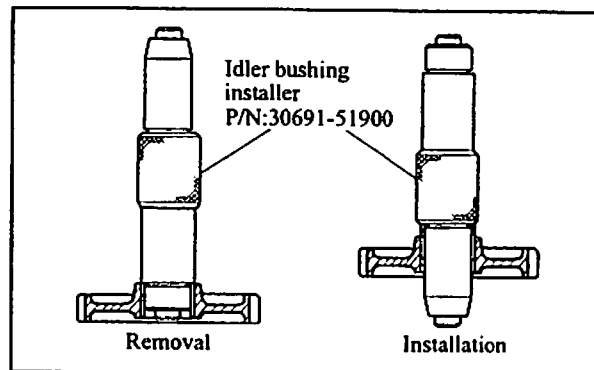
	Unit mm [in.]	
	Standard	Limit
Clearance between idler gear and shaft	0.025 to 0.075 [0.0010 to 0.0030]	0.100 [0.0039]



Measurement of idler gear inside diameter and shaft diameter

#### 3.4 Replacement of Idler Bushing

- (1) To replace the idler bushing, use the idler bushing installer.
- (2) Press-fit the bushing into the gear until the end face of the bushing is flush with the boss end face.
- (3) After installing the bushing, finish the inside diameter to  $\phi 36 \text{ H7} \left( \begin{smallmatrix} -0.025 \\ 0 \end{smallmatrix} \right) \text{ mm } 0.8 \text{ Ra}$  [ $1.42 \text{ H7} \left( \begin{smallmatrix} -0.001 \\ 0 \end{smallmatrix} \right) \text{ in.}$ ].

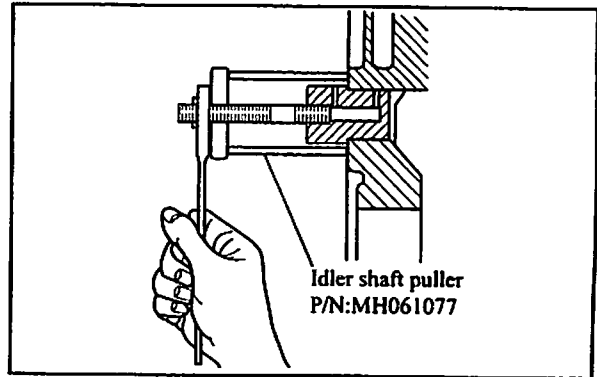


Replacement of idler bushing

**3.5 Replacement of Idler Shaft**

Use the idler shaft puller to remove the idler shaft.

**Note:** When driving the idler shaft into the crankcase, make sure that the oil hole in the idler shaft faces the top side of the crankcase.



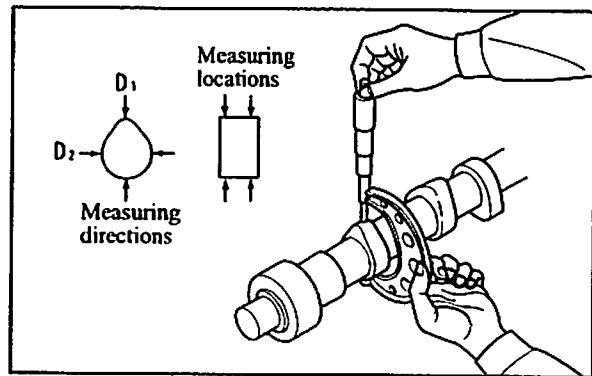
Removal of idler shaft

**3.6 Measurement of Cam Lift**

Measure the long axis and short axis of each cam with a micrometer, and, if the limit value is exceeded, replace.

Unit mm [in.]

		Nominal value	Standard	Limit
Cam lift	Inlet	D <sub>1</sub> 46.916 <sup>+0.1</sup> <sub>-0.3</sub> [1.848 <sup>+0.004</sup> <sub>-0.012</sub> ]	D <sub>1</sub> -D <sub>2</sub> 6.684 [0.2633]	D <sub>1</sub> -D <sub>2</sub> 6.184 [0.2436]
	Exhaust	D <sub>1</sub> 45.944 <sup>+0.1</sup> <sub>-0.3</sub> [1.810 <sup>+0.004</sup> <sub>-0.012</sub> ]	D <sub>1</sub> -D <sub>2</sub> 7.344 [0.2894]	D <sub>1</sub> -D <sub>2</sub> 6.844 [0.2697]



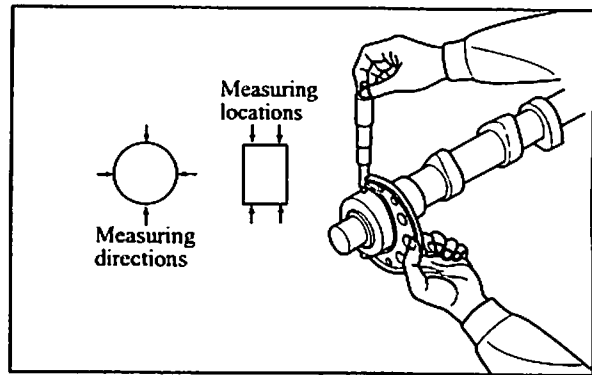
Measurement of cam lift

**3.7 Measurement of Camshaft Journal Diameter and Journal Bore Diameter**

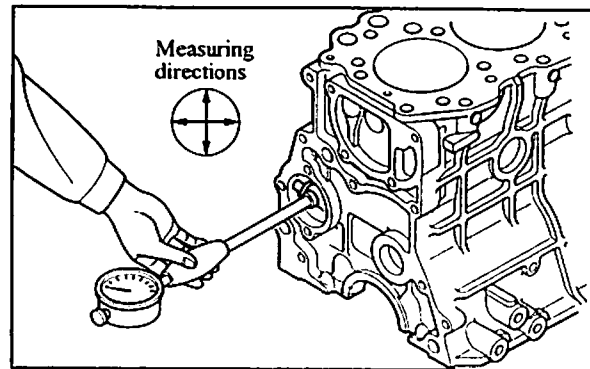
Measure the camshaft journal and the bore in the crankcase for camshaft, and, if the limit value is exceeded, replace the camshaft.

Unit mm [in.]

		Nominal value	Standard	Limit
Camshaft journal diameter	No. 1, 2	φ54 [2.1276]	53.94 to 53.96 [2.1252 to 2.1260]	53.90 [2.1237]
	No. 3	φ53 [2.0882]	52.94 to 52.96 [2.0858 to 2.0866]	52.90 [2.0843]
Clearance between camshaft journal and bore in crankcase for camshaft		-	0.07 to 0.11 [0.0028 to 0.0043]	0.15 [0.0059]
Camshaft bore diameter	No. 1, 2	φ54 [2.1276]	54.030 to 54.050 [2.1288 to 2.1296]	53.90 [2.1237]
	No. 3	φ53 [2.0882]	53.030 to 53.050 [2.0893 to 2.0901]	52.90 [2.0843]



Measurement of camshaft journal diameter



Measurement of camshaft bore diameter

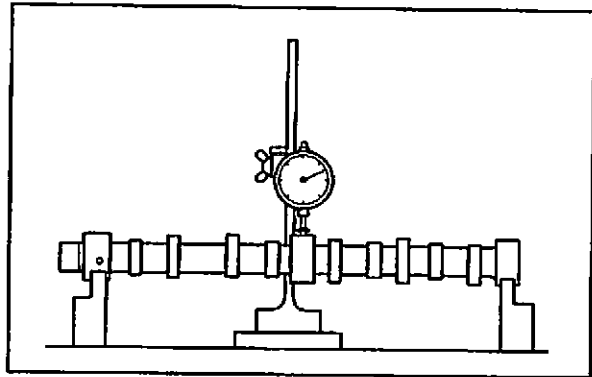
### 3.8 Measurement of Camshaft Deflection

Measure the camshaft deflection, and, if the limit value is exceeded, correct the camshaft with a press or replace it.

#### ⚠ CAUTION

With a dial gage set on the camshaft, rotate the camshaft one turn and read the gage indication. One half of the gage indication is the amount of deflection.

	Unit mm [in.]	
	Standard	Limit
Camshaft deflection	0.02 [0.0008] or less	0.05 [0.0020]

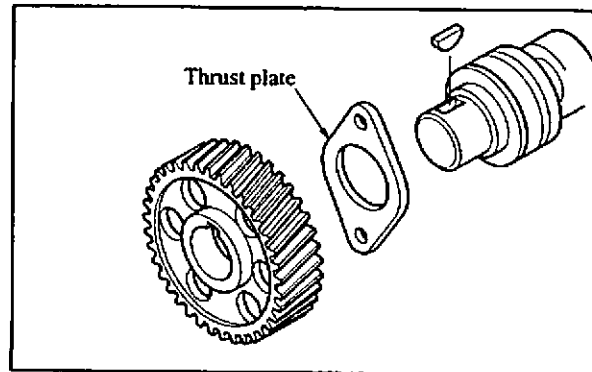


Measurement of camshaft deflection

### 3.9 Removal of Camshaft Gear

Use a hydraulic press to remove the camshaft gear.

**Note:** Do not remove the camshaft gear unless the camshaft, thrust plate or gear is replaced.

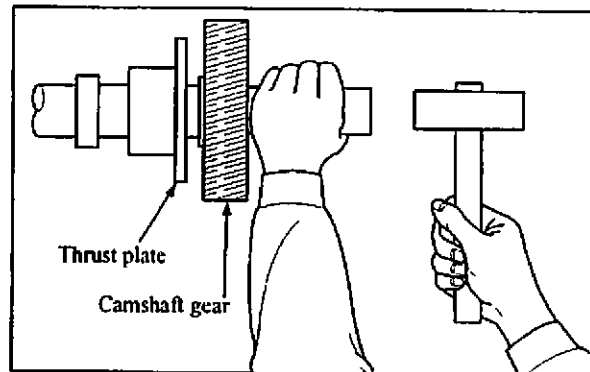


Removal of camshaft gear

### 3.10 Installation of Camshaft Gear and Thrust Plate

- (1) Install the key and thrust plate to the camshaft.
- (2) Heat the camshaft gear to a temperature of about 250 °C [482 °F] using a gear heater.
- (3) Strike the gear to install it.

**Note:** Before installing the camshaft gear, be sure to position the thrust plate in place.

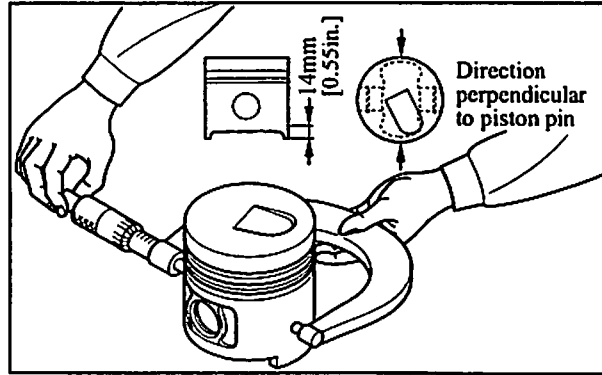


Installation of camshaft gear and thrust plate

4. Pistons, Connecting Rods, Crankshaft and Crankcase

4.1 Measurement of Piston Outside Diameter

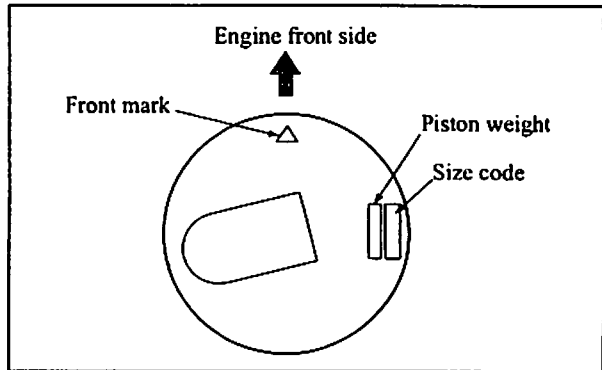
- (1) Using a micrometer, measure the diameter of each piston in a direction perpendicular to the piston pin at the piston skirt (shown in the diagram).  
If the limit value is exceeded, replace the piston.



Measurement of piston outside diameter

		Unit mm [in.]		
		Nominal value	Standard	Limit
Piston outside diameter	S.T.D	87.970 [3.4660]	87.955 to 87.985 [3.4654 to 3.4666]	87.770 [3.4581]
	0.25 [0.01] O.S	88.220 [3.4759]	88.205 to 88.235 [3.4753 to 3.4765]	88.020 [3.4680]
	0.50 [0.02] O.S	88.470 [3.4857]	88.455 to 88.485 [3.4851 to 3.4863]	88.270 [3.4778]
Weight difference in one engine			5 g [0.2 oz.] or less	

- (2) The piston weight is stamped on the top face of the piston.

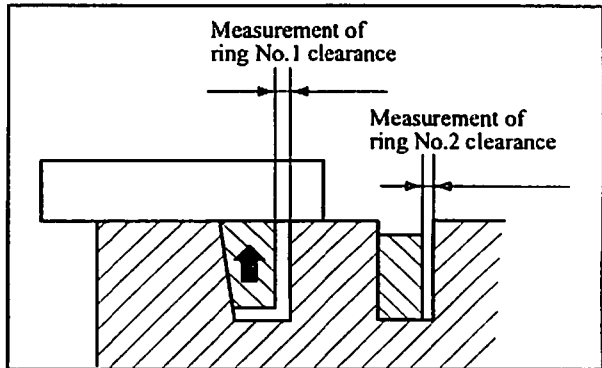


Piston weight stamp location

4.2 Inspection of Pistons and Piston Rings

(1) Inspection of piston ring grooves

- (a) Measure the clearance between each piston ring and the ring groove, and, if the limit value is exceeded, replace the piston ring.



Measurement of piston ring groove

		Unit mm [in.]	
		Standard	Limit
Ring No. 1		0.060 to 0.100 [0.0024 to 0.0039]	0.200 [0.0079]
Ring No. 2		0.045 to 0.080 [0.0018 to 0.0032]	0.150 [0.0059]
Oil ring		0.025 to 0.065 [0.0010 to 0.0026]	0.150 [0.0059]

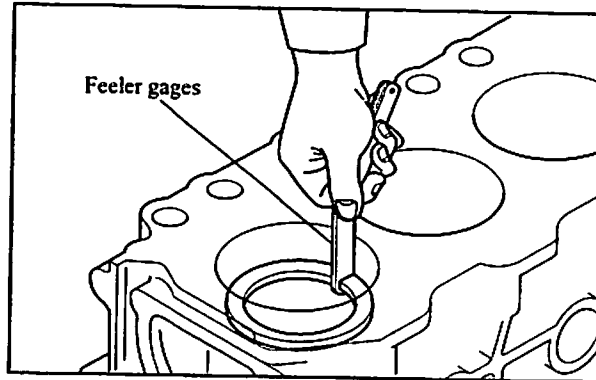
- (b) If the measurement of the clearance with a new ring still exceeds the limit value, replace the piston.

### 4.3 Measurement of Piston Ring End Gap

Place the piston ring in a gage or reference cylinder to measure the ring end gap. If the limit value is exceeded, replace all the rings as a set.

Inside diameter of gage	}	S.T.D	=88 <sup>+0.035</sup> <sub>0</sub> mm [3.46 <sup>+0.0014</sup> <sub>0</sub> in.]
		0.25 [0.01] O.S	=88.25 <sup>+0.035</sup> <sub>0</sub> mm [3.47 <sup>+0.0014</sup> <sub>0</sub> in.]
		0.50 [0.02] O.S	=88.50 <sup>+0.035</sup> <sub>0</sub> mm [3.48 <sup>+0.0014</sup> <sub>0</sub> in.]

Note: Using a piston, push the piston ring squarely into the gage.



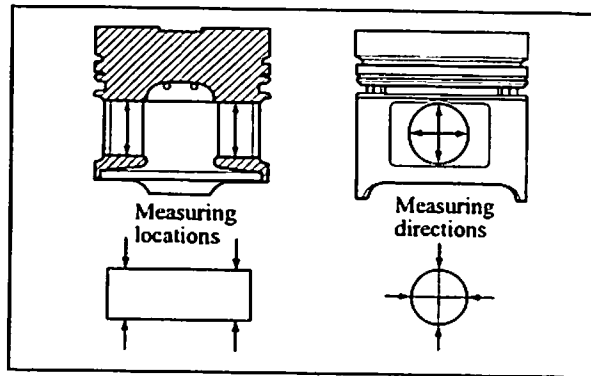
Measurement of piston ring end gap

		Unit mm [in.]	
		Standard	Limit
Piston ring end gap	Ring No. 1	0.25 to 0.40	1.50 [0.0591]
	Ring No. 2	[0.0100 to 0.0158]	
	Oil ring	0.30 to 0.50 [0.0118 to 0.0197]	

### 4.4 Measurement of Piston Pin Bore and Piston Pin

Measure the piston pin bore diameter and piston pin outside diameter, and, if the limit value is exceeded, replace the worn parts.

		Unit mm [in.]	
		Nominal value	Limit
Piston pin bore diameter	φ28 [1.1032]	28.000 to 28.010 [1.1032 to 1.1036]	
Piston pin outside diameter	φ28 [1.1032]	27.994 to 28.000 [1.1030 to 1.1032]	
Clearance between piston pin bore and piston pin	-	0.000 to 0.016 [0.000 to 0.0006]	0.050 [0.0020]

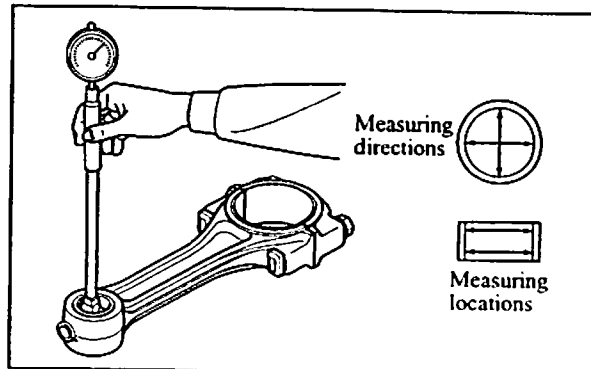


Measurement of piston pin bore and piston pin

### 4.5 Measurement of Clearance between Connecting Rod Bushing and Piston

Measure the connecting rod bushing inside diameter and piston pin outside diameter, and, if the limit value is exceeded, replace the worn parts.

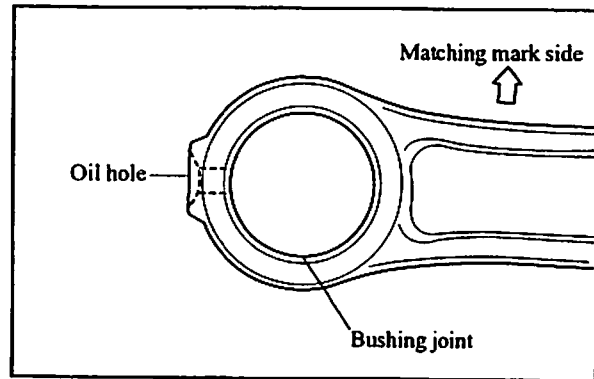
		Unit mm [in.]	
		Nominal value	Limit
Bushing inside diameter	φ28 [1.1032]	28.020 to 28.045 [1.1040 to 1.1050]	
Clearance between bushing and piston pin	-	0.020 to 0.051 [0.0008 to 0.0020]	0.080 [0.0032]



Measurement of inside diameter of connecting rod bushing

4.6 Replacement of Connecting Rod Bushings

- (1) To replace the connecting rod bushing, use the connecting rod bushing puller.
- (2) Align the oil holes of the bushing and connecting rod. Also position the bushing joint at the location shown in the diagram.
- (3) After installation, insert the piston pin, and make sure that the piston pin moves smoothly without excessive play.



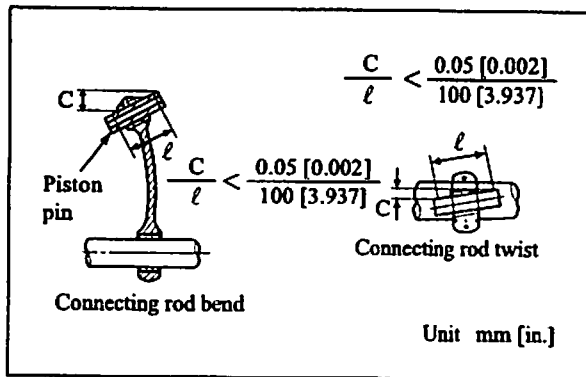
Replacement of connecting rod bushing

4.7 Inspection of Connecting Rods for Bend and Twist

- (1) To inspect, measure value T of C and  $\ell$ , and straighten the connecting rod with a press so that C is 0.05 mm [0.002 in.] or less per 100 mm [3.937 in.] of  $\ell$ .

Unit mm [in.]

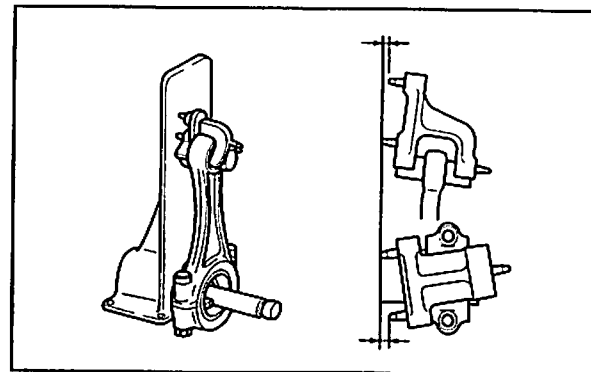
	Standard	Limit
Connecting rod bend and twist	0.05/100 [0.002/3.940] or less	0.15/100 [0.006/3.940]



Inspection of connecting rod for bend and twist

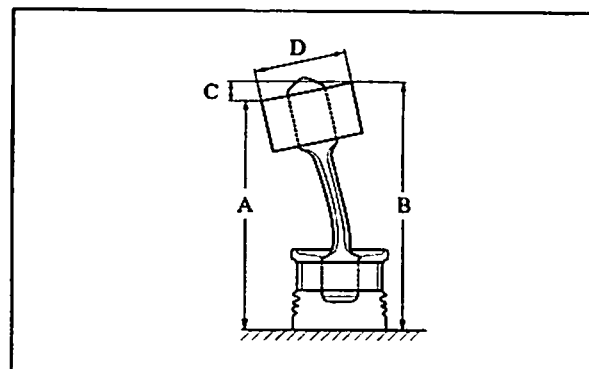
- (2) Generally, a connecting rod aligner is used to check the connecting rod for bend and twist.

Note: Tighten the connecting rod cap to the specified torque for the inspection of bend.



Measurement using connecting rod aligner

- (3) To inspect the connecting rod installed to a piston, place the piston on a surface plate, insert a round bar having the same diameter as the crankpin, then measure the height of the bar with a dial gage.

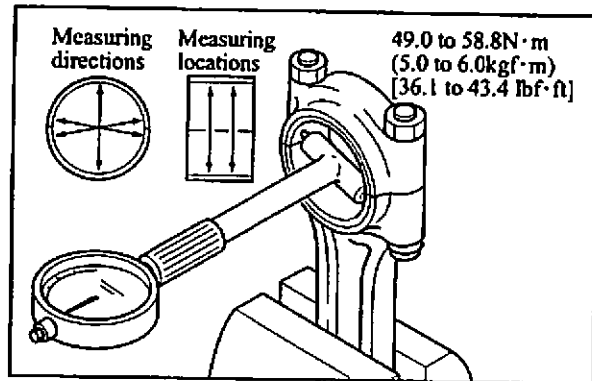


Measurement of bend with dial gage

4.8 Inspection of Oil Clearance of Connecting Rod Bearing

- (1) Install the bearing to the big-end bore of the connecting rod, tighten the connecting rod cap to the specified torque, and measure the bearing inside diameter.

	Nominal value	Standard	Limit
Connecting rod bearing inside diameter	φ58 [2.2852]	58.000 to 58.045 [2.2852 to 2.2870]	-

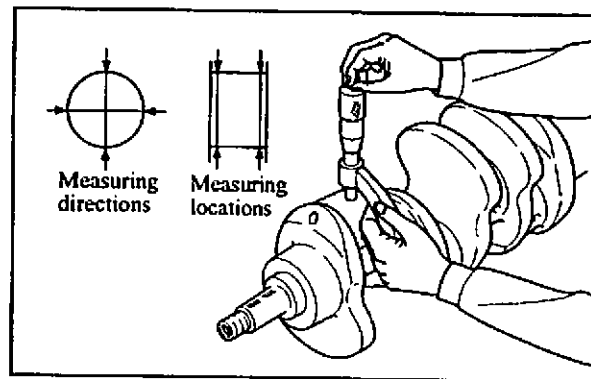


Measurement of inside diameter of connecting rod bearing

- (2) Measure the outside diameter of the crankpin of the crankshaft, and subtract it from the above-mentioned bearing inside diameter to obtain the oil clearance of the connecting rod bearing.

Unit mm [in.]

	Nominal value	Standard	Limit
Crankpin outside diameter (S.T.D)	φ58 [2.2852]	57.955 to 57.970 [2.2834 to 2.2840]	-
Oil clearance	-	0.030 to 0.090 [0.0012 to 0.0035]	0.20 [0.0079]



Measurement of outside diameter of crankpin

- (3) If the oil clearance exceeds the limit value, replace the bearing, and check the oil clearance again.
- (4) If the oil clearance still exceeds the limit value, use an undersize bearing (0.25 mm [0.0098 in.], 0.50 mm [0.0197 in.] or 0.75 mm [0.0295 in.] undersize). When using undersize bearings, refinish the crankpins to the following undersize dimension.

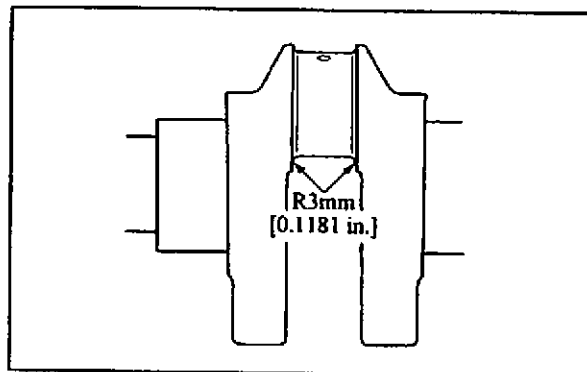
Crankshaft undersize finishing dimension

Unit mm [in.]

	Undersize Value	Finishing dimension
Crankpin undersize	0.25 [0.0098]	φ57.75 <sup>-0.030</sup> <sub>-0.045</sub> [2.27 <sup>-0.0012</sup> <sub>-0.0018</sub> ]
	0.50 [0.0197]	φ57.50 <sup>-0.030</sup> <sub>-0.045</sub> [2.26 <sup>-0.0012</sup> <sub>-0.0018</sub> ]
	0.75 [0.0295]	φ57.25 <sup>-0.030</sup> <sub>-0.045</sub> [2.25 <sup>-0.0012</sup> <sub>-0.0018</sub> ]

**CAUTION**

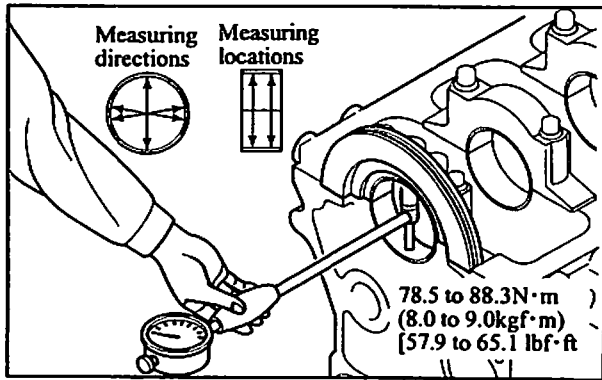
- (a) When regrinding journals of the crankshaft, be sure to refinish all journals to the same dimension.
- (b) Finish the fillet radius to R3 mm [0.1181 in.].



Crankshaft fillet finishing dimension I

4.9 Inspection of Oil Clearance of Main Bearing

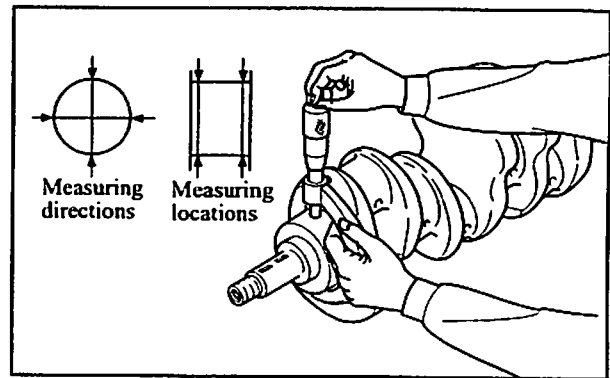
(1) Install the main bearing to the main bearing cap and crankcase, tighten the main bearing cap to the specified torque, and measure the bearing inside diameter.



Measurement of inside diameter of main bearing

(2) Measure the journal diameter of the crankshaft, and subtract it from the above-mentioned bearing inside diameter to obtain the oil clearance of the main bearing.

Unit mm [in.]			
	Nominal value	Standard	Limit
Journal diameter (S.T.D)	φ65 [2.5561]	64.965 to 64.985 [2.5596 to 2.5604]	-
Oil clearance	-	0.035 to 0.085 [0.0014 to 0.0033]	0.200 [0.0079]



Measurement of outside diameter of crank journal

(3) If the oil clearance exceeds the limit value, install a new bearing, and check the oil clearance again.

(4) If the oil clearance still exceeds the limit value, use an undersize bearing (0.25 mm [0.0098 in.], 0.50 mm [0.0197 in.] or 0.75 mm [0.0295 in.] undersize).

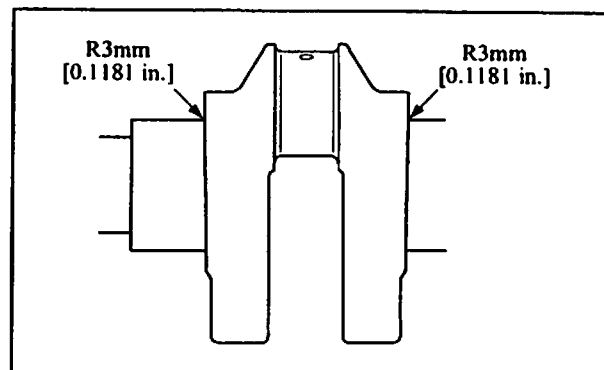
When using undersize bearings, refinish the crankpins to the following undersize dimension.

Crankshaft undersize finishing dimension

Unit mm [in.]		
	Undersize Value	Finishing dimension
Crankpin undersize	0.25 [0.0098]	φ64.75 <sup>+0.015</sup> <sub>-0.035</sub> [2.55 <sup>+0.0006</sup> <sub>-0.0014</sub> ]
	0.50 [0.0197]	φ64.50 <sup>+0.015</sup> <sub>-0.035</sub> [2.54 <sup>+0.0006</sup> <sub>-0.0014</sub> ]
	0.75 [0.0295]	φ64.25 <sup>+0.015</sup> <sub>-0.035</sub> [2.53 <sup>+0.0006</sup> <sub>-0.0014</sub> ]

**CAUTION**

- (a) When regrinding journals of the crankshaft, be sure to refinish all journals to the same dimension.
- (b) Finish the fillet radius to R3 mm [0.1181 in.].

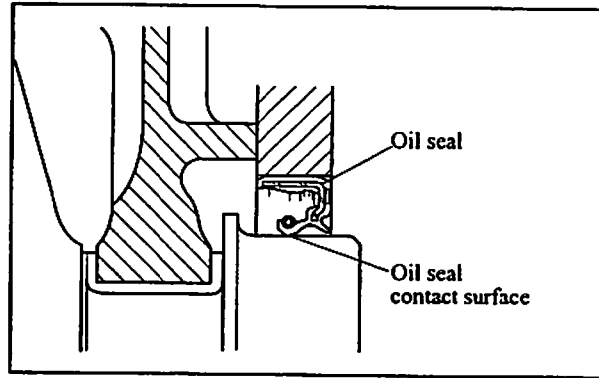


Crankshaft fillet finishing dimension 2



#### 4.10 Inspection of Oil Seal Contact Surface

Check the oil seal contact surface of the crankshaft back-end, and, if the crankshaft face has been excessively worn by the oil seal, replace the oil seal and oil sleeve with replacement parts.



Inspection of oil seal contact surface

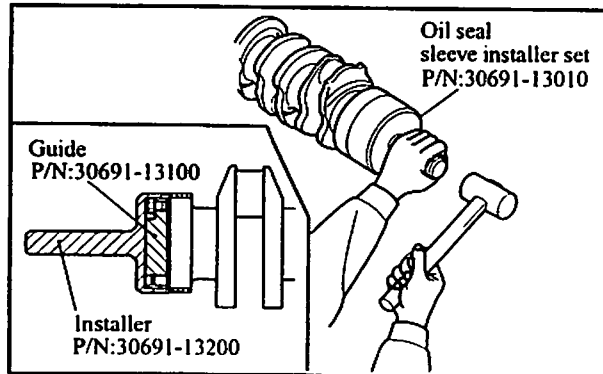
#### (1) Installation of oil seal sleeve

To install the oil seal sleeve, coat the inner surface of the sleeve with oil, and use the crankshaft sleeve installer for driving the sleeve into place.

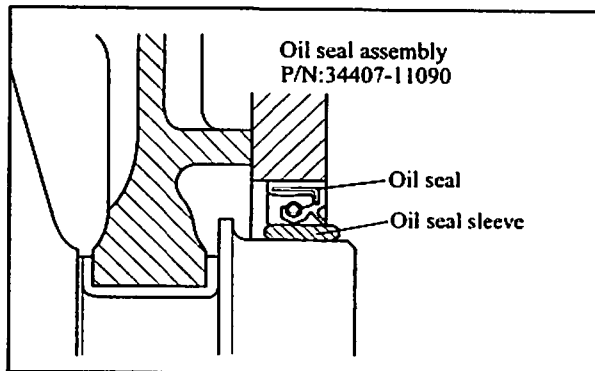
### ⚠ CAUTION

Be careful not to dent or scratch the outer surface of the oil seal sleeve.

When the oil seal slinger becomes worn after engine operation, remove the oil seal sleeve by following the procedure below, and replace it with a replacement oil seal assembly (oil seal and oil seal sleeve).



Installation of oil seal sleeve



Inspection of oil seal contact surface

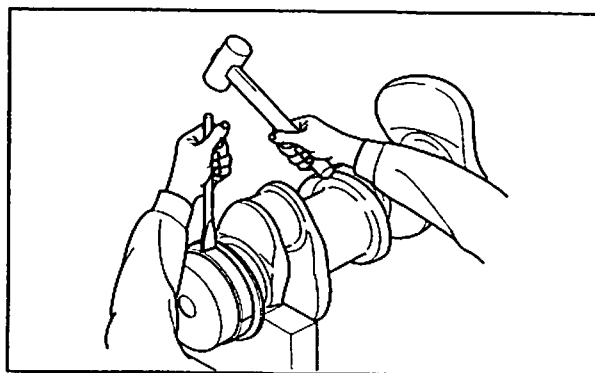
#### (2) Removal of oil seal sleeve

At three locations on the sleeve end face, hold a chisel at a right angle to the sleeve and strike with a hammer, and remove the sleeve when it becomes loose.

If this method does not allow the removal of the sleeve, hold the chisel in the axial direction and lightly tap to expand and loosen the sleeve.

### ⚠ CAUTION

Be careful not to damage the crankshaft with the chisel when removing the oil seal sleeve.



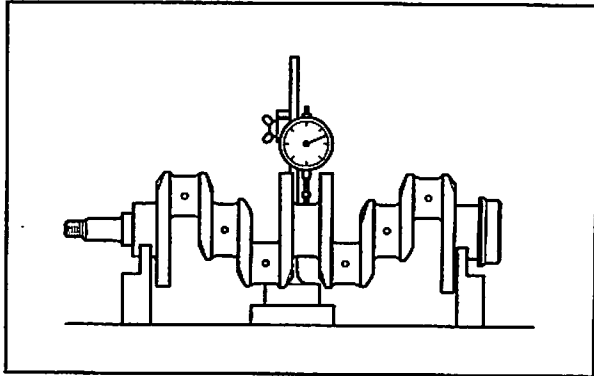
Removal of oil seal sleeve

**4.11 Measurement of Crankshaft Deflection**

Support the crankshaft on its front and rear journals in V-blocks, and measure the runout at the center journal with a dial gage. Compare the amount of runout with the standard. If the runout is small, correct by grinding. If the runout is large, straighten with a press.

If the runout exceeds the limit significantly, replace the crankshaft.

	Unit mm [in.]	
	Standard	Limit
Crankshaft deflection	0.02 [0.0008] or less	0.05 [0.0020]

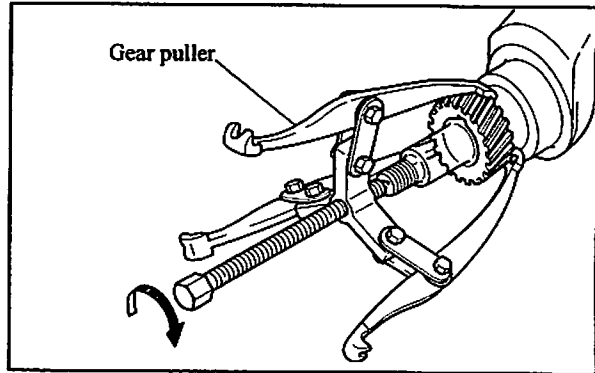


Measurement of crankshaft deflection

**4.12 Removal of Crankshaft Gear**

Use the gear puller to remove the crankshaft gear.

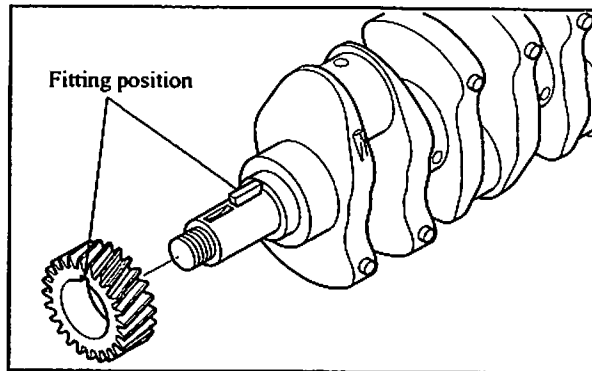
**Note:** Do not remove the crankshaft gear unless the crankshaft or gear is replaced.



Removal of crankshaft gear

**4.13 Installation of Crankcase Gear**

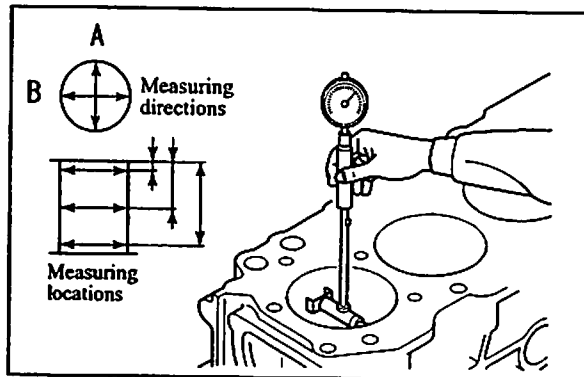
- (1) Heat the gear to a temperature of 100 to 150 °C [212 to 302 °F].
- (2) Install the key to the crankshaft.
- (3) Align the gear with the key and insert the gear fully.



Installation of crankshaft gear

4.14 Measurement of Cylinder Bore

- (1) Using a cylinder gage, measure the cylinder bore and cylindricity. If the limit value is exceeded even at one place, bore all cylinders and replace the pistons and piston rings with oversize pistons and piston rings. Measure at three locations each in directions A and B shown in the diagram.



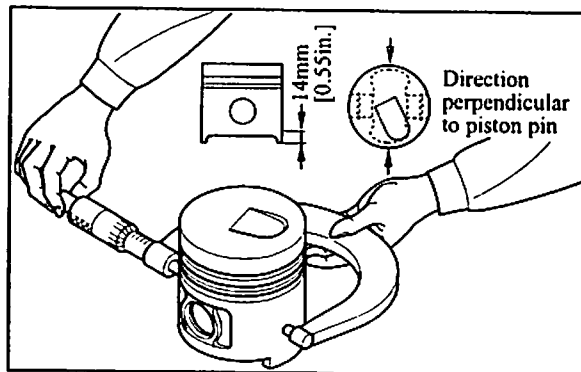
Measurement of inside diameter of cylinder

Unit mm [in.]

Type of piston and piston ring		Cylinder bore	
Size	Size code	Standard	Limit
S.T.D	STD	$\phi 88^{+0.035}_0$ [3.46 <sup>+0.0014</sup> ]	Reference value +0.2 [+0.0079]
0.25 [0.01] O.S	25 [0.984]	$\phi 88.25^{+0.035}_0$ [3.47 <sup>+0.0014</sup> ]	
0.50 [0.02] O.S	50 [1.969]	$\phi 88.50^{+0.035}_0$ [3.48 <sup>+0.0014</sup> ]	
Cylindricity of cylinder bore		0.015 [0.00059] or less	-

(2) Boring of cylinders

- (a) Since there are two piston oversizes (0.25 mm [0.0098 in.] and 0.50 mm [0.0197 in.] oversize) as indicated above, determine the appropriate piston size to be used based on the largest cylinder bore diameter.
- (b) Measure the outside diameter of the piston to be used.  
The piston diameter measuring points are shown in the diagram.
- (c) Based on the measurements of the piston outside diameter, calculate the finishing dimension to be achieved by boring.
- A: Piston outside diameter measurement (selected oversized piston) mm [in.]
  - B: Clearance between piston and cylinder (standard value) 0.03 mm [0.0012 in.]
  - C: Honing allowance 0.04 mm [0.0016 in.] or less in diameter



Measurement of piston outside diameter

$$\text{Finishing dimension} = A + B - C$$

- (d) Bore the cylinders to the calculated dimension.

**⚠ CAUTION**

Bore the cylinders in the order of the cylinder numbers to prevent distortion due to the heat generated by the boring operation.

- (e) Hone the cylinders to the final dimension (piston outside diameter + cylinder clearance).

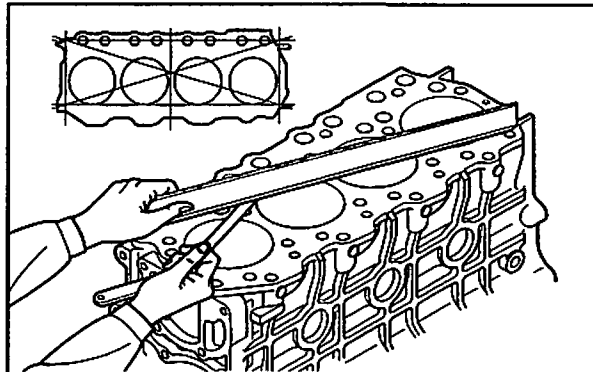
**4.15 Measurement of Distortion of Crankcase Upper Surface**

Using a straight edge and feeler gages, measure the warpage of the top face of the crankcase at the locations shown in the diagram.

If the limit value is exceeded, grind the crankcase face.

Unit mm [in.]

	Standard	Limit
Warpage of crankcase upper surface	0.05 [0.0020] or less	0.20 [0.0079]



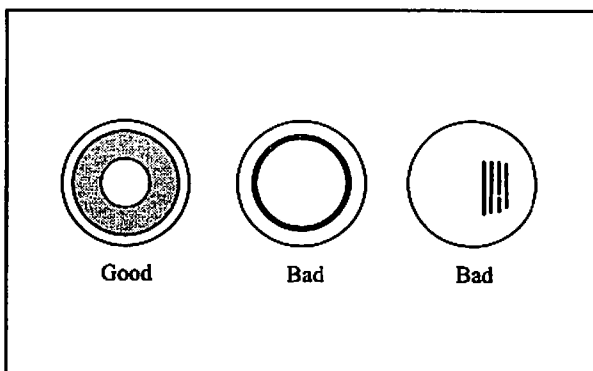
Measurement of warpage of crankcase upper surface

**⚠ CAUTION**

The maximum limit of stock to be removed from the crankcase and cylinder head by grinding should be less than 0.2 mm [0.0079 in.].

**4.16 Inspection of Cam Contacting Surfaces of Tappets**

Check the cam contact face of each tappet for wear, and replace badly worn tappets.



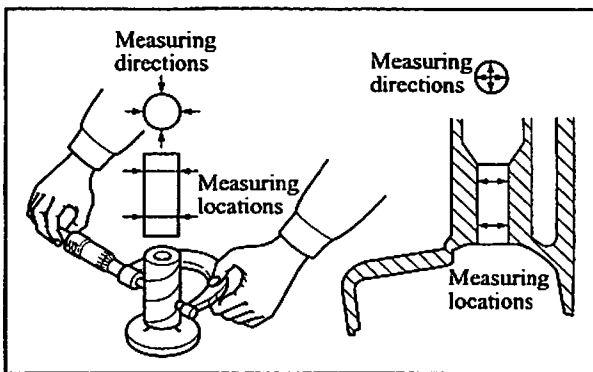
Cam contact face of tappet

**4.17 Measurement of Clearance between Tappet and Tappet Guide Bore**

Measure the clearance between each tappet and the diameter of the tappet guide bore in the crankcase, and, if the limit value is exceeded, replace the tappet.

Unit mm [in.]

	Nominal value	Standard	Limit
Diameter of tappet guide bore	φ14 [0.5516]	14.000 to 14.018 [0.5516 to 0.5523]	14.100 [0.5555]
Clearance between tappet and tappet guide bore	-	0.016 to 0.052 [0.0006 to 0.0020]	0.080 [0.0032]



Measurement of clearance between tappet and tappet guide bore

**Note:** If the tappet guide bores are worn beyond the limit value, replace the crankcase.

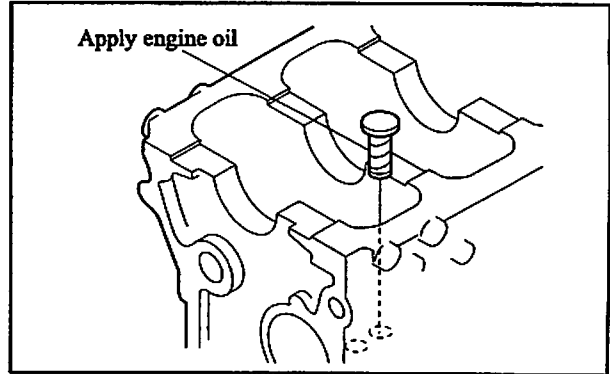
# REASSEMBLY OF ENGINE MAIN PARTS

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1. Pistons, Connecting Rods, Crankshaft and Crankcase

1.1 Installation of Tappets

- (1) Apply engine oil to the outside surfaces of tappets, and insert them into the tappet bores in the crankcase.
- (2) Make sure that the tappets rotate smoothly.



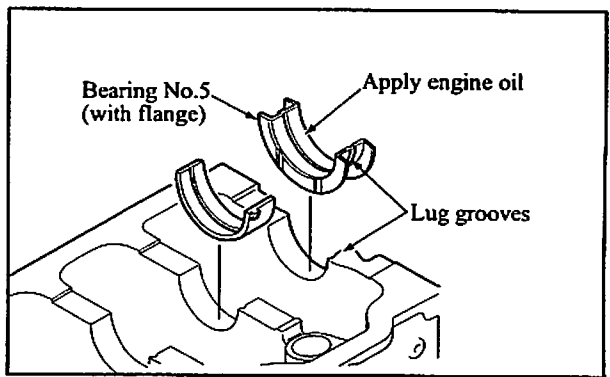
Installation of tappet

1.2 Installation of Main Bearings

- (1) Install the main bearings (upper and lower halves) to the crankcase and main bearing caps by inserting them into the lug grooves.

**Note:** Install the bearings with lug groove to the crankcase, and the bearings without lug groove to the main bearing caps.

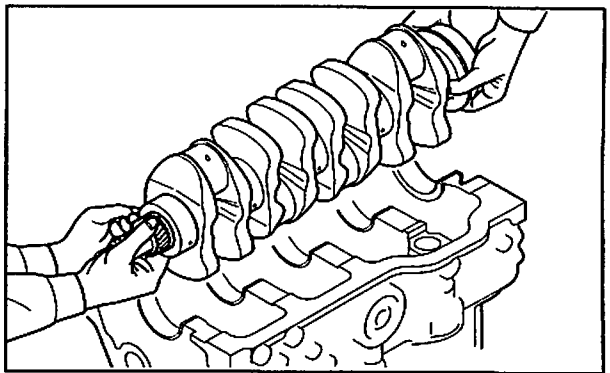
- (2) Install the flanged bearing to the aftermost (No. 5) journal.
- (3) Apply a small amount of engine oil to the inside surface of each bearing.



Installation of main bearing

1.3 Installation of Crankshaft

- (1) Wash the crankshaft thoroughly with a cleaning solution, and dry it with compressed air. After washing the crankshaft, make sure that there is no metal particles inside the oil holes or swelling of the chamfered sections of the oil holes.
- (2) Hold the crankshaft horizontally, and carefully place it into the crankcase.
- (3) Apply a small amount of engine oil to the crankshaft journals.



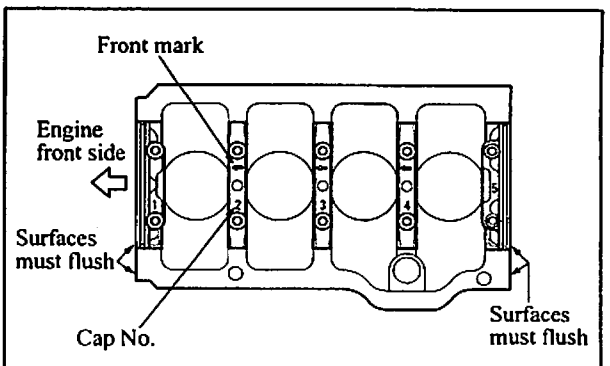
Installation of crankshaft

1.4 Installation of Main Bearing Caps

Fit the main bearings, making sure that the front marks (arrow) on the main bearing caps face the front of the engine and the cap numbers are in order from the front to the back.

**CAUTION**

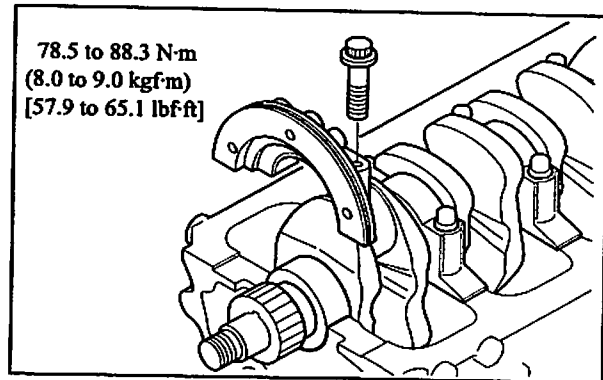
Make sure that the end faces of the bearing caps No. 1, 5 are flush with the crankcase end faces.



Installation of main bearing cap

**1.5 Tightening of Bearing Cap Bolts**

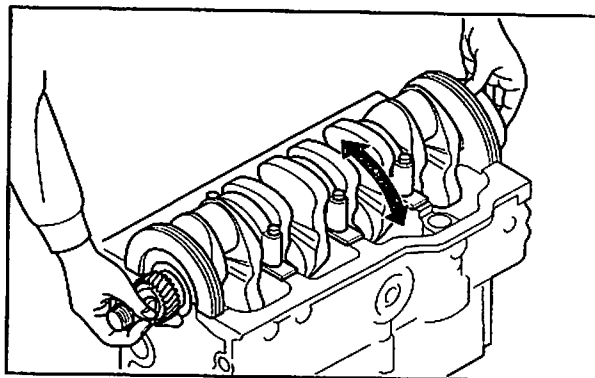
Tighten the main bearing cap bolts alternately to the specified torque.



Installation of main bearing cap bolt

**1.6 Inspection of Crankshaft for Smooth Rotation**

Make sure that the crankshaft rotates smoothly.



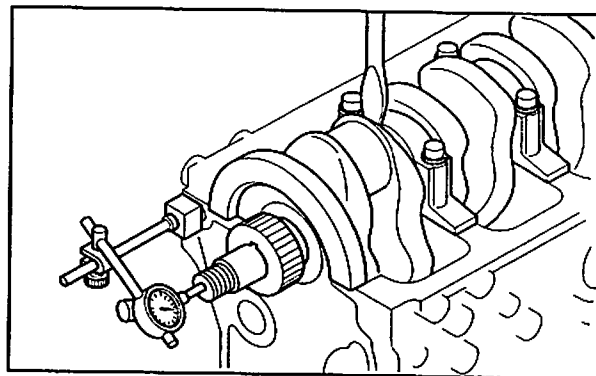
Inspection of crankshaft for smooth rotation

**1.7 Measurement of Crankshaft End Play**

(1) Measure the crankshaft end play.

	Unit mm [in.]	
	Standard	Limit
Crankshaft end play	0.100 to 0.204 [0.0039 to 0.0080]	0.300 [0.0118]

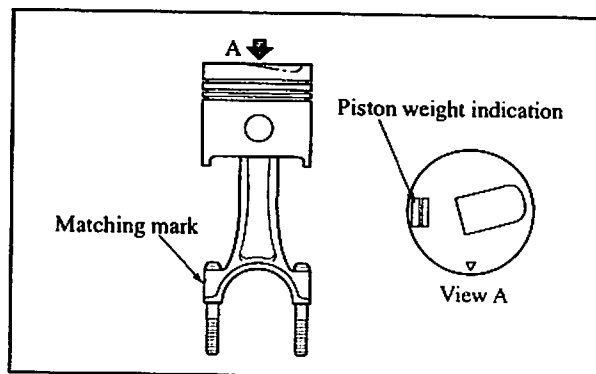
- (2) If the end play is too small, loosen the cap bolts, and retighten them.
- (3) If the limit value is exceeded, replace the flanged bearing.



Measurement of crankshaft end play

**1.8 Assembly of Pistons and Connecting Rods**

- (1) Assemble the piston and connecting rod by positioning the piston weight indication and the connecting rod matching mark face the same direction.
- (2) Coat the piston pin with engine oil, and install the pin to connect the connecting rod to the piston.

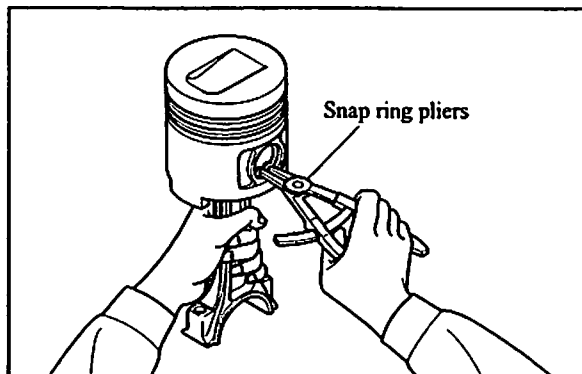


Assembly of piston and connecting rod 1

- (3) Install the snap rings in the grooves in the piston using ring pliers.

Check the snap rings for tension and proper fitting.

Note: The snap ring ends must be positioned toward the bottom of the piston.

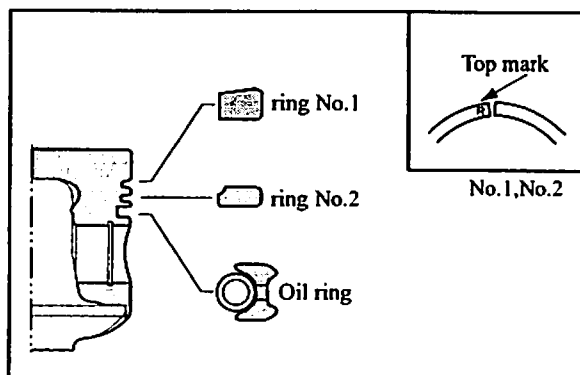


Assembly of piston and connecting rod 2

### 1.9 Installation of Piston Rings

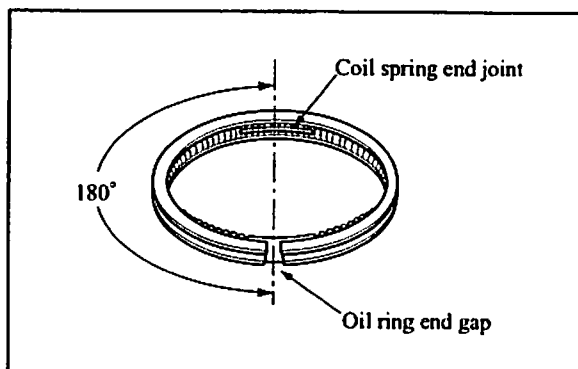
- (1) Using piston ring pliers, install the compression rings (No. 1, No. 2) and oil ring on the piston.

Note: The marks on rings No. 1 and No. 2 must be positioned toward the top of the piston.



Installation of piston rings on piston

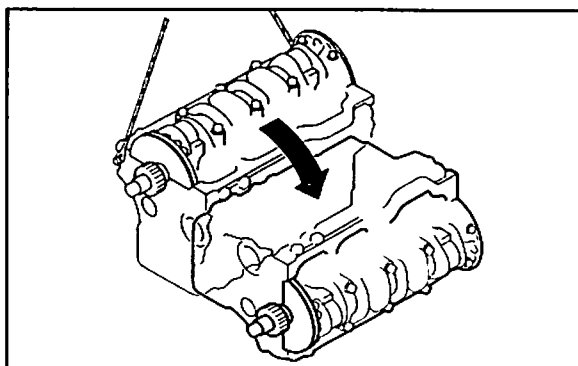
- (2) Install the oil ring in such a way that its ring end gap is positioned 180° from the joint of the oil spring.



Positioning of oil ring and coil spring

### 1.10 Laying Crankcase on Its Side

Gently lay the crankcase on its side.

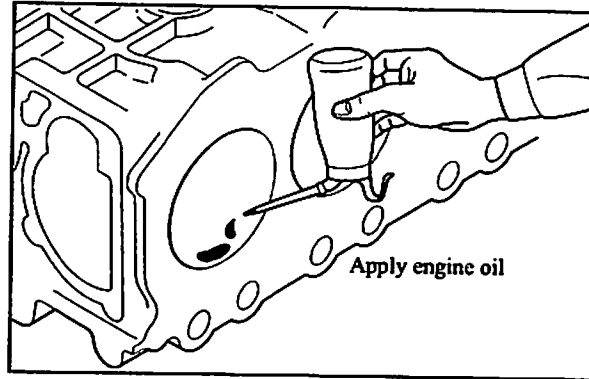


Laying of crankcase on its side



**1.11 Preparation for Piston Installation**

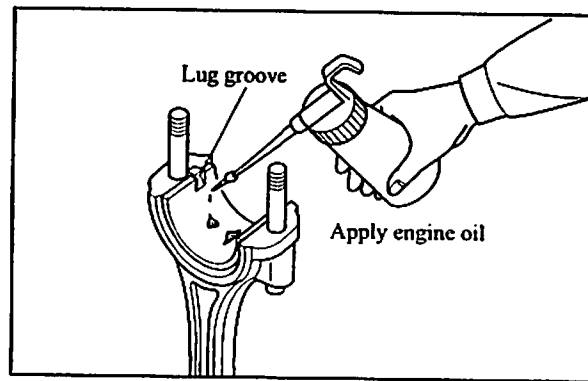
After cleaning the inside surface of the cylinder with a clean cloth, apply engine oil to the surface.



Preparation for piston installation

**1.12 Installation of Connecting Rod Bolts and Bearings**

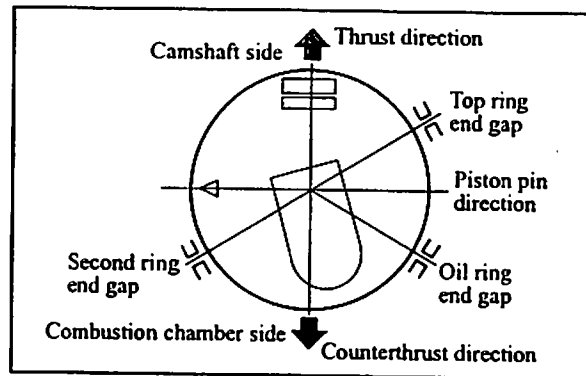
- (1) Before installing the bearing, insert the connecting rod bolts so that the notched face of the head is securely positioned.
- (2) Install the upper half of the connecting rod bearing to the big-end bore of the connecting rod by aligning the lug grooves, and apply engine oil to the inside surface.



Installation of connecting rod bearing

**1.13 Installation of Pistons**

- (1) Apply engine oil to the piston rings.
- (2) Set the piston ring end gaps away from one another, also making sure that they do not align with the pin direction, thrust direction or counterthrust direction.



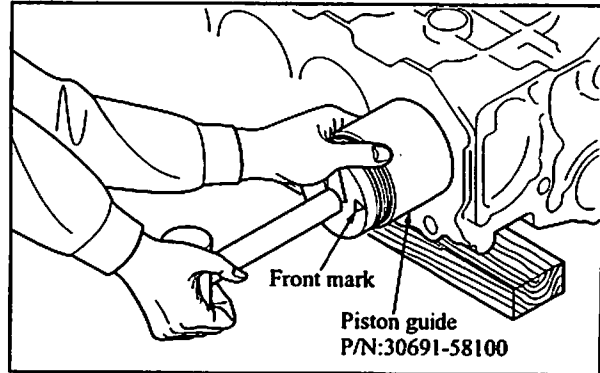
Installation of piston (1)

- (3) Bring the cylinder No. 1 (No. 4) crankpin to the top dead center.
- (4) Align the piston guide with the center of the cylinder, and hold it at the top surface of the crankcase by hand.
- (5) Position the "Trigona" mark stamped on the top surface of the piston toward the front of the crankcase, and insert the piston and connecting rod assembly into the cylinder using the installer.

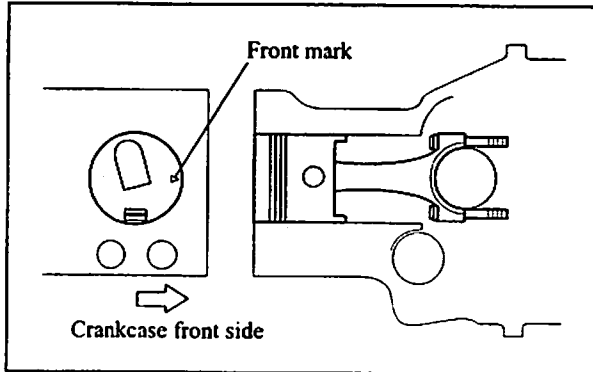
**Note:** After inserting the piston, make sure that the direction of the connecting rod big-end bore matches the crankpin direction.

- (6) Lightly tap the top surface of the piston with the handle of a hammer to fit the connecting rod big-end bore to the crankpin.

**Note:** Make sure that the connecting rod bearing upper half is in place by feeling with a finger.



Installation of piston (2)



Installation of piston (3)

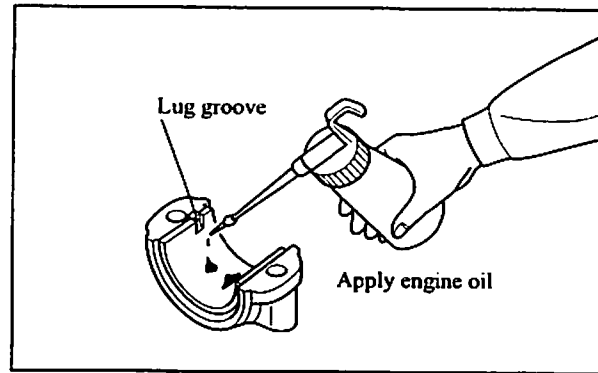
**CAUTION**  
Be careful not to damage the crankshaft with the big-end bore of the connecting rod.

#### 1.14 Installation of Connecting Rod Caps

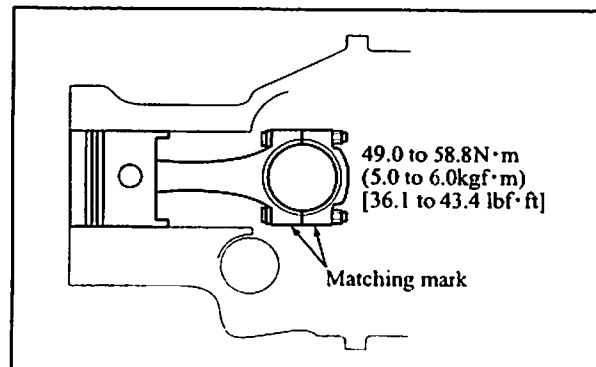
- (1) Install the connecting rod bearing lower half to the connecting rod cap by fitting it into the lug groove, and apply engine oil.
- (2) Install the connecting rod cap to the connecting rod (crankpin), making sure that the matching mark aligns with that on the connecting rod.
- (3) Tighten the connecting rod cap nuts finger tight.

**Note:** Conduct the above steps for cylinders No. 1 and No. 4 at the same time, and repeat the same steps for cylinders No. 2 and No. 3.

- (4) Tighten the connecting rod nuts alternately to the specified torque using a torque wrench.
- (5) Check the connecting rod end play, and, if the end play is too small, loosen the cap nuts and then retighten them.



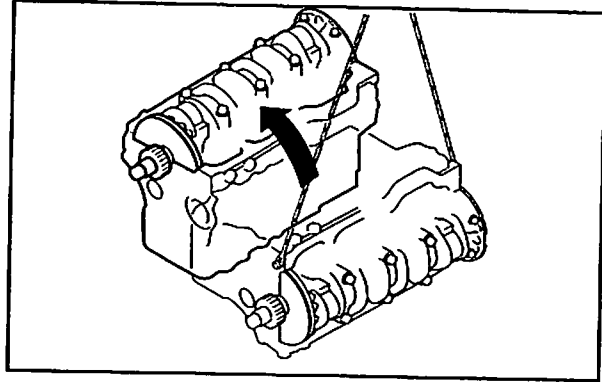
Installation of connecting rod cap (1)



Installation of connecting rod cap (2)

**1.15 Positioning Crankcase Upright**

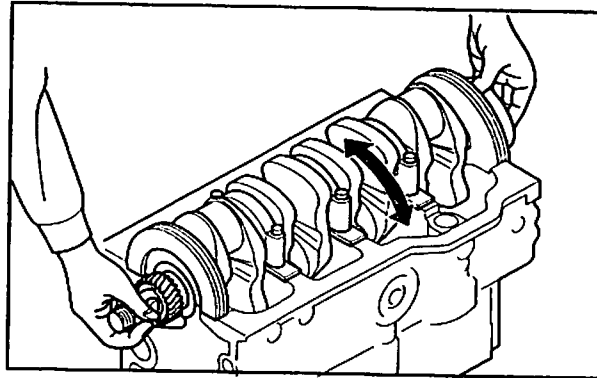
With the oil pan mounting side facing upward, stand the crankcase upright.



Positioning crankcase upright

**1.16 Inspection of Crankshaft for Smooth Rotation**

Make sure that the crankcase rotates smoothly.

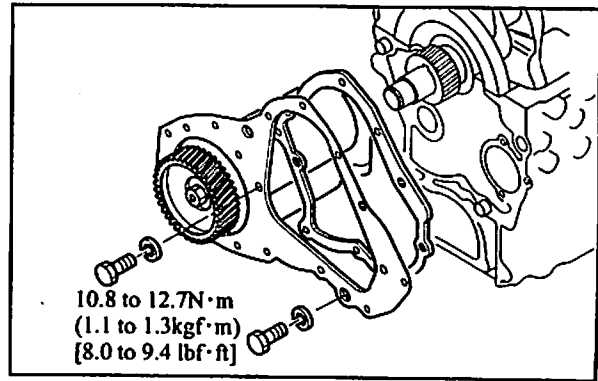


Inspection of crankcase for smooth rotation

2. Timing Gears, Camshaft and Oil Pan

2.1 Installation of Front Plate

- (1) Install the gasket and front plate (mounted with injection pump) to the front face of the crankcase, making sure that the dowel pins enter holes properly.
- (2) Tighten the two bolts to the specified torque.

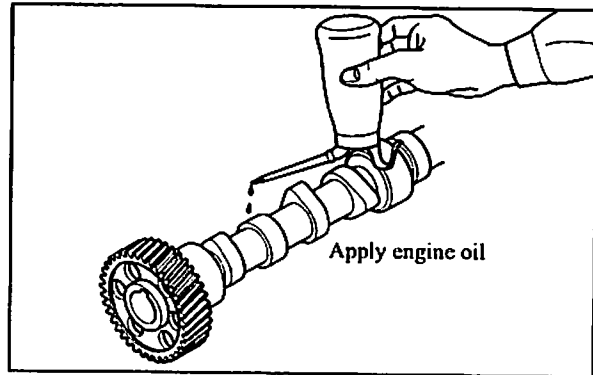


Installation of front plate

2.2 Installation of Camshaft

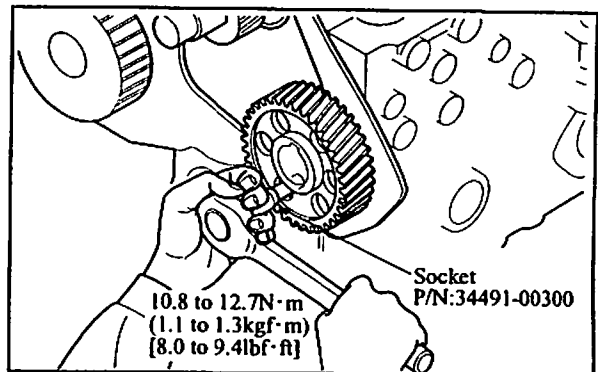
- (1) Apply engine oil to the camshaft journals and cams.
- (2) Insert the camshaft (mounted with gear) into the crankcase.

**⚠ CAUTION**  
Be careful not to damage the journals or cam lobes.



Application of engine oil to camshaft

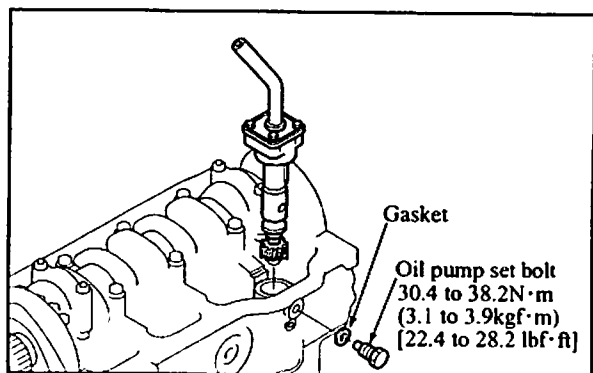
- (3) Using a torque wrench and the socket, tighten the thrust plate mounting bolts to the specified torque.
- (4) Make sure that the camshaft rotates smoothly. Also, move the camshaft back and forth to make sure there is sufficient end play.



Installation of camshaft

2.3 Installation of Oil Pump

- (1) Insert the oil pump into the mounting hole in the crankcase. Make sure that the oil pump gear engages properly with the oil pump drive gear on the camshaft.
- (2) Install the oil pump set bolt and gasket on the side of the crankcase, and tighten to the specified torque.

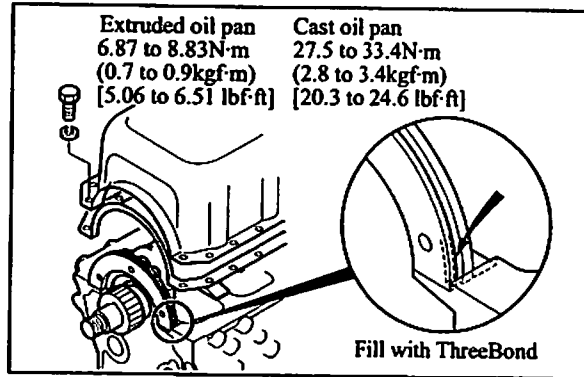


Installation of oil pump

**2.4 Installation of Oil Pan**

Clean both gasket contact surfaces and the mating parts to ensure they are free of dirt and grime.

- (1) Apply a liberal amount of ThreeBond 1207 or 1211 to the mating surfaces (grooves) of main bearing caps No. 1 and No. 5 and crankcase.  
A sufficient amount of the sealant should be applied so that a small amount is pushed out when the oil pan gasket is installed.
- (2) Install the oil pan gasket to the bottom surface of the crankcase, pushing the curved section into the grooves of main bearing caps No. 1 and No. 2 and the protruded sections into the grooves where ThreeBond was filled.
- (3) Install the oil pan and tighten the bolts to the specified torque.

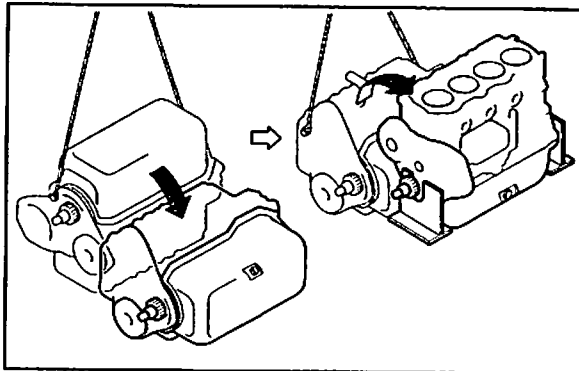


Installation of oil pan

**2.5 Reversal of Crankcase**

Gently lay the crankcase on its side, then position the crankcase upright.

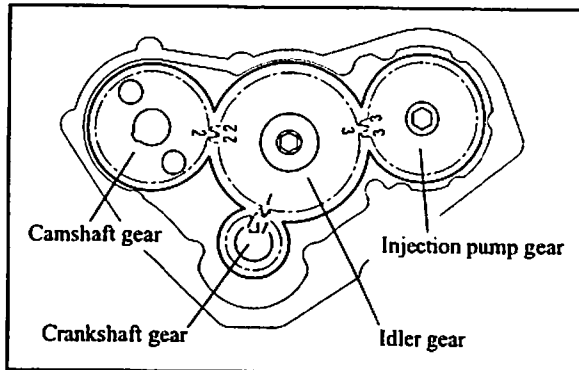
**CAUTION**  
Resting the crankcase with the oil pan on the bottom can cause the oil pan to crack.



Reversal of crankcase

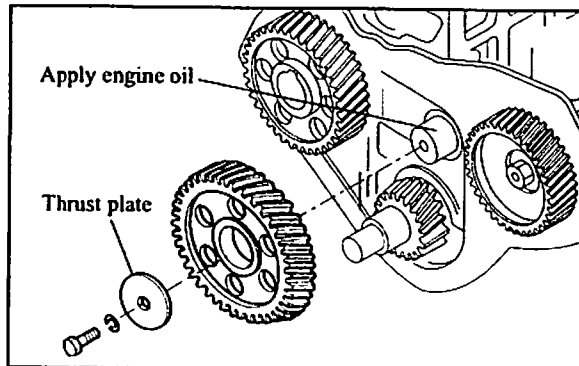
**2.6 Installation of Idler Gear**

- (1) Apply engine oil to the idler shaft.
- (2) Align the matching marks on all gears, and install the idler gear to the idler shaft.



Timing gear train

- (3) Put the thrust plate on the idler gear, and tighten the bolt.
- (4) Move the idler gear back and forth to make sure there is sufficient end play.

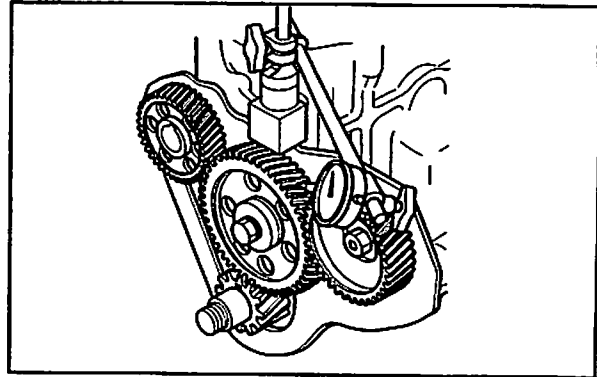


Installation of idler gear

**2.7 Inspection after Timing Gear Installation**

When the timing gears have been disassembled and reassembled, be sure to check the gear backlashes after reassembly.

Backlash	Unit mm [in.]	
	Standard	Limit
Crankshaft gear -idler gear	0.03 to 0.16 [0.0012 to 0.0063]	0.25 [0.0099]
Idler gear -camshaft gear	0.04 to 0.17 [0.0016 to 0.0067]	0.25 [0.0099]
Injection pump gear -idler gear	0.03 to 0.18 [0.0012 to 0.0071]	0.25 [0.0099]

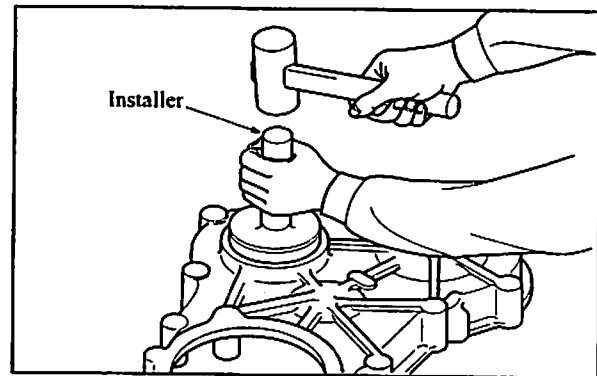


Measurement of timing gear backlash

**2.8 Installation of Oil Seal**

Install a new oil seal to the timing gear case using the installer.

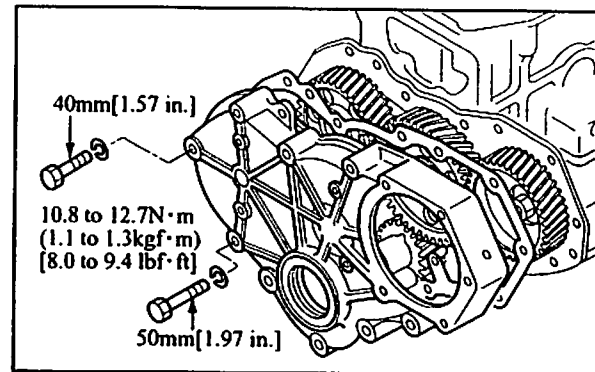
Make sure that the lip section of the oil seal faces toward the inside of the gear case and the oil seal is flush with the gear case face.



Installation of oil seal

**2.9 Installation of Timing Gear Case**

- (1) Install the baffle plate to the crankshaft.
- (2) Install the gasket and timing gear case to the crankcase, aligning the holes with the dowel pins.
- (3) Screw the bolts and tighten to the specified torque.



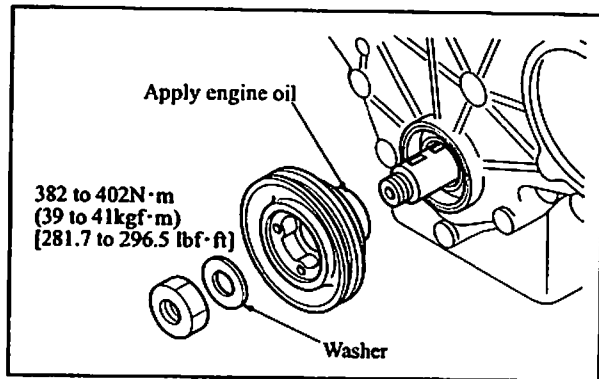
Installation of timing gear case

### 2.10 Installation of Crankshaft Pulley

- (1) Coat the oil seal contact surface of the pulley with engine oil.
- (2) Push the pulley onto the crankshaft, making sure that the notch on the pulley is aligned with the key.
- (3) By using the bolt holes located on the back-end of the crankshaft, prevent the crankshaft from rotating.
- (4) Place the washer and tighten the nut to the specified torque.

#### CAUTION

To ensure safety, make sure that the bolts and bar for the prevention of crankshaft rotation have sufficient strength.

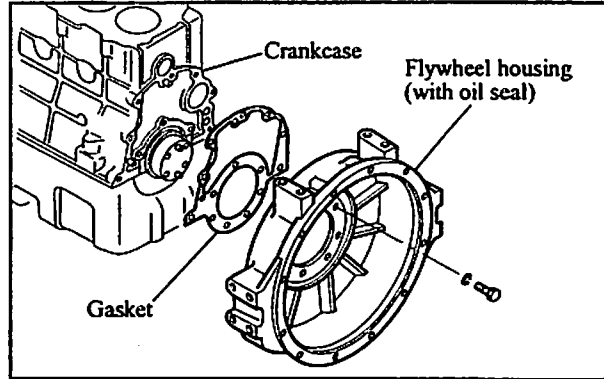


Installation of crankshaft pulley

### 3. Flywheel

#### 3.1 Installation of Flywheel Housing

- (1) Install the oil seal to the flywheel housing.
- (2) Coat the contact surfaces of the crankcase and flywheel with ThreeBond 1104.
- (3) Align the holes in the flywheel housing and gasket with the dowel pins on the crankcase, and install them to the crankcase.



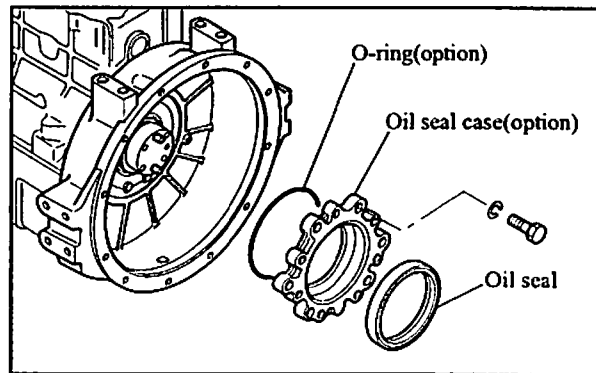
Installation of flywheel housing

#### 3.2 Installation of Oil Seal Case (Option)

- (1) Coat the outside surface of the oil seal with engine oil.
- (2) Install the oil seal on the oil seal case.
- (3) Coat the lip of the oil seal with engine oil.
- (4) Install the O-ring into the oil seal case, and install the oil seal case on the flywheel housing.

Note: The oil seal case must be installed with the "Q" mark facing up.

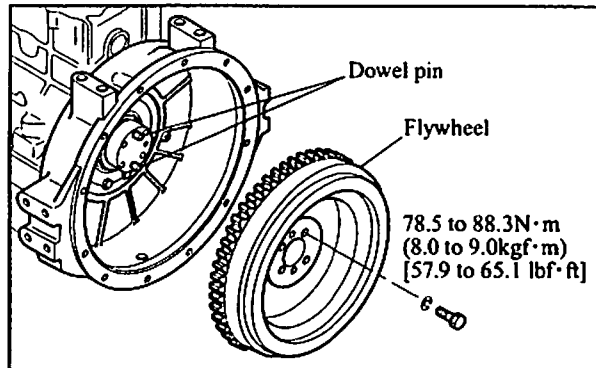
- (5) Secure the oil seal case with the bolts.



Installation of oil seal case (option)

#### 3.3 Installation of Flywheel

- (1) Install the flywheel to the crankshaft by aligning the hole with the dowel pin on the back-end of the crankshaft.
- (2) Place the washer and tighten the four bolts to the specified torque.



Installation of flywheel

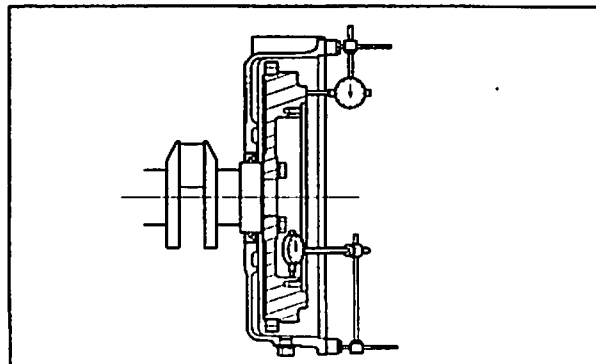
#### 3.4 Measurement of Flywheel Runout

Measure the flywheel runout with the flywheel installed to the crankshaft.

If the standard value is exceeded, check to the bolts for tightening condition and the mounting face for adhesion of foreign particles.

Unit mm [in.]

	Standard	Limit
Flywheel runout	0.10 [0.0039] or less	0.50 [0.0197]



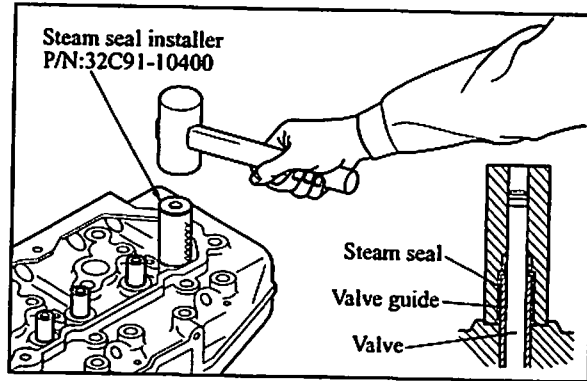
Measurement of face runout and circular runout



#### 4. Cylinder Head and Valve Mechanisms

##### 4.1 Installation of Valve Stem Seals

- (1) Apply engine oil to the valve stem, and insert it into the valve guide.
- (2) Place a new stem seal on the valve guide.
- (3) Using the stem seal installer, install the stem seal to the valve guide, making use of the valve stem as a guide.



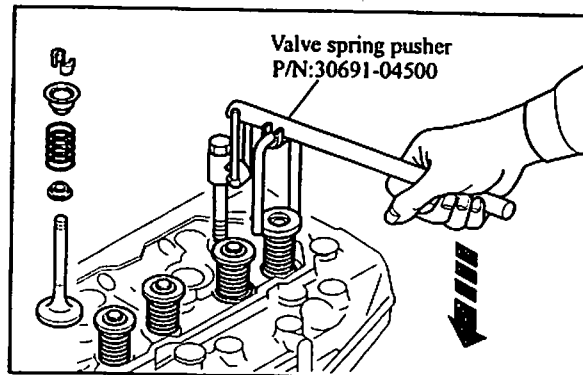
Installation of valve stem seal

##### 4.2 Installation of Valves and Valve Springs

- (1) Place the valve spring and retainer on the valve guide, and install the valve cotter using the valve spring pusher.

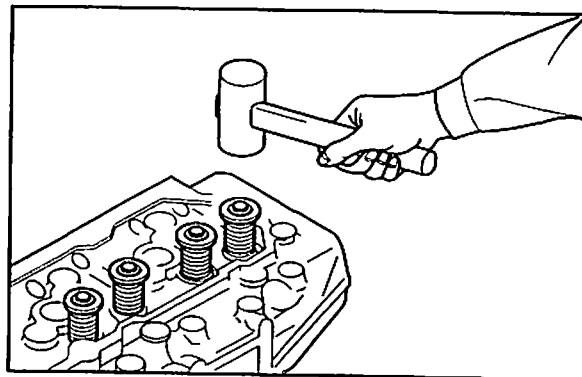
### CAUTION

Excessive compression of the valve spring can cause the retainer to contact the stem seal and damage the seal.



Installation of valve and valve spring

- (2) Using a soft-faced hammer, tap the top of the valve stem several times to make sure that the spring and valve cotter are securely installed.



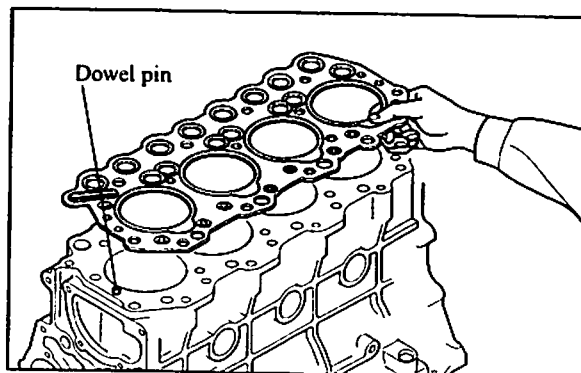
Confirmation of secure valve cotter installation

##### 4.3 Installation of Cylinder Head Gasket

- (1) Make sure that the top face of the crankcase and piston upper surfaces are clean and free of dust.
- (2) Place a new gasket on the crankcase, making sure that the dowel pins on the top face of the crankcase enter the holes in the gasket.

### CAUTION

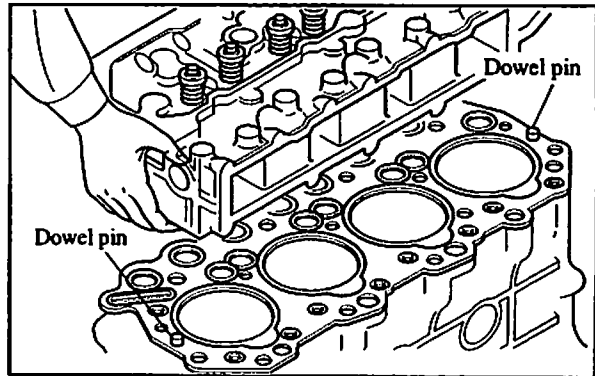
Do not use a liquid gasket.



Installation of cylinder head gasket

**4.4 Installation of Cylinder Head**

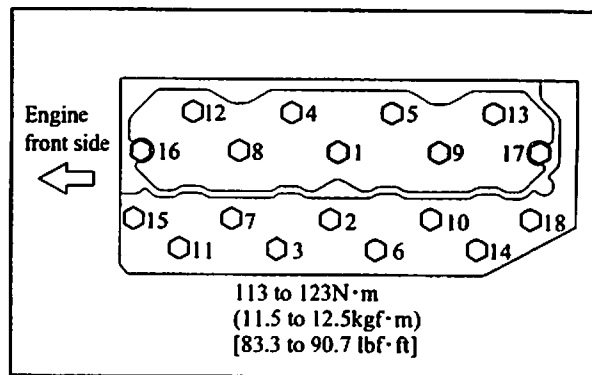
Place the cylinder head on the head gasket, making sure that the dowel pins on the top face of the crankcase enters the holes in the cylinder head.



Installation of cylinder head

**4.5 Tightening of Cylinder Head Bolts**

Tighten the cylinder head bolts, following the tightening sequence shown in the diagram two or three times before reaching the specified torque.

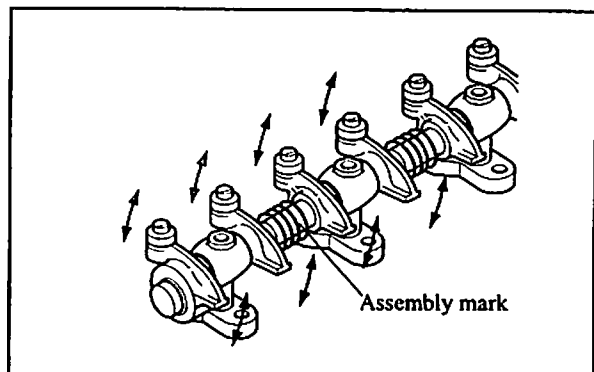


Cylinder head bolt tightening sequence

**4.6 Assembly of Rocker Arm and Rocker Shaft Assembly**

When installing the rocker arms, make sure that the shaft assembly marks face the front of the engine, as shown in the diagram.

After the assembly, make sure that the rocker arms move smoothly.



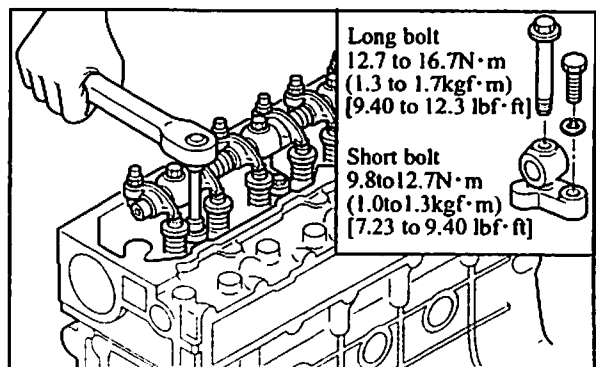
Assembly of rocker shaft assembly

**4.7 Installation of Pushrods**

- (1) Insert the pushrods in the cylinder head through the pushrod holes.
- (2) Make sure that the ball end of each pushrod rests securely on the curved surface of the tappet.

**4.8 Installation of Rocker Shaft Assembly**

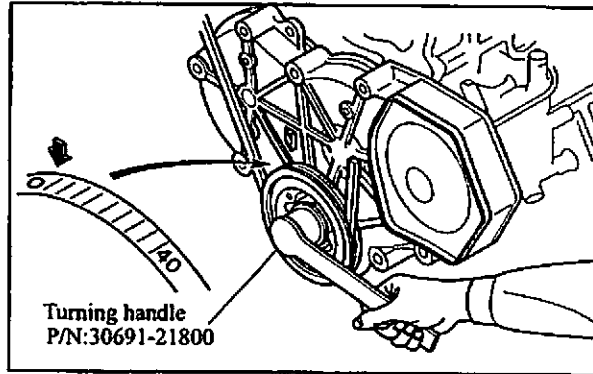
- (1) Install the valve caps.
  - (2) Tighten the rocker shaft bracket mounting bolts in reverse order of removal.
- Tighten the long bolts to the specified torque first and then the short bolts to the specified torque.



Installation of rocker shaft assembly

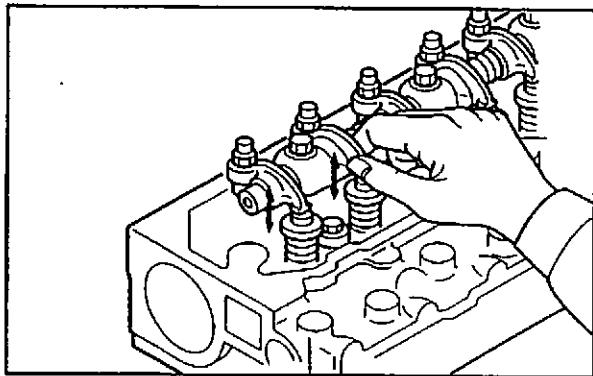
**4.9 Adjustment of Valve Clearances**

- (1) **Confirming the top dead center on the compression stroke for cylinder No. 1**
  - (a) By engaging the turning handle on the crankshaft pulley nut, turn the engine in the forward rotating direction (clockwise when viewed from the front of the engine).
  - (b) Stop turning when the "0" line stamped on the periphery of the crankshaft pulley aligns with the pointer on the timing gear case.



Turning engine

- (c) Move up and down the inlet and exhaust valve rocker arms of cylinder No. 1 to make sure that they are not being pushed up by the pushrods. The piston in cylinder No. 1 is at the top dead center on the compression stroke when the rocker arms are not being pushed by the pushrods (there is a clearance in each valve). If the rocker arms are being pushed up by the pushrods, turn the crankshaft one more turn.



Confirmation of top dead center on compression stroke for cylinder No. 1

(2) Adjusting the valve clearances

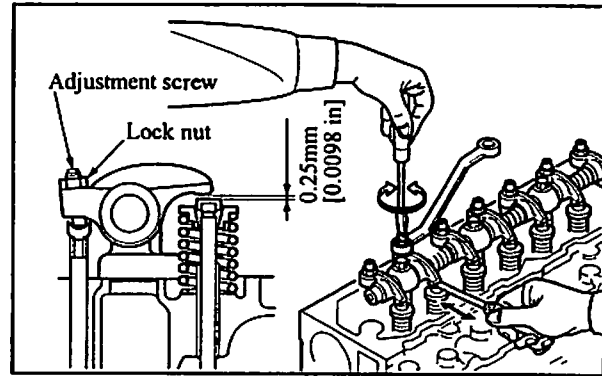
- (a) Insert a feeler gage between the rocker arm and valve cap to inspect the clearance.

		Unit mm [in.]
		Standard
Valve clearance (cold engine)	Inlet	0.25 [0.0098]
	Exhaust	0.25 [0.0098]

- (b) Loosen the lock nut, and turn the adjusting screw in either direction until the feeler gage is slightly gripped between the rocker arm and valve cap.  
 (c) After the adjustment, tighten the lock nut securely and recheck the clearance.  
 (d) Turn the engine, and check the valve clearances on the remaining cylinders.

The inspection sequence and turning angle are as follows.

Sequence (cylinder No.)	Turning angle
1-3-4-2	180°



Adjustment of valve clearance

**⚠ CAUTION**

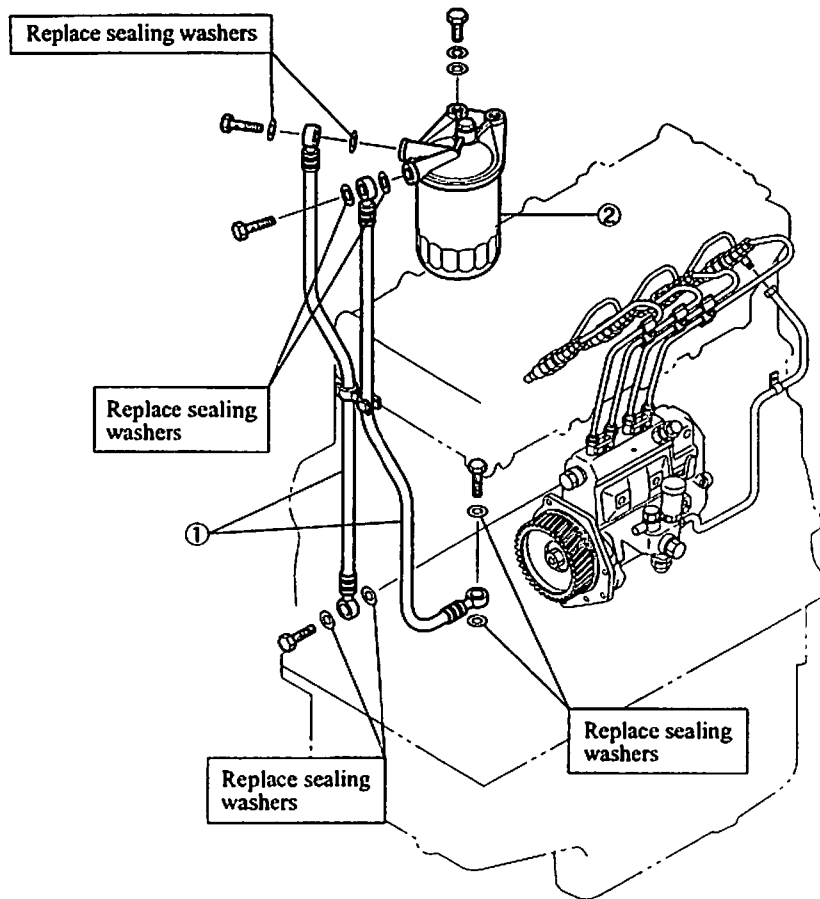
When adjusting the valve clearances after disassembly, rotate the crankshaft 2 or 3 turns after adjustment, and recheck the valve clearances to make sure that the clearances conform to the standard.

# REMOVAL OF FUEL SYSTEM

1. Fuel Filter.....	3 - 2
2. Fuel Injection Pipe, Fuel Leak-Off Pipe and Fuel Injection Nozzle.....	3 - 4
3. Fuel Injection Pump .....	3 - 6
Removal of Fuel Injection Pump .....	3 - 8

### 1. Fuel Filter

(For in-line fuel injection pump)



Removal of fuel filter (for in-line fuel injection pump)

<Removal sequence >

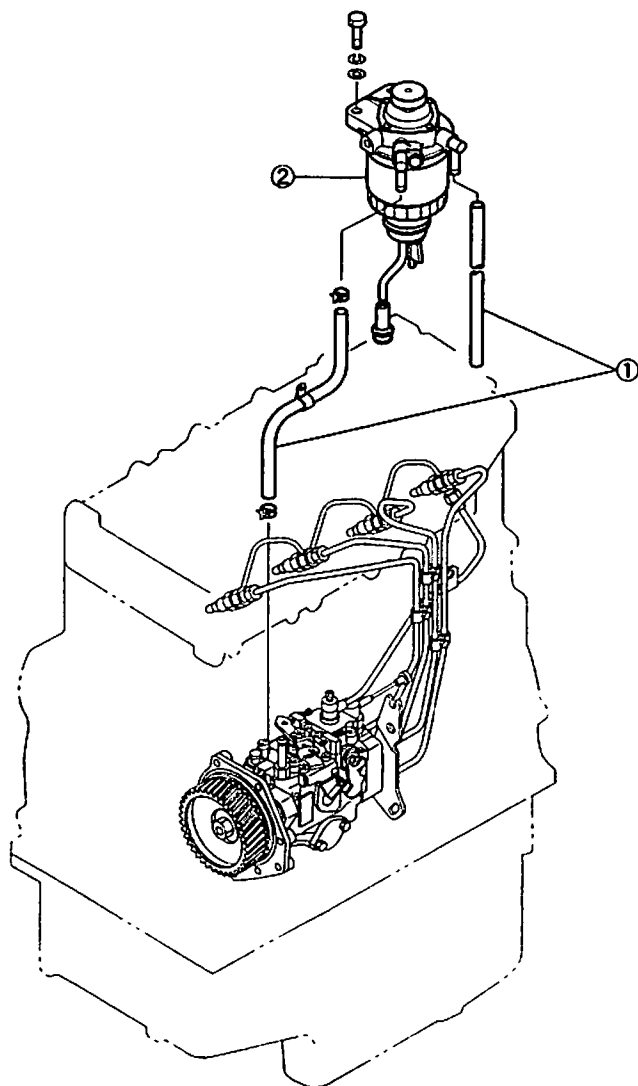
① Fuel hose

② Fuel filter

**⚠ CAUTION**

To prevent dust from entering the fuel system, cover all openings in the fuel injection pump and fuel hoses.

(For distributor-type fuel injection pump)



Removal of fuel filter (for distributor-type fuel injection pump)

<Removal sequence>

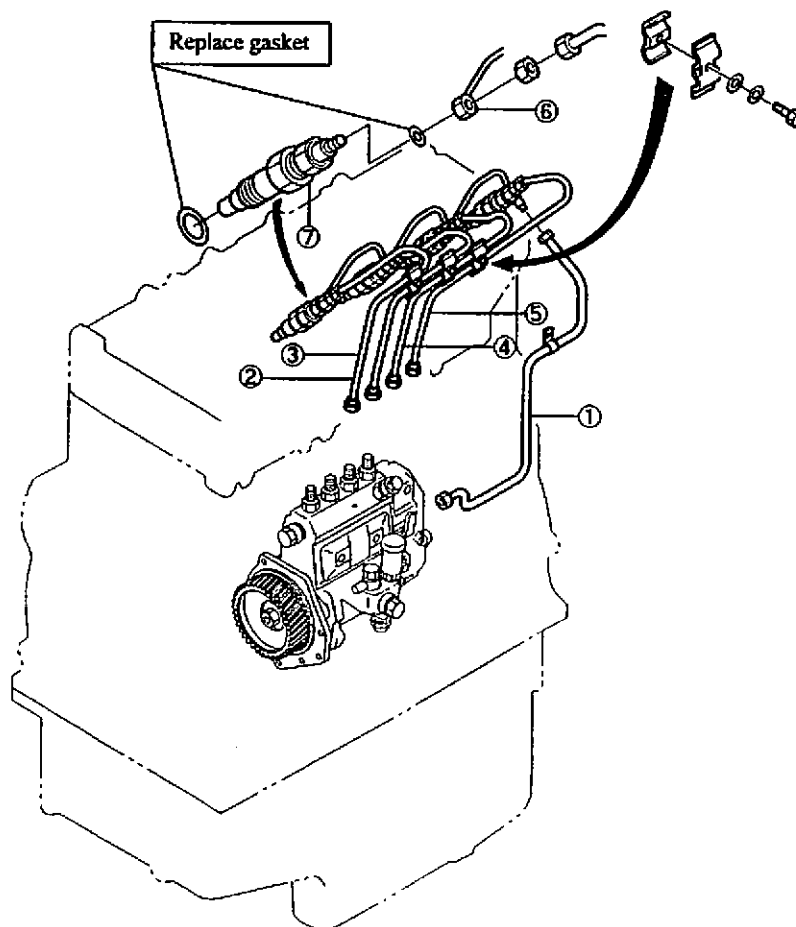
① Fuel hose

② Fuel filter

**⚠ CAUTION**

To prevent dust from entering the fuel system, cover all openings in the fuel injection pump and fuel hoses.

2. Fuel Injection Pipe, Fuel Leak-Off Pipe and Fuel Injection Nozzle  
(For in-line fuel injection pump)



Removal of fuel injection pipe, fuel leak-off pipe and fuel injection nozzle  
(for in-line fuel injection pump)

<Removal sequence >

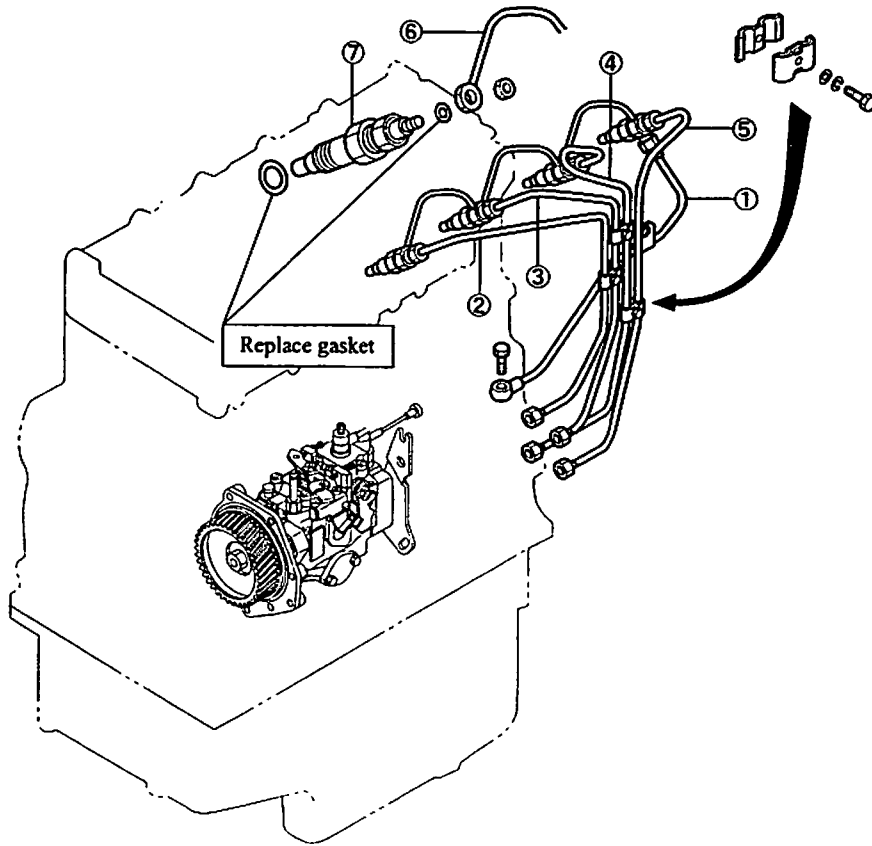
- |                            |                            |
|----------------------------|----------------------------|
| ① Fuel return pipe         | ⑤ Fuel injection pipe No.4 |
| ② Fuel injection pipe No.1 | ⑥ Fuel leak-off pipe       |
| ③ Fuel injection pipe No.2 | ⑦ Fuel injection nozzle    |
| ④ Fuel injection pipe No.3 |                            |

**⚠ CAUTION**

To prevent dust from entering the fuel system, cover all openings in the fuel injection pump, nozzle inlet connectors and injection pipes.



(For distributor-type fuel injection pump)



Removal of fuel injection pipe, fuel leak-off pipe and fuel injection nozzle  
(for distributor-type fuel injection pump)

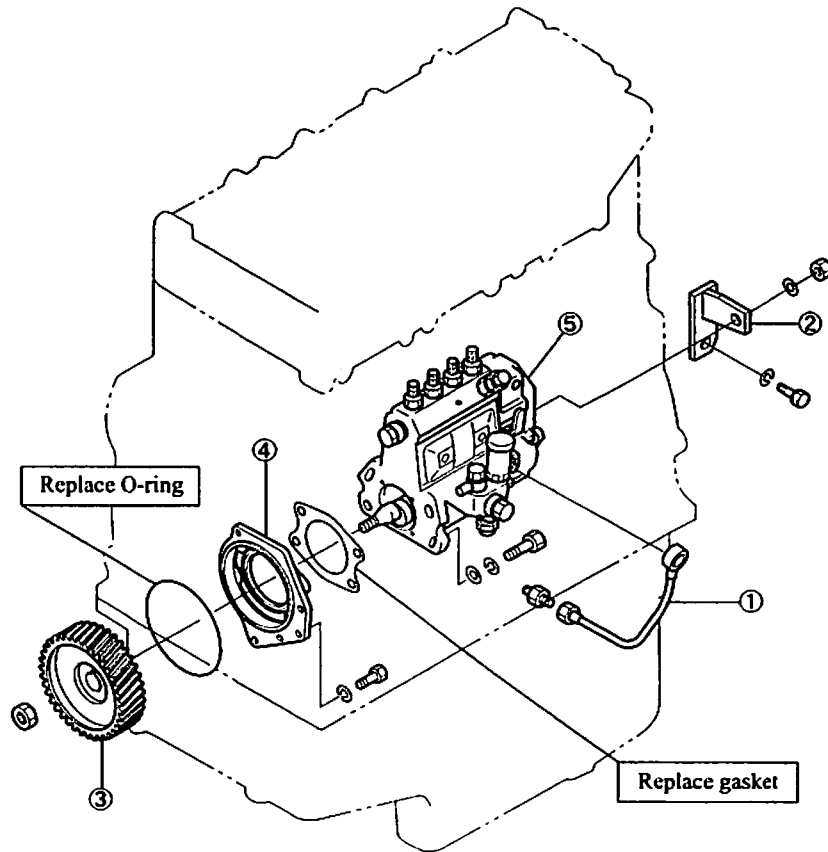
<Removal sequence>

- |                            |                            |
|----------------------------|----------------------------|
| ① Fuel return pipe         | ⑤ Fuel injection pipe No.4 |
| ② Fuel injection pipe No.1 | ⑥ Fuel leak-off pipe       |
| ③ Fuel injection pipe No.2 | ⑦ Fuel injection nozzle    |
| ④ Fuel injection pipe No.3 |                            |

**⚠ CAUTION**

To prevent dust from entering the fuel system, cover all openings in the fuel injection pump, nozzle inlet connectors and injection pipes.

### 3. Fuel Injection Pump (In-line fuel injection pump)



Removal of fuel injection pump (In-line fuel injection pump)

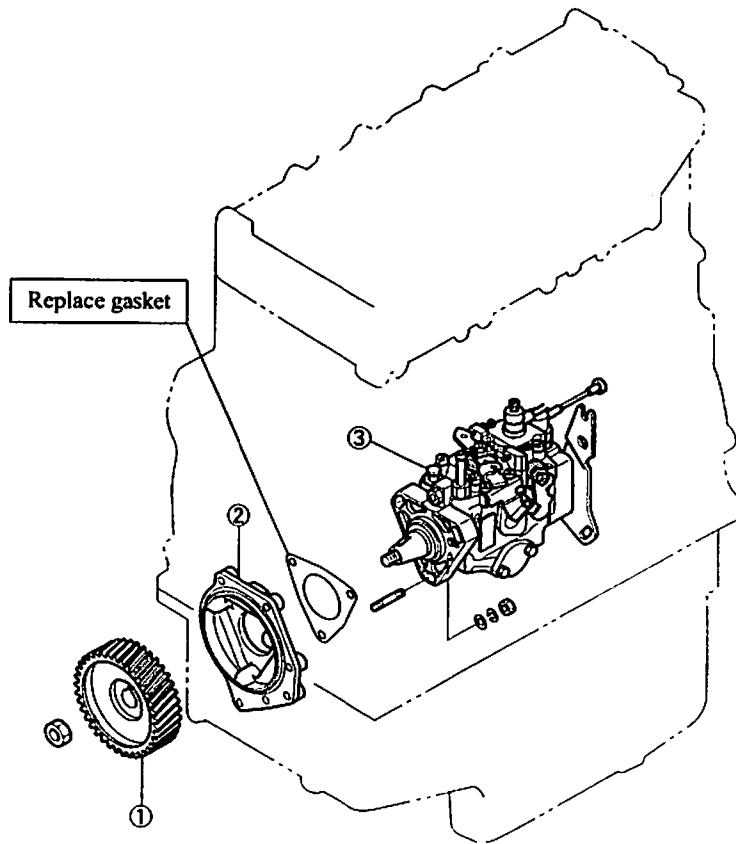
<Removal sequence >

- ① Oil pipe
- ② Pump bracket
- ③ Fuel injection pump gear
- ④ Fuel injection pump flange
- ⑤ Fuel injection pump

**⚠ CAUTION**

To prevent dust from entering the fuel system, cover all openings in the fuel injection pump.

(Distributor-type fuel injection pump)



Removal of fuel injection pump (Distributor-type fuel injection pump)

<Removal sequence >

- ① Fuel injection pump gear
- ② Fuel injection pump flange
- ③ Fuel injection pump

**⚠ CAUTION**

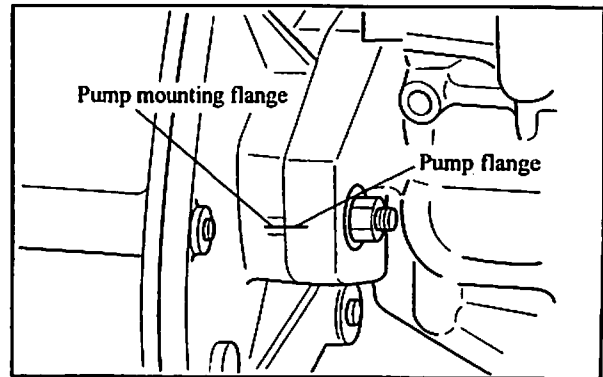
To prevent dust from entering the fuel system, cover all openings in the fuel injection pump.

## Removal of Fuel Injection Pump

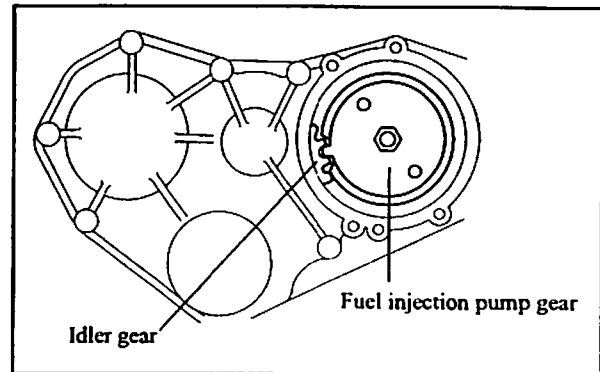
- (1) Check the alignment marks stamped on the flange of the fuel injection pump and the pump mounting flange.
- (2) Remove the front cover from the engine.
- (3) Place alignment marks on the fuel injection pump gear and idler gear.
- (4) Unscrew the mounting bolts from the fuel injection pump flange, and remove the fuel injection pump together with the flange from the front plate.

**Note:** (a) After the fuel injection pump is removed, do not turn the engine.

- (b) When removing the pump gear, loosen the gear retaining nut while the pump is mounted on the engine.



Removal of fuel injection pump 1



Removal of fuel injection pump 2

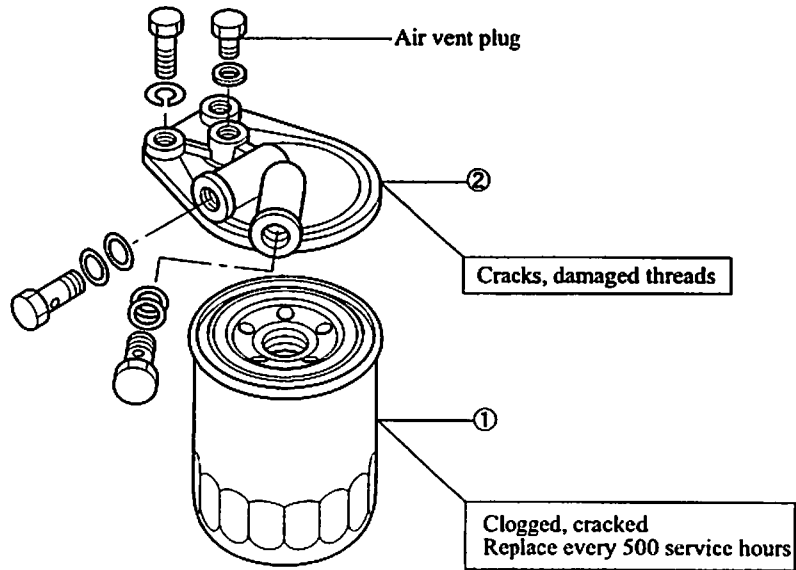
**DISASSEMBLY, INSPECTION AND REASSEMBLY OF  
FUEL SYSTEM**

- 1. Fuel Filter ..... 3 - 10
  - 1.1 Disassembly and Inspection of Fuel Filter..... 3 - 10
  - 1.2 Reassembly of Fuel Filter..... 3 - 12
  
- 2. Fuel Injection Nozzles ..... 3 - 14
  - 2.1 Disassembly of Fuel Injection Nozzles..... 3 - 14
  - 2.2 Inspection of Fuel Injection Nozzles ..... 3 - 14
  - 2.3 Reassembly of Fuel Injection Nozzles ..... 3 - 16

1. Fuel Filter

1.1 Disassembly and Inspection of Fuel Filter

(For in-line fuel injection pump)



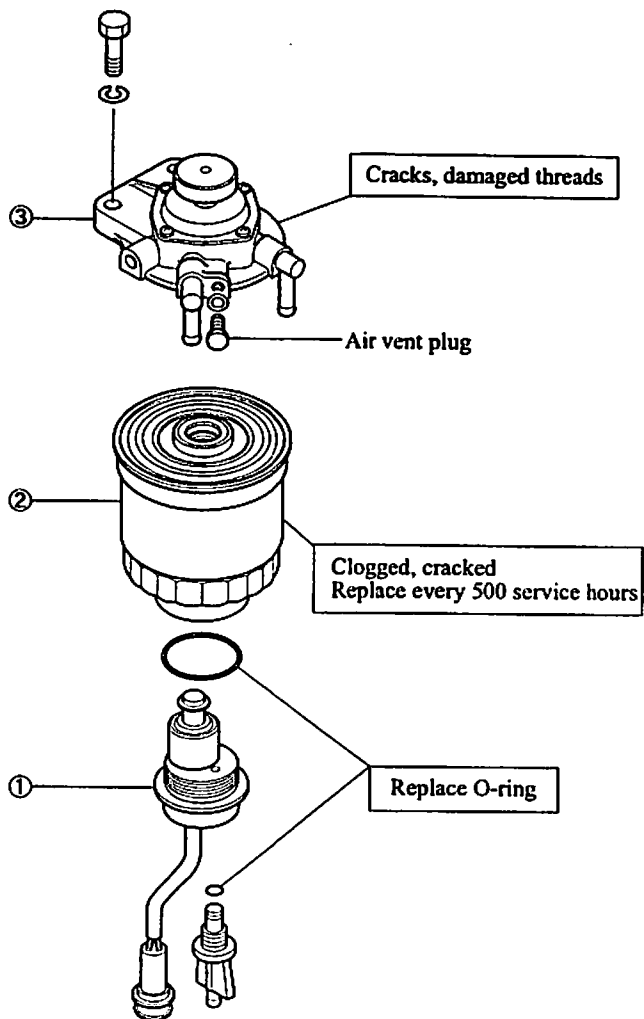
Disassembly and inspection of fuel filter (for in-line fuel injection pump)

<Disassembly sequence>

① Filter element

② Bracket

(For distributor-type fuel injection pump)



Disassembly and inspection of fuel filter (for distributor-type fuel injection pump)

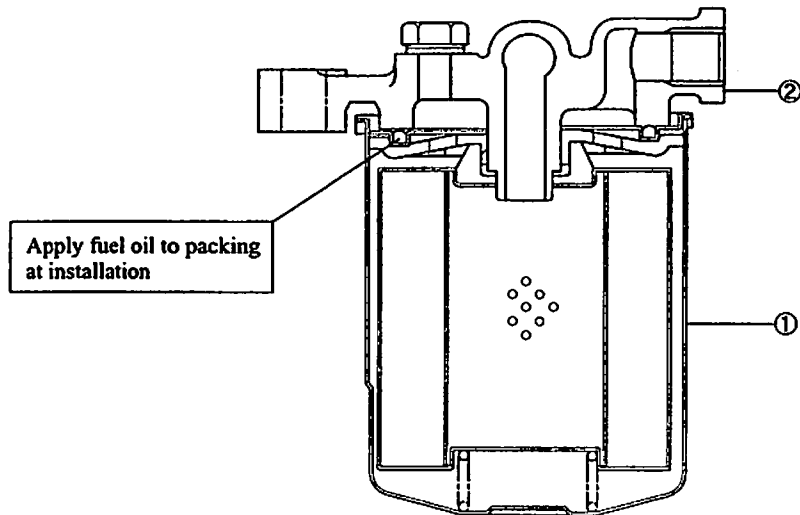
<Disassembly sequence >

① Level sensor assembly

② Filter element

③ Body

1.2 Reassembly of Fuel Filter  
(For in-line fuel injection pump)



Reassembly of fuel filter (for in-line fuel injection pump)

< Reassembly sequence >

②→①

Before installing the cartridge, clean the mounting surface of the cartridge, coat the gasket with clean fuel oil. Screw in the cartridge until the gasket contacts the seal surface of the bracket, then cartridge full turn by hand. (Do not use a filter wrench for installation.) Do not use a filter that has dents or scratches, since damaged filter can break during engine operation.

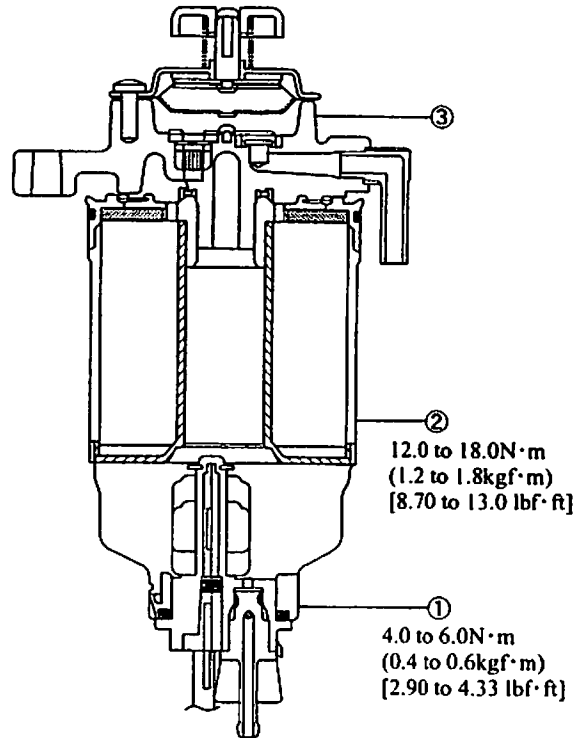
**⚠ CAUTION**

After installation, start the engine and check to make sure there is no fuel leak.

---



(For distributor-type fuel injection pump)



Reassembly of fuel filter (for distributor-type fuel injection pump)

< Reassembly sequence >

③→②→①

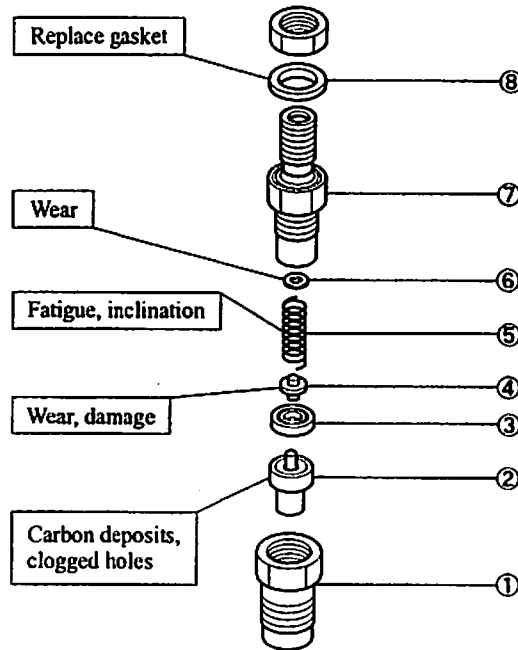
Do not use a filter that has dents or scratches, since damaged filter can break during engine operation.

**⚠ CAUTION**

After installation, start the engine and check to make sure there is no fuel leak.

## 2. Fuel Injection Nozzles

### 2.1 Disassembly of Fuel Injection Nozzles



Disassembly of fuel injection nozzle

<Disassembly sequence>

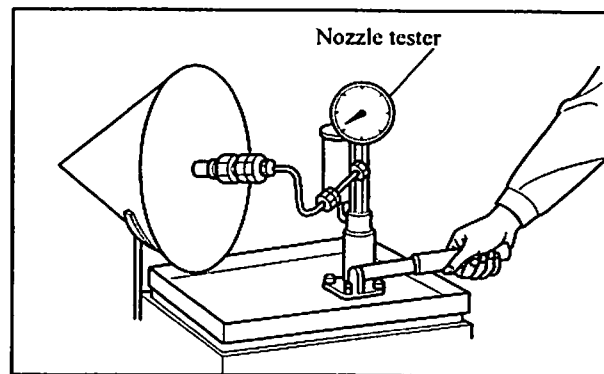
- |                        |         |          |                 |
|------------------------|---------|----------|-----------------|
| ① Nozzle retaining nut | ③ Piece | ⑤ Spring | ⑦ Nozzle holder |
| ② Nozzle tip assembly  | ④ Pin   | ⑥ Washer | ⑧ Gasket        |

### 2.2 Inspection of Fuel Injection Nozzles

Check each fuel injection nozzle for the following, and if defects are found, repair or replace the fuel injection nozzle.

- (1) Inspection of injection start pressure
  - (a) Install each fuel injection nozzle on the nozzle tester, and move the handle up and down to release air.
  - (b) Operate the handle of the tester at a rate of about 1 stroke per second, and read the indication on the pressure gage.

**Note :** The indication rises slowly, and the indicator oscillates during spraying. To obtain the injection start pressure value, read the indication when the indicator starts to oscillate.



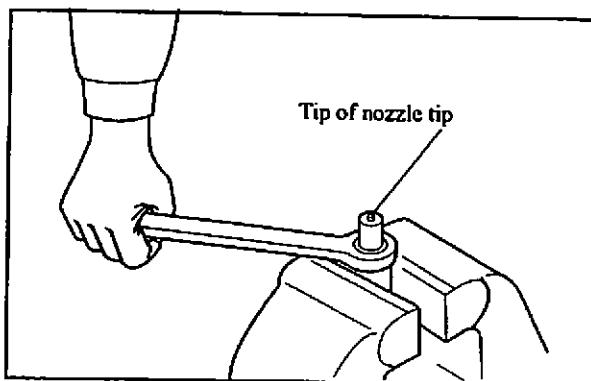
Inspection of fuel injection nozzle valve opening pressure

- (c) If the injection start pressure deviates significantly from the standard value, disassemble the fuel injection nozzle, and make an adjustment by changing the washer thickness.

		Unit MPa (kgf/cm <sup>2</sup> ) [psi]
Injection valve opening pressure	ND0PD21	Standard 11.77 to 12.75 (120 to 130) [1707 to 1850]
	ND15PD6	13.73 to 14.71 (140 to 150) [1991 to 2134]

Note : 0.1 mm [0.0039 in.] thickness of shims will change the injection pressure 0.98 MPa (10 kgf/cm<sup>2</sup>) [142 psi].

The shims are available in 10 different thickness from 1.25 to 1.70 mm [0.0492 to 0.0669 in.] increment of 0.05 mm [0.0020 in.]

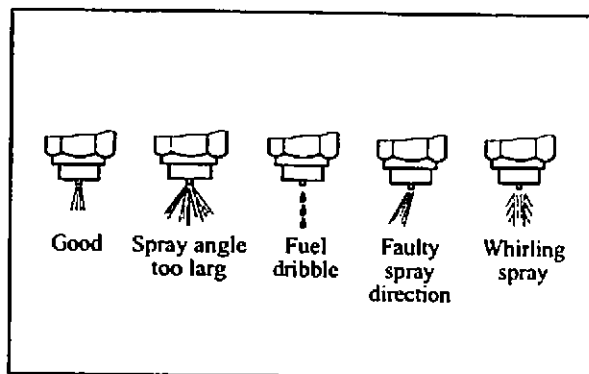


Replacement of fuel injection nozzle tip

**CAUTION**

Never tap the tip of the nozzle tip when removing the nozzle tip.

- (2) Inspection of fuel injection nozzle spray pattern
- When inspecting each fuel injection nozzle with the nozzle tester, also check the nozzle for clogs, spray pattern and leakage.
  - Make sure that fuel is sprayed straight from the nozzle when the handle of the tester is operated at a rate of about 1 stroke per second.



Inspection of spray pattern of fuel injection nozzle

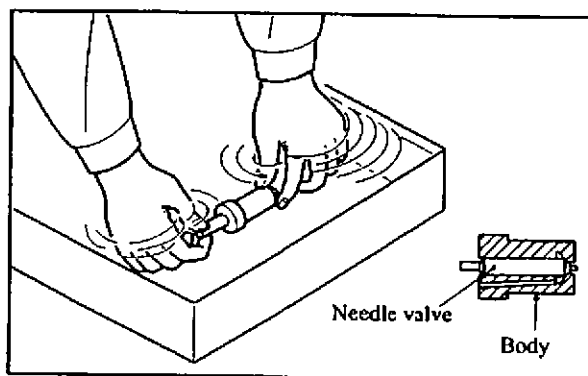
- (3) Cleaning and replacement of faulty nozzles
- Loosen the nozzle retaining nut, remove the nozzle tip, and clean the needle valve and body.

**CAUTION**

Never tap the tip of the nozzle tip when removing the nozzle tip.

- Use a fresh cleaning solution to clean the needle valve and body. After cleaning, assemble the needle valve and body in clean diesel fuel.

Note : The needle valve and body are precision finished. Handle them carefully, and do not change the combination of parts.



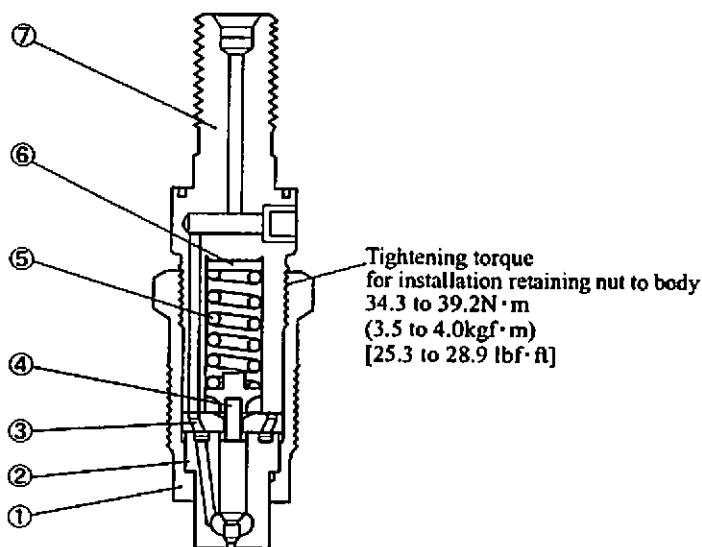
Cleaning of fuel injection nozzle tip

- (c) Tighten the nozzle retaining nut on the nozzle tip to the specified torque.
- (d) If the spray pattern is still not acceptable after adjustment and cleaning, replace the nozzle tip.

Note : (a) Never touch the sliding surface of the needle valve.

- (b) When installing a new nozzle tip, remove the seal film (synthetic resin film), and slide needle valve in the nozzle in a fresh cleaning solution to remove anti-rust oil coating thoroughly from the new nozzle.

### 2.3 Reassembly of Fuel Injection Nozzles



Reassembly of fuel injection nozzle

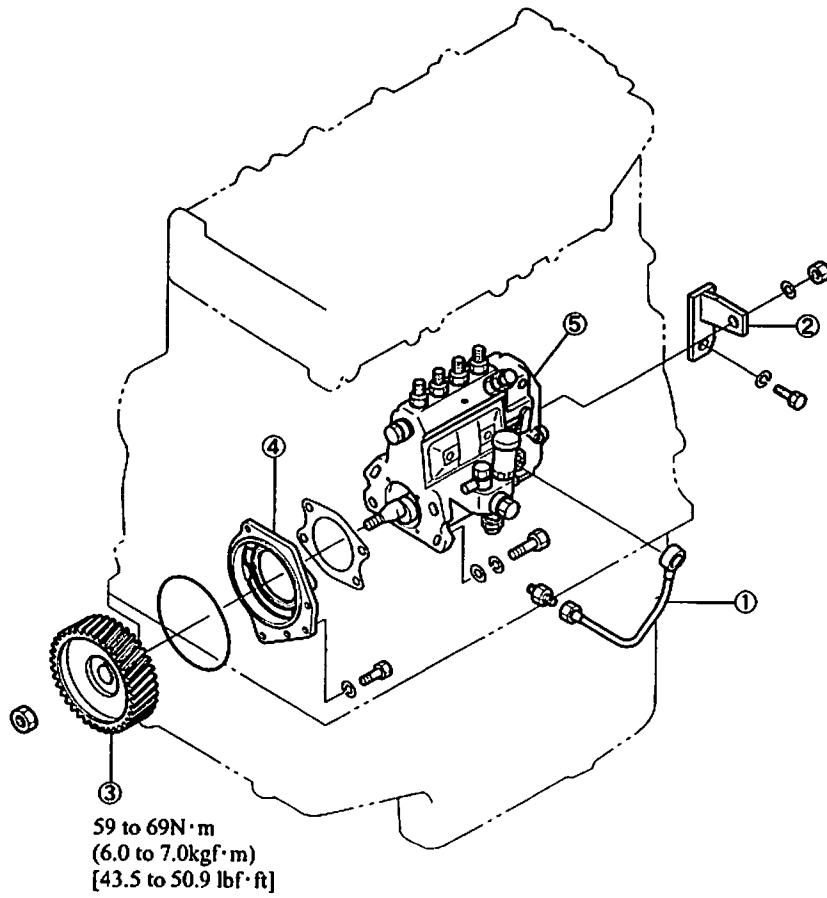
< Reassembly sequence >



# INSTALLATION OF FUEL SYSTEM

1. Fuel Injection Pump .....	3 -18
Installation of Fuel Injection Pump .....	3 -20
2. Fuel Injection Pipe, Fuel Leak-Off Pipe and Fuel Injection Nozzle.....	3 -21
3. Fuel Filter.....	3 -23

1. Fuel Injection Pump  
(In-line fuel injection pump)

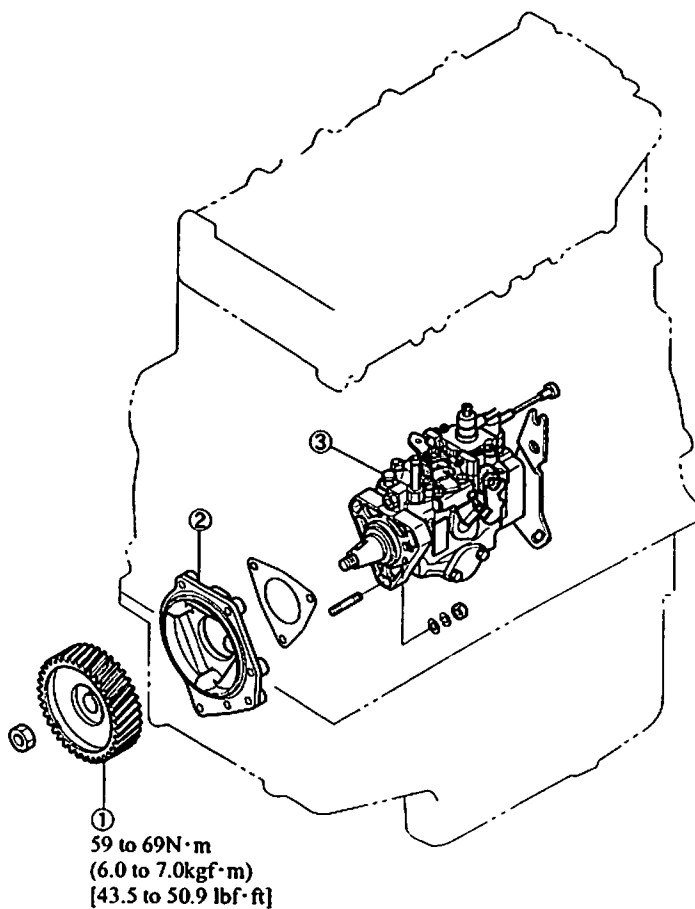


Installation of fuel injection pump (In-line fuel injection pump)

< Installation sequence >

⑤→④→③→②→①

(Distributor-type fuel injection pump)



Installation of fuel injection pump (Distributor-type fuel injection pump)

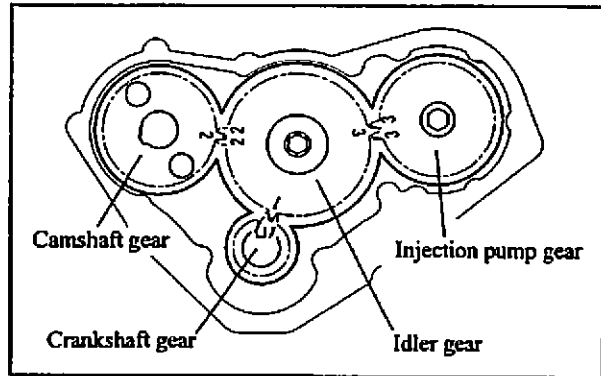
< Installation sequence >

③→②→①

## Installation of Fuel Injection Pump

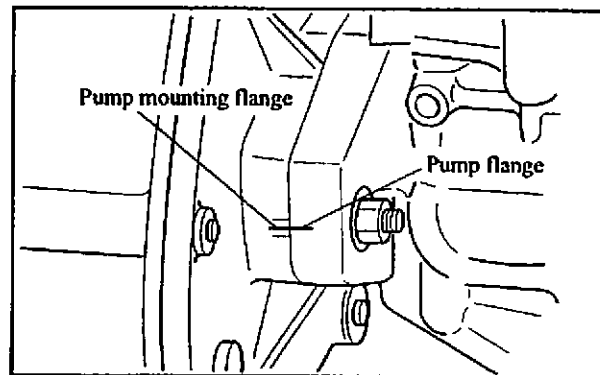
Install the fuel injection pump with the mark on the fuel injection pump gear aligned with the mark on the idler gear. Also ensure that marks on each timing gear are aligned as shown in the illustration.

**Note:** With these marks all aligned, the No.1 cylinder piston is at the top dead center on compression stroke.



Alignment of timing gear marks

Check the alignment marks stamped on the flange of the fuel injection pump and the pump mounting flange before tightening the mounting nuts.

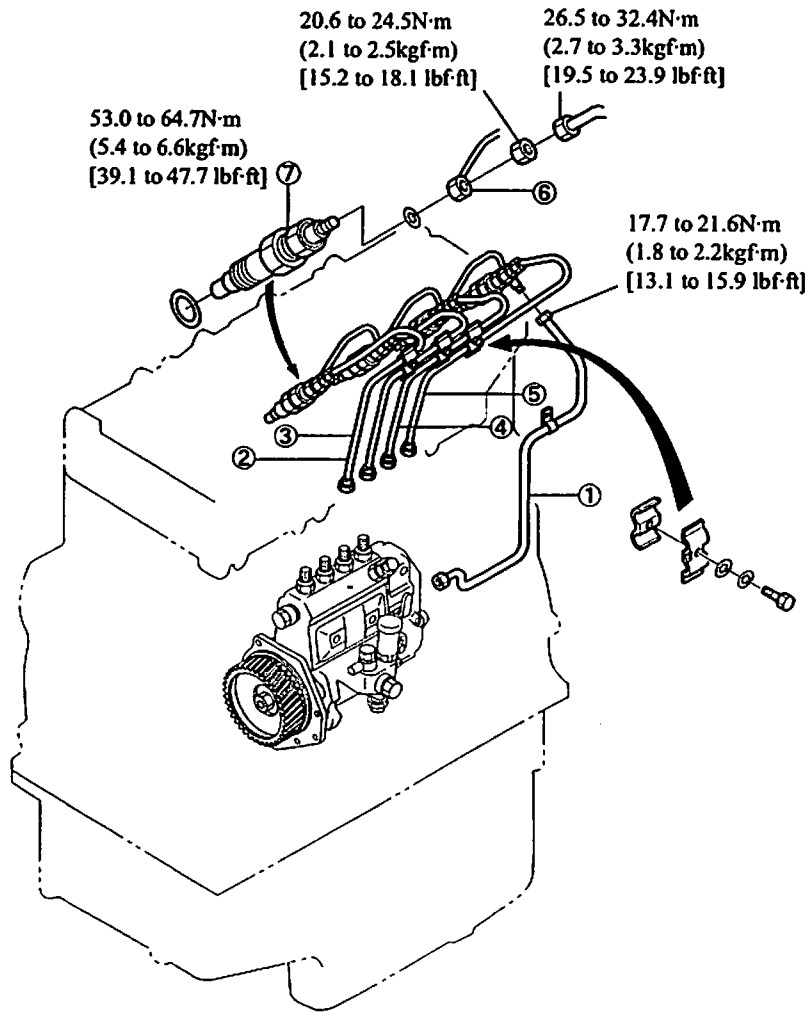


Installation of fuel injection pump



## 2. Fuel Injection Pipe, Fuel Leak-Off Pipe and Fuel Injection Nozzle

(For in-line fuel injection pump)

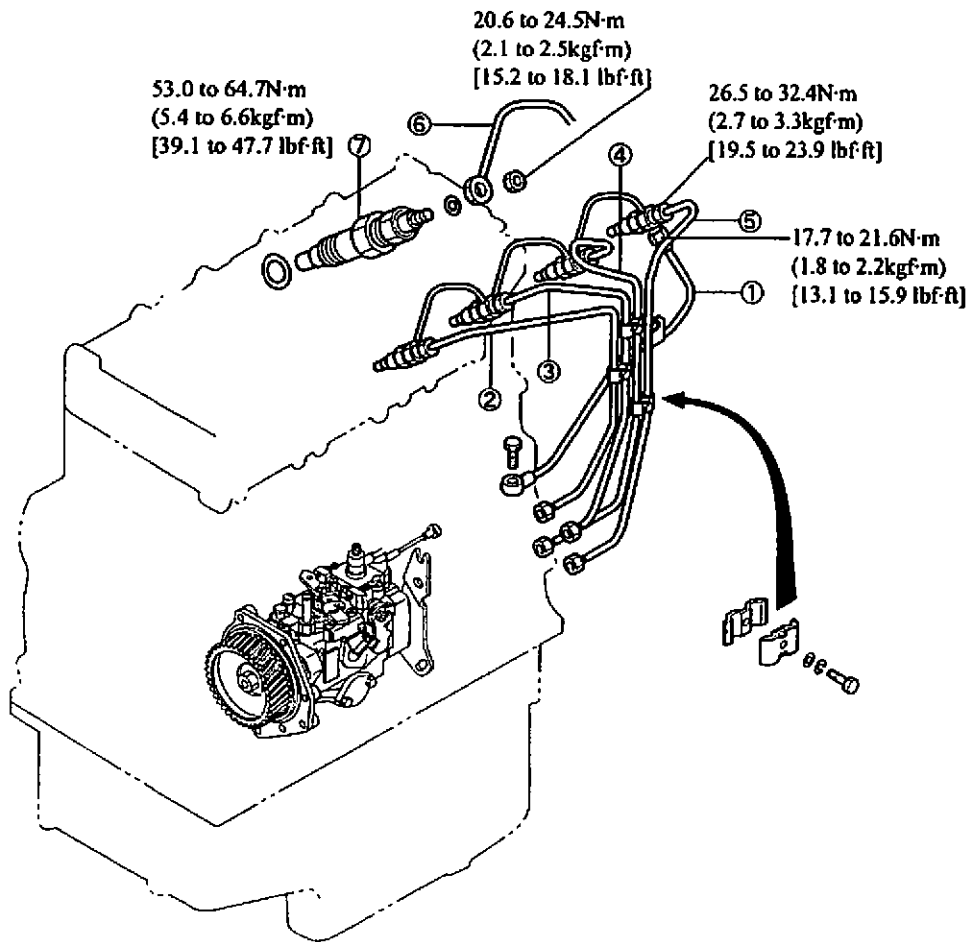


Installation of fuel injection pipe, fuel leak-off pipe and fuel injection nozzle  
(for in-line fuel injection pump)

< Installation sequence >

⑦→⑥→⑤→④→③→②→①

(For distributor-type fuel injection pump)



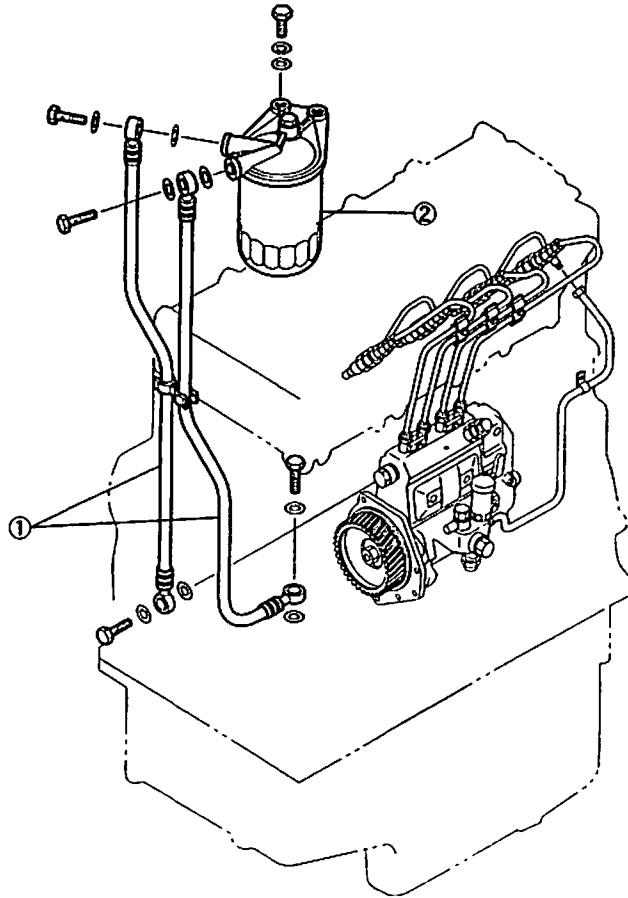
Installation of fuel injection pipe, fuel leak-off pipe and fuel injection nozzle  
(for distributor-type fuel injection pump)

< Installation sequence >



### 3. Fuel Filter

(For in-line fuel injection pump)

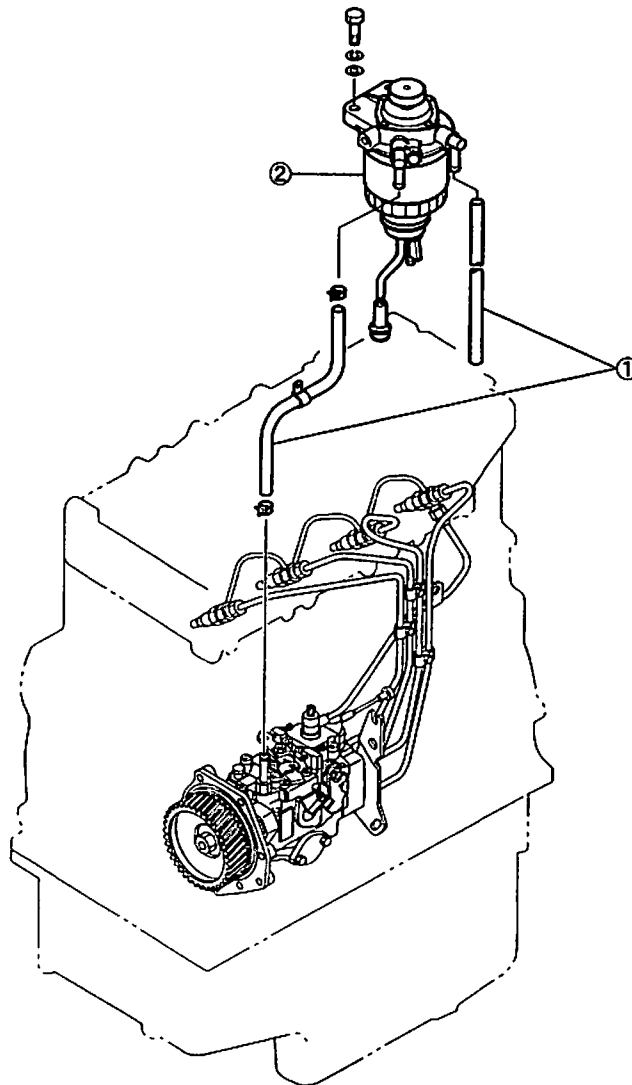


Installation of fuel filter (for in-line fuel injection pump)

< Installation sequence >

②→①

(For distributor-type fuel injection pump)



Installation of fuel filter (for distributor-type fuel injection pump)

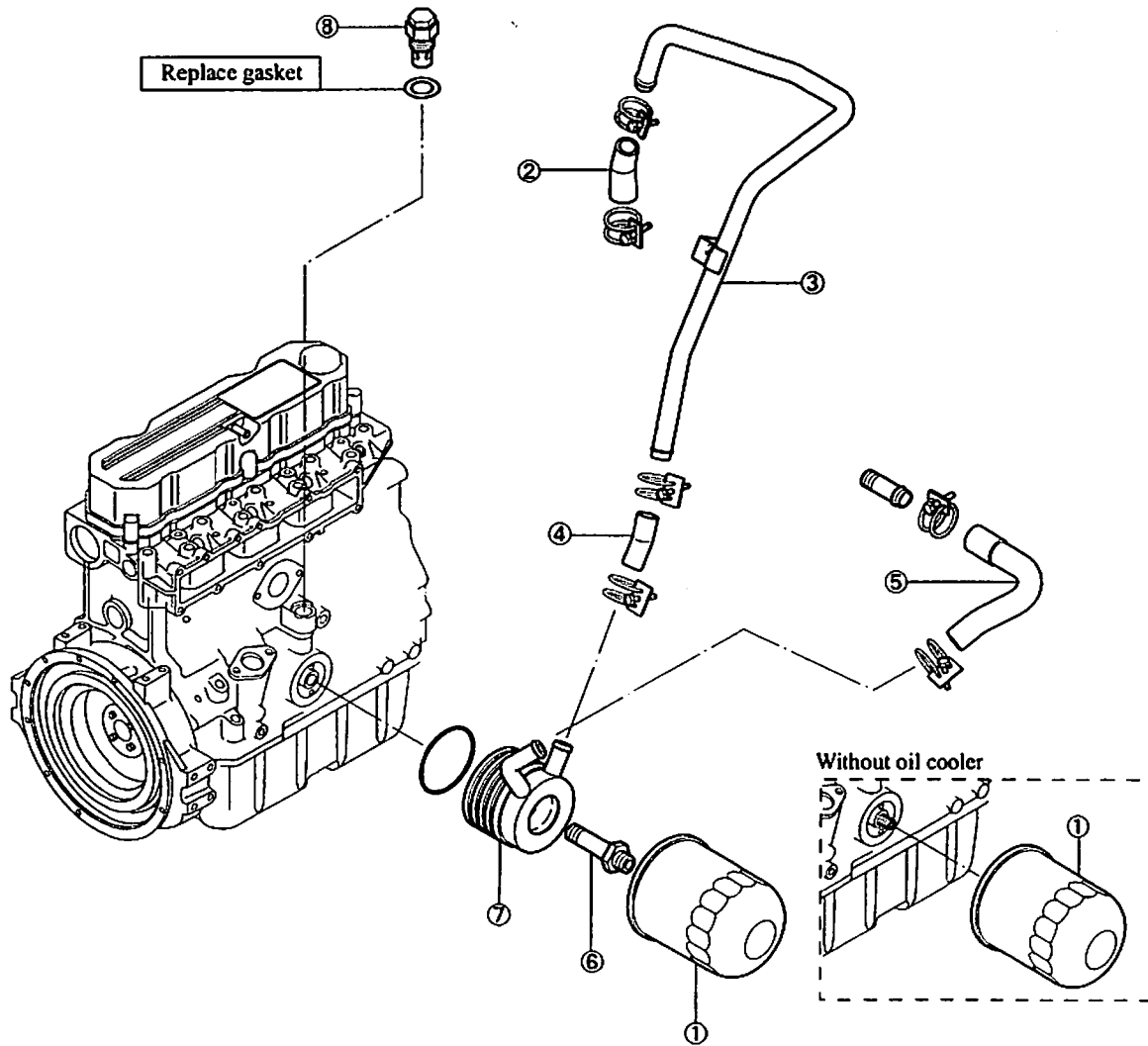
< Installation sequence >

②→①

# REMOVAL OF LUBRICATION SYSTEM

- 1. Oil Filter, Oil Cooler and Relief Valve ..... 4 - 2
- 2. Oil Pan, Oil Pump and Oil Pressure Switch ..... 4 - 3

1. Oil Filter, Oil Cooler and Relief Valve

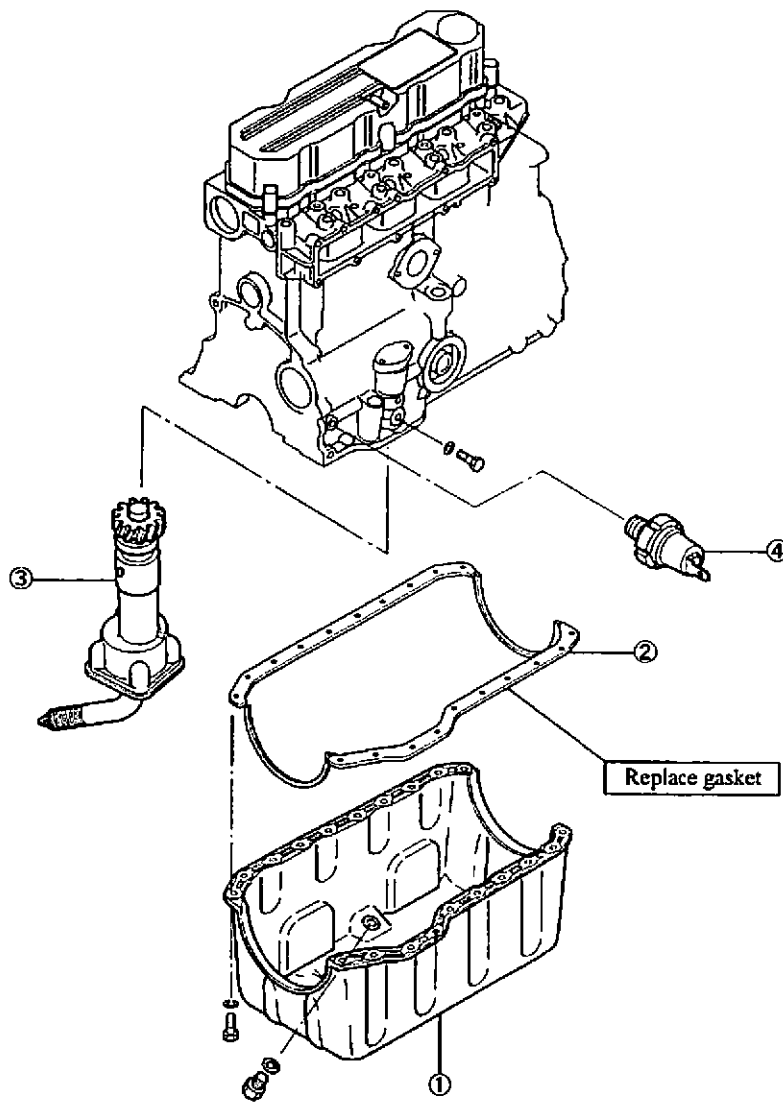


Removal of oil filter, oil cooler and relief valve

< Removal sequence >

- |                         |                |
|-------------------------|----------------|
| ① Oil filter            | ⑤ Water hose   |
| ② Rubber hose           | ⑥ Connector    |
| ③ Oil cooler water pipe | ⑦ Oil cooler   |
| ④ Rubber hose           | ⑧ Relief valve |

2. Oil Pan, Oil Pump and Oil Pressure Switch



Removal of oil pan, oil pump and oil pressure switch

< Removal sequence >

① Oil pan

② Oil pan gasket

③ Oil pump

④ Oil pressure switch

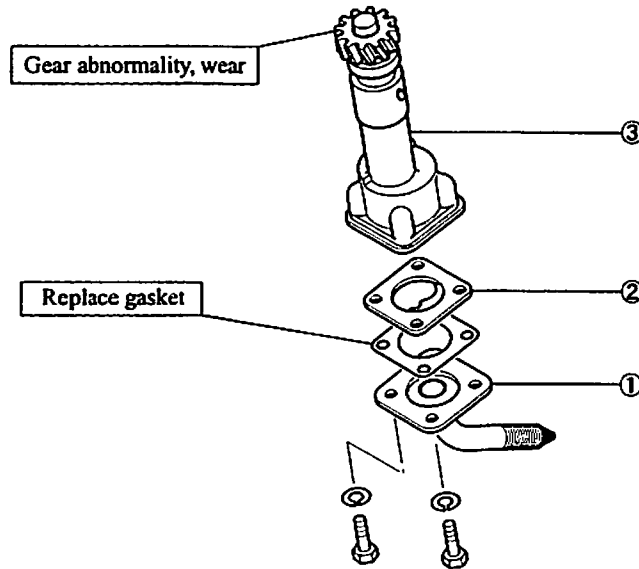
# DISASSEMBLY, INSPECTION AND REASSEMBLY OF LUBRICATION SYSTEM

1. Oil Pump .....	4 - 6
1.1 Disassembly and Inspection of Oil Pump.....	4 - 6
1.2 Measurement of Clearance between Outer Rotor and Inner Rotor .....	4 - 6
1.3 Measurement of Rotor and Case End Play.....	4 - 6
1.4 Measurement of Clearance between Outer Rotor and Pump Case .....	4 - 7
1.5 Reassembly of Oil Pump.....	4 - 7
2. Oil Filter, Oil Cooler and Relief Valve .....	4 - 8
2.1 Inspection of Oil Filter, Oil Cooler and Relief Valve .....	4 - 8
2.2 Adjustment of Relief Valve.....	4 - 8



1. Oil Pump

1.1 Disassembly and Inspection of Oil Pump



Disassembly and inspection of oil pump

<Disassembly sequence>

① Oil strainer

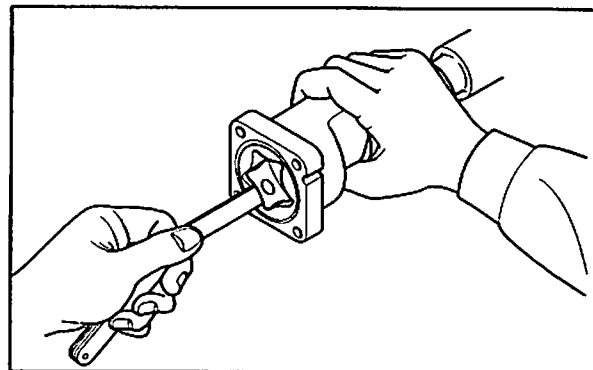
② Oil pump cover

③ Oil pump

1.2 Measurement of Clearance between Outer Rotor and Inner Rotor

Measure the clearance between the outer rotor and inner rotor, and, if the limit value is exceeded, replace the pump assembly.

	Unit mm [in.]	
	Standard	Limit
Clearance between outer rotor and inner rotor	0.13 to 0.15 [0.0051 to 0.0059]	0.20 [0.0079]

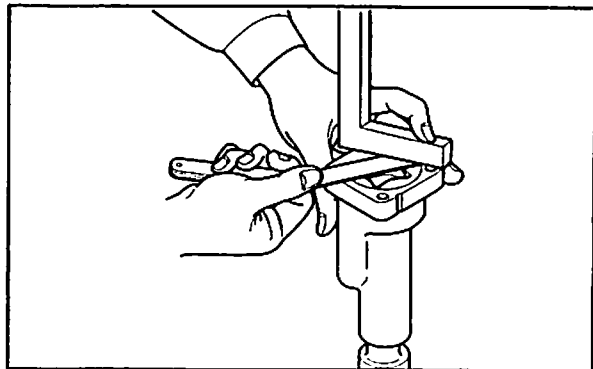


Measurement of clearance between outer rotor and inner rotor

1.3 Measurement of Rotor and Case End Play

Measure the rotor and case end play, and, if the limit value is exceeded, replace the pump assembly.

	Unit mm [in.]	
	Standard	Limit
Rotor and case end play	0.04 to 0.09 [0.0016 to 0.0035]	0.15 [0.0059]

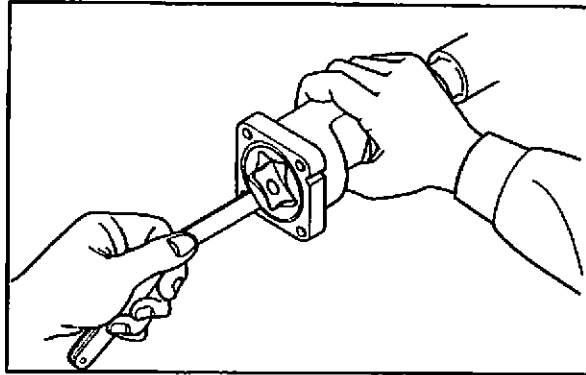


Measurement of rotor and cover end play

**1.4 Measurement of Clearance between Outer Rotor and Pump Case**

Measure the clearance between the outer rotor and pump case, and, if the limit value is exceeded, replace the pump assembly.

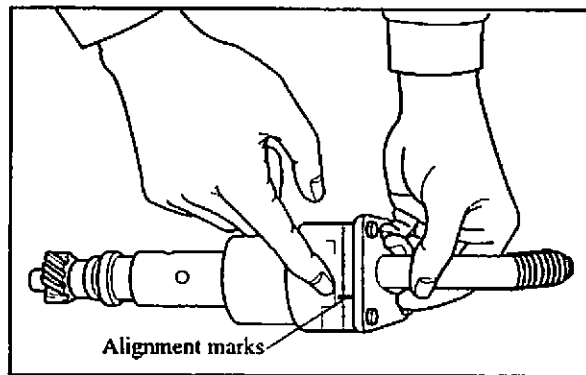
	Unit mm [in.]	
	Standard	Limit
Clearance between outer rotor and case	0.200 to 0.280 [0.0079 to 0.0110]	0.500 [0.0197]



Measurement of clearance between outer rotor and case

**1.5 Reassembly of Oil Pump**

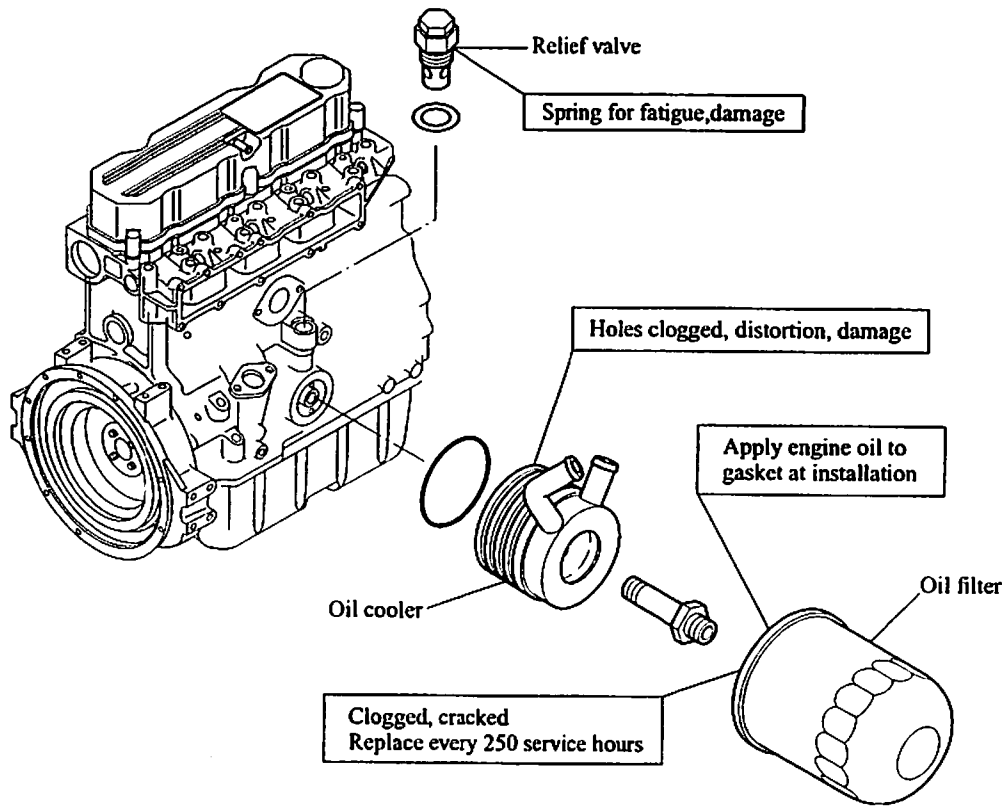
Install the outer rotor to the pump case, check the alignment mark (indentations) on the pump case cover, and then tighten the bolts. If the alignment marks are not aligned during the reassembly, the pump will not suck oil.



Alignment marks on pump case and pump case cover

2. Oil Filter, Oil Cooler and Relief Valve

2.1 Inspection of Oil Filter, Oil Cooler and Relief Valve



Inspection of oil filter, oil cooler and relief valve

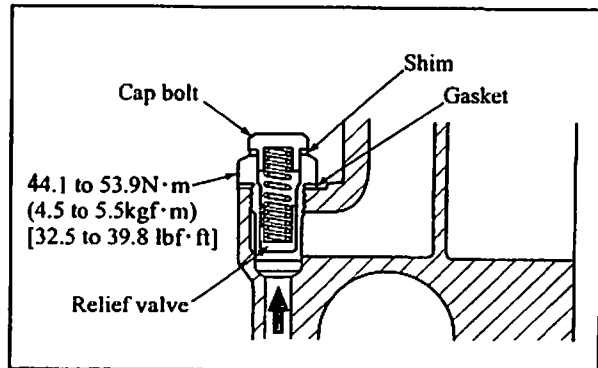
2.2 Adjustment of Relief Valve

- (1) Check the relief valve and valve seat for contact condition, and the spring for fatigue and damage, and replace any defective parts.
- (2) Measure the valve opening pressure (oil pressure when the engine is running at rated rpm) of the relief valve, and, if the standard value is exceeded, remove the cap bolt and make an adjustment by increasing or decreasing the shim thickness.

Engine oil pressure take-out port  
Next to oil filter

Rp 1/8 thread (PS 1/8)  
Unit MPa (kgf/cm<sup>2</sup>) [psi]

	Standard
Valve opening pressure	0.29 to 0.39 (3.0 to 4.0) [42.06 to 56.56]

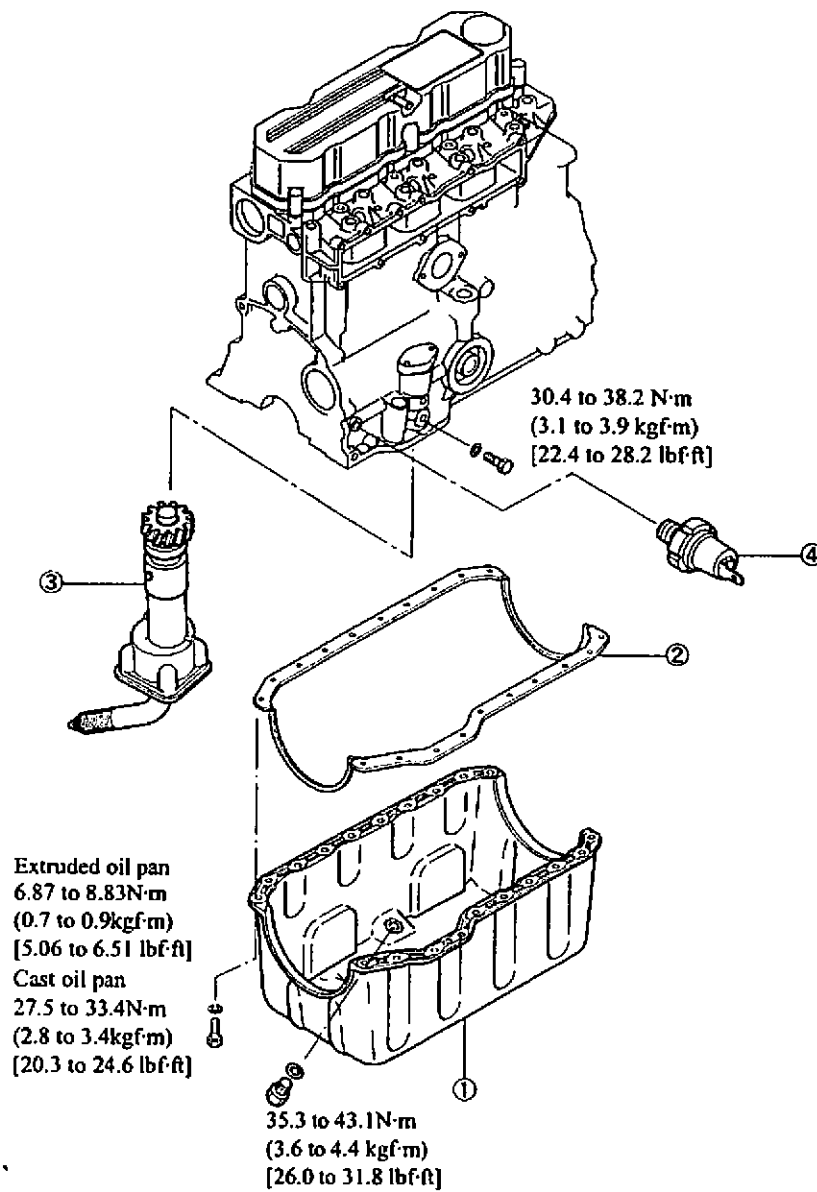


Installation of relief valve

# INSTALLATION OF LUBRICATION SYSTEM

1. Oil Pan, Oil Pump and Oil Pressure Switch ..... 4 -10
2. Oil Filter, Oil Cooler and Relief Valve ..... 4 -11

1. Oil Pan, Oil Pump and Oil Pressure Switch

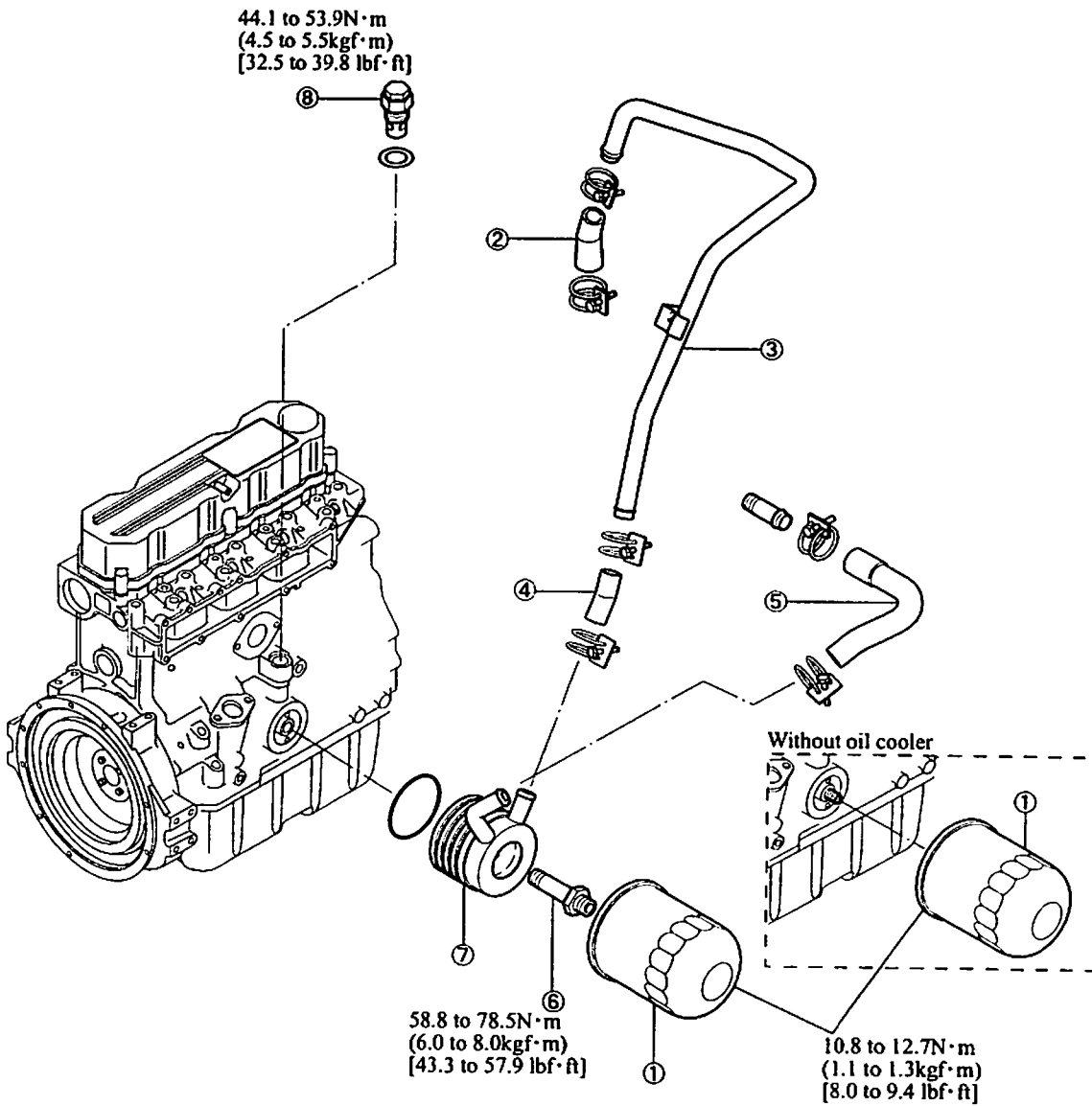


Installation of oil pan, oil pump and oil pressure switch

<Installation sequence>

④→③→②→①

2. Oil Filter, Oil Cooler and Relief Valve



Installation of oil filter, oil cooler and relief valve

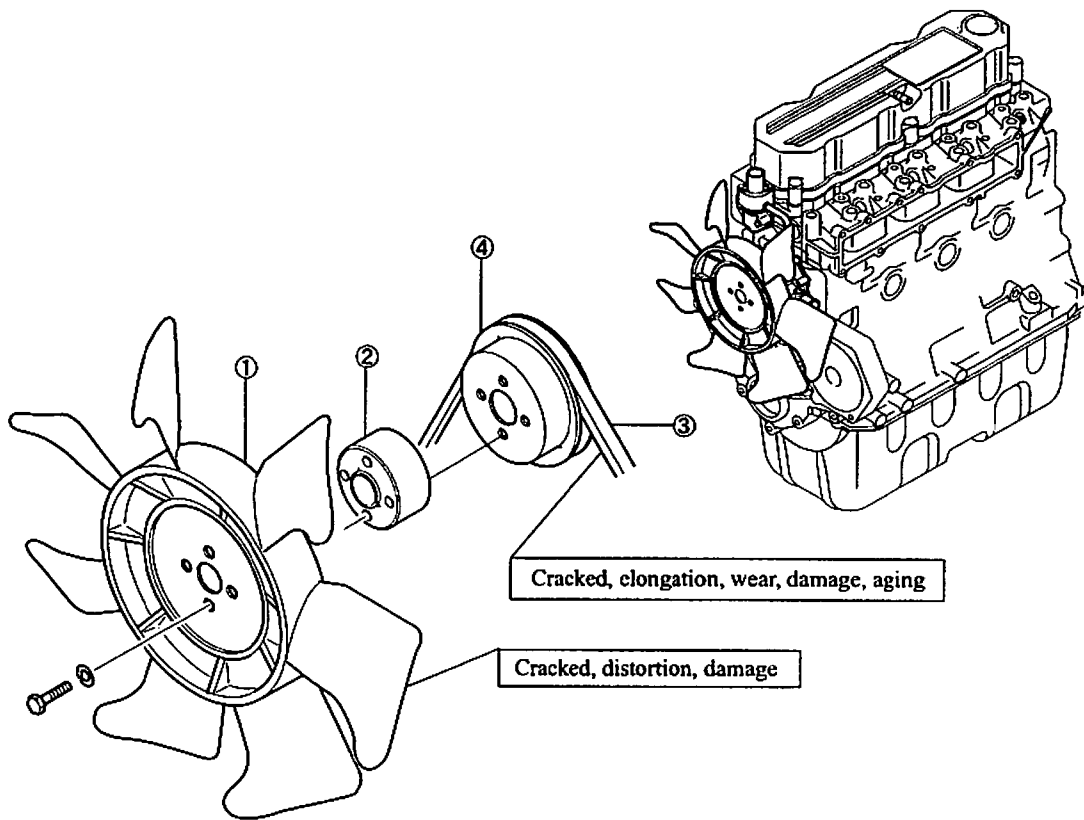
< Installation sequence >

⑧→⑦→⑥→⑤→④→③→②→①

# REMOVAL OF COOLING SYSTEM

1. Cooling Fan, Fan Pulley and V-Belt .....	5 - 2
2. Thermostat.....	5 - 3
3. Water Pump.....	5 - 4

1. Cooling Fan, Fan Pulley and V-Belt



Removal of cooling fan, fan pulley and v-belt

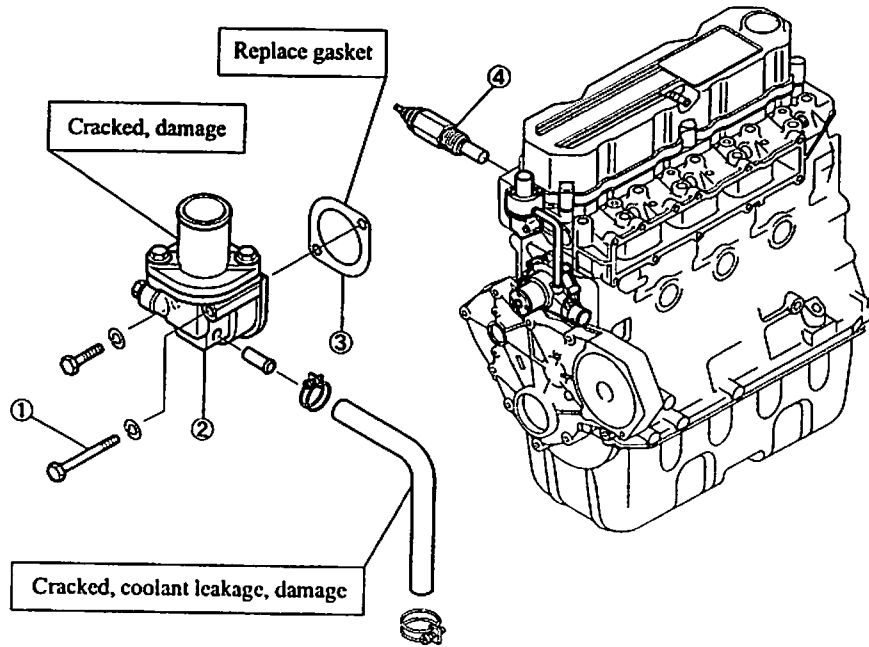
< Removal sequence >

- ① Cooling fan
- ② Fan spacer

- ③ V-belt
- ④ Water pump pulley



2. Thermostat



Removal of thermostat

< Removal sequence >

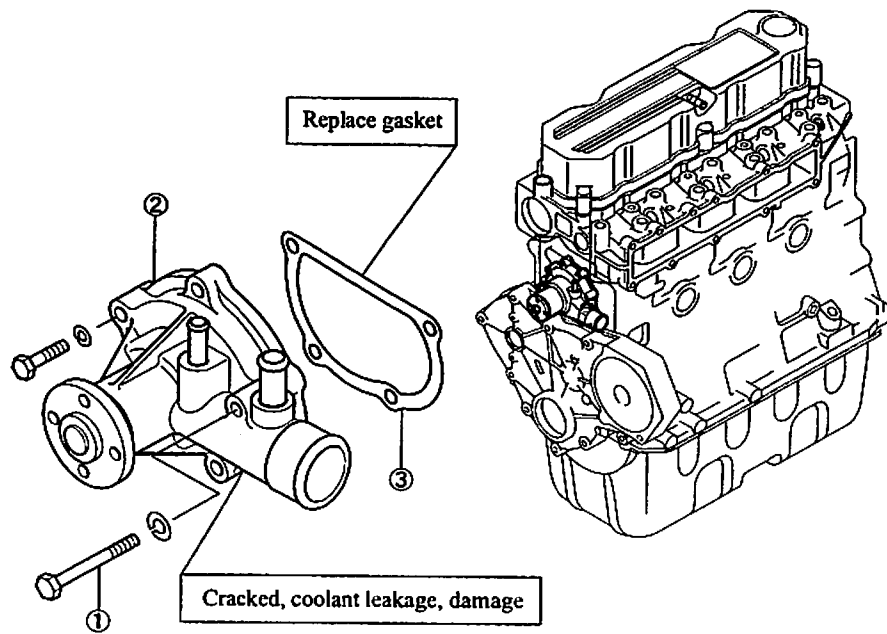
① Bolt

② Thermostat

③ Gasket

④ Thermo switch

3. Water Pump



Removal of water pump

< Removal sequence >

① Bolt

② Water pump

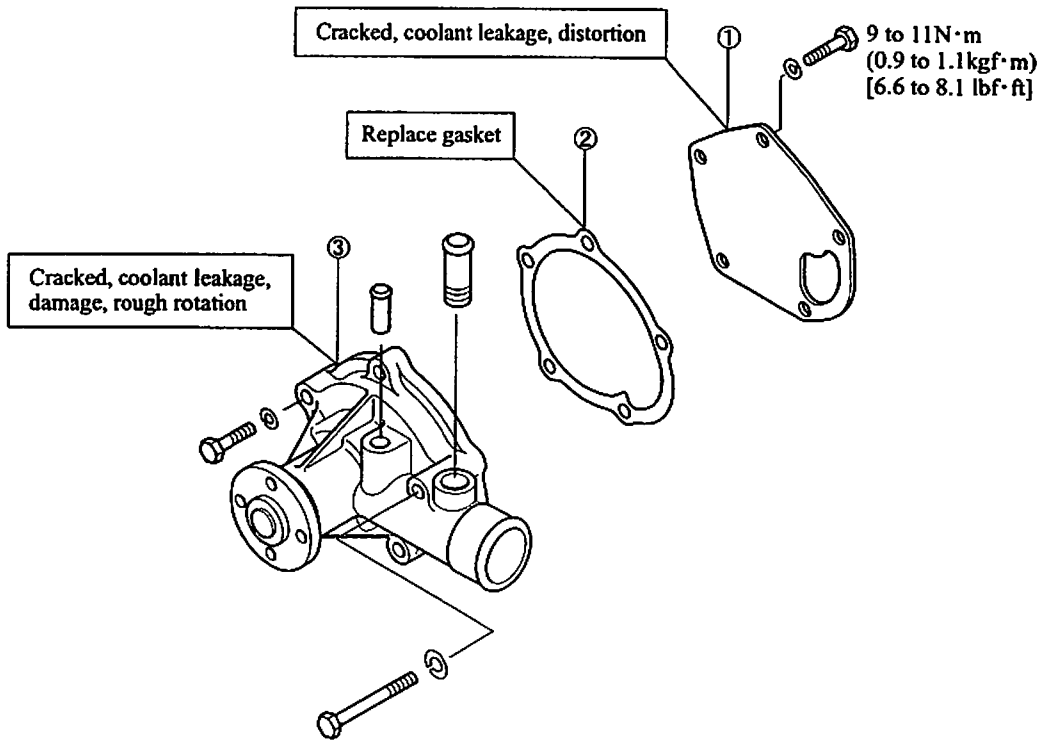
③ Gasket

# DISASSEMBLY, INSPECTION AND REASSEMBLY OF COOLING SYSTEM

1. Water Pump.....	5 - 6
1.1 Disassembly of Water Pump.....	5 - 6
1.2 Inspection of Water Pump.....	5 - 6
2. Thermostat.....	5 - 7
2.1 Disassembly of Thermostat.....	5 - 7
2.2 Inspection of Thermostat.....	5 - 7
3. Thermo Switch.....	5 - 8
Inspection of Thermo Switch.....	5 - 8

# 1. Water Pump

## 1.1 Disassembly of Water pump



Disassembly of Water pump

< Disassembly sequence >

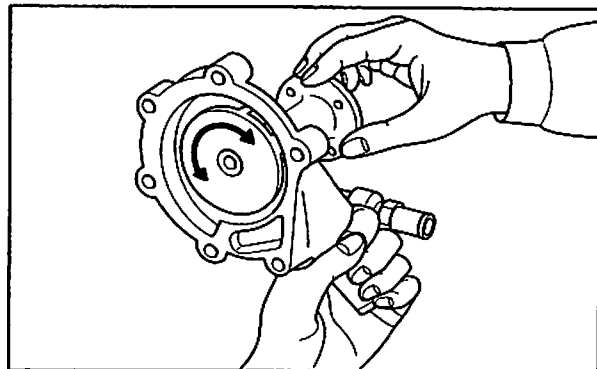
① Water pump cover

② Gasket

③ Water pump

## 1.2 Inspection of Water Pump

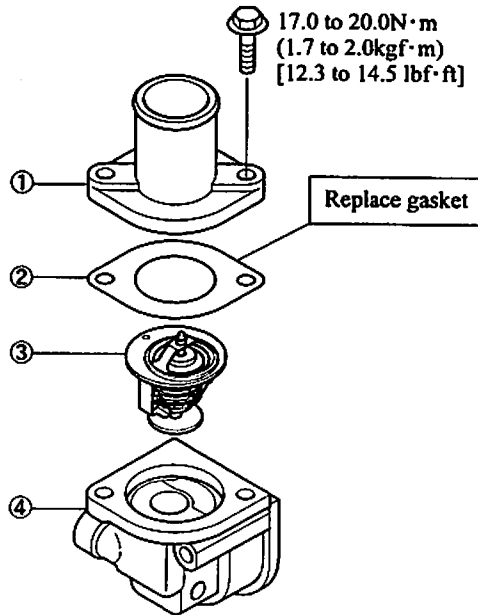
If the inspection of the impeller and shaft finds abnormal noise or rough rotation, replace the assembly.



Inspection of impeller and shaft rotation condition

2. Thermostat

2.1 Disassembly of Thermostat



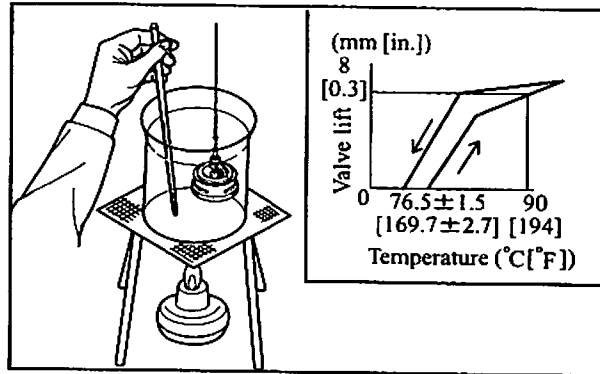
Disassembly of thermostat

< Disassembly sequence >

- ① Thermostat cover
- ② Gasket
- ③ Thermostat
- ④ Thermostat case

2.2 Inspection of Thermostat

To test the thermostat operation, immerse the thermostat in a container filled with water, and heat the water while measuring the water temperature. Record the temperature at which the valve starts to open and the temperature at which the valve lift becomes 8 mm [0.3 in.] or more.



Inspection of thermostat

	Standard
Temperature at which valve starts to open	76.5±1.5 °C [169.7±2.7 °F]
Temperature at which valve lift exceeds 8 mm [0.3 in.]	90 °C [194 °F]

- Note: (a) Stir the water in the container to ensure uniform temperature distribution.  
 (b) When installing the thermostat, be sure to check the valve opening temperature indication stamped on the upper face of the thermostat mounting flange.

### 3. Thermo Switch

#### Inspection of Thermo Switch

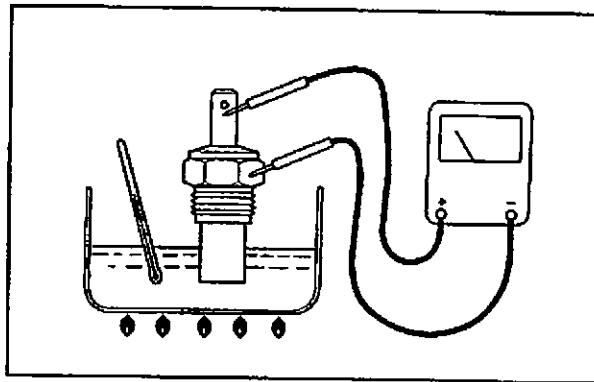
Immerse the temperature sensor in oil, and measure the resistance while increasing the oil temperature. If the temperature measurement exceeds the standard value significantly, replace the thermo switch.

Unit  $m\Omega$

Temperature	Standard
110 °C [230 °F]	12

**⚠ CAUTION**

Since the inspection requires heating of oil to high temperatures, be careful not to get burns or start a fire.

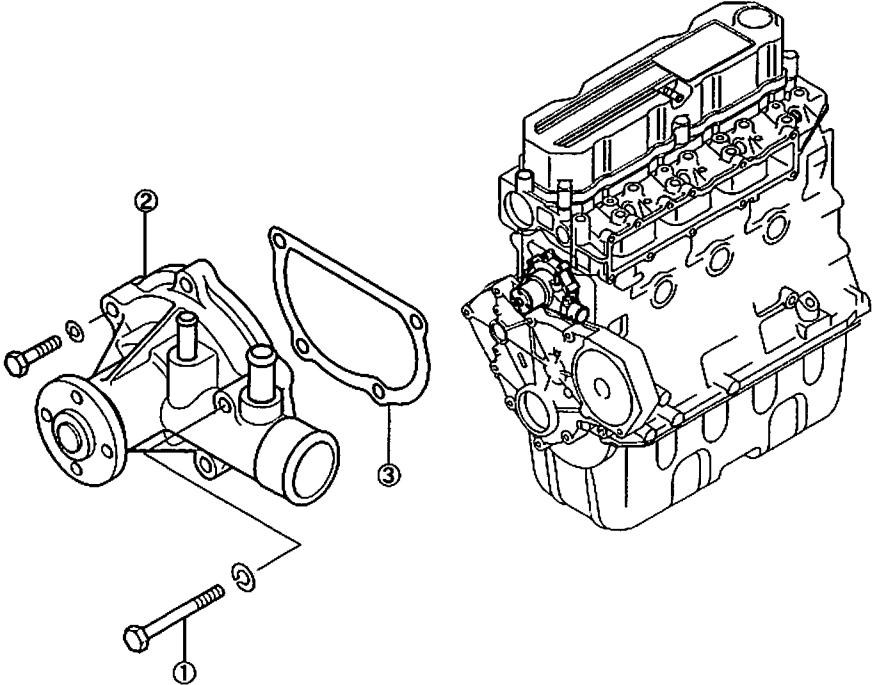


Inspection of thermo switch

# INSTALLATION OF COOLING SYSTEM

1. Water Pump ..... 5 - 10
2. Thermostat..... 5 - 11
3. Cooling Fan, Fan Pulley and V-Belt ..... 5 - 12

1. Water Pump



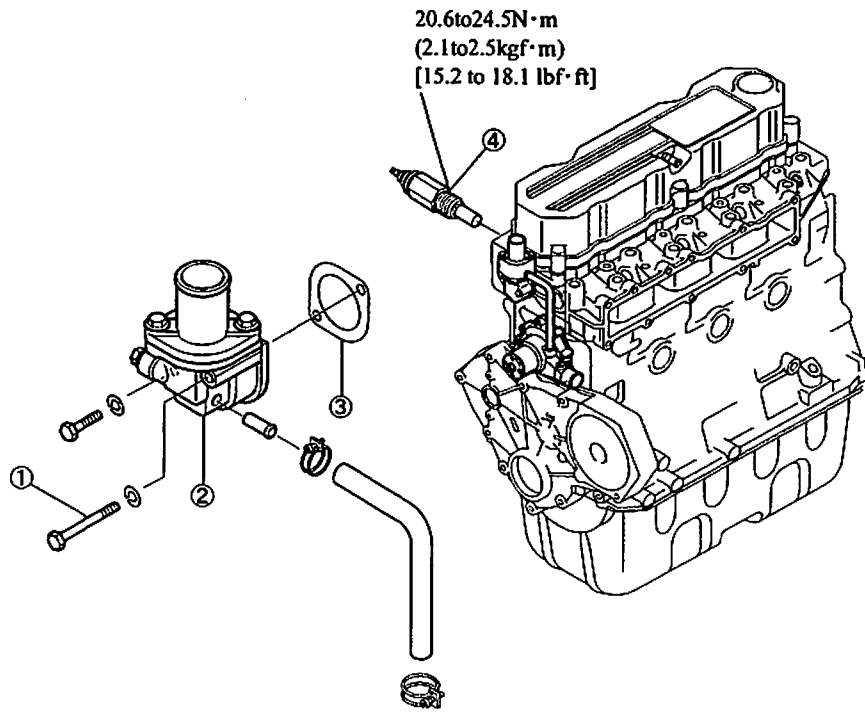
Installation of water pump

< Installation sequence >

- ③ → ② → ①



2. Thermostat

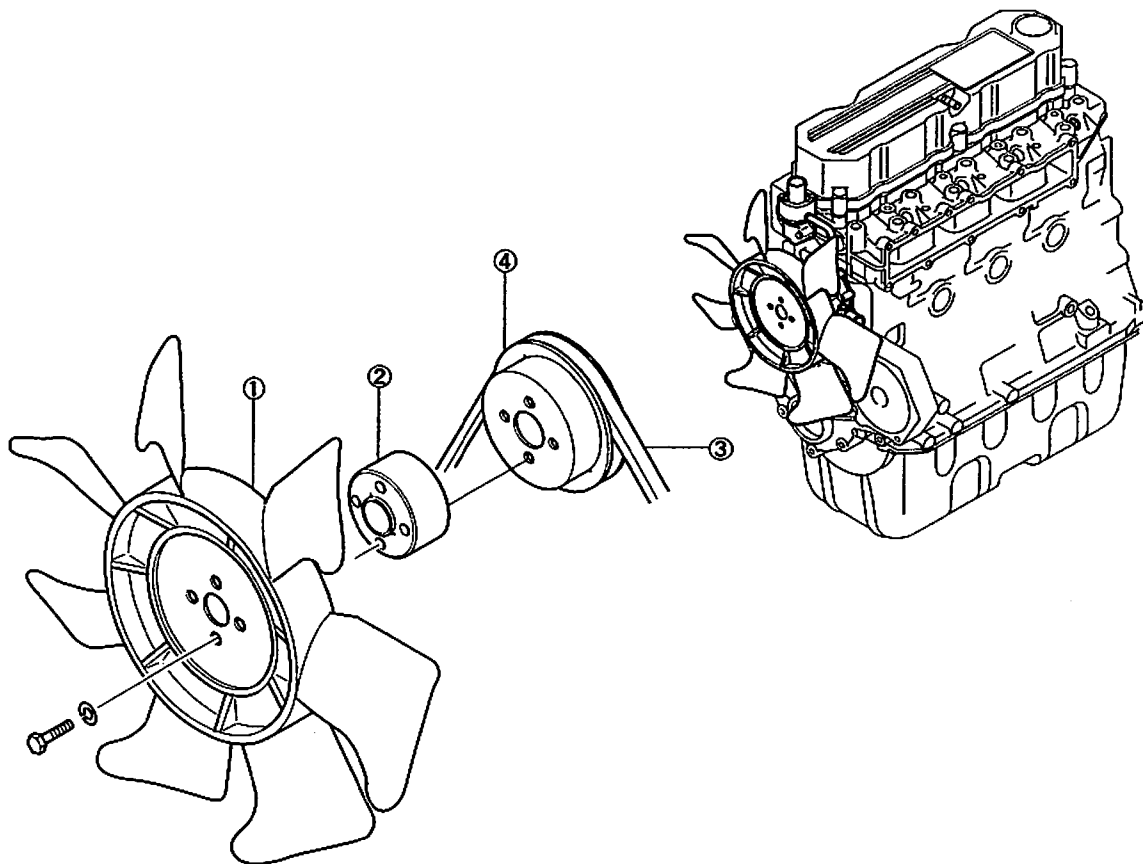


Installation of thermostat

< Installation sequence >

④ → ③ → ② → ①

3. Cooling Fan, Fan Pulley and V-Belt



Installation of cooling fan, fan pulley and v-belt

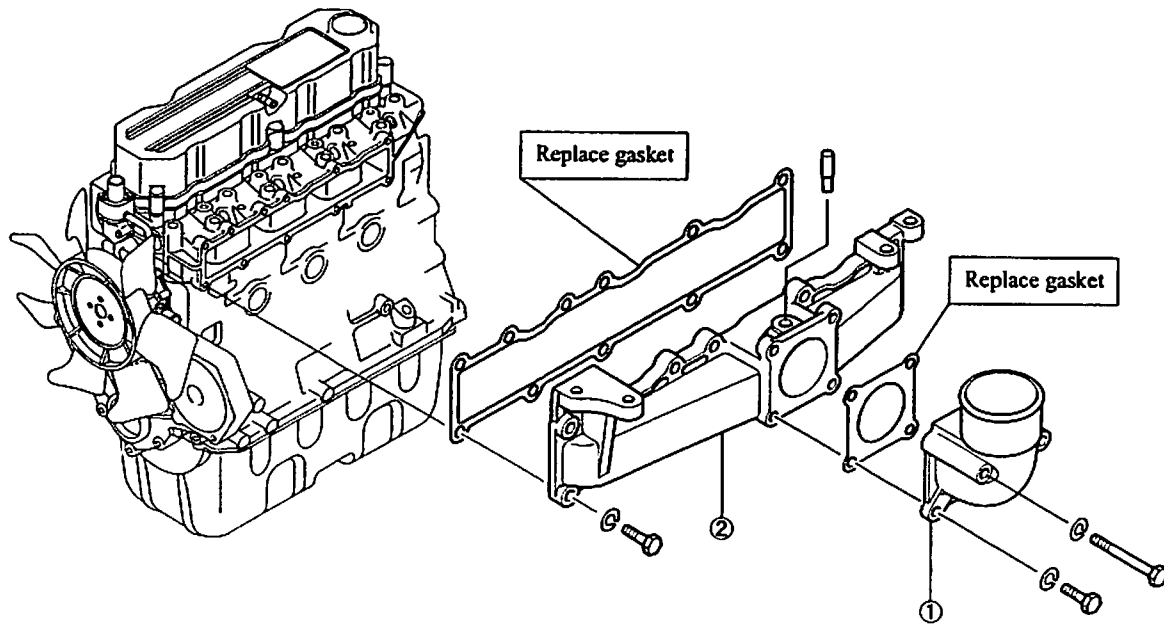
< Installation sequence >

④→③→②→①

# REMOVAL OF INLET AND EXHAUST SYSTEMS

1. Inlet Manifold.....	6 - 2
2. Exhaust Manifold .....	6 - 3

1. Inlet Manifold



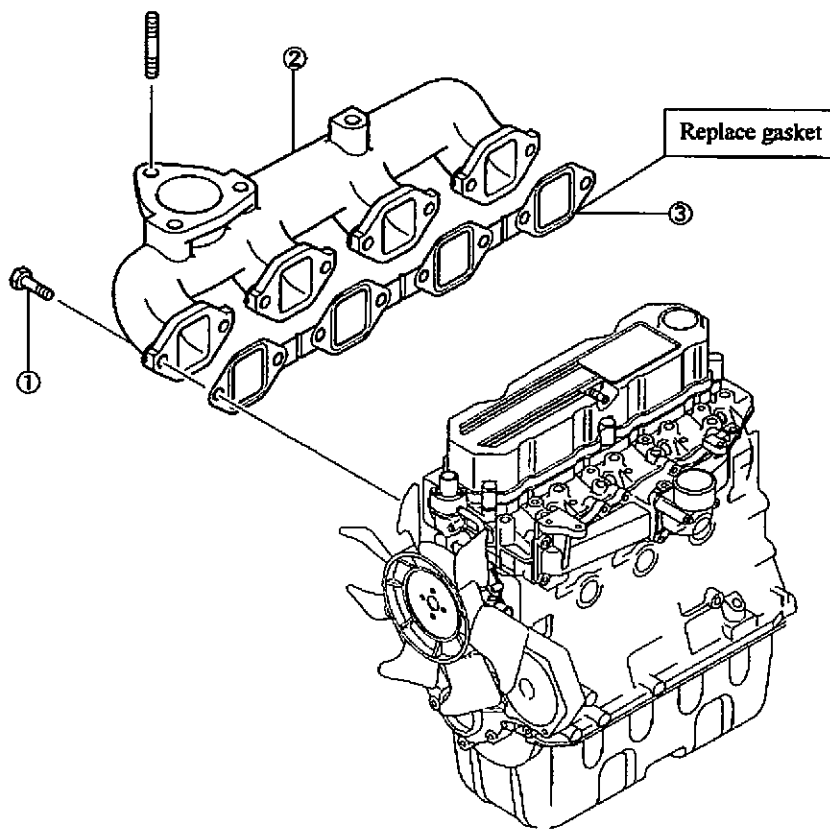
Removal of inlet manifold

< Removal sequence >

① Air inlet elbow

② Inlet manifold

2. Exhaust Manifold



Removal of inlet exhaust manifold

< Removal sequence >

① Bolt

② Exhaust manifold

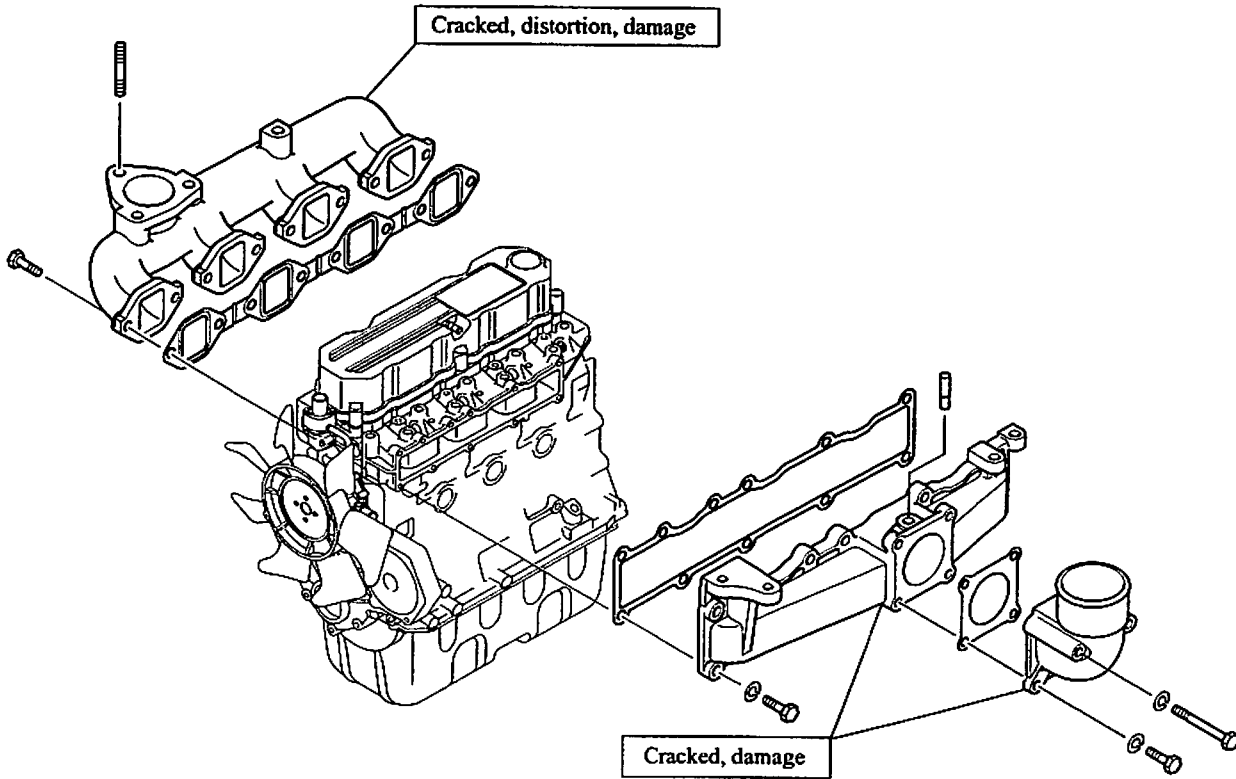
③ Gasket

# DISASSEMBLY, INSPECTION AND REASSEMBLY OF INLET AND EXHAUST SYSTEMS

1. Inlet Manifold and Exhaust Manifold .....	6 - 6
1.1 Inspection of Inlet Manifold and Exhaust Manifold.....	6 - 6
1.2 Measurement of Exhaust Manifold Distortion .....	6 - 6

1. Inlet Manifold and Exhaust Manifold

1.1 Inspection of Inlet Manifold and Exhaust Manifold



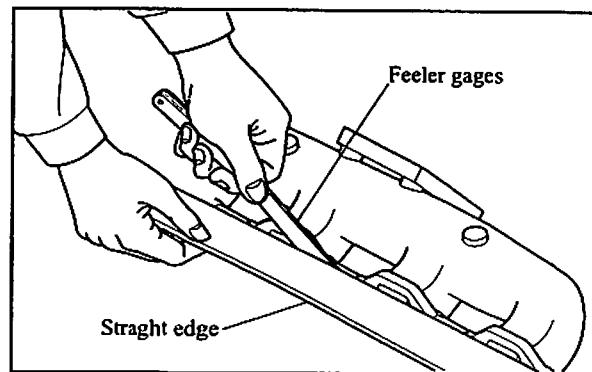
Inspection of inlet manifold, exhaust manifold

1.2 Measurement of Exhaust Manifold Distortion

Use a straight edge and feeler gages to measure the amount of distortion on the cylinder head contact surface of the exhaust manifold.

If the limit value is exceeded, reface the surface or replace the manifold.

Unit mm [in.]	
	Limit
Manifold distortion	0.15 [0.0059] or less



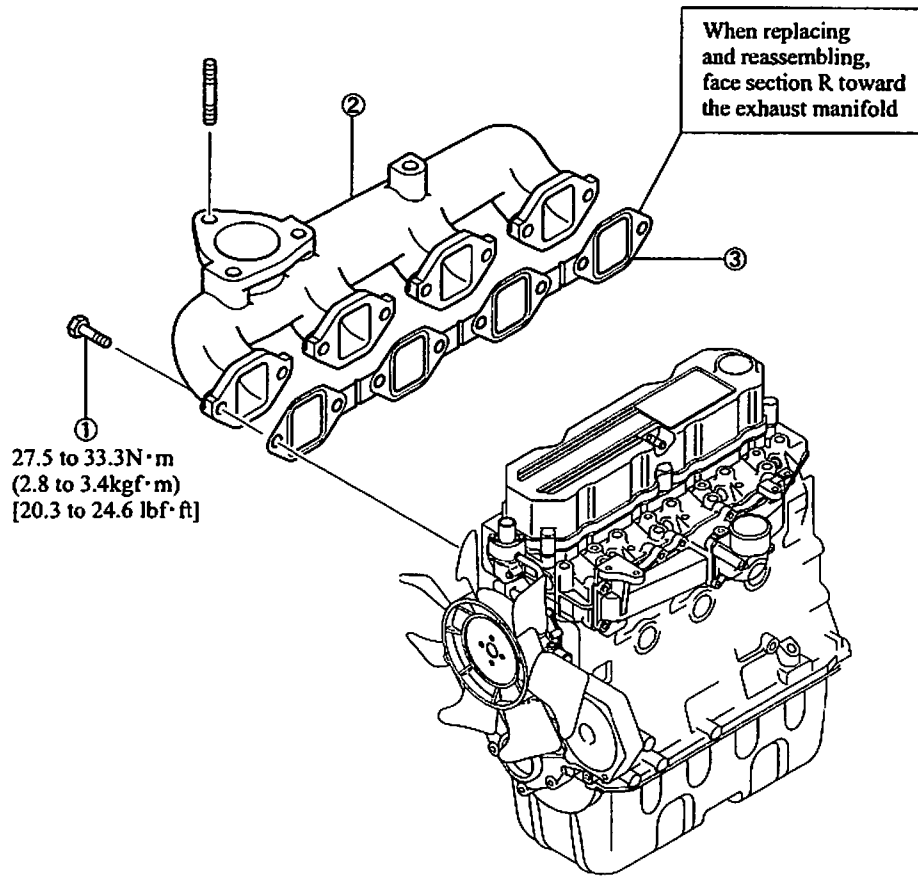
Measurement of exhaust manifold surface distortion

# INSTALLATION OF INLET AND EXHAUST SYSTEMS

1. Exhaust Manifold .....	6 - 8
2. Inlet Manifold.....	6 - 9



1. Exhaust Manifold

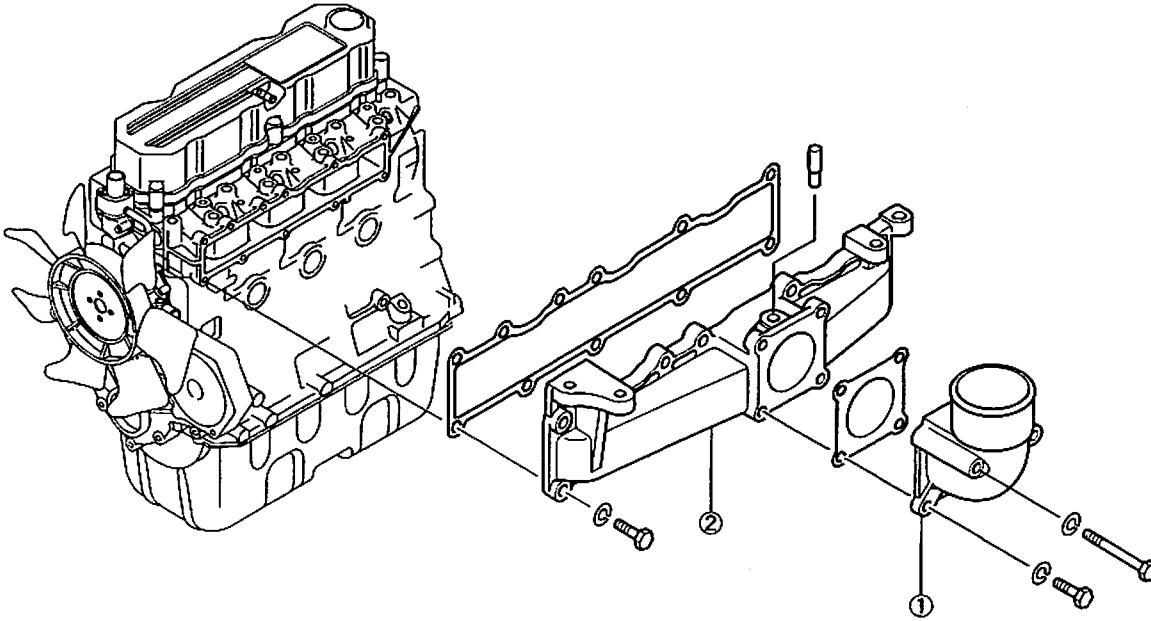


Installation of exhaust manifold

< Installation sequence >

③→②→①

2. Inlet Manifold



Installation of inlet manifold

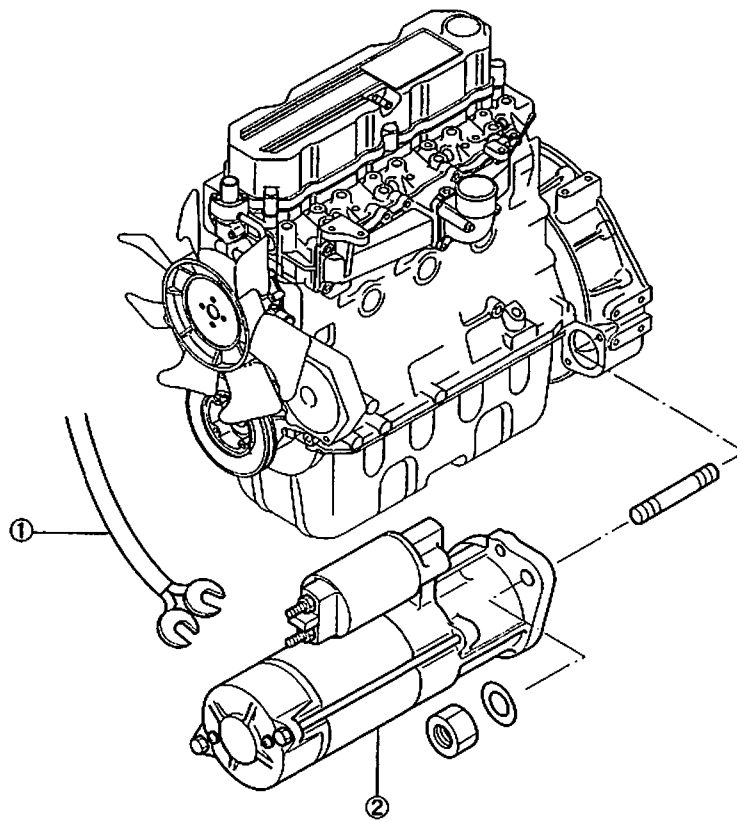
< Installation sequence >

②→①

# REMOVAL OF ELECTRICAL SYSTEM

1. Starter ..... 7 - 2
2. Alternator ..... 7 - 3
3. Glow Plugs..... 7 - 4

1. Starter



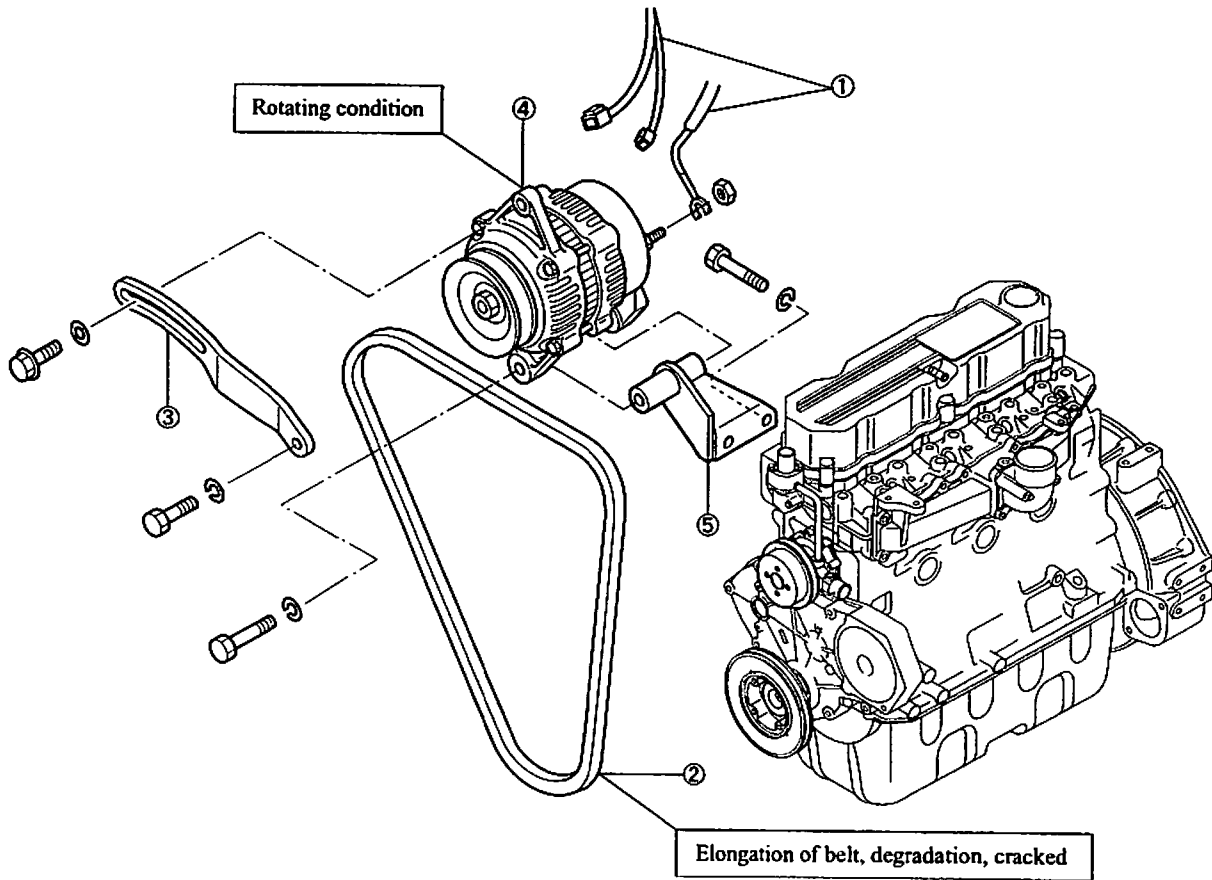
Removal of starter

< Removal sequence >

① Harness

② Starter

2. Alternator



Removal of alternator

< Removal sequence >

① Harness

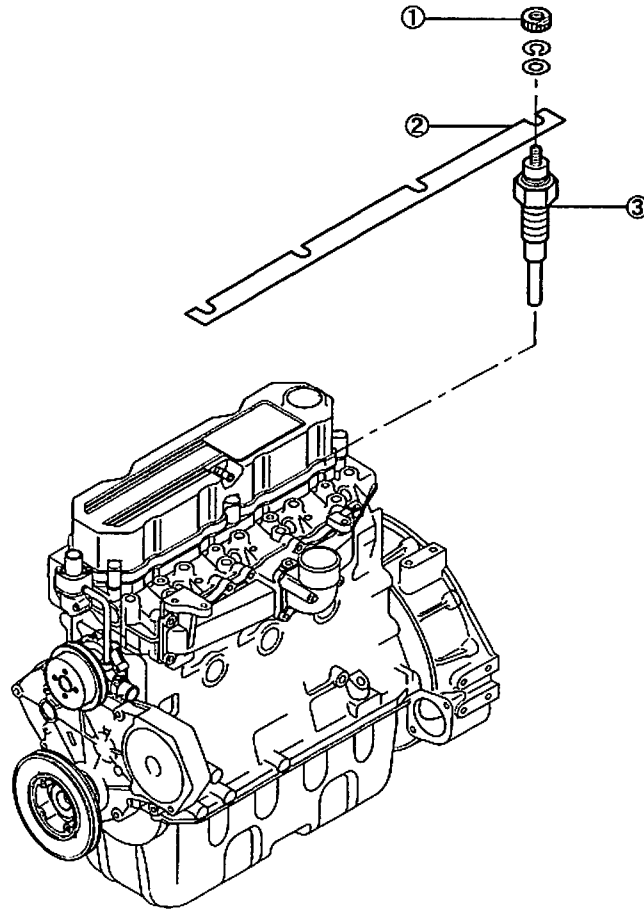
② V-Belt

③ Adjusting plate

④ Alternator

⑤ Bracket

### 3. Glow Plugs



Removal of glow plugs

< Removal sequence >

① Nut

② Connection plate

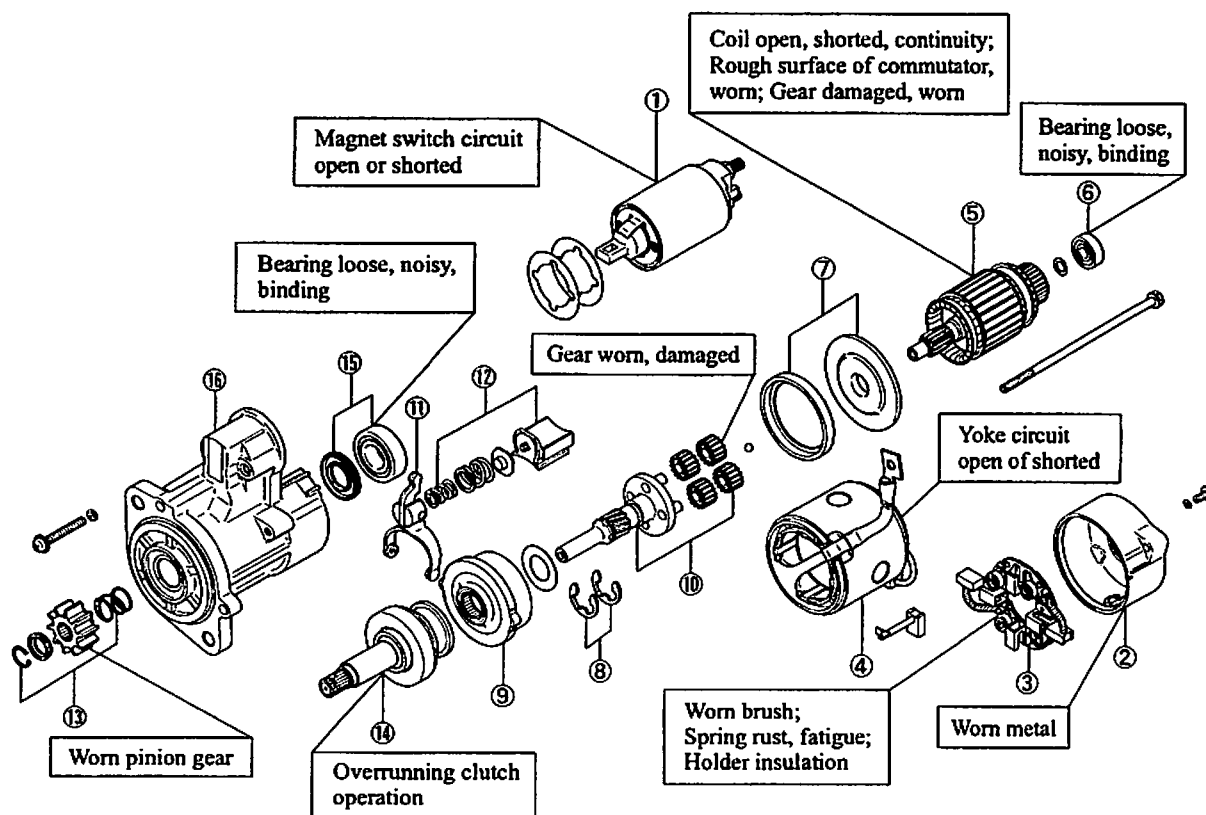
③ Glow plug

# DISASSEMBLY, INSPECTION AND REASSEMBLY OF ELECTRICAL SYSTEM

1. Starter .....	7 - 6
1.1 Disassembly and Inspection of Starter.....	7 - 6
1.2 Inspection of Starter .....	7 - 7
1.3 Reassembly of Starter .....	7 - 10
1.4 Inspection and Adjustment After Reassembly.....	7 - 11
2. Alternator .....	7 -12
2.1 On-Vehicle Inspection .....	7 -12
2.2 Disassembly of Alternator.....	7 -14
2.3 Inspection and Repair of Alternator.....	7 -16
2.4 Reassembly of Alternator .....	7 -18
3. Glow Plugs .....	7 -19
Inspection of Glow Plugs .....	7 -19

1. Starter

1.1 Disassembly and Inspection of Starter



Disassembly and inspection of starter

< Disassembly sequence >

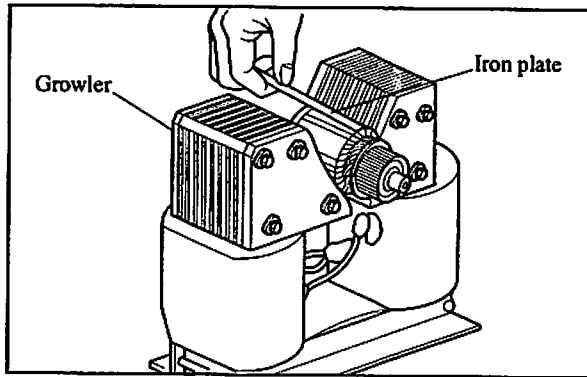
- |                          |                  |                          |
|--------------------------|------------------|--------------------------|
| ① Magnet switch assembly | ⑦ Packing        | ⑬ Pinion set             |
| ② Rear bracket           | ⑧ Washer         | ⑭ Overrunning clutch     |
| ③ Brush holder assembly  | ⑨ Internal gear  | ⑮ Bearing set            |
| ④ Yoke assembly          | ⑩ Gear           | ⑯ Front bracket assembly |
| ⑤ Armature assembly      | ⑪ Lever assembly |                          |
| ⑥ Bearing                | ⑫ Spring set     |                          |



1.2 Inspection of Starter

(1) Armature coil short-circuit test

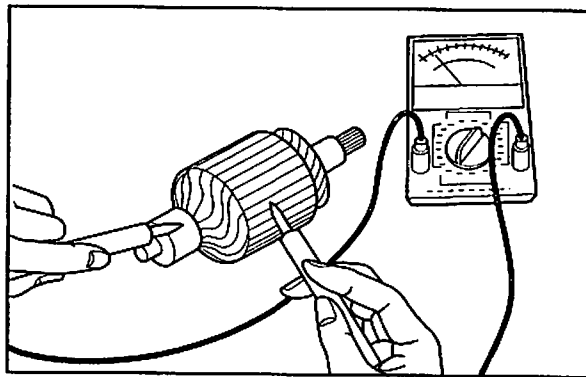
Place the armature on the growler. Set an iron piece parallel to the armature, and rotate the armature slowly by hand. If the iron piece is attracted to the coil or vibrates, there is a short-circuit; replace the armature.



Armature coil short-circuit test

(2) Armature coil grounding test

If there is continuity between the commutator and shaft (or core), replace the armature.



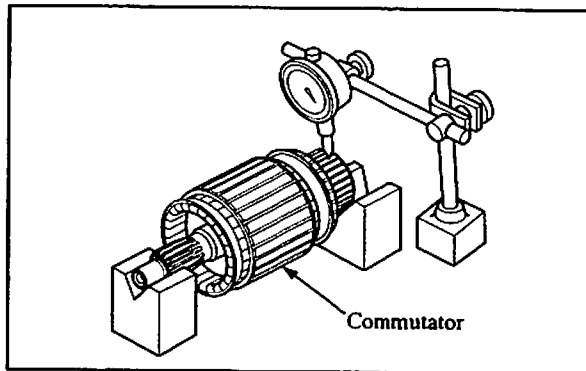
Armature coil grounding test

(3) Measurement of commutator runout

Measure the commutator runout using a dial gage. If the amount of runout exceeds the limit value, replace the armature. If the commutator surface is rough, refinish the surface with sand paper (#300 to #500). If the surface has ridges due to abrasion, replace the armature since it is not repairable.

Unit mm [in.]

	Limit
Commutator runout	0.10 [0.0039]



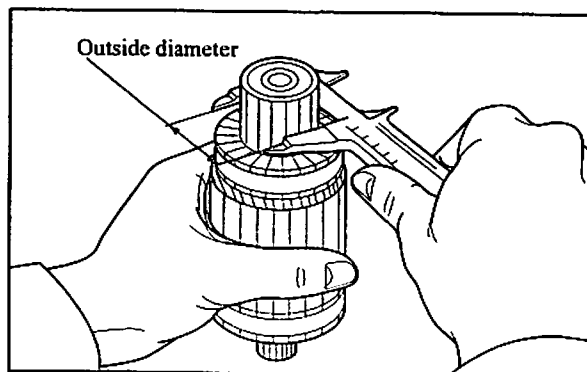
Measurement of commutator runout

(4) Measurement of commutator outside diameter

Measure the outside diameter of the commutator, and, if the limit value is exceeded, replace the armature.

Unit mm [in.]

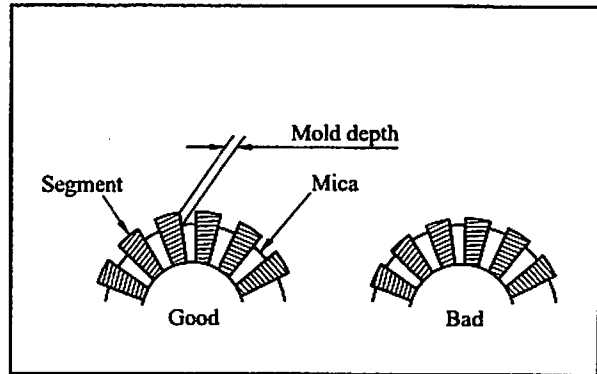
	Nominal value	Limit
Commutator outside diameter	φ32 [1.26]	31.4 [1.24]



Measurement of commutator outside diameter

- (5) **Measurement of mold depth between segments**  
 Clean the grooves between segments, and measure the mold depths between segments. If the limit value is exceeded, repair.

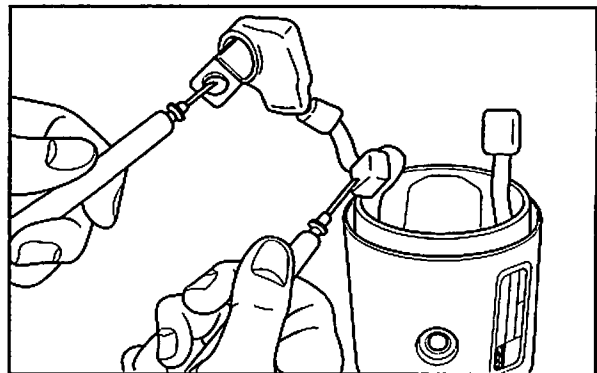
	Unit mm [in.]	
	Standard	Limit
Mold depth between segments	0.4 to 0.6 [0.0158 to 0.0236]	0.2 [0.0079]



Measurement of mold depth between segments

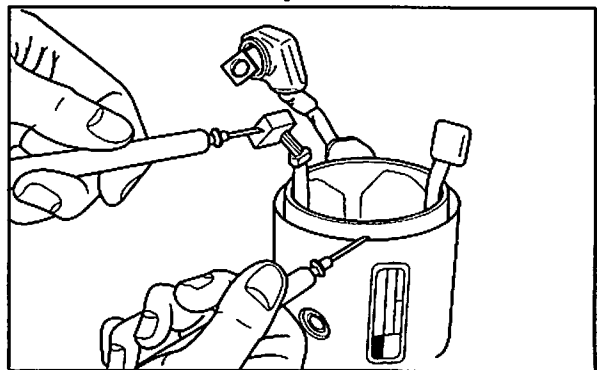
- (6) **Inspection of armature gear**  
 If the inspection of the armature gear finds abnormal wearing or chipped teeth, replace the armature.

- (7) **Yoke coil open-circuit test**  
 Check to see if there is continuity between the terminal lead wire and brush (positive). If there is no continuity, there is an open-circuit; replace the yoke assembly.



Yoke coil open-circuit test

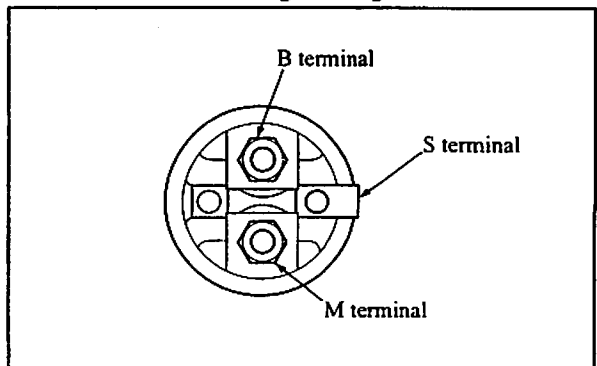
- (8) **Yoke coil grounding test**  
 Check to see if there is continuity between the yoke and brush (positive). If there is continuity, the yoke coil is grounded. Check the insulation, and replace the yoke assembly if the problem cannot be corrected.



Yoke coil grounding test

- (9) **Inspection of magnet switch**  
 Conduct the following continuity tests, and, if there is any problem, replace the magnet switch.

- (a) **Coil open-circuit test**  
 Check to see if there is continuity between terminal M and ground (case). There should be no continuity between terminal B and ground.
- (b) **Inspection of contact adhesion**  
 Check to make sure there is no continuity between terminal B and terminal M.

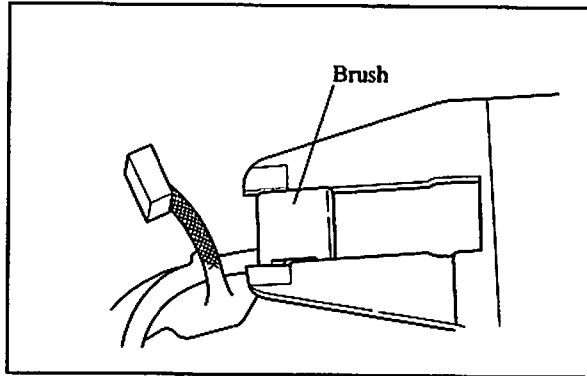


Inspection of magnet switch

(10) Measurement of brush length

Measure the length of each brush, and, if the limit value is exceeded, replace the brush. If the brush is unevenly worn or has a rough contact surface, refinish with sand paper (#300 to #500).

	Unit mm [in.]	
	Standard	Limit
Brush length	18 [0.7]	11 [0.4]

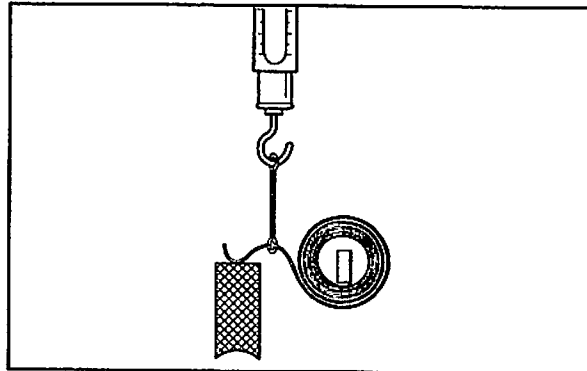


Measurement of brush length

(11) Measurement of brush spring tension

Measure the installation tension of each brush spring. Read the tension at the moment when the spring detaches from the brush. If the tension value is near the limit value, replace the brush spring.

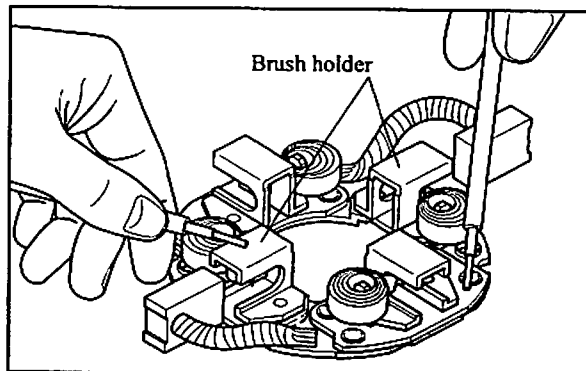
	Unit N (kgf) [lbf]		
	Nominal value	Standard	Limit
Brush spring tension	31 (3.2) [7.0]	26 to 36 (2.7 to 3.7) [5.8 to 8.1]	15 (1.5) [3.4]



Measurement of brush spring tension

(12) Inspection of brush holders for insulation

Using a tester, check to make sure that there is no continuity between the positive-side brush holder and negative-side brush holder plate. If there is continuity, replace the brush holder.

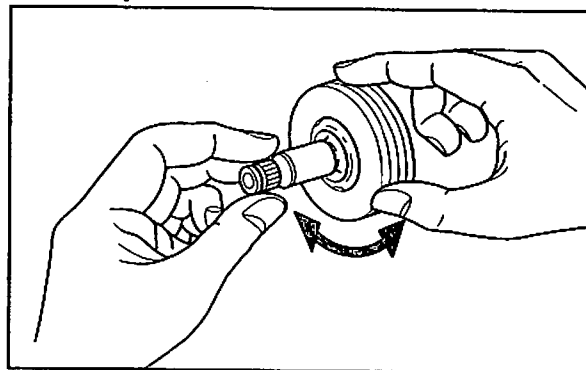


Inspection of brush holder for insulation

(13) Inspection of overrunning clutch

Make sure that the pinion shaft rotates smoothly in one direction, and locks in place when it is turned in the opposite direction.

If the pinion shaft does not rotate properly, replace the overrunning clutch (pinion shaft assembly).



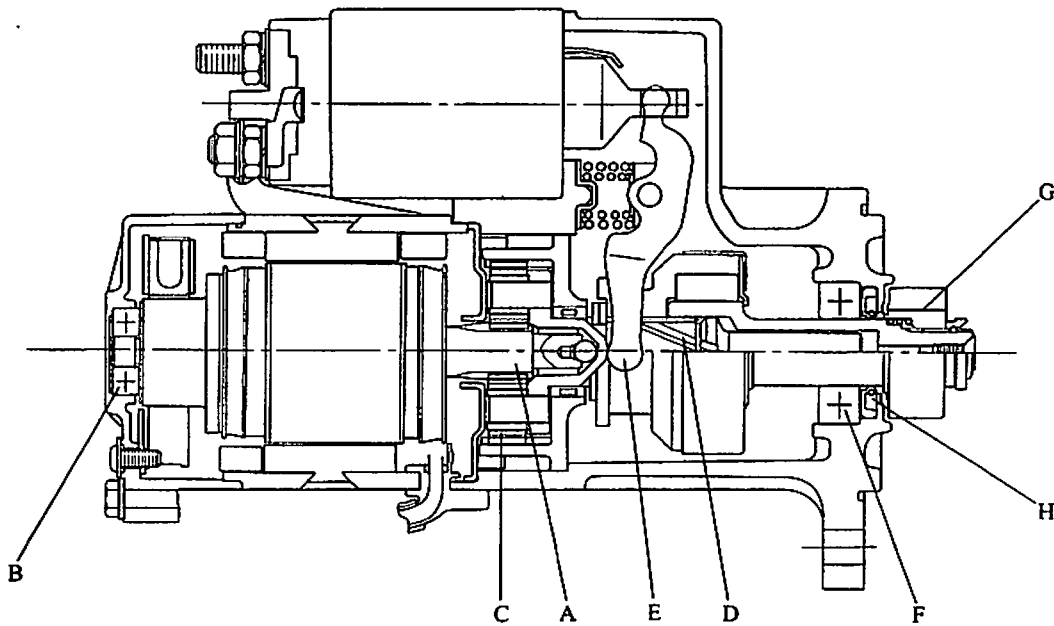
Inspection of overrunning clutch

1.3 Reassembly of Starter

Reassemble the starter by following the disassembly sequence in reverse, and observe the following during reassembly.

(1) Application of grease

In the case the starter has been overhauled, apply grease to the following sliding sections, gears and bearings.



Locations of grease application during starter reassembly

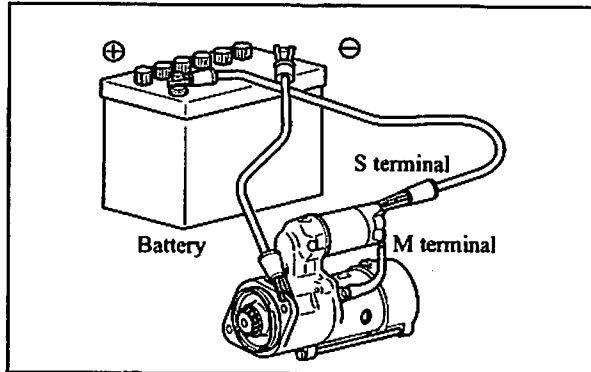
- |  |  |                        |
|--|--|------------------------|
| A Armature shaft gear  | C Reduction gear                           | F Pinion shaft bearing |
| B Armature rear-side bearing   | D Pinion shaft gear                        | G Pinion               |
| (Apply a small amount so that grease does not enter the commutator section.) | E Lever sliding section in magnetic switch | H Oil seal             |

1.4 Inspection and Adjustment after Reassembly

After reassembly, conduct the following inspections and tests.

(1) Adjustment of pinion gap

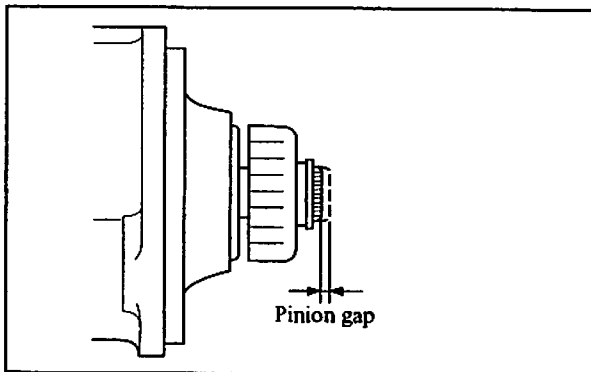
- (a) Since connecting the wires of the reassembled starter as shown in the diagram causes the pinion to extend and rotate slowly, disconnect the connector from terminal M to stop the rotation.



Adjustment of pinion gap (1)

- (b) Lightly push the tip of the extended pinion shaft with a finger, and measure the distance of the shaft movement to obtain the pinion gap measurement.

Adjust the pinion gap by varying the number of packings installed at the magnetic switch section so that it conforms to the standard value. When the number of packings is increased, the pinion gap decreases. If proper adjustment cannot be achieved by varying the number of packings, replace the lever assembly.



Adjustment of pinion gap (2)

Unit mm [in.]

	Standard
Pinion gap	0.5 to 2.0 [0.02 to 0.08]

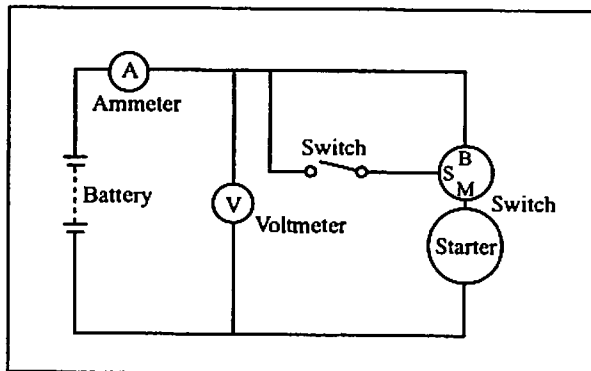
Note: To prevent the switch coil from overheating during inspection, do not supply electricity for more than 10 continuous seconds.

(2) No-load test

After the pinion gap adjustment, connect measurement instruments between the starter and battery as shown in the diagram to check no-load characteristics.

**CAUTION**

Use thick wires, and firmly tighten the connections at the terminals.



No-load test

	Voltage	Current	Rotation speed
No-load characteristic	11V	130 A or lower	3600 min <sup>-1</sup> or higher

**2. Alternator**

If a problem occurs in the charge system, check the following conditions to locate the cause of the problem. Only when inspection cannot be conducted on the alternator in the installed condition, dismount the alternator for inspection and repair.

Over-charging	Voltage regulator adjustment value is high.
	Faulty battery.
Over-discharging	Voltage relay adjustment value is low.
	Faulty alternator output.
	Power consumption is extremely high.
	Special load is used.
	Faulty wiring.

**2.1 On-Vehicle Inspection**

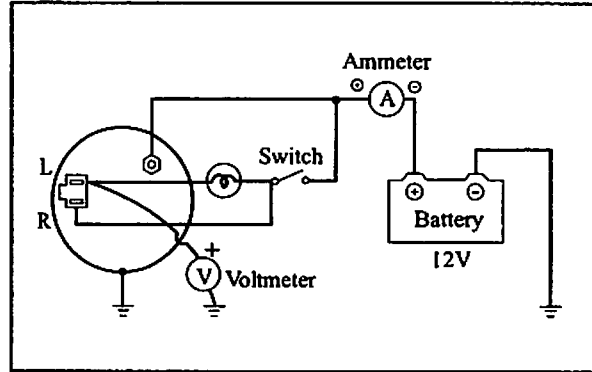
**(1) Cautions for handling**

Handle the alternator carefully, as incorrect handling can result in alternator damage or malfunctions.

- (a) Do not connect the battery cables in reverse. Note that the negative (-) cable is a grounding wire.
- (b) Do not use a high-voltage tester such as a megger.
- (c) When charging the battery, disconnect the cables from the battery terminals.
- (d) Do not disconnect the lead wire from terminal B of the alternator while the engine is operating.
- (e) Do not ground terminal B of the alternator since it is constantly applied with battery voltage.
- (f) Do not short-circuit or ground terminal L. (unit with integrated IC regulator)
- (g) When using a steam cleaner, do not allow steam to directly contact the alternator.

(2) Inspection of adjustment voltage (unit with integrated IC regulator)

- (a) Disconnect the cable from the positive (+) terminal of the battery, and connect an ammeter between the terminal and cable.
- (b) Connect a voltmeter between terminal L and ground.
- (c) Make sure that the voltmeter indicates "0" when the starter switch is turned off. Make sure that the voltmeter indicates a voltage level sufficiently lower than the battery voltage when the starter switch is turned on (without starting the engine).
- (d) Short-circuit the terminal of the ammeter, and start the engine.
- (e) Read the indication (adjustment voltage) on the voltmeter with the ammeter indicating 5A or lower, the engine operating at 1800 to 2500 min<sup>-1</sup>, and the lamp switches turned off.

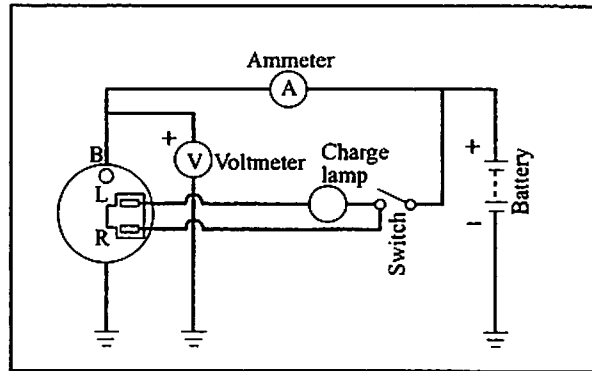


Inspection of adjustment voltage

	Unit V	
	Standard	V-A
Adjustment volt (at 20 °C [68 °F])	14.7±0.3	12-50

(3) Inspection of output (unit with integrated IC regulator)

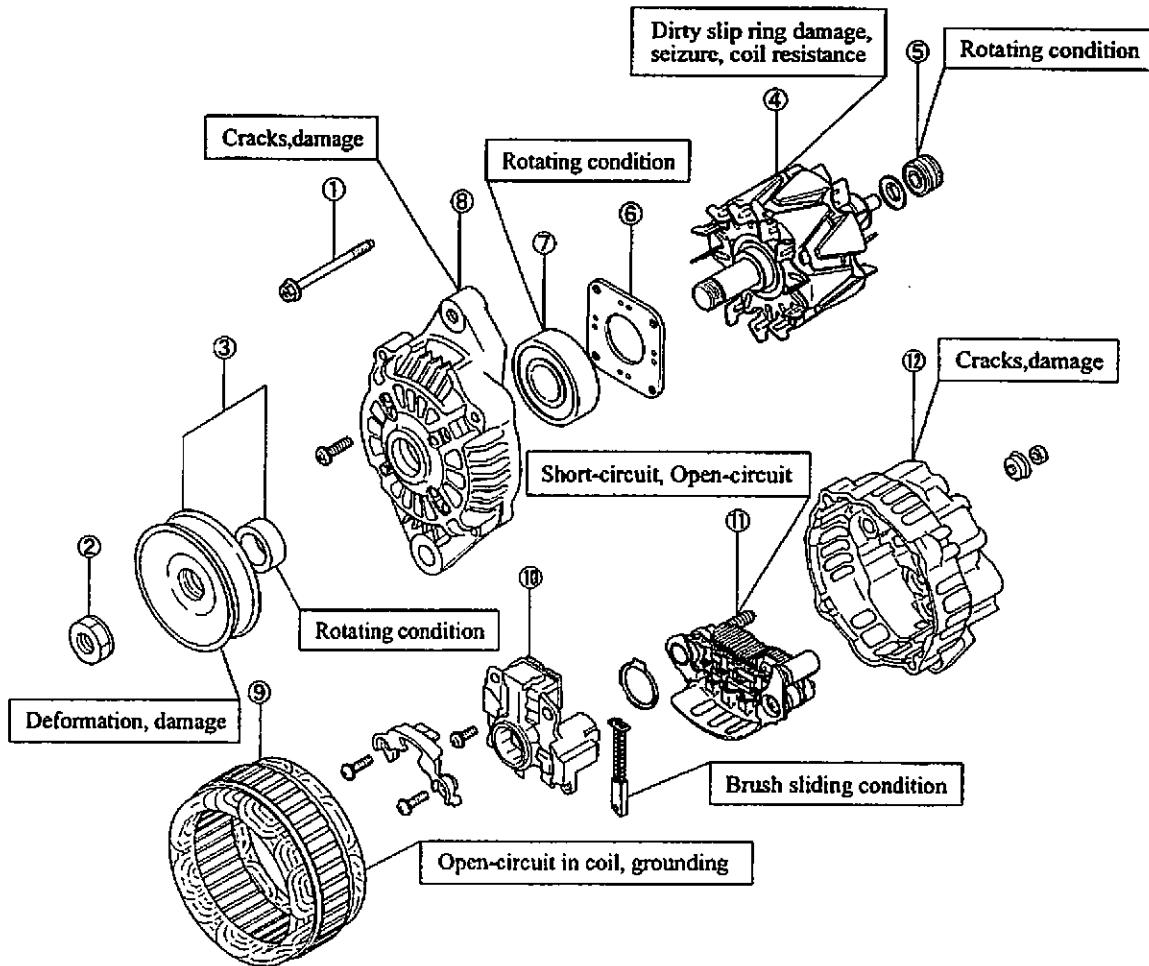
- (a) Disconnect the grounding cable from the battery.
- (b) Disconnect the wire from terminal B of the alternator, and connect an ammeter, then connect a voltmeter between terminal B and ground.
- (c) Reconnect the grounding cable to the battery.
- (d) Start the engine.
- (e) Immediately after the engine starts, turn on all load devices such as lamps.
- (f) Increase the engine speed, and read the maximum current at the specified alternator rotation speed when the voltmeter indicates 27.0 V. If the measured value conforms to the standard value, the alternator is normal.



Wiring for output test

		Output performance Standard	
Model		Terminal voltage/current	Rotation speed
Output characteristic (when warm)	A7T02077C	13.5 V/32 A or higher	2500 min <sup>-1</sup>
		13.5 V/47 A or higher	5000 min <sup>-1</sup>

2.2 Disassembly of Alternator



Disassembly of alternator

< Disassembly sequence >

- ① Through bolt
- ② Nut, washer
- ③ Pulley, spacer
- ④ Rotor

- ⑤ Rear bearing
- ⑥ Bearing retainer
- ⑦ Front bearing
- ⑧ Front bracket

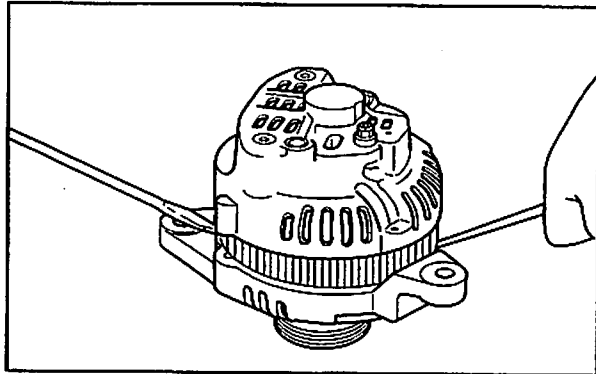
- ⑨ Stator core
- ⑩ Regulator assembly
- ⑪ Rectifier assembly
- ⑫ Rear bracket



- (1) Separation of front bracket from stator core  
 Insert the tip of a slotted screwdriver into the gap between the stator core and front bracket, and pry open.

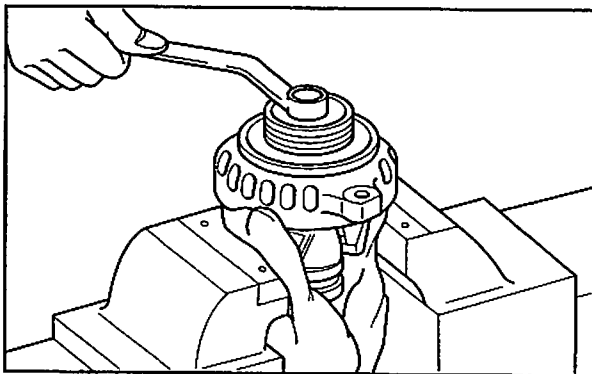
**⚠ CAUTION**

Do not insert the screwdriver too far into the assembly to prevent damaging the stator core.



Separation of front bracket from stator core

- (2) Removal of pulley  
 (a) After wrapping the rotor with a cloth for protection and holding it with a vice, unscrew the pulley nut, then remove the pulley and spacer.  
 (b) Remove the rotor from the front bracket.

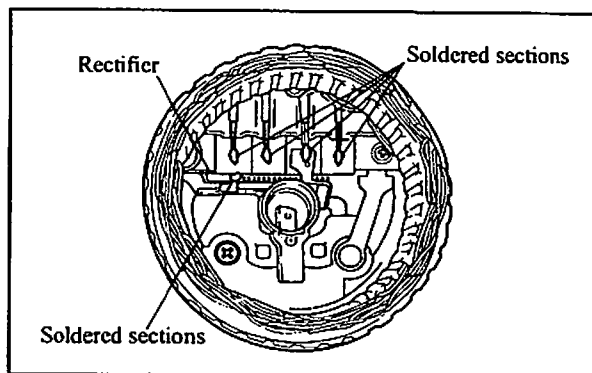


Removal of pulley

- (3) Removal of stator core and rectifier  
 (a) Disconnect the lead wires between the stator core and the rectifier at the soldered sections, and remove the stator core.

**⚠ CAUTION**

Melt the soldered sections as quickly as possible. Prolonged heating can damage the diodes.



Removal of stator core

- (b) Unscrew the rectifier mounting screws, and dismount the rectifier.

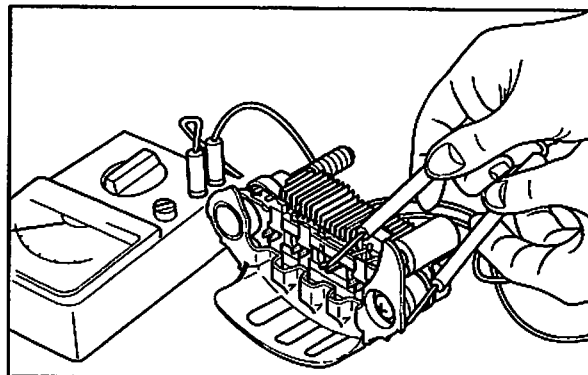
**2.3 Inspection and Repair of Alternator**

**(1) Inspection of diodes**

Conduct a continuity test with each diode in the rectifier.

(a) Using a tester, check continuity between each diode lead terminal and its case. If the resistance value is large in one direction and small in the opposite direction, the diode is normal.

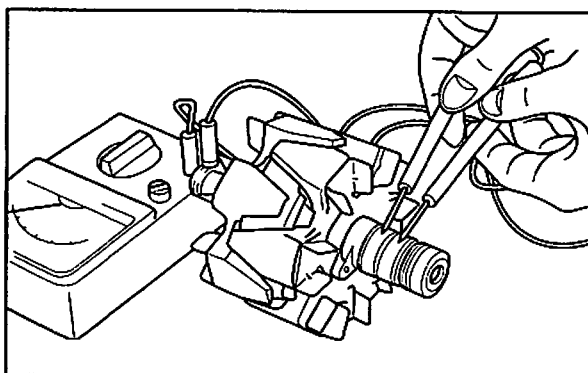
(b) If the resistance measurements are the same in both directions, replace the rectifier. Be sure to check all diodes.



**Inspection of diode**

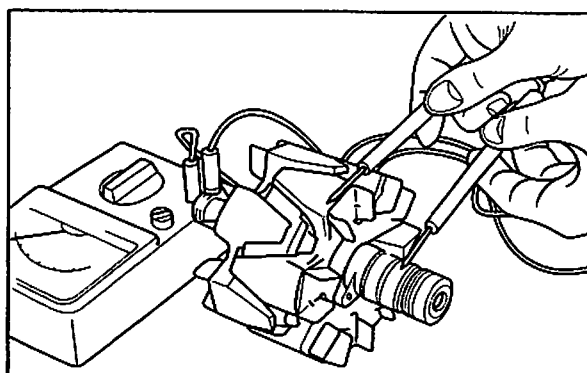
**(2) Inspection of field coil**

(a) Check continuity between snap rings. If there is no continuity, there is an open-circuit; replace the field coil.



**Field coil continuity test**

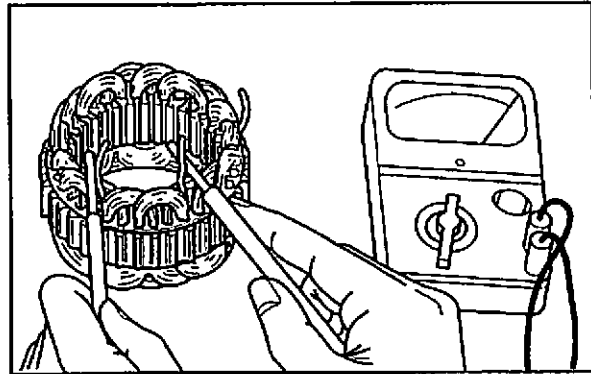
(b) Check continuity between the slip ring and shaft (or core). If there is continuity, there circuit is grounded; replace the field coil.



**Field coil grounding test**

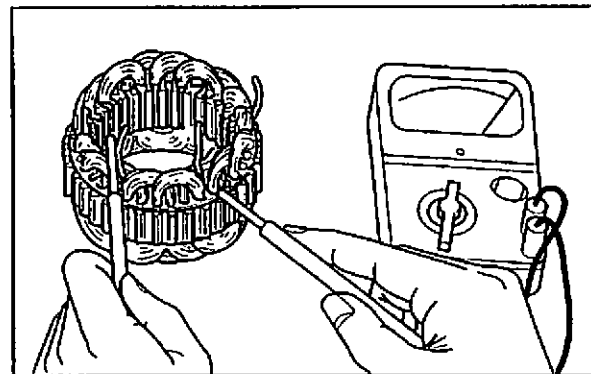
(3) Inspection of stator core

- (a) Check continuity between lead wires.  
If there is no continuity, there is an open circuit; replace the stator core.



Stator core continuity test

- (b) Check continuity between the stator core and each lead wire. If there is continuity, the stator core is grounded; replace the stator core.

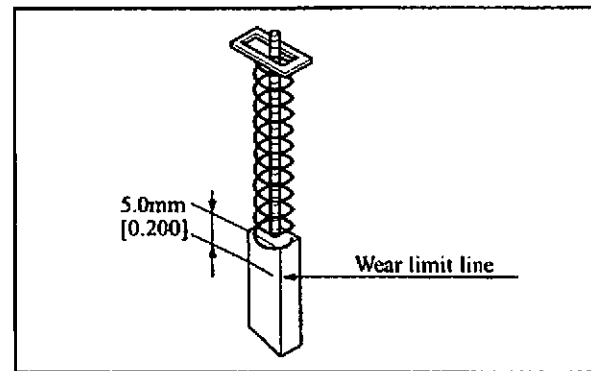


Stator core grounding test

(4) Inspection of brushes

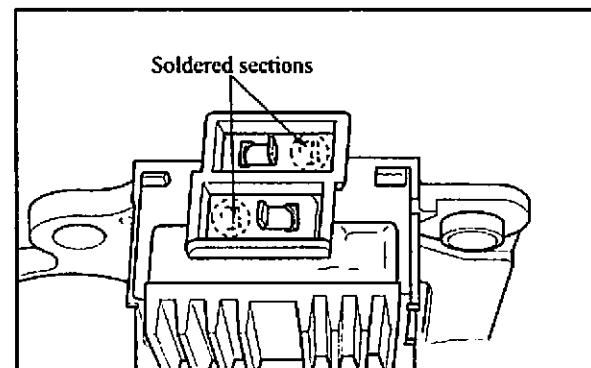
- (a) If the brushes are worn close to the wear limit (service limit), replace the brushes.

	Unit mm [in.]	
	Standard	Limit
Brush length	18.5 [0.730]	5.0 [0.200]



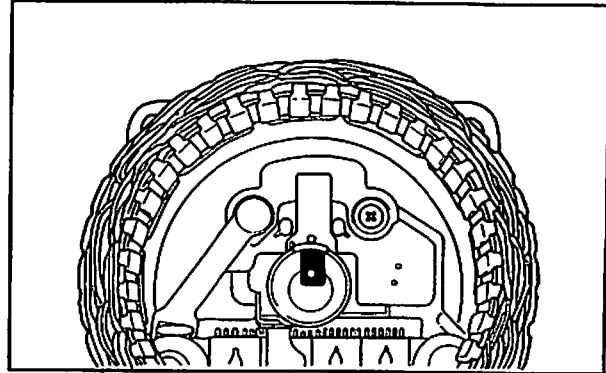
Inspection of brush

- (b) To remove the brushes and springs, disconnect the brush lead wires at the soldered sections.



Replacement of brushes (1)

- (c) To install new brushes, press them into the brush holders as shown in the diagram, then solder the lead wires.

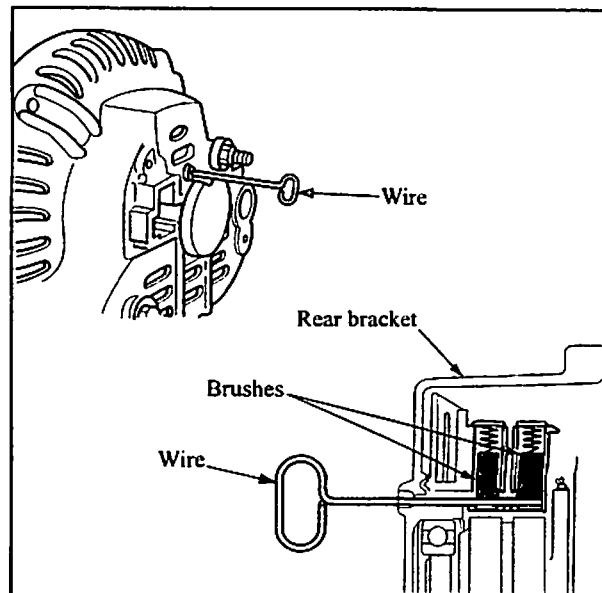


**Replacement of brushes (2)**

#### **2.4 Reassembly of Alternator**

To reassemble, follow the disassembly sequence in reverse, and observe the following during reassembly.

- (1) Locate the eccentric groove on the periphery of the rear bearing. Insert the rotation retaining snap ring so that the highest protruded section of the ring is positioned at the deepest section of the groove.
- (2) When replacing the rear bearing, press-fit the rear bearing so that the groove on the periphery of the bearing faces the snap ring side.
- (3) When press-fitting the rear bearing into the rear bracket, heat the rear bracket to 50 to 60 °C [122 to 140 °F] first.
- (4) Before installing the rotor to the rear bracket, lift the brushes by inserting a wire through a small hole in the rear bracket, then remove the wire after completing the reassembly.



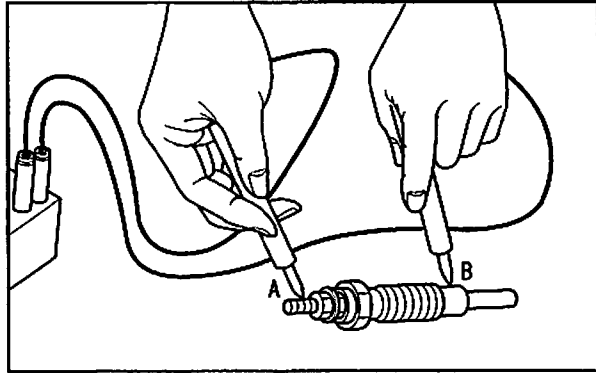
**Reassembly of alternator**

### 3. Glow Plugs

#### Inspection of Glow Plugs

As shown in the diagram, check continuity between the terminal and body, and, if there is no continuity or the resistance is high, replace the glow plug.

	Unit $\Omega$
	Standard
Resistance	1.0

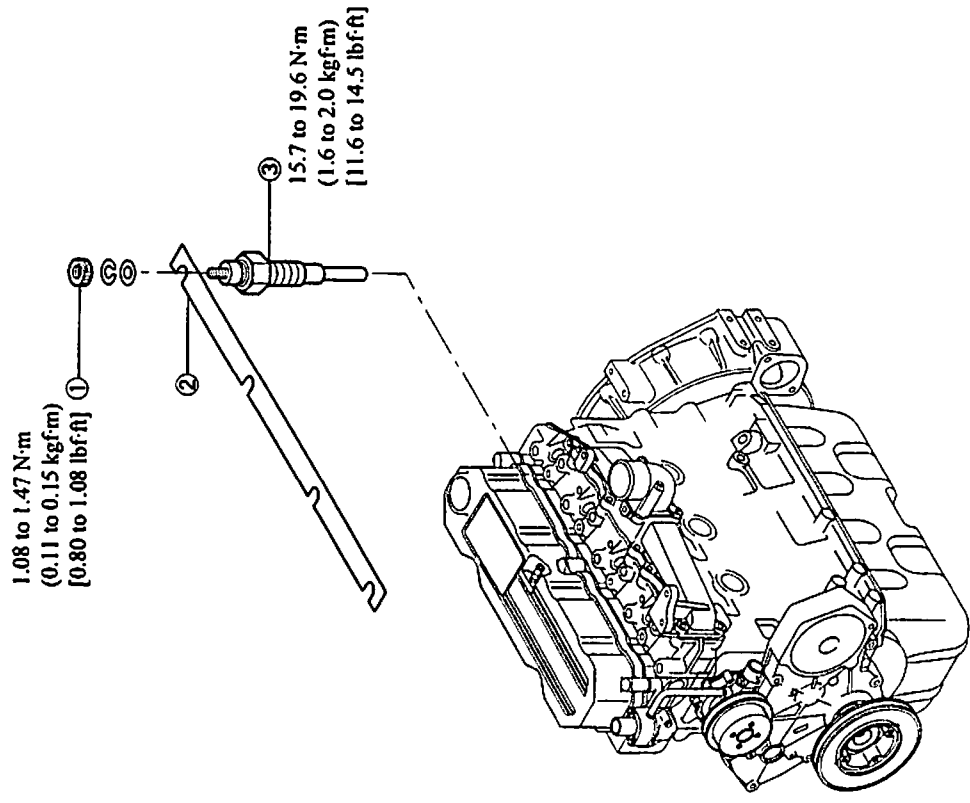


Inspection of glow plug

# INSTALLATION OF ELECTRICAL SYSTEM

1. Glow Plugs.....	7 -22
2. Alternator .....	7 -23
Installation of Alternator.....	7 -23
3. Starter .....	7 -24

1. Glow Plugs

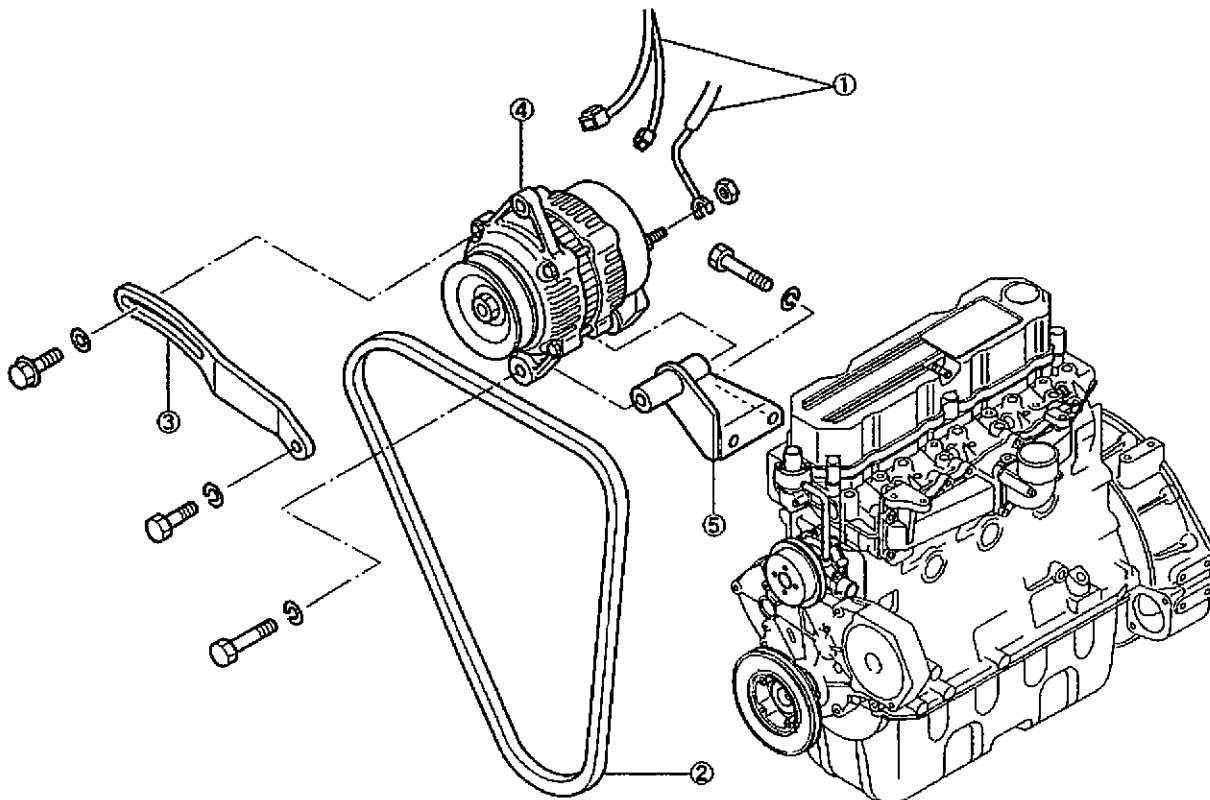


Installation of glow plug

< Installation sequence >

③→②→①

## 2. Alternator



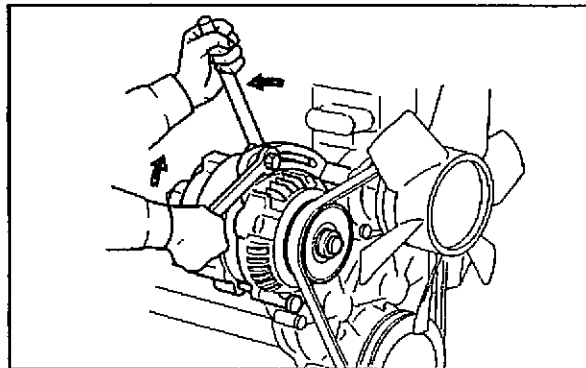
Installation of alternator

< Installation sequence >

⑤→④→③→②→①

### Installation of Alternator

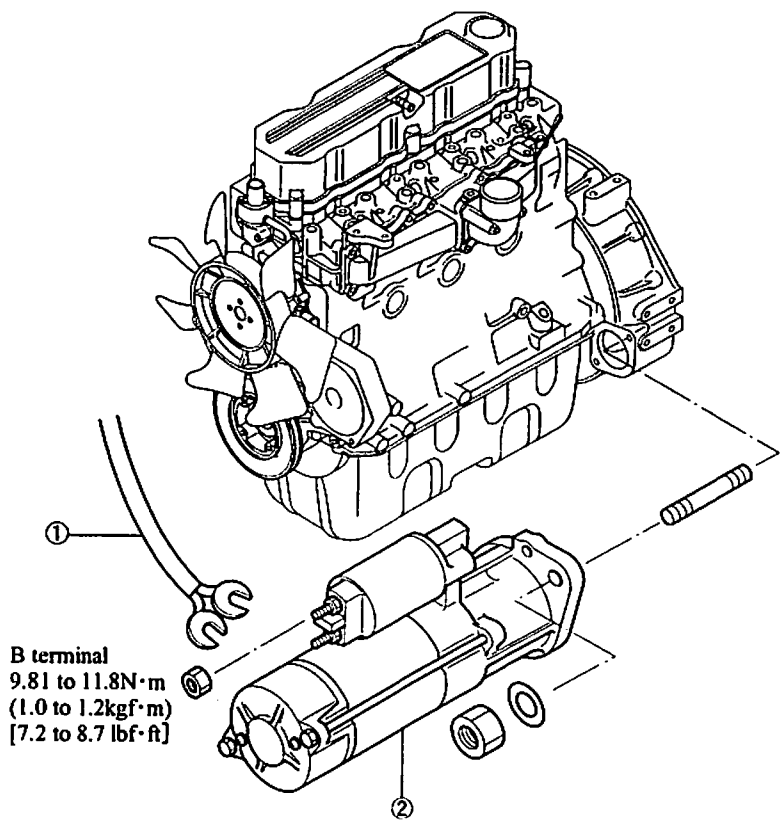
- (1) Install the fan belt on the alternator, and mount the alternator on the engine.  
Temporarily tighten all bolts.
- (2) Insert a bar between the alternator and crankcase, and adjust the belt tension by using the bar as leverage.  
While keep the alternator at that position, tighten the bolt that secures the alternator to the adjusting plate.
- (3) Check the belt tension, and, if it deviates from the standard value, loosen the bolt and repeat above step (2).



Keep of alternator



**3. Starter**



Installation of starter

< Installation sequence >

②→①

# INSPECTION, ADJUSTMENT, BREAK-IN OPERATION AND PERFORMANCE TESTS

<b>1. Adjustment of Engine</b> .....	<b>8 - 2</b>
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1.2 Draining of Fuel System .....	8 - 3
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**1. Adjustment of Engine**

**1.1 Inspection and Adjustment of Valve Clearance**

Inspect and adjust the valve clearance of the engine when the engine is cold.

Unit: mm [in.]

		Standard
Valve clearance (when engine is cold)	Inlet	0.25 [0.0098]
	Exhaust	

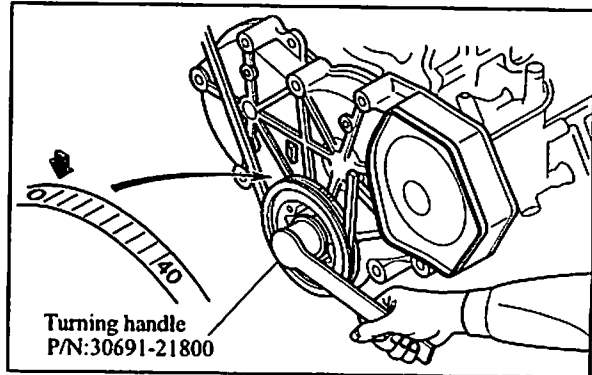
**(1) Inspecting valve clearance**

- (a) Inspect the valve clearance in the firing order by turning the crankshaft 180° in the normal direction to bring each piston to the top dead center on the compression stroke.

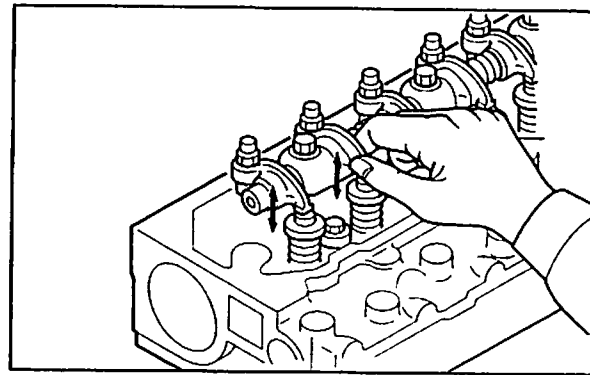
**Firing order**

Sequence (cylinder No.)	Turning angle
1-3-4-2	180°

- (b) Attach a socket and ratchet handle to the crankshaft pulley tightening nut, and turn the crankshaft.
- (c) When the No. 1 piston is at the top dead center on the compression stroke, the "0" line stamped on the circumference of the crankshaft pulley is aligned with the pointer of the timing gear case, and the inlet and exhaust valves are not lifted off their seats by the pushrods.
- (d) Insert a feeler gage between the rocker arm and valve cap to inspect the clearance.



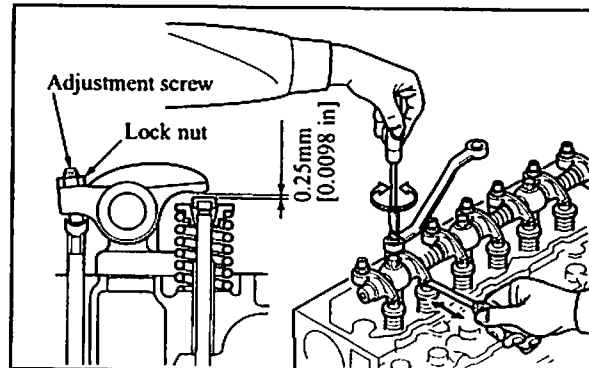
Checking top dead center of No. 1 piston on compression stroke (1)



Checking top dead center of No. 1 piston on compression stroke (2)

**(2) Adjusting valve clearance**

- (a) Loosen the lock nut, insert a feeler gage between the rocker arm and valve cap, and while measuring the clearance, tighten or loosen the adjusting screw until the feeler gage moves slightly tight.
- (b) After adjusting the clearance, securely tighten the lock nut, and inspect the clearance again.



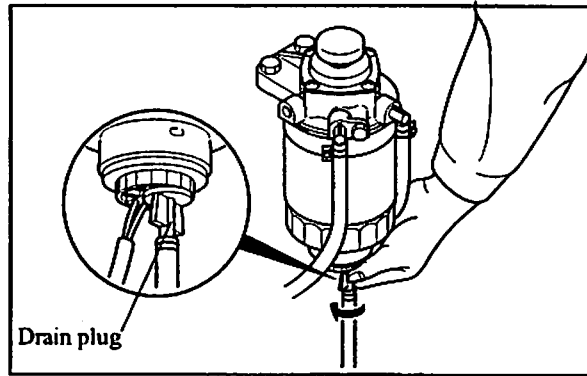
Adjusting valve clearance

## 1.2 Draining of Fuel System

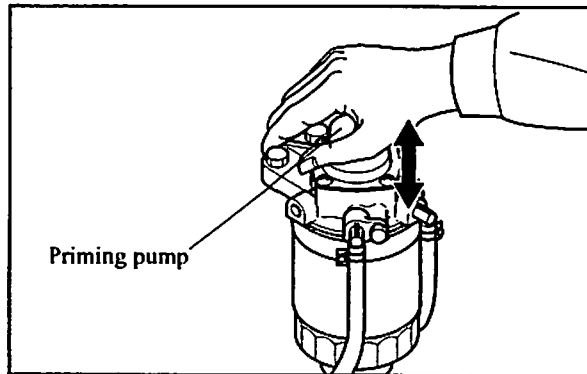
If water collects in an amount greater than the specified amount in the bottom of the fuel filter, it may enter the fuel system.

Drain the fuel system as described below.

- (1) Fuel filter (distributor-type fuel injection pump)
  - (a) Loosen the drain plug at the bottom of the fuel filter.
  - (b) Push the priming pump about seven times to feed the fuel rapidly to accelerate the draining of the fuel system.
  - (c) After draining the fuel system, securely tighten the drain plug.
  - (d) After draining the fuel system, be sure to bleed the fuel system.



Draining of fuel filter (1)



Draining of fuel filter (2)

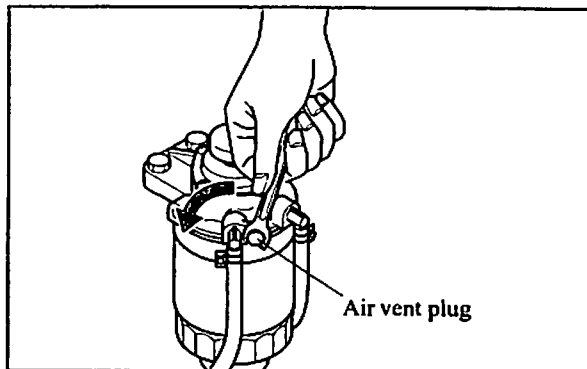
### **CAUTION**

When the fuel system is drained, the fuel is discharged at the same time. Thoroughly wipe off any fuel spilled on the surrounding parts.

## 1.3 Bleeding of Fuel System

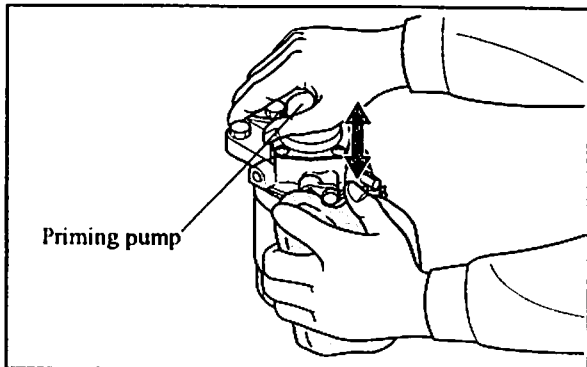
Start to bleed the fuel system from a location closest to the fuel tank, and move toward the engine in the order of the fuel filter and the fuel injection pump.

- (1) Fuel filter (distributor-type fuel injection pump)
  - (a) Loosen the air vent plug of the fuel filter with a wrench.



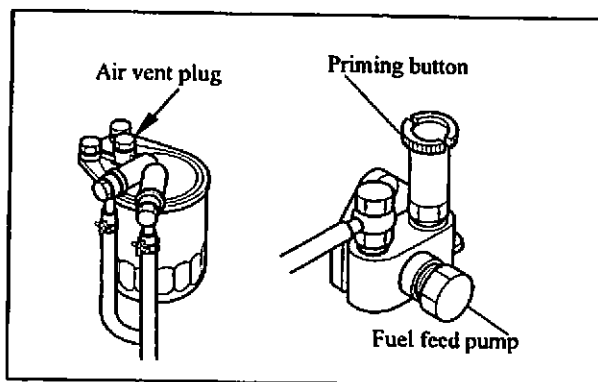
Bleeding of fuel filter (1)

- (b) Apply a cloth to the air vent plug, and repeatedly push the priming pump. The bleeding procedure is completed when no air bubbles appear in the fuel coming out of the air vent plug.
- (c) Securely tighten the air vent plug.



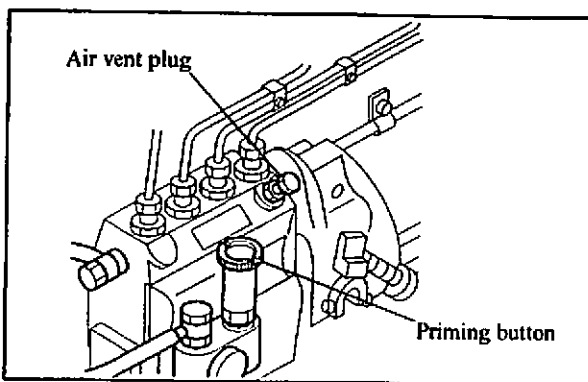
Bleeding of fuel filter (2)

- (2) **Fuel filter (in-line fuel injection pump)**
- (a) Loosen the air vent plug of the fuel filter by about 1.5 turns.
  - (b) Loosen the priming pump cap of the fuel feed pump by turning it counterclockwise, and move it up and down.
  - (c) Tighten the air vent plug when no air bubbles appear in the fuel coming out of it.



**Bleeding fuel filter (in-line fuel injection pump)**

- (3) **Fuel injection pump (in-line fuel injection pump)**
- (a) Loosen the air vent plug of the fuel injection pump by about 1.5 turns.
  - (b) Move up and down the priming pump cap.
  - (c) Tighten the air vent plug when no air bubbles appear in the fuel coming out of it. Before tightening the last air vent plug, lock the priming pump cap of the fuel feed pump by turning it clockwise while pushing it down.
  - (d) Bleed the right-hand fuel injection pump in the same way as the left-hand one.



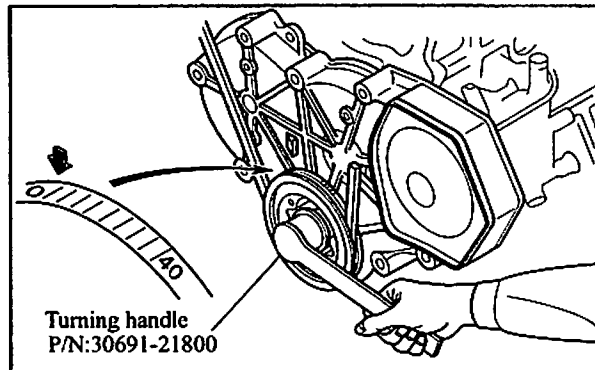
**Bleeding fuel injection pump  
(in-line fuel injection pump)**

- Note:**
- (a) If all of the vent plugs are tightened before the priming pump cap is locked, the fuel pressure acts on the fuel feed pump to make it impossible to return the priming pump cap to the original position.
  - (b) Thoroughly wipe off any fuel spilled from the air vent plugs with a cloth or the like.

#### 1.4 Inspection of Fuel Injection Timing (Distributor-type Fuel Injection Pump Specification)

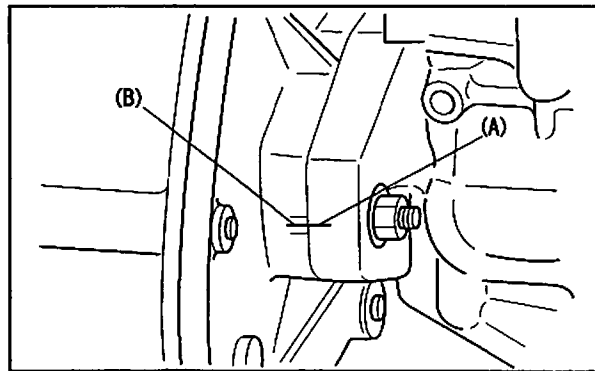
The fuel injection timing varies with the output, speed and other engine specifications. Be sure to check it according to the specification sheet.

- (1) Checking top dead center of No.1 piston on compression stroke
  - (a) Apply a special tool or turning socket to the crankshaft pulley tightening nut, and turn the crankshaft in the normal direction of engine rotation or clockwise when seen from the front of the engine.
  - (b) Stop turning the crankshaft when the "0" line stamped on the circumference of the crankshaft pulley is aligned with the pointer of the timing gear case.
  - (c) Move the rocker arms of the inlet and exhaust valves of the No. 1 cylinder up and down to check that the pushrods are not lifting both of the inlet and exhaust valves off their seats or that the inlet and exhaust valves both have no clearance.



Checking top dead center of No. 1 piston on compression stroke

- (2) Check that the alignment mark (A) of the fuel injection pump is aligned with the alignment mark (B) of the flange plate.



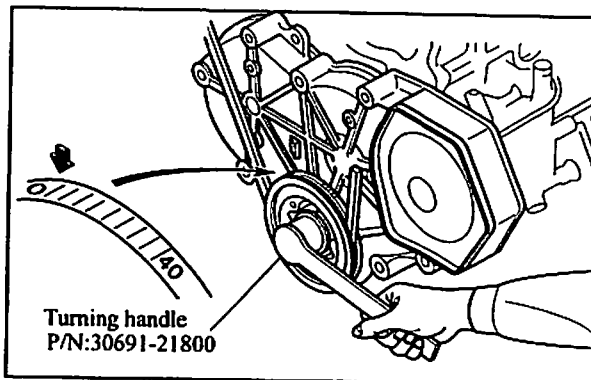
Alignment mark of fuel injection pump

**1.5 Inspection of Fuel Injection Timing (In-line Fuel Injection Pump Specification)**

The fuel injection timing varies with the output, speed and other engine specifications. Be sure to check it according to the specification sheet.

**(1) Checking top dead center of No.1 piston on compression stroke**

- (a) Apply a special tool or turning socket to the crankshaft pulley tightening nut, and turn the crankshaft in the normal direction of engine rotation or clockwise when seen from the front of the engine.
- (b) Stop turning the crankshaft when the "0" line stamped on the circumference of the crankshaft pulley is aligned with the pointer of the timing gear case.
- (c) Move the rocker arms of the inlet and exhaust valves of the No. 1 cylinder up and down to check that the pushrods are not lifting both of the inlet and exhaust valves off their seats or that the inlet and exhaust valves both have no clearance.



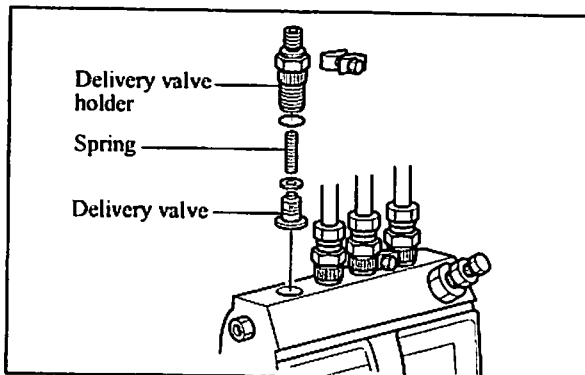
Checking top dead center of No. 1 piston on compression stroke

**(2) Inspecting fuel injection timing**

- (a) Bring the piston to the top, and check the top dead center.

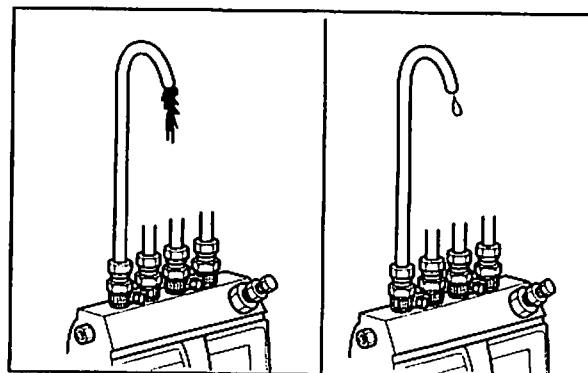
Remove the delivery valve holder from the No.1 plunger of the fuel injection pump, remove the delivery valve, spring and stopper, and install the delivery valve holder alone.

- (b) Install the spare injection pipe to the No.1 plunger. Face the other end of the pipe downward so that the flow-out condition of the fuel can be clearly seen.
- (c) Position the crankshaft at about 60° before the top dead center of the No.1 piston on the compression stroke.



Inspecting fuel injection timing (1)

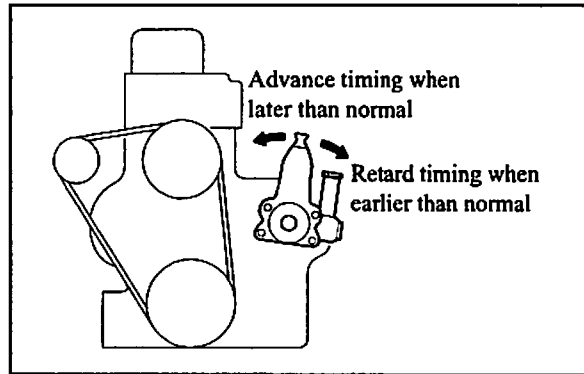
- (d) Feed the fuel by the priming pump, and slowly turn the crankshaft in the normal direction while allowing the fuel to flow out of the injection pipe.
- (e) Turn the crankshaft more slowly when the flow of the fuel out of the injection pipe is about to stop, and stop turning the crankshaft when the flow of the fuel out of the injection pipe is stopped.
- (f) Check that the line stamped on the crankshaft pulley and the pointer indicate the fuel injection timing.



Inspecting fuel injection timing (2)

**1.6 Adjustment of Fuel Injection Timing**

When the fuel is injected earlier than normal, turn the fuel injection pump away from the crankcase.  
 When the fuel is injected later than normal, turn the fuel injection pump toward the crankcase.



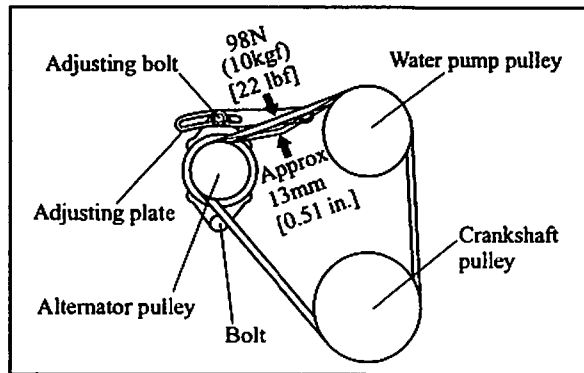
Adjustment of fuel injection timing

**1.7 Inspection and Adjustment of V-belt Tension**

Inspect the V-belt for the amount of deflection when it is strongly pressed down on with the thumb at the center of its span. Adjust the V-belt to proper tension by loosening all of the bolts securing the alternator and installing the alternator at an appropriate angle.

Unit: mm [in.]

	Standard
Deflection of V-belt	Approx. 13 [0.51] (Amount of belt deflection when pushed with force of 98N(10kgf)[22 lbf])



Inspection and adjustment of V-belt tension



1.8 Adjustment of Governor (Distributor-type Fuel Injection Pump Specification)

Inspection and adjustment of minimum no-load speed (low idle speed) and maximum no-load speed

**⚠ CAUTION**

- (a) Each engine has the minimum no-load speed (low idle speed) and maximum no-load speed checked on the test bench at the factory and has the setting bolts sealed. These settings can be inspected and adjusted at our designated service shop only.
- (b) After the governor parts are adjusted, seal all external stoppers as done at the time of factory shipment.
- (c) Whether the seals are intact or not has important bearing on the validity of claims under warranty. Be sure to seal all of the specified sections.
- (d) When inspecting and adjusting the governor, be prepared to operate the engine stop lever manually in anticipation of the engine overrunning (running at an extremely high speed).

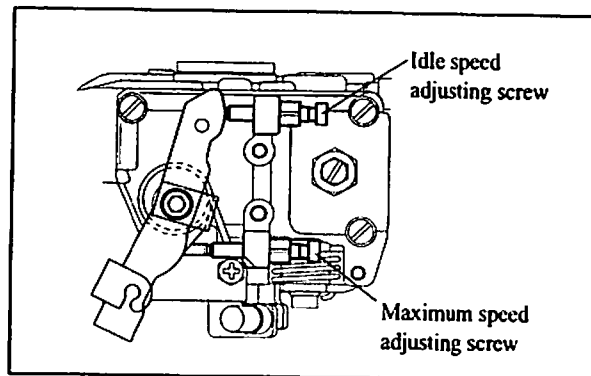
Inspect and adjust the governor after engine warm-up operation long enough for the water and oil temperatures to rise to 70°C [158°F].

(1) Starting engine

- (a) Pull the speed control lever to the high-speed side, and operate the starter switch.
- (b) The engine fires at a speed of about 150 min<sup>-1</sup> and then increases in speed. Operate the speed control lever to maintain the engine speed at 800 to 1000 min<sup>-1</sup>.
- (c) When the engine speed has stabilized, return the speed control lever to the low idle speed position.

(2) Setting low idle speed (setting minimum no-load speed)

For the engine to run at the minimum no-load speed, fix the speed control lever, and turn the idle speed adjusting screw.



Adjusting engine

**⚠ CAUTION**

If there is the speed range over which torsional vibration is likely to occur, avoid the speed range.

(3) Setting governor (setting maximum speed)

- (a) Hold the speed control lever in the specified maximum speed position.
- (b) Adjust the maximum speed adjusting screw (maximum speed setting screw) to the specified speed

1.9 Adjustment of Governor (In-line Fuel Injection Pump Specification)

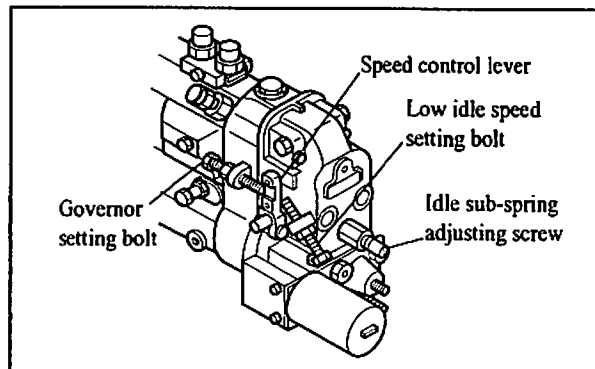
Inspection and adjustment of minimum no-load speed (low idle speed) and maximum no-load speed

**⚠ CAUTION**

- (a) Each engine has the minimum no-load speed (low idle speed) and maximum no-load speed checked on the test bench at the factory and has the setting bolts sealed. These settings can be inspected and adjusted at our designated service shop only.
- (b) After the governor parts are adjusted, seal all external stoppers as done at the time of factory shipment.
- (c) Whether the seals are intact or not has important bearing on the validity of claims under warranty. Be sure to seal all of the specified sections.
- (d) When inspecting and adjusting the governor, be prepared to operate the engine stop lever manually in anticipation of the engine overrunning (running at an extremely high speed).

Inspect and adjust the governor after engine warm-up operation long enough for the water and oil temperatures to rise to 70°C [158°F].

- (1) Starting engine
  - (a) Pull the speed control lever to the high-speed side, and operate the starter switch.
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  - (c) When the engine speed has stabilized, return the speed control lever to the low idle speed position.



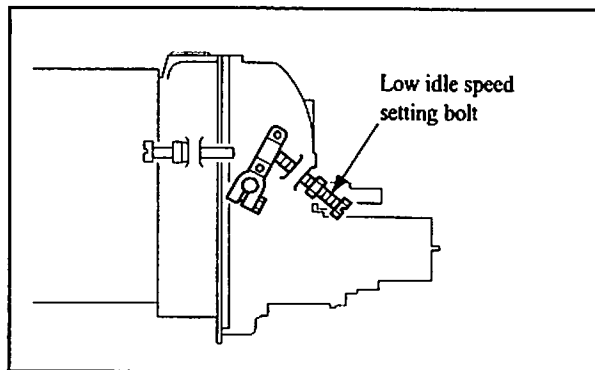
Starting engine

- (2) Setting low idle speed (setting minimum no-load speed)
  - (a) For the engine to run at the minimum no-load speed, fix the speed control lever, and turn the low idle speed setting bolt.

**⚠ CAUTION**

If there is the speed range over which torsional vibration is likely to occur, avoid the speed range.

- (b) Turn the low idle speed setting bolt clockwise to increase the speed.

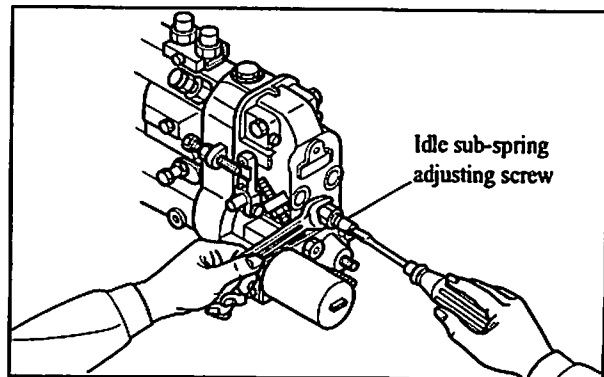


Setting low idle speed

- (c) If the engine speed does not stabilize, turn the idle sub-spring adjusting screw clockwise to bring the idle sub-spring into light contact with the tension lever and to stabilize the engine speed.

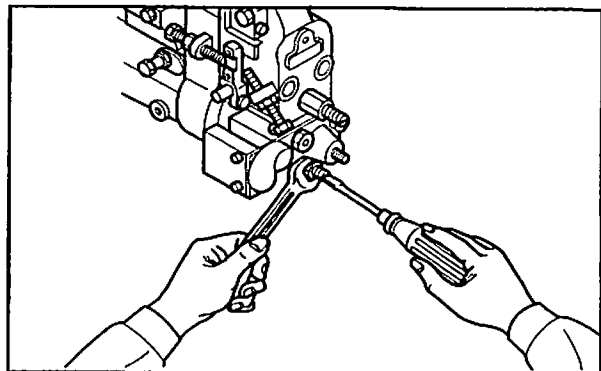
**⚠ CAUTION**

If the idle sub-spring is overtightened clockwise, the engine is likely to overrun during maximum no-load speed operation. Given this possibility, carefully adjust the engine speed stability.



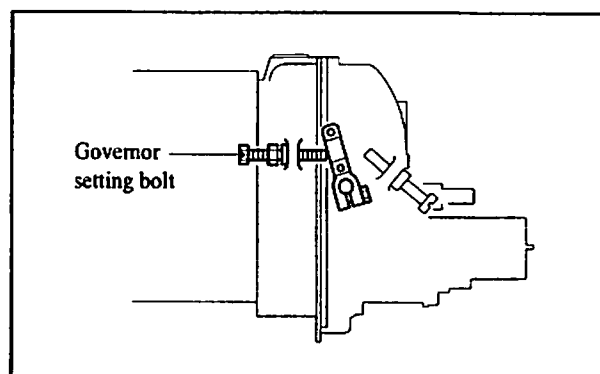
Adjusting engine speed stability

- (3) Setting rack (setting maximum output)
- (a) Free the torque spring adjusting screw. Hold the speed control lever at the specified engine output and speed.
  - (b) In this condition, check that the engine output and speed are stabilized.
  - (c) While maintaining the stabilized condition, adjust the full-load stopper bolt.
  - (d) Find the rated output position by tightening or loosening the full-load stopper bolt.
  - (e) When the rated output position is approximately determined, tighten the full-load stopper bolt, and then turn it counterclockwise by degrees. In the position where the engine speed is about to drop below the rated speed, fix the full-load stopper bolt, and securely tighten the lock nut.
  - (f) Check that the speed control lever is positioned on the high-speed side.
  - (g) The fuel injection (engine output) increases as the full-load stopper bolt is turned clockwise and decreases as the full-load stopper bolt is turned counterclockwise.



Setting rack

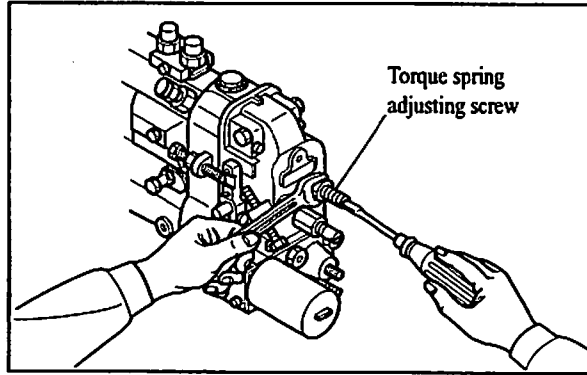
- (4) Setting governor (setting maximum speed)
- (a) While applying the full load to the engine, hold the speed control lever in the specified maximum speed position.
  - (b) Adjust the governor setting bolt (maximum speed setting bolt) to the specified speed position, and set it there.



Setting governor

(5) Setting torque spring (optional specification)

Set the speed control lever at the maximum speed, and apply the load to the engine. Turn the torque spring adjusting screw until the engine delivers the specified output at the specified speed. Fix the screw with the lock nut, and install a cap to the lock nut.



Setting torque spring

(6) Measuring speed variation

Measurement of speed variation at removal of load

- (a) Operate the speed control lever to set the engine at the rated output and speed.
- (b) From this condition, instantaneously remove the load to put the engine into the no-load condition. Operate the engine with the speed control lever fixed.
- (c) The engine speed temporarily jumps up and then lowers and stabilizes. Record the momentary maximum speed, stabilized speed, and time from the removal of the load to the stabilization of the speed.

Measurement of speed variation at application of load  
From the no-load condition, instantaneously apply the specified load to the engine. Record the momentary maximum speed, stabilized speed, and time from the application of the load to the stabilization of the speed.

Calculation of speed variation

Calculate the speed variation from the measured results. When the speed variation falls outside of the specified limits, adjust the governor notches.

**At removal of load**

Momentary speed variation (%)	Permanent speed variation (%)
$\frac{N_2 - N_1}{N_1} \times 100$	$\frac{N_3 - N_1}{N_1} \times 100$

$N_1$  = Engine speed before removal of load ( $\text{min}^{-1}$ )  
 $N_2$  = Engine speed at removal of load ( $\text{min}^{-1}$ )  
 $N_3$  = Stabilized engine speed after removal of load ( $\text{min}^{-1}$ )  
 $t_1$  = Stabilization time

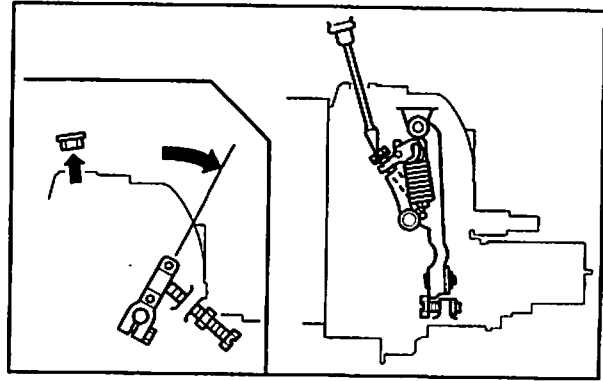
**At application of load**

Momentary speed variation (%)	Permanent speed variation (%)
$\frac{N_4 - N_5}{N_4} \times 100$	$\frac{N_4 - N_6}{N_4} \times 100$

$N_4$  = Engine speed before application of load ( $\text{min}^{-1}$ )  
 $N_5$  = Engine speed at application of load ( $\text{min}^{-1}$ )  
 $N_6$  = Stabilized engine speed after application of load ( $\text{min}^{-1}$ )  
 $t_2$  = Stabilization time

Measuring speed variation

- (7) Adjusting speed variation (adjusting governor notches)
- (a) Adjust the speed variation by turning the adjusting screw of the swivel lever.
  - (b) Remove the plug at the top of the governor, and set the speed control lever to the low idle speed position. The swivel lever turns up to reveal the head of the adjusting screw. Turn the adjusting screw with a flat-head screwdriver.
  - (c) The speed variation decreases as the adjusting screw is tightened and increases as the adjusting screw is loosened. One notch equals a quarter turn of the adjusting screw and changes the engine speed by three to five revolutions.
  - (d) Turning the adjusting screw changes the governor spring tension and hence the maximum speed. Readjust the governor setting bolt.
  - (e) The maximum speed increases as the adjusting screw is tightened and decreases as the adjusting screw is loosened.



**Adjusting speed variation**

**⚠ CAUTION**

The adjusting screw can be loosened by 20 notches (or 5 turns) from the position where it is fully tightened. It is dangerous if the adjusting screw is loosened more.

- (8) Sealing  
Seal each setting bolt.

**2. Break-In Operation**

When the engine is overhauled, it should be mounted on a dynamometer and operated for break-in and inspection.

**2.1 Starting Up**

- (1) Before starting the engine, check the levels of coolant, engine oil and fuel, and bleed the fuel and cooling systems.
- (2) With the fuel supply cut off, operate the starter and crank the engine for about 15 seconds to circulate engine oil.
- (3) Move the speed control lever slightly in the direction for increased fuel (do not move it to "full injection" position), and then turn the starter switch key to the [START] position to start the engine.
- (4) After the engine starts, let it operate at the minimum no-load speed (low idle speed) by moving the speed control lever.

**2.2 Inspection after Starting Up**

During the break-in operation, check the following. If an abnormality is found, stop the engine, investigate the cause, and take appropriate measures.

- (1) Lubricating oil pressure should be 0.29 to 0.49 MPa (3 to 5 kgf/cm<sup>2</sup>) [43 to 71 psi] at 1500 min<sup>-1</sup> or over 0.1 MPa (1 kgf/cm<sup>2</sup>) [14 psi] at 750 min<sup>-1</sup>.
- (2) Coolant temperature should be 75 to 85°C [167 to 185°F].
- (3) Lubricating oil temperature should be 70 to 90°C [158 to 194°F].
- (4) Check for leakage of oil, coolant and fuel.
- (5) Knocking should stop when the coolant temperature rises. The engine should not produce any other abnormal noise.
- (6) Check for exhaust color and abnormal odors.

**2.3 Break-In Period**

The following shows the relationship between the load in break-in operation and the operation time.

Break-in period			
	Engine speed (min <sup>-1</sup> )	Load	Time (min)
1	1000	No load	30
2	1500	25%	30
3	Rated speed (2300)	25%	10
4		50%	10
5		75%	30
6		100%	20

**2.4 Inspection and Adjustment after Break-In Operation**

- (a) Check the bolts and nuts for looseness.
- (b) Adjust the valve clearance.
- (c) Inspect the fuel injection timing.

### 3. Performance Tests

There are various performance test procedures. The following describes the procedures specified in "Earth moving machinery - Engines - Part 1: Test code of net power (JIS D0006-1)" and "Earth moving machinery - Engines - Part 2: Standard format of specifications and testing methods of diesel engines (JIS D0006-2)."

Other test items may be required in some applications. All test results should be evaluated comprehensively in order to determine the engine performance.

#### 3.1 Engine Equipment Condition

The engine must be equipped with standard auxiliary devices such as cooling fan, air cleaner and alternator.

#### 3.2 Test Items and Purposes

##### (1) Operation load test

Conduct this test to evaluate the engine output, torque, fuel consumption rate and governor performance under various load conditions.

##### (2) Continuous load test

Operate the engine continuously for 10 hours at 90% load (continuous load application) of nominal net brake power while the engine speed is maintained at revolutions corresponding to the nominal brake power. In this test, evaluate the fuel consumption rate and operating condition, and confirm that the engine is capable of continuous operation.

##### (3) Minimum no-load engine speed test

Conduct this test to confirm that the engine can operate stably at the specified minimum no-load speed.

#### 3.3 Other Inspections

Check for leakage of gases, coolant and oil; abnormal odors; and hunting. Make adjustment as needed.

#### 3.4 Engine Output Adjustment

Diesel engine output is affected by atmospheric pressure, temperature and humidity. Therefore, correction calculations must be performed to obtain the value of engine output under the standard atmospheric conditions.

##### (1) Standard atmospheric conditions:

Base temperature: 298 K (25°C) [77°F]

Atmospheric pressure: 100 kPa [750 mmHg]

Dry atmospheric pressure: 99 kPa [743 mmHg]

##### (2) Calculation of corrected power

Multiply the measured brake power or torque by the calculated diesel engine correction factor to obtain a corrected value.

$$\text{Corrected output} = \text{Correction factor } (\alpha_c) \times \text{Measured brake power}$$

Atmospheric conditions during test

Temperature ( $T$ ): 283 K (10°C) [50°F]  $\leq T \leq$  313 K (40°C) [104°F]

Dry atmospheric pressure ( $P$ ): 80 kPa (600 mmHg)  $\leq P \leq$  110 kPa (825 mmHg)

##### (3) Calculation of correction factor ( $\alpha_c$ )

$$\alpha_c = (fa)^{fm} \quad fa: \text{Atmospheric factor} \quad fm: \text{Engine factor}$$

###### (a) Calculation of atmospheric factor ( $fa$ )

① Natural aspiration engine and engine with mechanically driven air charger

$$fa = \left(\frac{99}{Pd}\right) \cdot \left(\frac{T}{298}\right)^{0.7}$$

② Turbocharged engine without air cooler or with air-to-air cooler

$$fa = \left(\frac{99}{Pd}\right)^{0.7} \cdot \left(\frac{T}{298}\right)^{1.2}$$

③ Turbocharged engine with air-to-liquid cooler

$$fa = \left(\frac{99}{Pd}\right)^{0.7} \cdot \left(\frac{T}{298}\right)^{0.7}$$

###### (b) Calculation of engine factor ( $fm$ )

$$fm = 0.036qc - 1.14$$

$qc$ : Corrected fuel supply volume

$$\text{① } qc = \frac{q}{r}$$

$$q = \frac{(z) \times (\text{Fuel flow rate } g/s)}{(\text{Stroke volume } \ell) \times (\text{Engine speed } \text{min}^{-1})}$$

$z = 120000$  (4-stroke cycle engine)

$r$ : Ratio between pressure at turbocharger or air cooler outlet and atmospheric pressure

( $r=1$  for natural aspiration engine)

###### ② Applicable range of engine factor ( $fm$ )

$$37.2 \leq qc \leq 65 \text{ mg}/(\ell\text{-cycle})$$

$$\left[ \begin{array}{l} \bullet qc \leq 37.2 \text{ mg}/(\ell\text{-cycle}) : fm=0.2 \text{ (constant)} \\ \bullet 65 \text{ mg}/(\ell\text{-cycle}) \leq qc : fm=1.2 \text{ (constant)} \end{array} \right]$$

###### (c) Range of correction equation use

The range of correction factor ( $\alpha_c$ ) is as follows:

$$0.9 \leq \alpha_c \leq 1.1$$

If this range is exceeded, indicate the corrected values and record the test conditions on the test record.

# OTHERS

1. Disassembly and Reassembly of General Parts.....	9 - 2
1.1 Oil Seals .....	9 - 2
1.2 O-rings.....	9 - 2
1.3 Bearings .....	9 - 3
1.4 Lock Plates.....	9 - 3
1.5 Split Pins and Spring Pins .....	9 - 3



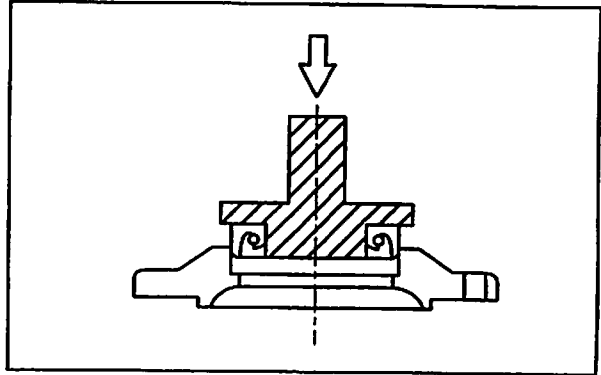
## 1. Disassembly and Reassembly of General Parts

### 1.1 Oil Seals

When installing oil seals, observe the following.

#### Installation of oil seals to housings

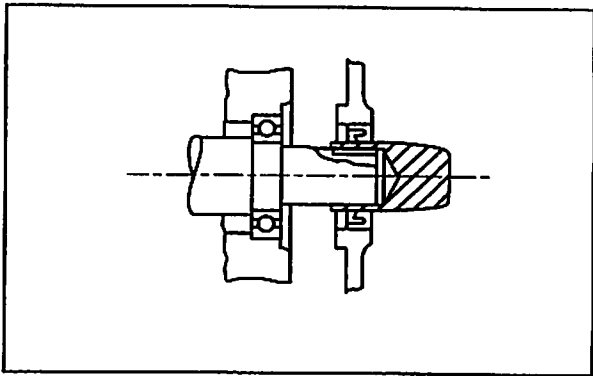
- (a) Check the seal lip for scratches and damage, and be sure to position the lip correctly.
- (b) Apply a small amount of grease to the periphery (housing contact surface) of the oil seal before installation.
- (c) Use an oil seal driver that guides the seal lip and presses the seal periphery, as shown in the diagram on the right. Striking the oil seal directly with a hammer causes seal damage and results in oil leaks.



Oil seal driver

#### Installation of oil seals to shafts

- (a) Apply grease to the oil seal lip.
- (b) Use an oil seal guide similar to the one shown in the diagram when installing an oil seal over the stepped portion, splines, threads or key grooves.

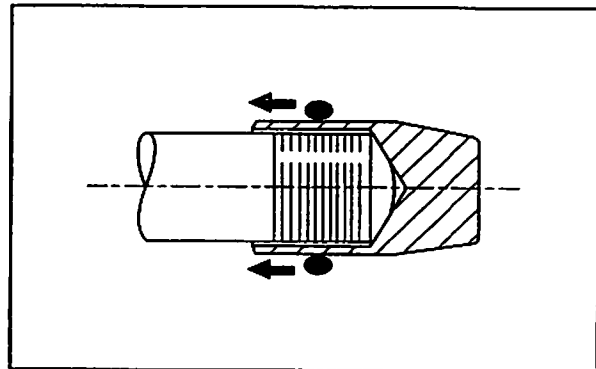


Oil seal guide

### 1.2 O-rings

Use an O-ring guide similar to the one shown in the diagram when installing an O-ring over the stepped portion, splines, threads or key grooves.

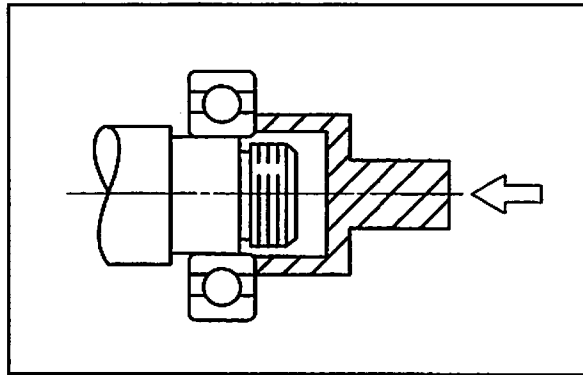
Be sure to apply a small amount of grease to the O-ring before installation.



O-ring guide

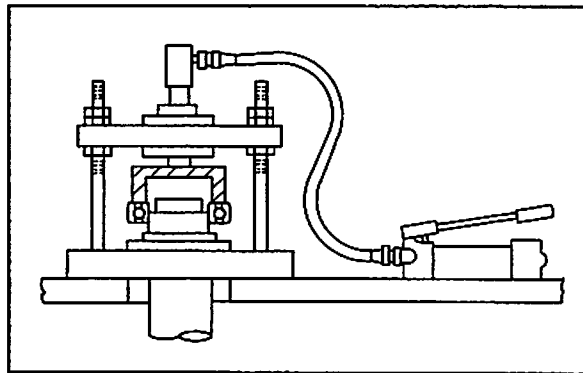
1.3 Bearings

- (1) When installing a bearing, be sure to push the inner or outer race that fits into the installation position. (When the inner race fits into the installation position, push the inner race into position. When the outer race fits into the installation position, push the outer race into position.) Be sure to use a bearing driver similar to the one shown in the diagram.



Bearing driver

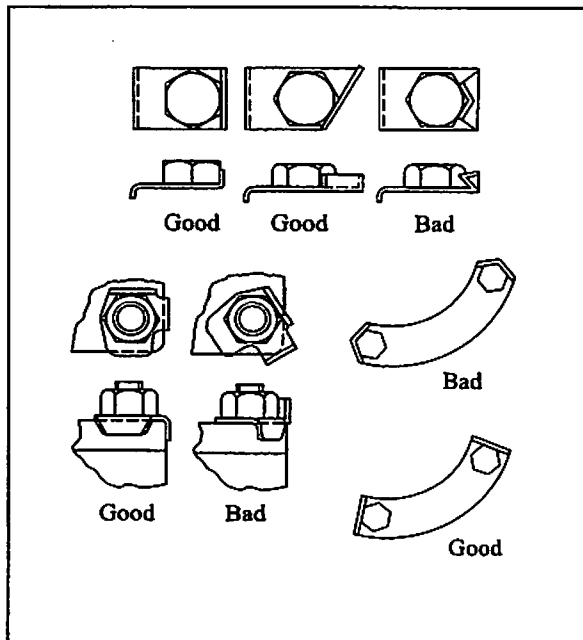
- (2) Use of a press minimizes the impact on the bearing and ensures proper installation.



Using press for bearing installation

1.4 Lock Plates

Be sure to bend lock plates.  
The diagram on the right shows the methods of bending representative lock plates.



Bending lock plate

1.5 Split Pins and Spring Pins

Generally, new split pins should be installed whenever split pins are removed.  
Be sure to bend split pins.  
Be sure to check spring pins for secure installation.

## **ENGINE INSPECTION RECORD SHEET**

- 1. Measurement of Cylinder Bore Diameter**
- 2. Measurement of Clearance between Valve Stem and Valve Guide, and Valve Stem Diameter**
- 3. Measurement of Valve Sinkage, Seat Width and Valve Margin**
- 4. Measurement of Distortion of Cylinder Head Bottom Surfaces**
- 5. Measurement of Oil Clearance of Connecting Rod Bearing**
- 6. Measurement of Rocker Arm Inside Diameter and Shaft Diameter**
- 7. Measurement of Piston Pin Bore Diameter and Piston Pin Diameter**
- 8. Measurement of Valve Clearance**
- 9. Measurement of Injection Pressure of Fuel Injection Nozzle**
- 10. Measurement of Clearance between Camshaft Journal Bore Diameter and Camshaft Bushing**
- 11. Measurement of Crankshaft End Play**

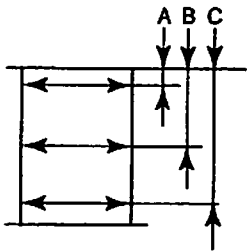
# ENGINE INSPECTION RECORD SHEET

No.1

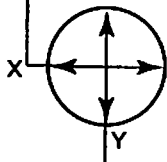
S4Q,S4Q2

Customer		Model		Date	
		Engine Serial No.			
Inspection Item	Measurement of Cylinder Bore Diameter			Unit	mm [in.]

**Measuring positions**



Square with piston pin



Parallel with piston pin

**Standards**

	Nominal value	Standard	Limit
Cylinder bore diameter	$\phi 88$ [3.46]	$88 \text{ }^{\pm 0.035}$ $[3.46 \text{ }^{\pm 0.0014}]$	Standard +0.2 [+0.0079]

**Measured values**

Name		Cylinder bore diameter		
No.	Position	A	B	C
1	X			
	Y			
2	X			
	Y			
3	X			
	Y			
4	X			
	Y			

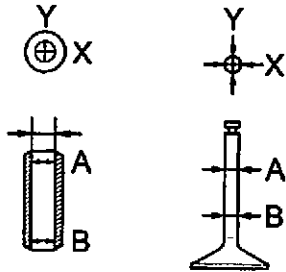
Remarks		Approved by	Examined by	Measured by

# ENGINE INSPECTION RECORD SHEET

S4Q,S4Q2

Customer		Model		Date	
		Engine Serial No.			
Inspection Item	Measurement of Clearance between Valve Stem and Valve Guide, and Valve Stem Diameter			Unit	mm [in.]

Measuring positions



Standards

		Nominal value	Standard	Limit
Valve guide bore diameter	Inlet	φ8 [0.3152]	8.020 to 8.035 [0.3157 to 0.3163]	-
	Exhaust	φ8 [0.3152]	8.020 to 8.035 [0.3157 to 0.3163]	-
Valve stem diameter	Inlet	φ8 [0.3152]	7.940 to 7.955 [0.3128 to 0.3134]	7.900 [0.3112]
	Exhaust	φ8 [0.3152]	7.920 to 7.940 [0.3120 to 0.3128]	7.850 [0.3093]
Clearance between valve stem and valve guide	Inlet	-	0.065 to 0.095 [0.0026 to 0.0037]	0.150 [0.0059]
	Exhaust	-	0.080 to 0.115 [0.0032 to 0.0045]	0.200 [0.0079]

Measured values

No.	Name Position	Valve guide bore diameter				Valve stem diameter				Clearance			
		A		B		A		B		A		B	
		X	Y	X	Y	X	Y	X	Y	Maximum	Minimum	Maximum	Minimum
1	Inlet												
	Exhaust												
2	Inlet												
	Exhaust												
3	Inlet												
	Exhaust												
4	Inlet												
	Exhaust												

Remarks		Approved by	Examined by	Measured by

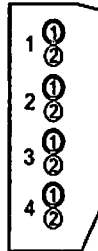
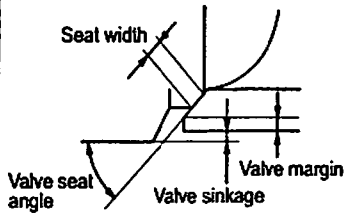
# ENGINE INSPECTION RECORD SHEET

No.3

S4Q,S4Q2

Customer		Model		Date	
		Engine Serial No.			
Inspection Item	Measurement of Valve Sinkage, Seat Width and Valve Margin			Unit	mm [in.]

**Measuring positions**



**Standards**

		Nominal value	Standard	Limit
Valve seat	Valve seat angle	30°		
	Seat width	1.18 [0.0465]	1.04 to 1.32 [0.0410 to 0.0520]	1.6 [0.0630]
	Valve sinkage	0.8 [0.0315]	0.7 to 0.9 [0.0276 to 0.0355]	1.3 [0.0512]
Valve margin		1.70 [0.0670]		Relacing permissible up to 1.20 [0.0473]

**Measured values**

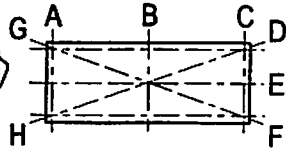
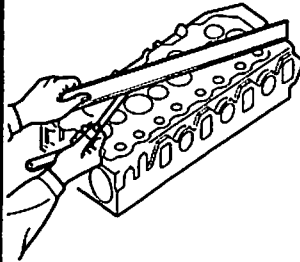
Name		Valve seat angle	Seat width	Valve sinkage	Valve margin
No.	Valve				
1	Inlet ①				
	Exhaust ②				
2	Inlet ①				
	Exhaust ②				
3	Inlet ①				
	Exhaust ②				
4	Inlet ①				
	Exhaust ②				

Remarks		Approved by	Examined by	Measured by

# ENGINE INSPECTION RECORD SHEET

			<b>S4Q,S4Q2</b>
<b>Customer</b>		<b>Model</b>	
		<b>Engine Serial No.</b>	<b>Date</b>
<b>Inspection Item</b>	<b>Measurement of Distortion of Cylinder Head Bottom Surface</b>		<b>Unit</b> mm [in.]

Measuring positions



Standards

	Standard	Limit
Distortion of cylinder head bottom surface	0.05 [0.0020] or less	0.20 [0.0080]

Measured values

Name	Distortion of cylinder head bottom surface							
No.	A	B	C	D	E	F	G	H
1								
2								
3								
4								

<b>Remarks</b>		<b>Approved by</b>	<b>Examined by</b>	<b>Measured by</b>

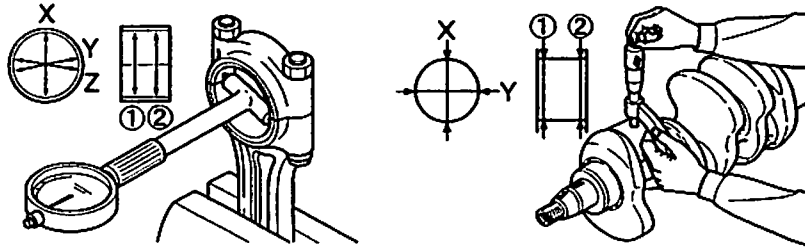
# ENGINE INSPECTION RECORD SHEET

No.5

S4Q,S4Q2

<b>Customer</b>		<b>Model</b>		<b>Date</b>	
		<b>Engine Serial No.</b>			
<b>Inspection Item</b>	<b>Measurement of Oil Clearance of Connecting Rod Bearing</b>			<b>Unit</b>	<b>mm (in.)</b>

**Measuring positions**



**Standards**

	Nominal value	Standard	Limit
Connecting rod bearing inside diameter	φ58 [2.2852]	58.000 to 58.045 [2.2852 to 2.2870]	-
Crankshaft pin outside diameter	φ58 [2.2852]	57.955 to 57.970 [2.2834 to 2.2840]	-
Connecting rod bearing oil clearance	-	0.030 to 0.090 [0.0012 to 0.0035]	0.20 [0.0079]

**Measured values**

No.	Position	Connecting rod bearing inside diameter			Crankshaft pin outside diameter		Oil clearance
		X	Y	Z	X	Y	
1	①						
	②						
2	①						
	②						
3	①						
	②						
4	①						
	②						

<b>Remarks</b>		<b>Approved by</b>	<b>Examined by</b>	<b>Measured by</b>

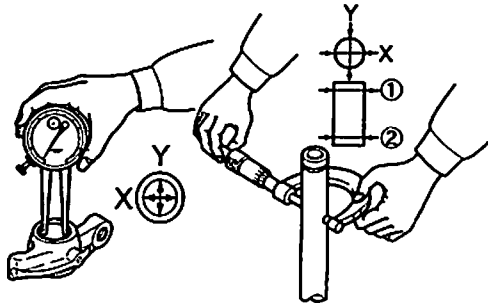


# ENGINE INSPECTION RECORD SHEET

S4Q,S4Q2

<b>Customer</b>		<b>Model</b>		<b>Date</b>	
		<b>Engine Serial No.</b>			
<b>Inspection Item</b>	<b>Measurement of Rocker Arm Inside Diameter and Shaft Diameter</b>	<b>Unit</b>	<b>mm (in.)</b>		

**Measuring positions**



**Standards**

	Nominal value	Standard	Limit
Rocker arm (bushing) inside diameter	φ19 [0.7490]	19.010 to 19.030 [0.7490 to 0.7500]	-
Rocker shaft outside diameter	φ19 [0.7490]	18.980 to 19.000 [0.7480 to 0.7490]	-
Clearance between rocker arm (bushing) and shaft	-	0.010 to 0.050 [0.0004 to 0.0020]	0.070 [0.0028]

**Measured values**

Name		Rocker arm inside diameter		Rocker shaft outside diameter		Clearance	
No.	Position	X	Y	X	Y	Maximum	Minimum
1	Inlet						
	Exhaust						
2	Inlet						
	Exhaust						
3	Inlet						
	Exhaust						
4	Inlet						
	Exhaust						

<b>Remarks</b>		<b>Approved by</b>	<b>Examined by</b>	<b>Measured by</b>

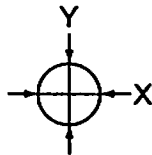
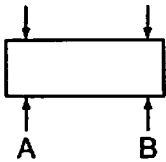
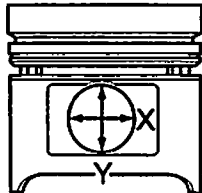
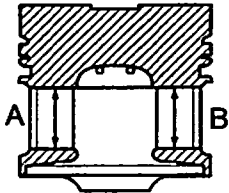
# ENGINE INSPECTION RECORD SHEET

No.7

S4Q,S4Q2

Customer		Model		Date	
		Engine Serial No.			
Inspection Item	Measurement of Piston Pin Bore Diameter and Piston Pin Diameter			Unit	mm [in.]

**Measuring positions**



**Standards**

	Nominal value	Standard	Limit
Piston pin bore diameter	φ28 [1.1032]	28.000 to 28.010 [1.1032 to 1.1036]	-
Piston pin diameter	φ28 [1.1032]	27.994 to 28.000 [1.1030 to 1.1032]	-
Clearance between piston pin bore and piston pin	-	0.000 to 0.016 [0.000 to 0.0006]	0.050 [0.0020]

**Measured values**

Name		Piston pin bore diameter		Piston pin diameter		Clearance	
No.	Position	X	Y	X	Y	Maximum	Minimum
1	A						
	B						
2	A						
	B						
3	A						
	B						
4	A						
	B						

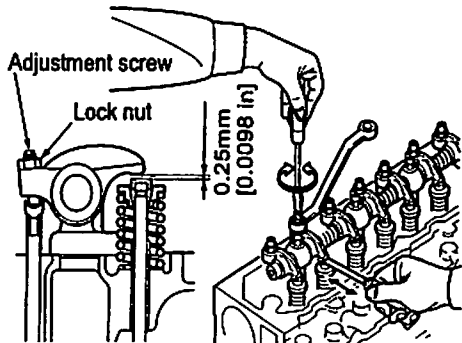
Remarks		Approved by	Examined by	Measured by

# ENGINE INSPECTION RECORD SHEET

S4Q,S4Q2

<b>Customer</b>	<b>Model</b>		<b>Date</b>		
	<b>Engine Serial No.</b>				
<b>Inspection Item</b>	<b>Measurement of Valve Clearance</b>			<b>Unit</b>	mm [in.]

**Measuring positions**



**Standards**

		Standard
Valve clearance (cold)	Inlet	0.25 [0.0098]
	Exhaust	0.25 [0.0098]

**Measured values**

No.		Valve Clearance	
		Inlet	Exhaust
1	Before adjustment		
	After adjustment		
2	Before adjustment		
	After adjustment		
3	Before adjustment		
	After adjustment		
4	Before adjustment		
	After adjustment		

<b>Remarks</b>		<b>Approved by</b>	<b>Examined by</b>	<b>Measured by</b>

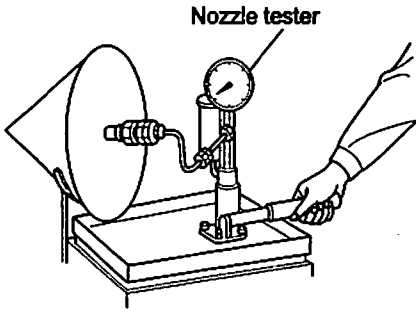
# ENGINE INSPECTION RECORD SHEET

No.9

S4Q,S4Q2

<b>Customer</b>	<b>Model</b>	<b>Date</b>	
	<b>Engine Serial No.</b>		
<b>Inspection Item</b>	<b>Measurement of Injection Pressure of Fuel Injection Nozzle</b>	<b>Unit</b>	<b>MPa (kgf/cm<sup>2</sup>) [psi]</b>

**Measuring positions**



**Standards**

	Nominal value	Standrad
<b>Valve opening pressure</b>	11.77 (120) [1707] {DN0PD21}	11.77to12.75 (120to130)[1707to 1850] {DN0PD21}
	13.73 (140)[1991] {DN15PD6}	13.73to14.71 (140to150)[1991to 2134] {DN15PD6}

Varies depending on specifications.

**Measured values**

No.	Injection pressure	Service hours (h)	Injection pressure
	Before adjustment		After adjustment
1			
2			
3			
4			

<b>Remarks</b>		<b>Approved by</b>	<b>Examined by</b>	<b>Measured by</b>

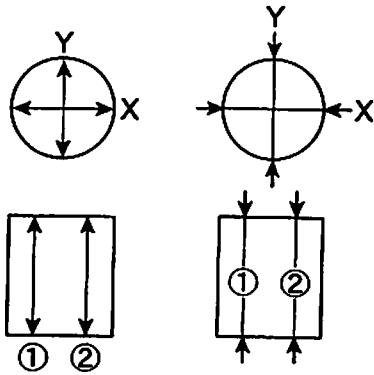
# ENGINE INSPECTION RECORD SHEET

S4Q,S4Q2

<b>Customer</b>		<b>Model</b>		<b>Date</b>	
		<b>Engine Serial No.</b>			
<b>Inspection Item</b>	<b>Measurement of Clearance between Camshaft Journal Bore Diameter and Camshaft Bushing</b>			<b>Unit</b>	mm [in.]

Measuring positions

Standards



		Nominal value	Standard	Limit
Camshaft journal diameter	No. 1, 2	φ54 [2.1276]	53.94 to 53.96 [2.1252 to 2.1260]	53.90 [2.1237]
	No. 3	φ53 [2.0882]	52.94 to 52.96 [2.0858 to 2.0866]	52.90 [2.0843]
Clearance between camshaft journal diameter and camshaft bore diameter of crankcase		-	0.07 to 0.11 [0.0028 to 0.0043]	0.15 [0.0059]
Camshaft bore diameter	No. 1, 2	φ54 [2.1276]	54.030 to 54.050 [2.1288 to 2.1296]	53.90 [2.1237]
	No. 3	φ53 [2.0882]	53.030 to 53.050 [2.0893 to 2.0901]	52.90 [2.0843]

Measured values

Name		Camshaft bushing bore diameter		Camshaft journal diameter		Clearance	
No.	Position	X	Y	X	Y	Maximum	Minimum
1	①						
	②						
2	①						
	②						
3	①						
	②						

<b>Remarks</b>		<b>Approved by</b>	<b>Examined by</b>	<b>Measured by</b>

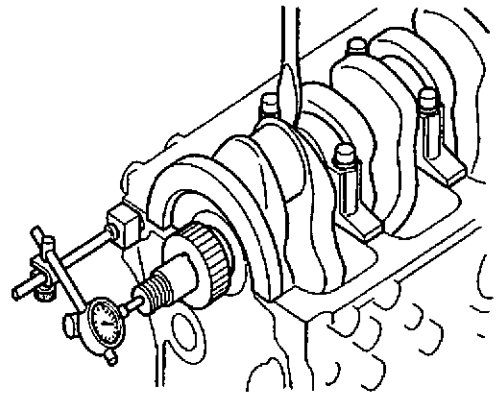
# ENGINE INSPECTION RECORD SHEET

No.11

S4Q,S4Q2

<b>Customer</b>		<b>Model</b>		<b>Date</b>	
		<b>Engine Serial No.</b>			
<b>Inspection Item</b>	<b>Measurement of Crankshaft End Play</b>			<b>Unit</b>	<b>mm [in.]</b>

**Measuring positions**



**Standards**

	Standard	Limit
Crankshaft end play	0.100 to 0.204 [0.0039 to 0.0080]	0.300 [0.0118]

**Measured values**

During disassembly	During reassembly

<b>Remarks</b>		<b>Approved by</b>	<b>Examined by</b>	<b>Measured by</b>



