# SERVICE MANUAL

## MITSUBISHI DIESEL ENGINE

# S12H-Y2PTAW

for EPA Tier2

October 2007

MITSUBISHI HEAVY INDUSTRIES, LTD.

Pub. No. 99266-A3100

# INTRODUCTION

This service manual describes the specifications and the maintenance and adjustment procedures of the S12H-Y2PTAW Diesel Engine that has met the exhaust emission regulations of the Environmental Protection Agency (EPA) of the United States.

If the engine is carefully maintained it will deliver a long productive life and efficient performance marked by power and economy.

Before you attempt to inspect, disassemble, or repair the engine, read this manual carefully to learn more about the engine and how to care for it properly. Take due care that the EPA exhaust emission regulations cannot be satisfied unless the engine is repaired by the methods described in this manual and by using the designated parts. All descriptions, illustrations, specifications and serial numbers in this manual are effective as of the date printing of this manual.

The information contained in this manual applies to the engine model produced at the time of publication. It should be noted that specifications and design may change due to improvements made thereafter.

Pub.No.99266-A31000

# How to use this manual

In this service manual, the S12H-Y2PTAW Diesel Engine 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.
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.
There is separate manual for the electronically controlled unit injector "PUE-H".

**CAUTION**

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.
Take care that the parts may be partly modified due to improvement, for example.
Work related to the exhaust emission regulations can be conducted only at our designated service factories.

## Methods of presentation

(1) Index numbers allotted to parts in exploded views are not only a call-out of part names listed in the text but also an indication of the sequence of disassembly.
(2) Inspections to be conducted during disassembly process are indicated in boxes in the relevant exploded views.
(3) Maintenance standards required for inspection and repair works are indicated in the appropriate positions in the text. They are also collectively indicated in Group 2, the General Contents group.
(4) Fasteners to be tightened in "wet" condition, or with engine oil applied, are identified by [Wet] placed after tightening torque values. If no such indication is suffixed, the fastener should be tightened in "dry" condition, or without lubricating with engine oil.
(5) In this manual, important safety or other cautionary instructions are emphasized with the following marks headed.

**! DANGER**

Indicates an immediately hazardous situation which, if not avoided, will result in death or serious injury.

**⚠ WARNING**

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

**⚠ CAUTION**

Indicates an immediately hazardous situation which, if not avoided, may result in minor or moderate injury.

**CAUTION**

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

Note:

Emphasizes important matter, or indicates information useful for operation or maintenance of the engine.

## Terms used in this manual

Nominal

means the rated (design) size or magnitude of a part to be measured.

Standard

means the quantitative requirement for dimension of a part, clearance between parts and performance. This is given in a form of tolerance. Therefore, the values shown are not in agreement with the design values.

Limit

means that, if this value is reached, the part must be repaired or replaced with a new part.

## Abbreviations

- BTDC: Before Top Dead Center
- ATDC: After Top Dead Center
- BBDC: Before Bottom Dead Center
- ABDC: After Bottom Dead Center
- TIR: Total Indicated Runout
- 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.A)
- MSDS: Material Safety Data Sheet
- SAE: Society of Automotive Engineers (U.S.A)

## 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$^2$
- 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 cm$H_2O$ (cmAq)
- Rotational speed: 1min$^{-1}$ = 1 rpm

# Safety Cautions

**⚠ WARNING**

## Fire and explosion

### Keep flames away

Store fuel and engine oil in a well ventilated designated area.
Make sure that the caps of fuel and engine oil containers are tightly closed.
Do not use flames, do not smoke, and do not work near a heater or other fire hazard where fuel or oil is handled or when cleaning solvent is being used for washing parts.
Wipe off spilled fuel, oil and LLC immediately and thoroughly. Spilled fuel, oil and LLC may ignite and cause a fire.

### Keep surrounding area tidy and clean

Do not leave combustible or explosive materials, such as fuel, engine oil and LLC, near the engine. Such substances can cause fire or explosion.
Remove dust, dirt and other foreign materials accumulated on the engine and surrounding parts thoroughly. Such materials can cause fire or the engine to overheat. In particular, clean the top surface of the battery thoroughly. Dust can cause a short-circuit.
Always operate the engine at a position at least 1 m [3.28 ft.] away from buildings and other equipment to prevent possible fire caused by engine heat.

### Avoid accessing crankcase until engine cools

Do not attempt to open the side cover of the crankcase before the engine cools down. Wait at least 10 minutes after stopping the engine.
Opening the cover when the engine is hot allows fresh air to flow into the crankcase, which can cause oil mist to ignite and explode.

### Care about fuel, oil and exhaust gas leakage

If any fuel, oil or exhaust gas leakage is found, immediately take corrective measures to stop it.
Such leakages, if left uncorrected, can cause fuel or engine oil to reach hot engine surfaces or hot exhaust gas to contact flammable materials, possibly leading to personal injury and/or damage to equipment.

### *Use explosion-proof lighting apparatus*

When inspecting fuel, engine oil, coolant, battery electrolyte, etc., use a flameproof light. An ordinary light, if accidentally broken, may ignite and cause an explosion.

### Prevent electrical wires from short-circuiting

Avoid inspecting or servicing the electrical system with the ground cable connected to the battery. Otherwise, a fire could result from short-circuiting. Be sure to disconnect the battery cable from the negative (-) terminal before beginning with the work procedure.
Short-circuits, possibly resulting in fire, may be caused by a loose terminal or damaged cable/wire. Inspect the terminals, cables and wires, and repair or replace the faulty parts before beginning with the service procedure.

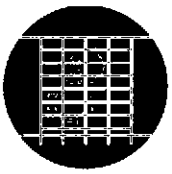
### Keep fire extinguishers and first-aid kit handy

Keep fire extinguishers handy, and become familiar with their usage.
Keep a first-aid kit at the designated place where it is easily accessible by anyone at any time.
Establish response procedures to follow in the event of fire or accident. Provide an emergency evacuation route, contact points, and means of communication in case of emergency.

⚠ WARNING

## Stay clear of all rotating and moving parts

### Install protective covers on rotating parts



Make sure the protective covers for engine rotating parts are properly installed as intended. Repair loose or damaged protective covers as necessary.

Never remove the covers guarding personnel from rotating parts, when the engine is operating.

When combining the engine with the engine-driven machine or radiator, always provide a cover on every exposed moving part such as driving belt and coupling.

Never remove protective covers.

### Ensure safety of neighboring people before starting engine

Before starting the engine, ensure that there is nobody in the neighborhood and that no tools are left on or near the engine. Verbally notify people around the engine or in the work area when starting the engine.

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

### Stay clear of moving parts during engine running

Do not approach rotating or sliding parts of the engine when the engine is in operation.

Keep objects likely to be caught by rotating parts away from such parts.

If any part of the clothing or outfitting is caught by a rotating part, serious bodily injuries could result.

### Lockout and Tagout

Be sure to lockout and tagout before starting inspection and maintenance.

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

To accomplish the lockout/tagout, remove the starter switch key, set the battery switch to OFF and attach a "Do Not Run" or similar caution tag to the starter switch. The starter switch key must be kept by the person who performs inspection and maintenance during the work.

In the case of pneumatic starting type, close the main valve of the air tank and post a tag saying "Do Not Open the Valve" or the like.

### Keep engine stopped during servicing

Be sure to stop the engine before proceeding to inspection and service procedure. Never attempt to make adjustments on the engine parts while the engine is running. Rotating parts such as belt can entangle your body and cause serious injuries.

### Always restore engine turning tools after use

Do not forget to remove the tools which have been used for turning the engine during inspection or servicing, after the procedure is finished. Remember also that the turning gear must be returned to the operating condition before starting the engine.

Starting the engine with the turning tools inserted or with the turning gear in engagement can lead to not only engine damage but also personal injuries.

⚠ WARNING

## Be careful of burns

### Do not touch the engine during or immediately after operation

Do not touch the engine during or immediately after operation to avoid risk of burns.

To conduct maintenance and inspection work, wait until the engine has cooled sufficiently, checking the temperature gauge.

### Slowly and carefully open radiator cap

Never attempt to open the radiator cap while the engine is running or immediately after the engine stops. Give a sufficient cooling time to the engine coolant before opening the cap.

When opening the radiator cap, slowly turn the cap to release internal pressure. To prevent scalds with steam gushing out, wear thick rubber gloves or cover the cap with a cloth.

Close the radiator cap tightly without fail.

The coolant is very hot and under pressure during engine running or just after the engine stops. If the radiator cap is not closed tightly, steam and hot coolant may gush out and can cause scalds.

### Add coolant only after the coolant temperature dropped

Do not add coolant immediately after the engine stops. Wait until the coolant temperature lowers sufficiently to avoid a risk of burns.

### Never remove heat shields

The exhaust system, which becomes extremely hot while the engine is operating, is provided with various heat shields. Do not remove these heat shields. If any of these heat shields have been removed owing to unavoidable circumstances during the work, be sure to restore them after the work is completed.

⚠ WARNING

## Be careful of exhaust fume poisoning

### Operate engine in well-ventilated area

If the engine is installed in an enclosed area and the exhaust gas is ducted outside, ensure that there is no exhaust gas leak from duct joints.

Take care that the exhaust gas is not discharged toward plants or animals.

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

⚠ WARNING

## Protect ears from noises

### 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

## Be careful of falling down

### Lift engine correctly

To lift the engine, always use a correct wire rope capable of withstanding the engine weight.
Attach the wire rope to the lifting *hangers provided on the engine us*ing a correct sling.
During lifting process, keep the engine in a well-balanced position by taking the center of gravity of the engine into consideration.
If the wire rope contacts the engine directly, place a cloth or other soft padding to avoid damage to the engine and wire rope.

### Do not climb onto the engine

Do not climb onto the engine, nor step on any engine parts located on the lateral sides.
To work on parts located on the upper section of engine, use a ladder, stool, etc., that is firmly secured.
Climbing on the engine may not only damage engine parts but also cause parts to fall off and result in personal injuries.

### Establish firm scaffold during work

When working on the upper part of the engine and other hard-to-reach places, use a stable work platform.
Standing on a decrepit stool or parts box may result in personal injury. Do not place any unnecessary objects on a work platform.

⚠ CAUTION

## Be careful of handling fuel, engine oil and LLC

### Use only specified fuel, engine oil and long-life coolant (LLC)

Use only the fuel, oil and LLC specified in this manual, and handle them carefully.
Use of any other fuel, oil or LLC, or improper handling may cause various engine problems and malfunctions.
Obtain the Material Safety Data Sheets (MSDS) issued by the fuel, oil and LLC suppliers, and follow the directions in the MSDSs for proper handling.

### Handle LLC (long life coolant) carefully

When handling LLC, always wear rubber gloves and protective face mask. If LLC or cooling water containing LLC comes into contact with your skin or eyes, or if it is swallowed, you would suffer from inflammation, irritation or poisoning.
Should LLC be accidentally swallowed, induce vomiting immediately and seek medical attention. Should LLC enter your eyes, flush them immediately with plenty of water and seek medical attention. If LLC splashes onto your skin or clothing, wash it away immediately with plenty of water.
Keep flames away from LLC. The LLC can catch flames, causing a fire.
Coolant containing LLC is a hazardous material. Do not dispose of it in unauthorized manner. Abide by the applicable law and regulations when discarding drained coolant.

### Proper disposal of waste oil and coolant (LLC)

Do not discharge waste engine oil or coolant into sewerage, river, lake or other similar places. Such a way of disposal is strictly prohibited by laws and regulations.
Dispose of waste oil, coolant and other environmentally hazardous waste in accordance with the applicable law and regulations, or consult a Mitsubishi dealer.

⚠ CAUTION

## Service battery

### Handle the battery correctly

- Never use flames or allow sparks to generate near the battery. The battery releases flammable hydrogen gas and oxygen gas. Any flames or sparks in the vicinity could cause an explosion.
- Do not use the battery the fluid level of which is lowered below the lower limit line. Sustained use of the battery could 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 the 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, keep the battery fluid off the mouth.
- Wear protective goggles and rubber gloves when working with the battery (when adding water, charging, etc.).
- If electrolyte is spilled onto the skin or clothing, immediately wash it away with lots of water. Use soap to thoroughly clean.
- The battery fluid can cause blindness if splashing into eyes. If it gets into eyes, immediately flush it away with plenty of clean fresh water, and seek immediate medical attention.
- If the battery fluid is accidentally swallowed, gargle with plenty of water, then drink lots of water, and seek immediate medical attention.

⚠ CAUTION

## When abnormality occurs

### Stop overheated engine after cooling run

Even if the engine comes to overheat, do not stop the engine immediately. Abrupt stopping of an overheated engine can cause the coolant temperature to rise, resulting in seized engine parts. If the engine comes to overheat, run 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 can cause the cylinder heads to crack due to sudden change in temperature. Add coolant little by little after the engine cools down to room temperature.

### *Avoid immediate restart after abnormal stop*

If the engine stops abnormally, do not restart the engine immediately. If the engine stops with an alarm, check and remedy the cause of the problem before restarting. Sustained use of the engine without any remedy could result in serious engine problems.

### Avoid continuous engine operation with too low oil pressure

If an abnormal engine oil pressure drop is indicated, stop the engine immediately, and inspect the lubrication system to locate the cause. Continuous engine operation with low oil pressure may cause bearings and other parts to seize.

### Stop the engine immediately if the fan belt breaks

If the fan belt breaks, stop the engine immediately. Continuous engine operation with the broken fan belt could cause the engine to overheat and thereby the coolant to boil into steam, which may gush out from the reserve tank or radiator, and cause personal injuries.

⚠ CAUTION

## Other cautions

### Modification of engine prohibited

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

Modification of the engine may not only cause engine damage but also produce personal injuries.

### Never change the ECM (Electronic Control Module) settings

Unauthorized modification of ECM settings may results in engine damage and / or personal injuries.

Modification of the ECM settings will void the manufacturer's warranty.

Only Mitsubishi and its authorized dealer can change and adjust settings.

### Pre-operational check and periodic inspection/maintenance

Be sure to perform the pre-operational checks and periodic inspection/maintenance as described in this manual.

Neglecting the pre-operational check or periodic inspection/maintenance can arouse various engine troubles such as damage to parts, eventually leading to serious accidents.

### Break-in operation

A new engine needs to be broken in for the first 50 hours of operation. During this period, do not subject the engine to heavy loads.

Operating a new engine under high loads or severe conditions during the break-in period can shorten the service life of the engine.

### Warming-up operation

After starting the engine, run the engine at low idling speeds for 5 to 10 minutes for warming-up. Start the work after this operation is completed.

Warm-up operation circulates the lubricant through the engine. Therefore, individual engine parts are well lubricated before they are subjected to heavy loads. This is very important for longer service life, high-performance and economical operation.

Do not conduct warm-up operation for a longer time than necessary. Prolonged warm-up operation causes carbon build-up in the cylinders that leads to incomplete combustion.

### Avoid engine operations in a overload condition

If the engine is considered to be in an overloaded condition which is identified by too much black smoke, etc., immediately reduce the load on the engine such that the correct output and load conditions may be achieved.

Overloading the engine causes not only high fuel consumption but also excessive carbon deposits inside the engine. Excessive carbon deposits can cause various engine problems and shorten the service life of the engine remarkably.

### Cooling operation before stopping engine

Always conduct the cooling operation (low speed idling) for 5 to 6 minutes before stopping the engine.

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.

### Protection of engine against water entry

Do not allow rainwater, etc. 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.

Starting the engine with water inside the combustion chambers can cause the water hammer action which may result in internal engine damage and serious accidents.

### Maintenance of air cleaner or pre-cleaner

The major cause of abnormal wear on engine parts is dust entering with intake air. Worn parts produce 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 instructions.

- Do not conduct maintenance of the air cleaner/pre-cleaner while the engine is operating. Engine operation without the air cleaner/precleaner in place allows foreign matters to enter the turbocharger, causing it to damage seriously.
- Remove the air cleaner/pre-cleaner slowly to prevent dust accumulated on the element from falling off. After removing the air cleaner or pre-cleaner, immediately cover the opening (inlet port in case of air cleaner; port in body in case of pre-cleaner) with plastic sheet or similar means to prevent dust from entering the engine.
- Air cleaners equipped with a dust indicator will issue an alarm if the element gets clogged. Service the cleaner as soon as possible if an alarm is issued.

### Observe safety rules at work site

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

Do not operate the engine if you are feeling ill.

Operation of the engine with reduced awareness may cause improper operation that could result in accidents. In such a case, inform your supervisor of your condition.

When working in a team of two or more people, use specified hand signals to communicate among workers.

### Work clothing and protective gear

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

When handling compressed air, wear safety goggles, hardhat, gloves and other necessary protective gear. Works without wearing proper protective gear could result in serious injuries.

### Use of tools optimum for each work

Always keep in mind to select most appropriate tools for the work to be performed and use them correctly. If tools are damaged, replace with new tools.

### Avoidance of prolonged time of starter operation

Do not operate the starter for more than 10 seconds at a time even if the engine does not start. Wait for at least 30 seconds before next engine cranking.

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

### Do not turn off battery switch during operation

If the battery switch is turned OFF when the engine is running, not only various meters will stop working but also the alternator may have its diode and transistor deteriorated.

### Cautionary instructions for transporting engine

When transporting the engine on a truck, consider the engine weight, width and height to ensure safety. Abide by road traffic law, road vehicles act, vehicle restriction ordinance and other pertinent laws.

### Avoid continuous engine operation in a low load condition

Do not operate the engine continuously for more than 10 minutes at a load of less than 30%. Engine operation in a low load condition increases the emission of unburned fuel. Therefore, a prolonged time of engine operation in a low load condition increases the quantity of unburned fuel adhering to engine parts, provoking the possibility of engine malfunctioning and shortening the service life of the engine.

### Ventilation of engine room

Always keep the engine room well ventilated. Insufficient amount of intake air causes the operating temperature to rise, resulting in poor output and lowered performance.

It is highly recommended to calculate the required amount of air supply to the engine and install an adequate ventilation system before installing the engine.

### Avoid contact with high-pressured fuel

Should fuel leak from a fuel injection pipe, do not touch the spouting fuel directly.

Fuel in the fuel injection pipes is under high pressure. If high-pressured fuel contacts you skin, it penetrates through the skin and may result in gangrene.

**⚠ CAUTION**

## About warning labels

### Maintenance of warning labels

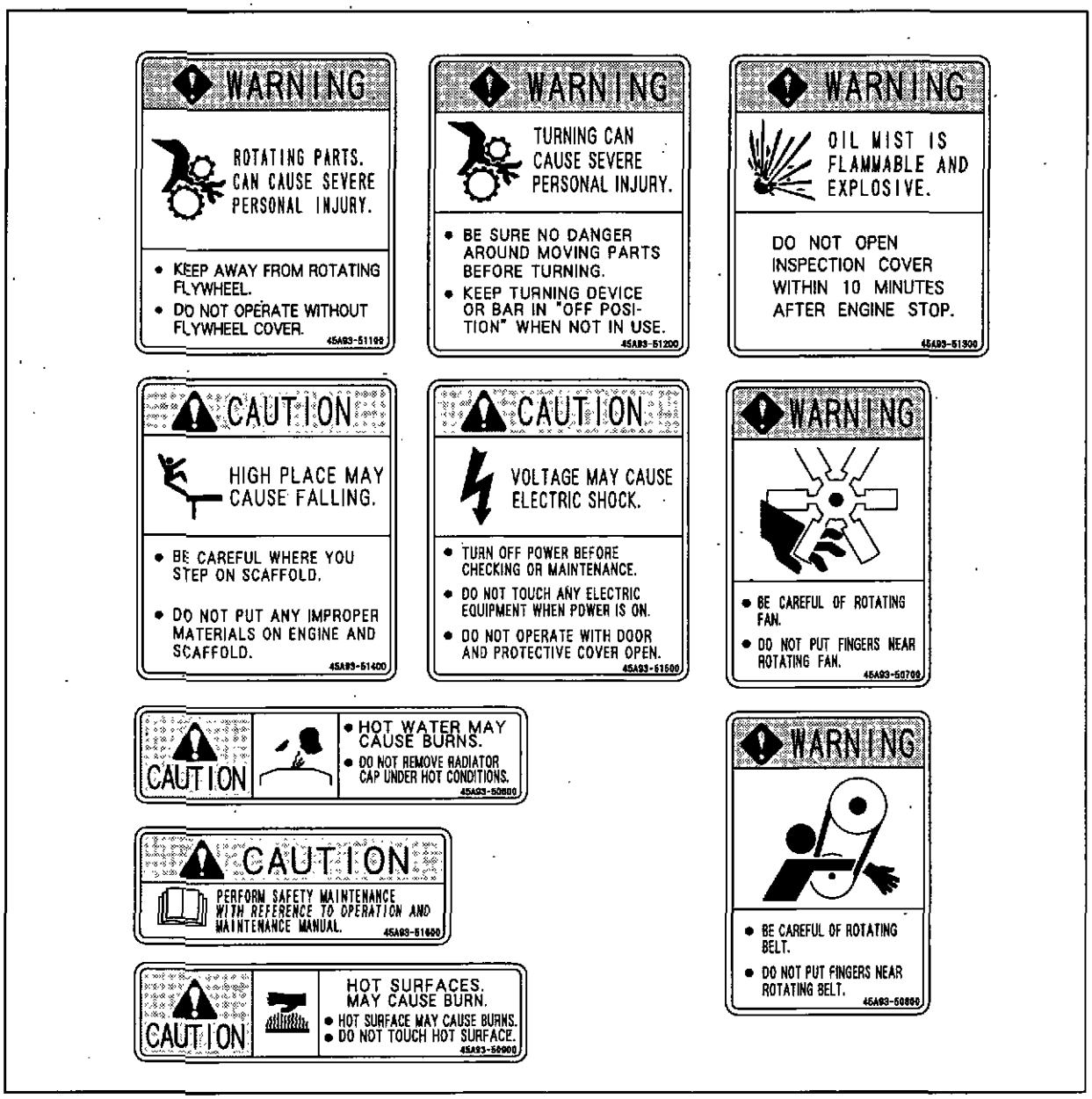
Make sure all warning/caution labels are legible.

Clean or replace the warning/caution labels when the description and/or illustration are not clear to read.

For cleaning the warning/caution labels, use a cloth, water and soap. Do not use cleaning solvents, gasoline or other chemicals to prevent the letters from getting blurred or the adhesion from being weakened.

Replace damaged or fractured labels with new ones.

If any engine part on which a warning label is attached is replaced with a new one, attach a new identical warning label to the new part.

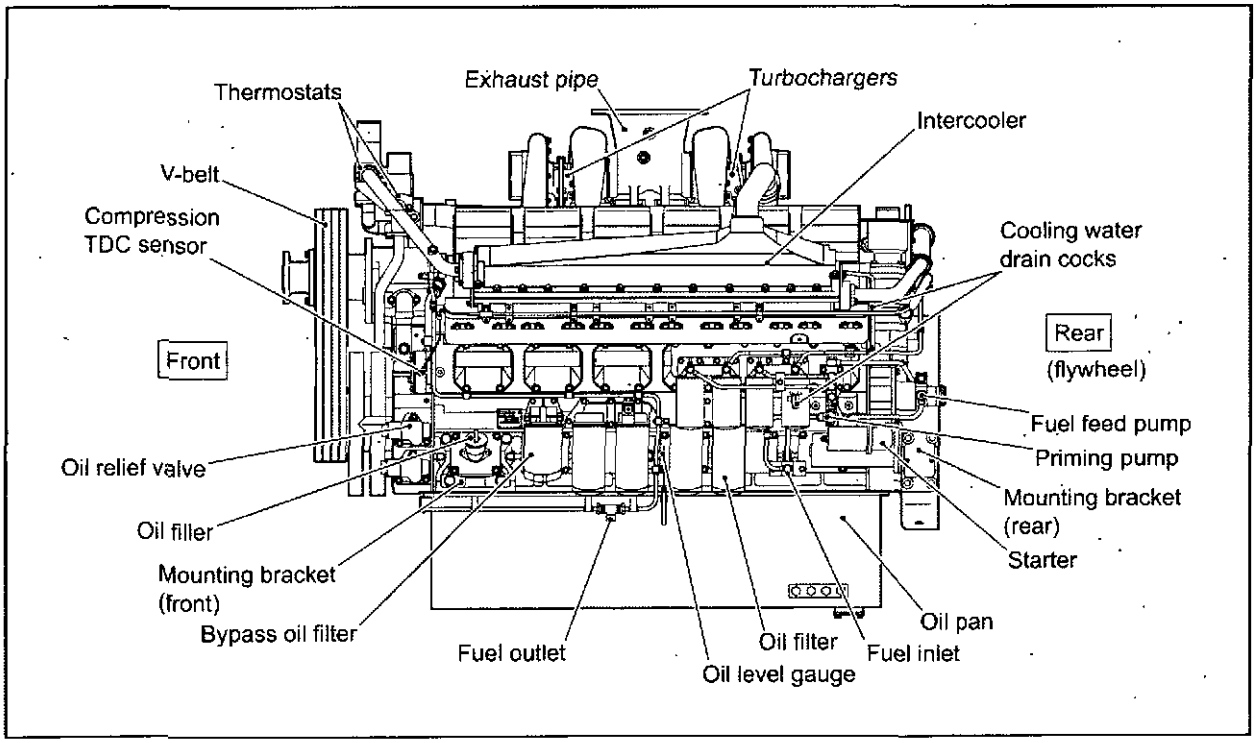



Warning labeles

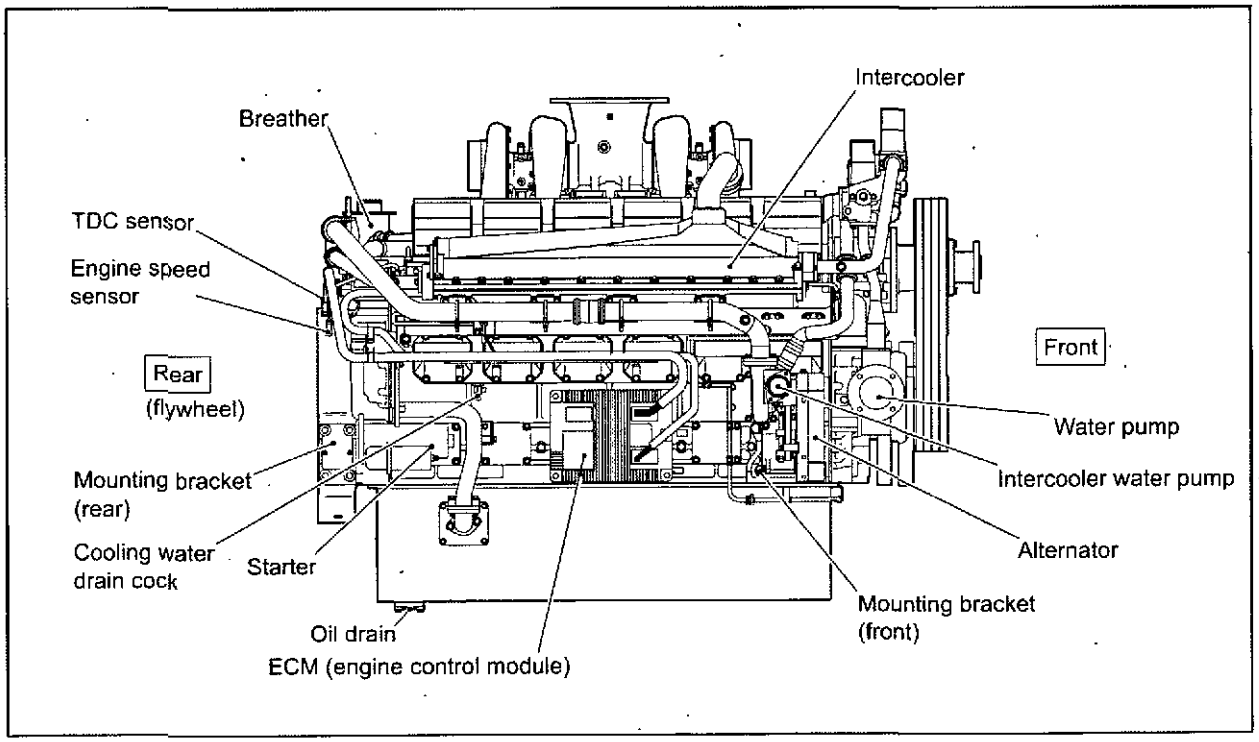
# GENERAL CONTENTS

# GENERAL

## 1. External view



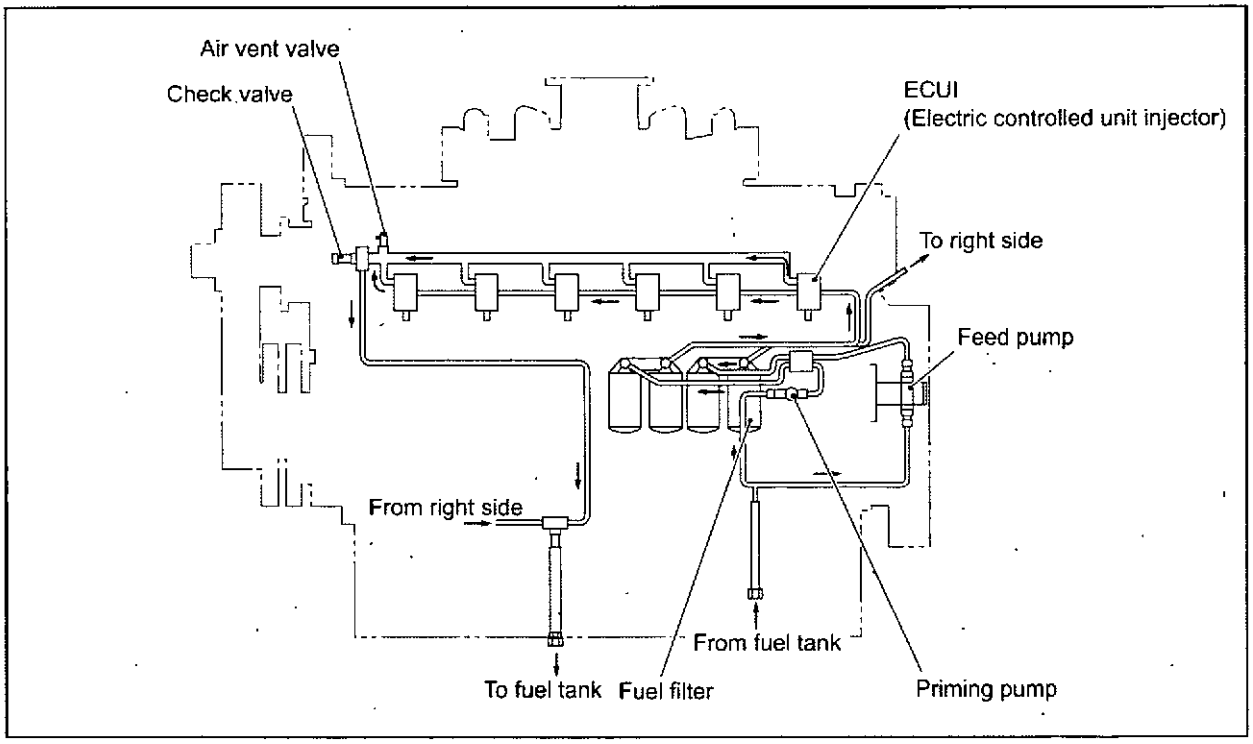

Left side view of the engine




Right side view of the engine

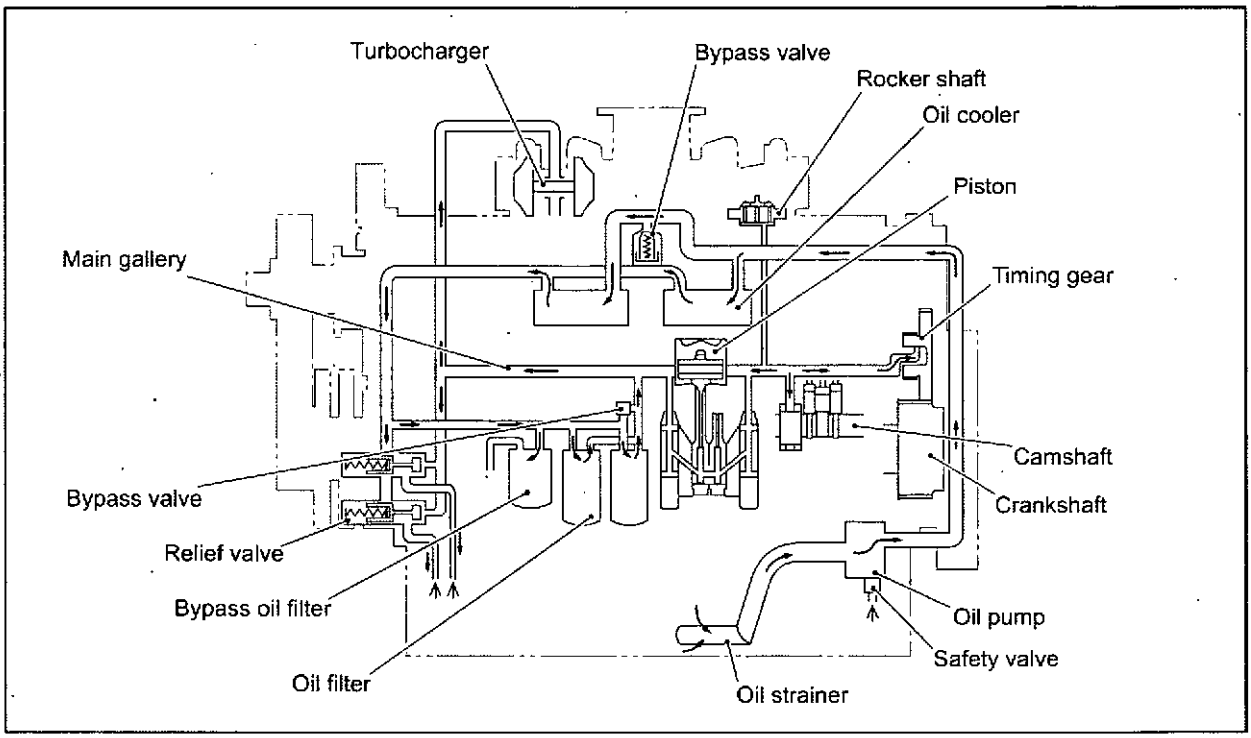
## 2. System flow diagrams

### 2.1 Fuel system - flow diagram



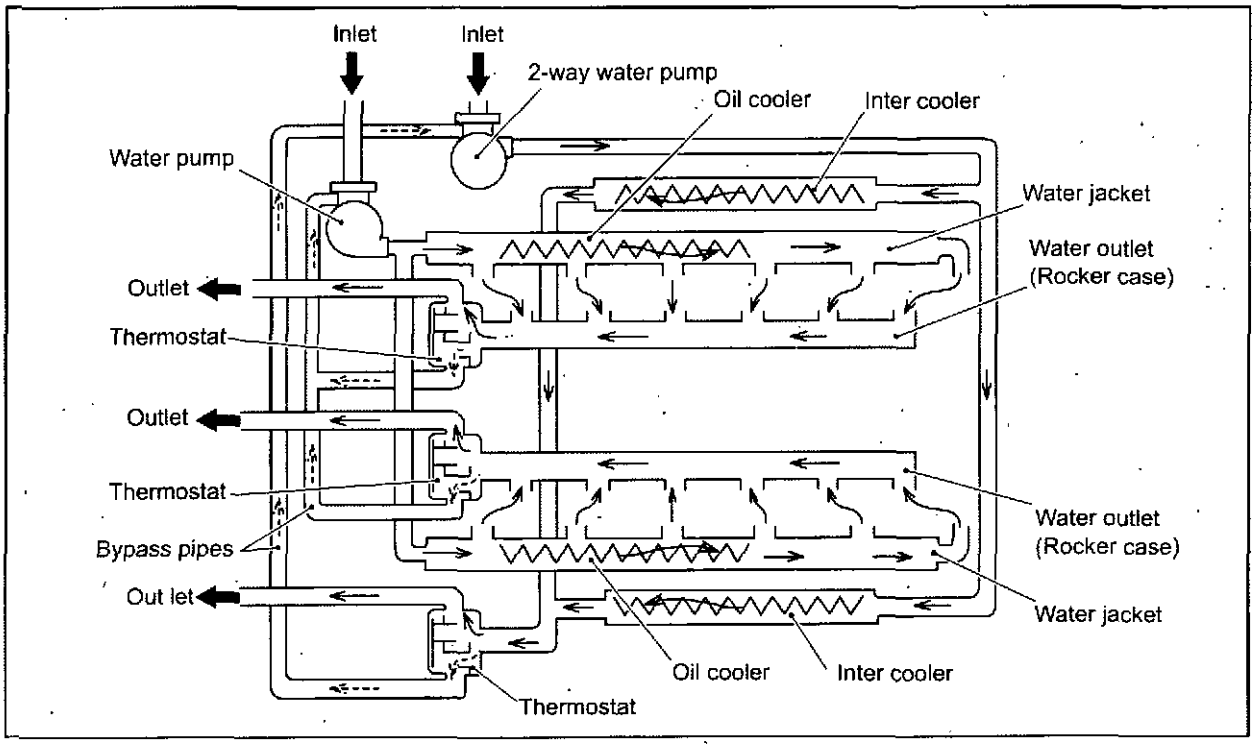

Fuel system - flow diagram

### 2.2 Lubrication system - flow diagram



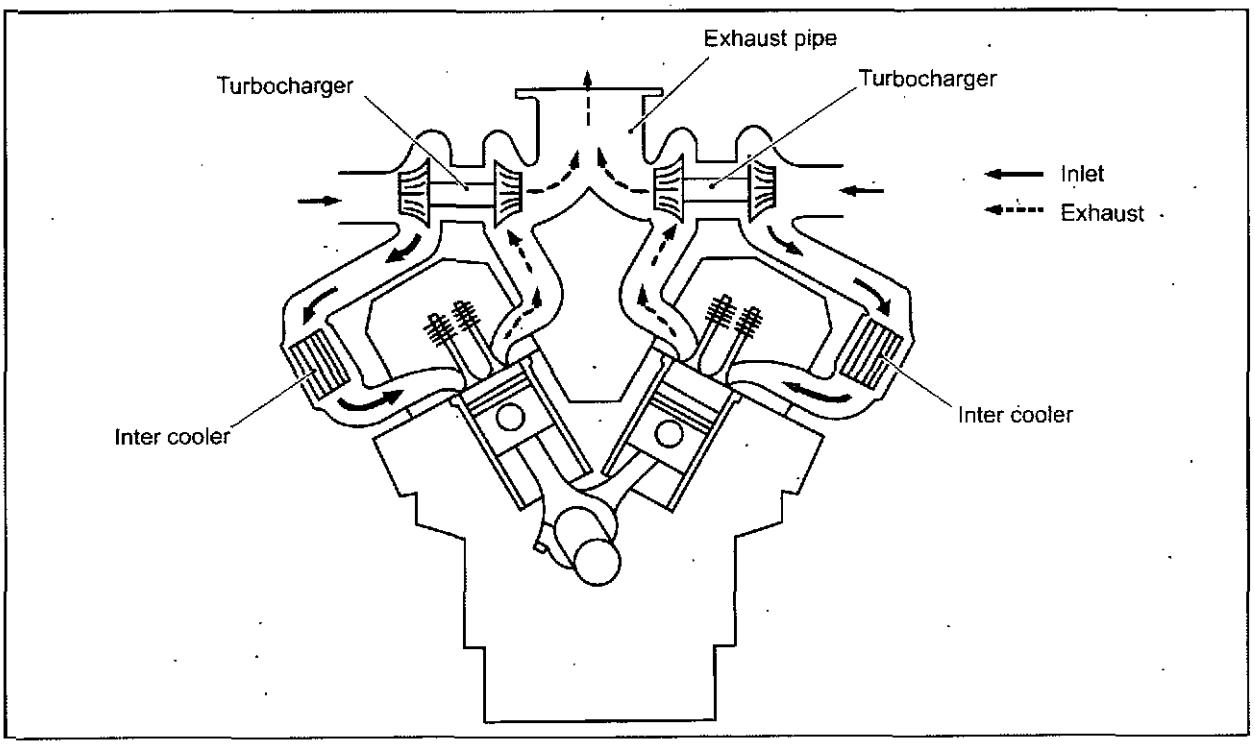

Lubrication system - flow diagram

## 2.3. Cooling system - flow diagram



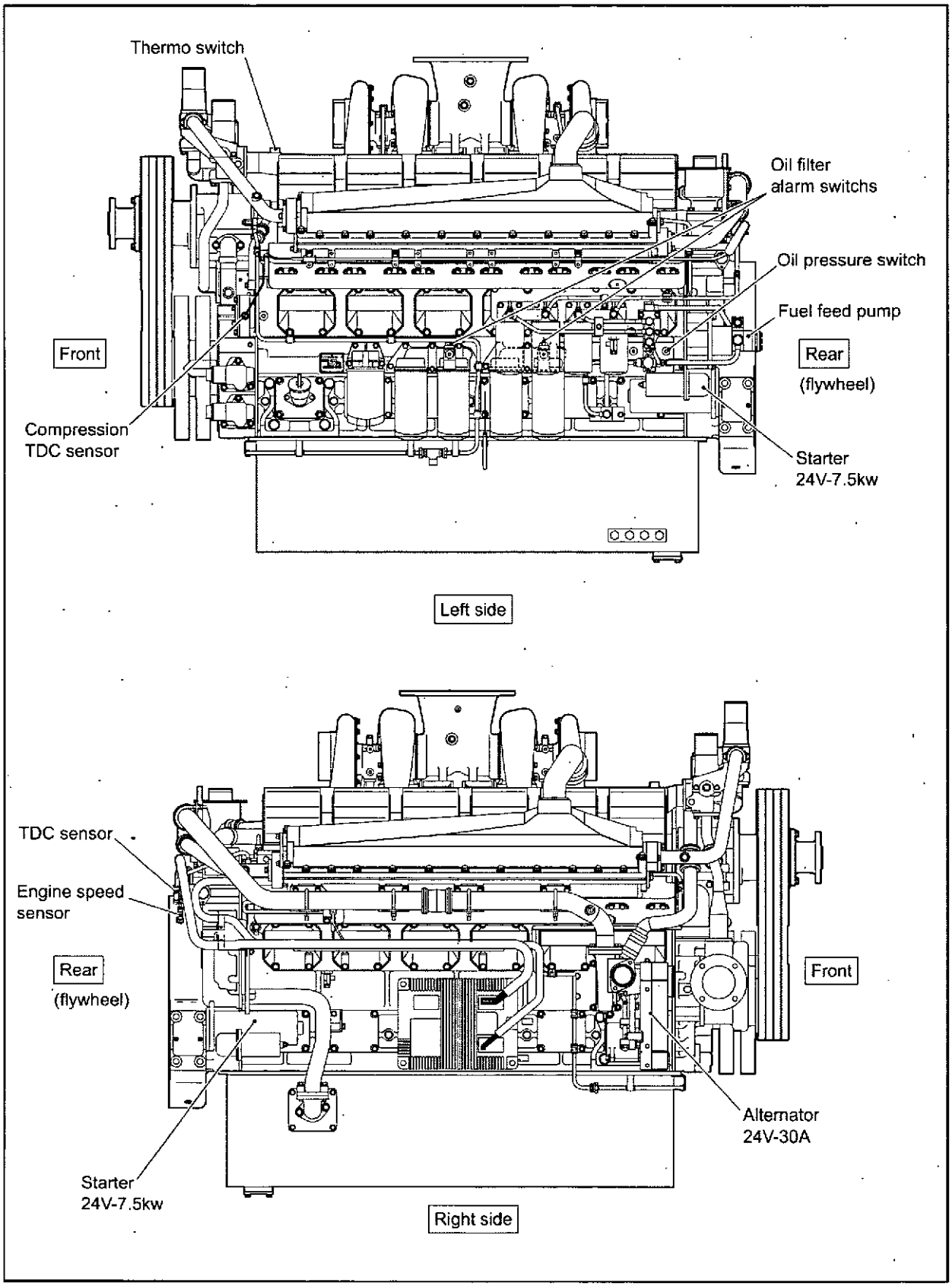

*Cooling system - flow diagram*

## 2.4 Inlet and exhaust system - flow diagram




Inlet and exhaust system - flow diagram

## 2.5 Electrical system - flow diagram



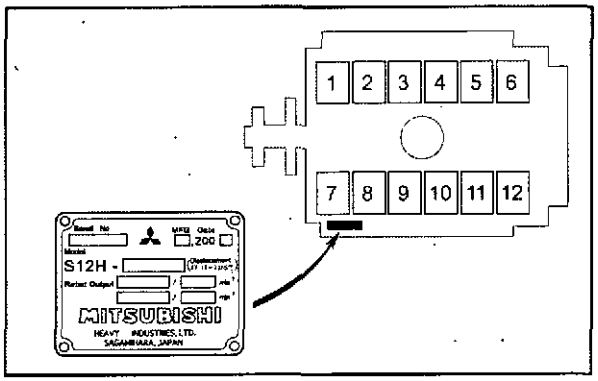

Electrical system - flow diagram

## 3. Engine serial number location

The engine serial number is stamped on the nameplate of the lateral side of the engine.

The rated engine output and speed are also stamped on the nameplate.

The numbers shown in the illustration mean the cylinder numbers.




Nameplate location

## 4. Main specifications

Table 1-1 Main specifications (1 / 3)

| Engine type | | | | S12H-Y2PTAW |
|---|---|---|---|---|
| Major specifications | Model | | | Water-cooled, 4-stroke cycle, turbocharged diesel |
| | No. of cylinders - arrangement | | | 12-V |
| | Combustion type | | | Direct injection |
| | Valve mechanism | | | Overhead |
| | Cylinder bore × stroke | | | 150 × 175 mm [5.91 × 6.89 in.] |
| | Displacement | | | 37.11 L [2264.45 cu in.] |
| | Compression ratio | | | 14.5 : 1 |
| | Fuel | | | Diesel fuel (ASTM, D975 No.1-D, No.2-D) |
| | Firing order | | | 1-12-5-8-3-10-6-7-2-11-4-9 |
| | Rotation of direction | | | Counterclockwise as viewed from flywheel |
| | Dimensions (without fan) | Length | | 2174 mm [85.59 in.] |
| | | Width | | 1673 mm [65.87 in.] |
| | | Height | | 1694 mm [9672 in.] |
| | Weight (Dry) | | | 4387 kg [9672 lb] |
| Basic engine | Cylinder liner | Type | | Wet type |
| | No. of piston rings | Compression rings<br>Oil ring | | Compression rings : 2<br>Oil ring (w/expander) : 1 |
| | Valve timing | Inlet valve | Open | BTDC 55° |
| | | | Close | ABDC 65° |
| | | Exhaust valve | Open | BBDC 65° |
| | | | Close | ATDC 55° |
| | Engine support method | | | 4-point support |
| | Starting system | | | Starter |
| Inlet and exhaust system | Turbocharger | Type | | TD13 |
| | | No. of units | | 2 |

Table 1-1 Main specifications (2 / 3)

| Engine type | | | | S12H-Y2PTAW |
|---|---|---|---|---|
| Lubrication system | Lubricating method | | | Forced circulation type (oil pump pressure feed type) |
| | Engine oil | Standard | | API service classification class CD or CF oil |
| | | Capacity | | Engine total: 200 L [53 U.S.gal.] approx.<br>Oil pan: 180 L [48 U.S.gal.] approx. |
| | Oil pump | Type | | Gear pump |
| | | Delivery capacity | | 450 L [119 U.S.gal] /min (at engine speed of 1800 $min^{-1}$) |
| | | Safety valve | Type | Piston valve |
| | | | Valve opening pressure | 1.4 ± 0.1 MPa {14 ± 1 kgf·cm²} [199 ± 14 psi] |
| | Relief valve | Type | | Main gallery pressure detection type |
| | | Valve opening pressure | | 0.58 ± 0.05 MPa {5.9 ± 0.5 kgf/cm²} [84 ± 7 psi] |
| | Oil cooler | Type | | Water-cooled, multi-plate type |
| | Oil filter | Type | | Cartridge paper-element type, filtration rating 20μm |
| | Bypass oil filter | Type | | Cartridge paper-element type, filtration rating 2μm |
| | Oil filter alarm | Type | | Piston valve type, built-in electric contact points |
| | | Valve opening pressure (differential pressure) | | $0.14\ ^{+0.03}_{0}$ MPa {$1.5\ ^{+0.3}_{0}$ kgf/cm²} [$21.34\ ^{+1.27}_{0}$ psi] |
| | Oil cooler bypass valve | Valve opening pressure | | 0.44 ± 0.05 MPa {4.5 ± 0.5 kgf/cm²} [64 ± 7.1 psi] |
| | Piston cooling nozzle (oil jet) | Valve opening pressure | | 0.29 ± 0.03 MPa {3 ± 0.3 kgf/cm²} [43 ± 4.3 psi] |
| Cooling system | Cooling method | | | Water-cooled, forced circulation |
| | Coolant capacity (engine) | | | Approx. 100 L [26 U.S.gal] |
| | Water pump | Type | | Centrifugal type |
| | | Delivery capacity | | 1600 L [383 U.S.gal]/min (at engine speed of 1800 $min^{-1}$) |
| | 2-way water pump | Type | | Centrifugal type |
| | | Delivery capacity | | 551 L [146 U.S.gal]/min (at engine speed of 1800 $min^{-1}$) |
| | Thermostat (water pump) | Type | | Wax type |
| | | Temperature at which valve starts opening | | 71 ± 2°C [160 ± 3.6°F] |
| | Thermostat (2-way water pump) | Type | | Wax type |
| | | Temperature at which valve starts opening | | 35 ± 2°C [95 ± 3.6°F] |
| | 2-way water pump belt | Type | | RIB 12PK |
| | | Manufacturer | | Mitsuboshi Belting, Ltd |
| | | Outside circumference | | 976 mm [38.43 in.] |

Table 1-1 Main specifications (3 / 3)

| Engine type | | | S12H-Y2PTAW |
|---|---|---|---|
| Fuel system | Unit injector | Model (abbreviation) | PUE-H Electronically Controlled Unit Injector |
| | | Manufacturer | Mitsubishi Heavy Industries, Ltd. |
| | | Plunger outside diameter | 14 mm [0.55 in.] |
| | | Impressed voltage | 120 ± 20 V |
| | | Poppet valve outside diameter | 10 mm [0.39 in.] |
| | Feed pump | Model | Trochoid type pump TOP-212HBMTGVB |
| | | Manufacturer | Nippon Oil Pump Co., Ltd. |
| | | Theretical delivery capacty | 12 cm³ [0.73 cu.in.]/rev |
| | Governor | Controller model | (Electronic)<br>Woodward<br>ECM3 |
| | Injection nozzle | Model | TE |
| | | Manufacturer | Bosch Corporation |
| | | No. of spray holes | 10 |
| | | Spray hole diameter | ø 0.22 mm [0.0087 in.] |
| | | Spray angle | 160° |
| | | Injection pressure | 29.4 MPa {300 kgf/cm²} [4268 psi] |
| | Fuel filter | | Type (paper element) Filtration accuracy of 5 µm |
| | Check valve | Valve opening pressure | 0.49 ± 0.025 MPa {5 ± 0.25 kgf/cm²} [71 ± 4 psi] |
| Electrical system | Voltage - polarity | | 24 V - Negative (-) ground |
| | Starter | Manufacturer | Nikko Electric Industry Co., Ltd. |
| | | Piston mesh type | Pinion shift |
| | | Output | 24 V - 7.5 kW |
| | | No. of units | 2 |
| | Alternator | Type | 3-phase alternating-current generator, built-in IC regulator |
| | | Manufacturer | Mitsubishi Electric Corporation |
| | | Output | 24 V - 30 A |
| | | Rated output generating speed | Hot 5000 min$^{-1}$ or less (at 27 V, 30 A) |
| | | Regulated voltage | 28.5 ± 0.5 V |
| | Magnetic relay (two starters for parallel operation) | Manufacturer | Nikko Electric Industry Co., Ltd. |
| | | Nominal voltage | 24 V |
| | | Rating | 30 sec. |
| | | Operating voltage | 8 to 24 V |
| | | Operating interval (at 24 V) | 1 ON-OFF cycle between SS and SW<br>2.5 to 3.0 sec. |
| | | Allowable temperature | -30 to +80 °C [-54 to +176 °F] |
| | | Grounding system | 2-wire system |
| | Alternator belt | Type | RIB 12PK |
| | | Manufacturer | Mitsuboshi Belting, Ltd |
| | | Outside circumference | 976 mm [38.43 in.] |

## 5. Tips on disassembling and reassembling

This service manual specifies the recommended procedures to be followed when servicing Mitsubishi engines. The manual also specifies the special tools that are required for the work, and the basic safety precautions to follow when working.

Note that this manual does not exhaustively cover potential hazards that could occur during maintenance, inspection and service work of engine.

When working on an engine, follow the relevant directions given in this manual and observe the following instructions:

**CAUTION**

Work related to the exhaust emission regulations can be conducted only at our designated service factories.

### 5.1 Disassembling

(1) Use correct tools and instruments. Serious injury or damage to the engine will result from using the wrong tools and instruments.

(2) Use an overhaul stand or work bench if necessary, and follow the disassembling procedures described in this manual.

(3) Keep the engine parts in order of removal to prevent losing them.

(4) Pay attention to assembling marks. Put your marks on the parts , if necessary, to ensure correct reassembling.

(5) Carefully check each part for defects during disassembling or cleaning. Do not miss symptoms which can not be detected after disassembling or cleaning.

(6) When lifting or carrying heavy parts, exercise utmost caution to ensure safety. Pay attention to balance of heavy parts when handling. (Get help, and use jacks, chain blocks and guide bolts as necessary.)

### 5.2 Reassembling

(1) Wash all engine parts, except such parts as oil seals, O-rings and rubber sheets, in cleaning oil and dry them with compressed air.

(2) Use correct tools and instruments.

(3) Use only high-quality lubricating oils and greases of appropriate types. Be sure to apply oil, grease or adhesive to the part wherever specified.

(4) Use a torque wrench to tighten parts correctly when their tightening torques are specified.
Refer to "List of Tightening Torque."

(5) Replace all gaskets and packings with new ones unless specified otherwise. Apply adhesive if necessary. Use only the proper amount of adhesive.

**CAUTION**

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

Work related to the exhaust emission regulations can be conducted only at our designated service factories.

# SERVICE DATA

# 1. Maintenance service data

## 1.1 General

Table 2-1 Maintenance service data table - General — Unit: mm [in.]

| Inspection point | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|
| Maximum speed (rated speed as reference value) | | 105 to 110 % | | 115 % | Rated speed is stamped on the nameplate |
| Minimum speed | | 700 to 800 min$^{-1}$ | | | |
| Compression pressure (at 120 min$^{-1}$) | | 2.4 MPa {24.4 kgf/cm$^2$} [347.1 psi] | | 1.9 MPa {19.3 kgf/cm$^2$} [274.5 psi] | When oil and water temperatures at 20 to 30°C [68 to 86 °F] |
| Lubricating oil pressure | Rated pressure | 0.39 to 0.67 MPa minimum | | 0.39 MPa | Oil temperature at 60 to 70 °C [140 to 158 °F] |
| | Idling | 0.2 to 0.29 MPa | | 0.1 MPa | |
| Valve timing | Inlet valve opens | BTDC 14° | ± 2° (crank angle) | | With 2 mm [0.08 in.] clearance on valve side, cold. Values are only for checking valve timing and are different from actual opening/closing time. |
| | Inlet valve closed | ABDC 23° | | | |
| | Exhaust valve open | BBDC 21° | | | |
| | Exhaust valve closed | ATDC 15° | | | |
| Valve clearance | Inlet | | 0.6 [0.024] | | Cold |
| | Exhaust | | 0.8 [0.031] | | |

## 1.2 Basic engine

Table 2-2 Maintenance service data table - Basic engine (1 / 5) — Unit: mm [in.]

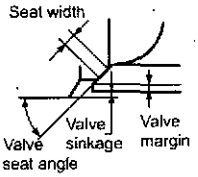
| Inspection point | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|
| Rocker | Rocker bushing inside diameter | ø 44 [1.73] | 44.000 to 44.075 [1.7323 to 1.7352] | 44.125 [1.7372] | |
| | Rocker shaft diameter | ø 44 [1.73] | 43.975 to 43.991 [1.7313 to 1.7319] | 43.030 [1.6941] | |
| Valve | Valve stem diameter | ø 10 [0.39] | 9.940 to 9.960 [0.3913 to 0.3921] | 9.910 [0.3902] | Same for inlet and exhaust valves. |
| | Valve guide inside diameter | ø 10 [0.39] | 10.000 to 10.015 [0.3937 to 0.3943] | 10.060 [0.3961] | |
| Valve seat and valve | Valve seat angle | | 30° | |   |
| | Valve sinkage | 0 | -0.1 to 0.1 [-0.0040 to 0.0040] | 1.0 [0.0394] | |
| | Seat width | 2.3 [0.091] | 2.15 to 2.45 [0.0846 to 0.0965] | 2.8 [0.110] | |
| | Valve margin | 3.0 [0.12] | 2.8 to 3.2 [0.110 to 0.126] | Refacing permissible up to 2.5 [0.098] | |
| | Clearance between cylinder head bore diameter and valve seat diameter | ø 55 [2.17] | -0.130 to -0.070 [-0.0051 to 0.0028] | | Minus (-) value indicates interference. |
| Valve spring | Free length | | 75.5 [2.776] | 74 [2.91] | |
| | Perpendicularity | | θ = 1.5°or less Δ = 2.0 [0.079] Lf = 75.5 [2.776] | Δ = 2.3 [0.091] at the end |   |
| | Installation length/load | | 61.8 [2.433]/ 403.3 N {41.13 kgf} [90.7 lbf] | | |

Table 2-2 Maintenance service data table - Basic engine (2 / 5) Unit: mm [in.]

| Inspection point | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|
| Valve push rod | Runout | | 0.5 [0.020] or less | 0.5 [0.020] | TIR |
| Helper spring | Free length | | 73 [2.87] | 71 [2.80] | |
| | Perpendicularity | | $\theta$ = 1.5°or less<br>$\Delta$ = 1.9 [0.075]<br>Lf = 73 [2.87] | $\Delta$ = 2.2 [0.087] at the end |  |
| | Installation length/load | | 69.6 [2.740]/ 242 N {24.7 kgf} [54.5 lbf] | | |
| UI helper push rod | Runout | | 0.5 [0.020] or less | 0.5 [0.020] | TIR |
| Cylinder head | Flatness of gasket surface | | 0.03 [0.0012] or less | 0.50 [0.0197] | Slightly reface, if necessary. |
| Cylinder liner | Inside diameter | ø 150 [5.91] | 150.000 to 150.040 [5.9055 to 5.9071] | 150.140 [5.9110] | |
| | Roundness | | 0.02 [0.0008] or less | | |
| | Cylindericity | | 0.02 [0.0008] or less | | |
| | Perpendicularity of flange bottom surface to cylinder liner longitudinal centerline | | 0.03 [0.0012] or less | | |
| | Cylinder liner collar protrusion above crankcase top surface | | 0.10 to 0.19 [0.0039 to 0.0075] | | |
| | Thickness of cylinder liner flange | | 15.15 to 15.19 [0.5965 to 0.5980] | | |
| | Height cylinder liner top ridge | | 0.16 to 0.24 [0.0063 to 0.0094] | | |
| Piston | Outside diameter (at piston skirt) | ø 150 [5.91] | 149.78 to 149.82 [5.8968 to 5.8984] | 149.68 [5.8929] | Measure diameter in direction perpendicular to piston pin. |
| | Weight difference in one engine | | ± 30 g [0.07 lb.] or less | | |
| | Pin bore diameter | ø 58 [2.28] | 58.002 to 58.012 [2.2835 to 2.2839] | 58.020 [2.2842] | |
| | Protrusion | | 0.38 to 0.89 [0.0150 to 0.0350] | | |
| Cylinder head gasket | Thickness when tightened | 1.8 [0.071] | 1.77 to 1.83 [0.0697 to 0.0720] | | |
| Piston and cylinder head | Clearance between piston top and cylinder head | | 0.88 to 1.45 [0.0346 to 0.0571] | | |

*Table 2-2 Maintenance service data table - Basic engine (3 / 5)* *Unit: mm [in.]*

| Inspection point | | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|---|
| Piston ring | Piston ring side clearance (with new rings) | No. 1 compression | 3.00 [0.1181] | 0.08 to 0.11 [0.0032 to 0.0043] | 0.20 [0.0079] | |
| | | No. 2 compression | 2.55 [0.1004] | 0.07 to 0.10 [0.0028 to 0.0039] | 0.15 [0.0059] | |
| | | Oil | 5.00 [0.1969] | 0.05 to 0.09 [0.0020 to 0.0035] | 0.15 [0.0059] | |
| | End gaps | No. 1 compression | | 0.6 to 0.8 [0.024 to 0.031] | 2.0 [0.079] | If gauge is not available, approximate value can be obtained at cylinder bore. |
| | | No. 2 compression | | 0.5 to 0.7 [0.020 to 0.028] | 2.0 [0.079] | |
| | | Oil | | 0.5 to 0.7 [0.020 to 0.028] | 2.0 [0.079] | |
| Piston pin | Outside diameter | | ø 58 [2.28] | 57.987 to 58.000 [2.2829 to 2.2835] | 57.970 [2.2823] | |
| Connecting rod | Bushing inside diameter | | ø 58 [2.28] | 58.020 to 58.040 [2.2842 to 2.2850] | 58.070 [2.2862] | |
| | Bend and twist | | | 0.05/100 [0.0020/3.94] or less | | |
| | End play (clearance) (rod and crankpin widths) | | 54 [2.13] × 2 | 0.6 to 0.9 [0.024 to 0.035] | 1.0 [0.039] | |
| | Big-end bore diameter (to be measured in combination with caps.) | | ø 110 [4.33] | 110.000 to 110.022 [4.3307 to 4.3316] | 110.047 [4.3326] | Roundness (Max. - Min.) less than 0.100 [0.0039] |
| Connecting rod bearing | Thickness of center | STD | 3.000 [0.1181] | 2.987 to 3.000 [0.1176 to 0.1181] | 2.950 [0.1161] | Replace bearings before limit is reached, regrind crankpins and use undersize bearings if limit is exceeded. |
| | | -0.25 [-0.0098] | 3.125 [0.1230] | 3.112 to 3.125 [0.1225 to 0.1230] | 3.075 [0.1211] | |
| | | -0.50 [-0.0197] | 3.250 [0.1280] | 3.237 to 3.250 [0.1274 to 0.1280] | 3.200 [0.1260] | |
| | | -0.75 [-0.0295] | 3.375 [0.1329] | 3.362 to 3.375 [0.1324 to 0.1329] | 3.325 [0.1310] | |
| | | -1.00 [-0.0394] | 3.500 [0.1378] | 3.487 to 3.500 [0.1373 to 0.1378] | 3.450 [0.1358] | |
| Flywheel | Face runout | | | 0.28 [0.0110] or less | | |
| | Radial runout | | | 0.13 [0.0051] or less | | |
| Damper | Face runout | | | 0.5 [0.020] or less | 1.5 [0.059] | Replace after major overhaul |
| | Radial runout | | | 0.5 [0.020] or less | 1.5 [0.059] | |
| Front accessory drive | Front idler shaft outside diameter | | ø 50 [1.97] | 49.950 to 49.975 [1.9665 to 1.9675] | 49.900 [1.9646] | |
| | Front idler gear bushing inside diameter | | ø 50 [1.97] | 50.000 to 50.025 [1.9685 to 1.9695] | 50.060 [1.9709] | |
| | Front idler gear end play | | | 0.3 to 0.5 [0.012 to 0.020] | 0.7 [0.028] | |
| | Backlash | Front crankshaft gear to front idler gear | | 0.11 to 0.28 [0.0043 to 0.0110] | 0.50 [0.0197] | Replace gears. |
| | | Front idler gear to water pump head gear | | 0.12 to 0.18 [0.0047 to 0.0071] | 0.50 [0.0197] | |

Table 2-2 Maintenance service data table - Basic engine (4 / 5) Unit: mm [in.]

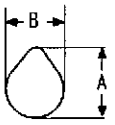
| Inspection point | | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|---|
| Timing gear | Rear idler shaft outside diameter | | ø 50 [1.97] | 49.950 to 49.975 [1.9665 to 1.9675] | 49.900 [1.9646] | Same for LH and RH idler shafts. |
| | Rear idler gear bushing inside diameter | | ø 50 [1.97] | 50.000 to 50.025 [1.9685 to 1.9695] | 50.060 [1.9709] | |
| | Rear idler gear end play | | | 0.3 to 0.5 [0.012 to 0.020] | 0.7 [0.028] | |
| | Backlash | Crankshaft gear to LH idler gear | | 0.11 to 0.26 [0.0043 to 0.0102] | 0.50 [0.0197] | Timing mark "1". Replace gears. |
| | | LH idler gear to LH camshaft gear | | 0.10 to 0.24 [0.0039 to 0.0094] | 0.50 [0.0197] | Timing mark "2". Replace gears. |
| | | LH idler gear to RH idler gear | | 0.12 to 0.22 [0.0047 to 0.0087] | 0.50 [0.0197] | Timing mark "3". Replace gears. |
| | | RH idler gear to RH camshaft gear | | 0.11 to 0.25 [0.0043 to 0.0098] | 0.50 [0.0197] | Timing mark "4". Replace gears. |
| Rear accessory drive | Feed pump drive gear bearing bore diameter | | ø 68 [2.68] | 67.961 to 67.991 [2.6756 to 2.6768] | | |
| | Bearing | Bore diameter | ø 40 [1.57] | 39.988 to 40.000 [1.5743 to 1.5748] | | |
| | | Outside diameter | ø 68 [2.68] | 67.987 to 68.000 [2.6766 to 2.6772] | | |
| | Feed pump drive shaft outside diameter | | ø 40 [1.57] | 39.995 to 40.011 [1.5746 to 1.5752] | | |
| | Backlash | Feed pump drive gear to LH camshaft gear | | 0.12 to 0.18 [0.0047 to 0.0071] | 0.50 [0.0197] | Replace gears. |
| Camshaft | Cam lift (major axis - minor axis) | Inlet | 14.35 [0.5650] | 14.25 to 14.45 [0.5610 to 0.5689] | |   |
| | | Exhaust | 9.25 [0.3642] | 9.15 to 9.35 [0.3602 to 0.3681] | | |
| | Runout | | | 0.10 [0.0039] or less | 0.16 [0.0063] | TIR Repair or replace. |
| | Journal outside diameter | | ø 100 [3.94] | 99.920 to 99.940 [3.9339 to 3.9346] | 99.860 [3.9315] | |
| | Camshaft bushing inside diameter (as installed in crankcase) | | ø 100 [3.94] | 100.038 to 100.095 [3.9385 to 3.9407] | 100.160 [3.9433] | |
| | End play | | 15 [0.59] | 0.2 to 0.4 [0.008 to 0.016] | 0.55 [0.0217] | Replace thrust plate. |
| | Follower shaft outside diameter | | ø 30 [1.18] | 29.959 to 29.980 [1.1795 to 1.1803] | 29.930 [1.1783] | |
| | Follower bushing inside diameter | | ø 30 [1.18] | 30.000 to 30.075 [1.1811 to 1.1841] | 30.125 [1.1860] | |
| | Tappet roller outside diameter | | ø 41 [1.61] | 40.95 to 41.05 [1.6122 to 1.6161] | 40.94 [1.6118] | |

Table 2-2 Maintenance service data table - Basic engine (5 / 5) Unit: mm [in.]

| Inspection point | | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|---|
| Crankshaft | Crankpin diameter | | ø 104 [4.09] | 103.900 to 103.920 [4.0905 to 4.0913] | 103.860 [4.0890] (Repair limit) | Replace with undersize bearing if worn beyond limit. |
| | Crankpin journal diameter | | ø 140 [5.51] | 139.930 to 139.950 [5.5090 to 5.5098] | 139.870 [5.5067] (Repair limit) | |
| | Distance between centers of journal and crankpin | | 87.5 [3.44] | 87.4 to 87.6 [3.441 to 3.449] | | |
| | Parallelism of journals and crankpins | | | 0.01 [0.0004] or less | 0.03 [0.0012] (Repair limit) | |
| | Roundness of journals and crankpins (diameter difference) | | | 0.01 [0.0004] or less | 0.03 [0.0012] (Repair limit) | |
| | Cylindericity of journals and crankpins (diameter difference) | | | 0.01 [0.0004] or less | 0.03 [0.0012] (Repair limit) | |
| | Fillet radius of pins and journals | | 7 [0.28] | 6.8 to 7.0 [0.268 to 0.276] | | |
| | Hardness of journals and crankpins | | | Hv> 620 | | |
| | *Angular deviation between pins* | | | ± 0.3° | | |
| | Runout | | | 0.08 [0.0032] or less | 0.20 [0.0079] (Repair limit) | TIR Repair or replace. |
| | End play (clearance between thrust plate journal width of crankshaft) | | 58 [2.28] | 0.200 to 0.400 [0.0079 to 0.0157] | 0.500 [0.0197] +1.18 [+0.0465] for crankshaft width | Replace thrust plate if worn down to limit. Use oversize thrust bearings if worn beyond limit. +0.25 [+0.0098], +0.50 [+0.0197], +0.75 [+0.0295] |
| Main bearing | Thickness of center | STD | 3.500 [0.1378] | 3.467 to 3.480 [0.1365 to 0.1370] | 3.425 [0.1348] | Replace bearings if worn down to limit. Regrind crank journals and use undersize bearings if worn beyond limit. |
| | | -0.25 [-0.0098] | 3.625 [0.1427] | 3.592 to 3.605 [0.1414 to 0.1419] | 3.550 [0.1398] | |
| | | -0.50 [-0.0197] | 3.750 [0.1476] | 3.717 to 3.730 [0.1463 to 0.1469] | 3.675 [0.1447] | |
| | | -0.75 [-0.0295] | 3.875 [0.1526] | 3.842 to 3.855 [0.1513 to 0.1518] | 3.800 [0.1496] | |
| | | -1.00 [-0.0394] | 4.000 [0.1575] | 3.967 to 3.980 [0.1562 to 0.1567] | 3.925 [0.1545] | |
| Crankcase | Flatness of gasket surface | | | 0.15 [0.0059] or less | 0.20 [0.0079] (Repair limit) | Slightly reface. |
| | Main bearing bore diameter | | ø 147 [5.79] | 147.000 to 147.025 [5.7874 to 5.7884] | 147.045 [5.7892] | |
| | Counterbore depth | | | 15.00 to 15.05 [0.5906 to 0.5925] | | |

## 1.3 Inlet and exhaust system

Table 2-3 Maintenance service data table - Inlet and exhaust system Unit: mm [in.]

| Inspection point | | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|---|
| Turbocharger | Inside diameter of bearing-fitted section of housing | | ø 30 [1.18] | 29.994 to 30.006 [1.1809 to 1.1813] | 30.006 [1.1813] | |
| | Bearing | Outside diameter | ø 30 [1.18] | 29.876 to 29.886 [1.1762 to 1.1766] | 29.876 [1.1762] | |
| | | Inside diameter | ø 18 [0.71] | 18.042 to 18.050 [0.7103 to 0.7106] | 18.050 [0.7106] | |
| | | Length | ø 17.5 [0.689] | 17.440 to 17.560 [0.6866 to 0.6913] | 17.440 [0.6866] | |
| | Shaft & turbine wheel | Journal diameter | ø 18 [0.71] | 17.9962 to 18.0038 [0.7085 to 0.7088] | 17.996 [0.7085] | |
| | | Shaft runout | | | 0.030 [0.0012] | TIR |
| | Piston ring end gap | | | 0.05 to 0.25 [0.0020 to 0.0098] | | |
| | Clearance between turbine wheel and turbine housing | | | 0.29 to 0.91 [0.0114 to 0.0358] | | |
| | Shaft & turbine wheel and play | | | 0.075 to 0.135 [0.0030 to 0.0053] | | |
| | Clearance between turbine backplate and back side of turbine wheel | | | 0.55 to 1.15 [0.0217 to 0.0453] | | |

## 1.4 Fuel system

Table 2-4 Maintenance service data table - Fuel system Unit: mm [in.]

| Inspection point | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|
| Injection nozzle | Injection starting pressure | 29.4 MPa {300 kgf/cm²} [4268 psi] | 28.9 to 30.9 MPa {295 to 315 kgf/cm²} [4196 to 4481 psi] | | |
| | Spray cone angle | 160° | | | Nozzle tester |
| Check valve | Valve opening pressure | 0.49 MPa {5 kgf/cm²} [71 psi] | 0.47 to 0.51 MPa {4.75 to 5.25 kgf/cm²} [68 to 75 psi] | | |

## 1.5 Lubrication system

Table 2-5 Maintenance service data table - Lubrication system Unit: mm [in.]

| | Inspection point | | | Normal value | Standard | Limit | Remark |
|---|---|---|---|---|---|---|---|
| Oil pump | Base tangent length of drive and driven gears | | | | 27.983 to 28.055 [1.1017 to 1.1045] | 27.93 [1.0996] | |
| | Clearance between drive and driven gear tips and case | | | | 0.095 to 0.140 [0.0037 to 0.0055] | 0.190 [0.0075] | |
| | Side clearance between drive and driven gears widths and oil pump case | | | 97 [3.82] | 0.095 to 0.155 [0.0037 to 0.0061] | 0.290 [0.0114] | |
| | Gear shaft diameter | | | ø 40 [1.57] | 39.984 to 40.000 [1.5742 to 1.5748] | 39.930 [1.5720] | |
| | Gear bushing inside diameter | | | | 40.040 to 40.059 [1.5764 to 1.5771] | 40.140 [1.5803] | |
| | Oil pump drive gear and crankshaft gear backlash | | | | 0.11 to 0.28 [0.0043 to 0.0110] | 0.50 [0.0197] | Replace gears. |
| | Safety valve | Valve opening pressure | | | 1.4 ± 0.1 MPa {14 ± 1 kgf/cm²} [199 ± 14psi] | | Change in oil pressure is 0.04 MPa {0.4 kgf/cm²} [5.7 psi] with 2 mm [0.08 in.] shim. |
| | | Spring | Set length | 73.4 [2.890] | | | |
| | | | Set load | 971 N {99.0 kgf} [218 lbf] | 902 to 1040 N {92 to 106 kgf} [203 to 234 lbf] | 834 N {85 kgf} [187 lbf] | |
| Bypass valve | Valve opening pressure | | | | 0.44 ± 0.05 MPa {4.5 ± 0.5 kgf/cm²} [64 ± 7.1 psi] | | |
| Relief valve | Valve opening pressure | | | | 0.58 ± 0.05 MPa {5.9 ± 0.5 kgf/cm²} [84 ± 7 psi] | | |
| Oil filter alarm | Valve opening pressure (differential pressure) | | | | $0.14\ ^{+0.03}_{0}$ MPa $\{1.5\ ^{+0.3}_{0}$ kgf/cm²$\}$ $[21.34\ ^{+4.27}_{0}$ psi] | | |
| Piston cooling nozzle (oil jet) | Valve opening pressure | | | | 0.29 ± 0.03 MPa {3 ± 0.3 kgf/cm²} [43 ± 4.3 psi] | | |

## 1.6 Cooling system

*Table 2-6 Maintenance service data table - Cooling system (1 / 2)* *Unit: mm [in.]*

| Inspection point | | | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|---|---|
| Water pump | Case bearing bore diameter | | | ø 120 [4.72] | 119.987 to 120.022 [4.7239 to 4.7253] | | |
| | Cover bearing bore diameter | | | ø 110 [4.33] | 110.005 to 110.040 [4.3309 to 4.3323] | | |
| | Bearing | Small | Inside diameter | ø 50 [1.97] | 49.988 to 50.000 [1.9680 to 1.9685] | | |
| | | | Outside diameter | ø 110 [4.33] | 109.985 to 110.000 [4.3301 to 4.3307] | | |
| | | Large | Inside diameter | ø 55 [2.17] | 54.985 to 55.000 [2.1648 to 2.1654] | | |
| | | | Outside diameter | ø 120 [4.72] | 119.985 to 120.000 [4.7238 to 4.7244] | | |
| | Shaft bearing journal diameter | | | ø 55 [2.17] | 55.011 to 55.024 [2.1658 to 2.1663] | | |
| | | | | ø 50 [1.97] | 50.011 to 50.024 [1.9689 to 1.9694] | | |
| | Valve front face clearance | | | 1.04 [0.0409] | 0.58 to 1.50 [0.0228 to 0.0591] | | |
| 2-way water pump | Inside diameter of bearing fitting bore in case | | | ø 62 [2.44] | 61.988 to 62.018 [2.4405 to 2.4420] | | |
| | Case bearing bore diameter | | | ø 68 [2.68] | 67.961 to 67.991 [2.6756 to 2.6768] | | |
| | Bearing | | Inside diameter | ø 28 [1.10] | 27.990 to 28.000 [1.1020 to 1.1024] | | |
| | | | Outside diameter | ø 68 [2.68] | 67.987 to 68.000 [2.6766 to 2.6772] | | |
| | Shaft bearing journal diameter | | | ø 28 [1.10] | 28.002 to 28.015 [1.1024 to 1.1030] | | |
| | Vane front face clearance | | | 0.8 [0.031] | 0.5 to 1.1 [0.020 to 0.043] | | |
| Thermostat | Temperature at which valve starts opening | | Primary | | 71 ± 2°C [160 ± 3.6°F] | | Check at atmospheric pressure |
| | | | Secondary | | 74 ± 2°C [165 ± 3.6°F] | | |
| | Temperature at which valve lift is 10 mm [0.39 in.] or more | | | | 85°C [185°F] | | |

Table 2-6 Maintenance service data table - Cooling system (2 / 2) Unit: mm [in.]

| Inspection point | | | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|---|---|
| Fan drive | Bearing bore diameter | | | ø 110 [4.33] | 109.987 to 110.022 [4.3301 to 4.3316] | | |
| | | | | ø 120 [4.72] | 119.987 to 120.022 [4.7239 to 4.7253] | | |
| | Bearing | Small | Inside diameter | ø 50 [1.97] | 49.988 to 50.000 [1.9680 to 1.9685] | | |
| | | | Outside diameter | ø 110 [4.33] | 109.985 to 110.000 [4.3301 to 4.3307] | | |
| | | Large | Inside diameter | ø 45 [1.77] | 44.988 to 45.000 [1.7712 to 1.7720] | | |
| | | | Outside diameter | ø 120 [4.72] | 119.985 to 120.000 [4.7238 to 4.7244] | | |
| | Shaft bearing journal diameter | | | ø 50 [1.97] | 50.002 to 50.013 [1.9686 to 1.9690] | | |
| | | | | ø 45 [1.77] | 45.002 to 45.013 [1.7717 to 1.7722] | | |

## 1.7 *Electrical system*

Table 2-7 Maintenance service data table - Electrical system

Unit: mm [in.]

| Inspection point | | | Nominal | Standard | Limit | Remark |
|---|---|---|---|---|---|---|
| Starter | Commutator | Diameter | ø 43<br>[1.69] | | ø 42<br>[1.65] | |
| | | Runout | | 0.06<br>[0.0024] less or | 0.10<br>[0.0039] | |
| | | Mica depth | | 0.7 to 0.9<br>[0.028 to 0.035] | 0.2<br>[0.008]<br>*(Repair limit)* | |
| | Height of brush | | | 22<br>[0.87] | 13<br>[0.51] | |
| | Tension of brush springs | | 44.13 N<br>{4.5 kgf}<br>[10 lbf] | 39.23 to 49.03 N<br>{4.0 to 5.0 kgf}<br>[8.8 to 11 lbf] | 39.23 N<br>{4.0 kgf}<br>[8.8 lbf] | |
| | Armature | Diameter of shaft front side | ø 20<br>[0.79] | 20.002 to 20.011<br>[0.7815 to 0.7878] | | Replace armature. |
| | | Diameter of shaft rear side | ø 10<br>[0.39] | 10.001to 10.007<br>[0.3937 to 0.3940] | | |
| | | Shaft runout | | 0.10<br>[0.0039] | | |
| | Pinion shaft | Shaft diameter on rear side | ø 30<br>[1.18] | 30.002 to 30.011<br>[1.1812 to 1.1815] | | |
| | | Clearance between shaft diameter and metal inside metal on front side | ø 19<br>[0.75] | 0.045 to 0.138<br>[0.0018 to 0.0054] | 0.25<br>[0.0098] | |
| | Armature end play | | | 0.2 to 0.6<br>[0.008 to 0.024] | | |
| | Measurement of pinion shaft end play | | | 0.2 to 0.6<br>[0.0080 to 0.024] | | |
| Alternator | Slip ring outside diameter | | ø 33<br>[1.30] | 32.8 to 33.2<br>[1.291 to 1.307] | 32.4<br>[1.276] | |
| | Brush height | | 21.5<br>[0.846] | | 8.0<br>[0.315] | Wear limit line indicated on brush. |
| | Brush spring tension | | 3.7 N<br>{0.38 kgf}<br>[0.84 lbf] | 3.1 to 4.3 N<br>{0.32 to 0.44 kgf}<br>[0.7 to 1.0 lbf] | 1.8 N<br>{0.18 kgf}<br>[0.4 lbf] | |
| Alternator belt | Tension | New belt | | 1373 ± 10 N<br>{140 ± 1.0 kgf}<br>[309 ± 2 lbf] | | |
| | | Retightening | | 961 ± 5 N<br>{98 ± 0.5 kgf}<br>[216 ± 1 lbf] | | |

# 2. Tightening torque table

## 2.1 Major bolt tightening torque

### 2.1.1 Basic engine

Table 2-8 Tightening torque list - Basic engine

| Description | Threads Dia × Pitch (mm) | Torque N·m | Torque kgf·m | Torque lbf·ft | Remark |
|---|---|---|---|---|---|
| Cylinder head | M22 × 2.5 | 539 ± 27.5 | 55 ± 2.8 | 398 ± 20.3 | [Wet] 2-step tightening method (Note a) |
| Rocker case | M12 × 1.25 | 108 ± 5.4 | 11 ± 0.55 | 80 ± 4.0 | |
| | M10 × 1.25 | 59 ± 2.9 | 6 ± 0.3 | 43 ± 2.2 | |
| Rocker shaft | M16 × 2 | 167 ± 8.3 | 17 ± 0.85 | 123 ± 6.1 | |
| Rocker arm (lock nut) | M12 × 1.25 | 64 ± 3.2 | 6.5 ± 0.33 | 47 ± 2.4 | |
| Bridge (lock nut) | M10 × 1.25 | 55 ± 2.7 | 5.6 ± 0.28 | 41 ± 2.0 | |
| Camshaft gear | M14 × 1.5 | 177 ± 8.8 | 18 ± 0.9 | 130 ± 6.5 | |
| Camshaft thrust plate | M12 × 1.25 | 108 ± 5.4 | 11 ± 0.55 | 80 ± 4.0 | |
| Camfollower shaft | M12 × 1.25 | 88 ± 4.4 | 9 ± 0.45 | 65 ± 33 | |
| Adapter (for fan drive) | M12 × 1.25 | 78 ± 3.9 | 8 ± 0.4 | 58 ± 2.9 | |
| Main bearing cap | M22 × 2.5 | 490 ± 24.5 | 50 ± 2.5 | 362 ± 18.1 | [Wet] (Note b) |
| Main bearing cap (side bolt) | M16 × 1.5 | 147 ± 7.4 | 15 ± 0.75 | 108 ± 5.4 | |
| Rear hanger | M16 × 1.5 | 255 ± 25.5 | 26 ± 2.6 | 188 ± 18.8 | |
| Piston cooling nozzle (oil jet) | M12 × 1.75 | 34 ± 1.8 | 3.5 ± 0.18 | 25 ± 1.3 | (Note c) |
| Timing gear case | M12 × 1.25 | 98 ± 4.9 | 10 ± 0.5 | 72 ± 3.6 | Tighten the crankcase |
| | M12 × 1.25 | 69 ± 3.4 | 7 ± 0.35 | 51 ± 2.5 | Tighten the rear plate and nuts. |
| | M16 × 1.5 | 255 ± 12.7 | 26 ± 1.3 | 188 ± 9.4 | |
| Rear plate | M12 × 1.25 | 108 ± 5.4 | 11 ± 0.55 | 80 ± 4.0 | |
| Oil pan | M10 × 1.25 | 39 ± 3.9 | 4 ± 0.4 | 29 ± 2.9 | |
| Front mounting bracket | M20 × 1.5 | 392 ± 39.2 | 40 ± 4.0 | 289 ± 28.9 | |
| Rear mounting bracket | M18 × 2.5 | 294 ± 29.4 | 30 ± 3.0 | 217 ± 21.7 | |
| Connecting rod bearing cap | M18 × 1.5 | 343 ± 17.7 | 35 ± 1.8 | 253 ± 13.0 | [Wet] 2-step tightening method (Note d) |
| Balance weight | M16 × 1.5 | 196 ± 9.8 | 20 ± 1.0 | 145 ± 7.2 | [Wet] |
| Flywheel | M22 × 1.5 | 588 ± 29.4 | 60 ± 3.0 | 434 ± 21.7 | [Wet] |
| Damper and crankshaft pulley | M22 × 1.5 | 490 ± 24.5 | 50 ± 2.5 | 362 ± 18.1 | |
| Rear idler shaft | M12 × 1.25 | 108 ± 5.4 | 11 ± 0.55 | 80 ± 4.0 | |
| Rear idler shaft thrust plate | M10 × 1.25 | 29 ± 1.45 | 3 ± 0.15 | 22 ± 1.1 | |
| Feed pump drive case | M12 × 1.25 | 108 ± 5.4 | 11 ± 0.55 | 80 ± 4.0 | |
| Feed pump oil seal case | M10 × 1.25 | 60 ± 3.0 | 6.1 ± 0.31 | 44 ± 2.2 | |
| Front gear case | M12 × 1.25 | 98 ± 9.8 | 10 ± 1.0 | 72 ± 7.2 | Tighten the crankcase |
| | M12 × 1.25 | 69 ± 6.9 | 7 ± 0.7 | 51 ± 5.1 | Tighten the front plate and nuts. |
| | M16 × 1.5 | 255 ± 25.5 | 26 ± 2.6 | 188 ± 18.8 | |
| Front plate | M12 × 1.25 | 108 ± 10.8 | 11 ± 1.1 | 80 ± 8.0 | |
| Front idler shaft | M12 × 1.25 | 108 ± 5.4 | 11 ± 0.55 | 80 ± 4.0 | |
| Front idler shaft thrust plate | M16 × 1.5 | 216 ± 10.8 | 22 ± 1.1 | 159 ± 8.0 | |
| UI gland stud | M16 × 2.0 | 127 ± 6.4 | 13 ± 0.65 | 94 ± 4.7 | Apply Loctite 271 |
| Bridge guide | M10 × 1.25 | 39 ± 2.0 | 4 ± 0.2 | 29 ± 1.4 | |
| SUS tube | M24 × 1.5 | 127 ± 6.4 | 13 ± 0.65 | 94 ± 4.7 | Apply Three Bond 1207C |

Note: (a) To tighten cylinder head bolts according to the angle method, follow the sequence described below.
1.Tighten to snug torque of 294 ± 14.7 N·m {30 ± 1.5 kgf·m} [217 ± 10.8 lbf·ft].
2.Tighten by turning 35 ± 1.5°.
3.Tighten by further turning 30 ± 1.5°. (total of 65 ± 3° turn)
4.Loosen all bolts, and tighten again according to the angle method. (2-step tightening method)
(b) To tighten main bearing cap bolts and main bearing cap side bolts, observe the specified sequence.
1.Tighten the main bearing cap bolts to the specified torque.
2.Tighten the side bolts on the right side of the engine to the specified torque.
3.Tighten the side bolts on the left side of the engine to the specified torque.
(c) To tighten piston cooling nozzles to the specified torque, be sure to use a torque wrench. Tightening without the use of a torque wrench can result in excessive tightening force, and this can cause check valve malfunctions and lead to seizing of pistons due to insufficient supply of lubricating oil during engine operation.
(d) To tighten connecting rod cap bolts according to the angle method, follow the sequence described below.
1.Tighten to snug torque of 147 ± 7.4 N·m {15 ± 0.75 kgf·m} [108 ± 5.4 lbf·ft].
2.Tighten by turning 45 ± 3°.
3.Loosen all bolts, and tighten again according to the angle method. (2-step tightening method)
(e) When [Wet] is indicated, apply engine oil to the threads and bearing surfaces of the bolts and nuts.

### 2.1.2 Inlet and exhaust system

Table 2-9 Tightening torque list - Inlet and exhaust system

| Description | Threads Dia × Pitch (mm) | Torque N·m | Torque kgf·m | Torque lbf·ft | Remark |
|---|---|---|---|---|---|
| Exhaust manifold | M10 × 1.5 | 49 ± 4.9 | 5.5 ± 0.5 | 36 ± 3.6 | |
| Turbocharger compressor wheel (nut) | M11 × 1.0 | - | - | - | Note left-handedthread |
| Compressor cover | M8 × 1.25 | 20 ± 2.0 | 2.0 ± 0.2 | 14 ± 1.4 | |
| Turbine housing | M10 × 1.5 | 24 ± 1.0 | 2.4 ± 0.1 | 17 ± 0.7 | |

Note: Tighten nut 9.8 N·m {1.0kgf·m} [7.2 lbf·ft] and loosen it. Retighten to 9.8 N·m {1.0kgf·m} [7.2 lbf·ft], and turn to the angle 80 ± 3°.

### 2.1.3 Fuel system

**( for ECUI torque information, refer to manual.)**

Table 2-10 Tightening torque list - Fuel system

| Description | Threads Dia × Pitch (mm) | Torque N·m | Torque kgf·m | Torque lbf·ft | Remark |
|---|---|---|---|---|---|
| EC unit injector gland (nut) | M16 × 1.5 | - | - | - | [Wet] Note |
| Fuel pipe (eye bolt) | M10 × 1.25 | 15 ± 1.5 | 1.5 ± 0.15 | 11 ± 1.1 | |
| Priming pump and fuel filter (eye bolt) | M14 × 1.5 | 22 ± 2.5 | 2.25 ± 0.25 | 16 ± 1.8 | |
| H/P IN fuel pump and F/O connector (eye bolt) | M16 × 1.5 | 34 ± 3.4 | 3.5 ± 0.35 | 25 ± 2.5 | |
| Feed pump (eye bolt) | M20 × 1.5 | 59 ± 5.9 | 6.0 ± 0.6 | 43 ± 4.3 | |
| Fuel filter air vent plug | M8 × 1.25 | 9 ± 1.0 | 0.9 ± 0.1 | 7 ± 0.7 | |
| Feed pump | M8 × 1.25 | 21 ± 1.0 | 2.1 ± 0.1 | 15 ± 0.7 | |
| Check valve jam nut | M12 × 1.25 | 56 ± 5.9 | 5.7 ± 0.6 | 41 ± 4.3 | |

Note: Tighten nut 177 ± 8.8 N·m {18 ± 0.9 kgf·m} [130 ± 6.5 lbf·ft] and loosen it. Retighten to 127 ± 6.9 N·m {13 ± 0.7 kgf·m} [94 ± 5.1 lbf·ft].

### 2.1.4 Lubrication system

Table 2-11 Tightening torque list - Lubrication system

| Description | Threads Dia × Pitch (mm) | Torque N·m | Torque kgf·m | Torque lbf·ft | Remark |
|---|---|---|---|---|---|
| Oil pump | M10 × 1.25 | 59 ± 5.9 | 6 ± 0.6 | 43 ± 4.3 | |
| Safety valve plug | M40 × 2.0 | 196 ± 19.6 | 20 ± 2.0 | 145 ± 14.5 | |
| Oil pump cover | M10 × 1.25 | 54 ± 19.6 | 5.5 ± 2.0 | 40 ± 14.5 | |
| Oil cooler pipe | M10 × 1.5 | 39 ± 4.9 | 4.0 ± 0.5 | 29 ± 3.6 | |
| Oil cooler element (nut) | M10 × 1.25 | 25 ± 4.9 | 2.5 ± 0.5 | 18 ± 3.6 | |
| Turbocharger oil pipe | M10 × 1.5 | 58 ± 2.9 | 5.9 ± 0.3 | 43 ± 2.2 | |
| Turbocharger drain pipe | M10 × 1.5 | 58 ± 2.9 | 5.9 ± 0.3 | 43 ± 2.2 | |

### 2.1.5 Cooling system

Table 2-12 Tightening torque list - Cooling system

| Description | Threads Dia × Pitch (mm) | Torque N·m | Torque kgf·m | Torque lbf·ft | Remark |
|---|---|---|---|---|---|
| Water pump (nut) | M12 × 1.25 | 108 ± 10.8 | 11 ± 1.1 | 80 ± 8.0 | |
| Water pump pulley (nut) | M30 × 1.5 | 392 ± 19.0 | 40 ± 2.0 | 289 ± 14 | |
| 2-way water pump pulley (nut) | M20 × 1.5 | 113 ± 4.9 | 11.5 ± 0.5 | 83 ± 3.6 | |
| Fan bolt | M12 × 1.25 | 33 ± 2.0 | 3.4 ± 0.2 | 25 ± 1.4 | |

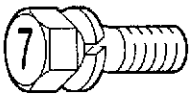
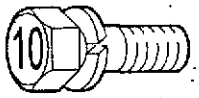
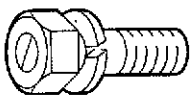
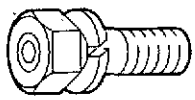
### 2.1.6 Electrical system

Table 2-13 Tightening torque list - Electrical system

| Description | Threads Dia × Pitch (mm) | Torque N·m | Torque kgf·m | Torque lbf·ft | Remark |
|---|---|---|---|---|---|
| Starter (nut) | M12 × 1.25 | 59 ± 5.9 | 6 ± 0.6 | 43 ± 4.3 | |
| Starter B terminal | M10 × 1.25 | 18 ± 2.0 | 1.8 ± 0.2 | 13 ± 1.4 | |
| Alternator pulley (nut) | M20 × 1.5 | 147 ± 14.7 | 15 ± 1.5 | 108 ± 10.8 | |

## 2.2 Standard bolt and nut tightening torque

Table 2-14 Standard bolt and nut tightening torque

| Description | Threads Dia × Pitch (mm) | Width across flats (mm) [in.] | Strength classification | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 7T | | | 10.9 | | |
| | | |  | | |  | | |
| | | | N·m | kgf·m | lbf·ft | N·m | kgf·m | lbf·ft |
| Metric automobile screw thread | M8 × 1.25 | 12 [0.47] | 17 | 1.7 | 13 | 30 | 3.1 | 22 |
| | M10 × 1.25 | 14 [0.55] | 33 | 3.4 | 24 | 60 | 6.1 | 44 |
| | M12 × 1.25 | 17 [0.67] | 60 | 6.1 | 44 | 108 | 11.0 | 80 |
| | M14 × 1.5 | 22 [0.87] | 97 | 9.9 | 72 | 176 | 17.9 | 130 |
| | M16 × 1.5 | 24 [0.94] | 145 | 14.8 | 107 | 262 | 26.7 | 193 |
| | M18 × 1.5 | 27 [1.06] | 210 | 21.4 | 155 | 378 | 38.5 | 279 |
| | M20 × 1.5 | 30 [1.18] | 291 | 29.7 | 215 | 524 | 53.4 | 386 |
| | M22 × 1.5 | 32 [1.26] | 385 | 39.3 | 284 | 694 | 70.8 | 512 |
| | M24 × 1.5 | 36 [1.42] | 487 | 49.7 | 359 | 878 | 89.5 | 648 |
| | M27 × 1.5 | 41 [1.61] | 738 | 75.3 | 544 | 1328 | 135.5 | 979 |
| | | |  | | |  | | |
| | | | N·m | kgf·m | lbf·ft | N·m | kgf·m | lbf·ft |
| Metric course screw thread | M10 × 1.5 | 14 [0.55] | 32 | 3.3 | 24 | 58 | 5.9 | 43 |
| | M12 × 1.75 | 17 [0.67] | 57 | 5.8 | 42 | 102 | 10.4 | 75 |
| | M14 × 2 | 22 [0.87] | 93 | 9.5 | 69 | 167 | 17.0 | 123 |
| | M16 × 2 | 24 [0.94] | 139 | 14.2 | 103 | 251 | 25.6 | 185 |
| | M18 × 2.5 | 27 [1.06] | 194 | 19.8 | 143 | 350 | 35.7 | 258 |
| | M20 × 2.5 | 30 [1.18] | 272 | 27.7 | 201 | 489 | 49.9 | 361 |
| | M22 × 2.5 | 32 [1.26] | 363 | 37.0 | 268 | 653 | 66.6 | 482 |
| | M24 × 3 | 36 [1.42] | 468 | 47.7 | 345 | 843 | 86.0 | 622 |
| | M27 × 3 | 41 [1.61] | 686 | 70.0 | 506 | 1236 | 126.0 | 912 |

Note: (a) This table lists the tightening torque for standard bolts and nuts.

(b) The numerical values in the table are for fasteners with spring washers.

(c) The table shows the standard values with a maximum tolerance value of ±10%.

(d) Use the tightening torque in this table unless otherwise specified.

(e) Do not apply oil to threaded portions. (Dry)

## 2.3 Standard eyebolt tightening torque

Table 2-15 Standard eyebolt tightening torque

| Threads Dia × Pitch (mm) | Width across flats (mm) [in.] | Strength classification 4T | | |
|---|---|---|---|---|
| | | N·m | kgf·m | lbf·ft |
| M8 × 1.25 | 12 [0.47] | 8 ± 1 | 0.8 ± 0.1 | 6 ± 0.7 |
| M10 × 1.25 | 14 [0.55] | 15 ± 2 | 1.5 ± 0.2 | 11 ± 1.5 |
| M12 × 1.25 | 17 [0.67] | 25 ± 3 | 2.5 ± 0.3 | 18 ± 2.2 |
| M14 × 1.5 | 19 [0.75] | 34 ± 4 | 3.5 ± 0.4 | 25 ± 3.0 |
| M16 × 1.5 | 22 [0.87] | 44 ± 5 | 4.5 ± 0.5 | 32 ± 3.7 |
| M18 × 1.5 | 24 [0.94] | 74 ± 5 | 7.5 ± 0.5 | 55 ± 3.7 |
| M20 × 1.5 | 27 [1.06] | 98 ± 10 | 10.0 ± 1.0 | 72 ± 7.4 |
| M24 × 1.5 | 32 [1.26] | 147 ± 15 | 15.0 ± 1.5 | 108 ± 11.1 |
| M27 × 1.5 | 41 [1.61] | 226 ± 20 | 23.0 ± 2.0 | 167 ± 14.8 |

(Dry)

## 2.4 Standard union nut tightening torque

Table 2-16 Standard union nut tightening torque

| Nominal diameter | Cap nut size M (mm) | Width across flats (mm) [in.] | N·m | kgf·m | lbf·ft |
|---|---|---|---|---|---|
| 63 | M14 × 1.5 | 19 [0.75] | 39 | 4 | 29 |
| 80 | M16 × 1.5 | 22 [0.87] | 49 | 5 | 36 |
| 100 | M20 × 1.5 | 27 [1.06] | 78 | 8 | 58 |
| 120 | M22 × 1.5 | 30 [1.18] | 98 | 10 | 72 |
| 150 | M27 × 1.5 | 32 [1.26] | 157 | 16 | 116 |
| 180 | M30 × 1.5 | 36 [1.42] | 196 | 20 | 145 |
| 200 | M30 × 1.5 | 36 [1.42] | 196 | 20 | 145 |
| 220 | M33 × 1.5 | 41 [1.61] | 245 | 25 | 181 |
| 254 | M36 × 1.5 | 41 [1.61] | 294 | 30 | 217 |

(Maximum tolerance value: ±10%, dry condition)

## 2.5 High-pressure fuel injection pipe tightening torque

Table 2-17 High-pressure fuel injection pipe tightening torque

| Cap nut size (mm) | N·m | kgf·m | lbf·ft |
|---|---|---|---|
| M12 × 1.5 | 39 ± 5 | 4 ± 0.5 | 29 ± 3.6 |
| M14 × 1.5 | 49 ± 5 | 5 ± 0.5 | 36 ± 3.6 |
| M18 × 1.5 | 59 ± 1 | 6 ± 1.0 | 43 ± 7.2 |

(Dry)

# SERVICE TOOLS

## 1. Special tools

Table 3-1 Special tools list (1 / 6)

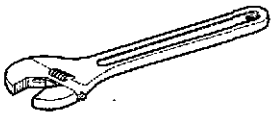
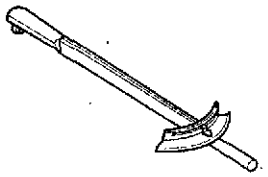
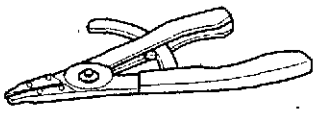
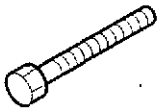
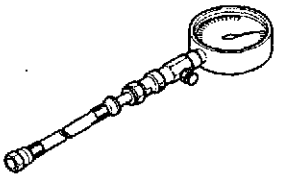
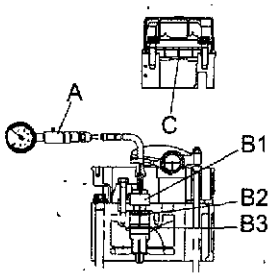
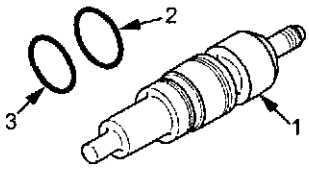
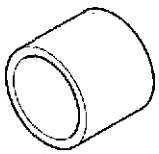
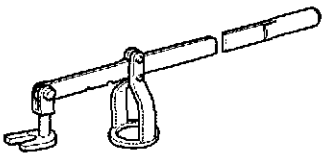
| Application | Tool name/Part No. | Shape | Use |
|---|---|---|---|
| General | Adjustable wrench<br>F9611-15000 |  | Max. open width:<br>20 mm {0.79 in.} |
| | Torque wrench<br>32191-03100 |  | Range applicable:<br>0 to 539 N·m<br>{0 to 55 kgf·m}<br>[0 to 398 lbf·ft] |
| | Ring pliers<br>45191-08400 |  | Snap ring<br>removal/installation |
| | Set bolt<br>64362-68500 |  | Flywheel removed<br>Jack bolt<br>M12 × 1.25 - 95 mm<br>[3.74 in.] |
| Inspection for overhaul need, and testing | Adapter assembly<br>35C91-12020 | Includes A through C | Compression pressure measurement |
| | A Compression gauge<br>35A91-03100 |  |  |
| | B<br>1. Gauge adapter<br>35C91-12200<br>2. O-ring<br>05507-10460<br>3. O-ring<br>05507-10420 |  | |
| | C Spacer<br>35C91-02100 |  | |
| Cylinder head and valve mechanism | Valve spring pusher<br>33591-04500 |  | Inlet/exhaust valve spring removal/installation Handle plate<br>Length: 600 mm [23.6 in.] |

Table 3-1 Special tools list (2 / 6)

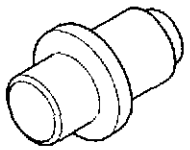
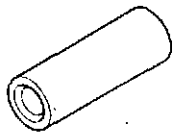
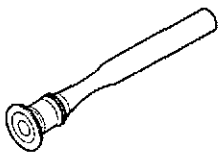
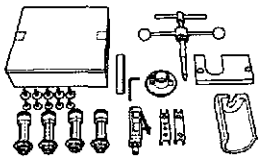
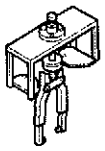
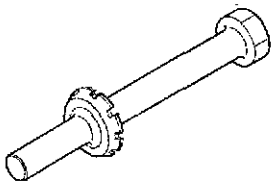
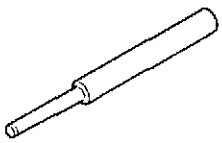
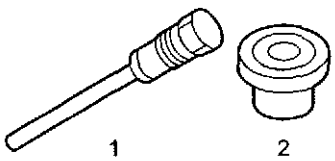
| Application | Tool name/Part No. | Shape | Use |
|---|---|---|---|
| Cylinder head and valve mechanism | Rocker bushing installer<br>35C91-01800 |  | Rocker bushing replacement |
| | Guide & seal installer<br>32591-10300 |  | Valve guide and stem seal installation |
| | Valve lapper<br>30091-08800 |  | Inlet/exhaust valve lapping |
| | Valve seat puller<br>32591-04200 |  | Valve seat removal |
| | Injector puller<br>35C91-11400 |  | EC unit injector removal |
| | SUS tube tool<br>35C91-00600 |  | EC unit injector SCS1 tube removal/installer |
| | Valve guide remover<br>33591-04300 |  | Valve guide removal |
| | 1. Valve seat cutter shaft<br>37591-06400<br>2. Valve seat cutter<br>37591-06430 |  | Valve seat correction |

Table 3-1 Special tools list (3 / 6)

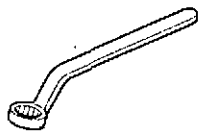
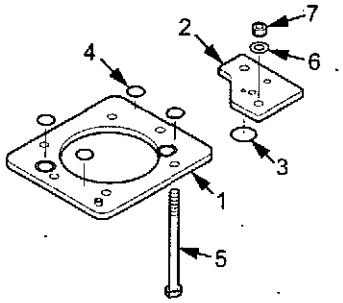
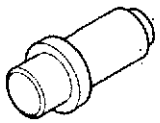
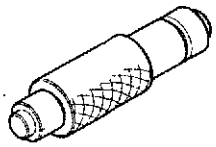
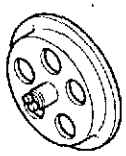
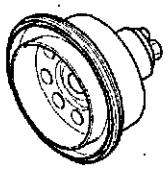
| Application | Tool name/Part No. | Shape | Use |
|---|---|---|---|
| Cylinder head and valve mechanism | Offset wrench<br>35C91-00500 |  | Valve clearance adjustment |
| | Leak tester assy.<br>35C91-03010<br>1. A plate<br>35C91-03100<br>2. B plate<br>35C91-03200<br>3. O-ring<br>F3153-04000<br>4. O-ring<br>F3153-02600<br>5. Bolt<br>35C91-03300<br>6. Plain washer<br>F2500-14000<br>7. Nut<br>F2300-14000 |  | Cylinder head water pressure testing |
| | Eye nut<br>37591-02400 |  | Cylinder head assembly removal/installation |
| | Follower bushing installer<br>35C91-01700 |  | Follower bushing removal/ installation |
| Front cover, flywheel and timing gear | Idler bushing puller<br>32591-02500 |  | Front and rear idler bushing removal/installation |
| | Rear seal installer assembly<br>35B91-06010 |  | Rear oil seal installation |
| | Front seal installer assembly<br>37591-05010 |  | Front oil seal installation |

Table 3-1 Special tools list (4 / 6)

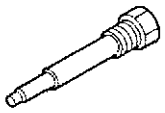
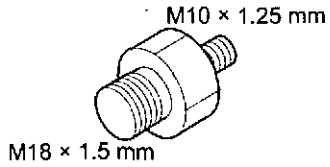
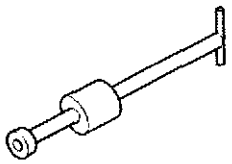
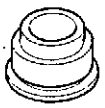
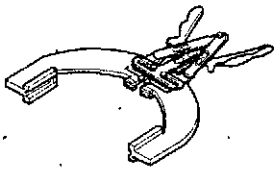
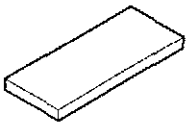
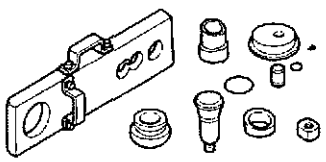
| Application | Tool name/Part No. | Shape | Use |
|---|---|---|---|
| Front cover, flywheel and timing gear | Cam gear stop bolt<br>35B91-06500 |  | Camshaft gear retaining |
| Crankcase | Cap remove adapter<br>32591-04300 |  | Main bearing cap removal |
| | *Nozzle remover*<br>33591-10101 |  | Main bearing cap removal |
| | *Cam bushing installer*<br>35C91-11600 |  | *Camshaft bushing removal/* installation |
| *Cylinder liner, piston* and connecting rod | *Ring expander*<br>37191-03200 |  | Piston ring removal/installa-*tion*<br>Range : ø 101.6 to 177.8 mm [4.000 to 7.000 in.] |
| | *Eye bolt*<br>MM321420 |  | *Piston removal/installation*<br>M10 × 1.5 mm |
| | *Projection plate*<br>37598-09201 |  | *Crankcase counterbore depth* measurement |
| | *Connecting rod bushing installer*<br>32591-18010 |  | *Connecting rod bushing* removal/installation |

Table 3-1 Special tools list (5 / 6)

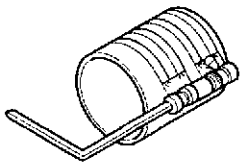
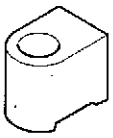
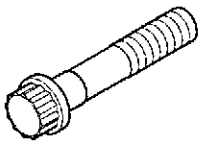
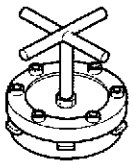
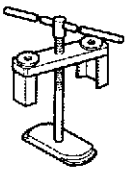
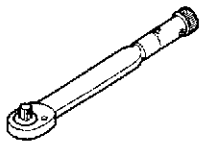
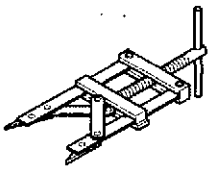
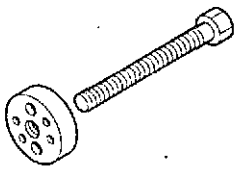
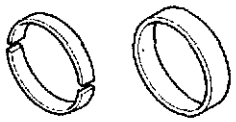
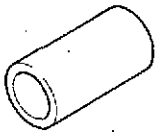
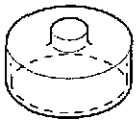
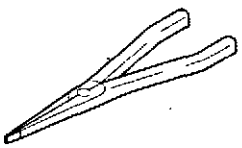
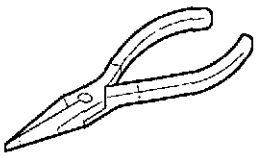
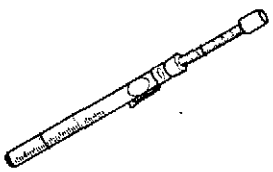
| Application | Tool name/Part No. | Shape | Use |
|---|---|---|---|
| Cylinder liner, piston and connecting rod | Piston installer<br>37191-07100 |  | Piston installation<br>Range : ø 88.9 to 177.8 mm<br>[3.500 to 7.000 in.] |
| | Liner pusher<br>37591-06200 |  | Cylinder liner collar protrusion measurement |
| | Bolt<br>37591-06300 |  | Cylinder liner collar protrusion measurement<br>M22 × 2.5 - 115 mm<br>[4.53 in.] |
| | Crankcase grinder<br>32591-04050 |  | Cylinder liner support ridge of crankcase adjustment |
| | Cylinder liner remover<br>32591-04100 |  | Cylinder liner removal |
| | Torque wrench<br>48493-00400 |  | ECUI terminal to harness tightening |
| | Connecting rod gauge<br>32691-01500 (01600) |  | Connecting rod end play measurement |
| Water pump | Water pump pliers<br>37591-03100 |  | Water pump cover snap ring removal |

Table 3-1 Special tools list (6 / 6)

| Application | Tool name/Part No. | Shape | Use |
|---|---|---|---|
| Water pump | Impeller remover<br>37591-03200 |  | Water pump impeller removal :<br>M18 × 1.5 mm |
| | Ring remover<br>37791-03400 |  | Water pump unit seal removal |
| | Ring installer<br>37791-03300 |  | Water pump unit seal installation |
| | Unit seal installer<br>37191-06300 |  | Water pump unit seal ring installation |
| Turbocharger | Plier<br>49160-90101 |  | Snap ring (49162-23200) installation/removal |
| | Plier<br>49160-90201 |  | Snap ring (49181-22300) installation/removal |
| V-belt | V-belt gauge<br>32591-09100 |  | Raw edge cog belt deflection measurement |
| EC unit injector | Height gauge<br>35C91-01900 |  | Plunger tappet height measurement |

Note: Refer to the service manual of the ECUI for the special tool servicing the ECUI.

# DETERMINATION OF OVERHAUL

## 1. Determining overhaul timing

**CAUTION**

When changing parts, be sure to our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

Work related to the exhaust emission regulations can be conducted only at our designated service factories.

In most cases, the engine should be overhauled when the compression pressure of the engine becomes low. An increase in engine oil consumption and blow-by gas are also considered to evaluate the engine condition. Besides, such symptoms as a decrease in output, increase in fuel consumption, decrease in oil pressure, difficulty of engine starting and increase in noise are also considered for judging the overhaul timing, although those symptoms are often affected by other causes, and are not always effective to judge the overhaul timing. Decreased compression pressure shows a variety of symptoms and engine conditions, 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 through the breather due to worn cylinder liners and piston rings (Visually check the blow-by amount)
(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 items (2) and (6) will result from improper fuel injection volume, fuel injection timing, worn plunger, faulty nozzles and also faulty conditions of electrical devices such as battery and starter. The most valid reason to overhaul an engine is a decrease in compression pressure due to worn cylinder liners and pistons, as described in item (4). In addition to this item, it is reasonable to take other problems into consideration for making the total judgement.

## 2. Testing compression pressure

**CAUTION**

(a) Be sure to measure the compression pressure for all the cylinders. It is not a good practice to measure the compression pressure for only one cylinder, and presume the compression pressure for the remaining cylinders.

(b) Also be sure to check engine speed when measuring the compression pressure, as compression pressure varies with engine speed.

(c) Measuring the compression pressure at regular intervals is important to obtain correct data.

(d) The compression pressure will be slightly higher in a new or overhauled engine due to new piston rings, valve seats, etc. Pressure will drop gradually by the wear of these parts.

(e) When measuring the compression pressure for cylinders one by one, do not remove other fuel injection nozzles, except for the one being measured, from their positions.

(1) Remove the unit injector from the cylinder head where the compression pressure is to be measured.

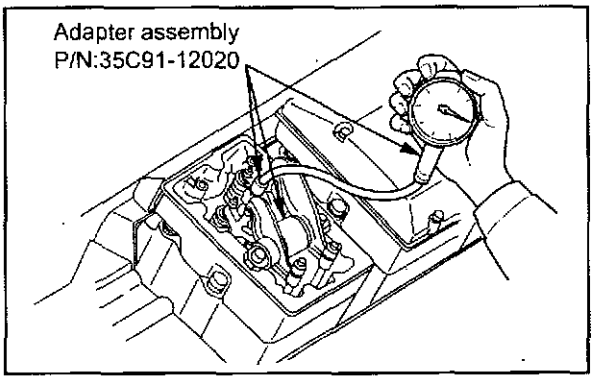
(2) Attach the adapter assembly to the injection nozzle mount and connect compression gauge.

(3) Crank the engine with the starter, then read the compression gauge indication while the engine is running at the specified speed.

(4) If the compression pressure is lower than the limit, overhaul the engine.

| Item | Standard | Limit |
|---|---|---|
| Compression pressure | 2.4 MPa {24.4 kgf/cm²} [347.1 psi] or more | 1.9 MPa {19.3 kgf/cm²} [274.5 psi] or more |

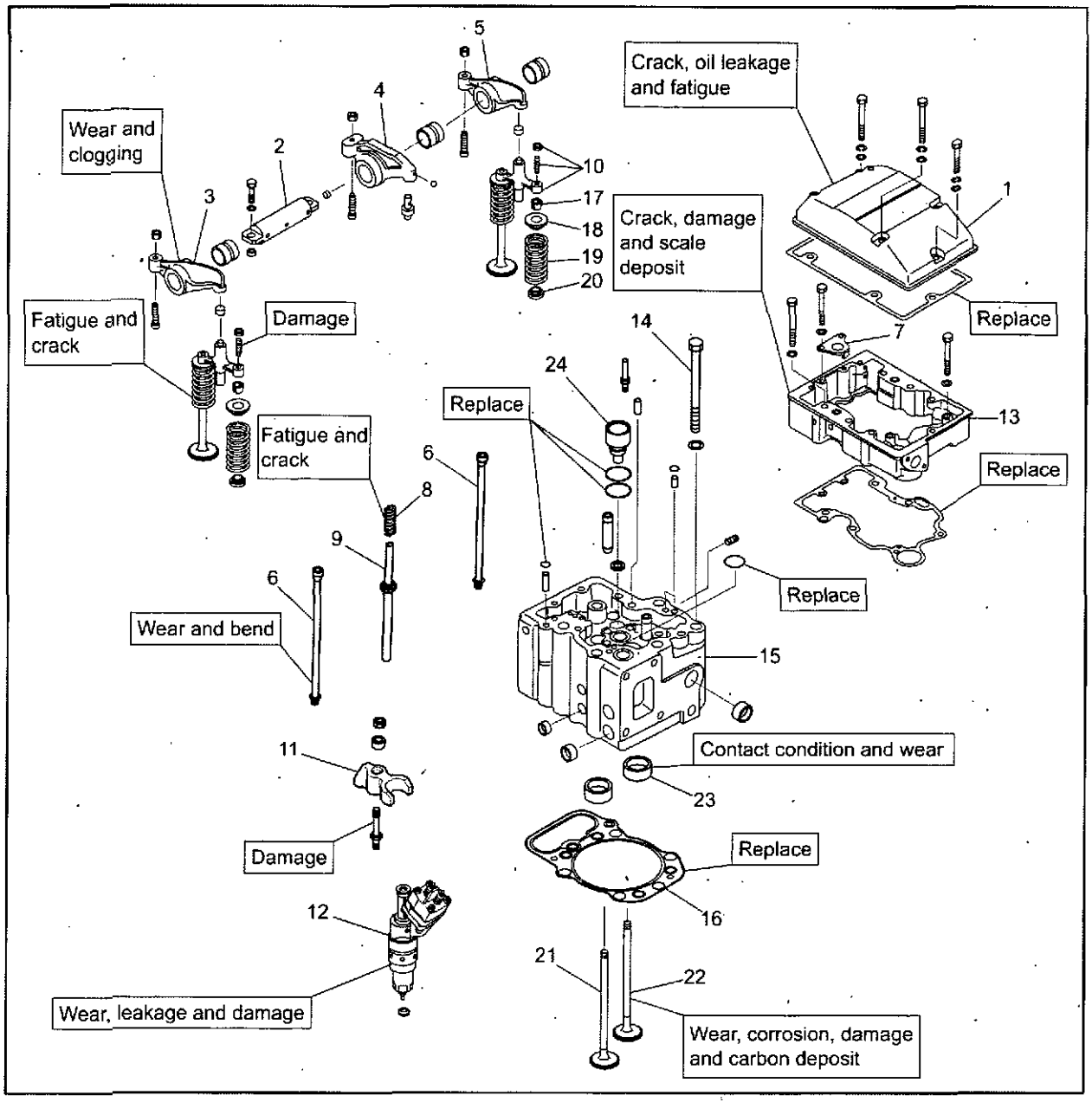
Note: Measure the compression pressure with the engine running at 120 $min^{-1}$.




Testing compression pressure

# DISASSEMBLY OF BASIC ENGINE

## 1. Disassembling and inspecting cylinder head and valve mechanism




Disassembling and inspecting cylinder head and valve mechanism

Disassembling sequence

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Rocker cover | 8 | Helper spring | 15 | Cylinder head (weight: approx. 33 kg [72.75 lb]) | 21 | EXH valve |
| 2 | Rocker shaft | 9 | UI helper push rod | | | 22 | IN valve |
| 3 | EXH rocker | 10 | Bridge, screw and nut | 16 | Cylinder head gasket | 23 | Valve seat |
| 4 | UI rocker | 11 | Gland | 17 | Cotter | 24 | SUS tube |
| 5 | IN rocker | 12 | EC unit injector | 18 | Rotor | | |
| 6 | IN & EXH push rod | 13 | Rocker case | 19 | Valve spring | | |
| 7 | Spring upper seat | 14 | Cylinder head bolt | 20 | Valve stem seal | | |

**CAUTION**

When changing parts, be sure to use our designated parts.

Unless our designated parts are used, the exhaust emission regulations cannot be met.

### 1.1 Removing harness

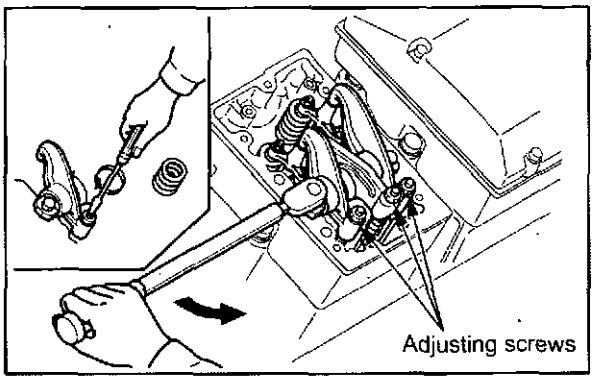
(1) Be sure to turn the ECUI off.

(2) Remove the two harnesses from the ECUI.

### 1.2 Removing rocker shaft assembly

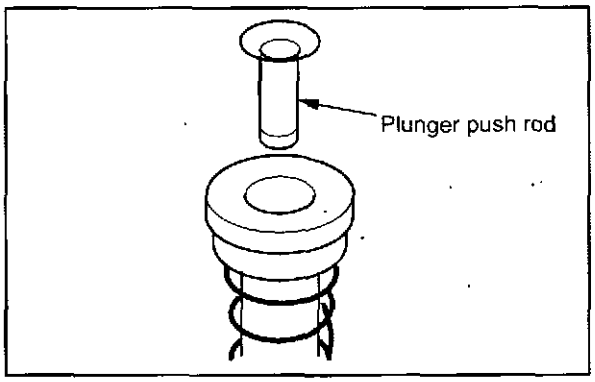
(1) Loosen the adjusting screw and make each rocker free.

(2) Remove each rokcer shaft assembly. Keep the rocker shaft assembly and mounting bolts together.




*Removing rocker shaft assembly*

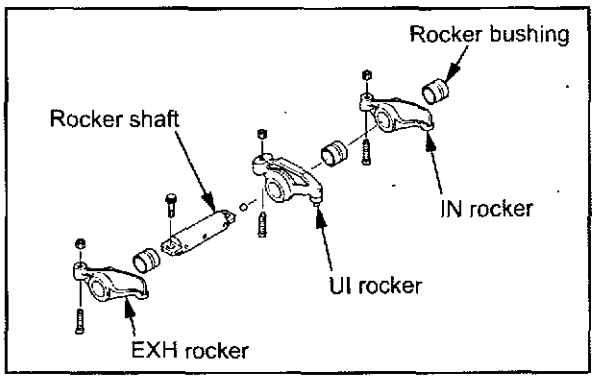
(3) Plunger push rod may be attached with ECUI rocker. In such a case, remove plunger push rod carefully before removing rocker shaft assembly.




Removing plunger push rod

### 1.3 Disassembling rocker shaft assembly

Be sure to arrange the parts of rocker shaft assembly in the order of disassembly. Reassemble the rocker shaft assembly in the reverse order of disassembly by making sure of the original combination of rocker arm and shaft assembly so that the same clearance between the rocker shaft and arms is restored when reassembling.




Disassembling rocker shaft assembly

### 1.4 Removing push rod

(1) Remove the IN & EXH push rod.

(2) Remove the spring upper seat.

(3) Remove the helper spring and UI helper push rod.

### 1.5 Removing valve bridge

Remove the valve bridge and bridge cap.

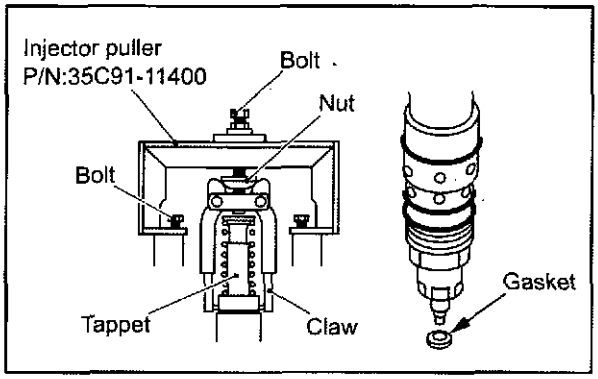
Note: Be careful not to drop bridge caps into the crankcase through the push rod holes.

### 1.6 Removing EC unit injector

**⚠ CAUTION**

Install the injector puller on the cylinder head before removing the gland nut. Removing the gland nut without the puller in place can cause the injector to eject abruptly.

(1) Install the unit injector puller on the cylinder head using bolts (rocker cover bolts or similar bolts). Put claws of the unit injector puller into holes on the unit injector. Turn nut by hand until the claws are securely inserted in the holes. Turn bolt to remove the injector.
(2) Remove the gland.
(3) Remove gasket from inside of the cylinder head using a wire or other tools.



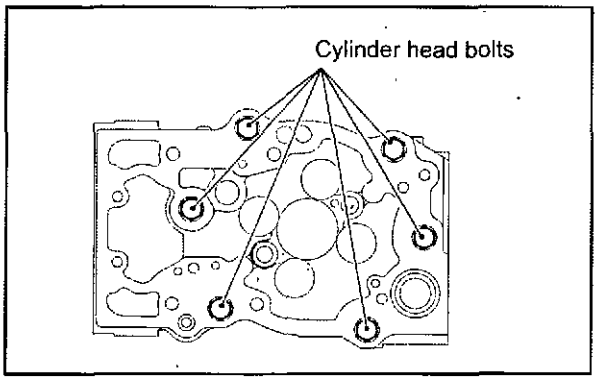

Removing EC unit injector

### 1.7 Removing rocker case

Unscrew the rocker cover mounting bolts, and dismount the rocker case.

### 1.8 Removing cylinder head bolt

Remove the cylinder head bolt.



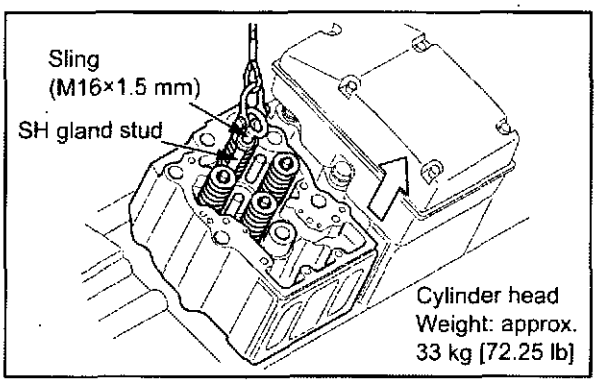

Removing cylinder head bolt

### 1.9 Removing cylinder head assembly

**CAUTION**

When removing the cylinder head gasket, be careful not to damage the cylinder head or crankcase surface with a screwdriver or other tools.

(1) Attach a sling to the SH gland stud of the cylinder head.
(2) Lift the cylinder head using eye bolt, as dowel pins are used to hold the cylinder heads in position.
(3) Remove the cylinder head gasket.

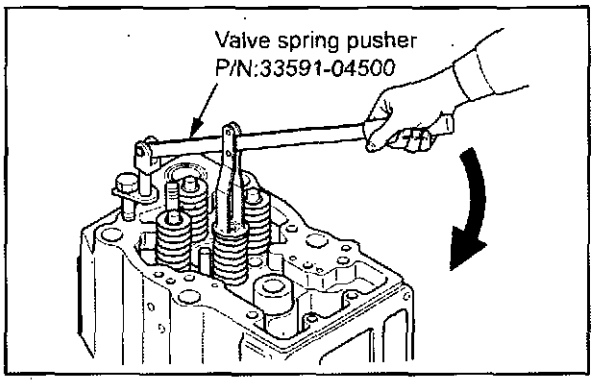



Removing cylinder head assembly

### 1.10 Removing valve and valve spring

Using a valve spring pusher, compress the valve spring evenly and remove the valve cotters.

Note: If valves are reusable, mark each valve seat and the mating valve guide for identifying their original positions. Do not mix valve seats with other valve guides.

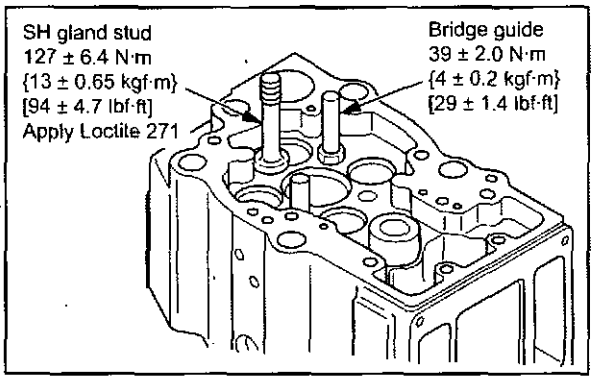



Removing valve and valve spring

### 1.11 Removing stud and guide

Do not remove the following parts from the cylinder head unless it is necessary. If any of these parts are removed, apply thread lock agent to the threads in the bolt holes, and install new parts.

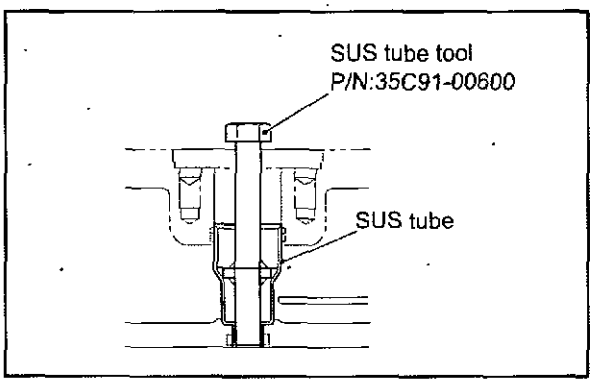
Note: Do not remove the bridge guide unless the valve guide is replaced.




Removing stud and guide

### 1.12 Removing SUS tube

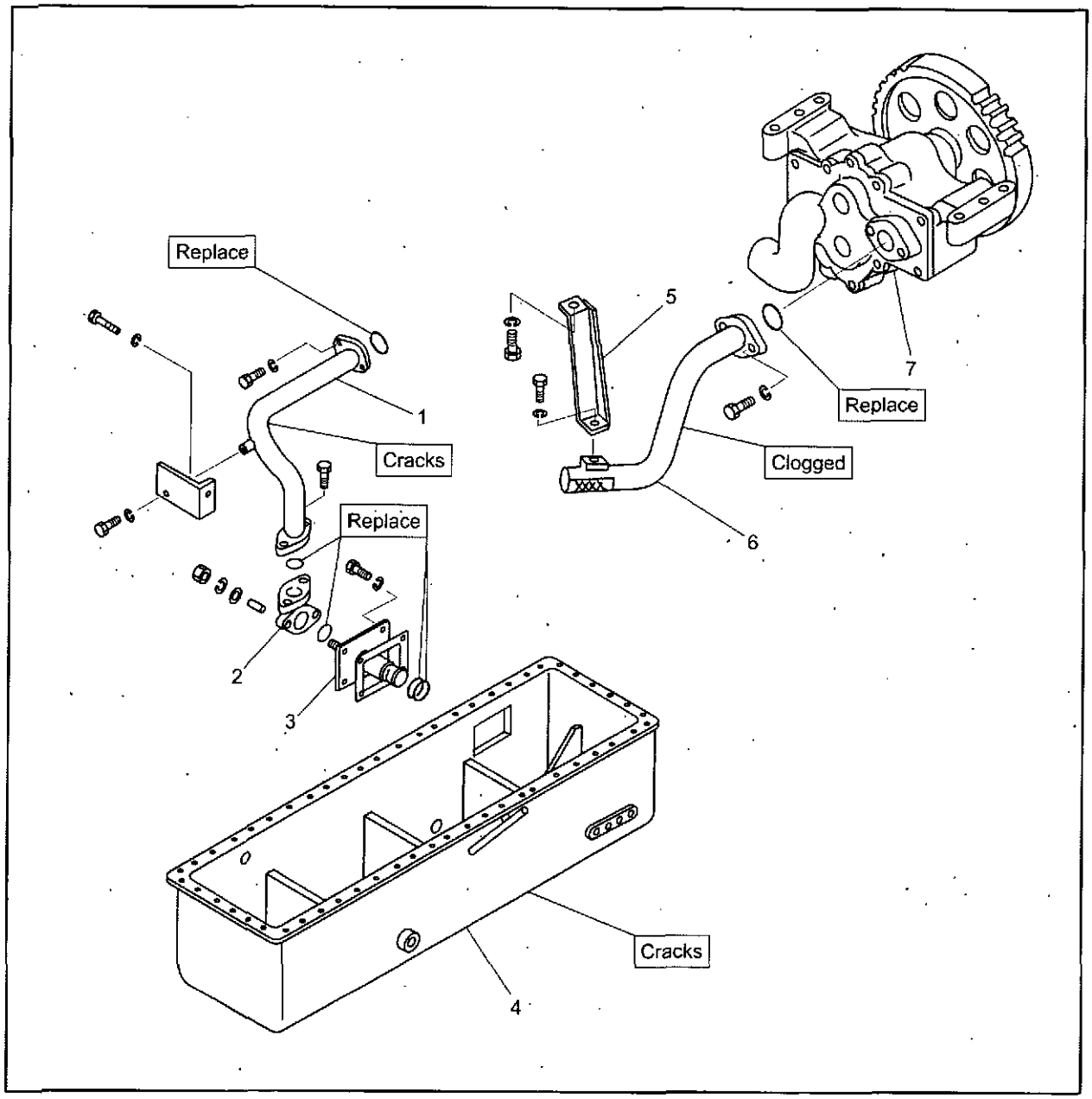
Using a SUS tube tool, remove the SUS tube.




Removing SUS tube

## 2. Disassembling and inspecting flywheel, timing gear and camshaft

Removing and inspecting oil pump

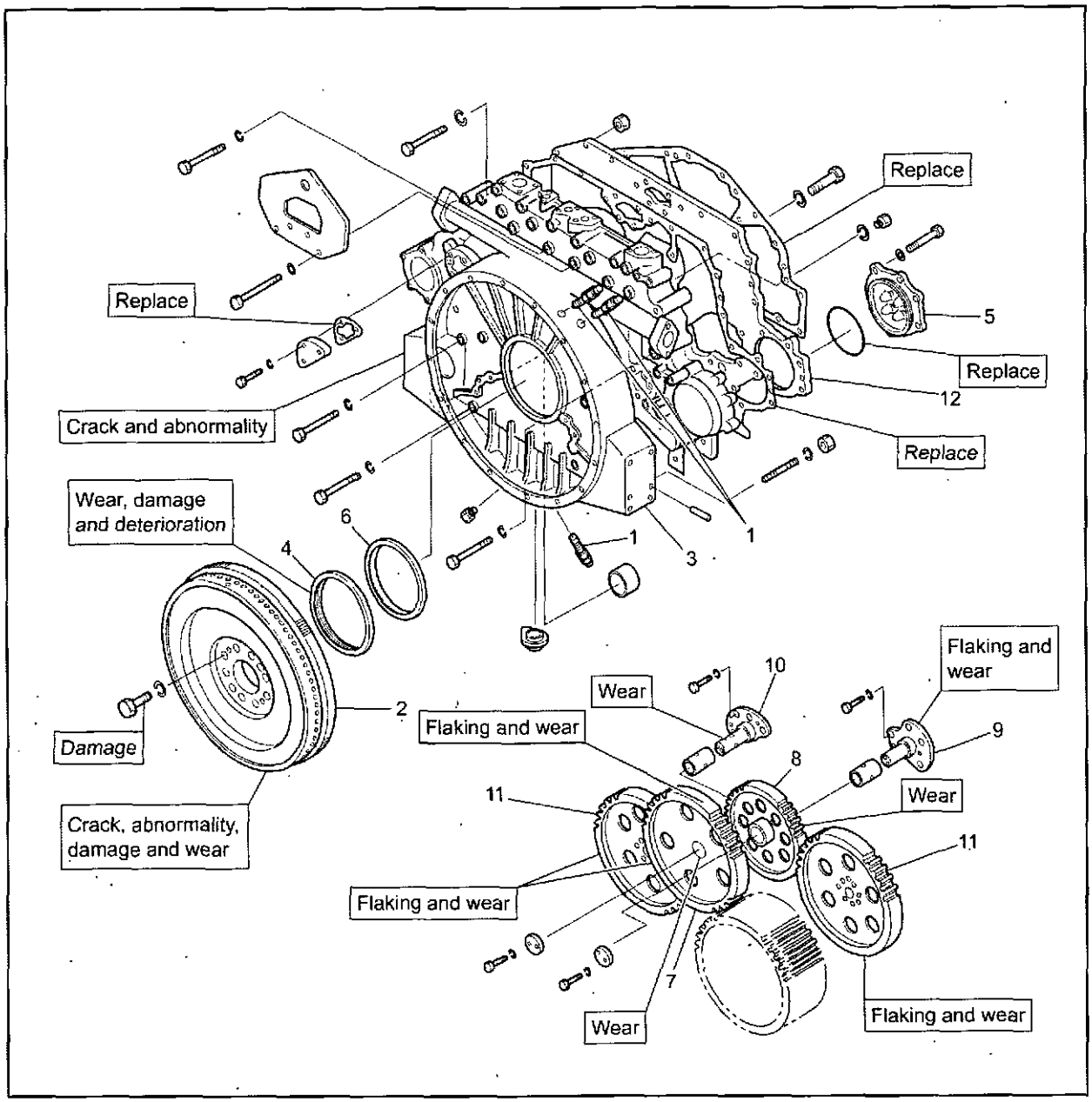



Removing and inspecting oil pump

Removing sequence

1 Oil pipe
2 Connector
3 Connector
4 Oil pan (weight: approx. 70 kg [154 lb])
5 Strainer stay
6 Oil strainer
7 Oil pump (weight: approx. 32.5 kg [72 lb])

Disassembling and inspecting flywheel and timing gear




*Disassembling and inspecting flywheel and timing gear*

Disassembling sequence

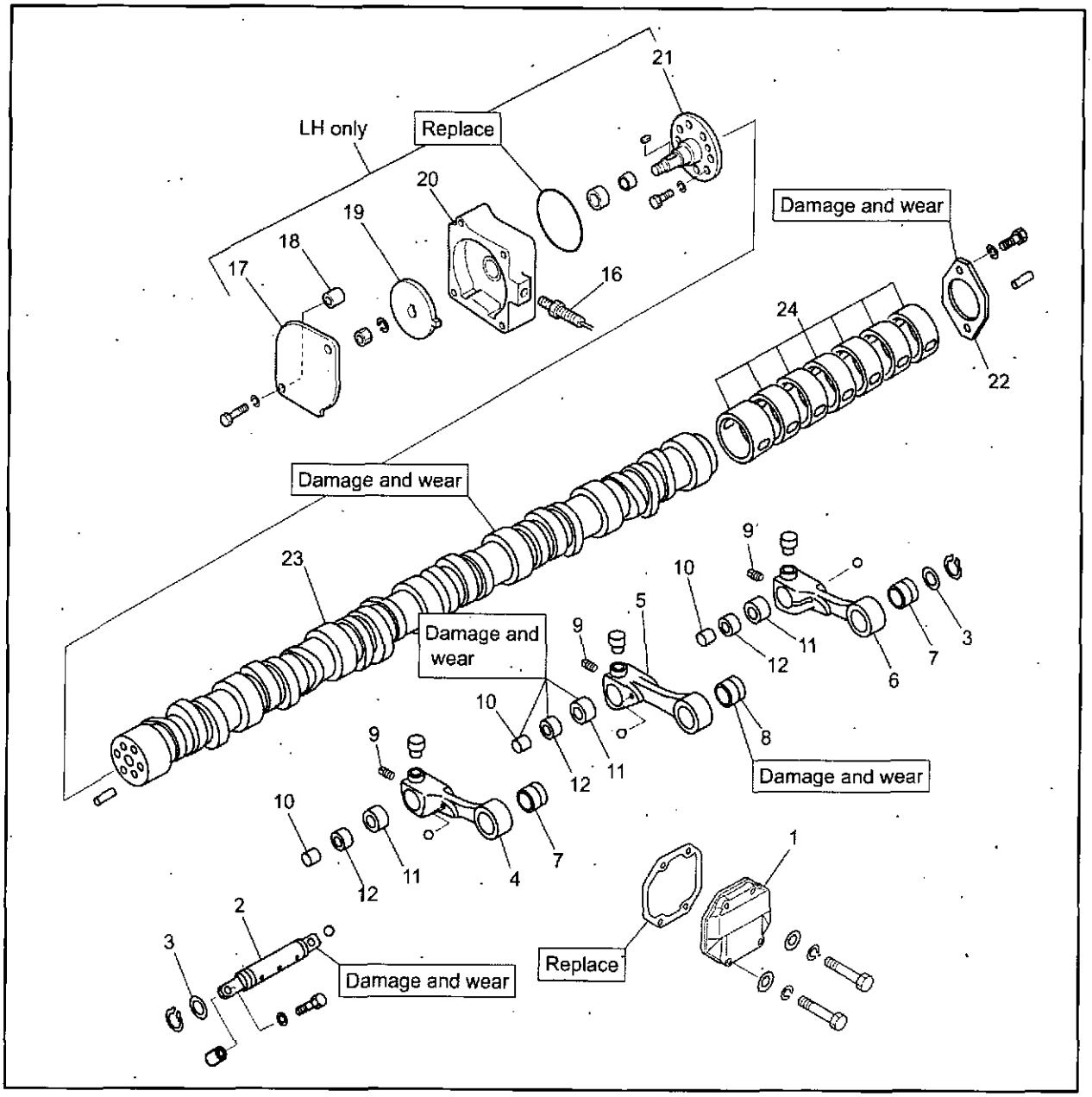
1 Pickup
2 Flywheel (weight: approx. 100 kg [220 lb])
3 Timing gear case (weight: approx. 170 kg [375 lb])
4 Oil seal
5 Cover
6 Slinger
7 LH idler gear
8 RH idler gear
9 RH idler shaft
10 LH idler shaft
11 Camshaft gear
12 Rear plate

**CAUTION**

When changing parts, be sure to use our designated parts.

*Unless our designated parts are used, the exhaust emission regulations cannot be met.*

Disassembling and inspecting cam follower and camshaft




Disassembling and inspecting cam follower and camshaft

Disassembling sequence

| | | | | | |
|---|---|---|---|---|---|
| 1 | Cam room cover | 9 | Set screw | 17 | Cam cover plate |
| 2 | Cam follower shaft | 10 | Roller pin | 18 | Spacer |
| 3 | Cam follower spacer | 11 | Tappet roller | 19 | Sensing blade |
| 4 | IN follower | 12 | Roller bushing | 20 | ECUI sensor case |
| 5 | UI follower | 13 | UI roller pin | 21 | ECUI coupling |
| 6 | EXH follower | 14 | UI tappet roller | 22 | Thrust plate |
| 7 | Follower bushing | 15 | UI roller bushing | 23 | Camshaft (weight: approx. 58.5 kg [129 lb]) |
| 8 | UI follower bushing | 16 | Cam sensor | 24 | Camshaft bushing |

### 2.1 Removing flywheel

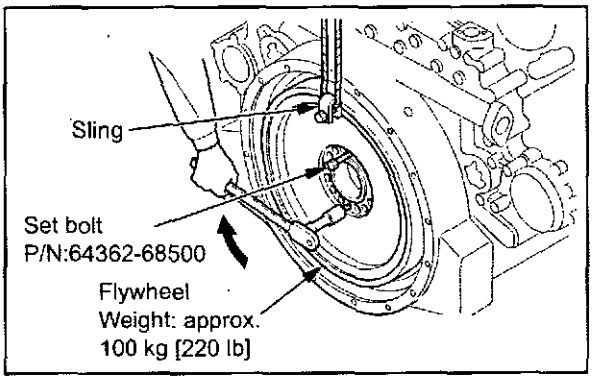
**⚠ CAUTION**

Be careful not to drop or hit the flywheel. Dropping or hitting the flywheel not only causes damage to the flywheel but also can result in personnel injury.

**CAUTION**

*Be sure to remove the pickups and starter before* removing the flywheel.

(1) Attach a lifting sling to the flywheel to prevent from falling off.
(2) Unscrew the flywheel mounting bolts.
(3) Screw two set bolts evenly into bolt holes and remove the flywheel.



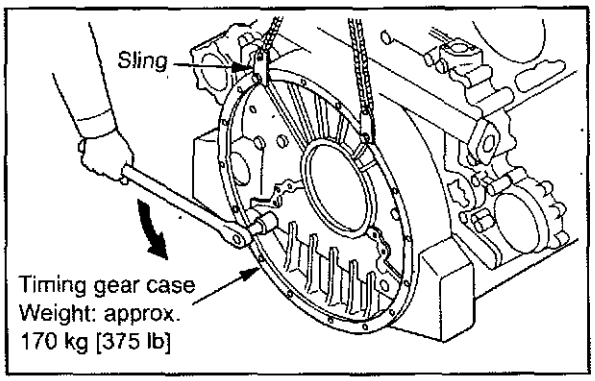

Removing flywheel

### 2.2 Removing timing gear case

**⚠ CAUTION**

Be careful not to drop or hit the timing gear case. Dropping or hitting the timing gear case could cause not only damage to the gear case but also lead to personnel injuries.

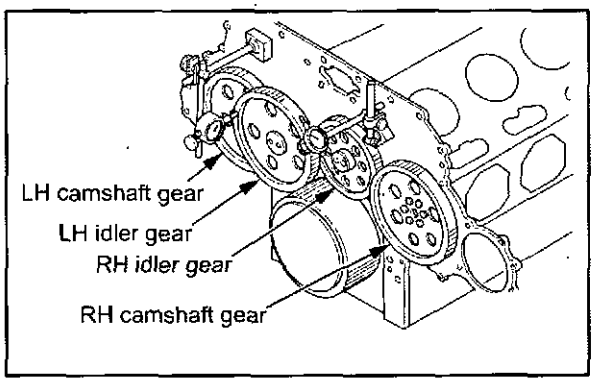
(1) Attach a lifting sling to the timing gear case to prevent it from falling out.
(2) Remove the timing gear case mounting bolts.
(3) While lifting and supporting the timing gear case, remove the timing gear case by sliding it out until the gear case is disengaged from the dowel pins. Be careful not to damage the oil seal.




Removing timing gear case

### 2.3 Measuring timing gear backlash and end play

Measure the backlash and end play of each gear, and make a note of them to determine for replacement.

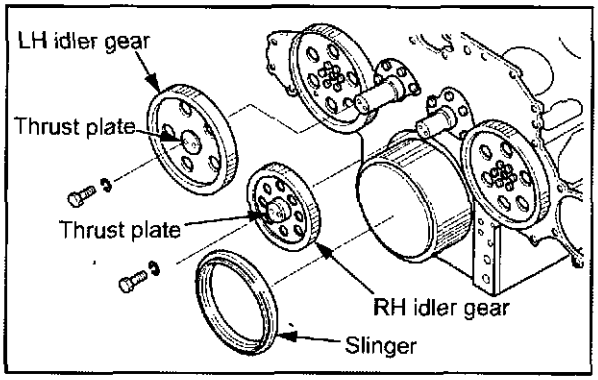



Measuring timing gear backlash end play

### 2.4 Removing idler gear

(1) Remove the slinger of the crankshaft.

(2) Remove the thrust plate mounting bolts, and remove the idler gear.




Removing idler gear

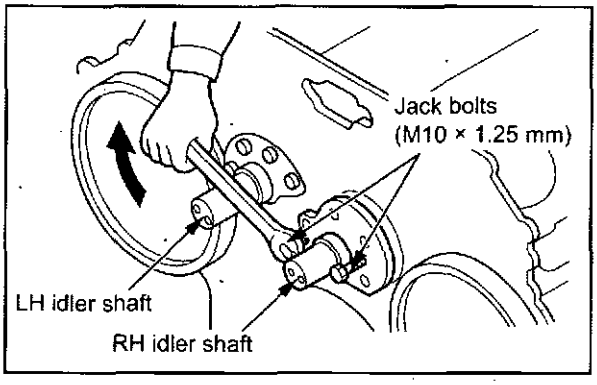
### 2.5 Removing idler shaft

**CAUTION**

Use jack bolts with convex and round end. Do not use jack bolts with sharp edge, as they could cause damage to the surface of crankcase.

Remove the idler shaft mounting bolts. Screw jack bolts evenly in the bolt holes, and remove the idler shaft.

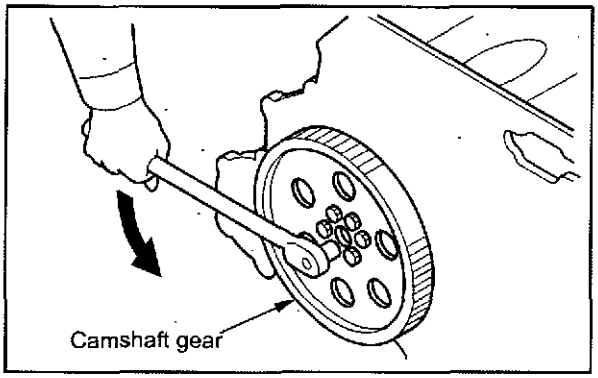
Note: Do not remove the idler shaft unless it is necessary.




Removing idler shaft

### 2.6 Removing camshaft gear

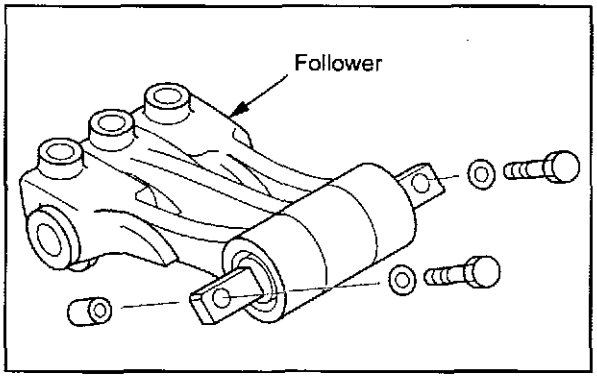
Unscrew the camshaft gear mounting bolts, and remove the camshaft gears by using gear puller.




Removing camshaft gear

### 2.7 Removing cam follower

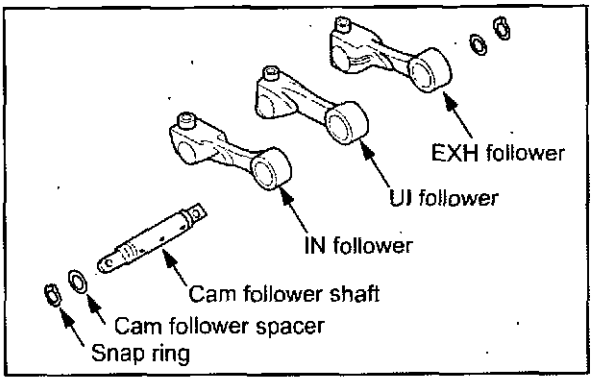
Unscrew the cam follower shaft mounting bolts, and remove the follower.




Removing cam follower

### 2.8 Disassembling cam follower

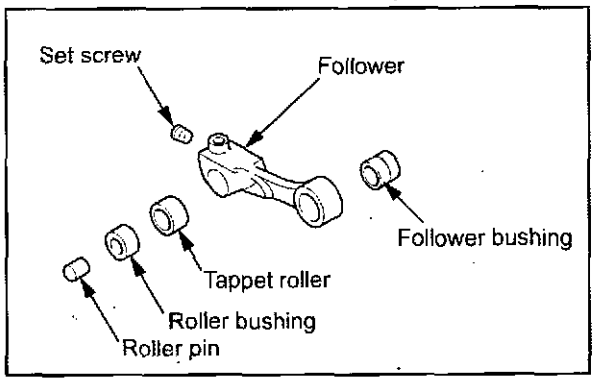
(1) Remove the snap rings from both ends, and remove the followers from the shaft.




Disassembling cam follower (1)

(2) Pull out the follower bushing from each follower.

(3) Remove the set screw, pull out the roller pin, and remove the tappet roller and roller bushing.




Disassembling cam follower (2)

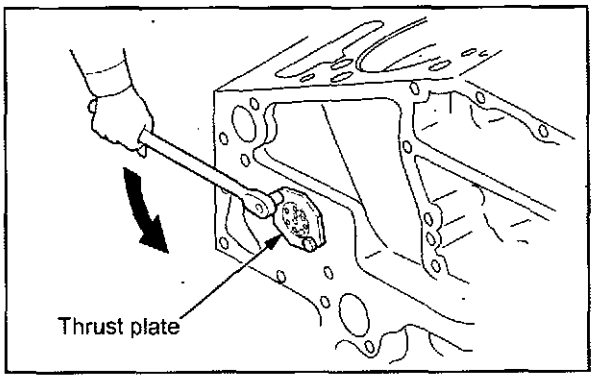
### 2.9 Removing camshaft

**CAUTION**

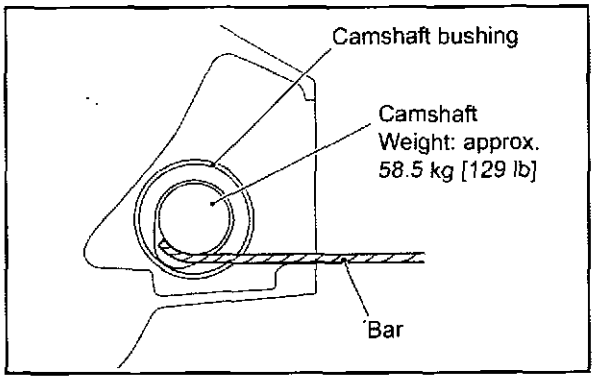
When removing the camshaft, take care not to damage the camshaft cam and bushing.

(1) Unscrew the thrust plate mounting bolts, and dismount the thrust plate.

(2) Support the camshaft with a bar inserted through the side cover mounting section, and remove the camshaft from the crankcase.

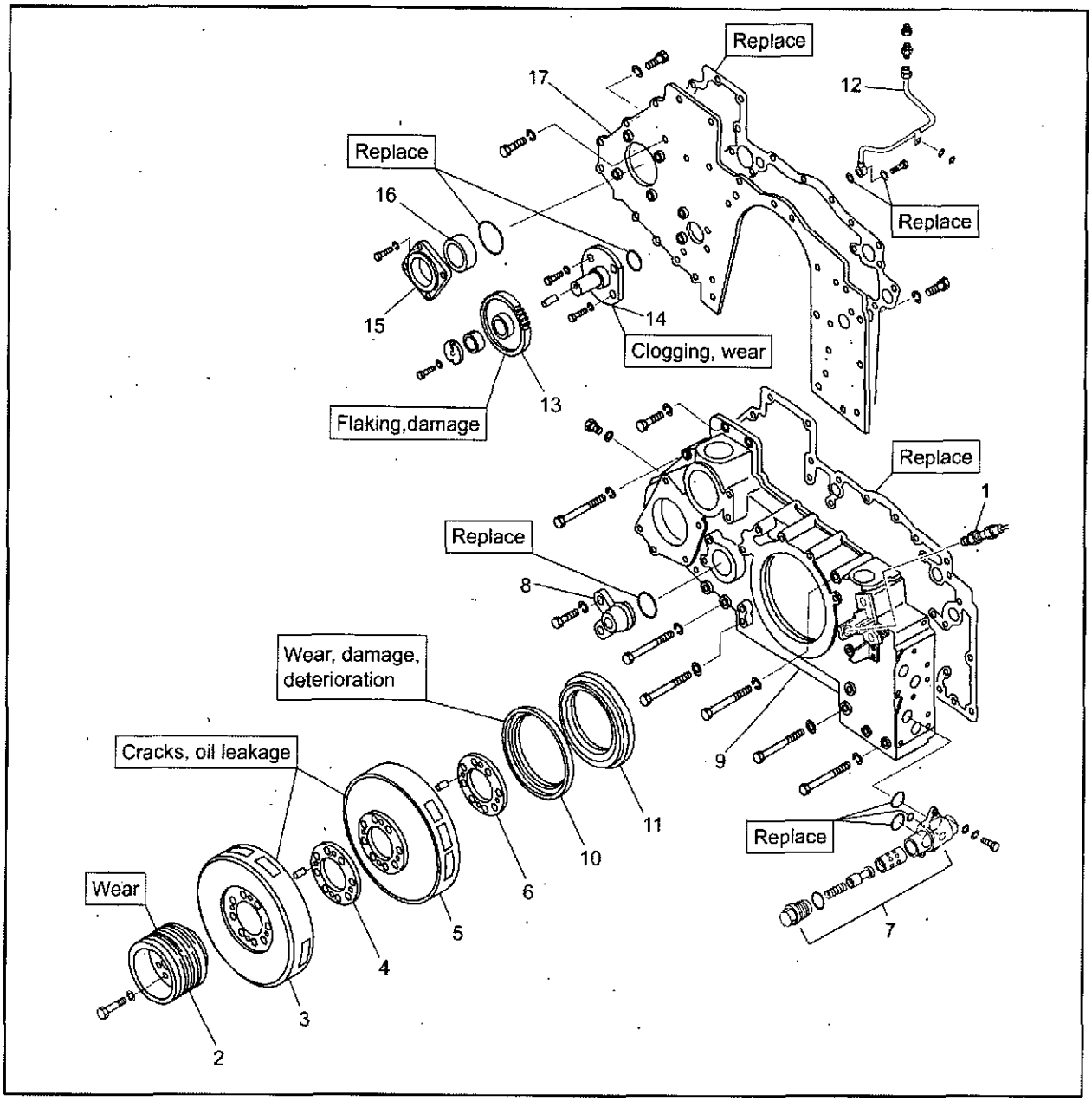



Removing thrust plate




Removing camshaft

## 3. Disassembling and inspecting damper and front accessory drive




Disassembling and inspecting damper and front accessory drive

Disassembling sequence

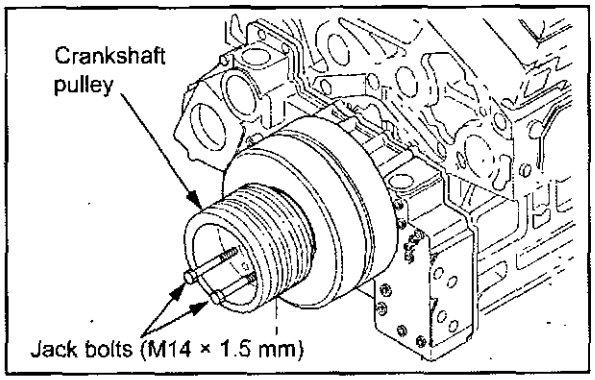
1 Pickup
2 Crankshaft pulley
3 Damper (front) (weight: approx. 53 kg [117 lb])
4 Spacer
5 Damper (rear) (weight: approx. 56 kg [123 lb])
6 Spacer
7 Relief valve
8 Cover
9 Front gear case (weight: approx. 54 kg [119 lb])
10 Oil seal
11 Slinger
12 Oil pipe
13 Front idler gear
14 Front idler shaft
15 Water pump bearing cover
16 Oil seal
17 Front plate

### 3.1 Removing crankshaft pulley

**CAUTION**

Use jack bolts with convex and round end. Do not use jack bolts with sharp edge, as they could cause damage to the surface of damper.

Remove the crankshaft pulley mounting bolts. Screwing jack bolts evenly into the bolt holes, remove the crankshaft pulley.



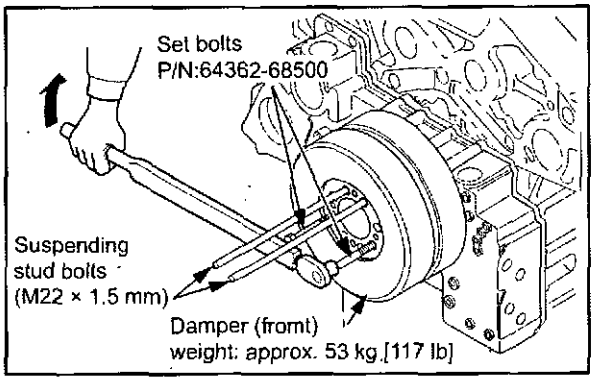

Removing crankshaft pulley

### 3.2 Removing damper

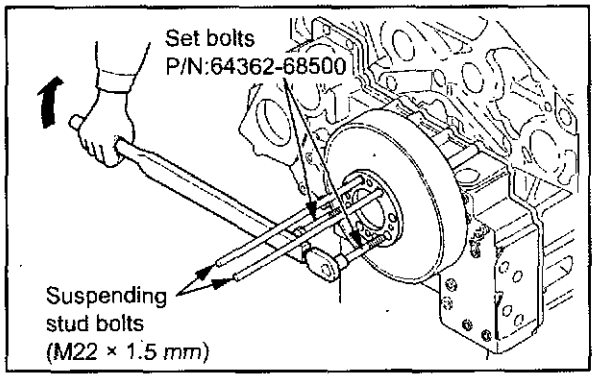
**CAUTION**

Use jack bolts with convex and round end. Do not use jack bolts with sharp edge, as they could cause damage to the surface of parts.

(1) Install the damper suspending stud bolts.
(2) Screw the set bolts evenly in the damper (front) pullout holes, and pull out the damper (front) to such a degree that it does not come off the dowel pins.
(3) Pass the hanging strap through the center hole in the damper (front). Using the hanging strap, suspend the damper (front) with a crane or the like.
(4) Screw in the damper (front) jack bolts further and remove the damper (front) held in suspension.

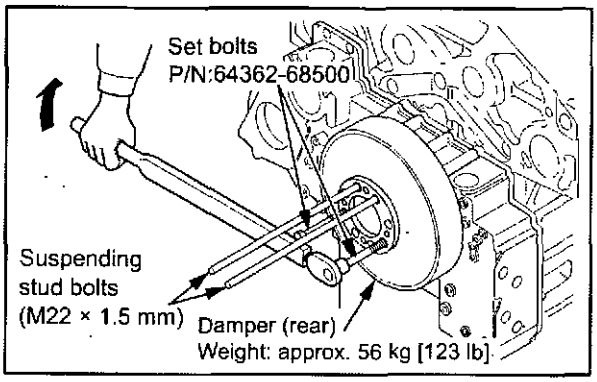



Removing damper (front)



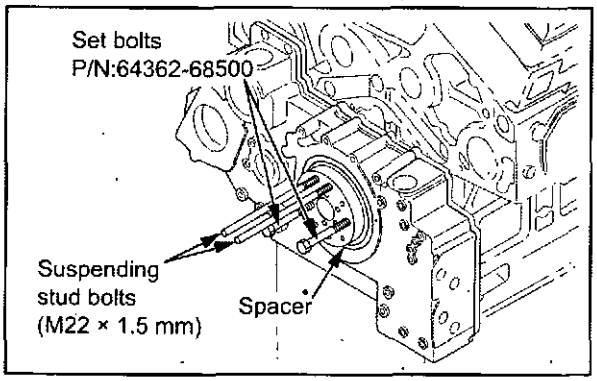

Removing sensing blade

(5) Screw the set bolts evenly in the damper (rear) pullout holes, and pull out the damper (rear) to such a degree that it does not come off the dowel pins.
(6) Pass the hanging strap through the center hole in the damper (rear). Using the hanging strap, suspend the damper (rear) with a crane or the like.
(7) Screw in the damper (rear) jack bolts further and remove the damper (rear) held in suspension.




Removing damper (rear)

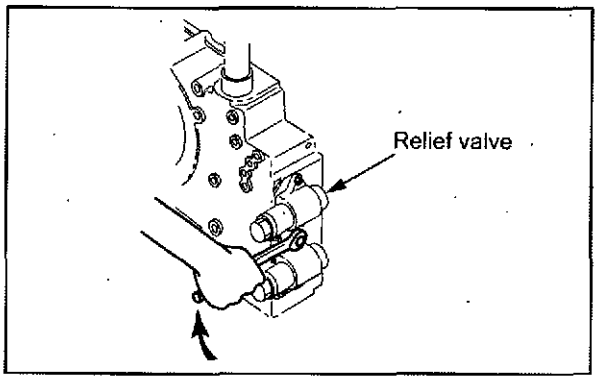
(8) Screw the set bolts evenly in the spacer pullout holes, and remove spacer.
(9) Remove the suspending stud bolts.




Removing spacer

### 3.3 Removing relief valve

Unscrew the relief valve mounting bolts, and dismount the relief valve.

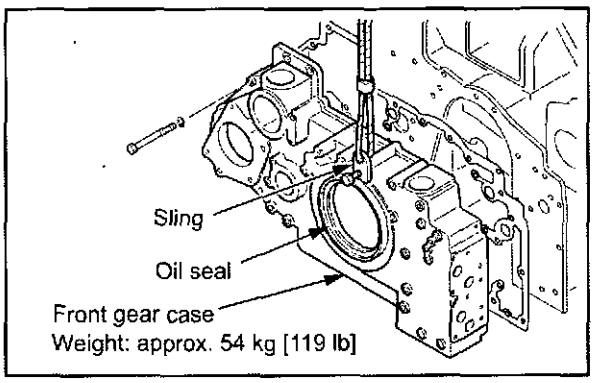



Removing relief valve

### 3.4 Removing front gear case

(1) Attach a sling to the front gear case.

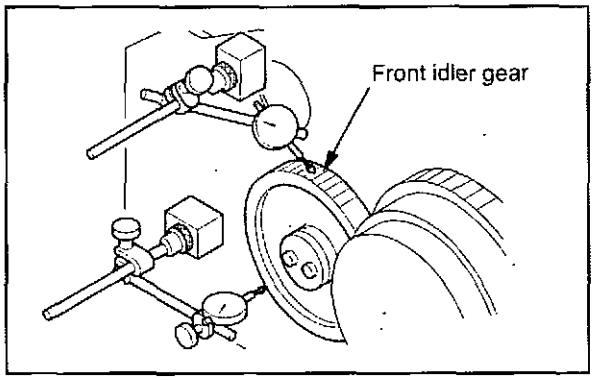
(2) Unscrew the front gear mounting bolts, and dismount the front gear case by suspending and pulling it out until the gear case is disengaged from the dwell pins. When removing the gear case, be careful not to damage the oil seal or bend the pointer by hitting.




Removing front gear case

### 3.5 Measuring front idler gear backlash and end play

Measure the backlash and the end play of the front idler gear, and make a note of them to use as a reference for parts replacement.

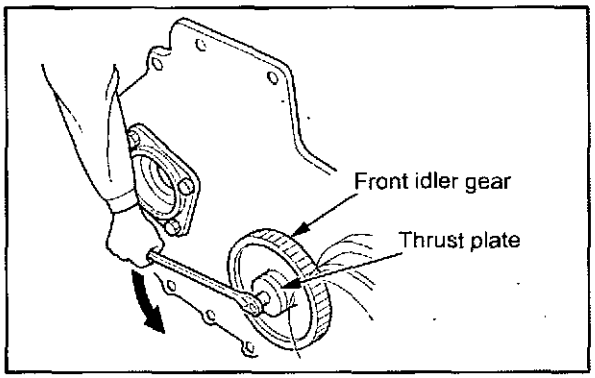



Measuring front idler gear backlash and end play

### 3.6 Removing front idler gear

(1) Remove the oil pipe.

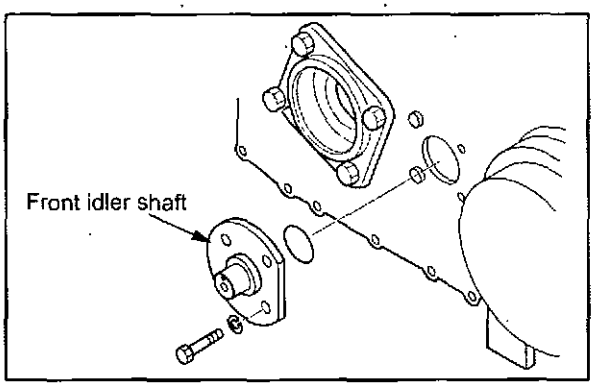
(2) Unscrew the thrust plate mounting bolts, and dismount the front idler gear and the thrust plate.




Removing front idler gear

### 3.7 Removing front idler shaft

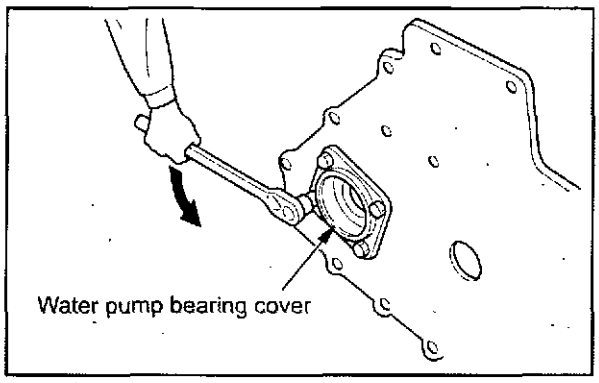
Do not remove the front idler shaft unless it is necessary. When removing the front idler shaft, unscrew the mounting bolts, and drive it out.




Removing front idler shaft

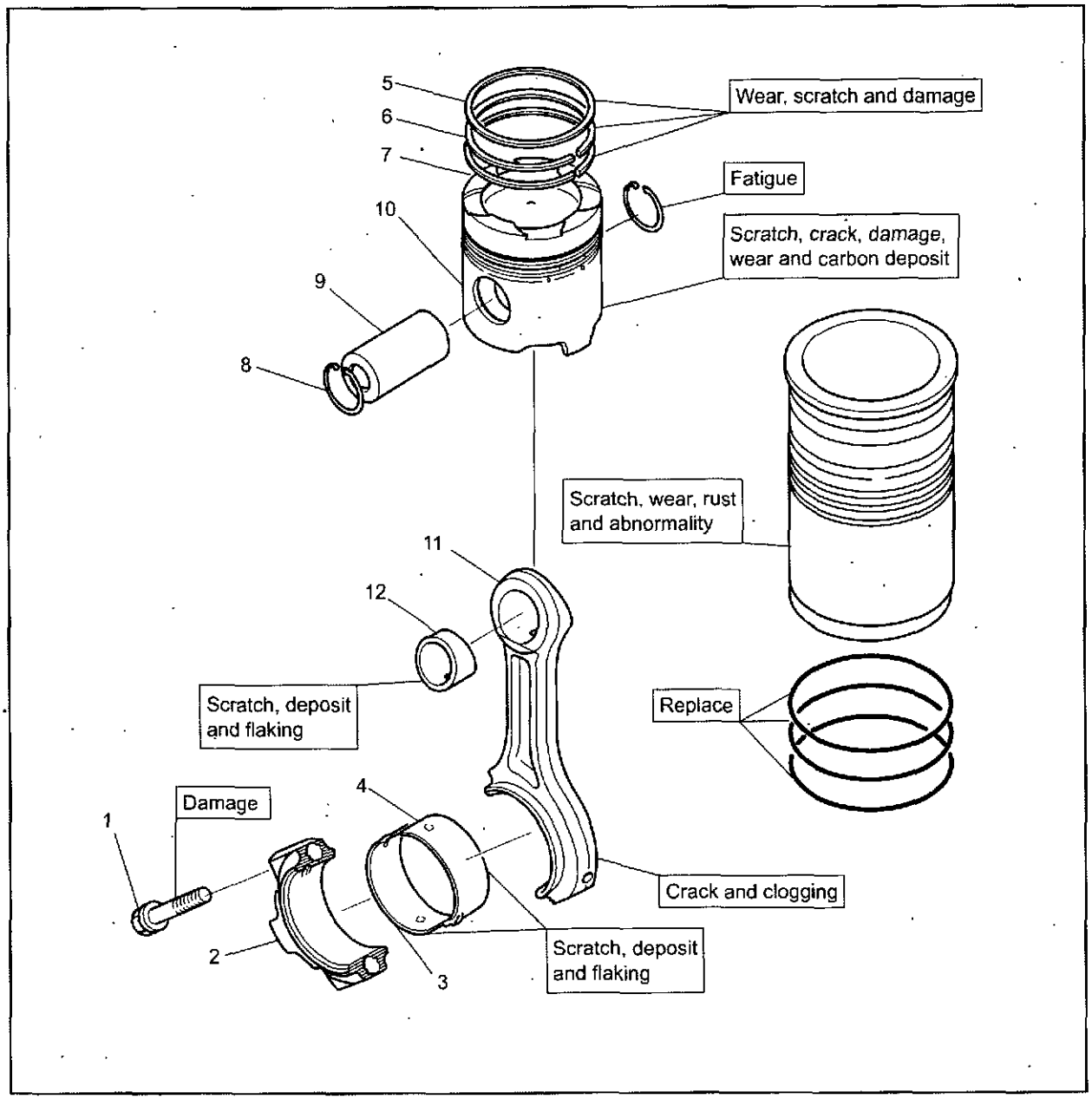
### 3.8 Removing bearing cover for oil and water pumps

Unscrew the bearing cover mounting bolts, and dismount the bearing cover.




Removing water pump bearing cover

## 4. Disassembling and inspecting cylinder liner, piston and connecting rod




*Disassembling and inspecting cylinder liner, piston and connecting rod*

Disassembling sequence

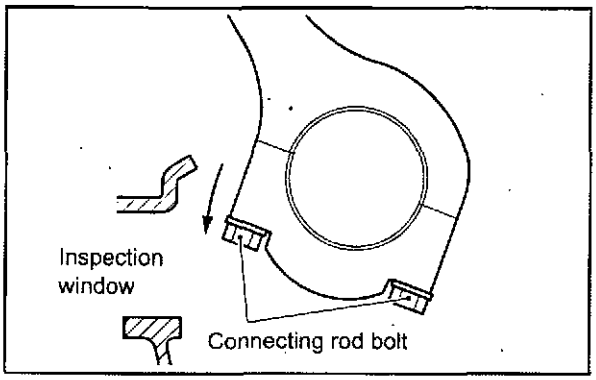
1 Bolt
2 Connecting rod cap
3 Connecting rod bearing, lower
4 Connecting rod bearing, upper
5 No. 1 compression ring
6 No. 2 compression ring
7 Oil ring
8 Snap ring
9 Piston pin
10 Piston
11 Connecting rod
12 Connecting rod bushing

**CAUTION**

When changing parts, be sure to use our designated parts.
Unless our designated parts are used, the exhaust emission regulations cannot be met.

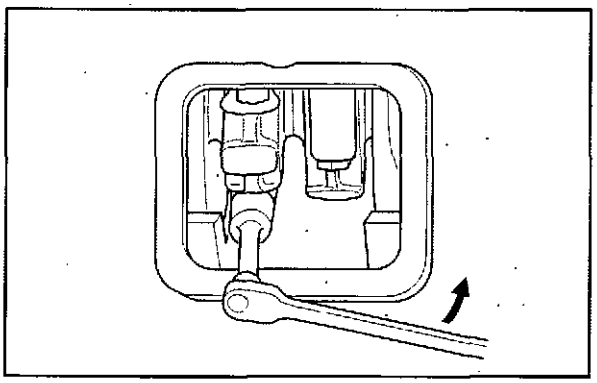
### 4.1 Removing connecting rod cap

(1) Turn the crankshaft until each connecting rod bolt comes to the position where it can be easily removed through the inspection window.




Removing connecting rod cap (1)

(2) Slowly and alternately loosen the upper and lower connecting rod bolts until they can be turned by hand.



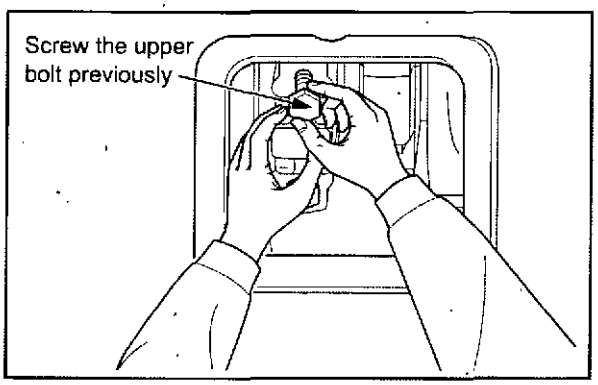
Removing connecting rod cap (2)

(3) Remove the upper connecting rod bolt first and then the lower connecting rod bolt while holding the connecting rod cap, and remove the connecting rod cap.

Note: (a) Do not damage the bearings by dropping them in the oil pan.

(b) Mark the connecting rod bearings for their cylinder numbers and the upper or lower position.

(c) When removing the connecting rod cap, pay attention to its mass, and take care not to drop it.




Removing connecting rod cap (3)

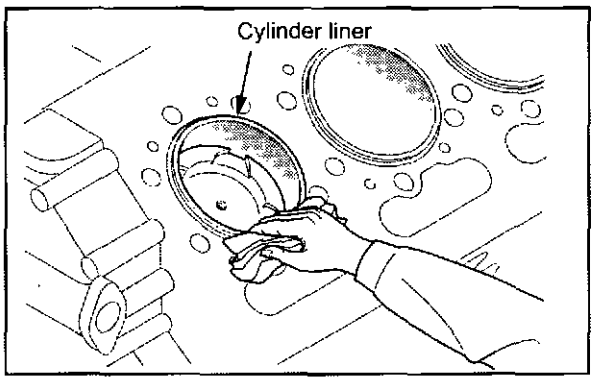
### 4.2 Removing carbon deposits from the upper part of cylinder liner

**CAUTION**

*Be sure to remove carbon deposits from the upper part* of the cylinder liner before removing the piston, as they could cause damage to the piston and piston ring.

Remove carbon deposits from the upper part of cylinder liner using a cloth or oil paper.

Note: Be careful not to damage the inner surface of the cylinder liner.




Removing carbon deposits from the upper part of cylinder liner

### 4.3 Pulling out piston

**⚠ CAUTION**

When holding the connecting rod with your hand to prevent it from swinging, be very careful, as you may suffer hand injuries from accidental movement of the connecting rod.

**CAUTION**

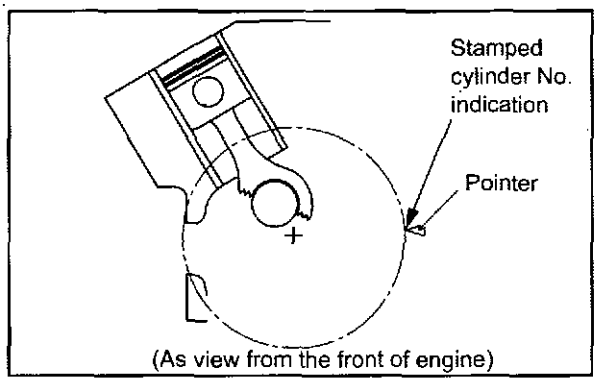
(a) When pulling out the piston, be careful not to drop the upper connecting rod bearing. Dropping the upper connecting rod bearing will cause damage to the cylinder liner and the crankshaft.

(b) Use care not to damage the cylinder liner by the swing of the connecting rod when pulling out the piston and connecting rod from the cylinder liner.

(c) When only a few pistons are left in the cylinders, the crankshaft tends to turn by itself. Be sure to hold the crankshaft to prevent it from turning while removing pistons.

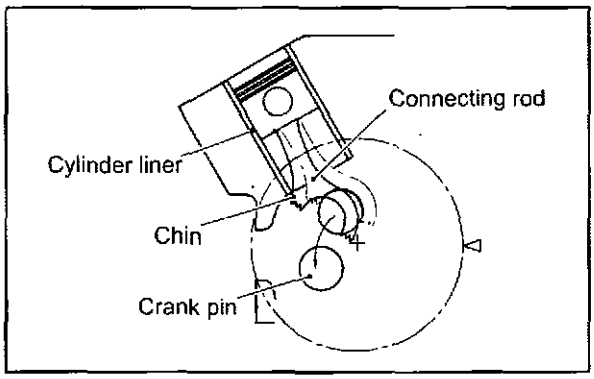
For the cylinders on the engine right bank

(1) *Turn the crankshaft to bring the piston to the top dead center.*




Positioning piston in top dead center

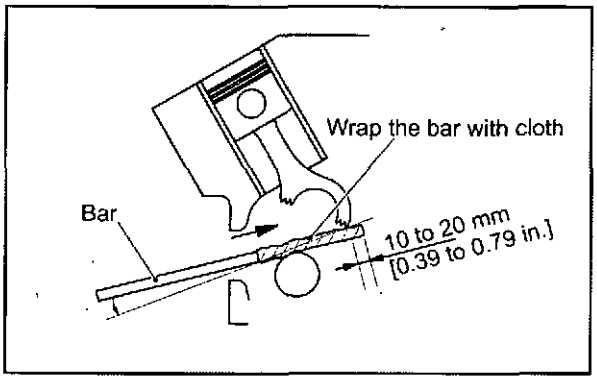
(2) Turn the crankshaft in the reverse direction until the bolt hole is visible through the inspection window on the side of the crankcase, and separate the crank pin from the connecting rod.




Removing crank pin

(3) Wrap a cloth around the bar, and insert the tip of the bar under the big end of the connecting rod. Then push the bar downwards using the crank pin as a fulcrum to raise the piston slightly.

Note: If the bar is inserted too deep, the bar may be caught in the cylinder liner and unable to raise the piston. Carefully insert the bar so that it protrudes about 10 to 20 mm [0.39 to 0.79 in.] from the tip of the connecting rod big end.

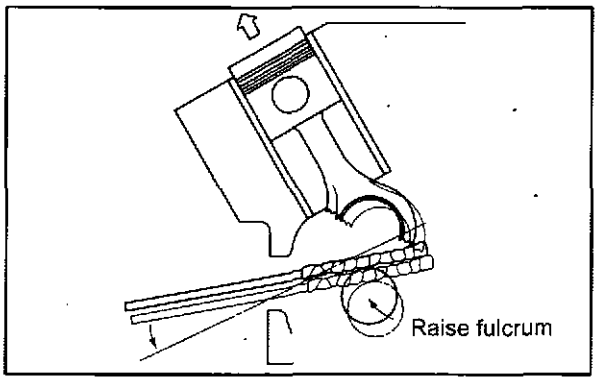



Inserting bar

(4) Slowly turn the crankshaft in the normal direction to raise the crank pin (fulcrum). Push the bar downwards to raise the piston.

**CAUTION**

Carefully raise the piston, making sure that the connecting rod does not interfere with the piston cooling nozzle.



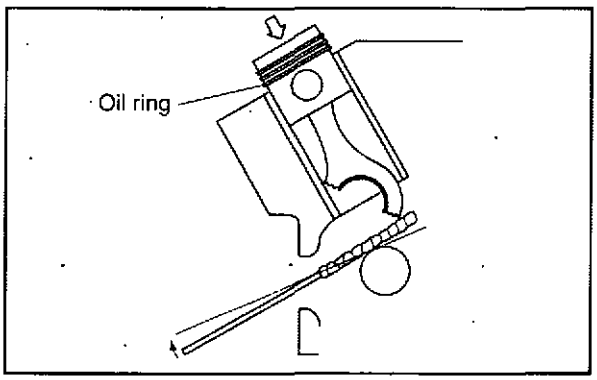

Lifting piston

(5) When the oil ring of the piston comes out from the top of the cylinder liner, carefully push the bar upwards to lower the piston slightly, and place the oil ring even with the top end of the liner.

**CAUTION**

(a) Do not push the bar upwards suddenly, as it could cause damage to the oil ring.

(b) Do not turn the piston, as it could cause damage to the piston cooling nozzle.



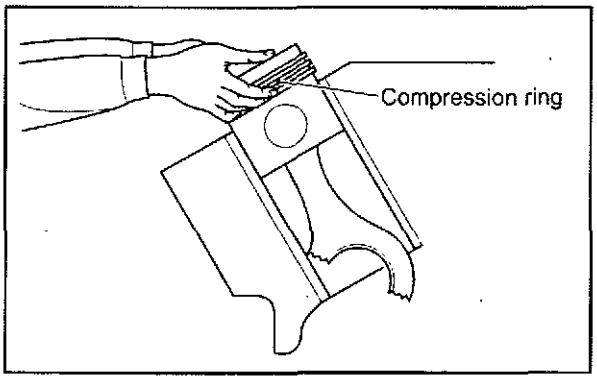

Positioning piston even with the top end of cylinder

(6) Firmly hold the compression ring of the piston in your hands, carefully pull up the piston to remove it from the top of the cylinder liner, and put the skirt of the piston in position on the top of the crankcase.

(7) Hold the piston with both hands, and pull the piston out of the cylinder liner.

**CAUTION**

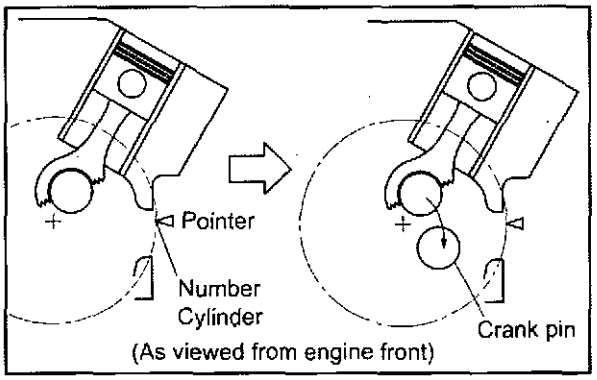
When removing piston and connecting rod from the cylinder liner, be careful not to damage the cylinder liner by the swing of the connecting rod.




Pulling out piston

For the cylinders on the engine left bank

Follow the removal procedure for the pistons of the right bank cylinders described above, and reverse the postion of the crankpin and the turing direction of crankshaft.




*Pulling out piston (for the left bank cylinders)*

### 4.4 Using piston remover

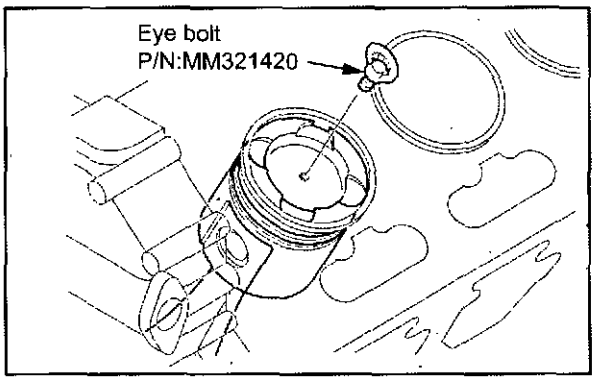
(1) Turn the crankshaft to bring the piston to approximately 50° after top dead center.

(2) Attach the piston remover (special tool) to the top of the piston.

(3) Slowly lift the piston and connecting rod out of the cylinder liner.

Note: (a) Do not put the pistons, piston pins, connecting rods, and connecting rod caps on the ground directly, but put them on an underlay such as a pallet.

(b) The pistons, piston pins, connecting rods, and connecting rod caps should be kept together for their cylinders. Mark the parts for their cylinders. Do not mix-up the parts for one cylinder to another. When reusing parts, always reinstall into the same cylinder as they were.




Removing piston (using piston remover)

### 4.5 Removing piston ring

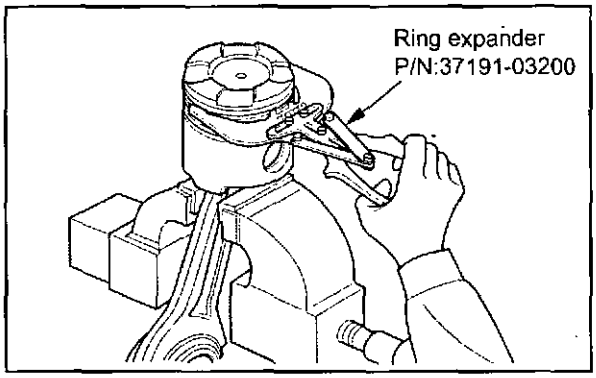
**⚠ CAUTION**

When removing the piston ring, be careful not to get caught your fingers between the piston and cylinder wall by the swing of the piston.

**CAUTION**

If the piston is forcibly moved and interfered with the connecting rod, the piston could be damaged.

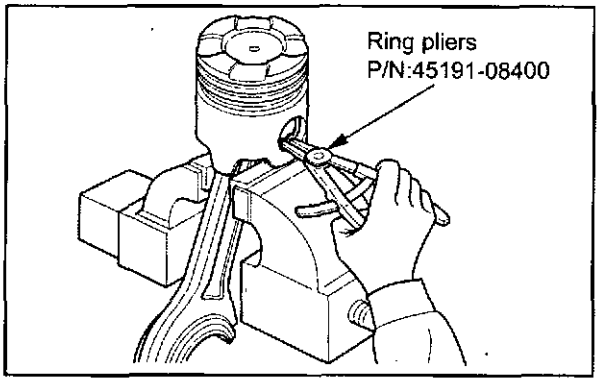
Hold the piston and connecting rod in a vise, and remove the piston ring using a ring expander.




Removing piston ring

### 4.6 Removing piston pin and piston

(1) Using ring pliers, remove the snap ring.




Removing piston pin and piston

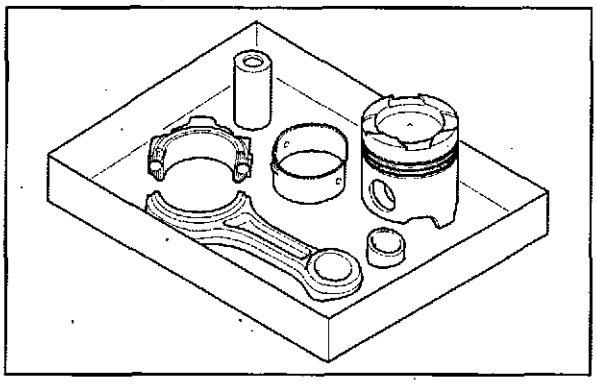
(2) Using a wooden block and mallet, remove the piston pin, and separate the piston from the connecting rod.

Note: (a) Do not tap the piston pin directly with a mallet.

(b) If the piston is stubborn, heat the piston with a piston heater or in hot water.

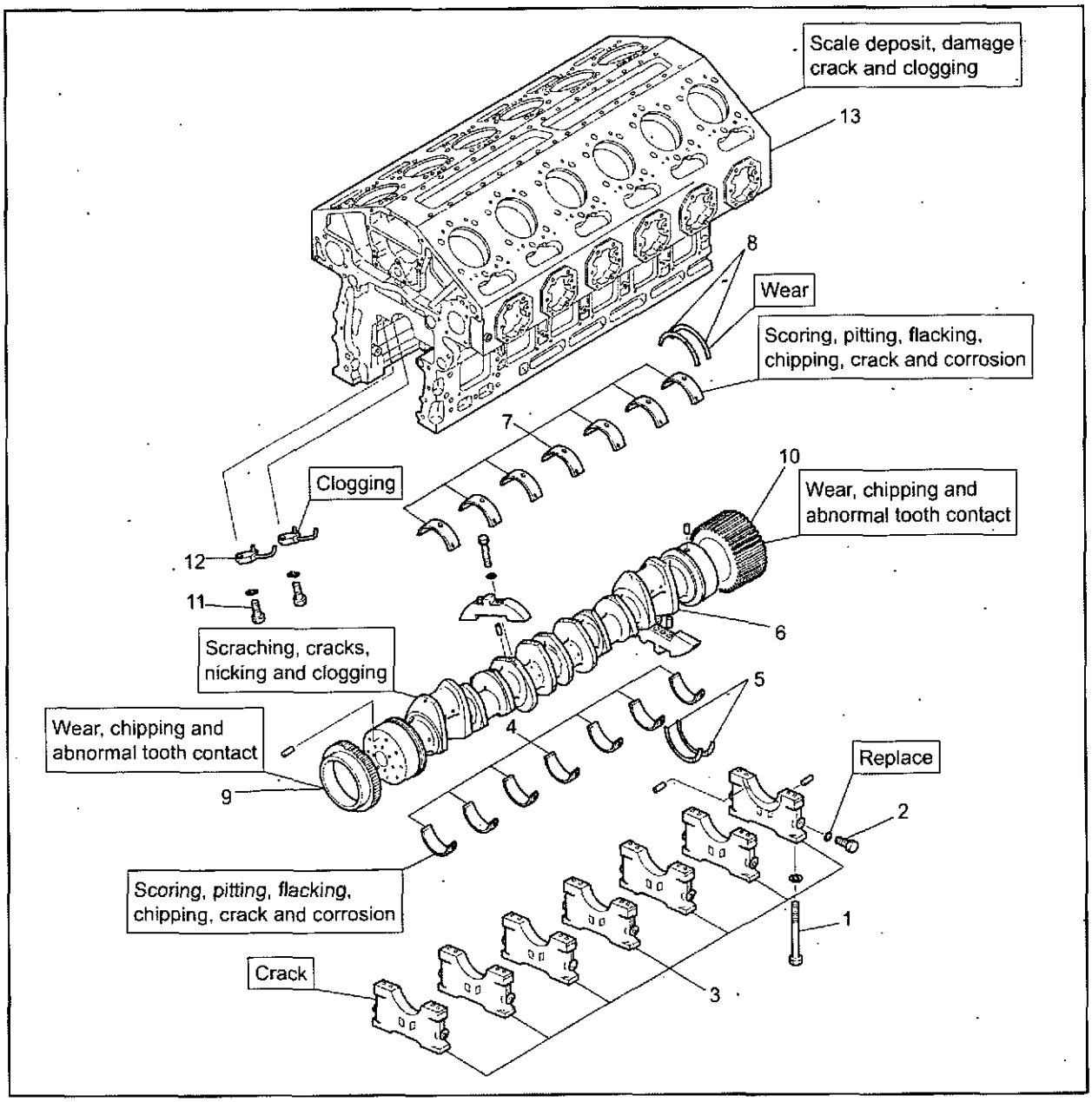
(c) Place removed pistons, piston pins, connecting rods, connecting rod bearings and connecting rod caps, not on the ground directly but on pallets or the like.

(d) Keep removed pistons, piston pins, connecting rods, connecting rod bearings and connecting rod caps as a set according to cylinder numbers, and mark the cylinder number. When the parts are reassembled, be sure to use them in the same cylinders as before.



Keeping pistons in order after disassembling

## 5. Disassembling and inspecting crankcase, crankshaft and main bearing



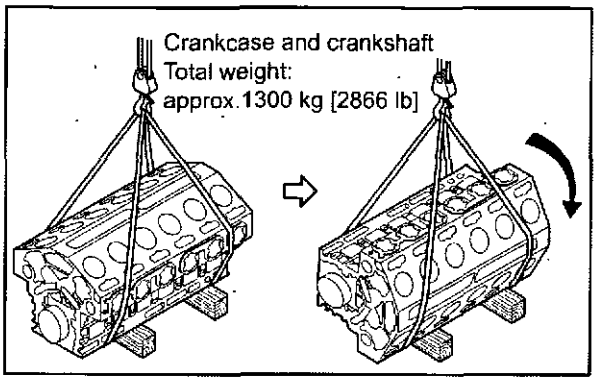

Disassembling and inspecting crankcase, crankshaft and main bearing

Disassembling sequence

1 Main bearing cap bolt
2 Side bolt
3 Main bearing cap
4 Main bearing (lower)
5 Thrust plate
6 Crankshaft
7 Main bearing (upper)
8 Thrust plate
9 Crankshaft gear (6 to 9 weight: Approx. 375 kg [827 lb])
10 Crankshaft gear (rear)
11 Check valve
12 Piston cooling nozzle
13 Crankcase (1 to 13 weight: Approx. 1300 kg [2866 lb])

### 5.1 Inverting crankcase

Lay the crankcase on a turntable and invert the crankcase.
When the turntable is not available, use a sqaure wooden block or a cloth to lay the crankcase on it to prevent the crankcase from damage, and using a crane and wire ropes, hoist the crankcase and lay it on the wooden block with its side faced downwards.
Then, change the positions of the wire ropes, and turn over the crankcase.




Inverting crankcase

### 5.2 Removing main bearing cap

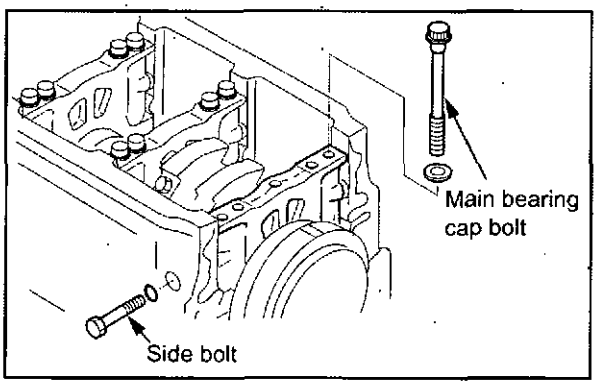
**⚠ CAUTION**

When removing the main bearing cap with a nozzle remover, take care not to get caught your fingers between the weight and the bar of the nozzle remover.

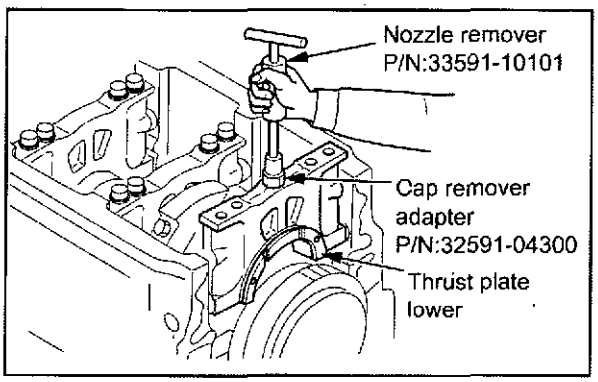
**CAUTION**

When lifting the main bearing cap away from the crankcase, be careful not to damage the lower main bearing or the lower thrust plate that are attached to the cap. Also be careful not to drop those parts, which may damage the crankshaft.
When removing the No. 7 main bearing cap, take care not to damage the thrust plate on both sides.

(1) Remove the main bearing cap bolt and the side bolt.
(2) Install the cap remover adapter to the main bearing cap.
(3) Install the nozzle remover to the adapter.
(4) Move the nozzle remover up and down to remove each main bearing cap.
(5) Remove the main bearing lower from the main bearing cap while paying attention to the lug position, and remove the thrust plate lower from the No. 7 main bearing cap.




Removing main bearing cap (1)




Removing main bearing cap (2)

### 5.3 Removing crankshaft

**CAUTION**

Remove the upper thrust plate on the front side first, otherwise the front upper thrust plate will fall off onto the crankcase when removing the crankshaft.

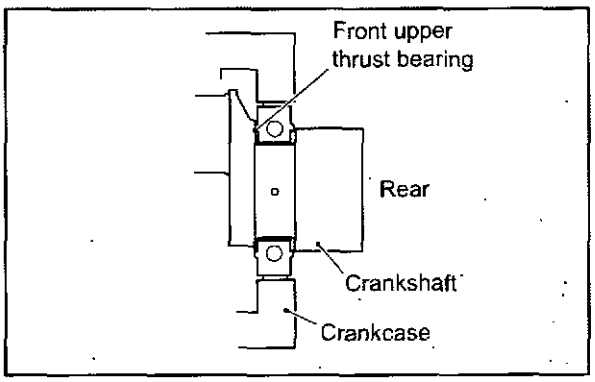
When placing the crankshaft onto a pallet or other stands, be careful not to damage the crankshaft. Once placed on a pallet, the crankshaft should be locked in place to prevent it from turning.

(1) Remove the front upper half of the thrust plate while rotating the crankshaft slowly.

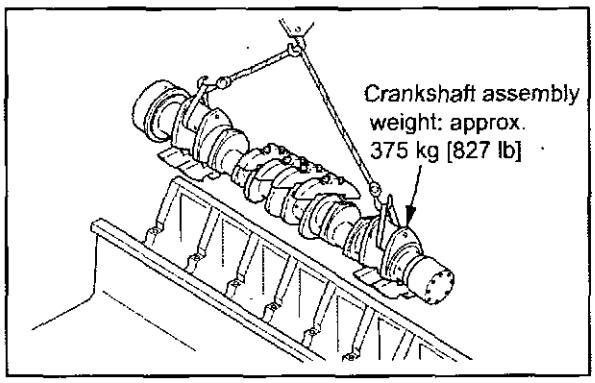
(2) Keeping the crankshaft in a horizontal position, slowly raise the crankshaft.

Note: Do not attach a metal chain or other hoisting devices directly onto the crankshaft, as they could damage the crankshaft. Place cloth belts or pads in position where a chain or other hoists are hooked before raising crankshaft.

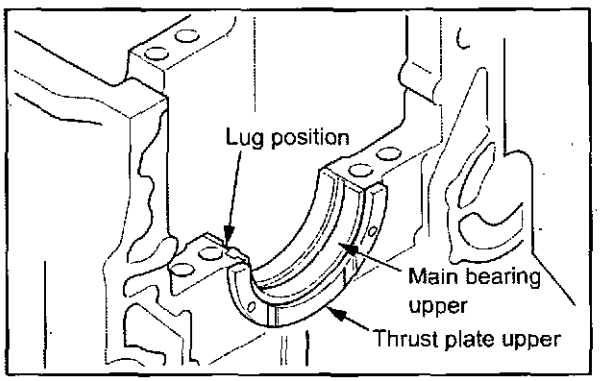
(3) Remove the upper main bearing from the crankcase, paying attention to the lug position, and remove the upper thrust plate on the rear side.




Removing crankshaft (1)




Removing crankshaft (2)




Removing crankshaft (3)

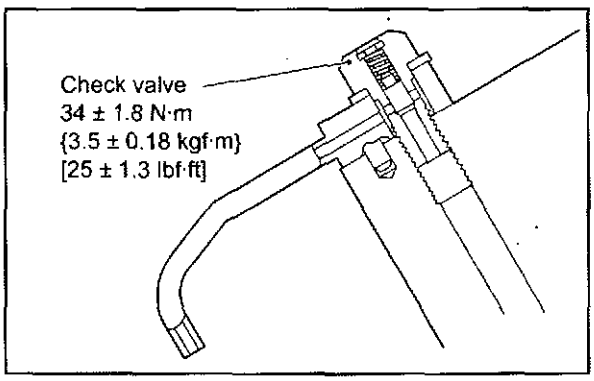
### 5.4 Removing piston cooling nozzle

**CAUTION**

When the piston cooling nozzle has been removed, be sure to tighten it to the specified torque.

Do not remove the piston cooling nozzles unless oil holes are clogged or the spray direction is faulty.

Note: Be sure to use a torque wrench to tighten the piston cooling nozzles to the specified torque. Tightening without using a torque wrench could result in excessive tightening force, which could cause the check valve to malfunction, possibly leading to piston seizure due to insufficient lubricating oil supply during engine operation.




Removing piston cooling nozzle

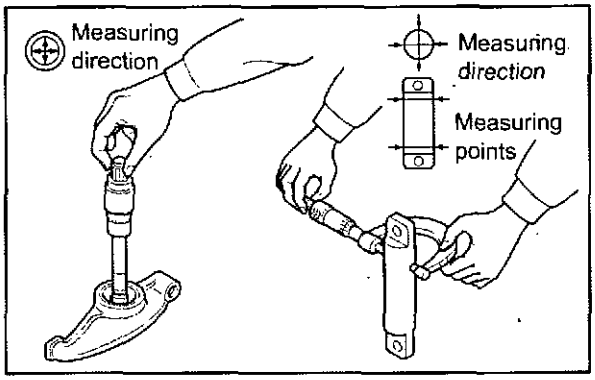
# INSPECTION AND REPAIR OF BASIC ENGINE

# 1. Inspecting and repairing cylinder head and valve mechanism

## 1.1 Measuring rocker bushing inside diameter and rocker shaft outside diameter

Measure the inside diameter of the rocker bushing and the outside diameter of the rocker shaft. If the inside diameter of rocker bushing exceeds the limit, replace the bushing, and if the outside diameter of shaft is less than the limit, replace the shaft.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Rocker bushing inside diameter | ø 44 mm [1.73 in.] | 44.000 to 44.075 mm [1.7323 to 1.7352 in.] | 44.125 mm [1.7372 in.] |
| Rocker shaft outside diameter | ø 44 mm [1.73 in.] | 43.975 to 43.991 mm [1.7313 to 1.7319 in.] | 43.030 mm [1.6941 in.] |



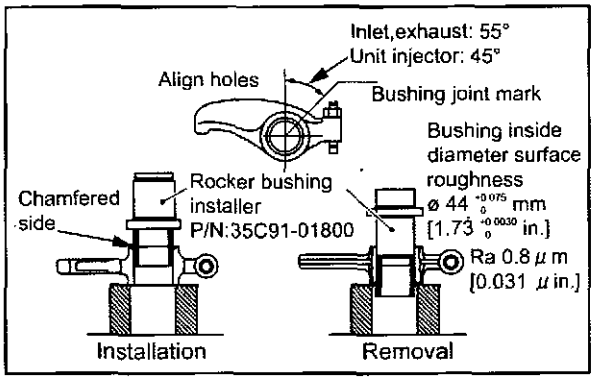

Measuring rocker arm inside diameter and rocker shaft diameter

## 1.2 Replacing rocker bushing

(1) Remove the rocker bushing using the rocker bushing puller.

(2) Install a new rocker bushing using the rocker bushing puller from the chamfered side of rocker bore with the rocker bushing positioning slit facing up.

(3) After installing the rocker bushing, measure the bushing inside diameter. If the measured value is out of the standard, ream the bore to the standard.

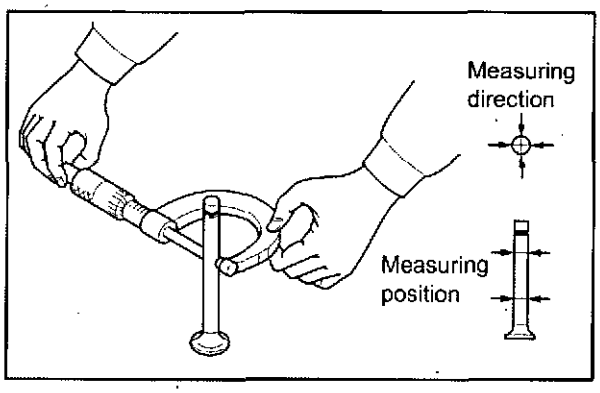



Replacing rocker bushing

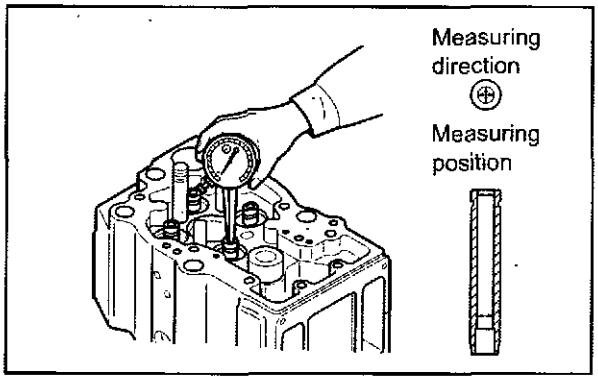
### 1.3 Measuring valve stem outside diameter and valve guide inside diameter

Measure the outside diameter of the valve stem and the inside diameter of the valve guide at the respective top and bottom ends in two crossing directions, since they are likely to wear more rapidly at both ends. If the measurement exceeds the limit, replace the part.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Valve stem outside diameter | ø 10 mm [0.39 in.] | 9.940 to 9.960 mm [0.3913 to 0.3921 in.] | 9.910 mm [0.3902 in.] |
| Valve guide inside diameter | ø 10 mm [0.39 in.] | 10.000 to 10.015 mm [0.3937 to 0.3943 in.] | 10.060 mm [0.3961 in.] |




Measuring valve stem diameter




Measuring valve guide inside diameter

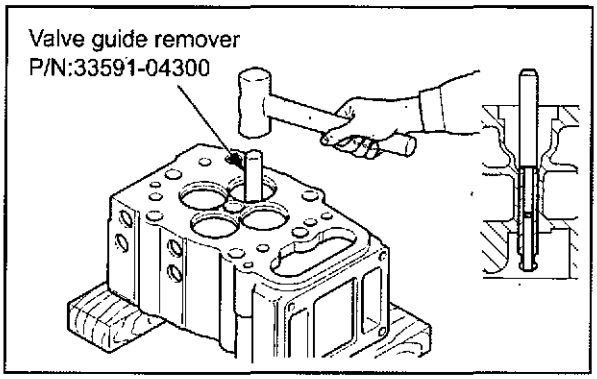
### 1.4 Replacing valve guide and stem seal

**CAUTION**

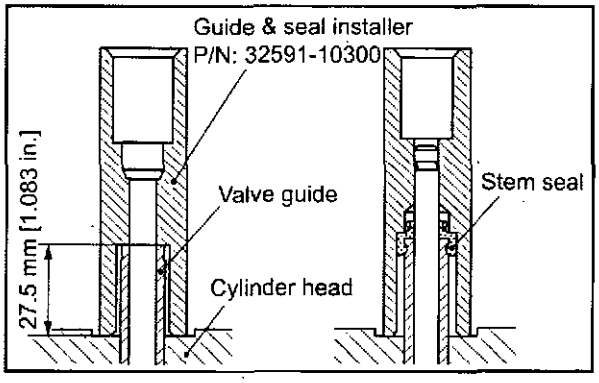
(a) The valve guide must be inserted to the specified depth. Be sure to use the guide/stem seal installer when press-fitting the valve guide.
(b) Do not apply oil or liquid gasket to the stem seal inside that comes in contact with the valve guide.
(c) Always replace the stem seal with a new one once it has been removed.

(1) Drive out the valve guide using the valve guide remover.
(2) Using the guide & seal installer, press-fit a new valve guide slowly into position.
(3) Press-fit a new stem seal onto the valve guide using the guide & seal installer.

Note: For initial lubrication of the stem seal lip, apply engine oil to the valve stem before installing the valve.




Removing valve guide




Installing valve guide and stem seal

### 1.5 Inspecting valve face

Apply a thin coat of Shinmyoutan or equivalent lead-free coloring paste on the valve face, and strike the valve face against the valve seat using a valve lapper to check for contact condition. If the contact is not even, or any defects are found, or if the limit is exceeded, reface or replace the valve.

Note: (a) Inspect the valve face after the valve guide is repaired or replaced.

(b) Do not rotate the valve when pressing the valve face coated with Shinmyoutan or equivalent lead-free dye against the valve seat.

(c) Always lap the valve and valve seat after the valve has been refaced or replaced.

| Item | | Standard | Limit |
|---|---|---|---|
| Valve seat | Valve seat angle | 30° | - |
| | Valve sinkage | -0.1 to 0.1 mm [-0.0040 to 0.0040 in.] | 1.0 mm [0.0394 in.] |
| | Seat width | 2.15 to 2.45 mm [0.0846 to 0.0965 in.] | 2.8 mm [0.110 in.] |
| Valve margin | | 2.8 to 3.2 mm [0.110 to 0.126 in.] | Refacing permissible up to 2.5 mm [0.098 in.] |

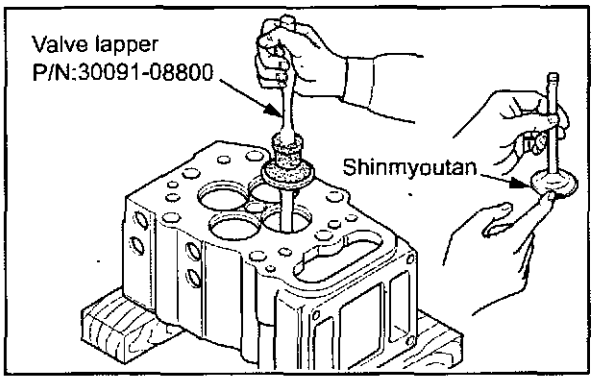
Use a depth gauge to measure the valve sinkage. Use a slide gauge to measure the seat width and the valve margin.

### 1.6 *Refacing valve face*

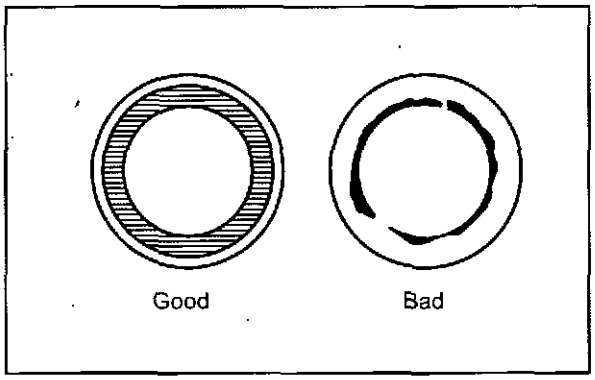
If the valve face is significantly worn out, reface the valve face using a valve refacer.

Note: (a) Grind the valve face using the valve refacer at the specified angle.

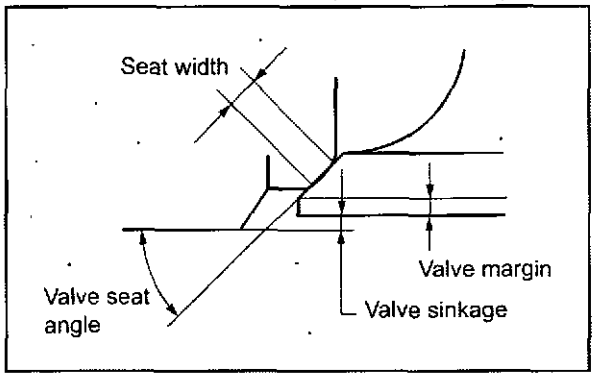
(b) Secure the valve margin width equal to or greater than the limit. If the dimensions after refacing *does not meet the specified values, replace the* valve with a new one.



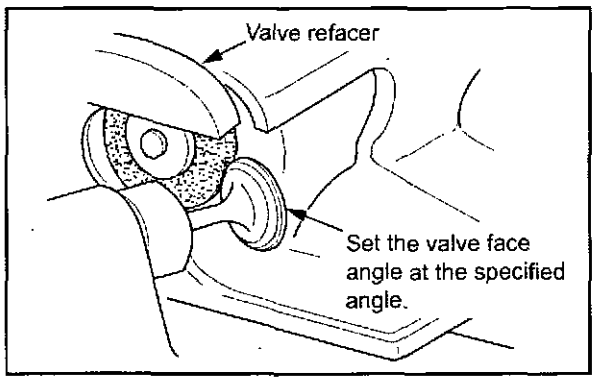

Inspecting valve face




Contact condition between valve seat and valve




Contact of valve seat and valve




Refacing valve face

### 1.7 Refacing valve seat

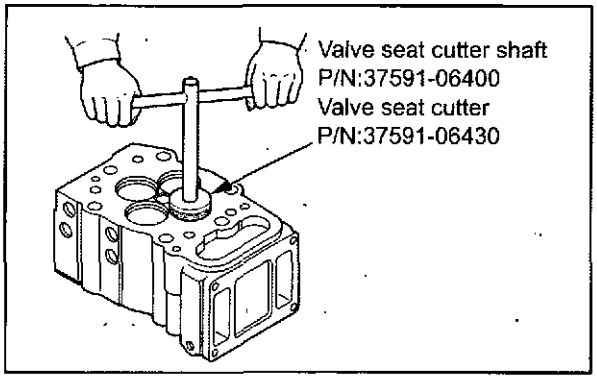
(1) Use the valve seat cutter or valve seat grinder to reface the valve seat. After refacing, sand the valve seat lightly using 400 grit sandpaper, inserting it between the cutter and valve seat.

(2) Lap the valve in the valve seat.

Note: (a) Valve seat refacing should be kept to an absolute minimum.

(b) If the valve seat width exceeds the limit due to wear or refacing, replace the valve seat with a new one.

(c) If the valve sinkage exceeds the limit after refacing, replace the valve seat with a new one.




Refacing valve seat

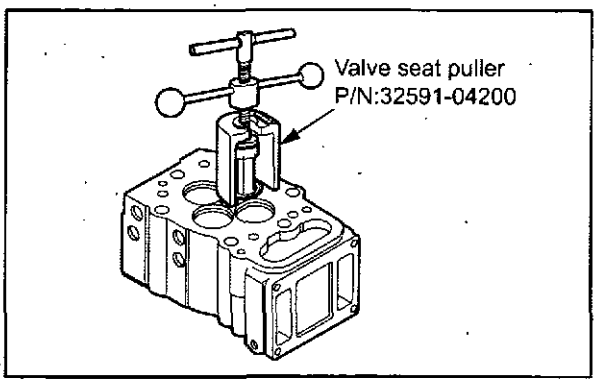
### 1.8 Replacing valve seat

**CAUTION**

Ensure the proper interference. Improper interference could cause the valve seat to fall off or the cylinder head to crack.

(1) Remove the valve seat insert using the valve seat puller.

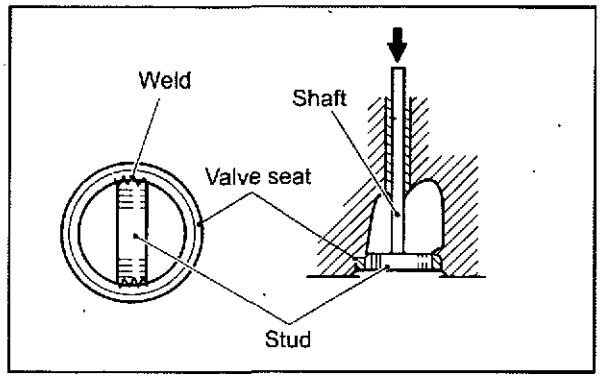
Note: Be careful not to damage the machined surface of cylinder head when removing the valve seat.




Removing valve seat using valve seat puller

(2) To remove the valve seat, weld a stud to the valve seat as illustrated. Then, insert a rod into the valve guide hole from the top of the cylinder head, and press out the valve seat with the rod.

Note: Be careful not to allow spatters to adhere to the machined surface of the cylinder head during welding.




Removing valve seat

(3) Before proceeding to valve seat fitting procedure, measure the inside diameter of the valve seat fitting bore in the cylinder head and the outside diameter of the valve seat insert to confirm that the specified interference is secured.

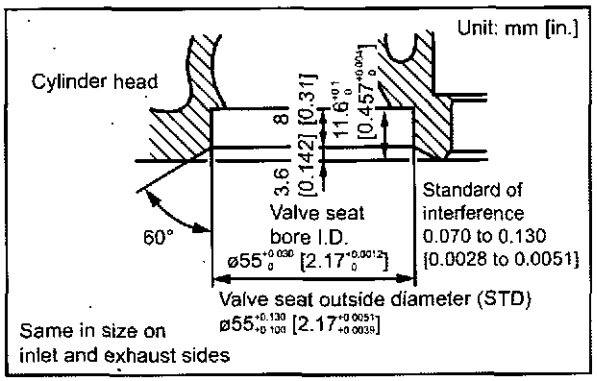
| Item | Nominal | Standard |
|---|---|---|
| Clearance between inside diameter of cylinder head bore and outside diameter of valve seat | ø 55 mm [2.17 in.] | -0.130 to -0.070 mm [-0.0051 to -0.0028 in.] |

Note: (a) Standard values prefixed with - (minus sign) indicate the interference fit.

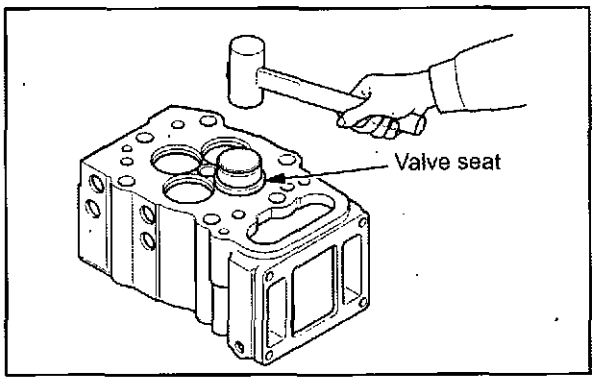
(b) Use a standard valve seat insert if the clearance meets the standard.

(4) Cool the valve seat at least for four minutes in liquid nitrogen before fitting it into the cylinder head that is kept at room temperature.

(5) Install the valve seat into the cylinder head using a installer.




Valve seat bore




Striking the valve seat

## 1.9 Lapping valve and valve seat

Always lap the valve against the valve seat after refacing the valve seat or after replacing the valve.

(1) Apply a thin coat of lapping compound evenly to the valve face.

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

(b) Compound spreads more evenly if it is mixed with a small amount of engine oil.

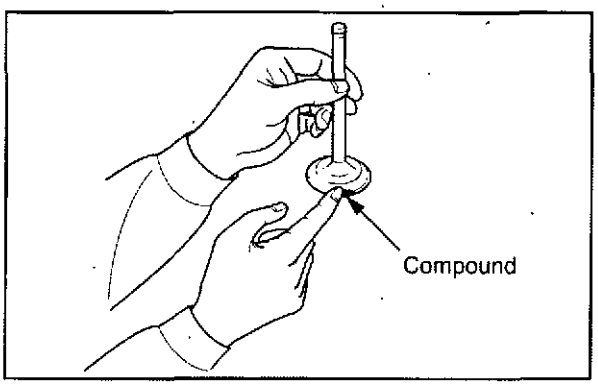
(c) Use medium-grain compound (120 to 150 mesh) for initial lapping, then use fine-grain compound (200 mesh or finer) for finishing.

(2) Use a valve lapper for lapping. Strike the valve against the valve seat while rotating the valve little by little.

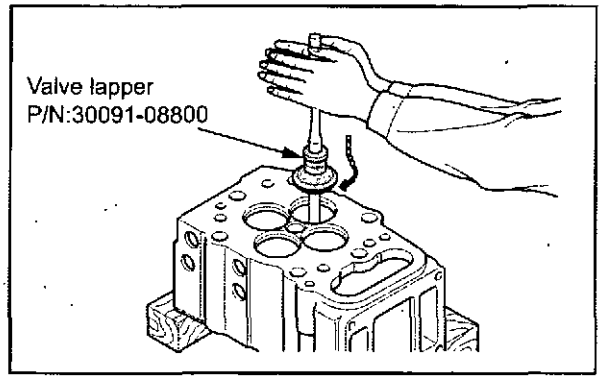
(3) Wash off the compound using diesel fuel.

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

(5) Check valve-to-seat contact.




Applying compound to valve face

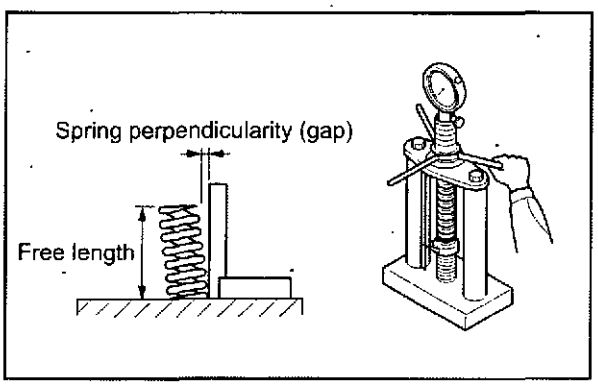



Lapping valve and valve seat

## 1.10 Measuring perpendicularity and free length of valve spring

Measure the perpendicularity and free length of the valve spring. If the limit is exceeded, replace the valve spring with a new one.

| | Item | Standard | Limit |
|---|---|---|---|
| Valve spring | Free length | 75.5 mm [2.776 in.] | 74 mm [2.91 in.] |
| | Perpendicularity |  θ = 1.5°or less Δ (gap) = 2.0 mm [0.079 in.] or less Lf = 75.5 mm [2.776 in.] | Δ = 2.3 [0.091] at the end |
| | Set length/ set force | 61.8 mm [2.433 in.]/ 403.3 N {41.13 kgf} [90.7 lbf] | - |
| Helper spring | Free length | 73 mm [2.87 in.] | 71 mm [2.80 in.] |
| | Perpendicularity |  θ = 1.5°or less Δ (gap) = 1.9 mm [0.075 in.] or less Lf = 73 mm [2.87 in.] | Δ = 2.2 [0.087] at the end |
| | Set length/ set force | 69.6 mm [2.740 in.]/ 24.2 N {24.7 kgf} [54.5 lbf] | - |



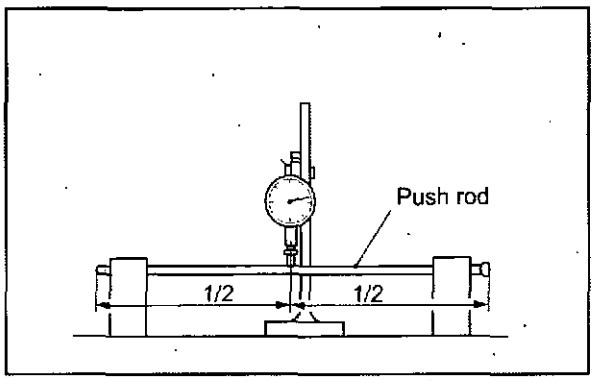

Measuring valve spring perpendicularity and free length

### 1.11 Measuring valve and UI helper push rod runout

Measure the runout of each push rod. Replace if the limit is exceeded.

| Item | Standard | Limit | Remark |
|---|---|---|---|
| Valve and UI helper push rod runout | 0.50 mm [0.020 in.] or less | 0.50 mm [0.020 in.] | TIR |

*Note: With a dial gauge set on the push rod, rotate the push rod on turn and read the gauge indication.*




Measuring valve and UI helper push rod runout

### 1.12 Measuring distortion of the bottom surface of the cylinder head

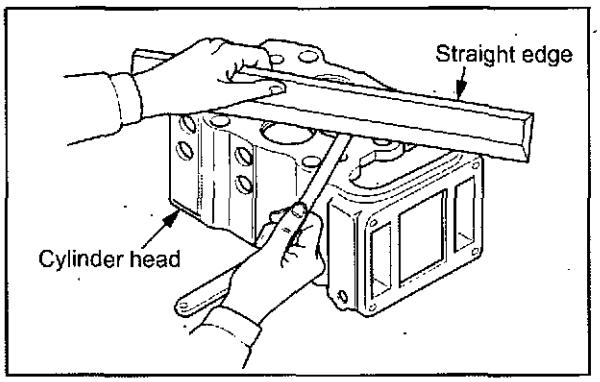
**CAUTION**

Refacing of cylinder head should be kept to an absolute minimum.

*Excessive grinding of the cylinder head may result in* defects such as defective combustion and stamping (contact between piston and valve).

With a straight edge placed on the bottom face of the cylinder head, measure the bottom face distortion using a *feeler gauge. If the measurement exceeds the limit, grind the* bottom face using a surface grinder.

| Item | Standard | Limit |
|---|---|---|
| Bottom surface distortion | 0.03 mm [0.0012 in.] or less | 0.50 mm [0.0197 in.] |



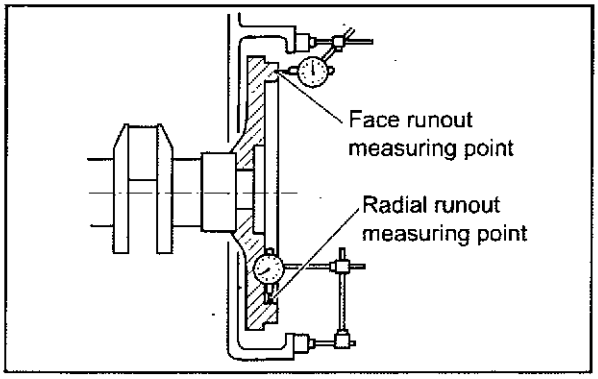

Measuring distortion of the bottom surface of the cylinder head

## 2. Inspecting and repairing flywheel, timing gear and camshaft

### 2.1 Measuring flywheel face and radial runouts

Measure the runouts of the flywheel in the installed condition. If the measured value exceeds the standard, check the bolt for looseness as well as the accumulation of foreign matter on the mounting face.

| Item | Standard |
|---|---|
| Face runout | 0.28 mm [0.0110 in.] or less |
| Radial runout | 0.13 mm [0.0051 in.] or less |

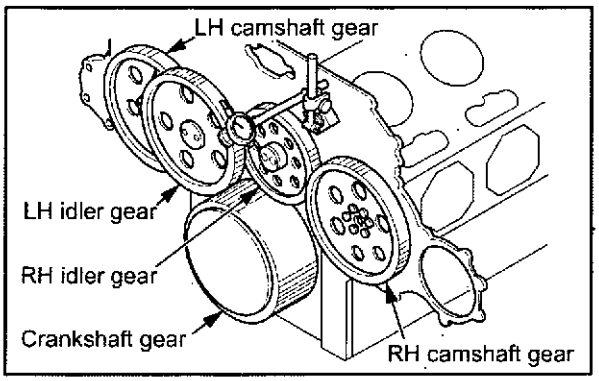



Measuring flywheel face and radial runouts

### 2.2 Measuring timing gear backlash

Measure the backlash of the timing gears by using one of the following two methods; measure the gear play with the dial gauge plunger applied to a tooth flank on the pitch circle at a right angle to the tooth axis, or measure the clearance between gears by inserting a feeler gauge between the gears at the tooth-to-tooth contacting area. Replace the faulty gear pair if the limit is exceeded.

| Item | Standard | Limit |
|---|---|---|
| Crankshaft gear to LH idler gear | 0.11 to 0.26 mm [0.0043 to 0.0102 in.] | 0.50 mm [0.0197 in.] |
| LH idler gear to LH camshaft gear | 0.10 to 0.24 mm [0.0039 to 0.0094 in.] | |
| LH idler gear to RH idler gear | 0.12 to 0.22 mm [0.0047 to 0.0087 in.] | |
| RH idler gear to RH camshaft gear | 0.11 to 0.25 mm [0.0043 to 0.0098 in.] | |

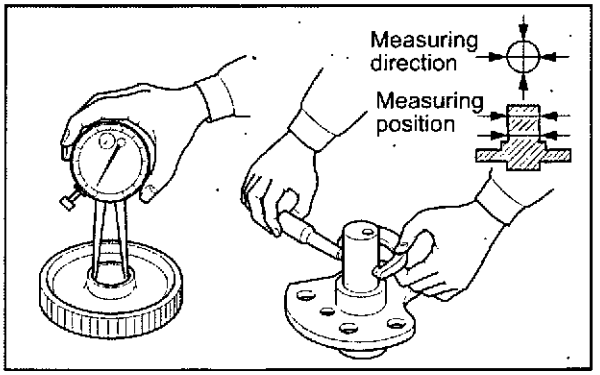



Measuring timing gear backlash

### 2.3 Measuring rear idler bushing inside dia. and rear idler shaft outside diameter

Measure the rear idler bushing inside diameter and the rear idler shaft outside diameter. If the inside diameter of rear idler bushing exceeds the limit, replace the rear idler bushing with a new one. If the outside diameter of rear idler shaft is less than the limit, replace the front rear idler shaft with a new one.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Rear idler bushing inside diameter | ø 50 mm [1.97 in.] | 50.000 to 50.025 mm [1.9685 to 1.9695 in.] | 50.060 mm [1.9709 in.] |
| Rear idler shaft outside diameter | ø 50 mm [1.97 in.] | 49.950 to 49.975 mm [1.9665 to 1.9675 in.] | 49.900 mm [1.9646 in.] |

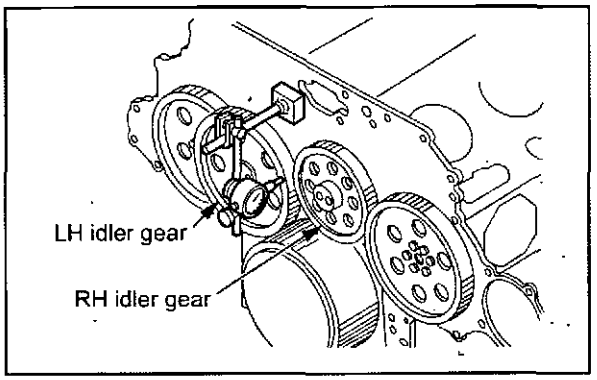



Measuring idler bushing inside dia. and shaft diameter

## 2.4 Measuring rear idler gear end play

Measure the end play of the rear idler gear. Replace the thrust plate with a new one if the limit is exceeded.

| Item | Standard | Limit |
|---|---|---|
| Rear idler gear end play | 0.3 to 0.5 mm [0.012 to 0.020 in.] | 0.7 mm [0.028 in.] |



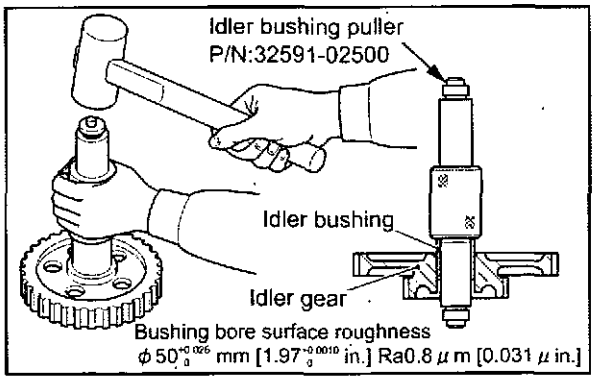

*Measuring idler gear end play*

## 2.5 Replacing rear idler bushing

(1) Use the idler bushing puller to replace rear idler bushing.

(2) After the bushing is fitted in the rear idler gear, use the removing side of the idler puller to drive the bushing farther until it sinks approx. 1 mm [0.04 in.] below the end face of the gear boss.

(3) After driving the bushing in position, measure the bushing inside diameter to ensure that it is within the standard. If the measurement is out of tolerance, ream the bore to the standard.

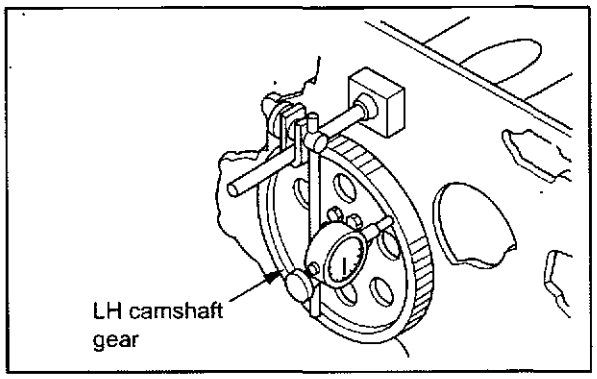



Replacing idler bushing

## 2.6 Measuring camshaft end play

Measure the camshaft end play with the camshaft gear attached. If the limit is exceeded, replace the thrust plate with a new one.

| Item | Standard | Limit |
|---|---|---|
| Camshaft end play | 0.2 to 0.4 mm [0.008 to 0.016 in.] | 0.55 mm [0.0217 in.] |

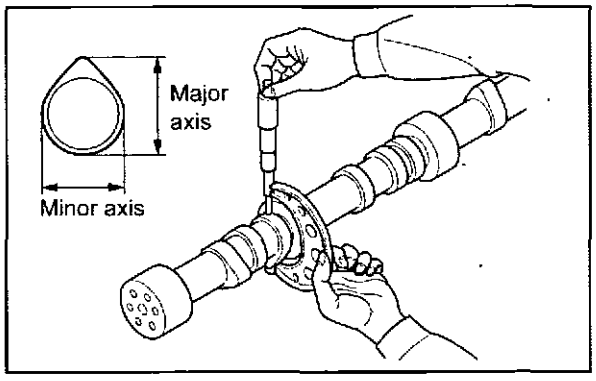



Measuring camshaft end play

## 2.7 Measuring cam lift

Measure the minor and major axes of cam to determine cam lobe lift. If the lift is less than the limit, replace the camshaft with a new one.

| Item | | Standard | Limit |
|---|---|---|---|
| Cam lift (major axis – minor axis) | Inlet | 14.25 to 14.45 mm [0.5610 to 0.5689 in.] | - |
| | Exhaust | 9.15 to 9.35 mm [0.3602 to 0.3681 in.] | - |



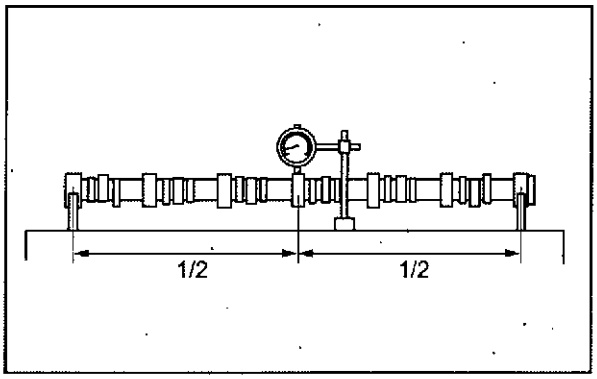

Measuring camshaft cam height

### 2.8 Measuring camshaft runout

Measure the camshaft runout using a dial gauge. If the limit is exceeded, correct the camshaft using a press, or replace the camshaft with a new one.

Note: With a dial gauge set on the camshaft, rotate the camshaft one turn and read the gauge indication.

| Item | Standard | Limit |
|---|---|---|
| Camshaft runout (TIR) | 0.10 mm [0.0039 in.] or less | 0.16 mm [0.0063 in.] |

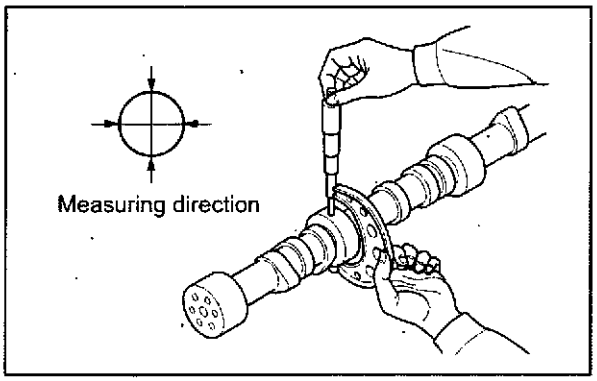



Measuring camshaft runout

### 2.9 Measuring camshaft journal outside diameter

Measure the diameter of each camshaft journal in two direction at right angles to each other. If the limit is exceeded, replace the camshaft with a new one.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Camshaft journal outside diameter | ø 100 mm [3.94 in.] | 99.920 to 99.940 mm [3.9339 to 3.9346 in.] | 99.860 mm [3.9315 in.] |




Measuring camshaft journal diameter

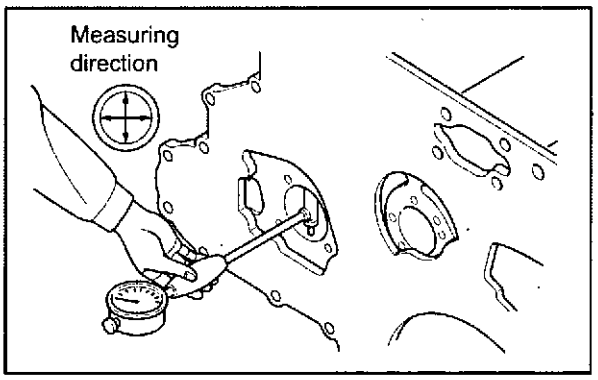
### 2.10 Inspecting camshaft bushing

(1) Check the inside surface of each bushing for damage, corrosion, delamination and other abnormalities. If any defect is found, replace the camshaft bushing with a new one.

(2) Measure the camshaft bushing inside diameter with the bushing installed in the crankcase. If the measurement exceeds the limit, replace the bushing with a new one.

Note: When measuring the inside diameter of the camshaft bushing, be careful not to cause damage to the inside surface of the bushing.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Camshaft bushing inside diameter | ø 100 mm [3.94 in.] | 100.038 to 100.095 mm [3.9385 to 3.9407 in.] | 100.160 mm [3.9433 in.] |

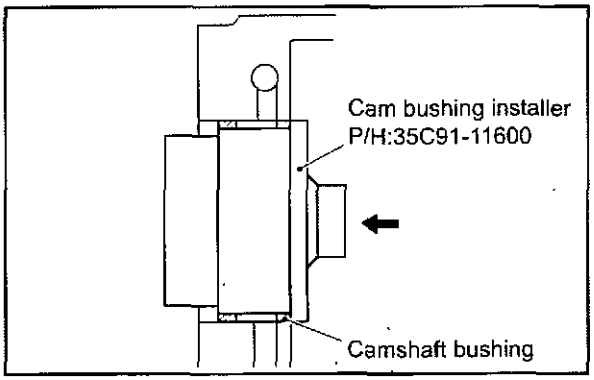



Measuring camshaft bushing inside diameter

## 2.11 Replacing camshaft bushing

### 2.11.1 Removing camshaft bushing

Using the cam bushing installer, remove the camshaft bushing.




Removing camshaft bushing

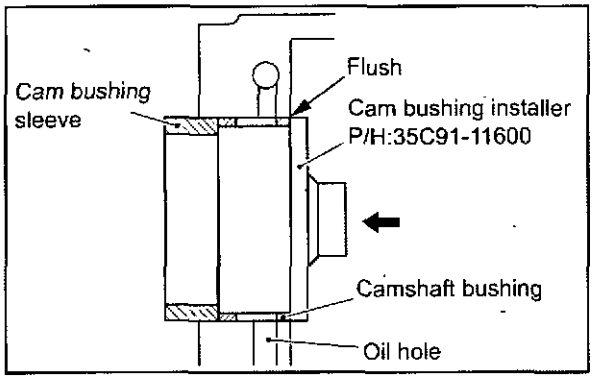
### 2.11.2 Installing camshaft bushing

(1) Insert the cam bushing installer into the camshaft bushing and install the cam bushing sleeve.

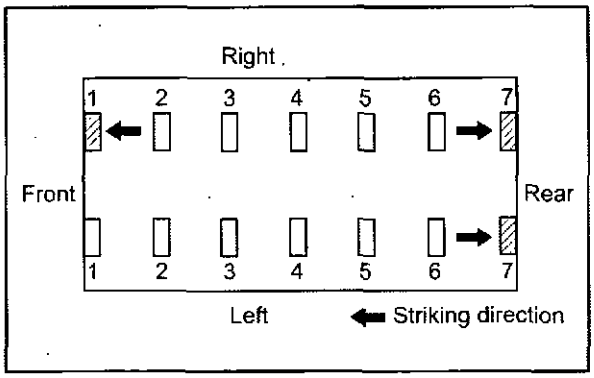
(2) With the cut of camshaft bushing facing upward, align the hole in the camshaft bushing with the hole in the crankcase, and fit the camshaft bushing into the camshaft fitting bore.

(3) Drive the cam bushing installer until the end face of cam shaft bushing becomes flush with the crankcase end face.

Note: Camshaft bushings of No.7 on the left bank and No.1 and No.7 on the right bank should be driven from the inner side of crankcase. Oil holes will not align if they are driven in the wrong direction.




Installing camshaft bushing (1)

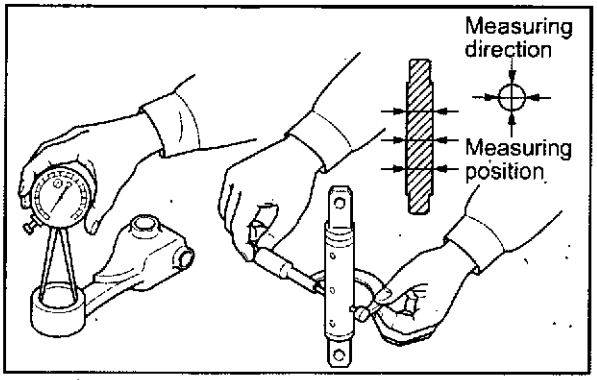



Installing camshaft bushing (2)

### 2.12 Measuring follower bushing inside diameter and follower shaft diameter

Measure the follower bushing inside diameter and follower shaft diameter. If the limit is exceeded, replace the worn parts.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Follower bushing inside diameter | ø 30 mm [1.18 in.] | 30.000 to 30.075 mm [1.1811 to 1.1841 in.] | 30.125 mm [1.1860 in.] |
| Follower shaft outside diameter | ø 30 mm [1.18 in.] | 29.959 to 29.980 mm [1.1795 to 1.1803 in.] | 29.930 mm [1.1783 in.] |



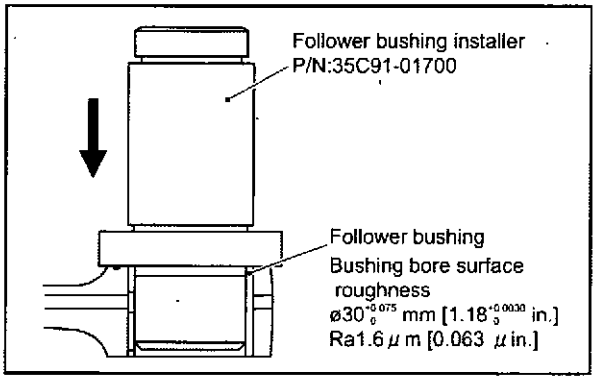

Measuring follower bushing inside diameter and follower shaft diameter

### 2.13 Replacing follower bushing

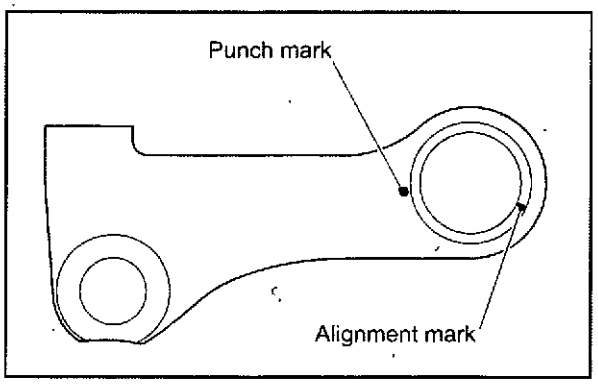
(1) To replace the bushing, use the follower bushing installer.

(2) Install the bushing with placing the bushing notch to opposite angles of the punch mark (oil hole match mark for bushing) on the follower.

(3) After installing the bushing, make sure the bushing inside diameter is within the standard. If it exceeds the standard, ream the bushing.




Replacing follower bushing



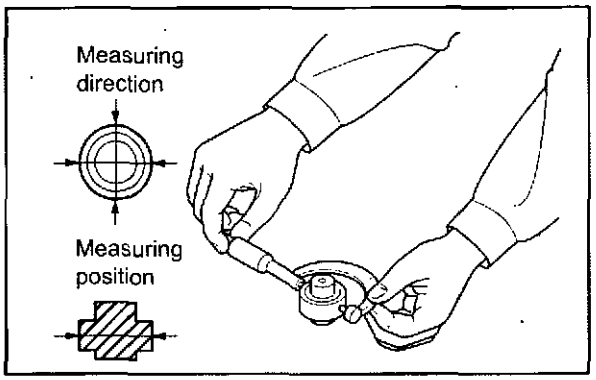

Installing location of follower bushing

### 2.14 Measuring tappet roller diameter

Measure the tappet roller diameter.

If the limit is exceeded, replace the tappet roller.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Tapper roller diameter | ø 41 mm [1.61 in.] | 40.95 to 41.05 mm [1.6122 to 1.6161 in.] | 40.94 mm [1.6118 in.] |

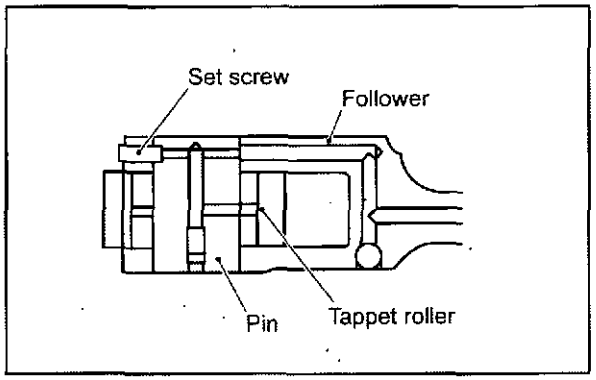



Measuring tappet roller

### 2.15 Replacing tappet roller

(1) When installing the tappet roller on the follower, watch the pin of hole with the follower. For this purpose, drive in the pin set screw to match with the follower set screw.

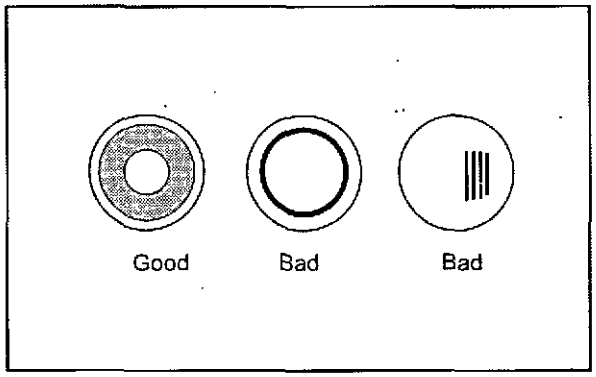
(2) Apply loctite to the set screw and tighten the screw, then retighten it.




Replacing tappet roller

### 2.16 Inspecting tappet

Inspect the cam contact surface of the tappets. Fit new tappets if the surface is excessively worn or damaged.




Contact surface of tappet and cam

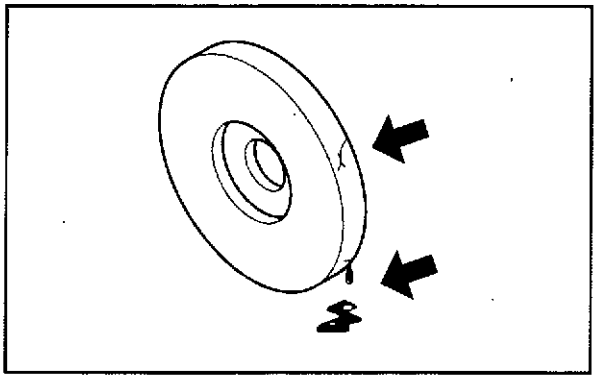
## 3. Inspecting and repairing damper and front gear

### 3.1 Inspecting damper

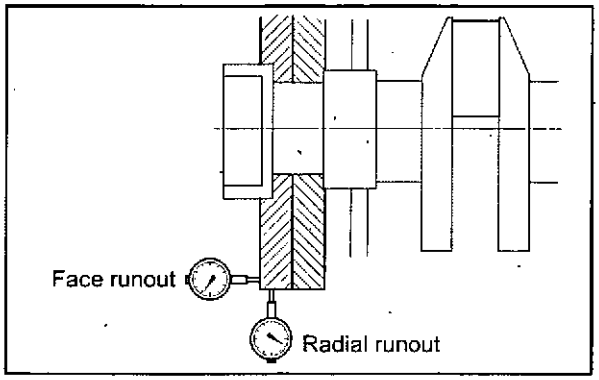
(1) Check the damper for cracks around the outer periphery, swelling and/or cracks in the end plate, silicone oil leakage and discoloration and separation of coating due to thermal effect.
If any defect is found, replace the damper with a new one.

(2) With the damper installed on the engine, measure the face and radial runouts of the damper in the following manner: Attach the dial gauge plunger on the outer circumference of the damper to measure the radial runout, or on the end face near the perimeter to measure the face runout, and slowly turn the crankshaft. If the limit is exceeded, replace the damper with a new one.

| Item | Standard | Limit |
|---|---|---|
| Face runout | 0.5 mm [0.020 in.] or less | 1.5 mm [0.059 in.] |
| Radial runout | 0.5 mm [0.020 in.] or less | 1.5 mm [0.059 in.] |



Inspecting damper visually

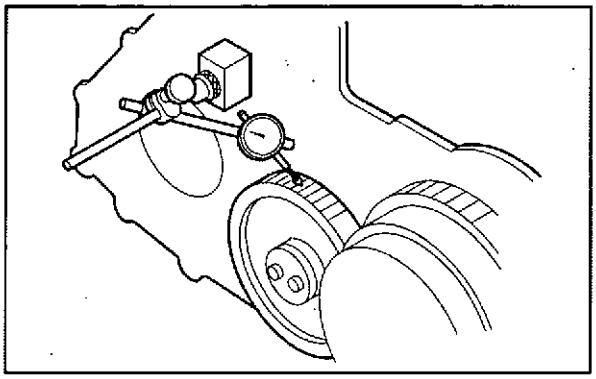



Measuring damper face and radial runouts

### 3.2 Measuring front gear backlash

Set a dial gauge squarely to the axial direction so that it is in contact with the pitch circle of the gear, and measure the backlash between the gears. If a dial gauge is not available, measure the backlash by inserting feeler gauges between the teeth of the gear. If the limit is exceeded, replace the gear.

| Item | Standard | Limit |
|---|---|---|
| Front crankshaft gear to front idler gear | 0.11 to 0.28 mm [0.0043 to 0.0110 in.] | 0.50 mm [0.0197 in.] |
| Front idler gear to water pump gear | 0.12 to 0.18 mm [0.0047 to 0.0071 in.] | |

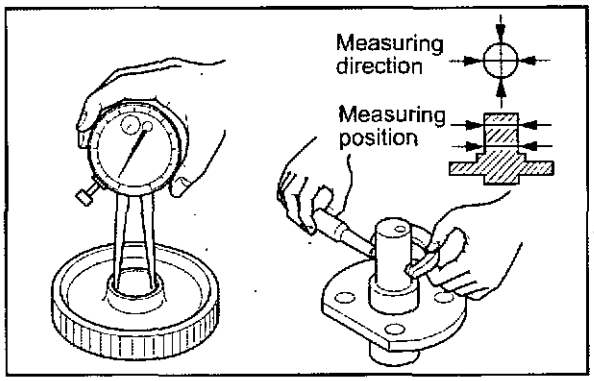


Measuring front idler gear backlash

### 3.3 Measuring front idler bushing inside dia. and front idler shaft outside diameter

Measure the front idler bushing inside diameter and idler shaft diameter. If the limit is exceeded, replace the worn parts.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Front idler bushing inside diameter | ø 50 mm [1.97 in.] | 50.000 to 50.025 mm [1.9685 to 1.9695 in.] | 50.060 mm [1.9709 in.] |
| Front idler shaft outside diameter | ø 50 mm [1.97 in.] | 49.950 to 49.975 mm [1.9665 to 1.9675 in.] | 49.900 mm [1.9646 in.] |

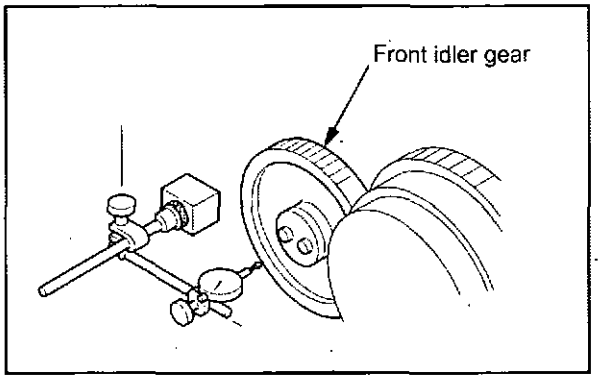



Measuring front idler bushing inside dia. and shaft diameter

### 3.4 Measuring front idler gear end play

Measure the end play of the front idler gear. Replace the thrust plate with a new one if the limit is exceeded.

| Item | Standard | Limit |
|---|---|---|
| Front idler gear end play | 0.3 to 0.5 mm [0.012 to 0.020 in.] | 0.7 mm [0.028 in.] |



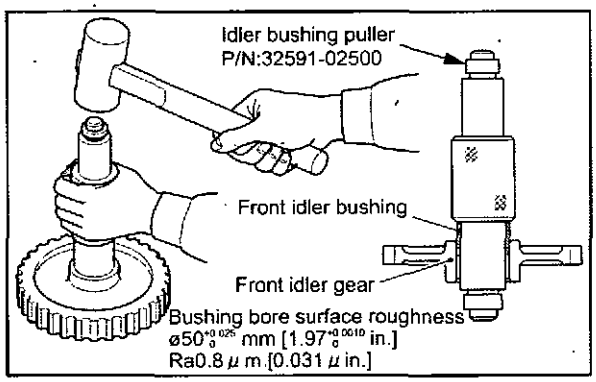

Measuring front idler gear end play

### 3.5 Replacing front idler bushing

(1) Use the idler bushing puller to replace front idler bushing.

(2) After the bushing is fitted in the front idler gear, use the removing side of the idler puller to drive the bushing farther until it sinks approx. 1 mm [0.04 in.] below the end face of the gear boss.

(3) After driving the bushing in position, measure the bushing inside diameter to ensure that it is within the standard. If the measurement is out of tolerance, ream the bore to the standard.




Replacing front idler bushing

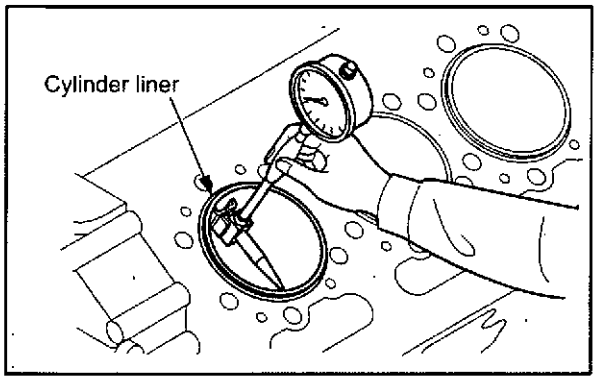
## 4. Inspecting and repairing cylinder liner, piston and connecting rod

### 4.1 Measuring cylinder liner inside diameter

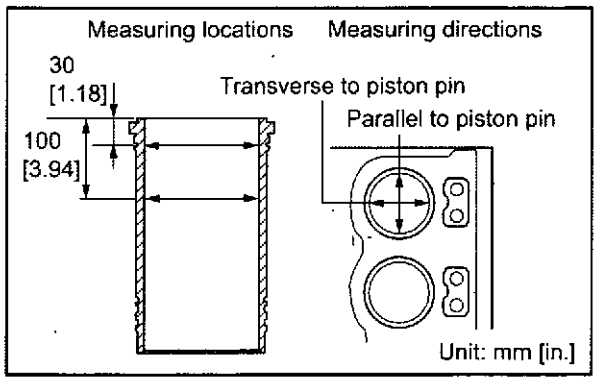
Measure the inside diameter of the cylinder liners at two levels each, i.e., upper (with much stepped wear) and middle levels, in both directions parallel to and perpendicular to the piston pin direction.

Replace the cylinder liner if the limit is exceeded.

| | Item | Nominal | Standard | Limit |
|---|---|---|---|---|
| Cylinder liner | Inside diameter | ø 150 mm [5.91 in.] | 150.000 to 150.040 mm [5.9055 to 5.9071 in.] | 150.140 mm [5.9110 in.] |
| | Roundness | - | 0.02 mm [0.0008 in.] or less | - |
| | cylindericity | - | 0.02 mm [0.0008 in.] or less | - |
| | Perpendicularity of flange bottom surface to cylinder liner longitudinal centerline | - | 0.03 mm [0.0012 in.] or less | - |




Measuring cylinder liner inside diameter




Cylinder liner dimension measuring position

### 4.2 Measuring cylinder liner flange protrusion

**CAUTION**

If the amount of protrusion is insufficient, the cylinder head gasket will fail to seal the bores hermetically, resulting in gas or water leakage.

Measure the cylinder liner flange protrusion at each cylinder.

The method of measuring the cylinder liner flange protrusion differs depending on whether the cylinder liner is replaced or not.

| Item | Standard |
|---|---|
| Cylinder liner collar protrusion above crankcase top surface | 0.10 to 0.19 mm [0.0039 to 0.0075 in.] |

### 4.2.1 When cylinder liner is not replaced

(1) Make sure that the top surface of crankcase and the upper end of cylinder liner are clean before measurement.

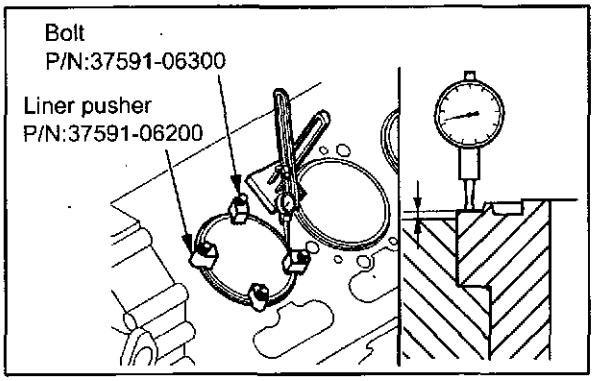
(2) Attach the liner holders on equally spaced 4 locations of the cylinder liner upper rim and tighten the bolts of the holders evenly to press the cylinder liner against the crankcase top surface.

Note: When using cylinder head bolts to secure liner holders, be sure to use a head bolt spacer.

(3) Apply the dial gauge plunger to the top surface of the crankcase, and zero the dial gauge.

(4) Measure the flange protrusion at four locations on the top of the cylinder liner, and obtain the mean value.

(5) If the mean value of the protrusion is smaller than the standard, insert a shim under the cylinder liner flange.

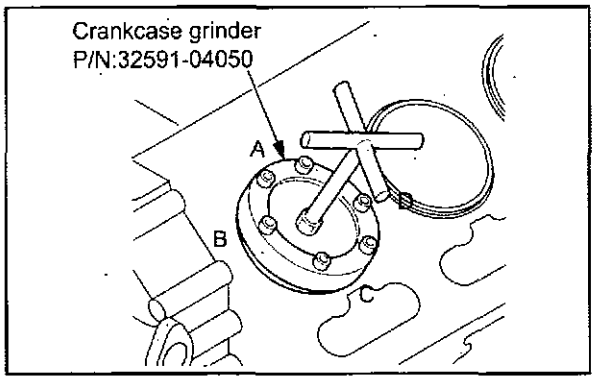



Measuring cylinder liner collar protrusion

### 4.2.2 When cylinder liner is replaced

(1) Remove the old cylinder liner, and check the cylinder liner seating surface on the crankcase.

(2) If there is any evidence of uneven contact, grind the seating surface using the crankcase grinder such that the difference in depth at points A, B, C and D is less than 0.05 mm [0.0020 in.].



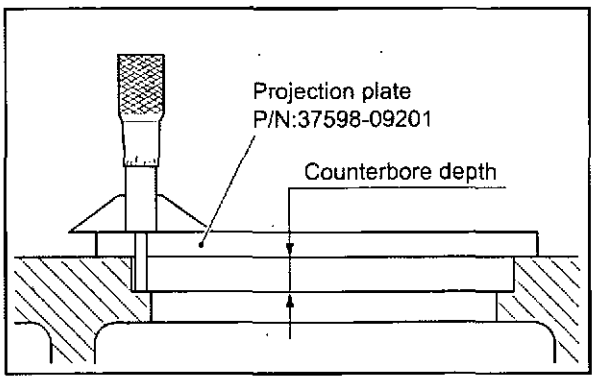

Measuring crankcase counterbore depth

(3) Measure the depth of the counterbore in the crankcase. Because of the possibility of the crankcase top surface distortion, use a projection plate when measuring.

(4) Calculate the mean value of the 4 measurements at points A, B, C and D.

(5) Measure the thickness of the projection plate (standard: 15 mm [0.6 in.]) using a micrometer. Determine the actual counterbore depth from the top surface of the crankcase by subtracting the projection plate thickness from the measured counterbore depth.

| Item | Standard |
|---|---|
| Crankcase counterbore depth | 15.00 to 15.05 mm [0.5906 to 0.5925 in.] |



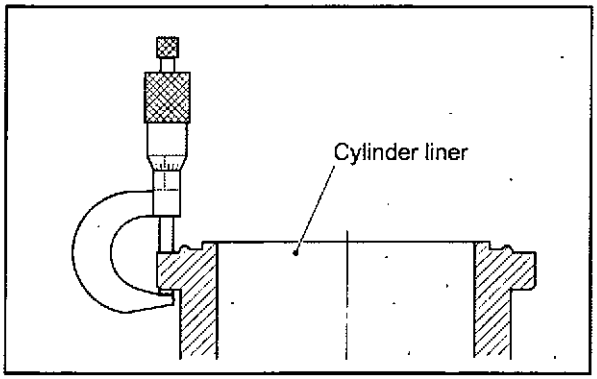

Measuring crankcase counterbore depth

(6) Measure the thickness of the cylinder liner flange using a micrometer

| Item | Standard |
|---|---|
| Thickness of cylinder liner flange | 15.15 to 15.19 mm [0.5965 to 0.5980 in.] |

(7) Calculate the cylinder liner flange protrusion by subtracting the counterbore depth from the thickness of the cylinder liner flange.

(8) If the calcurated value is smaller than the standard, place a shim of an appropriate thickness under the cylinder liner flange.



Thickness of cylinder liner collar

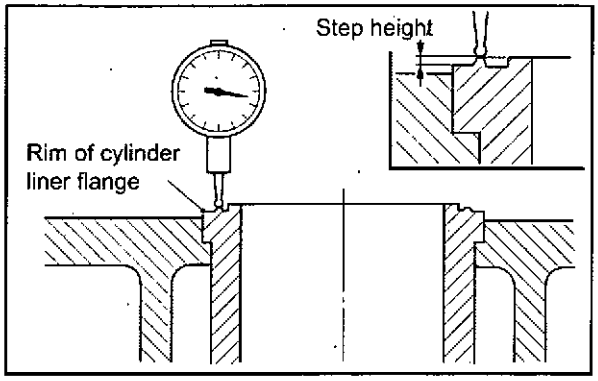
### 4.2.3 Measuring cylinder liner top ridge height

(1) Place the dial gauge plunger on the top surface of the cylinder liner flange, and zero the dial gauge.

(2) Measure the height of the annular top ridge of the cylinder liner at four locations, and obtain the mean value.

(3) If the mean value is smaller than the standard, or the ridge is fractured, replace the cylinder liner with a new one.

| Item | Standard |
|---|---|
| Height of cylinder liner top ridge | 0.16 to 0.24 mm [0.0063 to 0.0094 in.] |



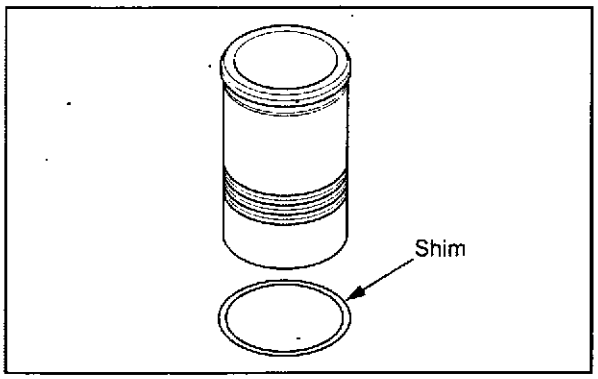
Measuring cylinder liner top ridge height

### 4.2.4 Inserting cylinder liner shim

Pull out the cylinder liner, and insert a shim between the cylinder liner and the crankcase.

Note: Shims shown in the following table are available for adjustment. Select a shim which makes the cylinder liner flange projection the largest within the tolerance of the standard.

| Shim thickness | Part No. |
|---|---|
| 0.05 mm [0.0020 in.] | 35C07-09600 |
| 0.10 mm [0.0039 in.] | 35C07-09200 |
| 0.15 mm [0.0059 in.] | 35C07-09700 |
| 0.20 mm [0.0079 in.] | 35C07-09300 |
| 0.25 mm [0.0098 in.] | 35C07-09800 |
| 0.30 mm [0.0118 in.] | 35C07-09400 |
| 0.35 mm [0.0138 in.] | 35C07-09900 |
| 0.40 mm [0.0157 in.] | 35C07-09500 |



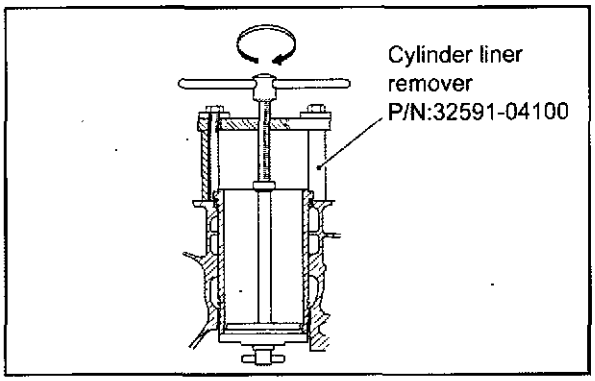
Inserting cylinder liner shim

### 4.3 Replacing cylinder liner

**CAUTION**

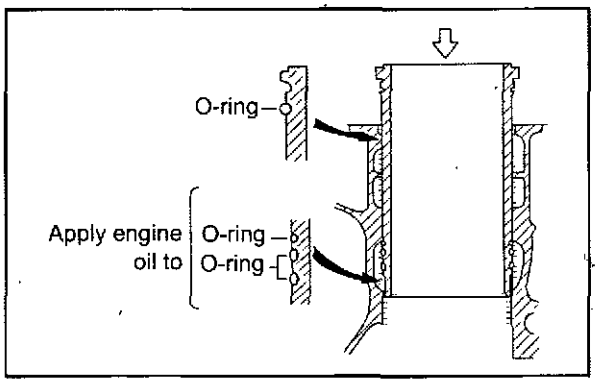
Apply engine oil to the O-rings to prevent them from twisting.

(1) Using the cylinder liner remover, remove the cylinder liner.




Removing cylinder liner

(2) Install new O-rings to the new cylinder liner.

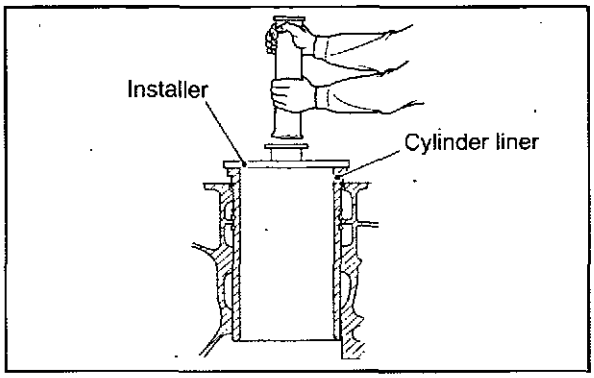



Installing cylinder liner O-ring

(3) Slowly insert the cylinder liner into the bore in the crankcase. Using the installer, lightly tap the cylinder liner until its flange rests snugly on the seating surface of the crankcase. Then, give several light taps on the liner to settle.

Note: (a) After the installation, conduct a water-pressure leak test to check for air-tightness.

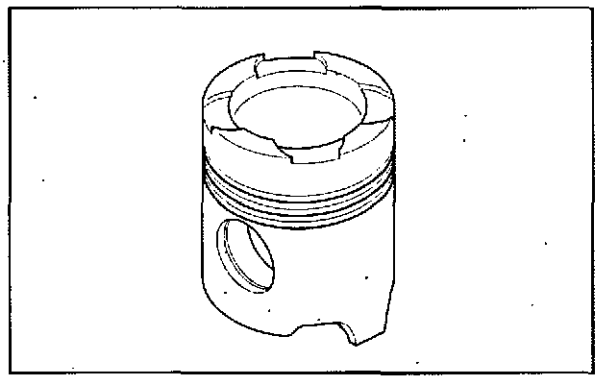
(b) Check the cylinder liner flange protrusion from the crankcase top surface.




Installing cylinder liner

### 4.4 Visual inspection of piston

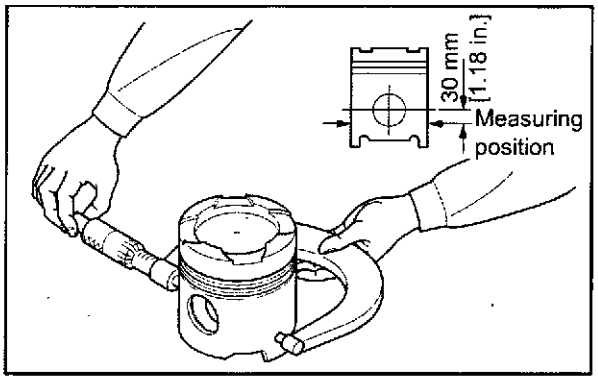
Check the combustion surface of the piston and the piston pin bore. If any defect is found, replace the piston with a new one.



Inspecting piston visually

### 4.5 Measuring piston outside diameter

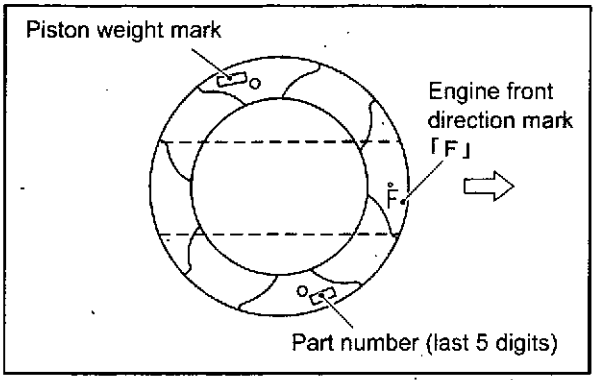
(1) Measure the piston outside diameter of the piston skirt at right angles to the piston pin. If it is less than the limit, replace the piston with a new piston. When replacing piston, be sure to select a piston so that the piston weight difference in one engine is kept within the permissible range.




Measuring piston outside diameter

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

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Piston outside diameter | ø 150 mm [5.91 in.] | 149.78 to 149.82 mm [5.8968 to 5.8984 in.] | 149.68 mm [5.8929 in.] |
| Weight difference | - | in one engine ± 30 g[± 0.07 lb] or less | - |




Piston weight stamp location

### 4.6 Measuring clearance between piston ring groove and piston ring

**CAUTION**

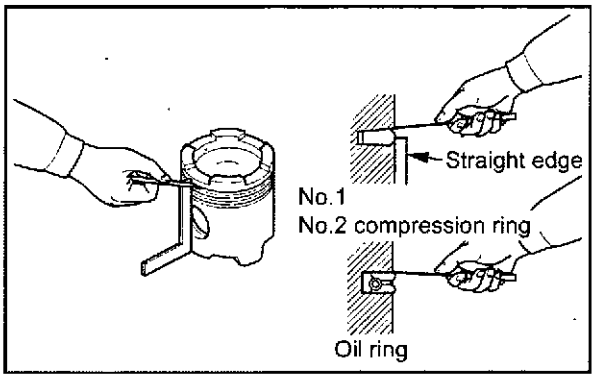
Remove carbon deposits from pistons and check the entire circumference of the piston.

(1) Remove deposits such as carbon from each ring groove.

(2) Check each ring groove for wear or damage. If it is worn or damaged, replace the piston with a new one.

(3) Insert the piston ring into the piston ring groove. Apply a straight edge and insert thickness gauges to measure the clearance between ring and ring groove.
If the limit is exceeded, replace the piston ring with a new one.

(4) When the piston ring has been replaced, measure the clearance again, and if the limit is exceeded, then replace the piston with a new one.



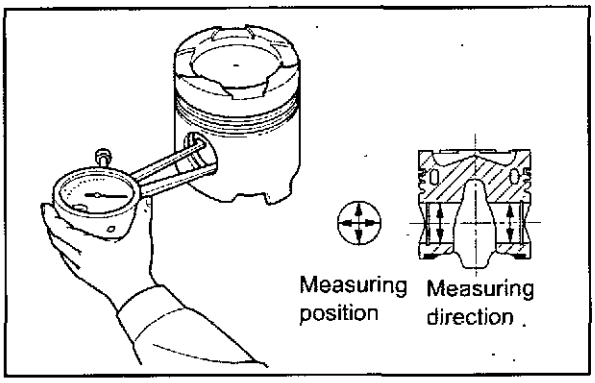

Measuring piston ring side clearance

| Item | | Nominal | Standard | Limit |
|---|---|---|---|---|
| Piston ring side clearance (With new rings) | No.1 compression | 3.00 mm [0.1181 in.] | 0.08 to 0.11 mm [0.0032 to 0.0043 in.] | 0.20 mm [0.0079 in.] |
| | No.2 compression | 2.55 mm [0.1004 in.] | 0.07 to 0.10 mm [0.0028 to 0.0039 in.] | 0.15 mm [0.0059 in.] |
| | Oil | 5.00 mm [0.1969 in.] | 0.05 to 0.09 mm [0.0020 to 0.0035 in.] | 0.15 mm [0.0059 in.] |

### 4.7 Measuring piston pin bore

Measure the piston pin bore diameter. If the limit is exceeded, replace the piston with a new one.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Piston pin bore diameter | ø 58 mm [2.28 in.] | 58.002 to 58.012 mm [2.2835 to 2.2839 in.] | 58.020 mm [2.2842 in.] |




Measuring piston pin bore

### 4.8 Measuring piston protrusion

**CAUTION**

Piston protrusion must always meet the standard, as the amount of protrusion not only influences on the engine performance, but also it is important to prevent valve interference.

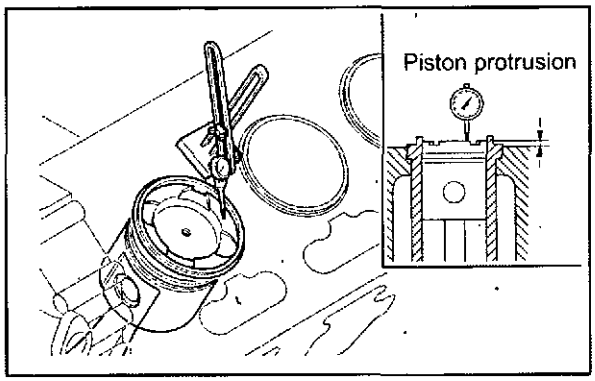
Measure the protrusion of each piston following the instructions below. If the measured value does not meet the standard, inspect the clearances between various parts involved.

(1) Bring the piston to the top dead center.

(2) Apply the dial gauge plunger to the top surface of the crankcase, and zero the dial gauge.

(3) Measure the protrusion at four points on the piston head, and calculate the mean value.

Note: Subtract the mean value from the thickness of the gasket compressed by tightening the cylinder head, and the clearance between the piston top and cylinder head will be determined.




Measuring piston protrusion

| Item | Standard |
|---|---|
| Piston protrusion | 0.38 to 0.89 mm [0.015 to 0.035 in.] |
| Thickness when tightened (cylinder head gasket) | 1.77 to 1.83 mm [0.0697 to 0.0720 in.] |
| Clearance between piston and cylinder head | 0.88 to 1.45 mm [0.0346 to 0.0571 in.] |

## 4.9 Replacing standard of piston ring

**CAUTION**

Replace the piston rings with new ones at every periodical overhaul even if they are considered to be reusable. Sustained use of such piston rings can lead to abnormal engine operation such as increased blow-by combustion gas.

Piston rings should be replaced with new ones at every overhaul unless otherwise specified.

However, at an engine disassembly made for some reason before the next periodical overhaul, the piston ring replacement is not required, provided that no abnormalities are found when making the following inspections.

### 4.9.1 Visual inspection of piston ring

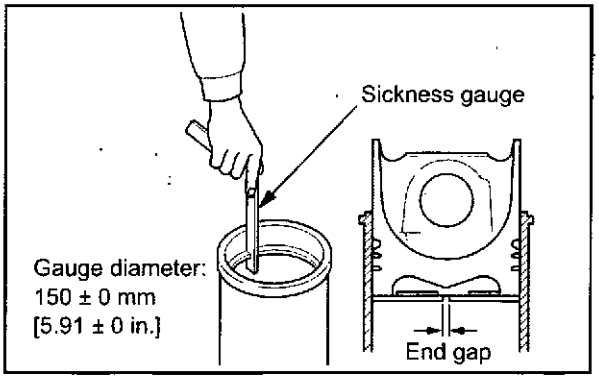
Check sliding parts for injurious seizures, sticking, abnormal wear and plating peeling due to carbon biting. If any defect is found, replace piston rings with new ones.

### 4.9.2 Measuring piston ring end gap

Place the piston rings in a gauge or a new cylinder liner, and measure the gap of each ring with feeler gauges. If the limit is exceeded, replace all the rings as a set.

Note: Using a piston, push the piston ring squarely into the gauge or the cylinder liner.

| Item | | Standard | Limit |
|---|---|---|---|
| Piston ring end gap | No.1 compression | 0.6 to 0.8 mm [0.024 to 0.031 in.] | 2.0 mm [0.079 in.] |
| | No.2 compression | 0.5 to 0.7 mm [0.020 to 0.028 in.] | |
| | Oil ring | 0.5 to 0.7 mm [0.020 to 0.028 in.] | |



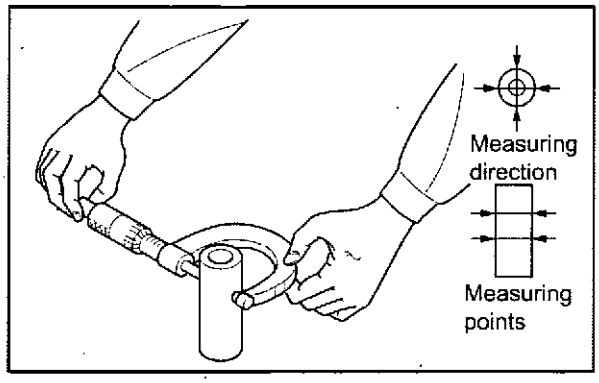

Measuring piston ring end gap

## 4.10 Measuring piston pin outside diameter

Measure the piston pin outside diameter.

If it is less than the limit, replace the piston pin with a new one.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Piston pin outside diameter | ø 58 mm [2.28 in.] | 57.987 to 58.000 mm [2.2829 to 2.2835 in.] | 57.970 mm [2.2823 in.] |

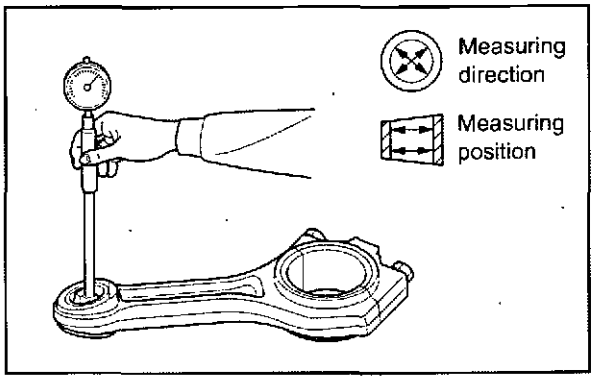



Measuring piston pin diameter

### 4.11 Measuring connecting rod bushing inside diameter

Measure the inside diameter of the connecting rod bushing. If the limit is exceeded, replace the connecting rod bushing with a new one.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Connecting rod bushing inside diameter | ø 58 mm [2.28 in.] | 58.020 to 58.040 mm [2.2842 to 2.2850 in.] | 58.070 mm [2.2862 in.] |




Measuring connecting rod bushing inside diameter

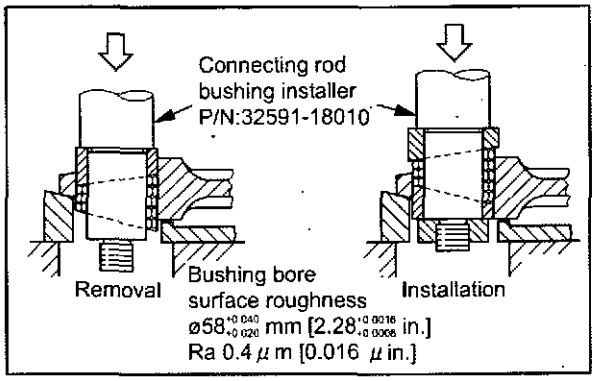
### 4.12 Replacing connecting rod bushing

(1) Use the connecting rod bushing installer to replace the connecting rod bushings. (The usage of the connecting rod bushing installer is described later.)

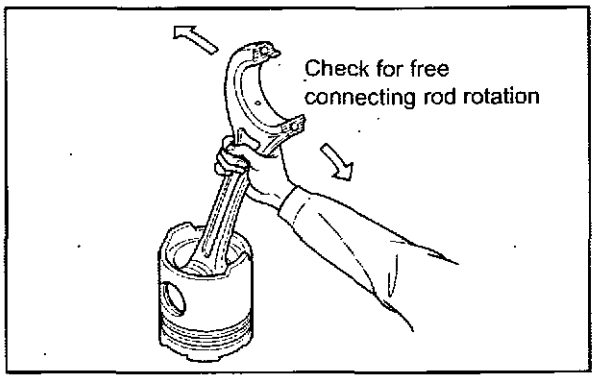
(2) Align the oil hole in the bushing with that in the connecting rod.

(3) After press-fitting the bushing, measure the bushing inside diameter. If the measurement is out of tolerance, ream the bore to the standard. Note that the out-of-parallelism with respect to the big end bearing must be maintained within 0.05 mm [0.0020 in.].

(4) After press-fitting the bushing, insert the piston pin and check that the connecting rod is allowed to swing smoothly without any excessive play.




Replacing connecting rod bushing

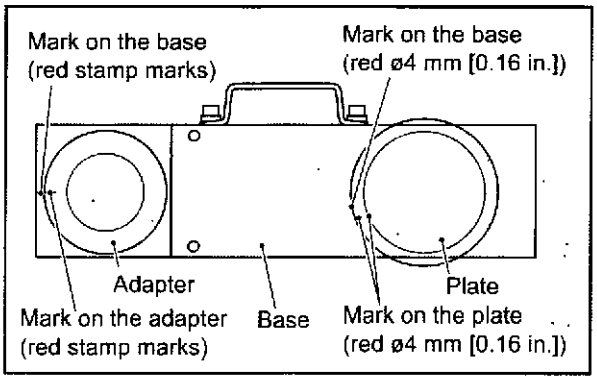



Inspecting connecting rod movement

### 4.12.1 Usage of connecting rod bushing installer

(1) Install the adapter on the base with the match marks (red scribed lines) in alignment.

(2) Install the plate on the base with the match marks (ø 4 mm [0.16 in.] red dots) in alignment.

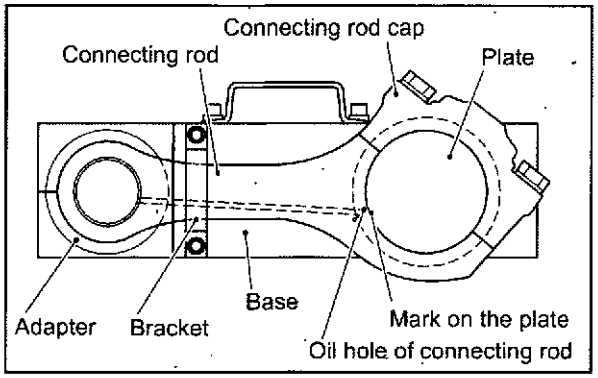



Connecting rod bushing installation procedure (1)

(3) Assemble the connecting rod to the connecting rod cap without fitting the connecting rod bearing.

(4) Install the connecting rod assembly on the base while aligning the oil hole in the connecting rod big end with the match mark (ø 4 mm [0.16 in.] red dot) for the plate and the connecting rod small end with the adapter.

(5) Secure the connecting rod in place with the bracket.



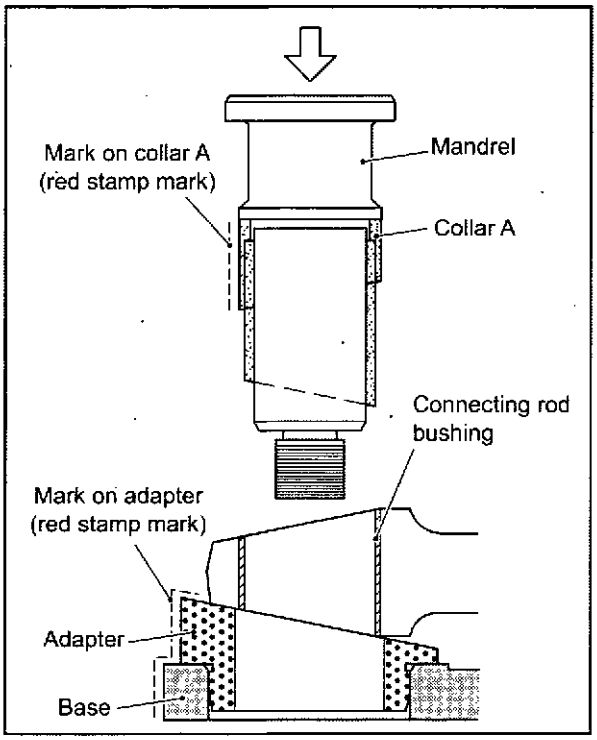

Connecting rod bushing installation procedure (2)

### 4.12.2 Removing connecting rod bushing

(1) Lubricate the inside surface of the connecting rod bushing with engine oil.

(2) Attach the collar A to the mandrel and insert the assembly into the connecting rod bushing while aligning the match mark (red scribed line) on the collar A with that on the adapter.

(3) Using a press, apply pressure slowly on the head of the mandrel to force out the connecting rod bushing.




Connecting rod bushing installation procedure (3)

### 4.12.3 Press fitting of connecting rod bushing

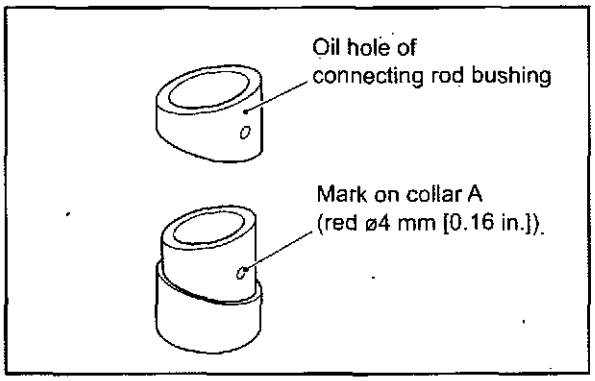
**CAUTION**

(a) Be sure to confirm that the match marks (red scribed lines) on collars A and B are in alignment.

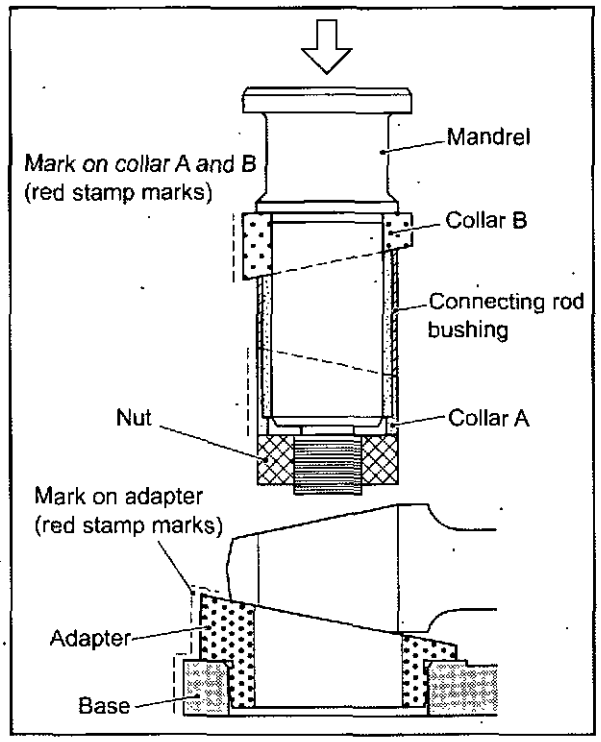
(b) Be sure to confirm that the oil hole in the connecting rod bushing is in alignment with the match mark (ø 4 mm [0.16 in.] red dot) on collar A.

(1) Install a new connecting rod bushing onto the collar A while aligning the oil hole in the connecting rod bushing with the match mark (ø 4 mm [0.16 in.] red dot) on the collar A.

(2) Install collars A and B to the mandrel and secure them with the nut.

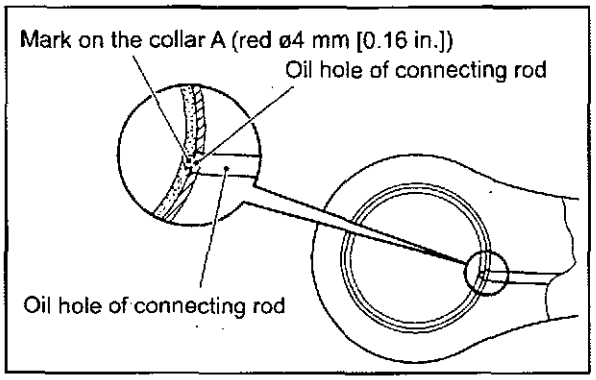



Connecting rod bushing installation procedure (4)




Connecting rod bushing installation procedure (5)

(3) Apply engine oil to the outer periphery of the connecting rod bushing. Align the oil hole in the connecting rod bushing with the match mark (red scribed line) on the collar, then press the bushing into the connecting rod.




*Connecting rod bushing installation procedure (6)*

### 4.13 Inspecting connecting rod bend and twist

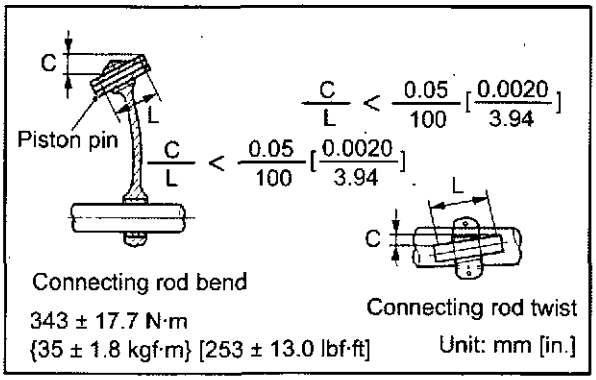
(1) Measure the dimensions of C and L in the illustration to check bend and twist of the connecting rod. Straighten the connecting rod with a press to meet the standard. If the standard is exceeded after correction, replace the connecting rod with a new one.

(2) In general, a connecting rod aligner is used to check bend and twist.

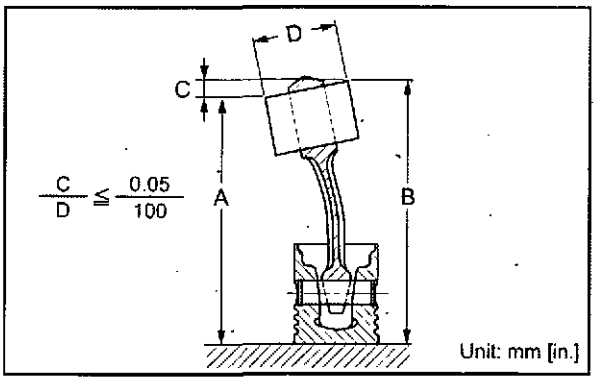
Note: Before checking bend, tighten the connecting rod cap to the specified torque.

(3) To inspect the connecting rod with the piston installed, turn the piston upside down and place it on a surface plate. Insert a round bar having the same diameter as the crankpin into the big-end bore, and measure the height of the bar using a dial gauge.

| Item | Standard |
|---|---|
| Connecting rod bend and twist (C/D) | 0.05/100 mm [0.0020/3.94 in.] or less |



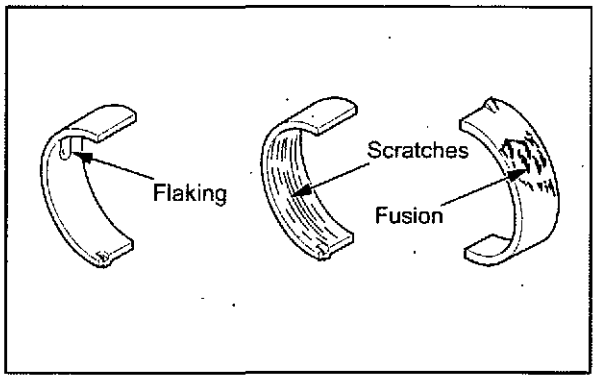

Inspecting connecting rod bend and twist




Measuring connecting rod bend (using dial gauge)

### 4.14 Inspecting connecting rod bearing

Inspect the connecting rod bearings. If any defect is found, replace it with a new one.




Measuring connecting rod end play (1)

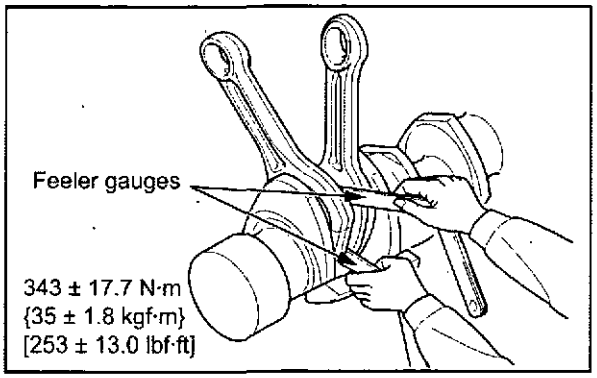
### 4.15 Measuring connecting rod end play

(1) Install the connecting rods onto the respective crankpins and tighten the connecting rod cap bolts to the specified torque.

(2) Measure the clearance to the crank arm (end play) at two positions (above and below the crankpin).

(3) If the limit is exceeded, replace the connecting rod with a new one.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| End play (Connecting rod width and crankpin width) | 54 mm [2.13 in.] × 2 | 0.6 to 0.9 mm [0.024 to 0.035 in.] | 1.0 mm [0.039 in.] |



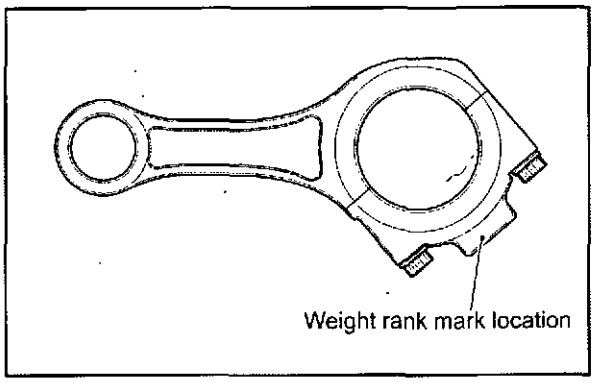

Measuring connecting rod end play (2)

### 4.16 Weight difference of connecting rod assembly in one engine

When replacing a connecting rod, be sure to check the weight rank of the connecting rod. In one engine, all the connecting rods must be of the same weight rank.

| Weight rank table | | |
|---|---|---|
| Weight rank | Weight | Tolerance |
| A | 7100 g [251 oz.] | ± 20 g [0.71 oz.] |
| B | 7200 g [254 oz.] | |
| C | 7300 g [258 oz.] | |
| D | 7400 g [261 oz.] | |
| E | 7500 g [265 oz.] | |
| F | 7600 g [268 oz.] | |
| G | 7700 g [272 oz.] | |
| H | 7800 g [275 oz.] | |

Note: The weight rank of the connecting rod assembly is also stamped on the caution plate.



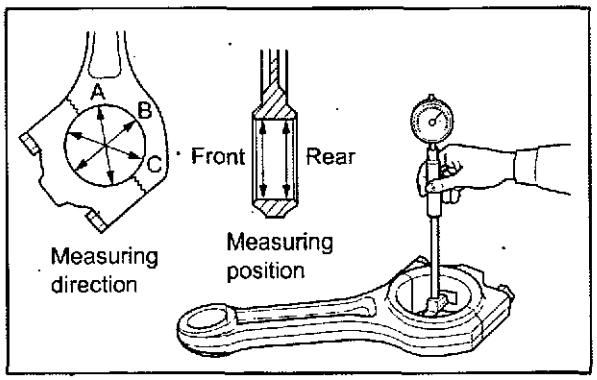

Connecting rod weight rank mark position

### 4.17 Measuring connecting rod big end bore diameter and roundness

Measure the connecting rod bore diameter at the front and rear ends respectively in the directions A, B and C as shown in the illustration. The out-of-roundness is determined by subtracting the minimum value from the maximum value among the measurements of A, B and C.

If the limit is exceeded, replace the connecting rod with a new one.

| Item | Nominal | Standard | Limit | Out-of-roundness limit |
|---|---|---|---|---|
| Connecting rod big-end bore diameter | ø 110 mm [4.33 in.] | 110.000 to 110.022 mm [4.3307 to 4.3316 in.] | 110.047 mm [4.3326 in.] | 0.100 mm [0.0039 in.] |




Measuring connecting rod big-end bore diameter

### 4.18 Inspecting serrated portion of connecting rod big end

Inspect the serrated portion of the connecting rod big end with magnetic particle method. If any defect is found, replace the connecting rod assembly.

### 4.19 Measuring connecting rod bearing thickness

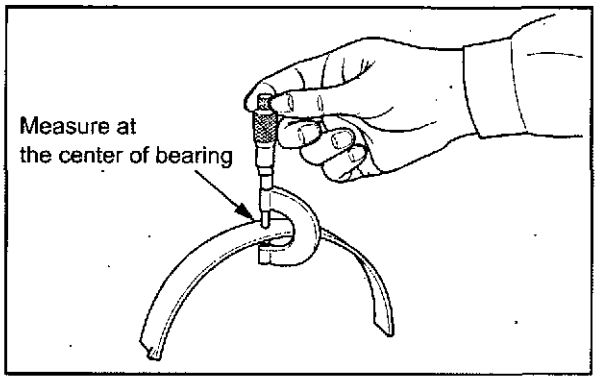
Measure the thickness of each bearing shell at its center.

If the measurement exceeds the limit, replace both upper and lower bearing shells as a set.

Note: Replacement bearings are available in four undersizes:

-0.25, -0.50, -0.75 mm and -1.00 mm

| Item | | Nominal | Standard | Limit |
|---|---|---|---|---|
| Connecting rod bearing thickness | STD | 3.000 mm [0.1181 in.] | 2.987 to 3.000 mm [0.1176 to 0.1181 in.] | 2.950 mm [0.1161 in.] |
| | -0.25 mm [-0.01 in.] | 3.125 mm [0.1230 in.] | 3.112 to 3.125 mm [0.1225 to 0.1230 in.] | 3.075 mm [0.1211 in.] |
| | -0.50 mm [-0.02 in.] | 3.250 mm [0.1280 in.] | 3.237 to 3.250 mm [0.1274 to 0.1280 in.] | 3.200 mm [0.1260 in.] |
| | -0.75 mm [-0.03 in.] | 3.375 mm [0.1329 in.] | 3.362 to 3.375 mm [0.1324 to 0.1329 in.] | 3.325 mm [0.1309 in.] |
| | -1.00 mm [-0.04 in.] | 3.500 mm [0.1378 in.] | 3.487 to 3.500 mm [0.1373 to 0.1378 in.] | 3.450 mm [0.1358 in.] |




Measuring connecting rod bearing thickness

## 5. Inspecting and repairing crankcase, crankshaft, and main bearing

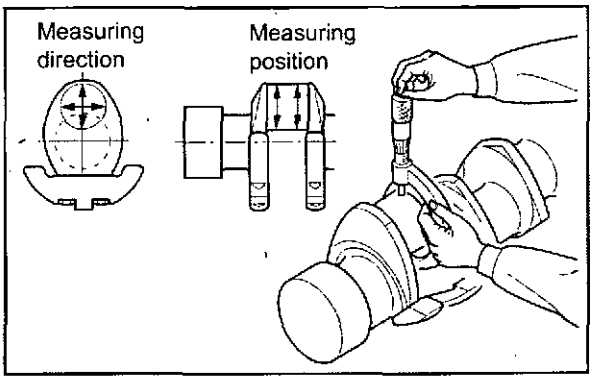
### 5.1 Measuring crankshaft crankpin and journal outside diameters

(1) Measure the outside diameter of the crankpins and crank journals. If the limit is exceeded, grind the pin or journal to fit the diameter of the next undersize bearing.

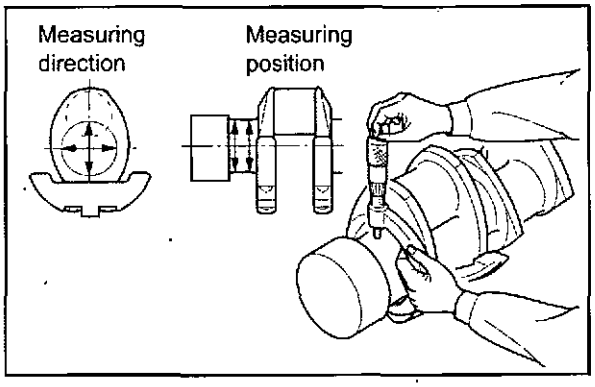
(2) Determine the out-of-roundness and the out-of-cylindericity (taper) based on the outside diameters that have been measured.

(3) If the limit is exceeded on a crankshaft in which -1.00 mm *[-0.0394 in.] undersize bearings are used, replace* the crankshaft with a new one.

| Item | | Nominal | Standard | Limit |
|---|---|---|---|---|
| Crankpin diameter | | ø 104 mm *[4.09 in.]* | 103.900 to 103.920 mm *[4.0905 to 4.0913 in.]* | 103.860 mm *[4.0890 in.]* |
| Crank journal diameter | | ø 140 mm [5.51 in.] | 139.930 to 139.950 mm [5.5090 to 5.5098 in.] | 139.870 mm [5.5067 in.] |
| Distance between centers of journal and crankpin | | 87.5 mm [3.44 in.] | 87.4 to 87.6 mm [3.441 to 3.449 in.] | - |
| Pin and journal | Parallelism | - | Deviation of 0.01 mm [0.0004 in.] or less over entire pin length | 0.03 mm [0.0012 in.] (repair limit) |
| | Roundness | - | Diameter difference 0.01 mm [0.0004 in.] or less | 0.03 mm [0.0012 in.] (repair limit) |
| | Cylindericity | - | Diameter difference 0.01 mm [0.004 in.] or less | 0.03 mm [0.0012 in.] (repair limit) |
| | Hardness | - | Hv>620 | - |
| | Surface accuracy | - | Ra 0.2 µm [0.008 µin.] | - |
| Fillet radius of crank pin | | R7 [0.28 in.] | 6.8 to 7.0 mm [0.268 to 0.276 in.] | - |
| Fillet radius of journal | | R7 [0.28 in.] | 6.8 to 7.0 mm [0.268 to 0.276 in.] | - |
| Angular deviation between pins | | - | ± 0.3° | - |




Measuring crankpin diameter



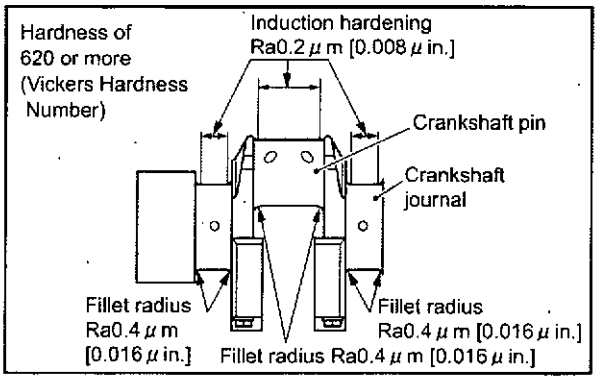

Measuring crankshaft journal diameter

## 5.2 Grinding crankshaft

Grind the crankshaft journal (or pin) in the diameter that fit the inside diameter of the next undersize main (or connecting) bearing. By doing so, the fitness check with an actual bearing can be omitted.

When grinding, be careful not to change the fillet radius and width. If the surface hardness is considered to have been reduced considerably, re-harden the crankshaft and check for flaws by means of magnetic particle inspection.

Ensure that the surface finish accuracy of the crankpins and journals is kept within the standard even after the correction by grinding.




Grinding crankshaft

Grinding dimensions for undersize crankshaft

| Grinding parts | Undersize | Finish dimension | Out-of-roundness | cylindericity |
|---|---|---|---|---|
| Crankpin diameter | 0.25 mm [0.0098 in.] | 103.65 to 103.67 mm [4.0807 to 4.0815 in.] | 0.01 mm [0.0004 in.] or less in diameter difference | 0.01 mm [0.0004 in.] or less in diameter difference |
| | 0.50 mm [0.0197 in.] | 103.40 to 103.42 mm [4.0709 to 4.0716 in.] | | |
| | 0.75 mm [0.0295 in.] | 103.15 to 103.17 mm [4.0610 to 4.0618 in.] | | |
| | 1.00 mm [0.0394 in.] | 102.90 to 102.92 mm [4.0512 to 4.0520 in.] | | |
| Crankshaft journal outside diameter | 0.25 mm [0.0098 in.] | 139.68 to 139.70 mm [5.4992 to 5.500 in.] | | |
| | 0.50 mm [0.0197 in.] | 139.43 to 139.45 mm [5.4894 to 5.4901 in.] | | |
| | 0.75 mm [0.0295 in.] | 139.18 to 139.20 mm [5.4795 to 5.4803 in.] | | |
| | 1.00 mm [0.0394 in.] | 138.93 to 138.95 mm [5.4697 to 5.4705 in.] | | |

### 5.3 Measuring crankshaft end play

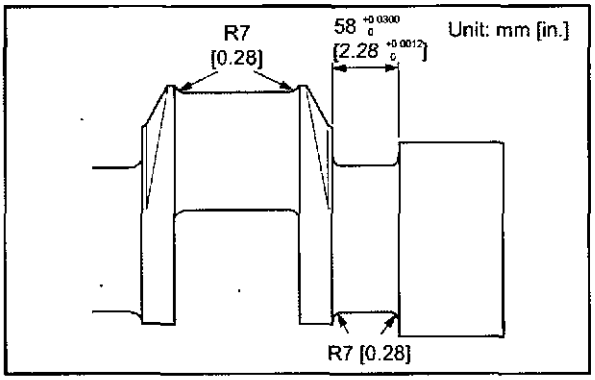
(1) Measure the crankshaft end play (clearance between the crank arm at the thrust force receiving journal and the bearing cap with thrust plate attached). If the limit is exceeded, replace the thrust plate with a new one.

(2) If the limit is still exceeded after a new thrust plate has been installed, use an oversize thrust plate.

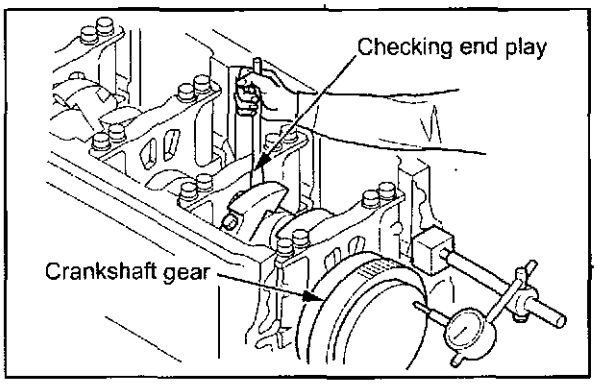
Note: In general, the rear thrust bearing wears faster than the front thrust bearing. Therefore, in most cases, the correction is achieved by replacing the rear thrust plate with a next oversize one.

| Item | Standard | Limit |
|---|---|---|
| Crankshaft end play | 0.200 to 0.400 mm [0.0079 to 0.0157 in.] | 0.500 mm [0.0197 in.] |

| Oversize | Used on one side | Used on both sides | Tolerance |
|---|---|---|---|
| +0.25 mm O.S. [0.0098 in.] | 58.25 mm [2.2933 in.] | 58.50 mm [2.3031 in.] | $^{+0.03}_{0}$ mm [$^{+0.0012}_{0}$ in.] |
| +0.50 mm O.S. [0.0197 in.] | 58.50 mm [2.3031 in.] | 59.00 mm [2.3228 in.] | |
| +0.75 mm O.S. [0.0295 in.] | 58.75 mm [2.3130 in.] | 59.50 mm [2.3425 in.] | |




Width of crankshaft thrust bearing surface




Measuring crankshaft end_play

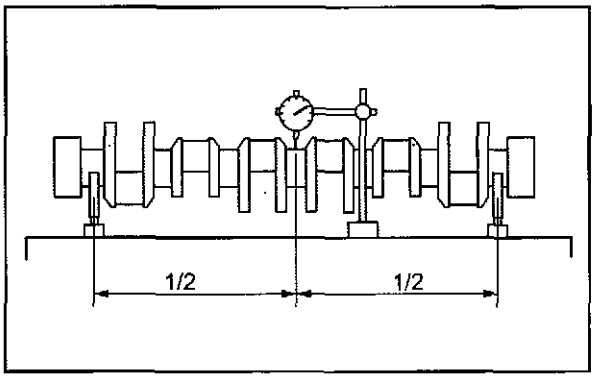
### 5.4 Measuring crankshaft runout

Support the crankshaft at the front and rear journals with V-blocks, and measure the crankshaft runout at the center journal using a dial gauge. If the runout deviates from the standard only slightly, grind the crankshaft to repair. If the runout exceeds the standard considerably, straighten the crankshaft using a press.

If the limit is exceeded, replace the crankshaft.

If the crankshaft has been repaired by grinding or pressing, inspect the crankshaft for cracks and other harmful damage using a magnetic particle method.

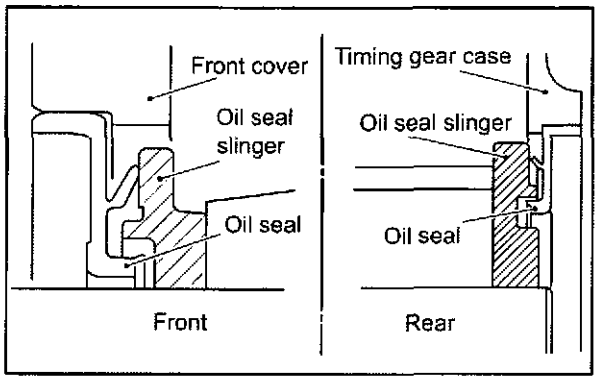
| Item | Standard | Limit |
|---|---|---|
| Crankshaft runout (TIR) | 0.08 mm [0.0032 in.] or less | 0.20 mm [0.0079 in.] |




Measuring crankshaft runout

### 5.5 Replacing oil seal slinger

Inspecting the oil slinger visually. If any such abnormalities that can lead to oil leakage are found, replace the slinger with a new one as follows.

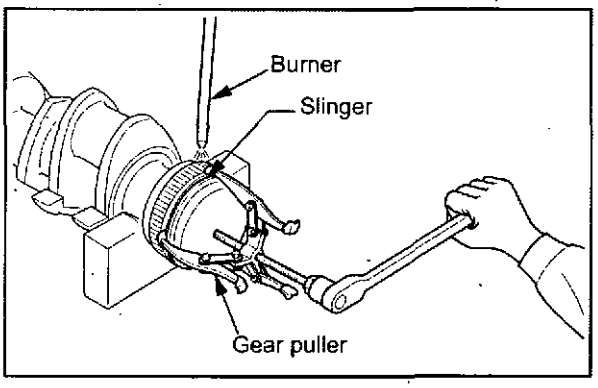



Replacing oil seal slinger

#### 5.5.1 Removing oil seal slinger

Pull out the slinger from the crankshaft using a gear puller while warming it with a burner.

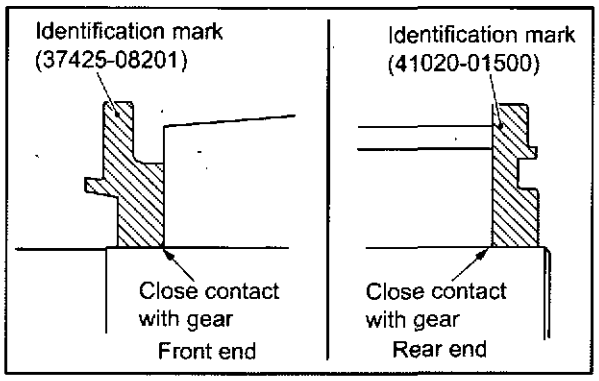
Note: Do not heat the slinger for longer than necessary.




Removing slinger

#### 5.5.2 Installing oil seal slinger

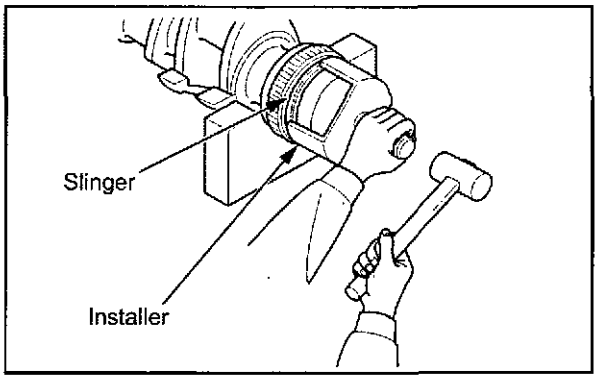
Identify the front slinger and the rear slinger, and pay attention to the installation directions.




Installing oil seal slinger (1)

(1) Front end, rear end

Heat the slinger to a temperature of 110°C [230°F] or higher. Using the slinger installer, strike the slinger into the crankshaft until it seats on the crankshaft gear.



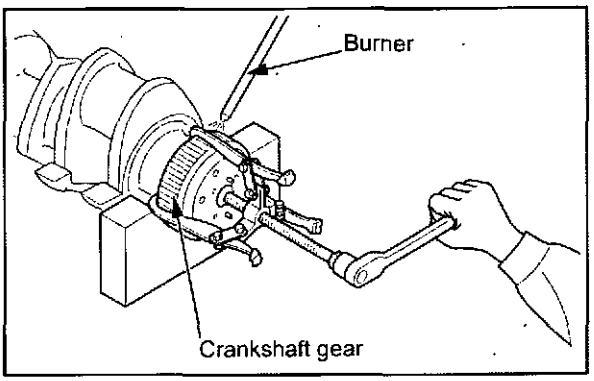

Installing oil seal slinger (2)

### 5.6 Replacing crankshaft gear

#### 5.6.1 Removing crankshaft gear

Using a gear puller, remove the gear from the crankshaft.

Note: Do not strike the gear with a hammer.




Removing crankshaft gear

#### 5.6.2 Installing crankshaft gear

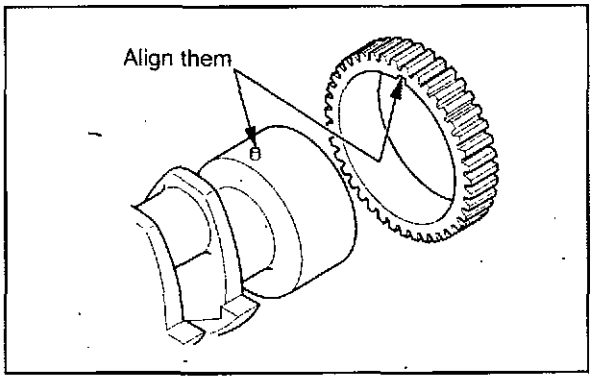
**CAUTION**

(a) *Install the crankshaft gear until it comes into contact with the crankshaft flange.*

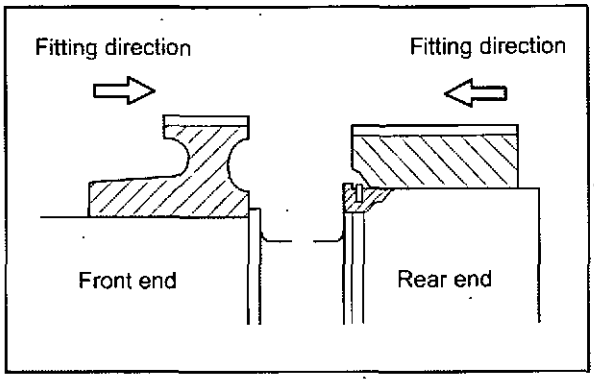
(b) Be sure to install the gear in the correct orientation.

(1) Before installing the crankshaft gear, measure the crankshaft diameter and the bore diameter of the crankshaft gear to confirm that the specified amount of interference is assured.

(2) Heat the crankshaft gear to a temperature of 180 to 200°C [356 to 392°F]. Position the crankshaft gear such that its notch is aligned with the dowel pin on the crankshaft, and tap the end face of the gear lightly with a copper hammer to fit the gear into position.



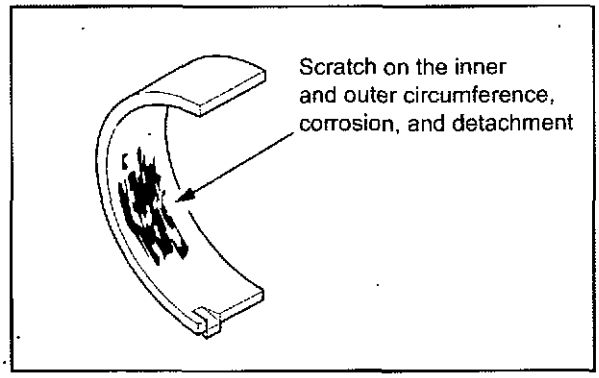

Installing crankshaft gear




Fitting direction of crankcase

### 5.7 *Inspecting main bearing surface*

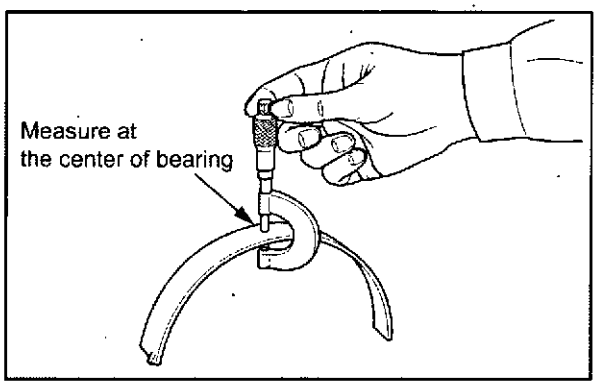
Check the inside surface of each main bearing shell for abnormal contact, scratches, corrosion and peeling from foreign material. Also check the outside surface of each bearing shell which comes into contact with the crankcase or main bearing cap for abnormal seating.




Inspecting main bearing surface

## 5.8 Measuring thickness of main bearing shell

Measure the thickness of each main bearing shell at its center. If the measurement exceeds the limit, replace both upper and lower main bearing shells as a set.




Measuring main bearing thickness

| Item | | Nominal | Standard | Limit |
|---|---|---|---|---|
| Thickness of main bearing shell at center | STD | 3.500 mm [0.1378 in.] | 3.467 to 3.480 mm [0.1365 to 0.1370 in.] | 3.425 mm [0.1348 in.] |
| | -0.25 mm [-0.0098 in.] | 3.625 mm [0.1427 in.] | 3.592 to 3.605 mm [0.1414 to 0.1419 in.] | 3.550 mm [0.1398 in.] |
| | -0.50 mm [-0.0197 in.] | 3.750 mm [0.1476 in.] | 3.717 to 3.730 mm [0.1463 to 0.1469 in.] | 3.675 mm [0.1447 in.] |
| | -0.75 mm [-0.0295 in.] | 3.875 mm [0.1526 in.] | 3.842 to 3.855 mm [0.1513 to 0.1518 in.] | 3.800 mm [0.1496 in.] |
| | -1.00 mm [-0.0394 in.] | 4.000 mm [0.1575 in.] | 3.967 to 3.980 mm [0.1562 to 0.1567 in.] | 3.925 mm [0.1545 in.] |

Note: Replacement shells for main bearing are available in four undersizes: -0.25, -0.50, -0.75 and -1.00 mm [-0.0098, -0.0197, -0.0295 and -0.0394 in.].

## 5.9 Replacing main bearing

If the bearing clearance exceeds the limit, replace the main bearings or re-grind the crankshaft journals to the next undersize and use corresponding undersize bearings. If each crankshaft journal is ground correctly to the next undersize, every replacement main bearing can be used readily without performing any polishing to match it to the bore.

### 5.10 Measuring crankcase top surface distortion

**CAUTION**

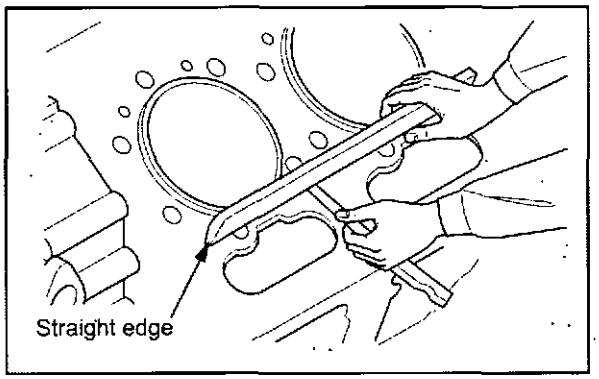
Refacing of cylinder head should be kept to an absolute minimum.

Excessive grinding of the cylinder head may result in defects such as defective combustion and stamping (contact between piston and valve).

Apply a straight edge to the top surface of the crankcase and measure its distortion using a feeler gauge. If the distortion exceeds the limit, grind the cylinder head using a surface grinder.

Note: Do not overgrind the cylinder head, as the piston protrusion deviates from the standard value.

| Item | Standard | Limit |
|---|---|---|
| Distortion of crankcase top surface | 0.15 mm [0.0059 in.] or less | 0.20 mm [0.0079 in.] (repair limit) |



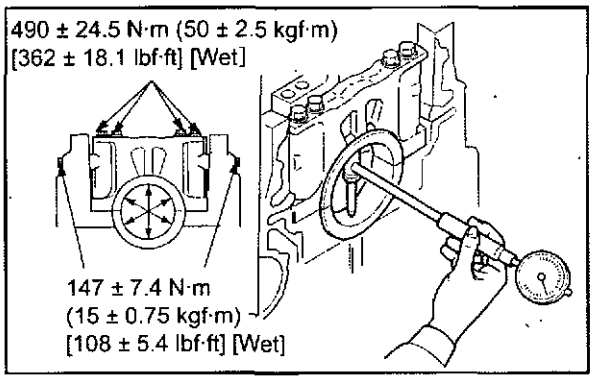

Measuring crankcase top surface distortion

### 5.11 Measuring main bearing fitting bore

(1) Secure the end bearing cap to the specified torque.

(2) Measure the housing diameter in vertical and two diagonal directions.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Measuring inside diameter of main bearing housing | ø 147 mm [5.79 in.] | 147.000 to 147.025 mm [5.7874 to 5.7884 in.] | 147.045 mm [5.7892 in.] |




Measuring main bearing fitting bore

# REASSEMBLY OF BASIC ENGINE

# 1. Reassembling crankcase, crankshaft and main bearing

## 1.1 Installing main bearing upper shells

**CAUTION**

(a) When installing the main bearing shells, do not apply engine oil to the outer periphery of the shells and main bearing fitting bores in the crankcase. Install the main bearings after cleaning off foreign matters as well as oil and grease from these surfaces using cleaning solvent and shop towels.

(b) Install the main bearings correctly. Do not confuse upper shells with lower shells. The upper shells are identified by a machined oil groove. The lower shells have no oil groove and are finished flat. The main bearings are installable even if the upper shell is confused with lower shell, but such installation could cause the crankshaft to get severely damaged. Be very careful not to confuse the upper shell with the lower shell.

(c) Be careful not to damage the main bearing when installing.

(1) Lay the crankcase upside down on a work bench.

(2) Clean the main bearing fitting bores and main bearing cap seating surface using cleaning solvent and shop towel, and make sure that these surfaces are free from any foreign matter.

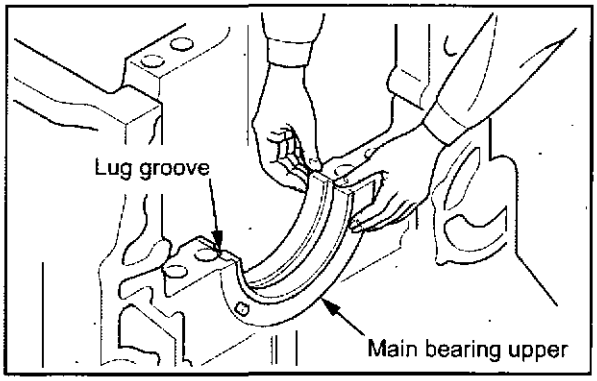
(3) Make sure that the main bearing upper and lower shells are neither damaged nor contaminated.

(4) Fit the main bearing upper shells in the crankcase bores while aligning their lugs with the corresponding notches in the crankcase.

Note: (a) Make the main bearing end protrusion from the crankcase bore even at both ends.

(b) The oil hole in the upper main bearing shell will be aligned with the oil hole in the crankcase by fitting the lug of the upper shell into the notch in the crankcase.

(5) Apply an even coat of engine oil to the inside surface of each main bearing upper shell.




Installing main bearing upper

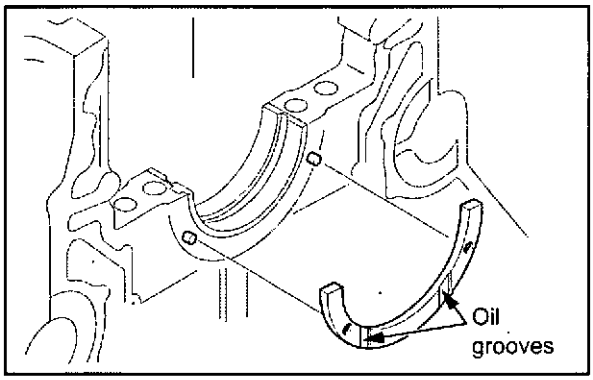
### 1.2 Installing thrust plates

**CAUTION**

Be careful not to damage the thrust plates when installing.

(1) With the grooves of thrust plates facing outward, install the thrust plates to the crankcase outside face of rearmost bearing, and to the main bearing cap.

(2) After installing the crankshaft, install the thrust plate to the crankcase inside face with the groove of thrust plate facing inward.




Installing thrust plate

### 1.3 Installing crankshaft

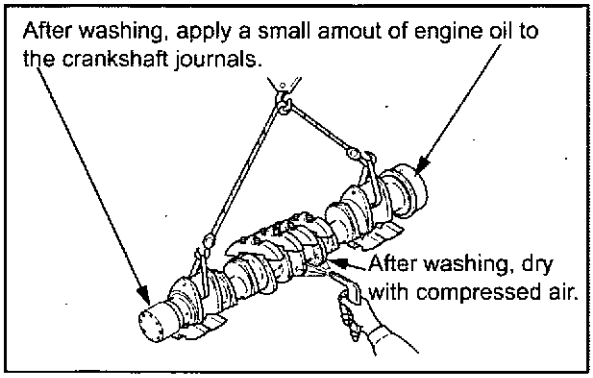
(1) Make sure that the main bearing upper shells that are installed in the crankcase bores have their inner periphery (the surface comes into contact with the journal) lubricated with an even coat of fresh engine oil.

(2) Wash the crankshaft thoroughly with cleaning oil and dry it completely by blowing compressed air. Then, apply an even coat of fresh engine oil to the crankshaft journals.

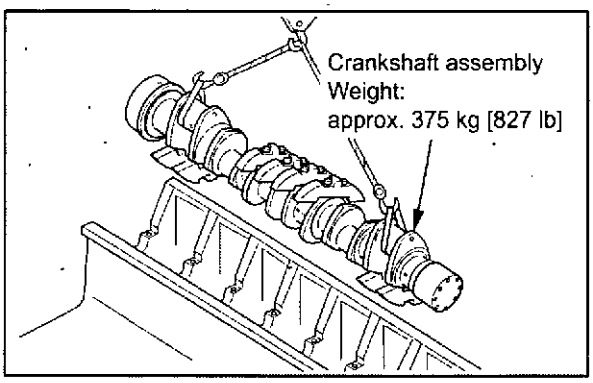
Note: When cleaning the crankshaft, pay special attention to the oil holes in the crank journals and crankpins, and make sure that they are free from any foreign matter.

(3) Sling up the crankshaft horizontally, then move it above the crankcase and lower it slowly into position.

Note: When lifting the crankshaft with a chain block, do not attach a metal hook or similar fitting directly onto the crankshaft. Such metal fittings can damage the crankshaft easily. Always lift the crankshaft using cloth belts or pads on the supporting points.




Washing crankshaft




Assembling crankshaft

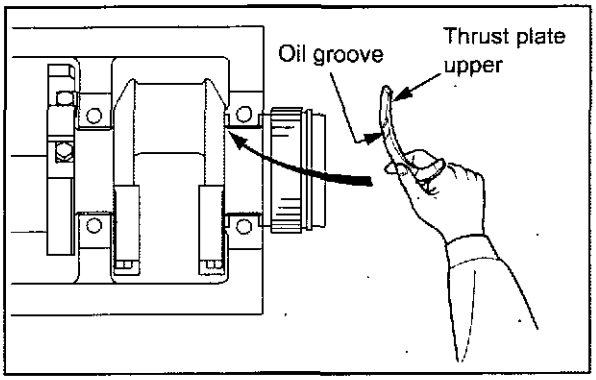
### 1.4 Installing upper thrust plates

**CAUTION**

Be careful not to cause damage to thrust plates when installing.

Install the upper thrust plates onto the front and back of rearmost journal through the clearances between the crankcase and crankshaft.

Note: Be sure to install both thrust plates with the oil grooves facing outward (away from the journal) respectively.




Installing thrust plate upper

### 1.5 Installing lower main bearing and lower thrust plate

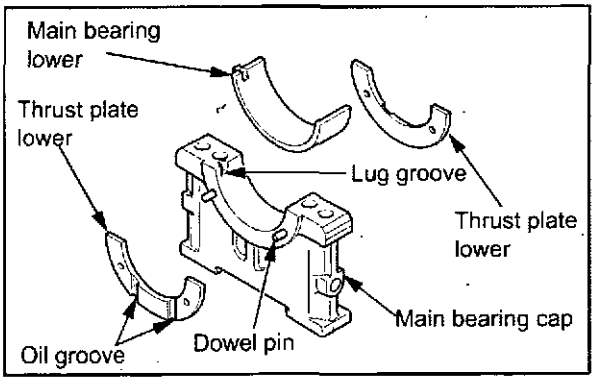
(1) Install the lower main bearing, aligning with the lug groove of the main bearing cap.

Note: Make a protrusion amount of bearings even.

(2) Evenly apply a small quantity of engine oil to the inner peripheral surface of each lower main bearing.

(3) Install the lower thrust plate, aligning with the dwell pin on the rearmost main bearing cap.

Note: Install the lower thrust plate so that its oil groove faces outward.




Installing lower main bearing and lower thrust plate

### 1.6 Installing main bearing caps

(1) Make sure that the inner periphery (the surface comes into contact with the journal) of the main bearing lower shells fitted in the main bearing caps and the outside surface of the thrust plates are lubricated with an even coat of fresh engine oil.

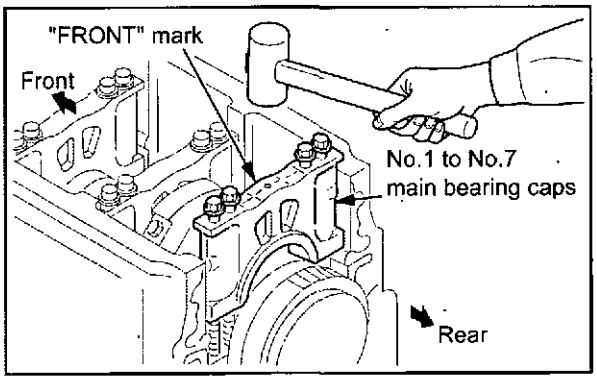
(2) Install the main bearing caps in numerical order from the front end of engine toward the rear end so that the embossed bearing number faces toward the rear end (all lug grooves are aligned in the same side).

(3) Apply engine oil to the thread of bearing cap bolts and screw them in the bearing cap slightly, then fit the caps in the crankcase using the bolts as a guide.

(4) Tap each bearing cap with a soft-head hammer to drive it into position.

Note: The No.1 bearing cap should be installed so that its end face is flush with the crankcase surface.

(5) Through the respective side bolt holes, make sure that the main bearing caps are firmly in position, and then remove the main bearing cap bolts that has been used as a guide.




Installing main bearing cap

### 1.7 *Installing main bearing cap bolts*

**CAUTION**

Be sure to observe the specified tightening sequence when installing the main bearing cap bolts and side bolts.

(1) Apply engine oil to the threads of the main bearing cap bolts and their washers. Then, screw them in the bearing caps and tighten the caps loosely.

(2) Tighten the main bearing cap bolts as follows:

(a) Tighten the main bearing cap bolts alternately to the specified torque.

(b) Tighten the side bolts on the right side of the engine to the specified torque.

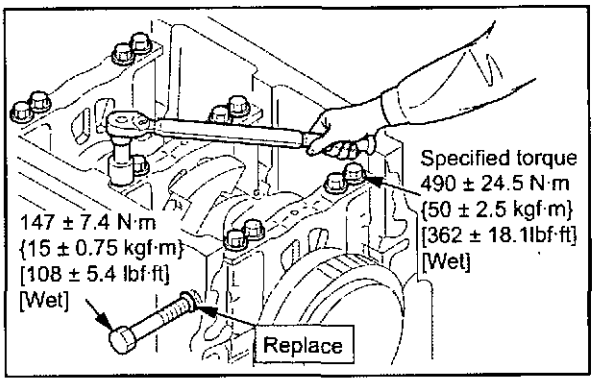
(c) Tighten the side bolts on the left side of the engine to the specified torque.

Note: Replace the O-rings with new ones.

Make sure that the camshaft turns freely.

(3) Tighten the main bearing cap bolt and side bolts to the specified torque. Then, tighten the rearmost bearing cap bolts and both side bolts loosely.

Measure the crankshaft end play in this condition.




Installing main bearing cap bolt

### 1.8 Measuring crankshaft end play

(1) Attach the dial gauge plunger to the rear end face of the crankshaft.

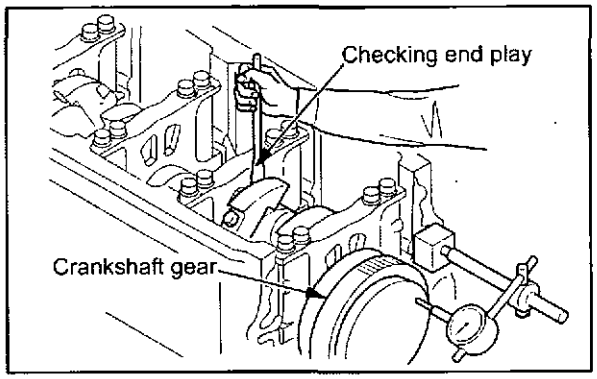
(2) Move the crankshaft longitudinally with a suitable bar and read the difference between when the crankshaft is fully pushed forward and when it is fully pushed rearward to check that it is in agreement with the end play standard value.

(3) Tighten the rearmost bearing cap bolts and side bolts to the specified torque, then measure the end play again to verify that it is correct.

(4) Revalidate that all of the bearing cap bolts and side bolts are tightened correctly.

(5) Once again, make sure that the crankshaft turns freely.

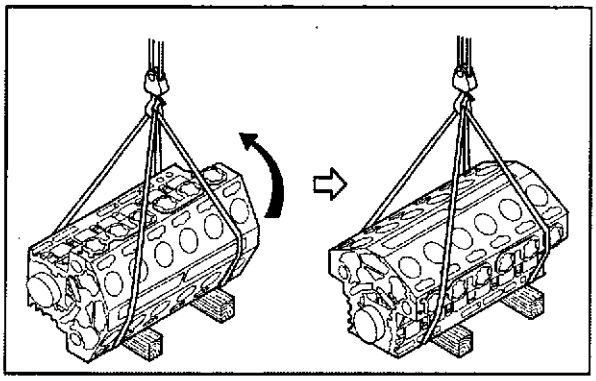
| Item | Standard | Limit |
|---|---|---|
| Crankshaft end play | 0.200 to 0.395 mm [0.0079 to 0.0156 in.] | 0.500 mm [0.0197 in.] |




Measuring crankshaft end play

### 1.9 Inverting crankcase

Using a chain block and shackle or similar tool, turn the crankcase to lay it on its side. Then, fasten wire ropes to the crankcase and turn it over.



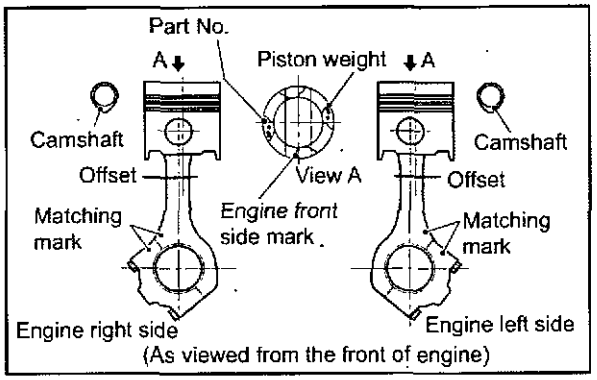
Inverting crankcase

## 2. Reassembling cylinder liner, piston and connecting rod

### 2.1 Reassembling piston and connecting rod

(1) Apply engine oil to the piston pin, and reassemble the piston and the connecting rod by inserting the piston pin, observing the orientation of piston and connecting rod shown in the illustration.

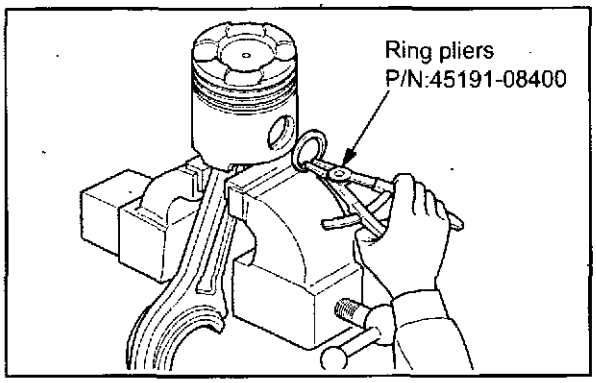
Note: The pistons and piston pins are assembled to each other in clearance fit. However, the piston pins are more easily inserted into the pistons if the pistons are warmed up with a heater or in hot water.




Assembling direction of piston and connecting rod

(2) Using ring pliers, install the snap ring. Check the snap ring for its tension, and make sure the ring fits snugly in the groove.

Note: Install all the snap rings so that their end gap faces toward the bottom of the piston.



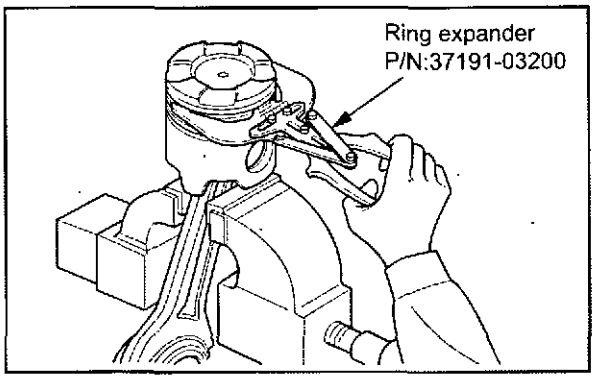

Reassembling piston and connecting rod

### 2.2 Reassembling piston

**CAUTION**

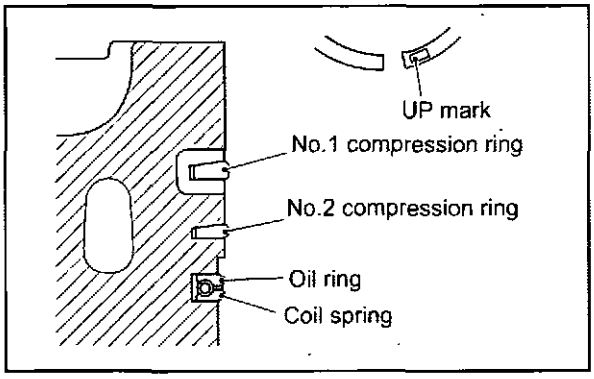
Every piston ring has a top mark such as "R" near the end gap. Install all piston rings with this mark facing upward.

If the rings are installed upside down, it could cause malfunctions such as excessive oil consumption or an engine seizing.



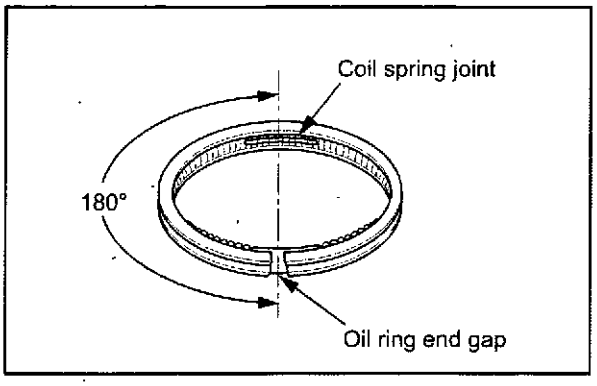

Reassembling piston ring

(1) Install the piston rings to the piston with a ring expander.




*Piston/piston ring orientation*

(2) Install the oil ring with its end gap 180° away from the joint of the coil spring, as shown in the illustration.

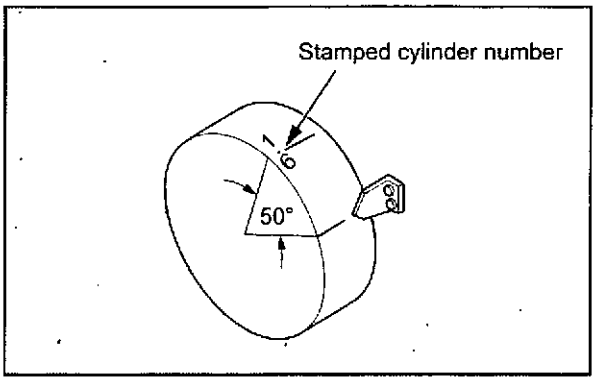



Oil ring end gap/
coil spring joint orientation

### 2.3 Preparation for installing pistons

(1) For the right bank

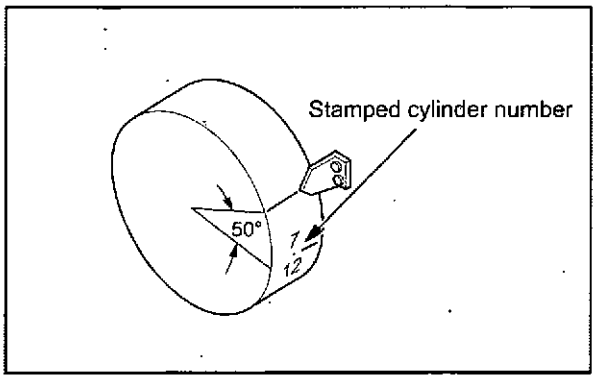
To facilitate piston installation, temporarily install the damper and the pointer. Turn the crankshaft in the normal turning direction to bring the stamped mark of the installing cylinder number to the position approximately 50° before top dead center.




Preparation for installing piston to right-bank cylinder

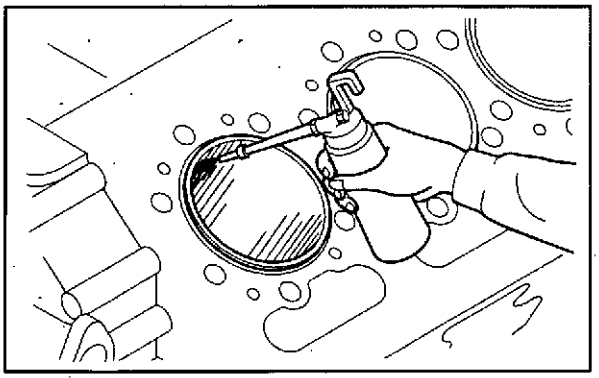
(2) For the left bank

Turn the crankshaft in the normal turning direction to bring the stamped mark of the installing cylinder number to the position approximately 50° after top dead center.




Preparation for installing piston in left-bank cylinder

(3) Clean the cylinder liner inner surface and the crankpin with a shop towel, and apply engine oil to the cylinder liner.



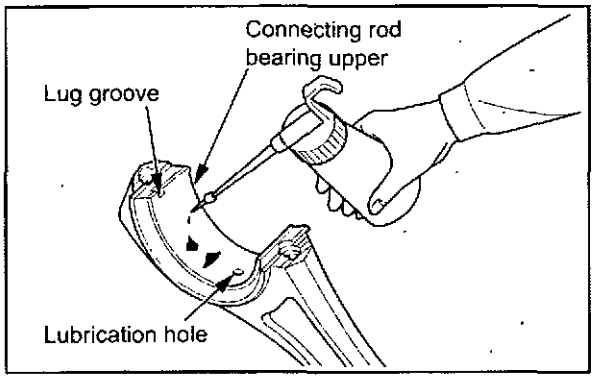
Applying engine oil to cylinder

### 2.4 Installing upper connecting rod bearing

**CAUTION**

Do not apply oil to the bearing outer surface, as the oil could cause the bearing seizure.

Fit the connecting rod bearing upper shell into the connecting rod big end while aligning its lug with the lug groove, and apply engine oil to the inner surface of the shell. Make sure that the lubrication hole of the bearing and the lubrication hole of the connecting rod are aligned.




*Installing upper connecting rod bearing*

### 2.5 Installing piston

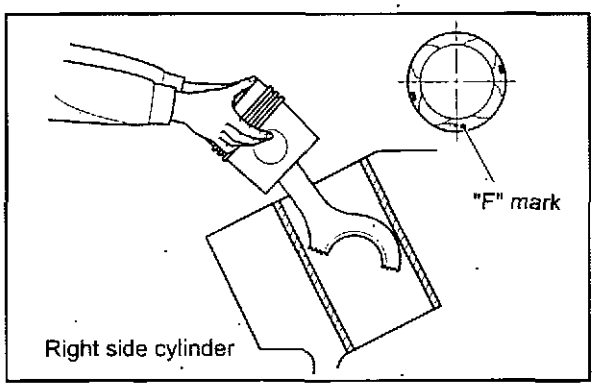
**⚠ CAUTION**

Take utmost care to insure that your fingers are not caught between the oil ring and cylinder liner.

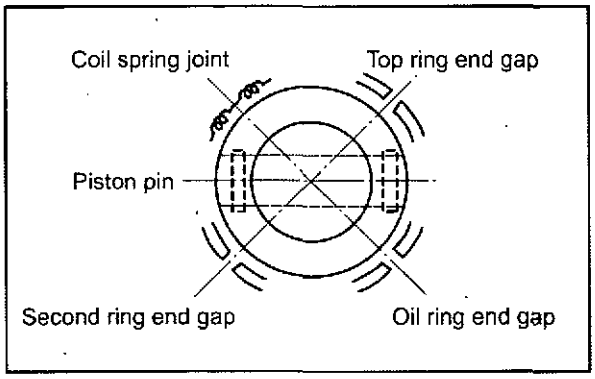
**CAUTION**

(a) Make sure that the "CAM arrow" on the piston top points the camshaft side.
(b) Checking through the inspection window on the side of crankcase, make sure that the connecting rod does not come into contact with the piston cooling nozzle when installing piston.
(c) Do not turn the piston, as it could cause damage to the piston cooling nozzle.
(d) To protect the oil ring from damage due to shock, gently insert the piston.

(1) Insert the connecting rod into the cylinder liner, taking care not to damage the cylinder liner, and slowly lower the piston to the upper surface of the crankcase.
(2) Apply engine oil to the piston rings. Then, place the end gaps equally spaced each other, avoiding thrust and anti-thrust direction, and pin direction.

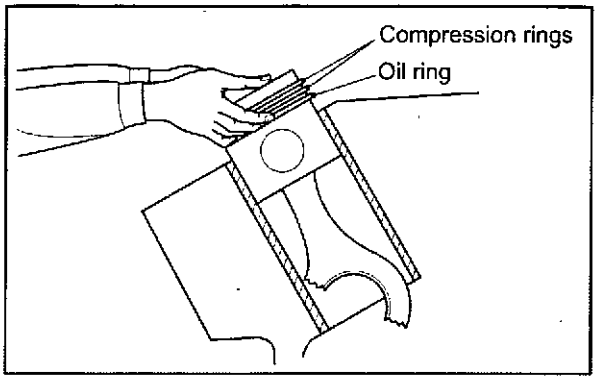



Installing piston (1)



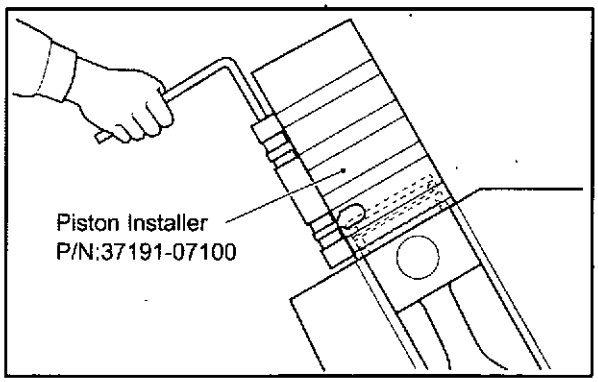

Installing piston (2)

(3) Hold the piston with your hands on the compression rings, and carefully insert the piston skirt into the cylinder liner.



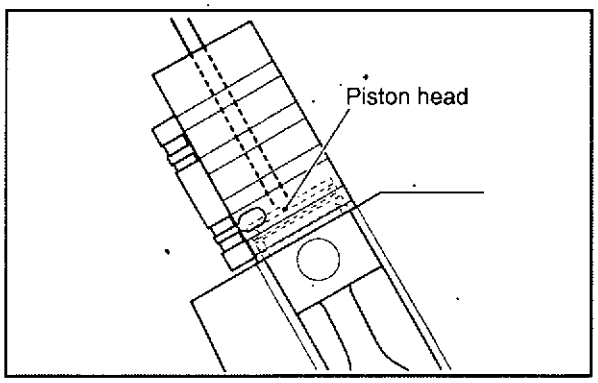

Installing piston (3)

(4) Revalidate that the piston ring end gaps are positioned correctly. Apply engine oil to the piston rings. Lubricate the inside surface of the piston installer with engine oil. Clamp the piston rings with the piston installer.



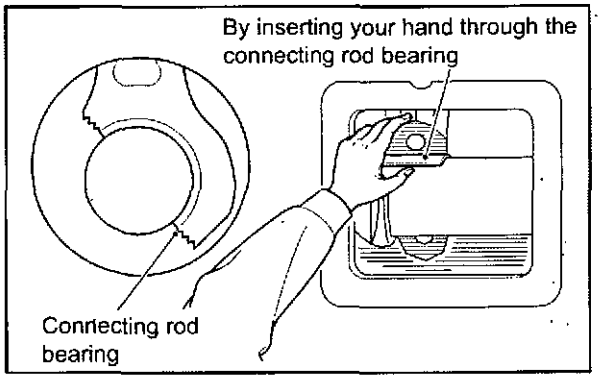

Installing piston (4)

(5) Insert piston into cylinder liner and tap the piston head with a soft-head hammer to install.
If the piston is stubborn, move the connecting rod big end back and forth through the inspection window on the side face of crankcase.




Installing piston (5)

(6) Insert your hand through the inspection window on the side face of the crankcase to check that the connecting rod bearing upper shell is positioned in place. If it is not, push the bearing upward with your hand to adjust.




Installing piston (6)

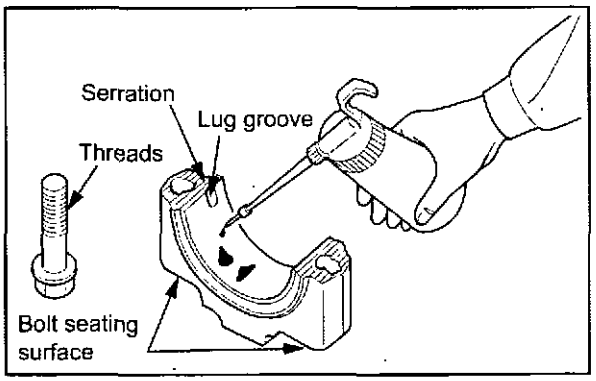
### 2.6 Installing connecting rod cap

**CAUTION**

(a) Make sure that the mating mark on the connecting rod bearing cap and the mating mark on the connecting rod are on the same side and in alignment.

(b) When fitting the connecting rod caps, make sure that dust, metal particles, etc. are not caught in the serrations in the cap, between bolt seating surfaces and in the bolt threads.

| Parts | Position |
|---|---|
| Connecting rod bearing lower | Inside surface |
| Connecting rod cap | Bolt seat surface on the serration area |
| Connecting rod bolt | Threads |




Installing connecting rod cap (1)

(1) Fit the connecting rod bearing lower shell in the bearing cap while aligning its lug with the notch in the bearing cap.

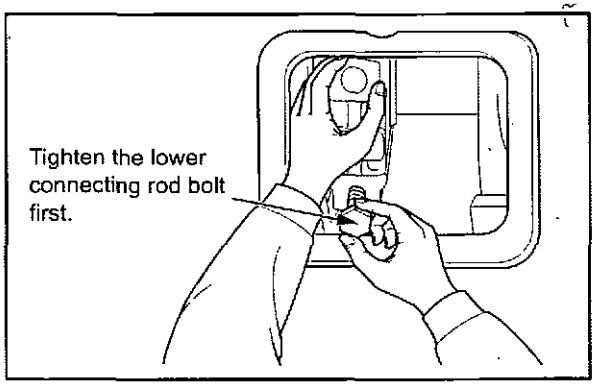
(2) Apply engine oil to the bearing cap bolt threads and seating surface, and the inside surface of the connecting rod bearing lower shell.

(3) Check that the match mark on the bearing cap and the match mark on the connecting rod are on the same side and in alignment, then install the connecting rod bearing cap to the connecting rod.

(4) With your finger, touch the joint between the connecting rod and cap to check for misalignment. Tighten the bolts after validating that they are flush with each other.

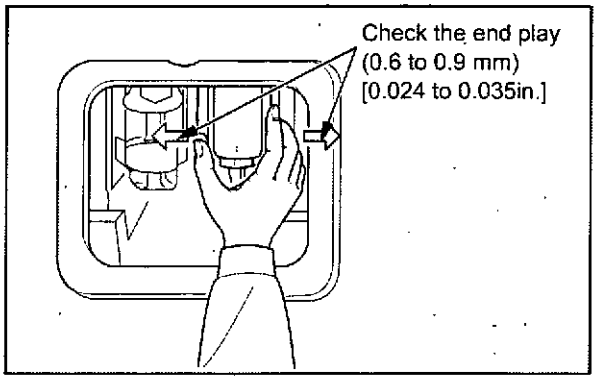
Note: Lightly hold the upper part of the cap by hand, and loosely tighten the lower bolt first to prevent the cap from falling into the oil pan.

(5) Check that the match mark on the bearing cap and the match mark on the connecting rod are on the same side and in alignment, then install the connecting rod bearing cap to the connecting rod.




Installing connecting rod cap (2)

(6) With the bolts tightened loosely, measure the end play of the connecting rod to verify that the clearance is even at above and below the crankpin.

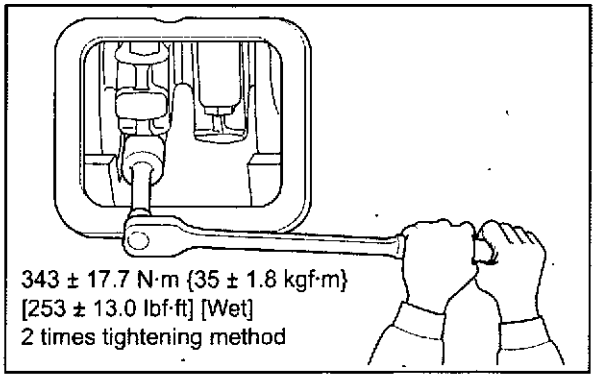



Installing connecting rod cap (3)

(7) With the bolts tightened loosely, measure the end play of the connecting rod to verify that the clearance is even at above and below the crankpin.

(8) Tighten the connecting rod cap bolts to the specified torque. Then, loosen the bolts completely and tighten them again to the specified torque.
Measure the end play again.

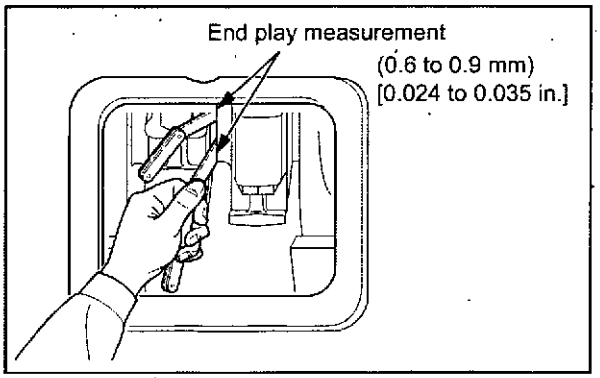
Note: When tightening the connecting rod cap bolts according to the angle method, follow the sequence described below.
(a)Tighten the bolts with a snug torque of 147±7.4 N·m {15±0.75 kgf·m} [108±5.4 lbf·ft].
(b) Further tighten them by turning 45°±3°.
(c) Loosen all bolts, and then tighten them again in the same manner as above. (2-time tightening method)




Installing connecting rod cap (4)

**CAUTION**

Before installing the cylinder head, measure the piston protrusion at all cylinders to verify that they are normal.




Installing connecting rod cap (5)

### 2.7 Measuring piston protrusion

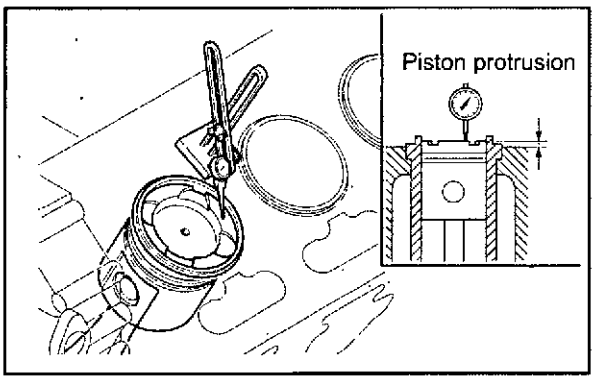
**CAUTION**

Before installing the cylinder head, measure the piston protrusion on all cylinders to verify that they are normal.

(1) Bring the piston to the top dead center.

(2) Attach the dial gauge plunger to the top surface of the crankcase, and zero the dial gauge.

(3) Measure the protrusion at four points on the piston head, and calculate the mean value.




Measuring piston protrusion

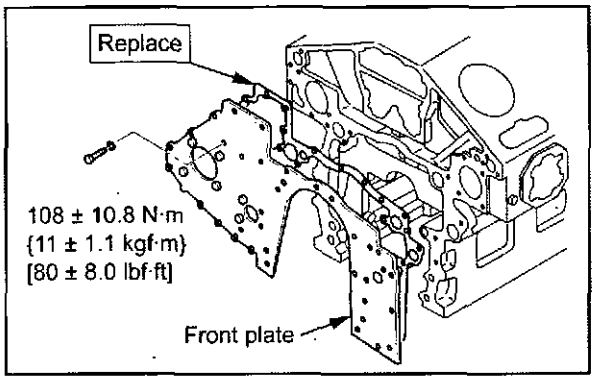
## 3. Reassembling damper and front accessory drive

### 3.1 Installing front plate

(1) Apply sealant (Heldite) to the front plate mounting surface of the crankcase, then attach the packing in place. Apply the same sealant to the packing and install the front plate.

(2) Replace the dowel pins if they are worn or the front plate is replaced.

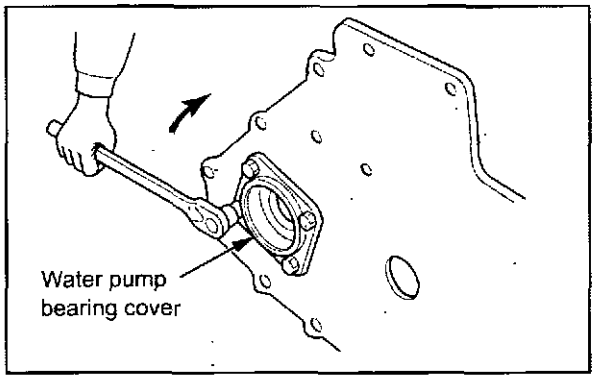
(3) Check that the lower end of the front plate is flush with the bottom surface of the crankcase. Cut off any excess packing neatly.




Installing front plate

### 3.2 Installing water pump bearing cover

Insert the water pump bearing cover into the front plate, then tighten the cover mounting bolts.

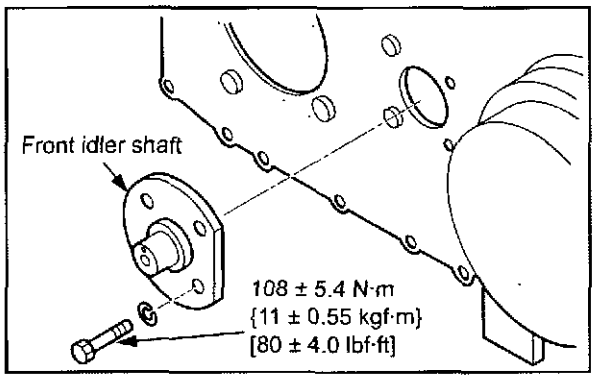



Installing water pump bearing cover

### 3.3 Installing front idler shaft

(1) Drive the idler shaft into position using a guide bolt.

(2) Tighten the idler shaft mounting bolts to the specified torque.

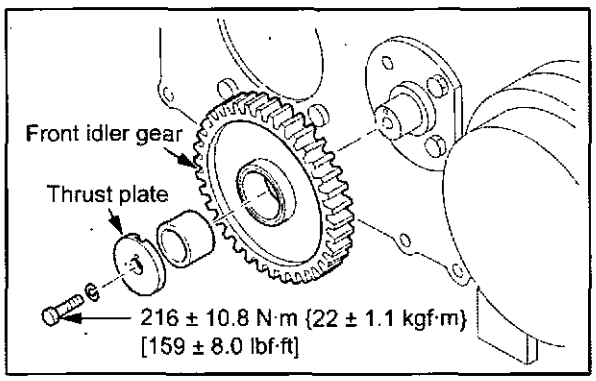



Installing front idler shaft

### 3.4 Installing front idler gear

(1) Install the idler gear onto the shaft and fit the thrust plate to the idler gear.

(2) Tightening the thrust plate bolts to the specified torque.




Installing front idler gear

### 3.5 Installing front gear case and pointer

(1) Apply sealant (Heldite) to the surface of the crankcase to which each front gear case packing is fitted, then fit the packing in place. Apply the same sealant to each packing and install the front gear case.

(2) Replace the dowel pins if they are worn out or the cover is replaced.

(3) Tighten the case mounting bolts evenly to the specified torque.

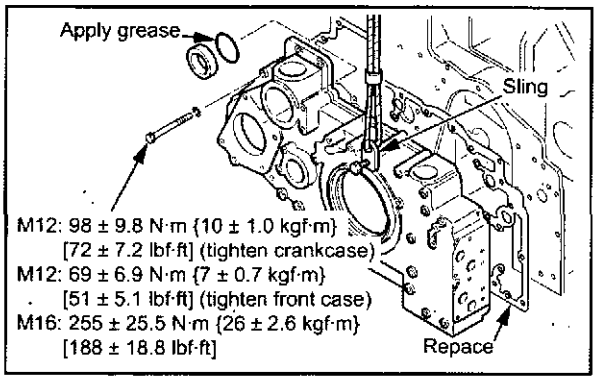
(4) Check that the lower end of the front gear case is flush with the bottom of the crankcase. Cut off any excess packing neatly.

(5) Install the oil seal in the front gear case.

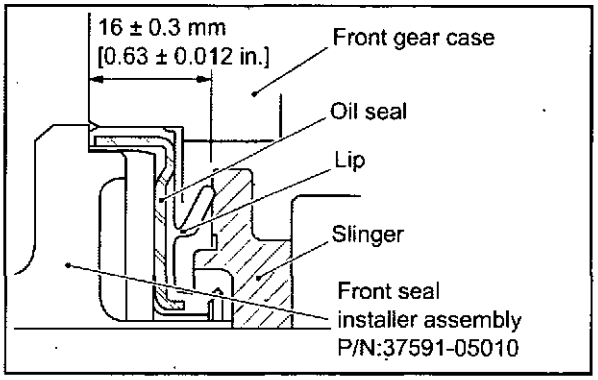
(6) Apply engine oil to the lip of the oil seal.

(7) Using the front seal installer assembly, install the oil seal into the illustrated position relative to the slinger.

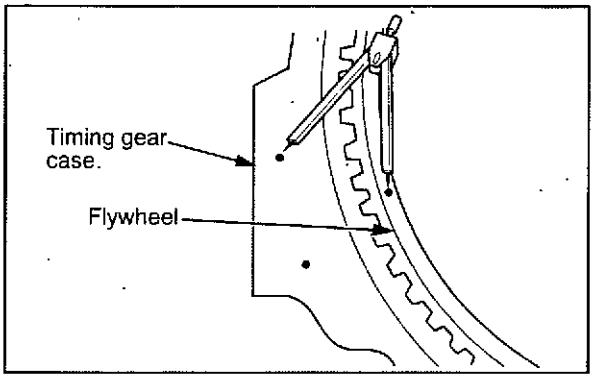
(8) When the pointer has been removed, or if the pointer has been accidentally moved from its position, the pointer must be placed in the correct position by finding top dead center of the compression stroke in the following manner: (for No.1 cylinder as an example)
Turn the flywheel so that its punch mark is positioned at the same distance from the two punch marks stamped on the timing gear case. This position is considered to be the top dead center of the compression stroke of No.1 cylinder piston (also No.6).




Installing front gear case



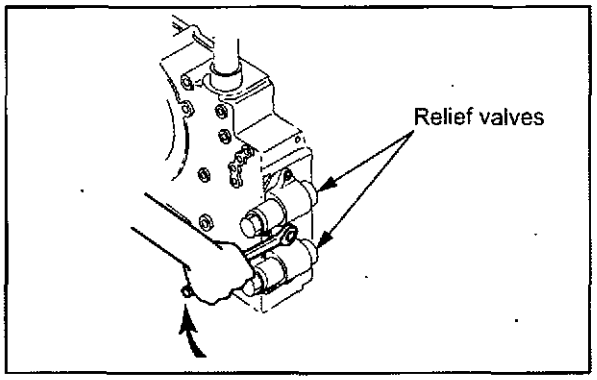

Installing oil seal and slinger




When pointer was removed or dislocated accidentally

### 3.6 Installing relief valve

Install the relief valve using the mounting bolts.




Installing relief valve

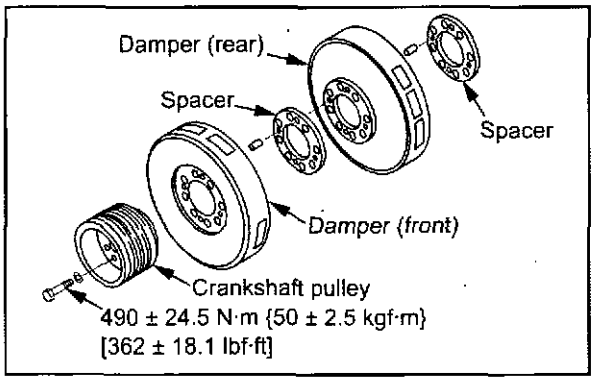
### 3.7 Installing damper and crankshaft pulley

(1) Install the spacer, damper (rear), spacer, damper (front) and crankshaft pulley.

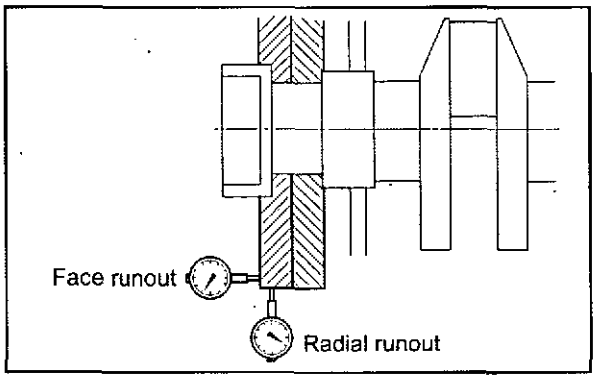
(2) Tighten the crankshaft mounting bolts to the specified torque.

(3) Check face and radial runouts of the damper.

| Item | Standard | Limit |
|---|---|---|
| Face runout | 0.5 mm [0.020 in.] or less | 1.5 mm [0.059 in.] |
| Radial runout | 0.5 mm [0.020 in.] or less | 1.5 mm [0.059 in.] |




Installing damper and crankshaft pulley




Measuring damper face and radial runout

## 4. Reassembling flywheel, timing gear and camshaft

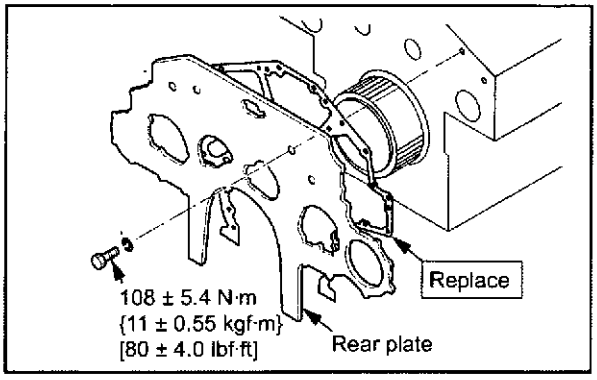
### 4.1 Installing rear plate

(1) Apply sealant (ThreeBond 1211) to the rear plate attaching portion of the crankcase, and install the packing on that portion.

(2) Apply the same sealant (ThreeBond 1211) to the packing, and then install the rear plate.

Note: If the dowel pins are worn or when the plate is replaced, replace the dowel pins with new ones.

(3) Make sure that the rear plate bottom is flush with the crankcase bottom. If the packing is protruding, cut off the excess neatly.

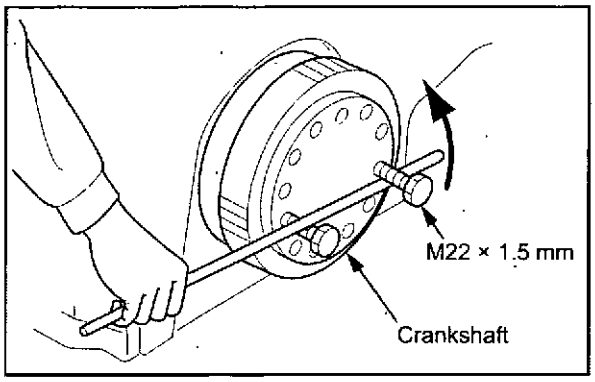



Installing rear plate

### 4.2 Rotating crankshaft

(1) Install two bolts in the flywheel mounting holes of the crankshaft.

(2) Rotate the crankshaft with a bar using the bolts to bring the No.1 cylinder at the top dead center.

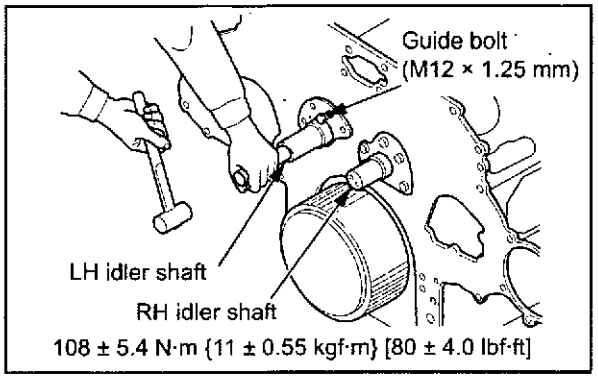



Rotating crankshaft

### 4.3 Installing front idler shaft

(1) Drive the front idler shaft into position using a guide bolt.

(2) Tighten the front idler shaft mounting bolts to the specified torque.



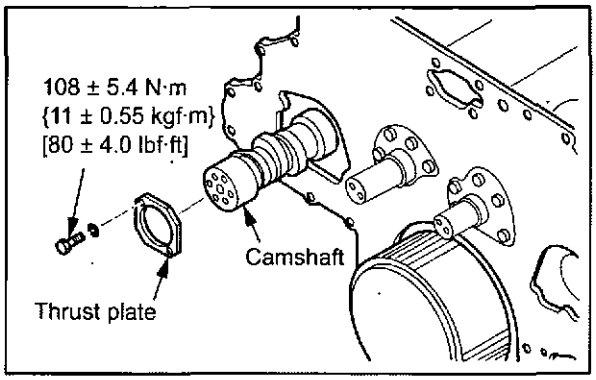

Installing idler shaft

### 4.4 Installing camshaft

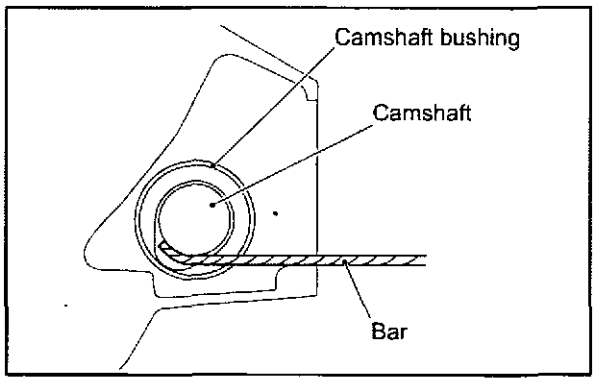
**CAUTION**

When installing the camshafts, support them with a protector such as a pad from the crankcase window to prevent damage to their cam lobes and bushings.

(1) Apply engine oil to the inside surface of the camshaft bushing.
(2) While supporting the camshaft with a bar, insert it into the crankcase.
(3) Install the thrust plate.
(4) Tighten the thrust plate mounting bolts to the specified torque.
(5) Make sure that the camshaft rotates freely.



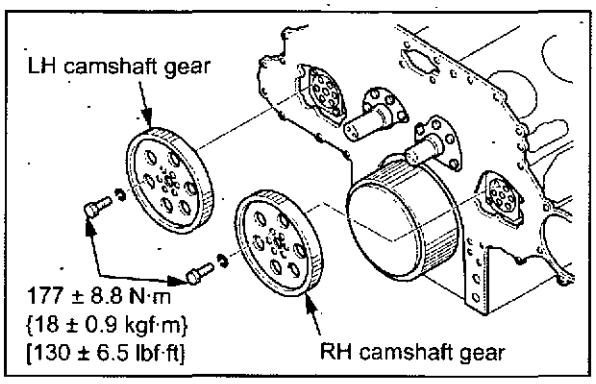

Installing camshaft (1)




Installing camshaft (2)

### 4.5 Installing camshaft gear

(1) Install each camshaft gear by aligning its hole with the dowel pin on the camshaft.
(2) Tighten the camshaft gear mounting bolts to the specified torque.
(3) After installing the camshaft gear, make sure the camshaft rotates freely.



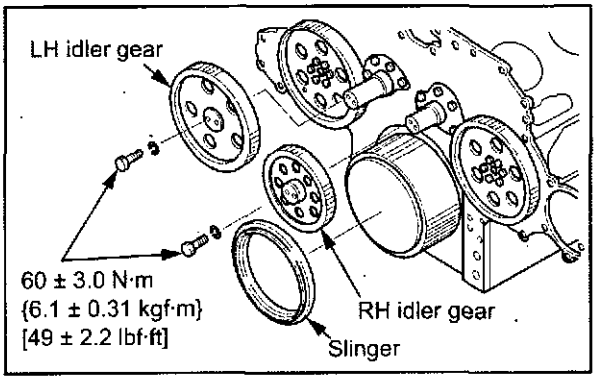

Installing camshaft gear

### 4.6 Installing rear idler gear

(1) Install the rear idler gear with its match marks aligned with the marks on the crankshaft gear and camshaft gear, and then install the thrust plate.

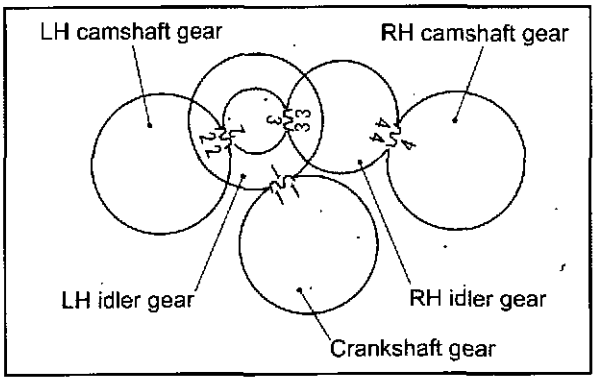
(2) Tighten the thrust plate mounting bolts to the specified torque.

(3) Insert the slinger into the crankshaft.




Installing idler gear

(4) Ensure that the match marks on the timing gears are aligned as shown in the illustration.

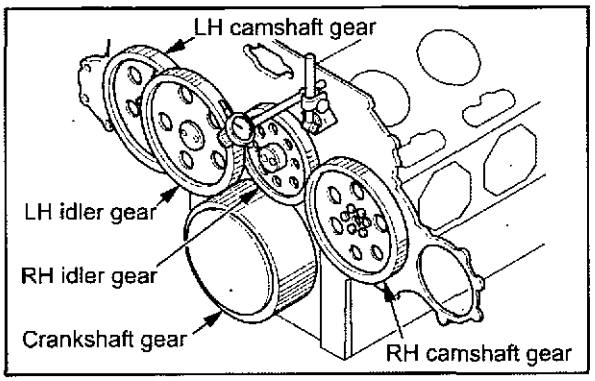



Timing gear train (viewed from flywheel) [Timing gear engagement when No.1 piston is at compression top dead center]

### 4.7 Measuring timing gear backlash

To measure backlash, apply a dial gauge to the circumference of gear shaft at the right angle to the shaft, or insert feeler gauges into the meshing between two gears. Replace the gear if the limit is exceeded.

| Item | Standard | Limit |
|---|---|---|
| Crankshaft gear to LH idler gear | 0.11 to 0.26 mm [0.0043 to 0.0102 in.] | 0.50 mm [0.0197 in.] |
| LH idler gear to LH camshaft gear | 0.10 to 0.24 mm [0.0039 to 0.0094 in.] | |
| LH idler gear to RH idler gear | 0.12 to 0.22 mm [0.0047 to 0.0087 in.] | |
| RH idler gear to RH camshaft gear | 0.11 to 0.25 mm [0.0043 to 0.0098 in.] | |



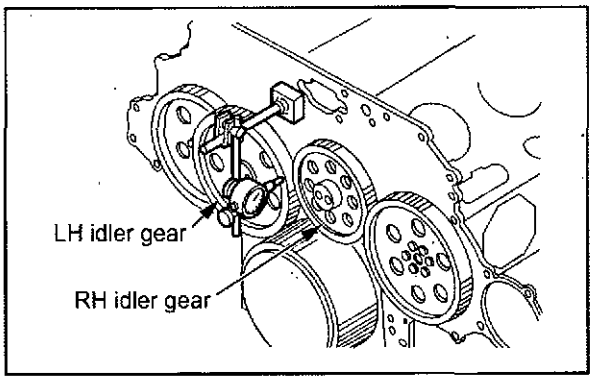

Measuring timing gear backlash

### 4.8 Measuring idler gear end play

Using a feeler gauge or dial gauge, measure the end play of idler gear.

If the measured value exceeds the limit, replace the thrust plate with a new one.

| Item | Standard | Limit |
|---|---|---|
| End play of idler gear | 0.3 to 0.5 mm [0.012 to 0.020 in.] | 0.7 mm [0.028 in.] |

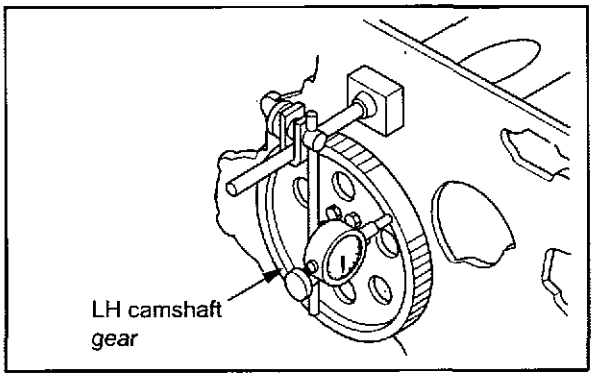



Measuring idler gear end play

### 4.9 Measuring camshaft end play

Measure the camshaft end play with the camshaft gear attached. If the end play exceeds the limit, replace the thrust plate with a new one.

| Item | Standard | Limit |
|---|---|---|
| Camshaft end play | 0.2 to 0.4 mm [0.008 to 0.016 in.] | 0.55 mm [0.0217 in.] |

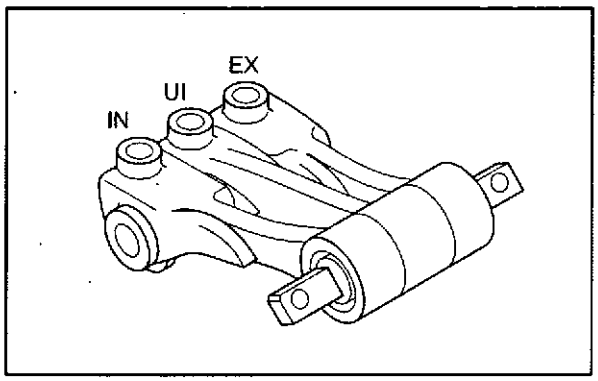



Measuring camshaft end play

### 4.10 Reassembling follower

(1) For reassembling follower, refer to inspection and repair section.

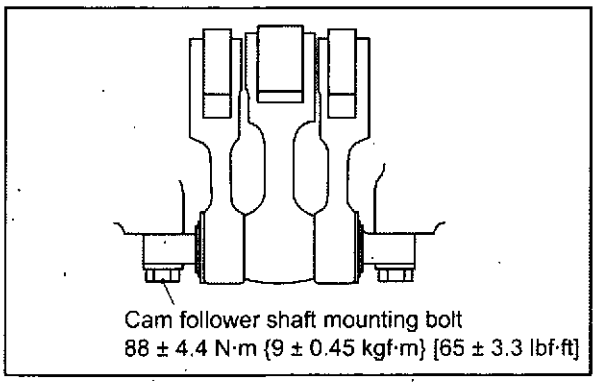
(2) When installing the followers to the cam follower shaft, be sure to arrange the IN, UI and EX followers from the side in that order, as shown in the diagram.




Reassembling follower

### 4.11 Installing follower

Tighten the cam followers shaft mounting bolts to the specfied torque for secure installation of followers.




Installing follower

### 4.12 Installing timing gear case

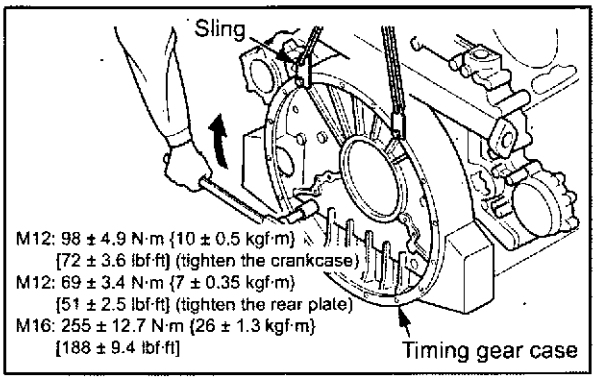
**⚠ CAUTION**

Be careful not to drop or bump the timing gear case against a rigid object, as it can cause damage to the timing gear case, but also can cause personal injury.

(1) Apply sealant (ThreeBond 1211) to the timing gear case mounting surface of the rear plate, then place the packing in position.
Apply the same sealant to the packing.

(2) Attach a sling to the timing gear case, align it with the dowel pin.

(3) Tighten the timing gear case mounting bolts to the specified torque.




Installing tining gear case

### 4.13 Installing rear oil seal

Use the rear oil seal installer assembly to install the rear oil seal.

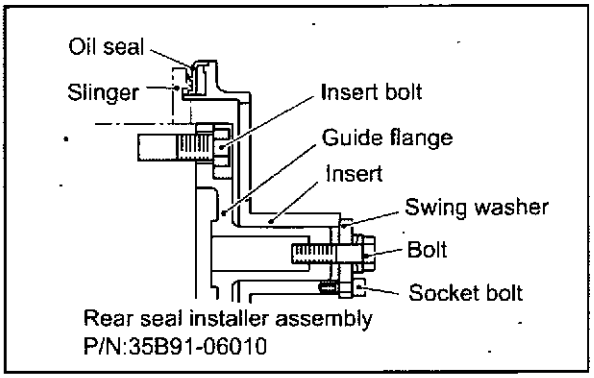
(1) Install the guide to the crankshaft rear end, and secure it with the insert bolts.

(2) Fit the oil seal to the installer and install the installer to the guide.

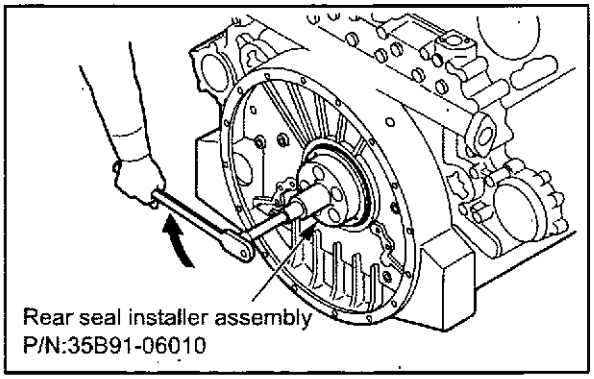
(3) Tighten the bolt mounted on the installer to install the oil seal into the timing gear case.

(4) Loosen the socket bolt and push the swing washer out of the bolt, then pull out the installer.

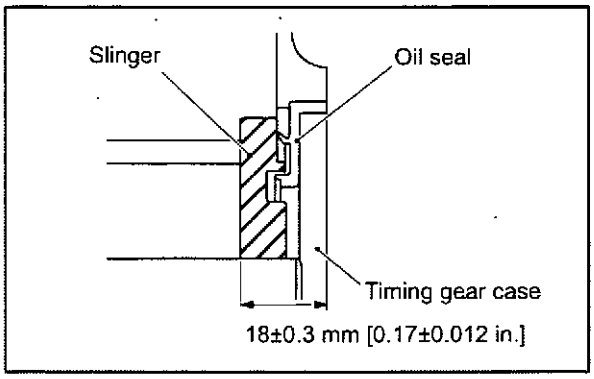
(5) Remove the insert bolts and remove the guide from the crankshaft.




Installing rear oil seal (1)




Installing rear oil seal (2)



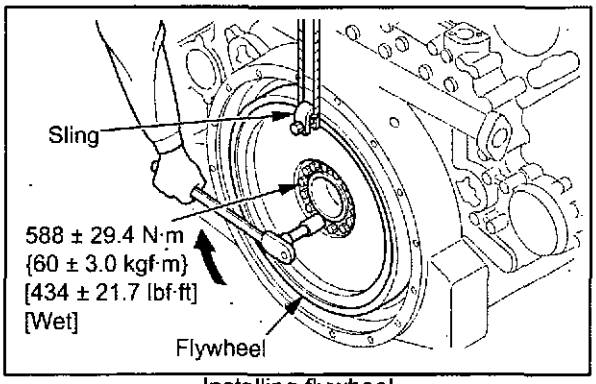

Installing rear oil seal (3)

### 4.14 Installing flywheel

**⚠ CAUTION**

Be careful not to drop or hit the flywheel, as it could not only cause damage to the flywheel, but it could result in personal injuries.

(1) Check the mounting surfaces of flywheel and crankshaft for foreign matter or damage.
(2) Attach a lifting device to the flywheel.
(3) Install the flywheel by aligning its holes with the dowel pins on the crankshaft.
(4) Coat the threads and bolt seat surfaces of the flywheel mounting bolts with engine oil, then tighten the bolts to the specified torque.
(5) Check the face and radial runouts of the flywheel.

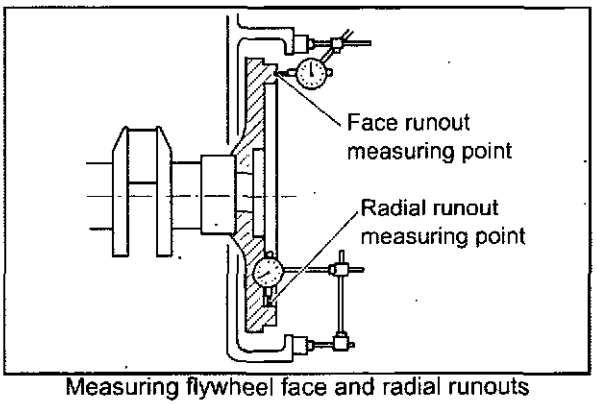


Installing flywheel

### 4.15 Measuring flywheel face and radial runouts

Measure the runouts of the flywheel in the installed condition. If the measured value exceeds the standard, check the bolt for looseness as well as the accumulation of foreign matter on the mounting face.

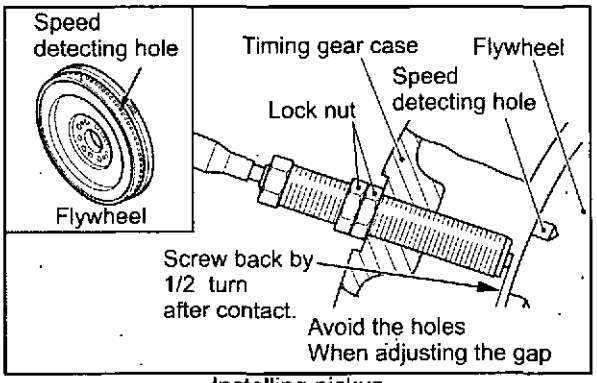
| Item | Standard |
|---|---|
| Flywheel face runout | 0.28 mm [0.0110 in.] or less |
| Flywheel radial runout | 0.13 mm [0.0051 in.] or less |



Measuring flywheel face and radial runouts

### 4.16 Installing pickup

(1) Turn the crankshaft to position the center of the pickup mounting hole to the flywheel circumference avoiding the speed defecting holes.
(2) Insert the pickup into the hole slowly and carefully by hand.
(3) When the tip of pickup comes into contact with the flywheel circumference, loosen the pickup so that the clearance to the ring gear meets the standard.
(4) Secure the pickup with the locknut.

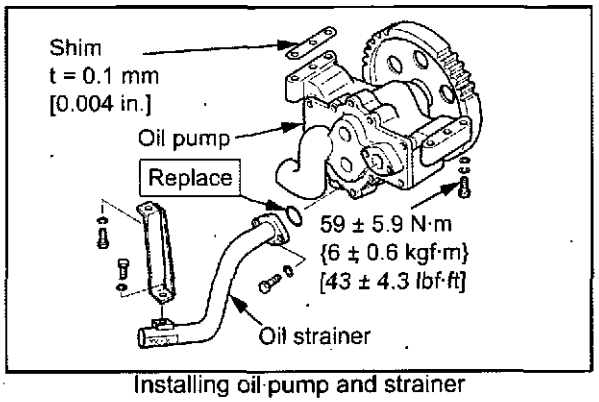


Installing pickup

### 4.17 Installing oil pump and oil strainer

(1) Fit a new O-ring in the oil pipe and install the oil pump, oil strainer and oil pipe as a set to the crankcase.
(2) Check the backlash between the oil pump idler gear and crankshaft gear. If the backlash is less than the standard, adjust it by placing an appropriate shim on the mounting surface.

| Item | Standard | Limit |
|---|---|---|
| Oil pump drive gear and crankshaft gear backlash | 0.11 to 0.28 mm [0.0043 to 0.0110 in.] | 0.50 mm [0.0197 in.] |

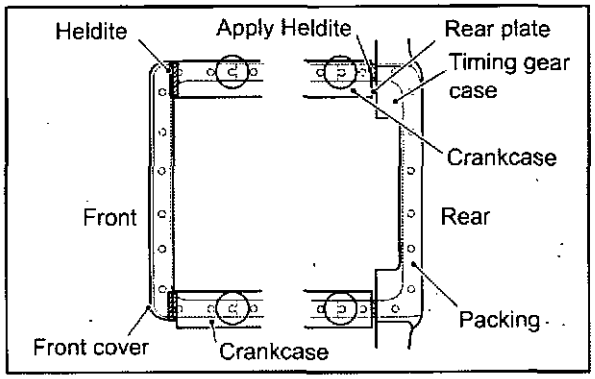


Installing oil pump and strainer

### 4.18 Installing oil pan

(1) Apply Heldite to the lower mating surfaces of the front cover and the crankcase.

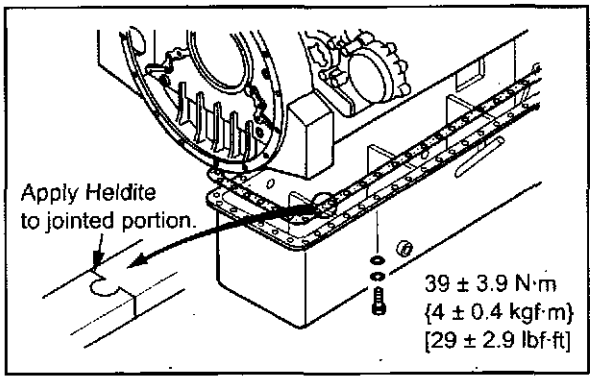
(2) Apply Heldite to the lower mating surfaces of the crankcase, rear plate and timing gear case.




Installing oil pan (1)

(3) Apply sealant (Heldite) to the each joint (4 locations) of the oil pan gasket, and install the gasket onto the oil pan.

(4) Tighten the oil pan mounting bolts to the specified torque.




Installing oil pan (1)

### 4.19 Installing cam sensor

(1) Attach the coupling to the front of the camshaft.

(2) Attach the oil seal and oil seal case to the coupling.

(3) Attach the sensing blade to the coupling.

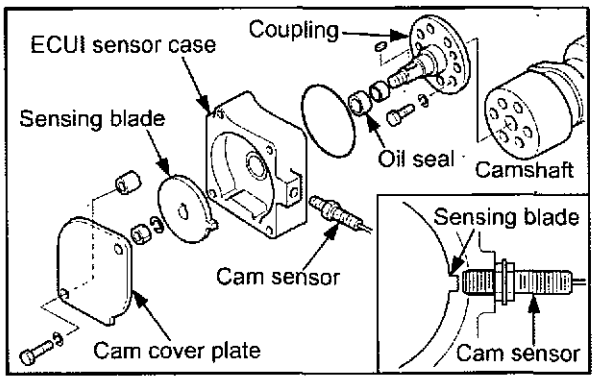
(4) Turn the crankshaft to set the prong of sensing blade to the cam sensor installation hole of the oil seal case.

(5) Install the compression cam sensor.

(6) Adjust the gap between the sensor and the sensing blade.

(7) Install the cam cover plate.

(8) Turn the crankshaft to No.1 cylinder compression top dead center.




Installing cam sensor

# 5. Reassembling cylinder head and valve mechanism

## 5.1 Reassembling cylinder head assembly

### 5.1.1 Installing SUS tube

(1) Insert O-ring into the cylinder head, and apply grease to the inner periphery of O-ring.

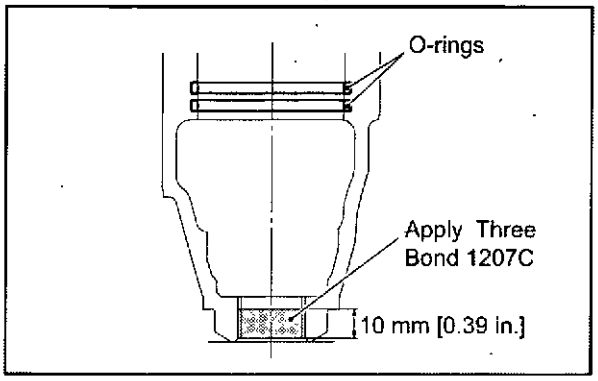
(2) Apply liquid packing (ThreeBond 1207C) to the thread about 10 mm [0.39 in] in height from the bottom of cylinder head thread.

Note: When applying liquid packing, be careful not to allow the liquid gasket to get on no other portion.

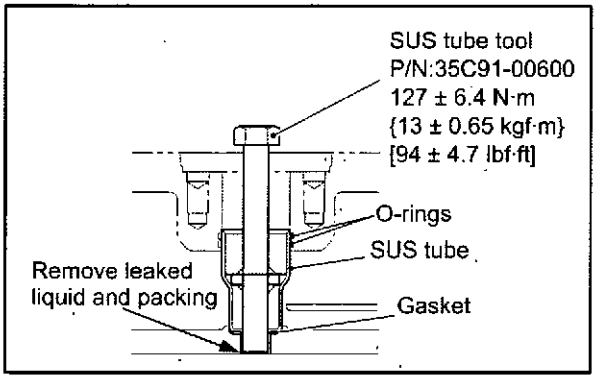
(3) Install the gasket to the cylinder, and insert the SUS tube.

(4) Tighten the SUS tube to the specified torque using a SUS tube tool.

Note: Completely wipe off protruding liquid packing which will extrude between cylinder head and SUS tube.




Installing SUS tube (1)




Installing SUS tube (2)

### 5.1.2 Reassembling valve and valve spring

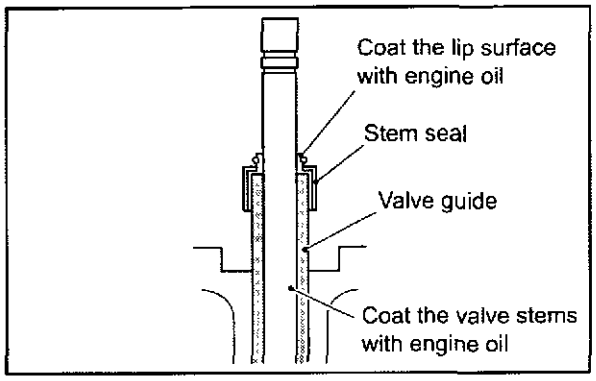
**CAUTION**

Be careful when inserting the valve through the stem seal, as the edge of valve can cause damage to the lip of the stem seal.

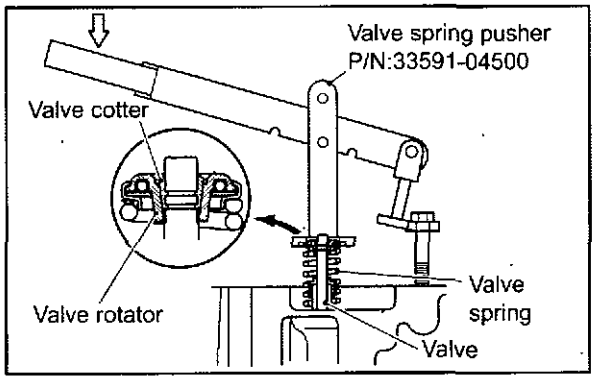
(1) Lubricate the valve stem with engine oil, then fit the valve onto the valve guide.

(2) Insert the stem seal through the valve guide using a guide and seal installer.

(3) Install the valve spring and rotator on the valve guide. Fit the valve cotters into position using the valve spring pusher.

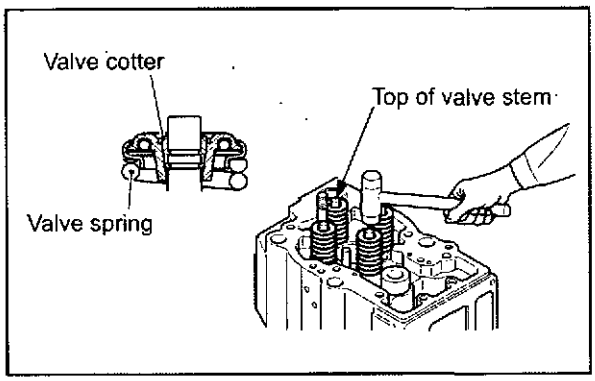



Reassembling cylinder head assembly (1)




Reassembling cylinder head assembly (2)

(4) Tap the top of the valve stem lightly several times with a soft-head hammer to make sure that the valve spring and valve cotters are properly installed and seated firmly.




Reassembling cylinder head assembly (3)

### 5.2 Applying liquid gasket

**CAUTION**

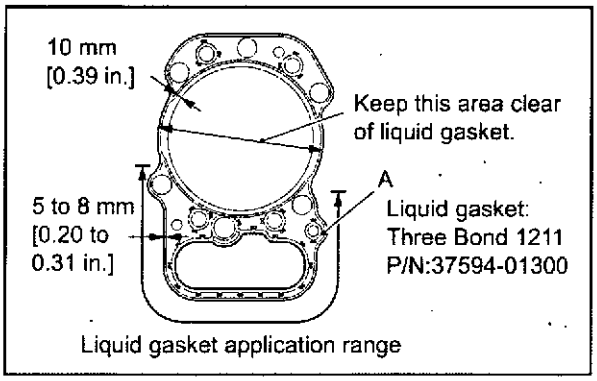
(a) Do not apply liquid gasket more than necessary. Excess liquid gasket could come into contact with O-rings, and cause deformation of O-rings. When applying gasket to portions A and B, in particular, take utmost care since there is little clearance to the O-rings.

(b) Keep the perimeter of the bores clear of liquid gasket. Liquid gasket on such areas could cause gas leakage.

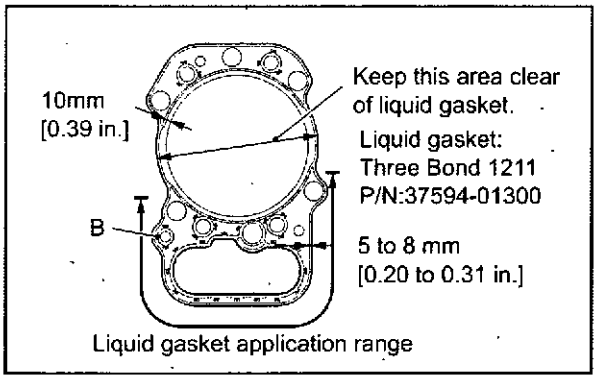
(1) Wipe off oil, grease and dirt thoroughly from the cylinder head gasket.

(2) Apply a thin coat of liquid gasket to both sides of the cylinder head gasket around the tappet holes and oil passages. Beads of liquid gasket should be 5 to 8 mm [0.20 to 0.31 in.] from the cylinder head gasket outer edge with a thickness of 0.2 to 0.5 mm [0.008 to 0.020 in.]. The particular applying ranges are as illustrated at right.

Note: After applying liquid gasket, install the cylinder head as soon as possible, as the gasket will be dried up readily.




Liquid gasket coating area (head side)

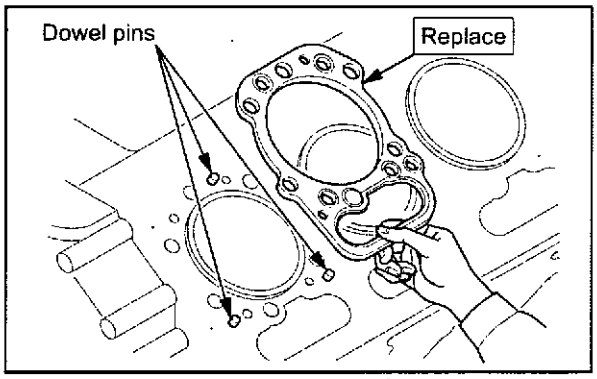



Liquid gasket coating area (crankcase side)

### 5.3 Installing cylinder head gasket

(1) Wipe off oil, grease and other stains from the cylinder head bottom surface and the crankcase upper surface with a shop towel.

(2) Install the cylinder head gasket that has been coated with liquid gasket onto the crankcase with the dowel pin and the hole in alignment.




Installing cylinder head gasket

### 5.4 Installing cylinder head assembly

**CAUTION**

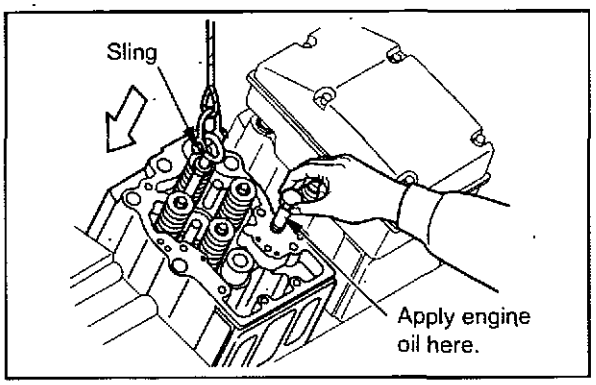
(a) Before installing the cylinder head, measure the piston protrusion at all cylinders to verify that they are normal.

(b) After applying engine oil to the cylinder head bolts, remove excess oil before installation.

(1) Attach a sling to the SH gland stud, connect a shackle and wire rope, then lift the cylinder head assembly.

(2) Apply engine oil to the threads and seat surfaces of the head bolts, then tighten the head bolts.

(3) Position the head properly by aligning the holes with the dowel pins, and temporarily tighten the cylinder head bolts while keeping the head slightly lifted.




Installing cylinder head assembly

### 5.5 Installing cylinder head bolt

The tightening of cylinder head bolts can be accomplished in two ways, i.e., 2-time tightening method and angle tightening method.

#### 5.5.1 2-time tightening method

(1) Tighten the cylinder head bolts to the specified torque in the illustrated order.

(2) Loosen all the tightened bolts, then retighten them as described above.

#### 5.5.2 Angle tightening method

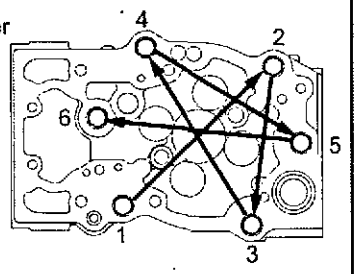
(1) Tighten the cylinder head bolts to snug torque (initial torque) in the indicated sequence.

(2) Tighten each bolt in the indicated sequence by turning 35 ± 1.5°.

(3) Then, tighten an additional 30 ± 1.5° (total of 65 ± 3°) in the indicated sequence.

(4) Loosen all bolts, and retighten as described above (2-time tightening)

Tightening torque for 2-step tightening method
539 ± 27.5 N·m {55 ± 2.8 kgf·m}
[398 ± 20.3 lbf·ft]
[Wet] Snug torque for angle tightening method
294 ± 14.7 N·m
{30 ± 1.5 kgf·m}
[217 ± 10.8 lbf·ft]

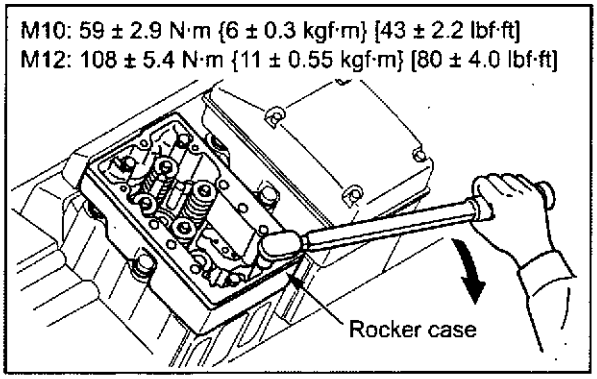



Head bolt tightening sequence

### 5.6 Installing rocker case

(1) Align hole of rocker case with dowen pin, install the rocker case.

(2) Tighten the rocker case mounting bolts to the specified torque.




Installing rocker case

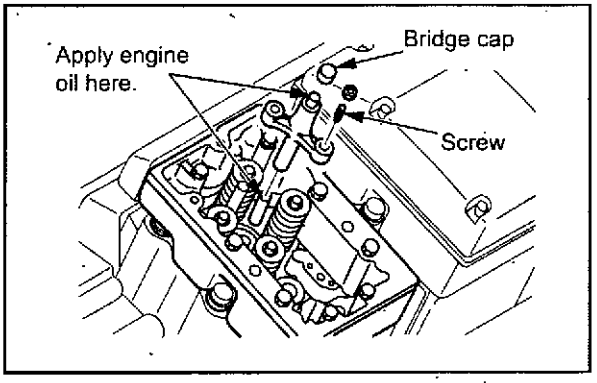
### 5.7 Installing bridges and bridge cap

(1) Apply engine oil to the bridge guide.

(2) Install the bridge onto the bridge guide so that the screw-fitted end of the bridge is positioned on the exhaust manifold side.

(3) Using the set screw, adjust the height of valve so that it is flush with the top of the other valve, and tighten the lock nut to the specified torque.

(4) Fit the bridge cap onto the bridge after applying a thin coat of engine oil to the seating surface. At this time, take care not to drop the cap inside the crankcase through the push rod hole.




Installing bridge and bridge cap

### 5.8 Installing electronically controlled unit injector

**CAUTION**

(a) Handle the injection nozzle with utmost care to prevent contamination by dust, or O-ring damage.

(b) Make sure the old gasket is completely removed from the bottom section of the stainless tube. The injector may be damaged if a new gasket is installed on top of the previous gasket.

(1) Apply grease to the gasket, and attach the gasket to the unit injector.

(2) Thoroughly clean the area where the copper tube is installed in the cylinder head so that no foreign particles such as dust may not remain. Dust in the hole may result in gas leakage or fuel leakage.

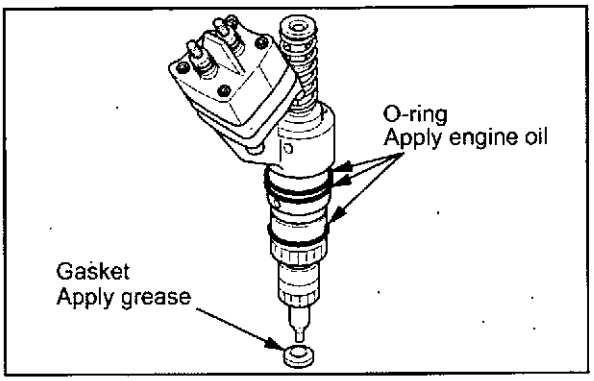
(3) Completely remove the gasket from the bottom inner surface of the stainless tube using a wire or other tool.

(4) Apply grease, silicone oil or lubricant to the outer surface of O-rings.

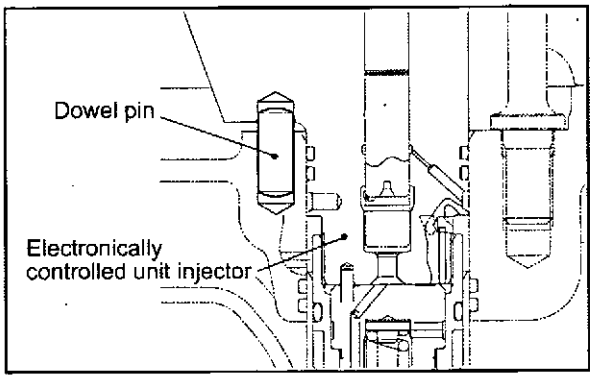
(5) Aligning the injector dowel pin with the dowel hole of cylinder head, insert the unit injector into the cylinder head.

(6) Insert the gland, and tighten the fixing nut by hand. Make sure that the unit injector is fully inserted, that the dowel pin is in the dowel hole, and that the gland is positioned properly.

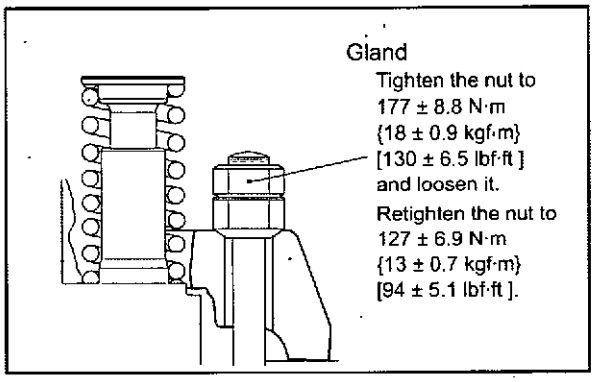
(7) Tighten the fixing nut to the specified torque.




Installing electronically controlled unit injector




Installing electronically controlled unit injector




Installing gland

### 5.9 Installing rocker shaft assembly

**⚠ CAUTION**

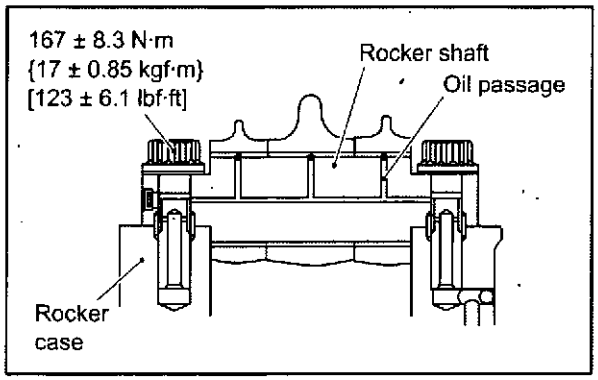
(a) After assembly, move the rocker arm up and down to make sure the rocker arm moves freely.

(b) When tightening the rocker shaft mounting bolts, tighten the bolt that also secures the rocker case first.

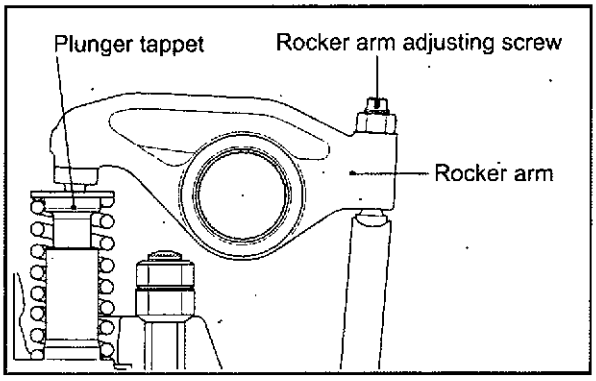
(1) Align the pin hole of the rocker shaft with the positioning pin, and install the rocker shaft assembly to the rocker case.

(2) Tighten the rocker shaft assembly mounting bolts to the specified torque.

(3) Tighten the rocker arm adjusting screw firmly so that there is no looseness of the rocker arm.

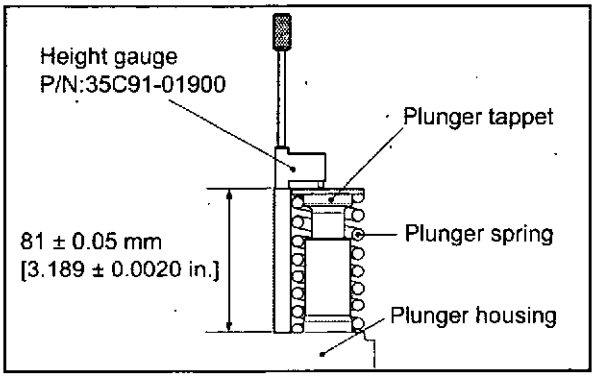



Installing rocker shaft assembly




Adjusting rocker arm adjusting screw

(4) Adjust the plunger tappet height between the spring seat of plunger housing and the tappet end, to the standard value when the plunger is positioned its compression top dead center. (Cam profile is base circle.)



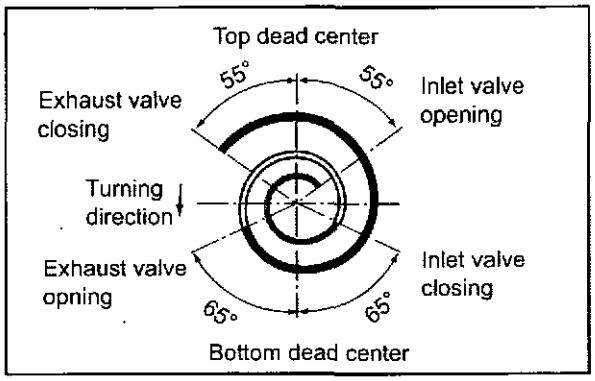

Measuring plunger tappet height

### 5.10 Inspecting valve timing

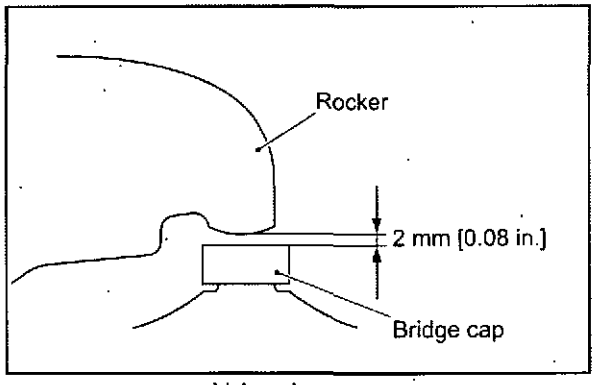
The valve timing will be set in the specified range if each gear is assembled according to the match marks. For verification, however, inspect the valve timing as follows:

(1) Make sure that the No.1 piston is at the top dead center on compression stroke.

(2) Using a 2 mm [0.08 in.] thick feeler gauge, adjust the valve clearance of both inlet and exhaust valves of the No.1 cylinder to 2 mm [0.08 in.].

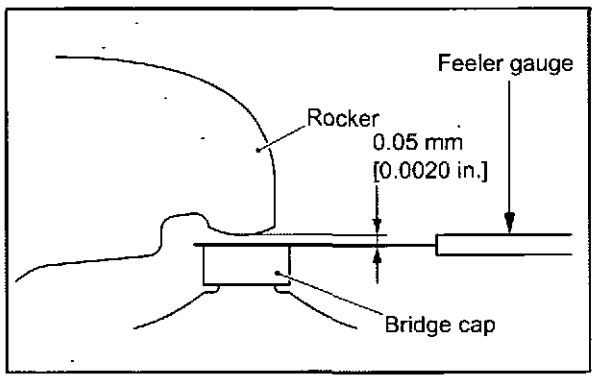



Valve timing diagram
(when valve clearance is standard value)

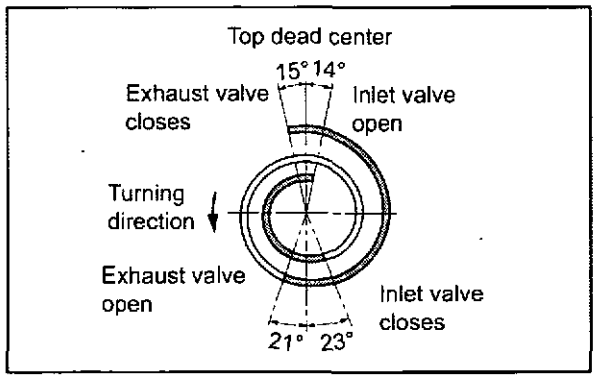



Valve clearance
(with 2 mm [0.08 in.] clearance added to valve)

(3) With a 0.05 mm [0.0020 in.] thick feeler gauge inserted between the bridge cap and the rocker, slowly rotate the crankshaft to determine the position where the feeler gauge becomes hard to move (i.e., the valve begins to open) and the position where the gauge becomes easy to move (i.e., the valve is closed). Check to see if these positions agree with the angular positions shown in the valve timing diagram with a 2 mm [0.08 in.] clearance held on each valve.




Valve clearance
(with 0.05 mm [0.0020 in.] clearance added to valve)




Valve timing diagram
(with 2 mm [0.08 in.] clearanae added to the valve)

### 5.11 Adjusting valve clearance

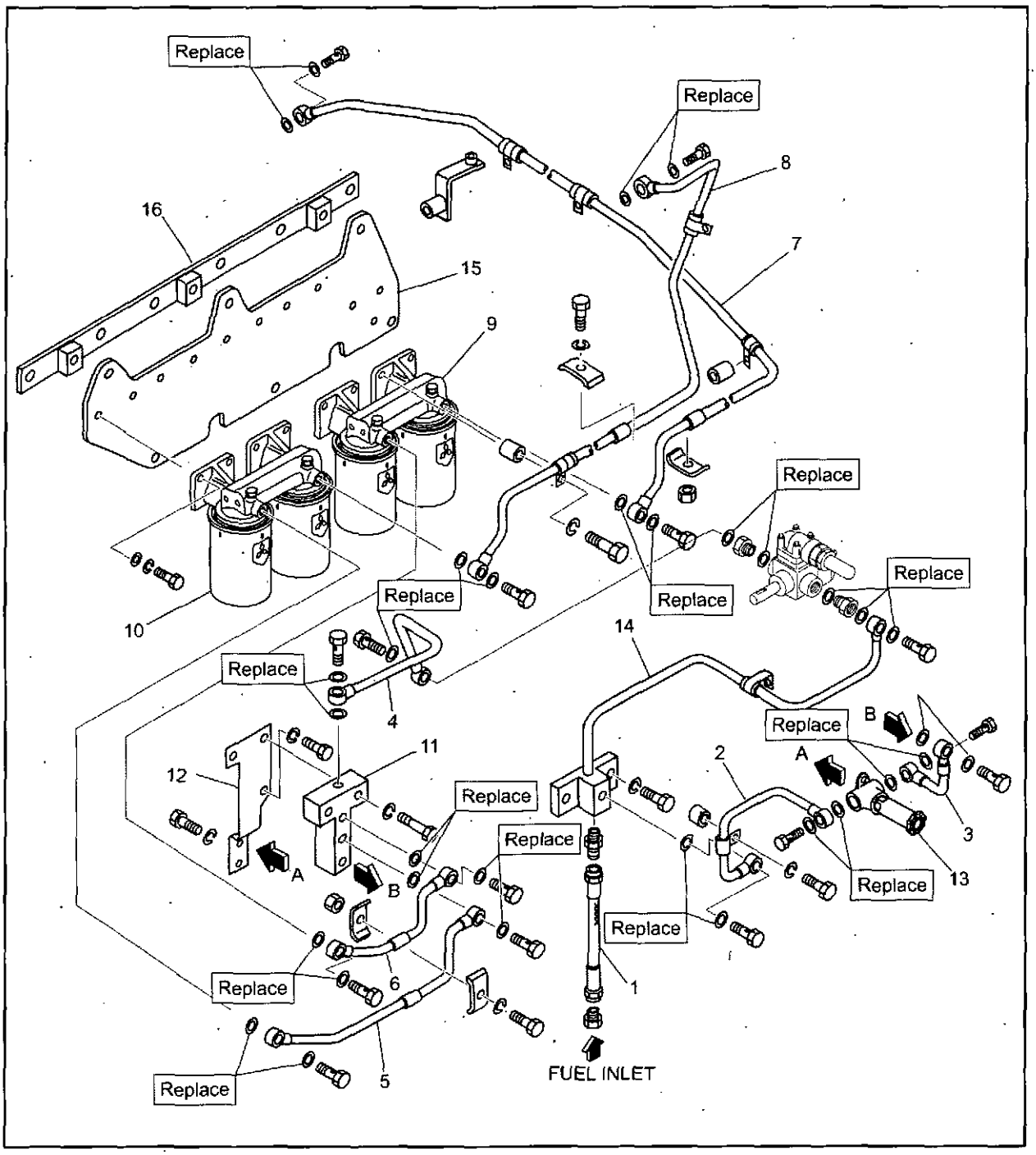
Adjust the valve clearance.

For adjusting procedures, refer to "Adjustment and Operation."

# FUEL SYSTEM

# 1. Removing fuel system

## 1.1 *Removing and inspecting fuel filter and fuel pipe*

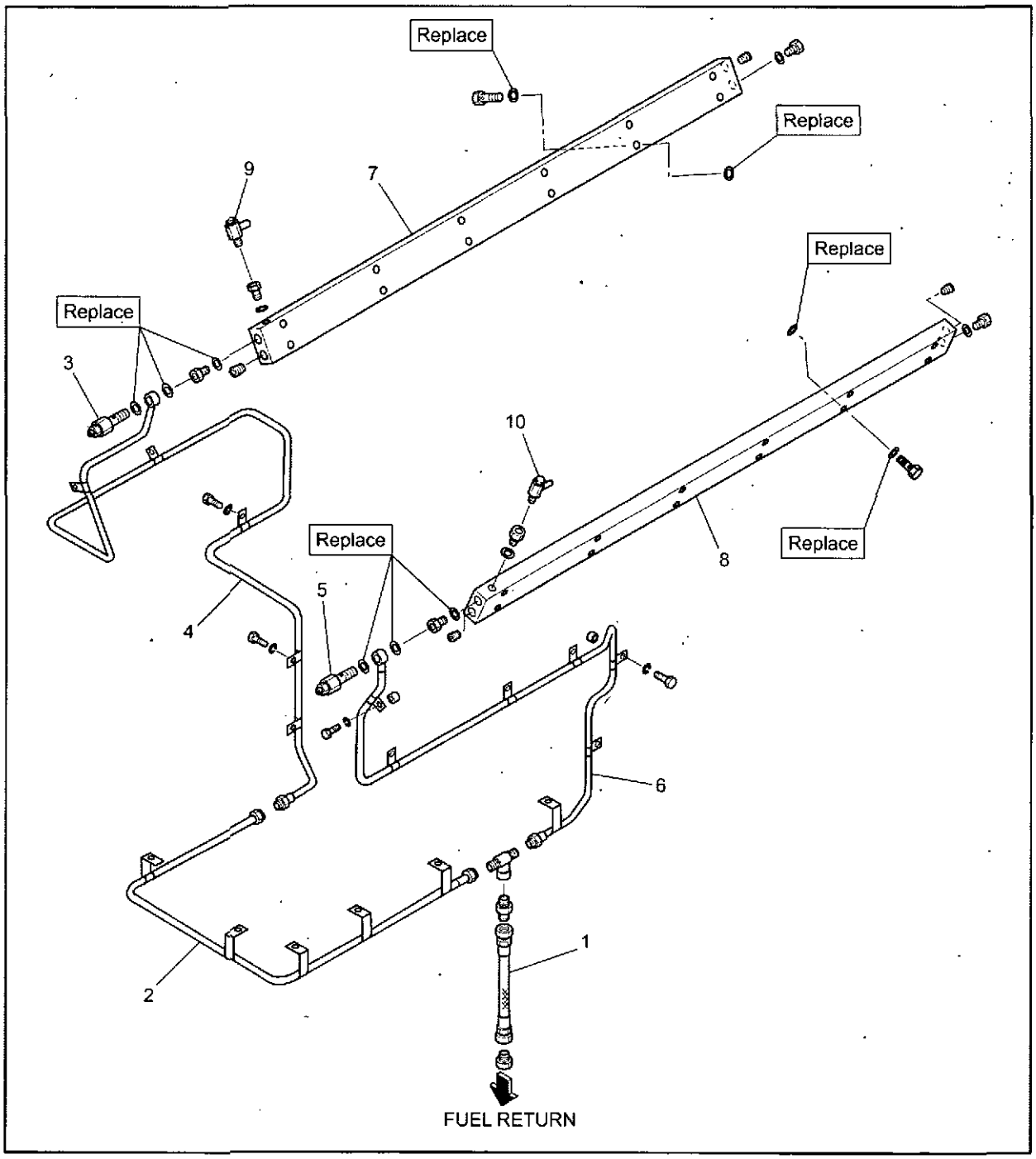



Removing and inspecting fuel filter and fuel pipe

Removing sequence

1 *Inlet pipe*
2 Fuel pipe
3 Fuel pipe
4 Fuel pipe
5 Fuel pipe (rear)
6 Fuel pipe (front)
7 *Fuel pipe (R.H)*
8 Fuel pipe (L.H)
9 Fuel filter (R.H)
10 Fuel filter (L.H)
11 Connector
12 Priming pump bracket
13 *Priming pump*
14 Fuel filter
15 Bracket
16 Bracket

## 1.2 Removing and inspecting fuel pipe and fuel return pipe

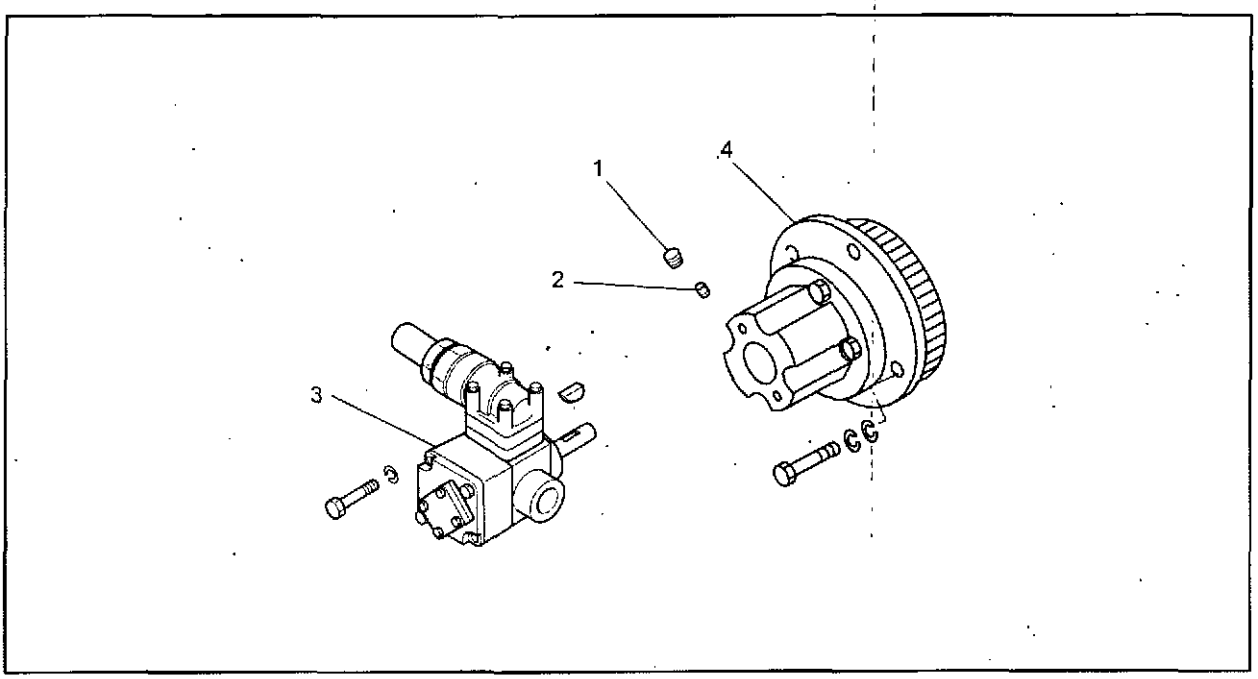



Removing and inspecting fuel pipe and fuel return pipe

Removing sequence

1 Drain pipe
2 Return pipe (R.H)
3 Check valve
4 Return pipe (R.H)
5 Check valve
6 Return pipe (L.H)
7 Fuel pipe (R.H)
8 Fuel pipe (L.H)
9 Air valve (R.H)
10 Air valve (L.H)

### 1.3 Removing fuel feed pump and accessory drive



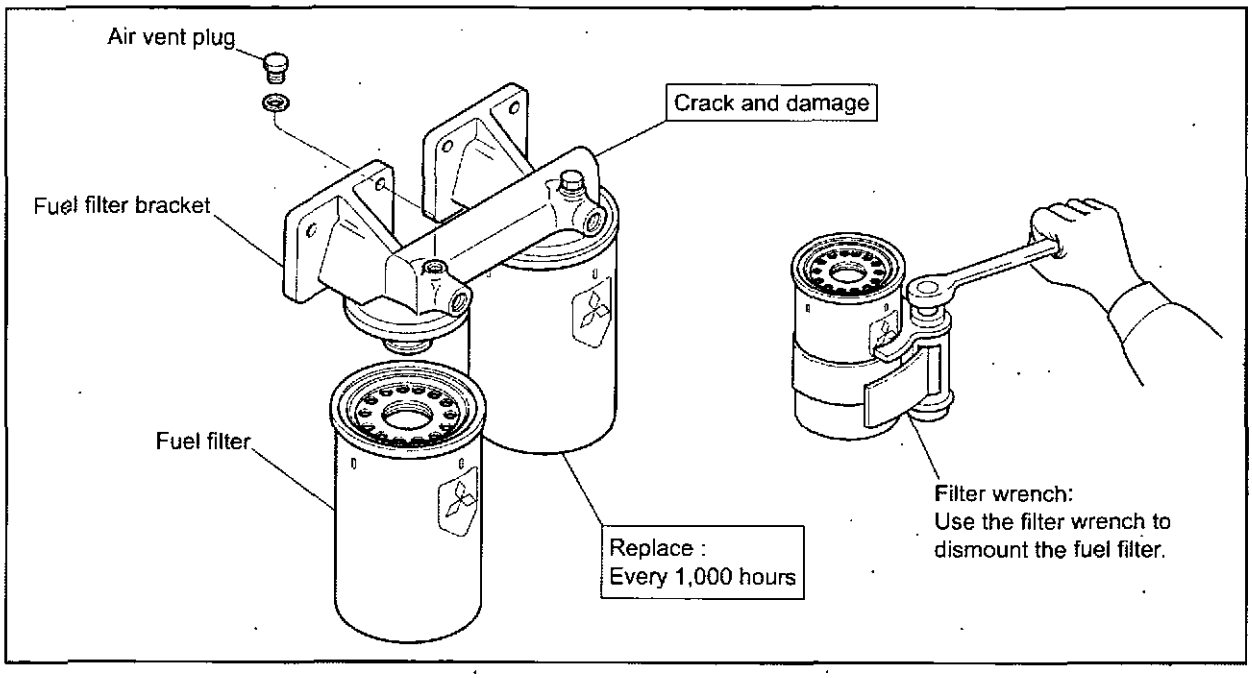

Removing fuel feed pump and accessory drive

Removing sequence

1 Plug
2 Set screw
3 Fuel feed pump
4 Accessory drive

## 2. Disassembling, inspecting and reassembling fuel system

### 2.1 Disassembling and inspecting fuel filter




Disassembling and inspecting fuel filter

### 2.2 Reassembling fuel filter

**⚠ WARNING**

Make sure that there is no flame when handling fuel. Wipe off any spilled fuel to prevent a fire.

**CAUTION**

(a) Hand tighten the fuel filter. Do not use the filter wrench.

(b) Be careful not to dent or scratch the surface of the fuel filter.

(1) Prepare a new fuel filter and make sure that the gasket is securely set on the groove.

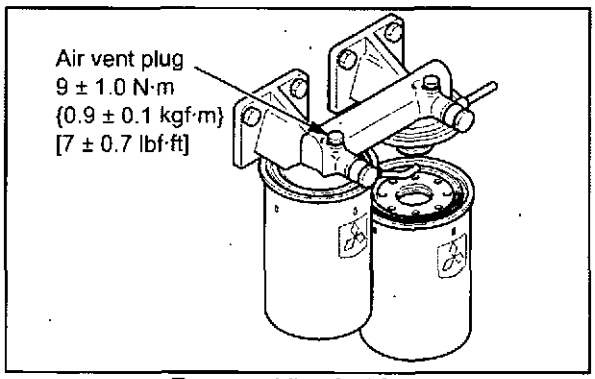
(2) Apply clean fuel oil on the gasket.

(3) Mount the fuel filter on the filter bracket. When the gasket of the fuel filter comes into contact with the mounting surface of the filter bracket, tighten the fuel filter by 3/4 to 1 turn.

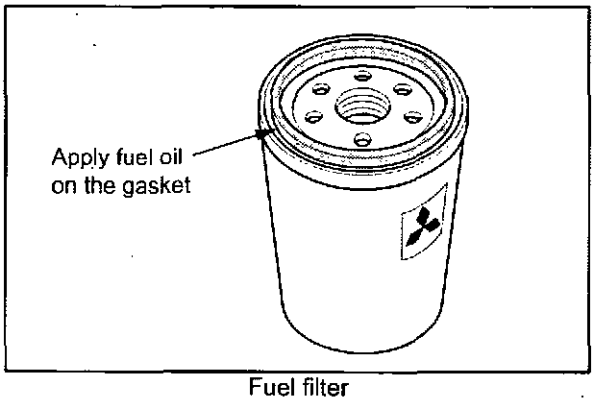
(4) When the fuel filter has been installed, bleed the air from the fuel filter.

(5) Start the engine and idle for a few minutes.

(6) Make sure that no fuel is leaking from the fuel filter mounting surface. If a leak is found, loosen the filter, and tighten the filter again after verifying that the gasket is not damaged.

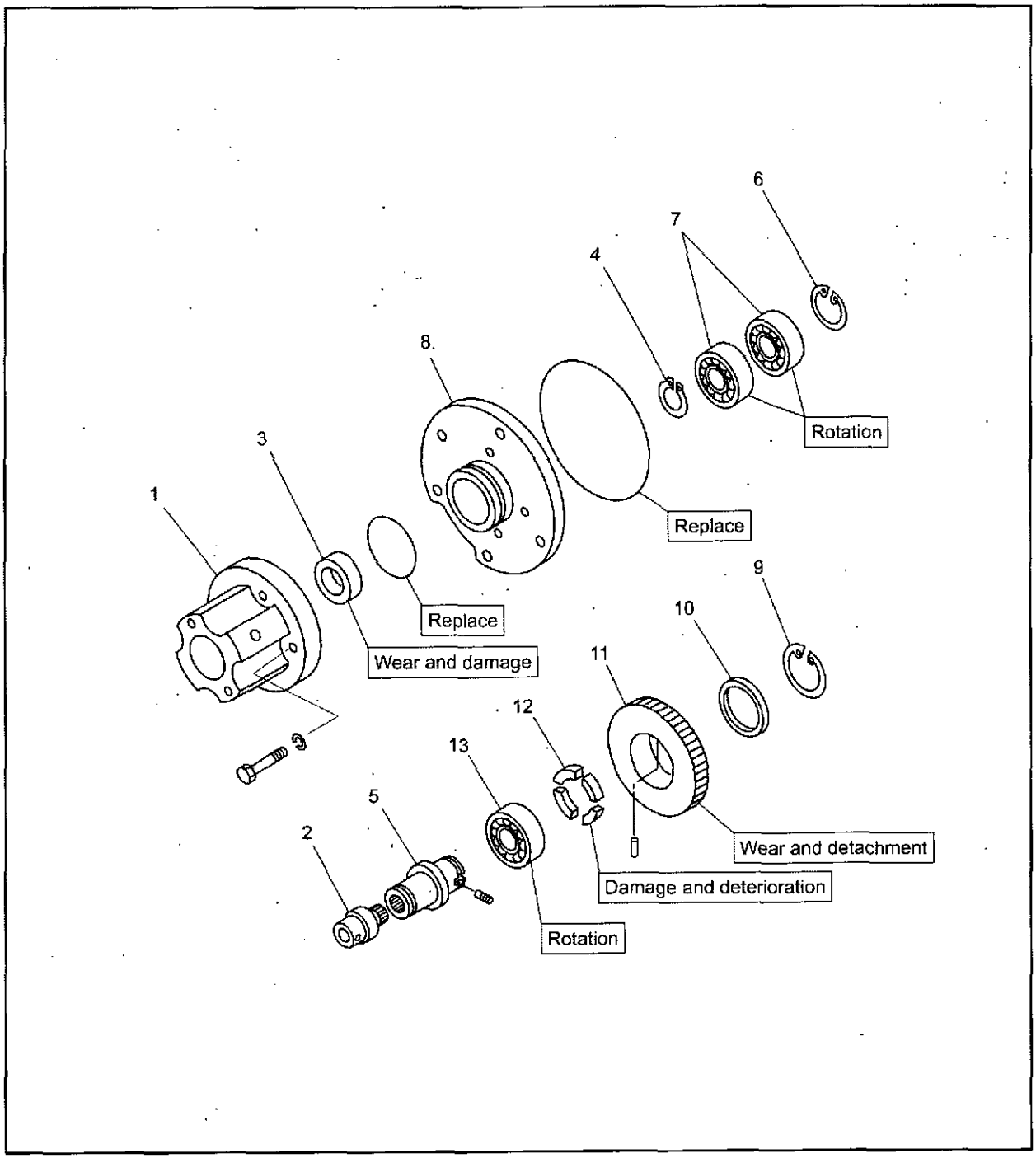



Reassembling fuel filter




Fuel filter

## 2.3 Disassembling and inspecting accessory drive




*Disassembling and inspecting accessory drive*

Disassembling sequence

1 Oil seal case
2 Adapter shaft
3 Oil seal
4 Snap ring
5 Feed pump drive shaft
6 Snap ring
7 Ball bearing
8 Feed pump drive case
9 Snap ring
10 Washer
11 Feed pump drive gear
12 Rubber
13 Ball bearing

## 2.4 Inspecting accessory drive

Outside and inside diameters of bearing-fitted sections

Rotate each bearing, and if it does not rotate smoothly, replace the bearing.

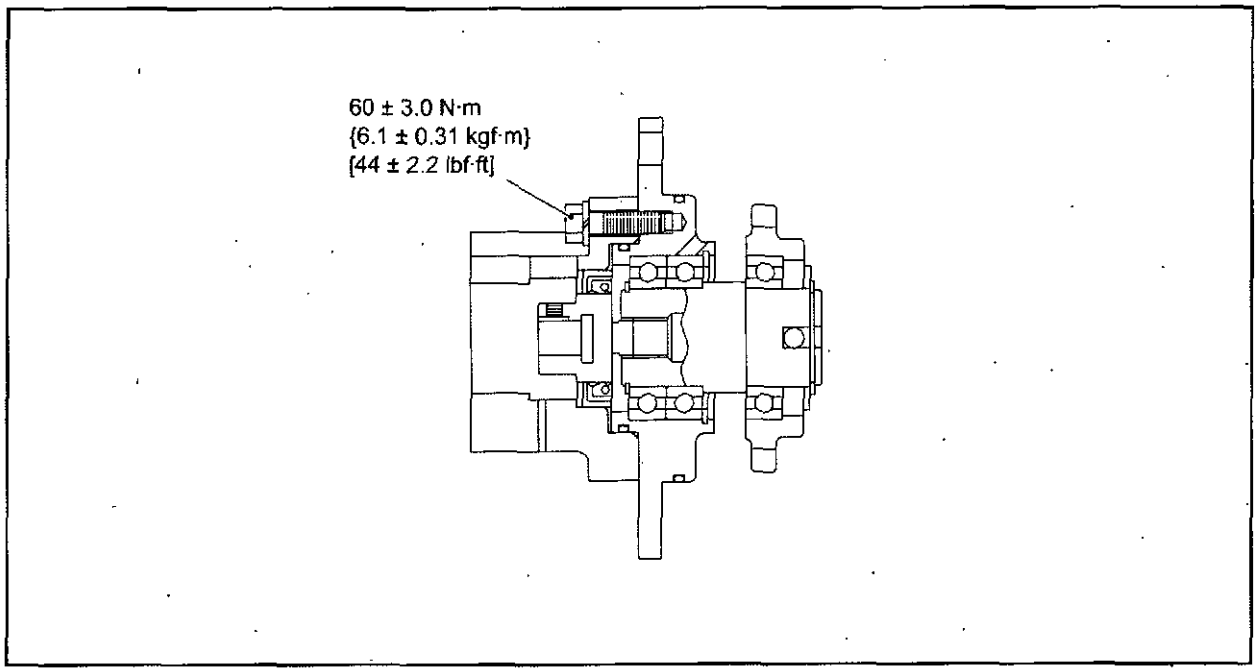
Inspect the bearing journals of the drive shaft, and replace the drive shaft if worn.

Inspect the bearing housing of the drive case, and replace the drive case if worn.

Inspect the drive shaft and oil seal, and replace if any abnormality is found.

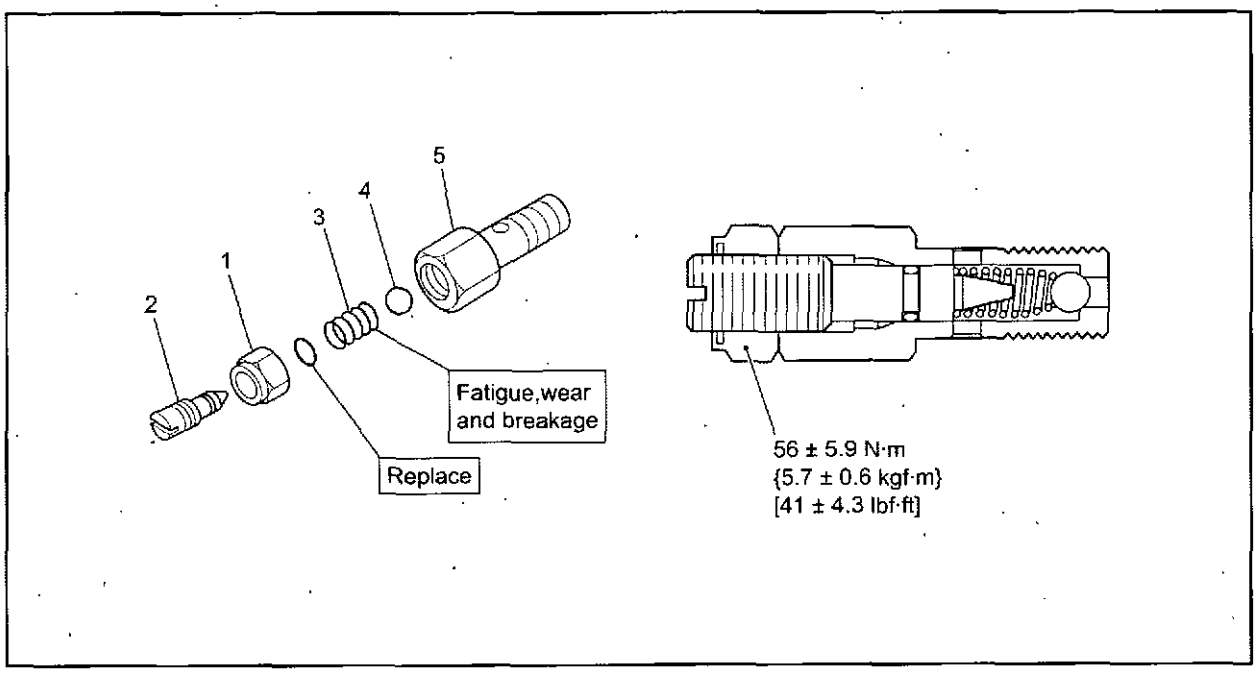
| Item | | Nominal | Standard |
|---|---|---|---|
| Feed pump drive gear bearing bore diameter | | ø 68 mm [2.68 in.] | 67.961 to 67.991 mm [2.6756 to 2.6768 in.] |
| Bearing | Bore diameter | ø 40 mm [1.57 in.] | 39.988 to 40.000 mm [1.5743 to 1.5748 in.] |
| | Outside diameter | ø 68 mm [2.68 in.] | 67.987 to 68.000 mm [2.6766 to 2.6772 in.] |
| Feed pump drive shaft bearing joural diameter | | ø 40 mm [1.57 in.] | 39.995 to 40.011 mm [1.5746 to 1.5752 in.] |

## 2.5 Reassembling accessory drive




Reassembling accessory drive

## 2.6 Disassembling, inspecting and reassembling check valve



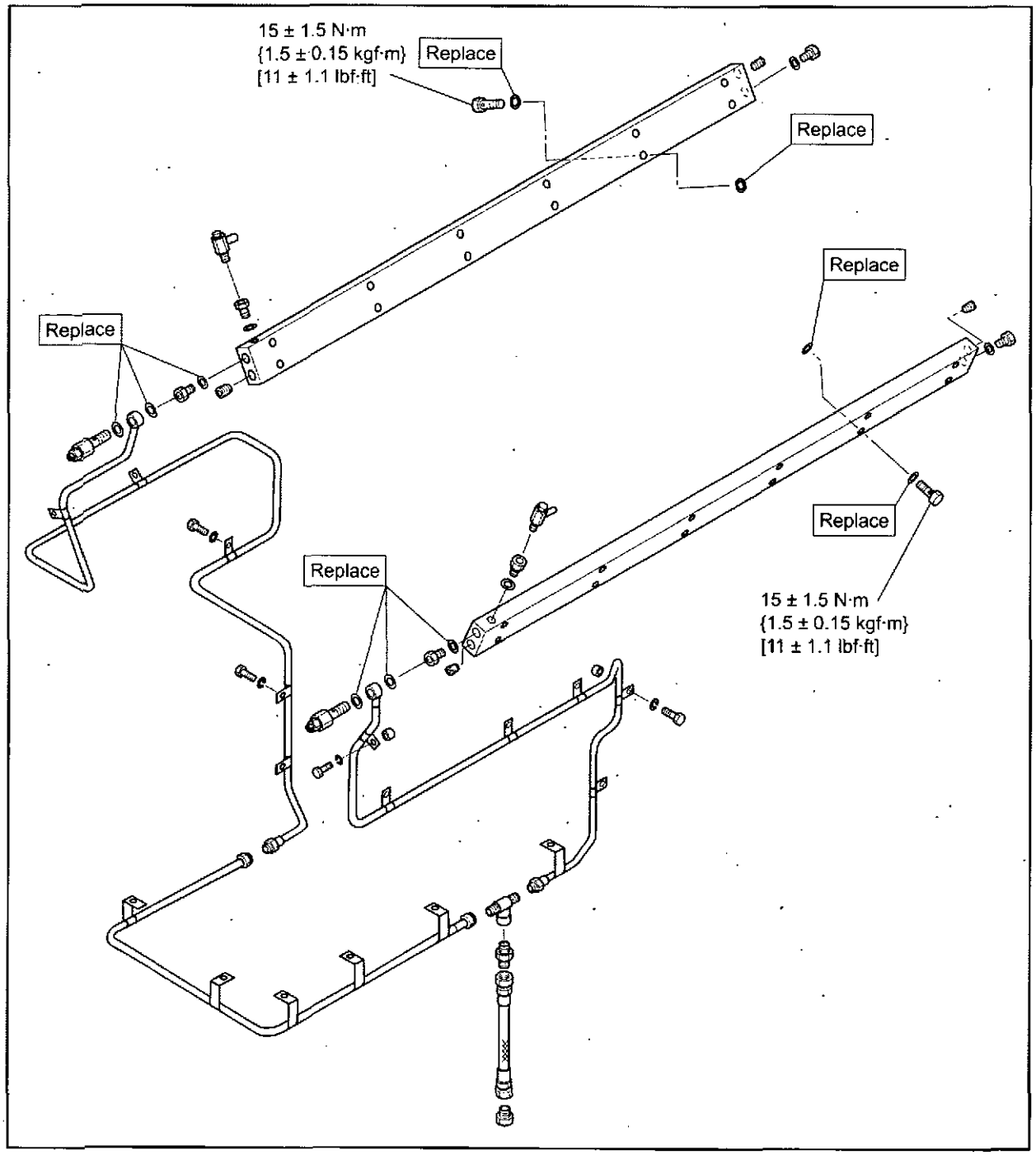

Disassembling, inspecting and reassembling check valve

Disassembling sequence

1 Jam nut
2 Screw
3 Valve spring
4 Ball
5 Valve body

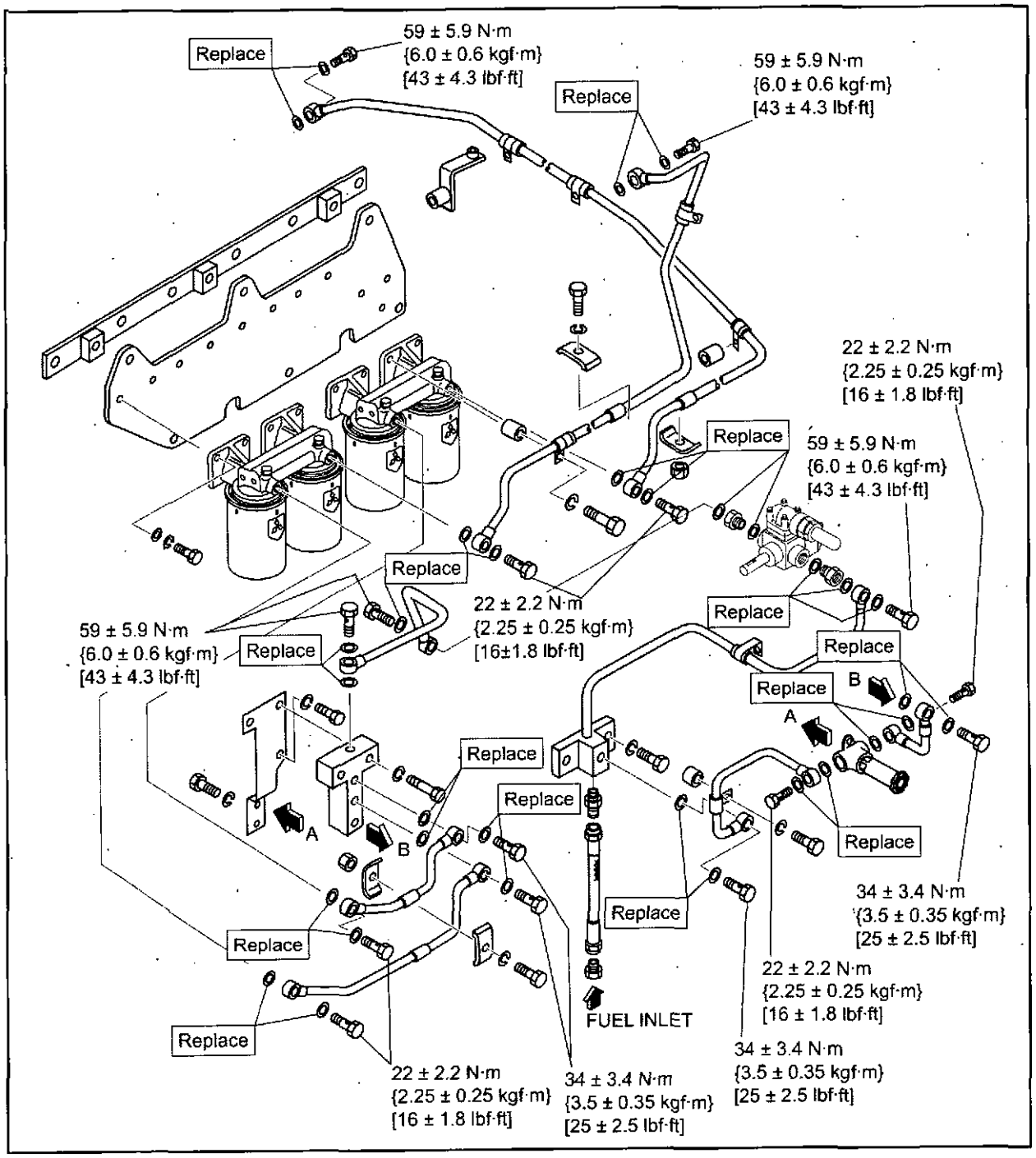
## 3. Installing fuel system

### 3.1 Installing fuel pipe and fuel return pipe




Installing fuel pipe and fuel return pipe

### 3.2 Installing fuel filter and fuel pipe

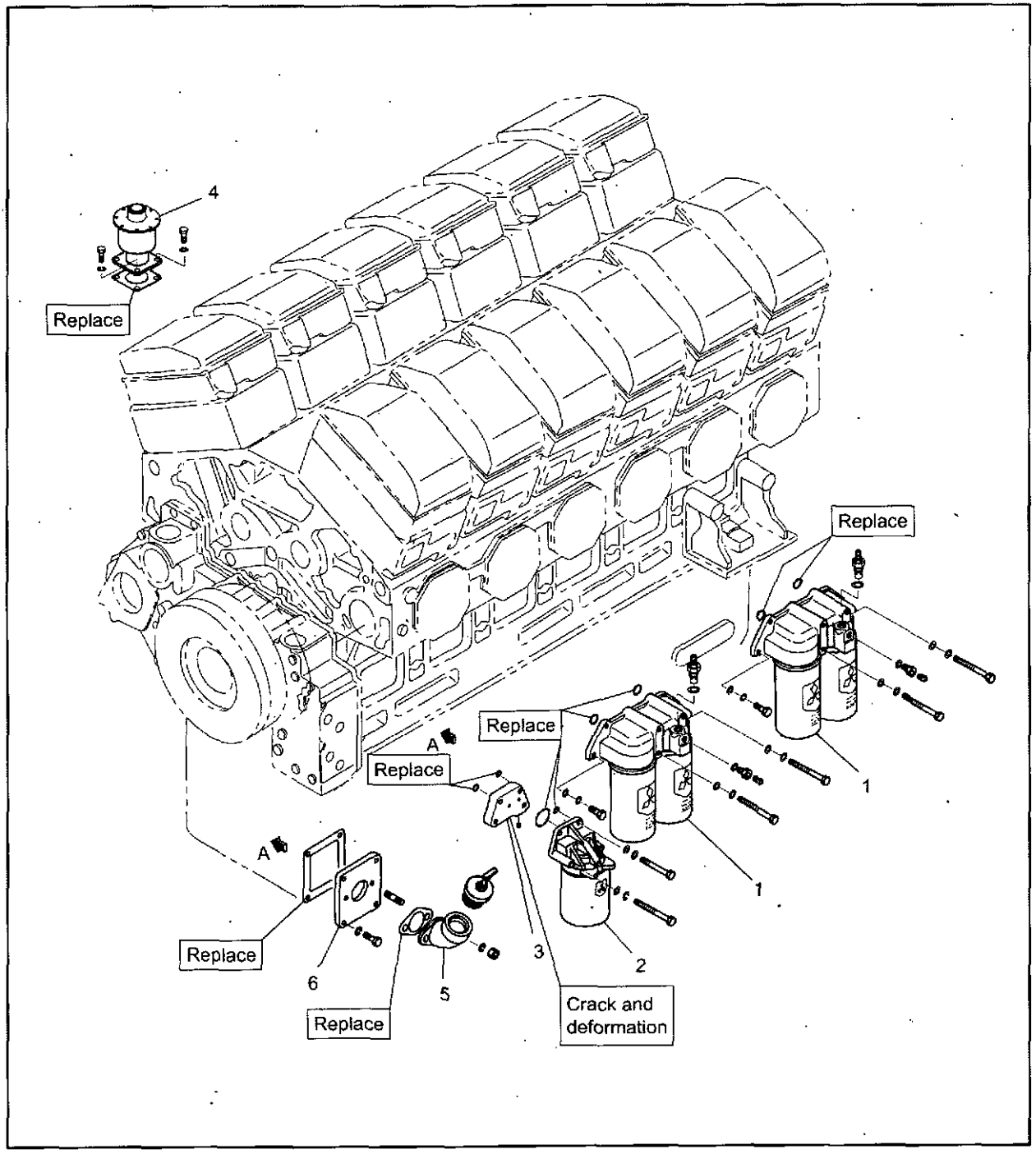



Installing fuel filter and fuel pipe

# LUBRICATION SYSTEM

# 1. Removing and inspecting lubrication system

## 1.1 *Removing and inspecting oil filter, oil bypass filter and breather*

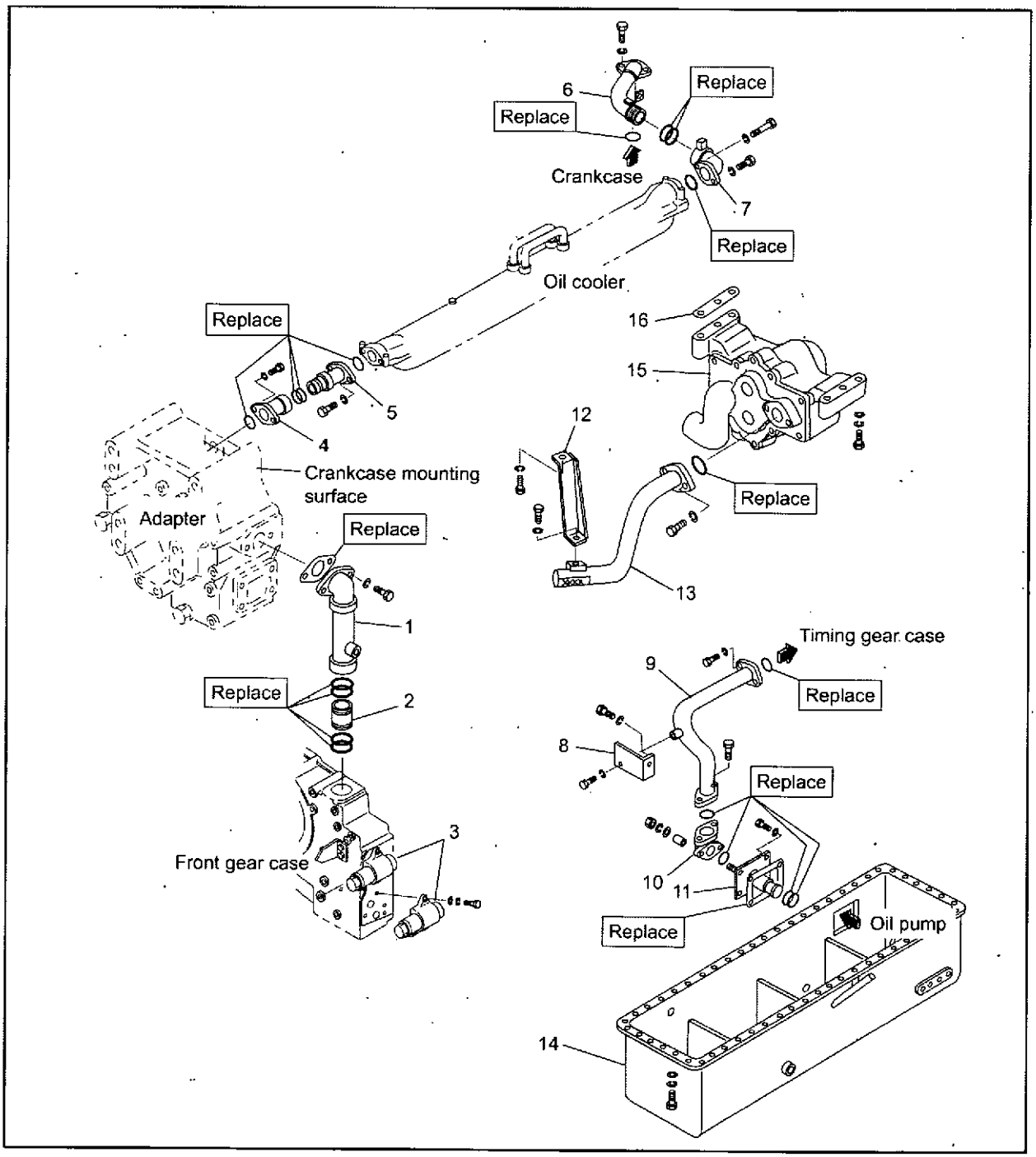



Removing and inspecting oil filter, oil bypass filter and breather

Removing sequence

| | | |
|---|---|---|
| 1 Oil filter | 3 Spacer | 5 Oil filler |
| 2 Bypass filter | 4 Breather | 6 Cover |

## 1.2 Removing and inspecting oil pipe (1)

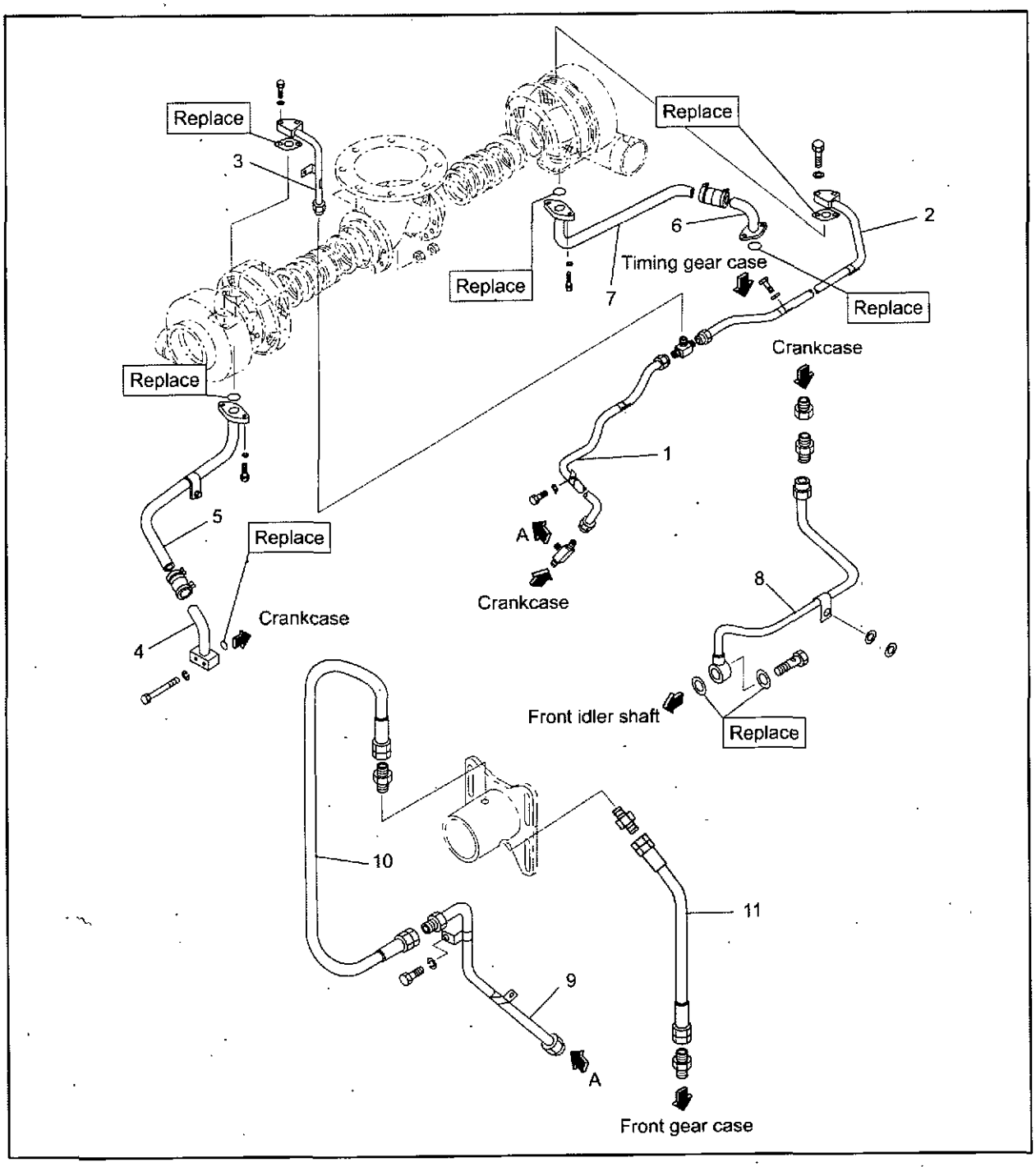



Removing and inspecting oil pipe (1)

Removing sequence

1 Oil pipe
2 Connector
3 Relief valve
4 Connector
5 Connector
6 Oil pipe
7 Connector
8 Stay
9 Oil pipe
10 Connector
11 Connector
12 Strainer stay
13 Oil strainer
14 Oil pan (weight: approx. 70kg [154 lb])
15 Oil pump (weight: approx. 33kg [73 lb])
16 Shim

### 1.3 Removing and inspecting oil pipe (2)

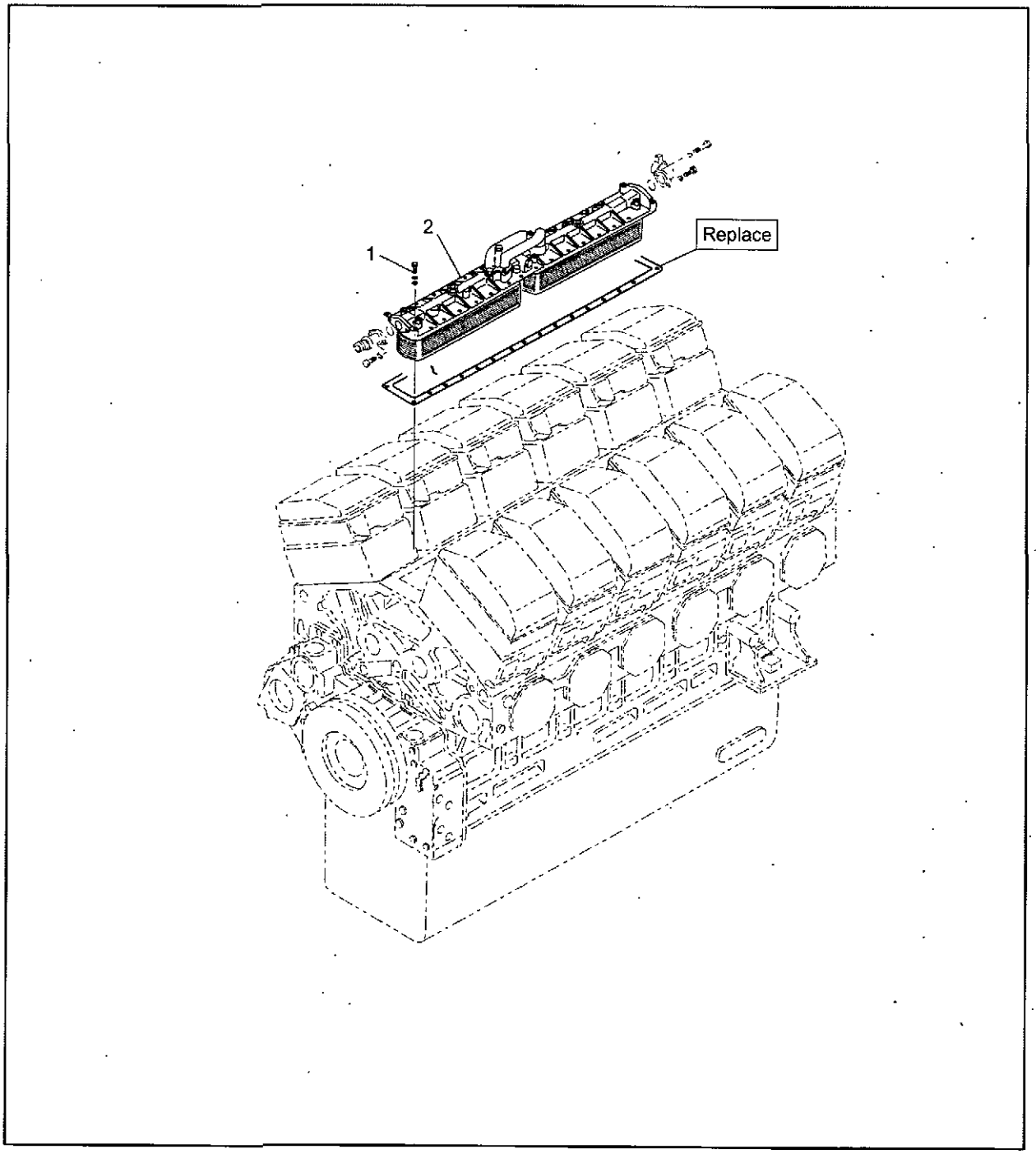



Removing and inspecting oil pipe (2)

Removing sequence

1 Oil pipe
2 Oil pipe
3 Oil pipe
4 Drain pipe
5 Drain pipe
6 Drain pipe
7 Drain pipe
8 Oil pipe
9 Fan pipe
10 Flexible pipe
11 Flexible pipe

## 1.4 Removing and inspecting oil cooler



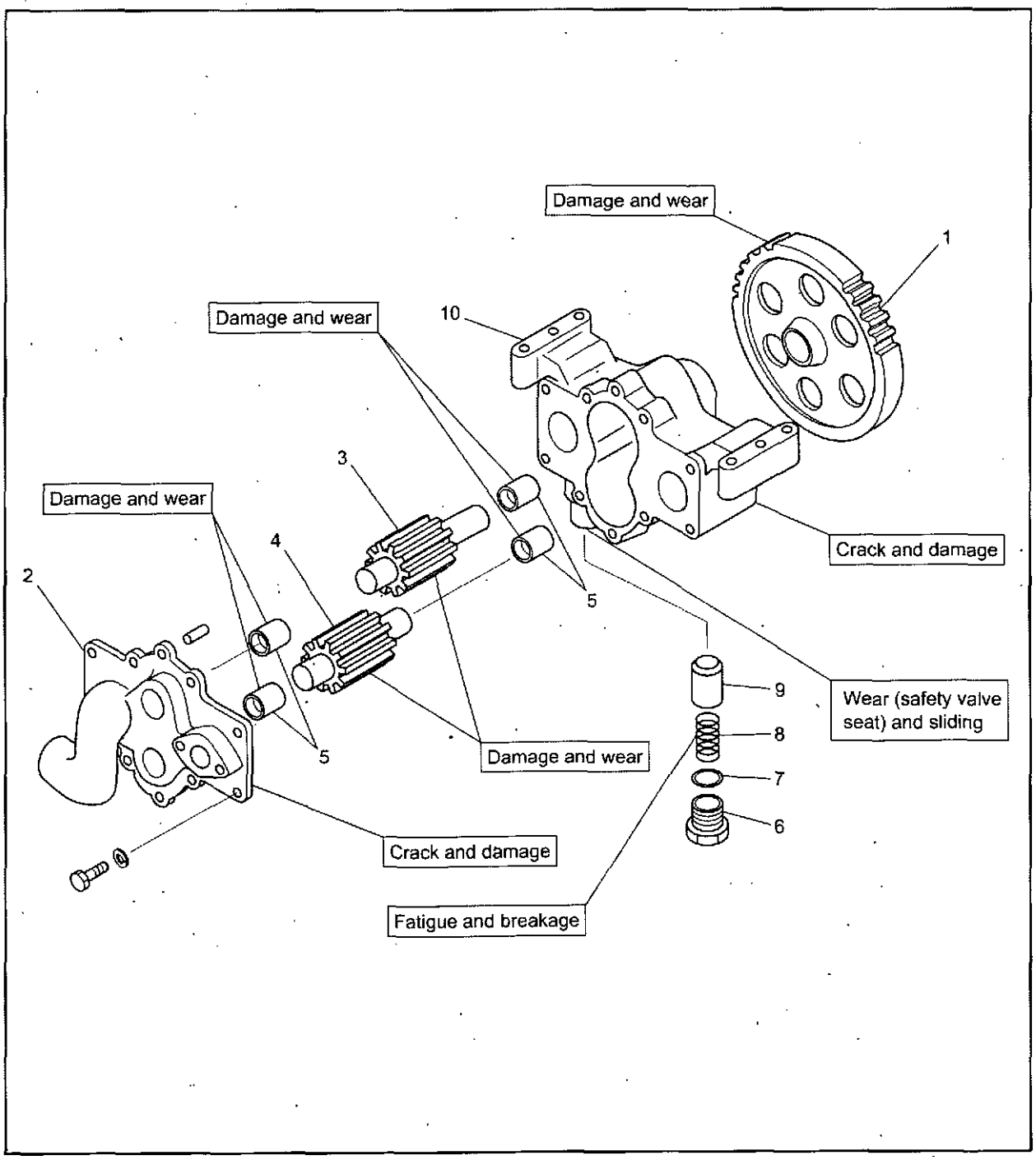

Removing and inspecting oil cooler

Removing sequence

1 Bolt
2 Oil cooler

## 2. Disassembling, inspecting and reassembling lubrication system

### 2.1 Disassemblig and inspecting oil pump and safety valve




Disassemblig and inspecting oil pump and safety valve

Disassembling sequence

1 Driven gear
2 Pump cover
3 Driven gear
4 Driven gear
5 Bushing
6 Safety valve
7 Shim
8 Spring
9 Safety valve
10 Oil pump case

## 2.2 Inspecting oil pump and safety valve

### 2.2.1 Measuring base tangent length of drive and driven gears

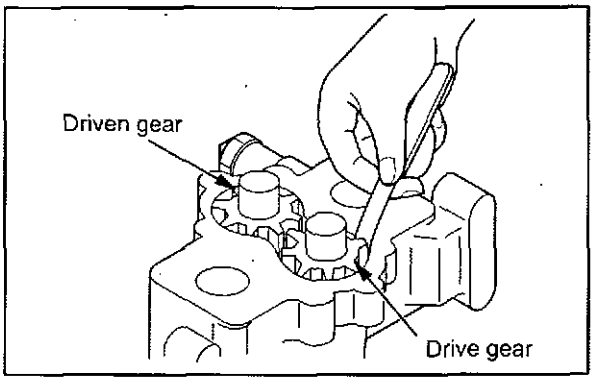
Measure the base tangent length of drive and driven gears. If the measured value exceeds the limit, replace the gear.

| Item | Standard | Limit |
|---|---|---|
| Base tangent length of drive and driven gears | 27.983 to 28.055 mm [1.1017 to 1.1045 in.] | 27.93 mm [1.0996 in.] |

### 2.2.2 Measuring end clearance between gears and case

Measure the end clearance between gear width and case depth. If the limit is exceeded, replace gears/case with a new one.

| Item | Standard | Limit |
|---|---|---|
| Clearance between gears tips and case | 0.095 to 0.140 mm [0.0037 to 0.0055 in.] | 0.190 mm [0.0075 in.] |

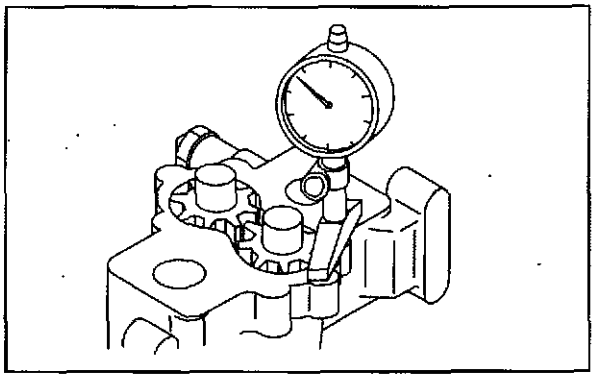



Measuring end clearance between gears and case

### 2.2.3 Measuring side clearance between gears and case

Measure the side clearance between gear teeth and case bore. If the limit is exceeded, replace gears or case with a new one.

| Item | Standard | Limit |
|---|---|---|
| Measuring side clearance between drive and driven gear widths and oil pump case | 0.095 to 0.155 mm [0.0037 to 0.0061 in.] | 0.290 mm [0.0114 in.] |



Measuring side clearance between gears and case

### 2.2.4 Measuring drive and driven gear shaft outside diameters and bushing inside diameter

(1) Inspect the gear teeth. If any defects are found, replace the gear with a new one.

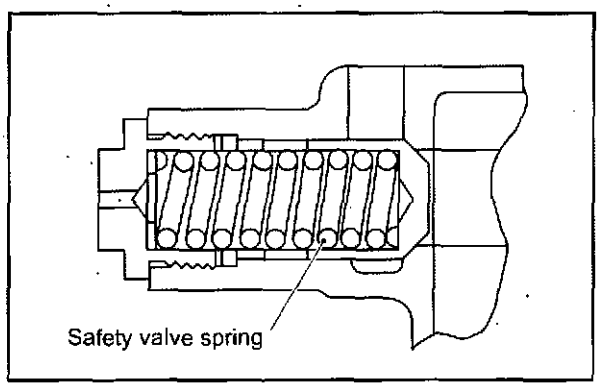
(2) Measure the drive and driven gear shaft outside diameters and the bushing inside diameter. If any of the gear and bushing combination exceeds the limit, replace it with the new set of such parts.

| Item | Nominal | Standard | Limit |
|---|---|---|---|
| Gear shaft diameter | ø 40 mm [1.57 in.] | 39.984 to 40.000 mm [1.5742 to 1.5764 in.] | 39.930 mm [1.5720 in.] |
| Bushing inside diameter | | 40.000 to 40.059 mm [1.5764 to 1.5771 in.] | 40.140 mm [1.5803 in.] |

### 2.2.5 Inspecting oil pump safety valve spring

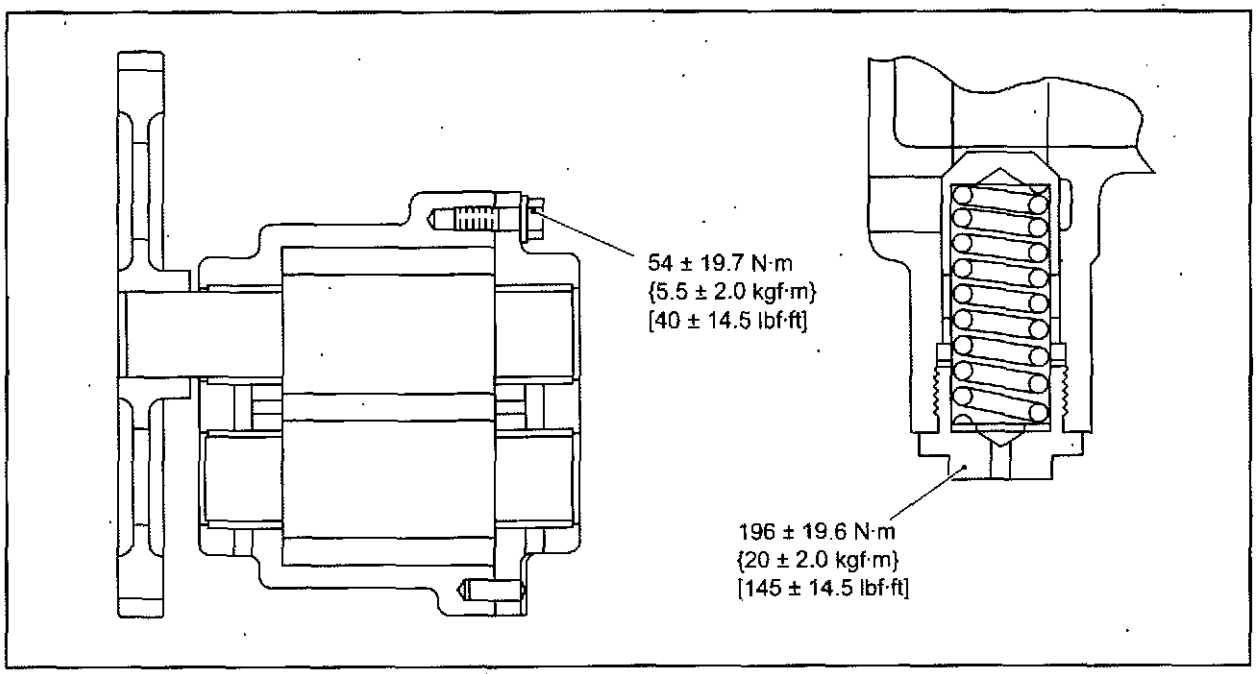
Inspect oil pump safety valve spring for settling and damage. If significant settling, wear, or damage is found, replace the safety valve spring.

| Item | Standard | Limit |
|---|---|---|
| Safety valve spring installation length/load | 73.4 mm [2.890 in.]/ 902 to 1040 N {92 to 106 kgf} [203 to 234 lbf] | 73.4 mm [2.890 in.]/ 834 N {85 kgf} [187 lbf] |




Inspecting safety valve

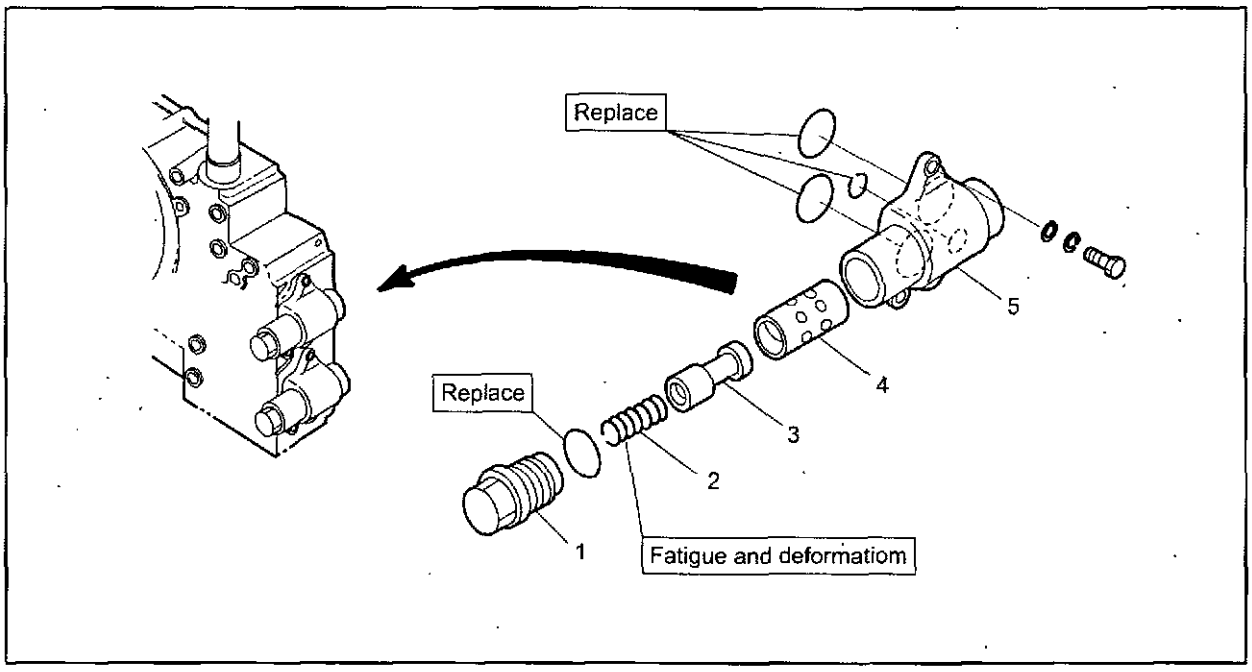
## 2.3 Reassembling oil pump and safety valve




Reassembling oil pump and safety valve

Note: Lubricate individual parts with engine oil during reassembly. Apply a thick coat of engine oil to the threads and seating surfaces of the nuts and bolts before tightening them.

## 2.4 Disassembling and inspecting relief valve




Disassembling and inspecting relief valve

Disassembling sequence

1 Plug
2 Spring
3 Relief valve
4 Sleeve
5 Case

## 2.5 Measuring relief valve pressure

(1) Remove the taper plug (PT1/8) on the upper surface of the oil filter bracket, and set a pressure gauge.

(2) Conduct a warm-up operation until the oil temperature reaches 70 to 90°C [158 to 194°F].

(3) Measure the oil pressure at idle and maximum speed respectively.

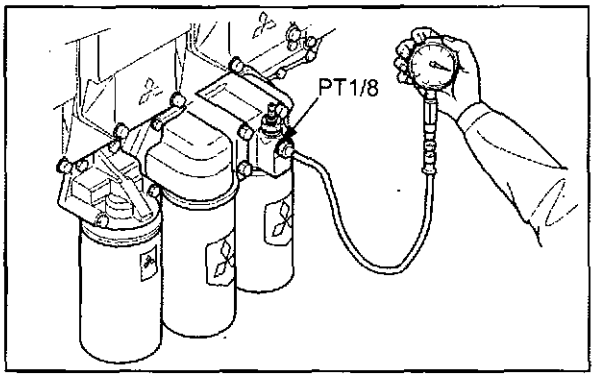
(4) If the measured oil pressure is different from the standard pressure, remove the oil pipe, and adjust the pressure by inserting a shim between the spring and plug.

A shim with a thickness of 2 mm [0.08 in.] changes the relief valve pressure by approximately 0.04 MPa {0.4 kgf/cm²} [5.8 psi].

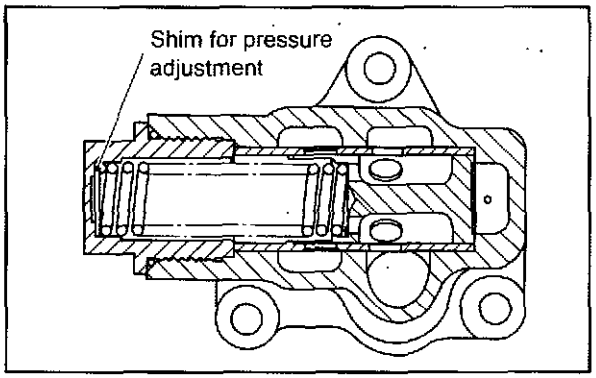
Note: When the oil temperature is low, the oil pressure may rise above the set pressure, but it returns to the set pressure as the oil temperature rises.

(5) If the pressure does not change even after installing the adjusting shim, replace the relief valve and spring.

| Item | Standard |
|---|---|
| Set pressure (at max. speed) | 0.39 to 0.67 MPa {4 to 7 kgf/cm²} [56.89 to 99.56 psi] |
| Relief valve opening pressure | 0.58 ± 0.05 MPa {5.9 ± 0.5 kgf/cm²} [84 ± 7 psi] |

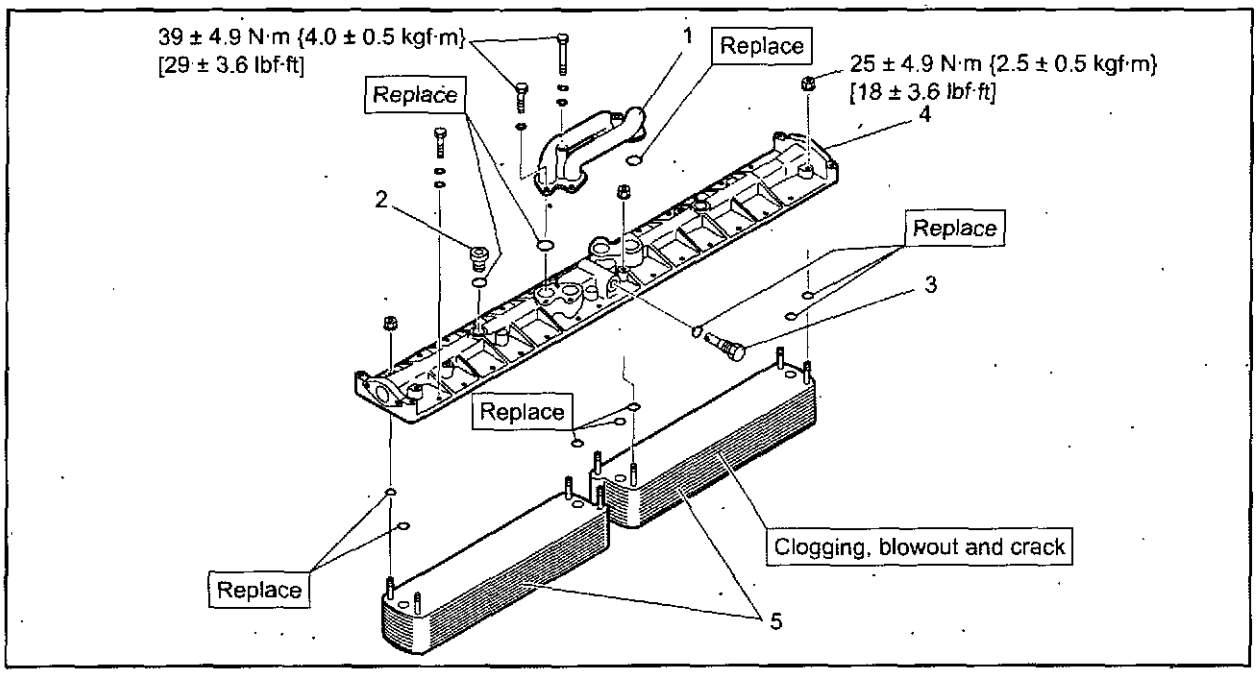



Pressure measurement point




Installing shim for relief valve adjustment

## 2.6 *Disassembling and inspecting oil cooler*



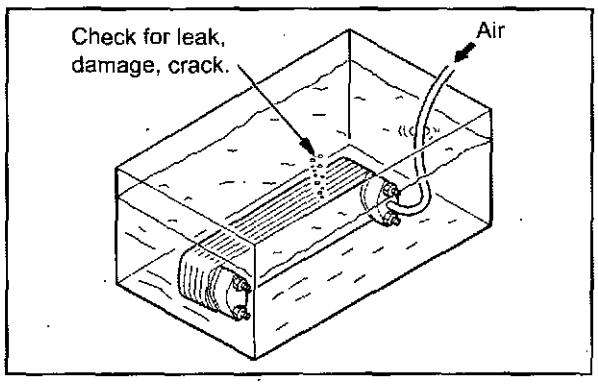

Disassembling and inspecting oil cooler

Disassembling sequence

1 Pipe
2 Plug
3 Bypass valve
4 Cover
5 Element

## 2.7 Inspecting oil cooler

Check oil passages in the element by blowing through them with compressed air of 1.47 MPa {15 kgf/cm²} [213 psi] for damage and cracks. If any leakage or damage is found, replace the element with new one.



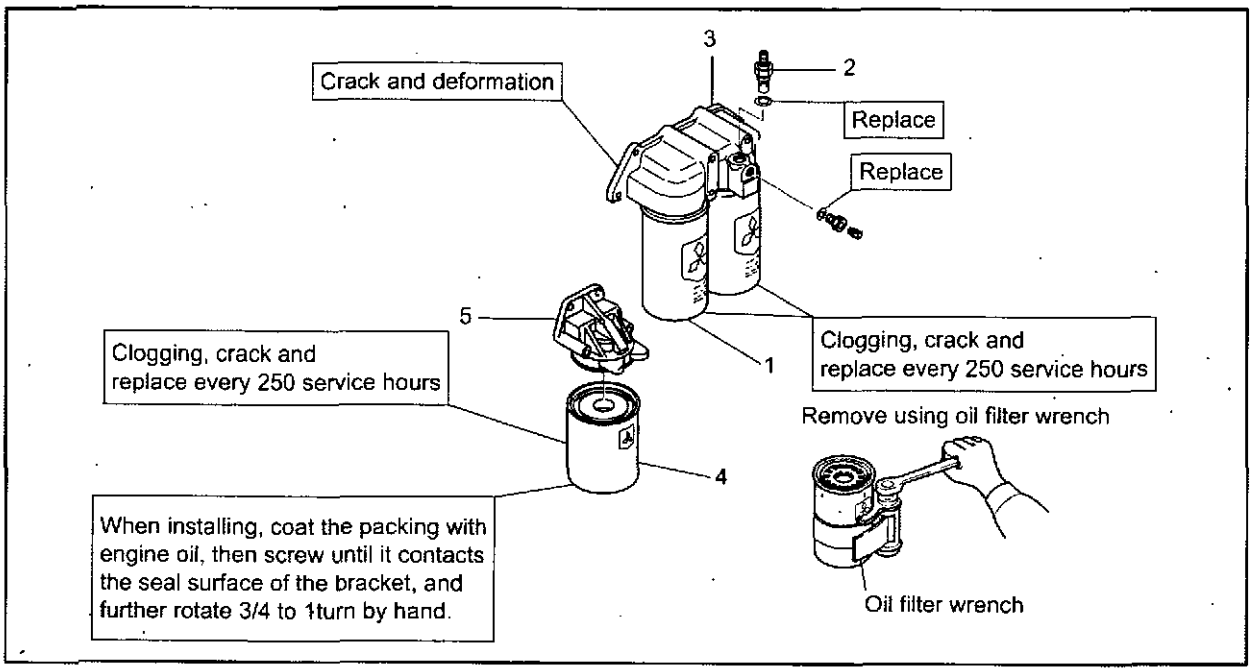

Inspecting oil cooler

## 2.8 Reassembling oil cooler

To reassemble, follow the disassembly sequence in reverse, and observe the followings:

(1) Use new gaskets and O-rings during reassembly.
(2) Thoroughly clearn oil passages using a wash oil, and dry them with compressed air.

## 2.9 Disassembling and inspecting oil filter, oil bypass filter and oil filter alarm



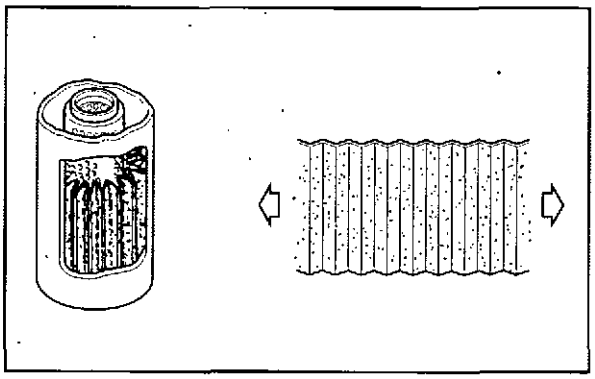

Disassembling and inspecting oil filter, oil bypass filter and oil filter alarm

Disassembling sequence

1 Oil filter element
2 Oil filter alarm
3 Oil filter bracket
4 Bypass filter element
5 Bypass filter bracket

## 2.10 Inspecting oil filter

When replacing the oil filter, sample the oil (500 ml [30.5 cu.in.]) and check for metal and other particles. If metal or other particles are found, cut and unfold the element, and inspect the color and shape of metal particles trapped in the element to identify the cause.



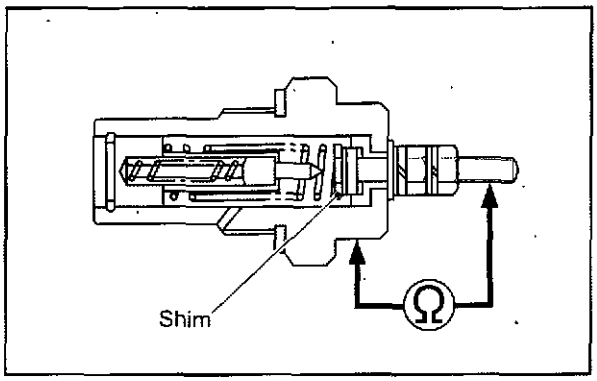
Inspecting oil filter

### 2.11 Inspecting oil filter alarm

(1) Use a tester to check the alarm for insulation and continuity. If the alarm is found to be defective, disassemble and repair. If the bakelite or rubber insulations are deteriorated or damaged, replace the alarm.

(2) If the filter alarm lamp lighting pressure exceeds the standard, replace the alarm with a new one.

| Item | Standard |
|---|---|
| Oil filter alarm lightening pressure | $0.15\ ^{+0.03}_{0}$ MPa<br>$\{1.5\ ^{+0.3}_{0}$ kgf/cm²$\}$<br>$[21.34\ ^{-4.27}_{0}$ psi$]$ |




Inspecting oil filter alarm

### 2.12 Reassembling oil filter, oil bypass filter and oil filter alarm

**⚠ CAUTION**

After completing reassembly, start the engine and check for oil leaks.

To reassemble, follow the disassembly sequence in reverse.

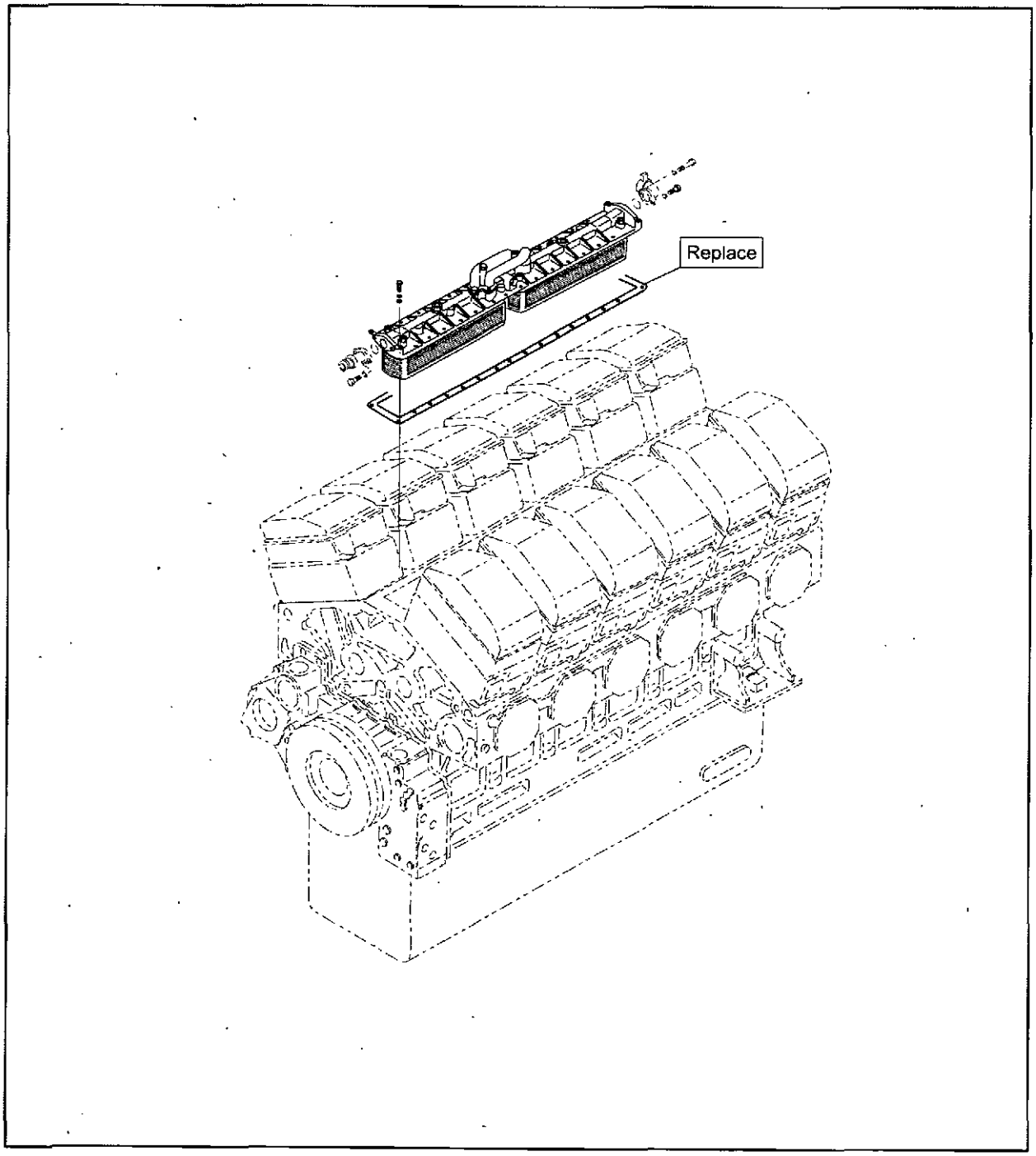
(1) Use new packings and O-rings during reassembly.

(2) Mount the bracket prior to installing the cartridge oil filter.

(3) Before installing the cartridge, clean its fitting surface and apply fresh fuel oil to the gasket. When the gasket contacts the sealing surface of the bracket, tighten the cartridge by 3/4 to 1 turn by hand. (Do not use a filter wrench, as the filter may be damaged/dented. Never use any damaged/dented filter.)

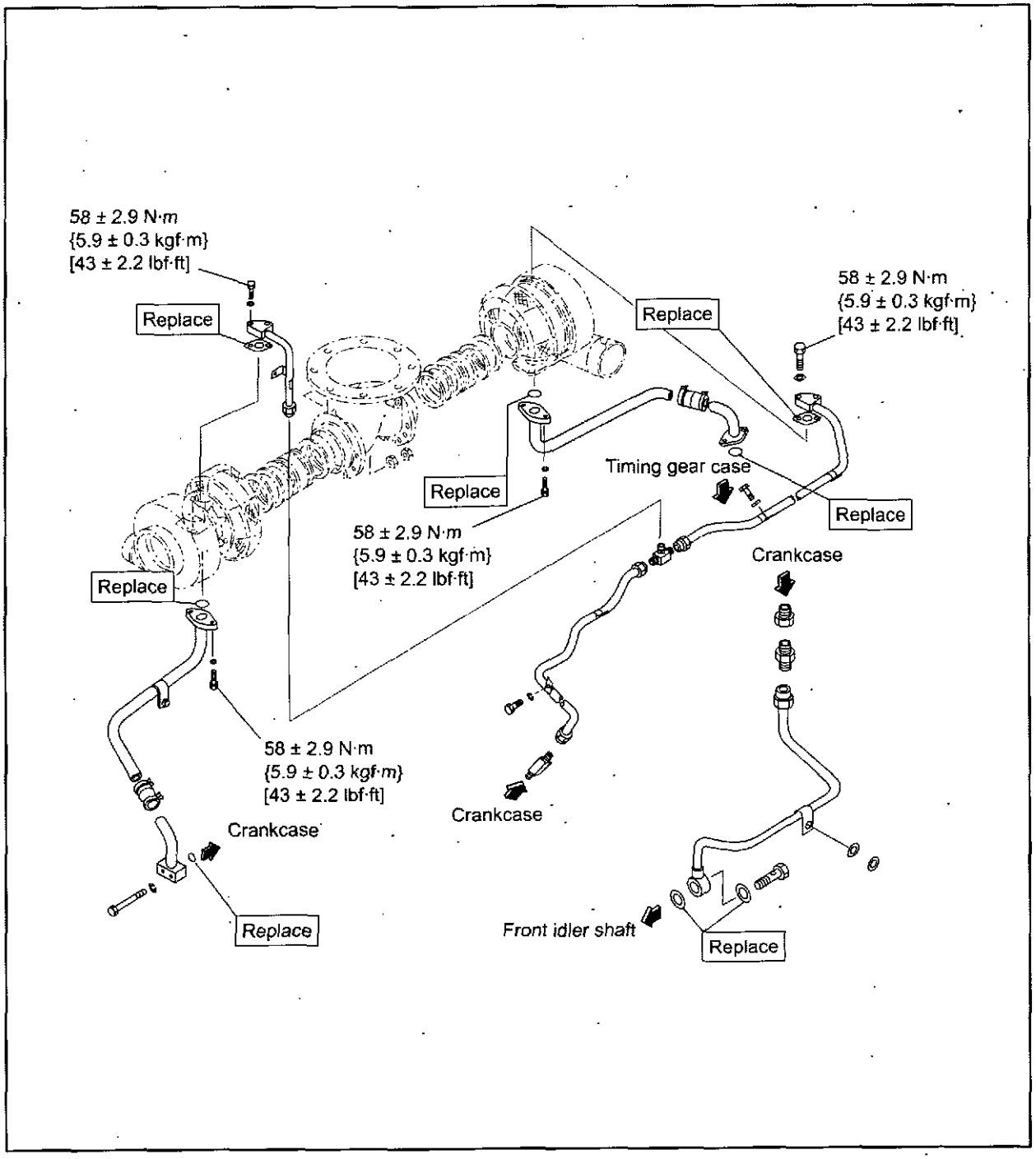
## 3. Installing lubrication system

### 3.1 Installing oil cooler



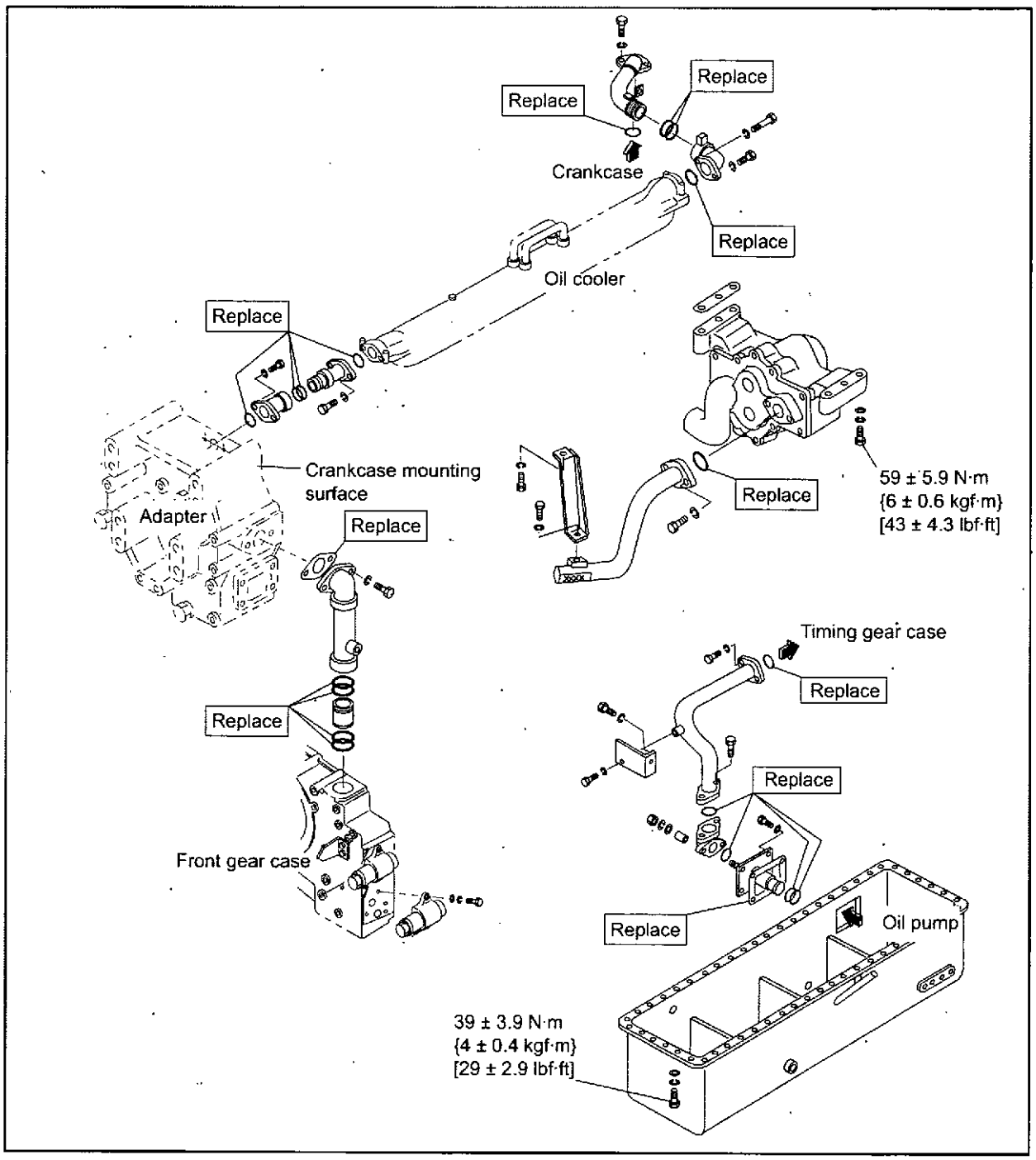

Installing oil cooler

### 3.2 Installing oil pipe (1)




Installing oil pipe (1)

### 3.3 Installing oil pipe (2)

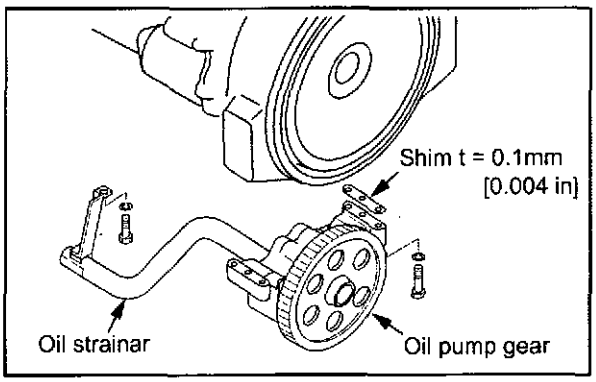



Installing oil pipe (2)

### 3.3.1 Installing oil pump and strainer

Measure the backlash between oil pump gear and crankshaft gear. If the backlash is too small, adjust it by fitting a shim to the pump gear mounting face.

| Item | Standard | Limit |
|---|---|---|
| Oil pump drive gear and crankshaft gear backlash | 0.11 to 0.28 mm [0.0043 to 0.0110 in.] | 0.50 mm [0.0197 in.] |




Installing oil pump and strainer

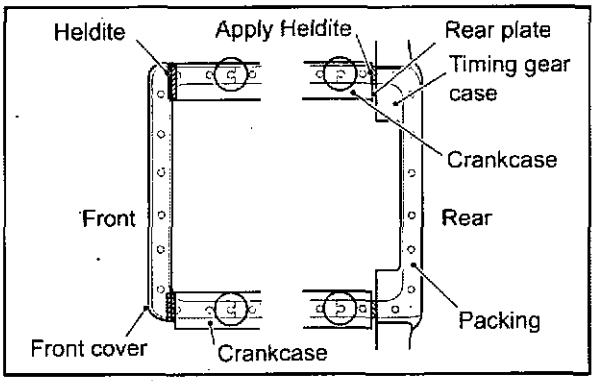
### 3.3.2 Installing oil pan

(1) Apply Heldite to the lower mating surfaces between the front cover and the crankcase.

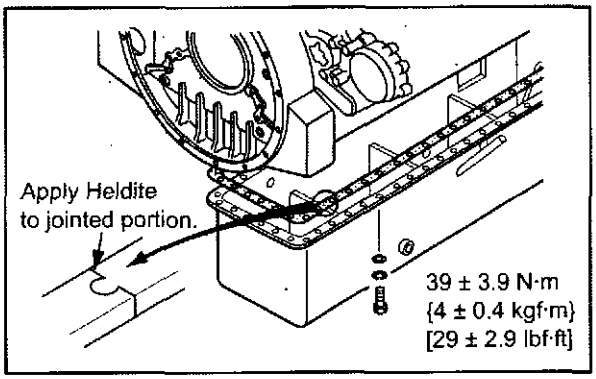
(2) Apply Heldite to the lower mating surfaces of the crankcase, rear plate and timing gear case.

(3) Apply sealant (Heldite) to the joint surfaces of separated portions (4 locations) of the oil pan packing, and install the packing to the oil pan.

(4) Tighten the oil pan mounting bolts to the specified torque.

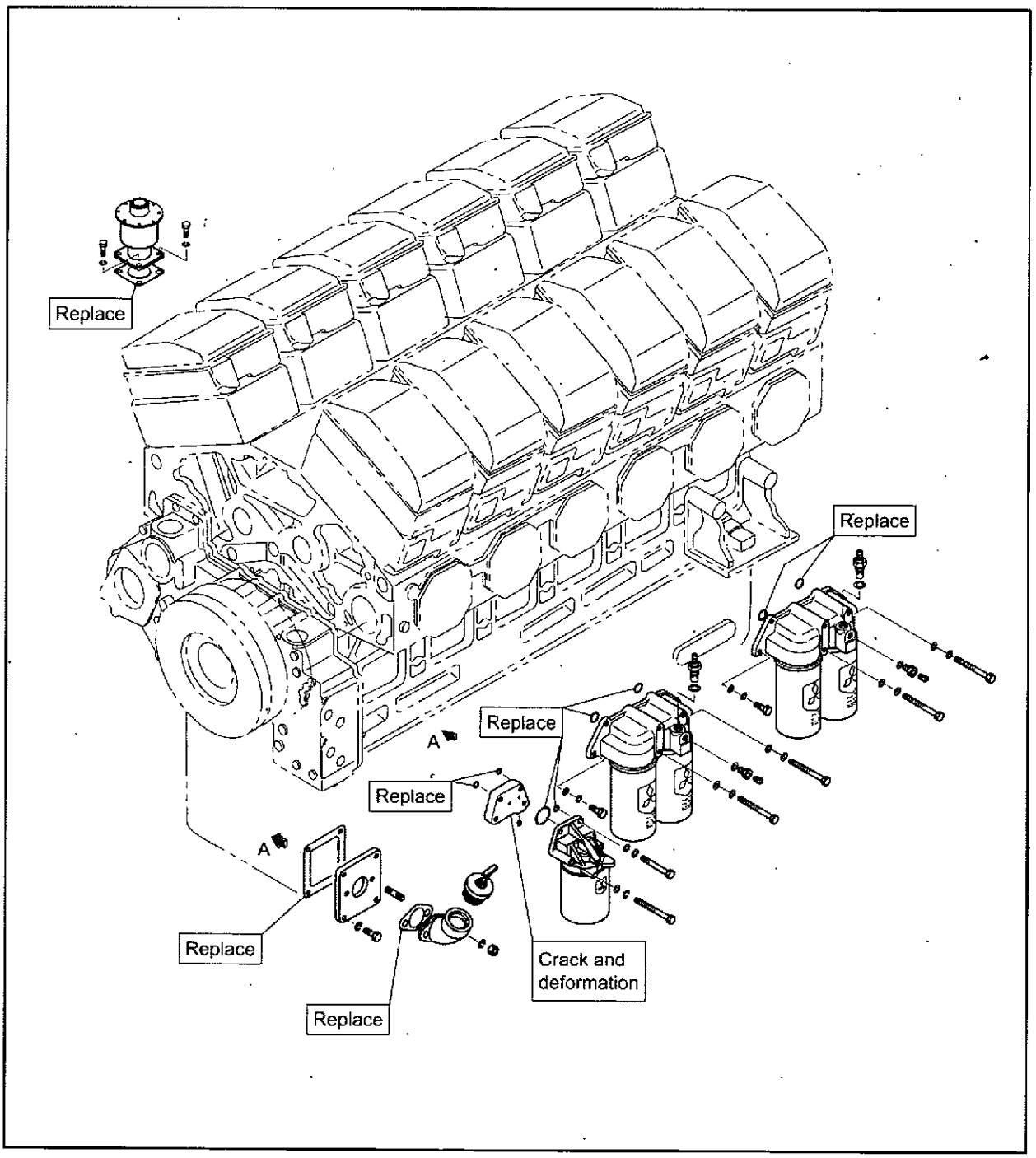



Installing oil pan (1)




*Installing oil pan (2)*

### 3.4 Installing oil pipe (2)

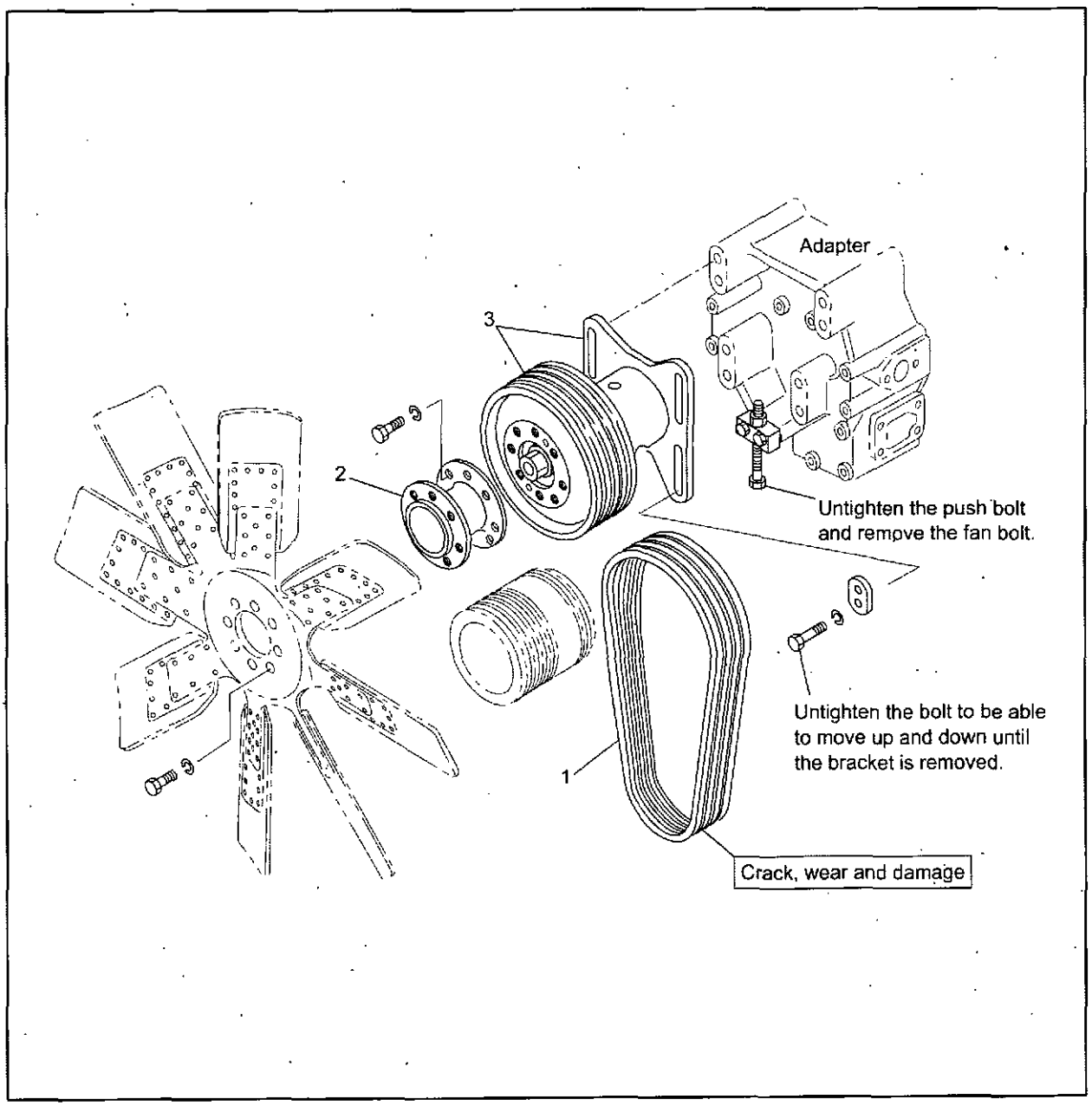



Installing oil filter, oil bypass filter and breather

# COOLING SYSTEM

# 1. Removing and inspecting cooling system

## 1.1 Removing and inspecting fan and fan drive

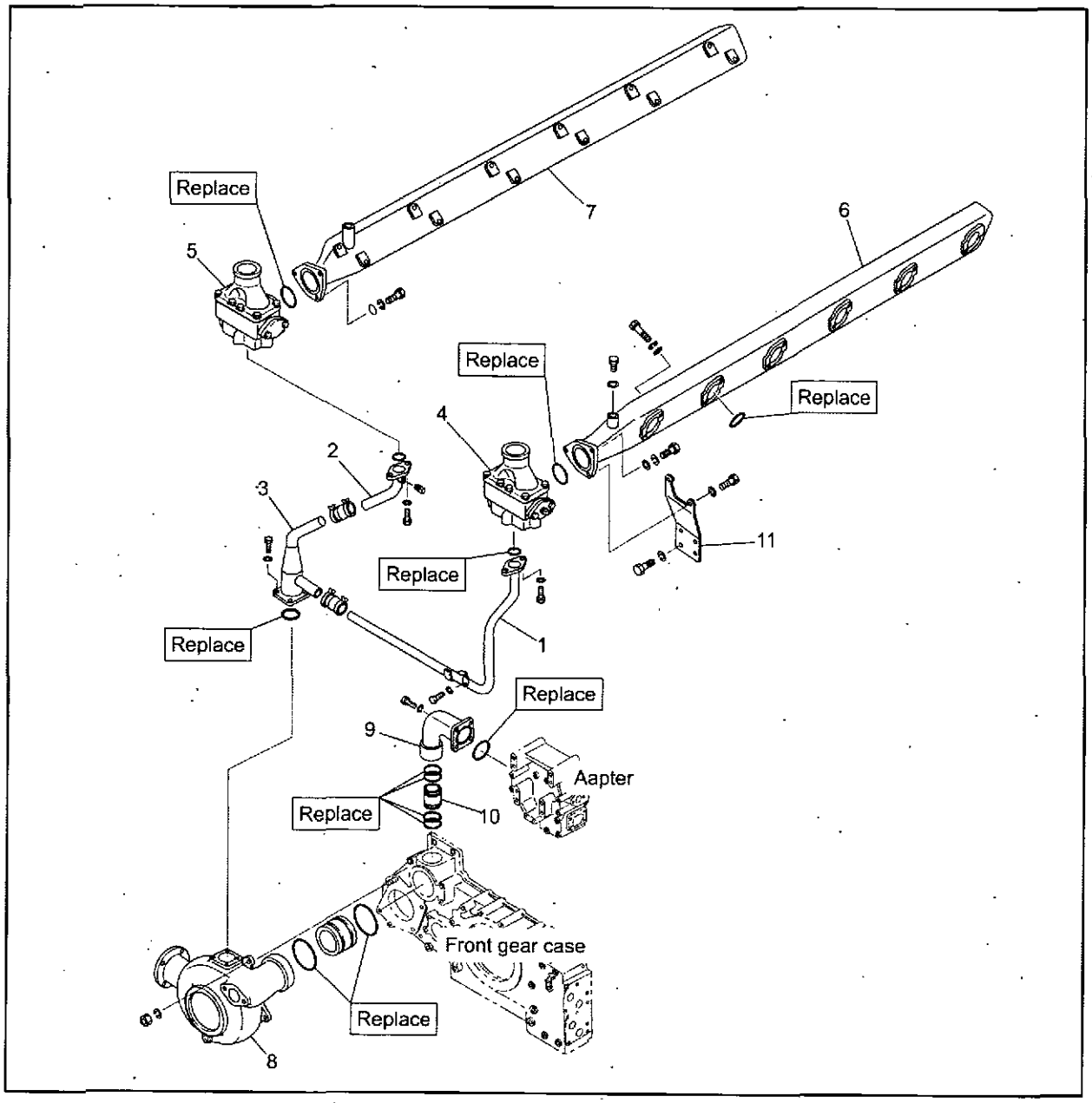



Removing and inspecting fan and fan drive

Removing sequence

1 Fan drive V-belt
2 Spacer
3 Fan Pulley and fan drive (weight: approx. 45 kg [99 lb])

## 1.2 Removing and inspecting water pump and water outlet pipe

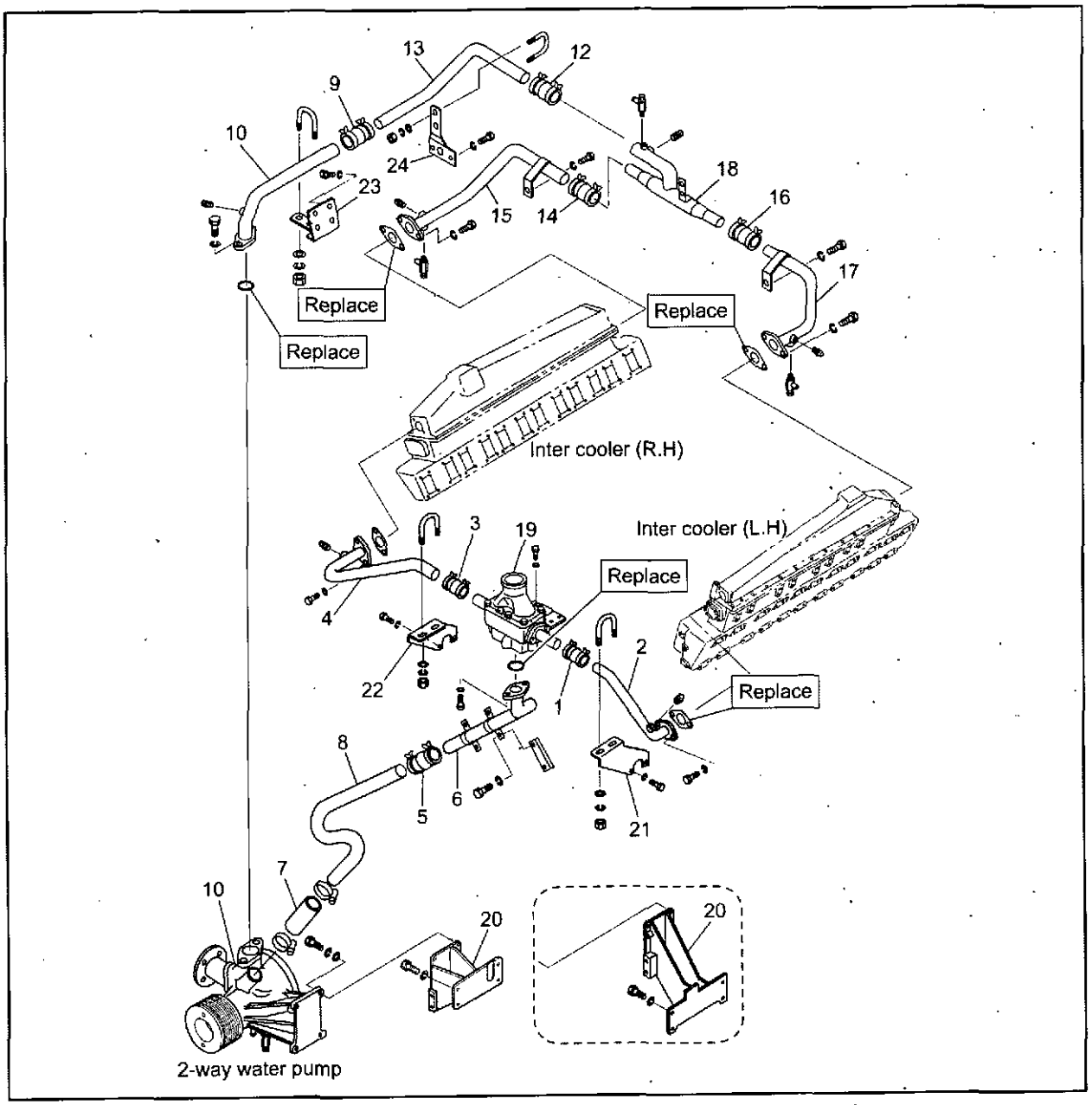



Removing and inspecting water pump and water outlet pipe

Removing sequence

1 Bypass pipe (L.H)
2 Bypass pipe (R.H)
3 Bypass pipe (R.H)
4 Thermostat assembly
5 Thermostat assembly
6 Water outlet pipe (L.H)
7 Water outlet pipe (R.H)
8 Water pump (weight: Approx. 40 kg [88 lb])
9 Water pipe
10 Connector
11 Stay

### 1.3 Removing and inspecting 2-way water pump and intercooler water pipe

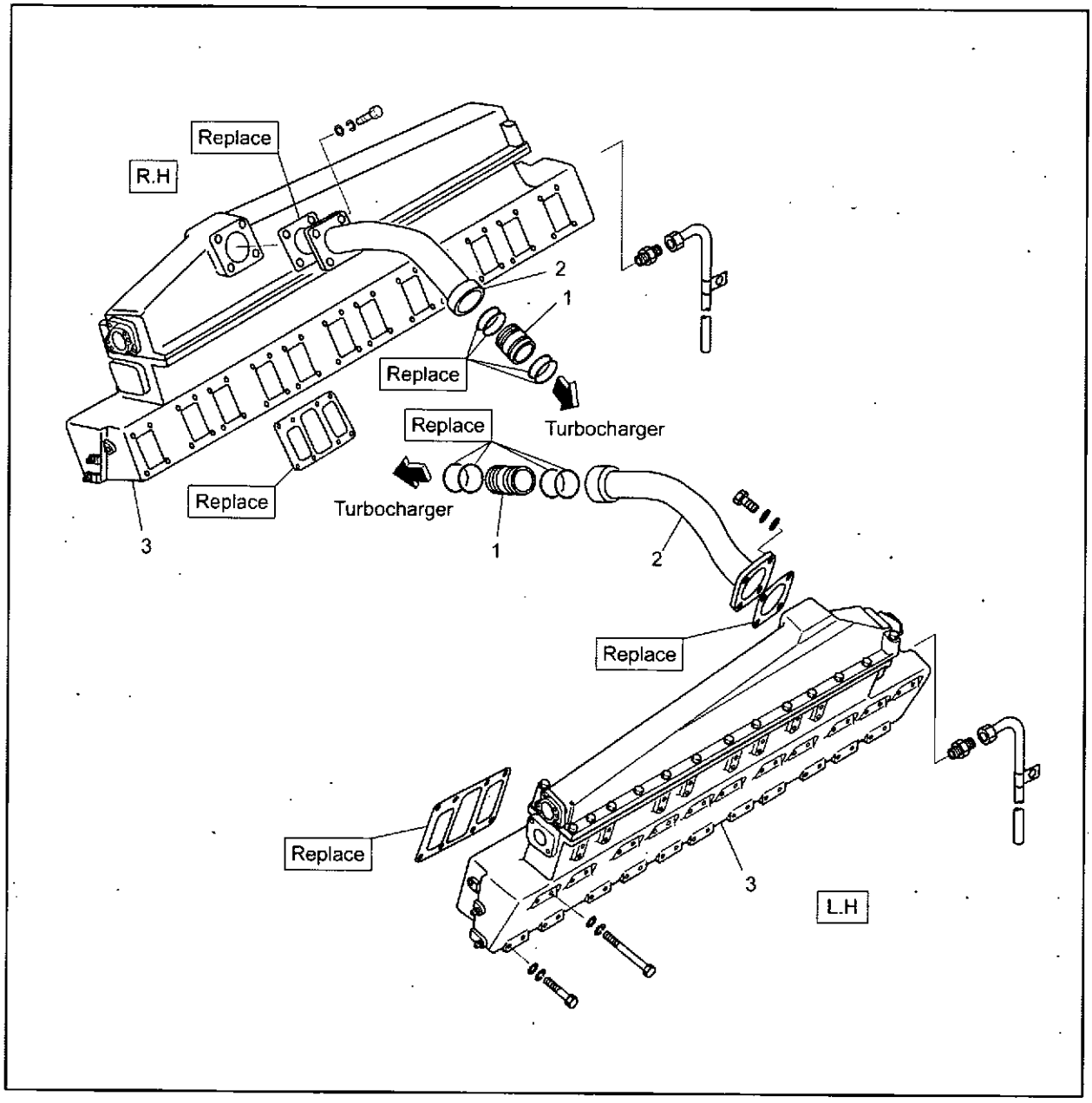



Removing and inspecting 2-way water pump and intercooler water pipe.

Removing sequence

1 Coupling
2 Intercooler pipe
3 Coupling
4 Intercooler pipe
5 Coupling
6 Water pipe
7 Rubber hose
8 Water pipe
9 Coupling
10 Water pipe
11 2-way water pump
12 Coupling
13 Water pipe
14 Coupling
15 Intercooler pipe
16 Coupling
17 Intercooler pipe
18 Water pipe
19 Thermostat assembly
20 Bracket
21 Pipe stay
22 Pipe stay
23 Pipe stay
24 Water pipe stay

## 1.4 Removing and inspecting intercooler



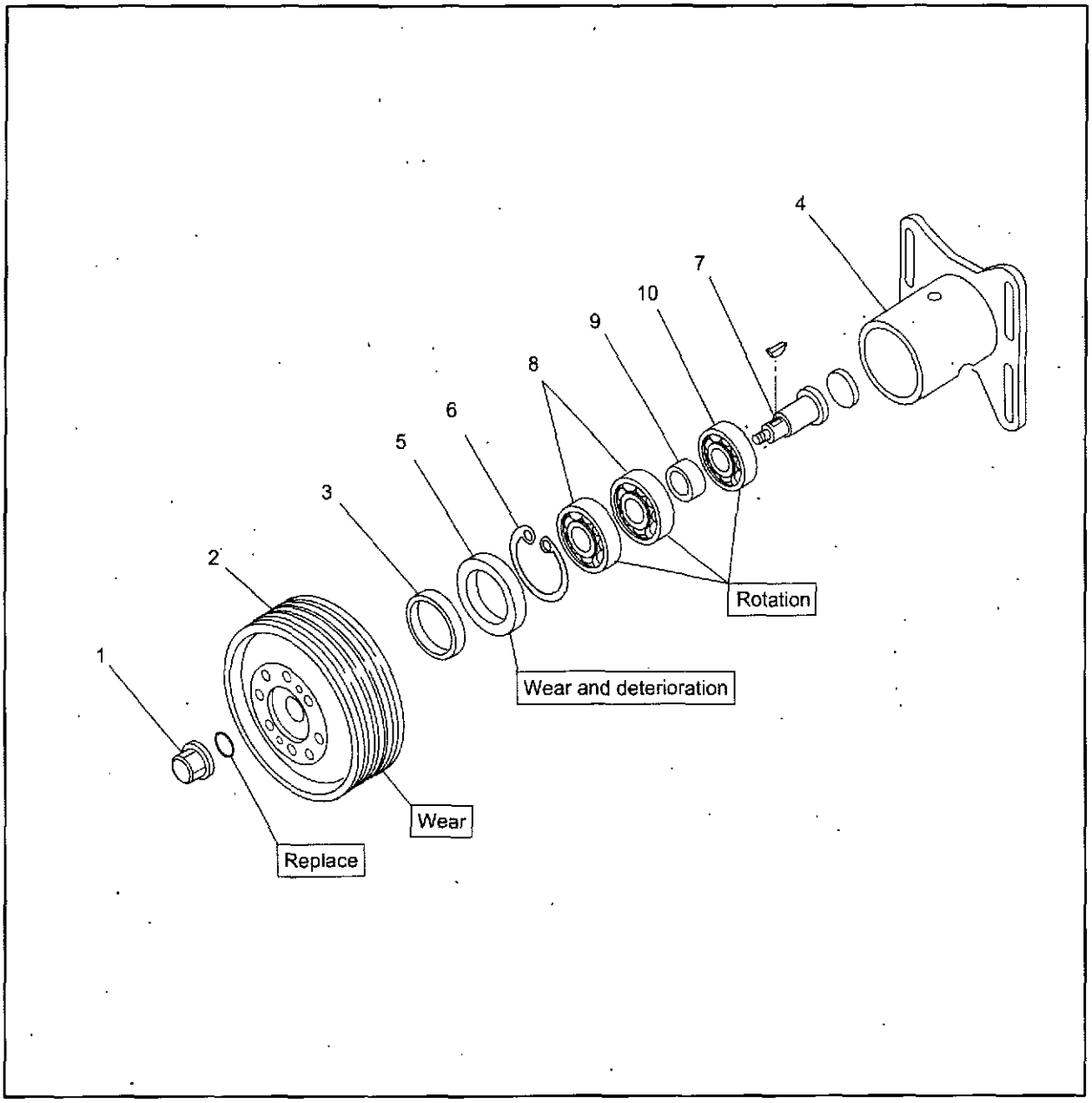

Removing and inspecting intercooler

Removing sequence

1 Joint
2 Inlet duct
3 Intercooler assembly

## 2. Disassembling, inspecting and reassembling cooling system

### 2.1 *Disassembling and inspecting fan pulley and fan drive*




Disassembling and inspecting fan pulley and fan drive

Disassembling sequence

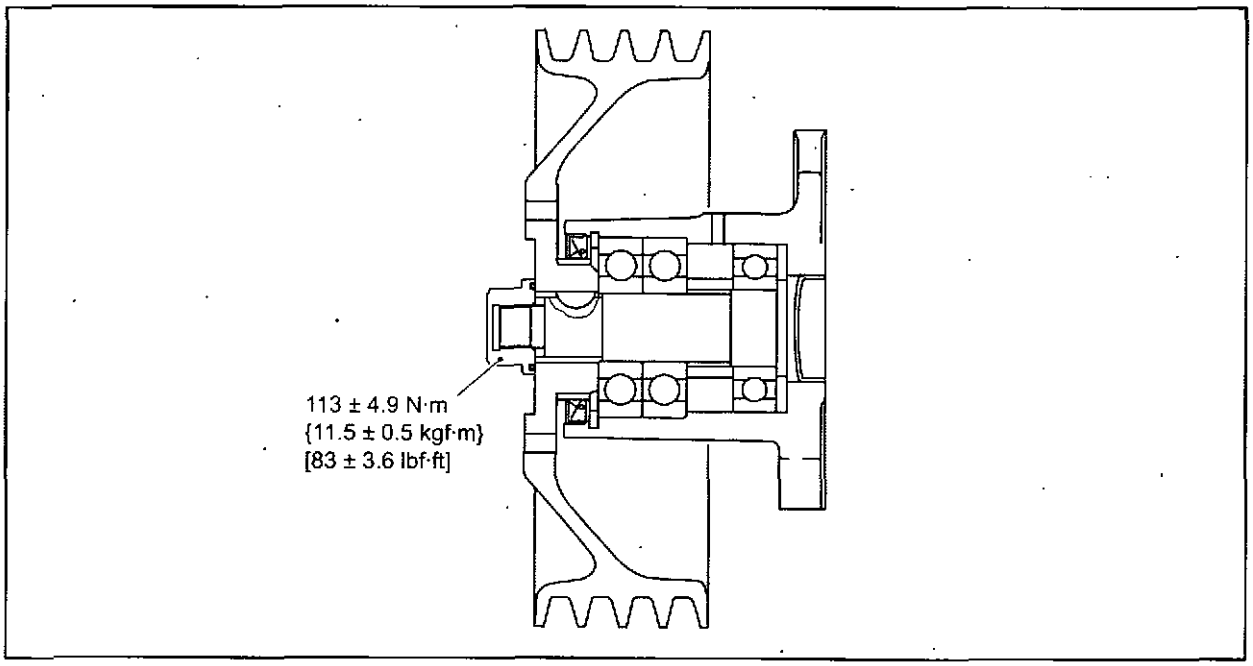
1 Cap nut
2 Fan pulley
3 Sleeve
4 Bracket
5 Oil seal
6 Snap ring
7 Shaft
8 Ball bearing
9 Spacer
10 Ball bearing

## 2.2 Inspecting fan drive

Measure the diameter of bearing fitting sections of the shaft and case. If they are out of the standard range, damaged or worn excessively, replace the bearing and shaft or case.

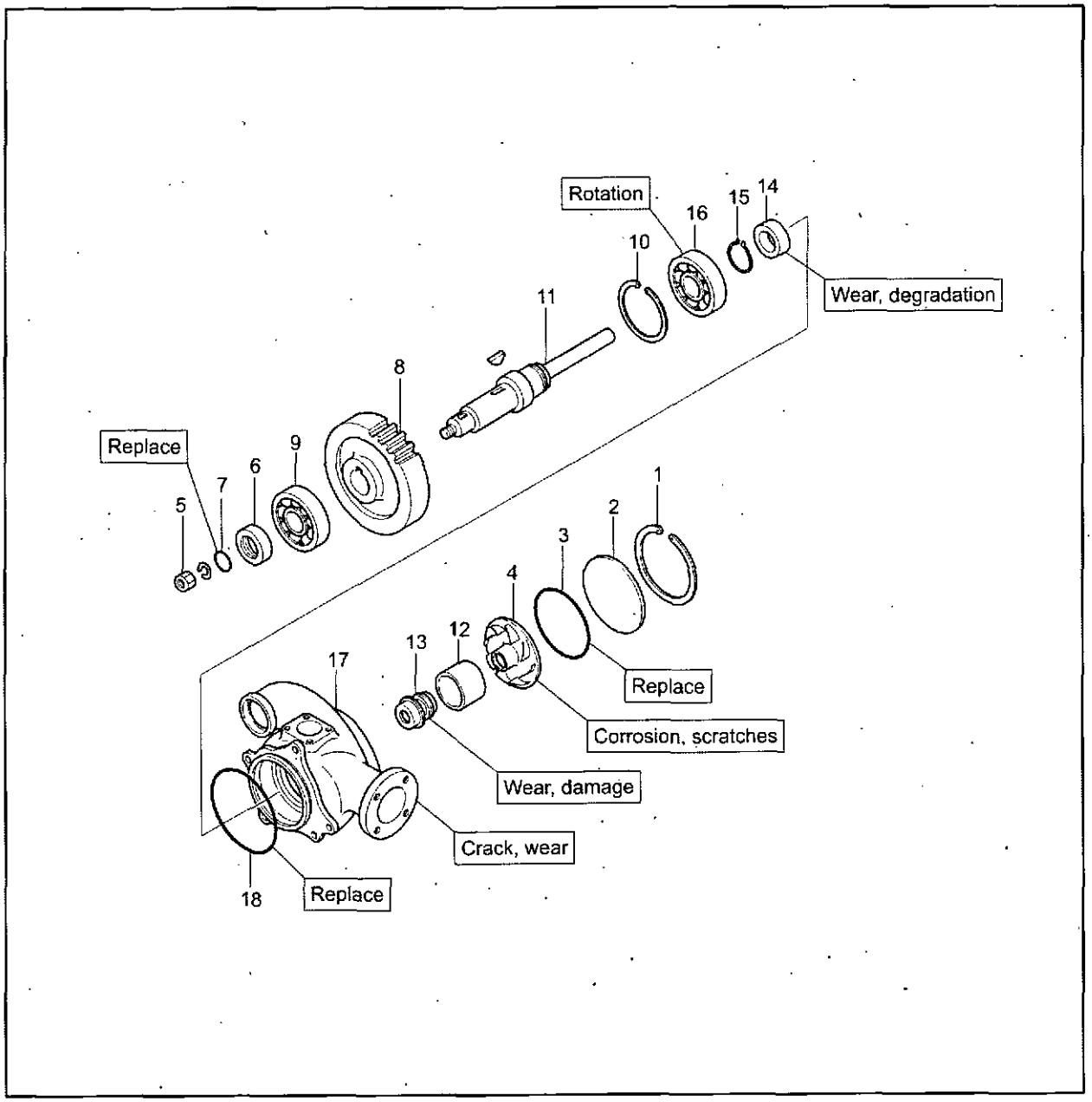
| Item | | | Nominal | Standard |
|---|---|---|---|---|
| Bracket bearing bore diameter | | | ø 110 mm [4.33 in.] | 109.987 to 110.022 mm [4.3301 to 4.3316 in.] |
| | | | ø 120 mm [4.72 in.] | 119.987 to 120.022 mm [4.7239 to 4.7253 in.] |
| Bearing | Small | Bore diameter | ø 50 mm [1.97 in.] | 49.988 to 50.000 mm [1.9680 to 1.9685 in.] |
| | | Outside diameter | ø 110 mm [4.33 in.] | 109.885 to 110.000 mm [4.3262 to 4.3307 in.] |
| | Large | Bore diameter | ø 45 mm [1.77 in.] | 44.988 to 45.000 mm [1.7712 to 1.7720 in.] |
| | | Outside diameter | ø 120 mm [4.72 in.] | 119.985 to 120.000 mm [4.7238 to 4.7244 in.] |
| Shaft bearing journal diameter | | | ø 50 mm [1.97 in.] | 50.002 to 50.013 mm [1.9686 to 1.9690 in.] |
| | | | ø 45 mm [1.77 in.] | 45.002 to 45.013 mm [1.7717 to 1.7722 in.] |

## 2.3 Reassembling fan pulley and fan drive




Reassembling fan pulley and fan drive

## 2.4 Disassembling and inspecting water pump




Disassembling and inspecting water pump

Disassembling sequence

| | | |
|---|---|---|
| 1 Snap ring | 7 O-ring | 13 Unit seal |
| 2 Cover | 8 Water pump gear | 14 Oil seal |
| 3 O-ring | 9 Bearing | 15 Snap ring |
| 4 Water pump impeller | 10 Snap ring | 16 Bearing |
| 5 Nut | 11 Water pump shaft | 17 Pump case (weight: approx. 28 kg [62 lb]) |
| 6 Oil seal sleeve | 12 Ring | 18 O-ring |

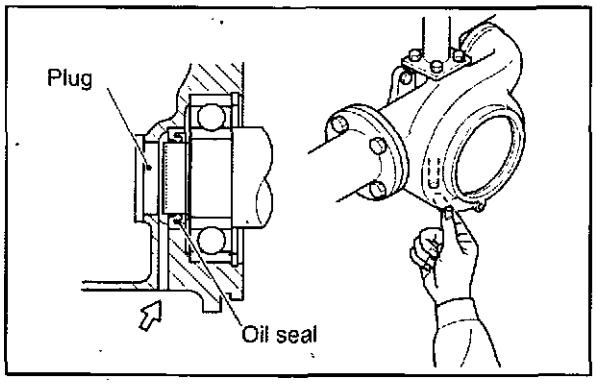
### 2.4.1 Inspecting water pump mounted on engine

With fingers, touch the drain port at the center of the pump case bottom.

If it is wet with water, check the unit seal conditions.

If oil is present, the oil seal is defective.

Replace the oil seal.



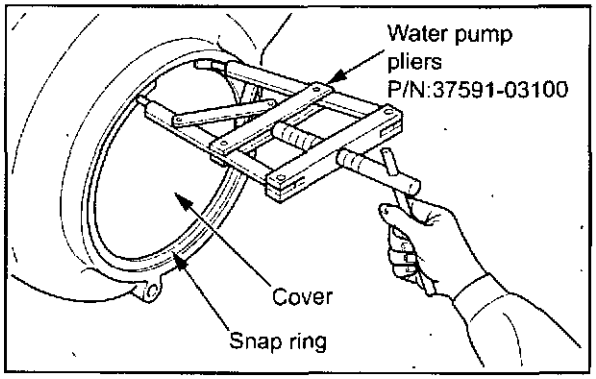

Inspecting pump mounted on engine

### 2.4.2 Removing impeller

**CAUTION**

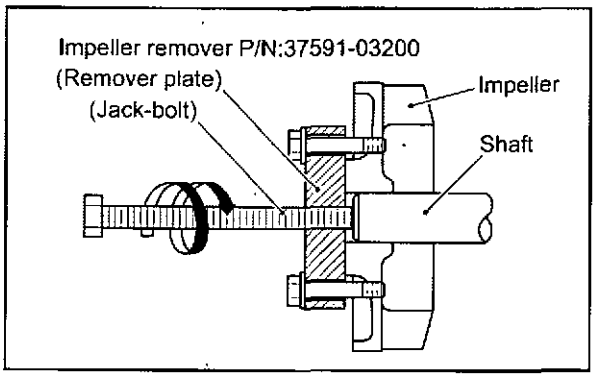
Be careful not to damage the water pump shaft, impeller, etc. when removing impeller from the shaft.

(1) Using the water pump pliers, remove the snap ring that holds the cover in position, then dismount the cover.




Removing water pump cover

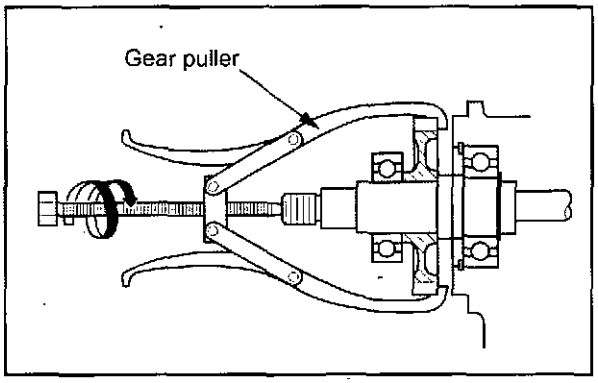
(2) Using the impeller remover, pull out the impeller.



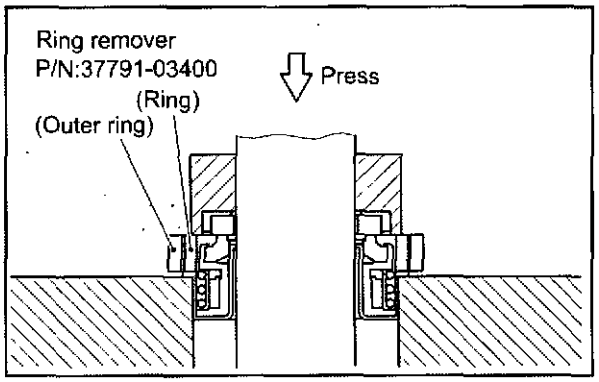

Removing water pump impeller

### 2.4.3 Removing water pump gear

(1) Remove the oil seal sleeve.
(2) Remove the gear and ball bearing together using the gear puller.
(3) Remove the snap ring from the impeller side ball bearing.
(4) Install two ring halves of the ring remover between the unit seal and pump case as shown in the illustration.
(5) Install the outer ring over the ring halves to secure the ring halves.
(6) Hold the pump case and push out the shaft by pressing the impeller side of the shaft in the direction of arrow using a hand press.




Removing water pump gear



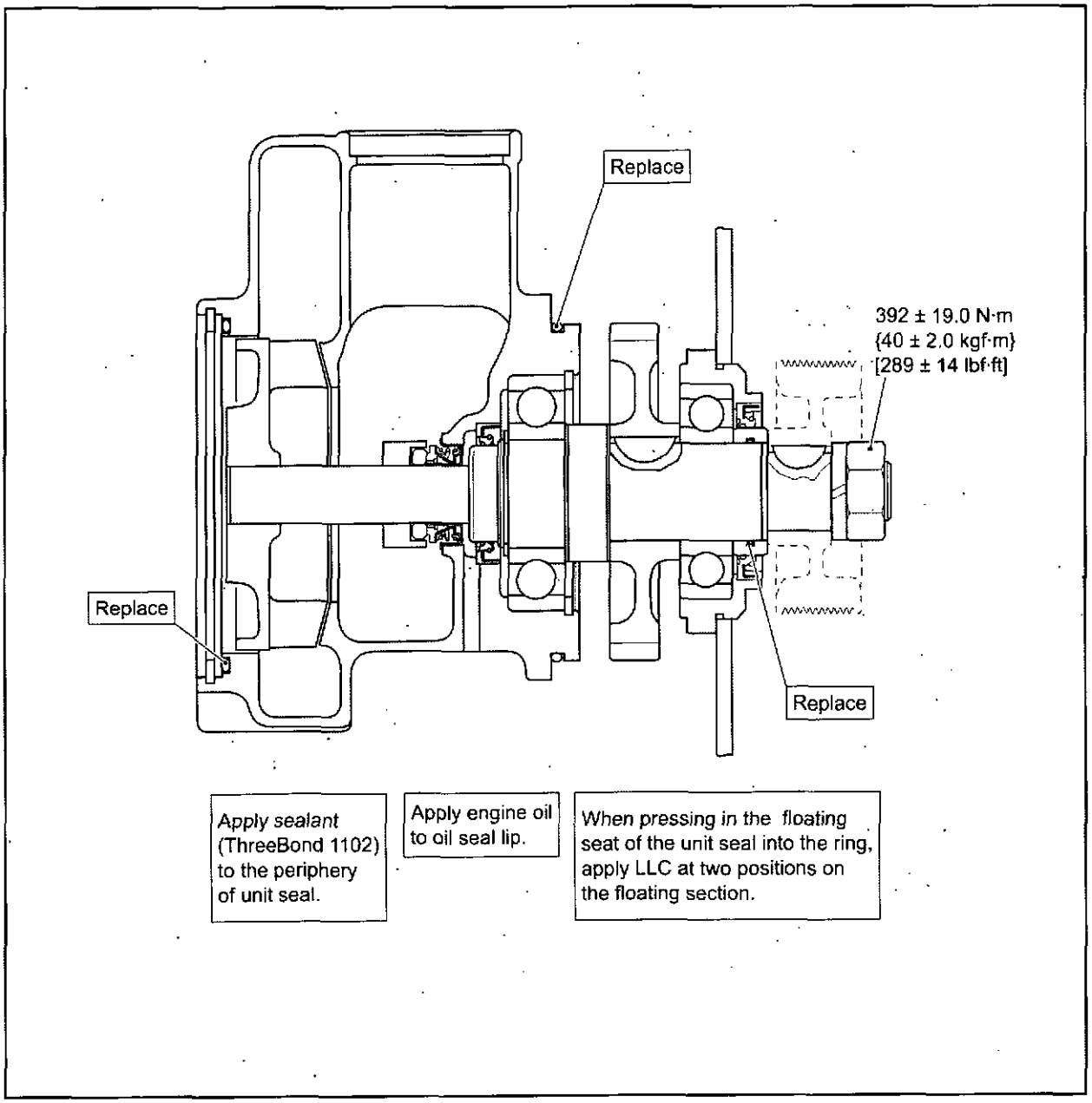

Removing water pump shaft

## 2.5 Inspecting water pump

Measure the water pump case bore and the shaft diameter at the bearing fitting portions as well as the inside and outside diameters of the bearings. If any of the measurements is out of the standard, replace with a new one.

| Item | | | Nominal | Standard |
|---|---|---|---|---|
| Pump case bearing bore inside diameter | | | ø 120 mm [4.72 in.] | 119.987 to 120.022 mm [4.7239 to 4.7253 in.] |
| Cover bearing bore inside diameter | | | ø 110 mm [4.33 in.] | 110.005 to 110.040 mm [4.3309 to 4.3323 in.] |
| Bearing | Large | Outside diameter | ø 120 mm [4.72 in.] | 119.985 to 120.000 mm [4.7238 to 4.7244 in.] |
| | | Inside diameter | ø 55 mm [2.17 in.] | 54.985 to 55.000 mm [2.1648 to 2.1654 in.] |
| | Small | Outside diameter | ø 110 mm [4.33 in.] | 109.985 to 110.000 mm [4.3301 to 4.3307 in.] |
| | | Inside diameter | ø 50 mm [1.97 in.] | 49.988 to 50.000 mm [1.9680 to 1.9685 in.] |
| Shaft bearing fitting section outer diameter | | | ø 55 mm [2.17 in.] | 55.011 to 55.024 mm [2.1658 to 2.1663 in.] |
| | | | ø 50 mm [1.97 in.] | 50.011 to 50.024 mm [1.9689 to 1.9694 in.] |
| Clearance at the front of impeller | | | 1.04 mm [0.0409 in.] | 0.58 to 1.50 mm [0.0228 to 0.0591 in.] |

### 2.6 *Reassembling water pump*



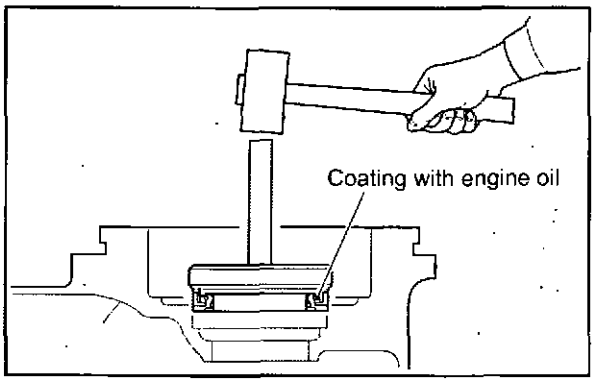

Reassembling water pump

Install new O-rings, oil seals and unit seals in reassembly.

### 2.6.1 Installing water pump oil seal

(1) Using unit seal installer, press-fit the oil seal, making sure that oil seal surface is flush with the case face.

(2) Be sure to coat the oil seal lip with engine oil.



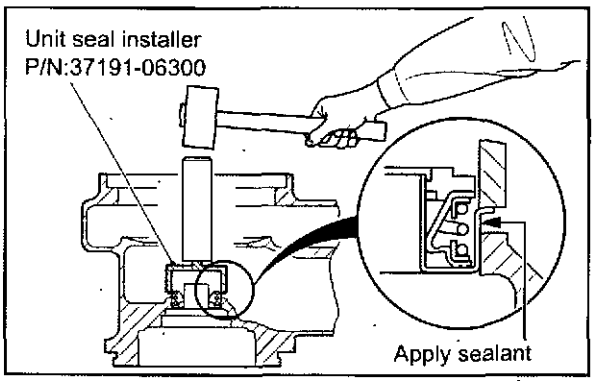

Installing water pump oil seal

### 2.6.2 Installing unit seal

(1) Apply sealant (ThreeBond 1102) to the circumference of the unit seal.

(2) Drive the unit seal into the case using a unit seal installer.

Note: Always replace the unit seal with a new one once it has been removed from the pump case.

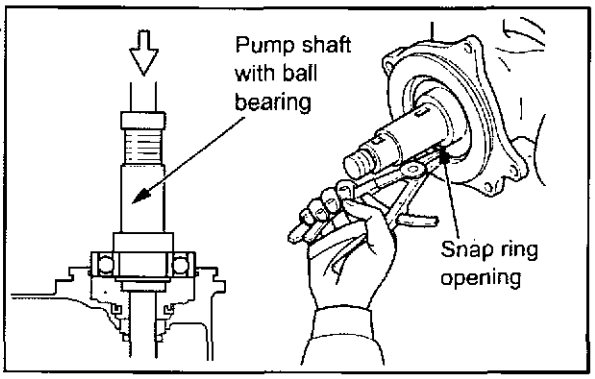



Installing unit seal

### 2.6.3 Installing ball bearing on the impeller side

Press the pump shaft with ball bearing at the impeller side into the case using a press.

Install the snap ring into the case with its ends facing downward.

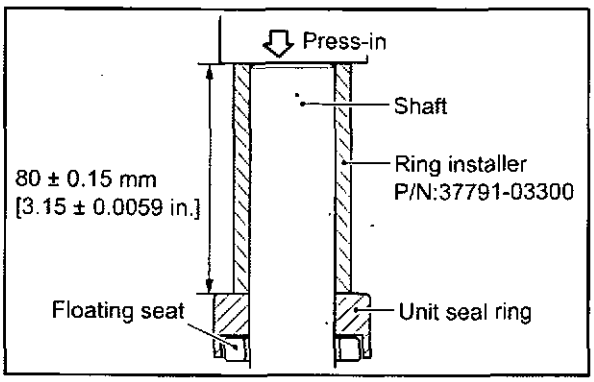



Installing ball bearing for impeller-side

### 2.6.4 Installing unit seal ring

Press in the unit seal ring with unit seal floating seat slowly to the specified position using the ring installer and a press.

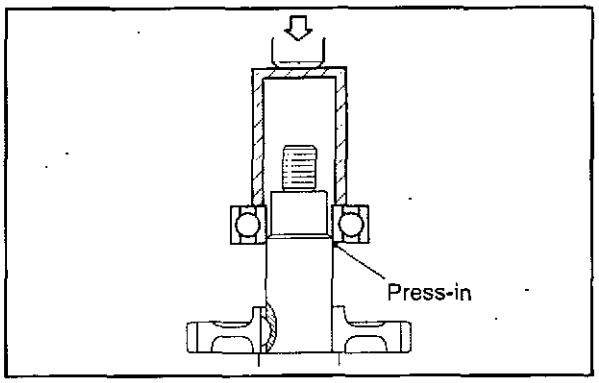
Note: When pressing in the floating seat of the unit seal into the ring, apply LLC at two positions on the floating section.




Reassembling unit seal ring

### 2.6.5 Installing ball bearing on the nut side

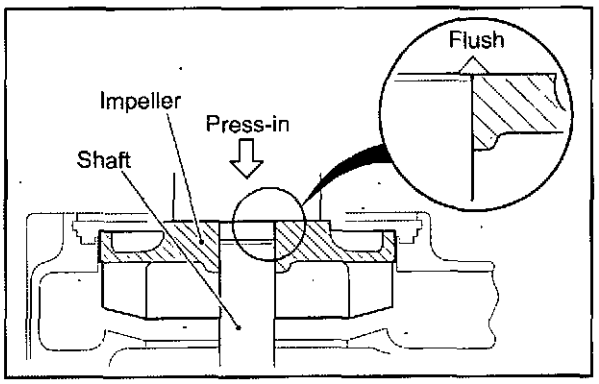
Install the gear into the shaft while aligning its key with keyway. Press in the ball bearing at the nut end using a press.




Installing ball bearing for nut-side

### 2.6.6 Press-fitting water pump impeller

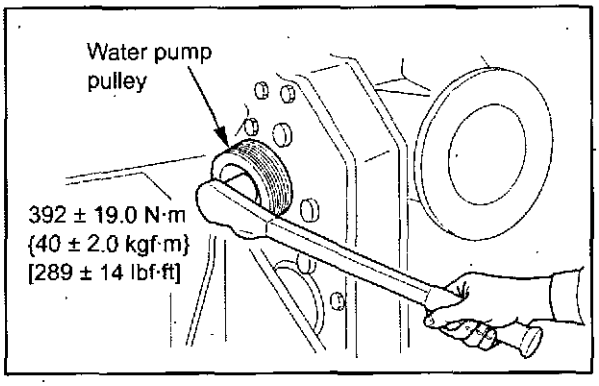
Press in the impeller using a press. Make the end of the impeller boss flush with the end of pump shaft.




Press-fitting water pump impeller

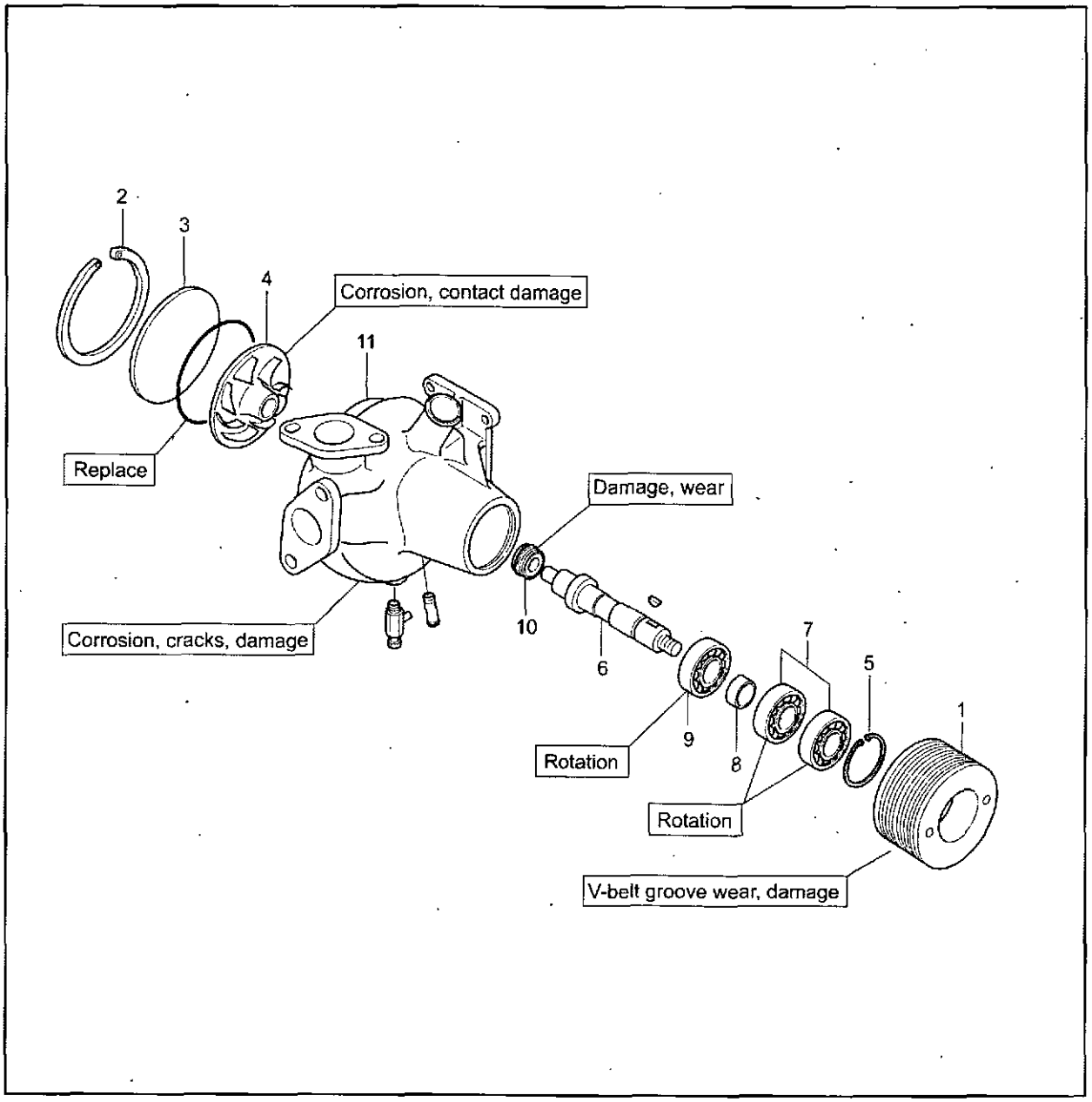
### 2.6.7 Installing water pump pulley

After installing the water pump assembly, install the water pump pulley at the back of the pump shaft and tighten the nut to the specified torque.




Installing water pump pulley

## 2.7 Disassembling and inspecting 2-way water pump




Disassembling and inspecting 2-way water pump

Disassembling sequence

1 Pulley
2 Snap ring
3 Cover
4 Impeller
5 Snap ring
6 Shaft
7 Ball bearing
8 Spacer
9 Ball bearing
10 Unit seal
11 Case

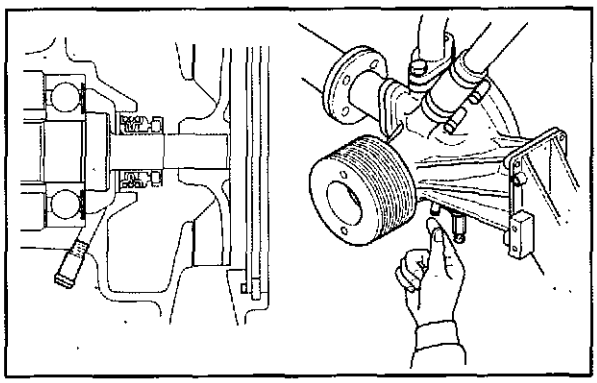
### 2.7.1 Inspecting water pump mounted on engine

With fingers, touch the drain port at the center of the pump case bottom.

If it is wet with water, check the unit seal conditions.

If oil is present, the oil seal is defective.

Replace the oil seal.



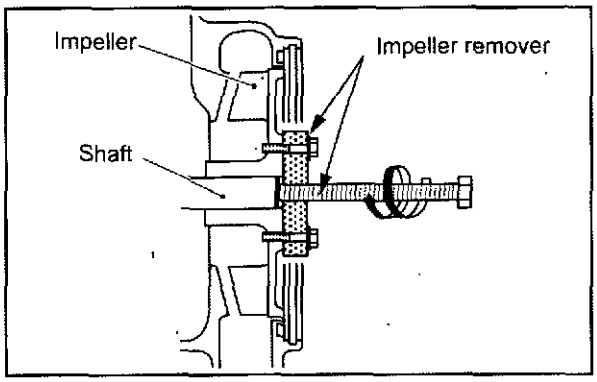
Inspecting 2-way water pump as mounted

### 2.7.2 Removing impeller

**CAUTION**

Be careful not to damage the water pump shaft, impeller, etc. when removing impeller from the shaft.

(1) Using the water pump pliers, remove the snap ring that holds the cover in position, then dismount the cover.




Removing water pump impeller

(2) Using the impeller remover, pull out the impeller.

### 2.7.3 Removing water pump shaft

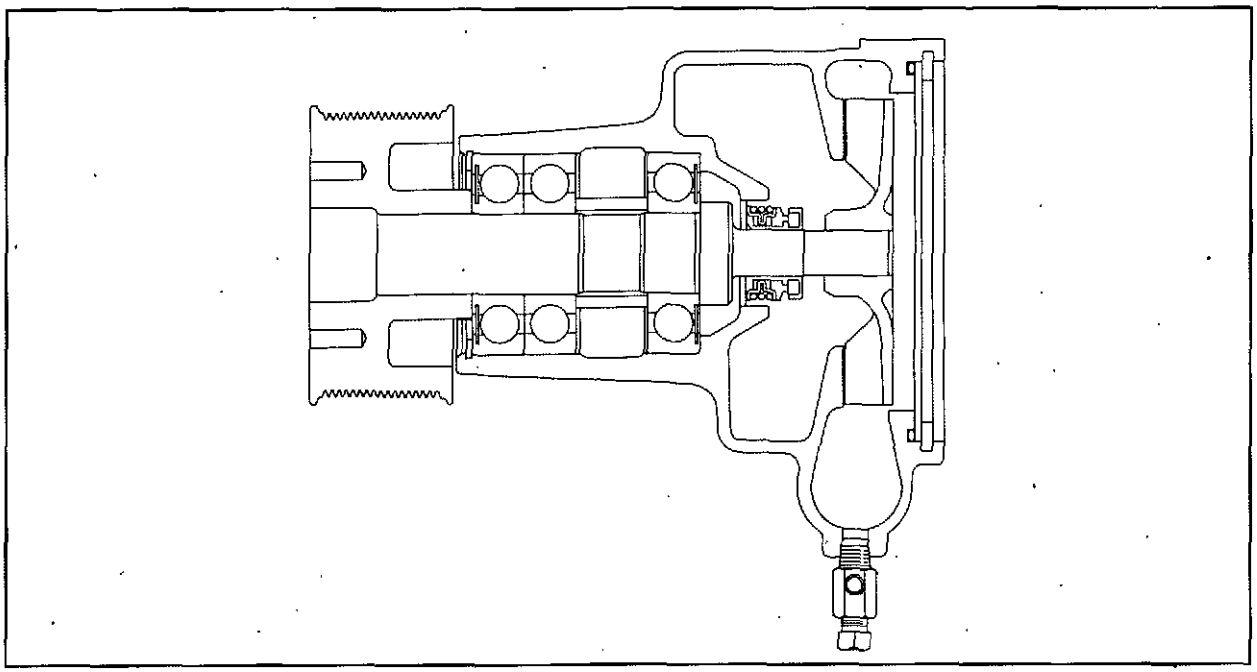
Remove the snap ring from the front bearing, carefully drive out the pump shaft complete with the bearing toward the gear side by using a press or soft-head mallet.

## 2.8 Inspecting 2-way water pump

Measure the water pump case bore and the shaft diameter at the bearing fitting portions as well as the inside and outside diameters of the bearings. If any of the measurements is out of the standard, replace the part with a new one.

| Item | | Nominal | Standard |
|---|---|---|---|
| Inside diameter of bearing fitting bore in case | | ø 62 mm [2.44 in.] | 61.988 to 62.018 mm [2.4405 to 2.4420 in.] |
| Case bearing bore diameter | | ø 68 mm [2.68 in.] | 67.961 to 67.991 mm [2.6756 to 2.6768 in.] |
| Bearing | Inside diameter | ø 28 mm [1.10 in.] | 27.990 to 28.000 mm [1.1020 to 1.1024 in.] |
| | Outside diameter | ø 68 mm [2.68 in.] | 67.987 to 68.000 mm [2.6766 to 2.6772 in.] |
| Shaft bearing journal diameter | | ø 28 mm [1.10 in.] | 28.002 to 28.015 mm [1.1024 to 1.1030 in.] |
| Clearance at the front of impeller | | 0.8 mm [0.031 in.] | 0.5 to 1.1 mm [0.020 to 0.043 in.] |

## 2.9 Reassembling 2-way water pump



Reassembling 2-way water pump

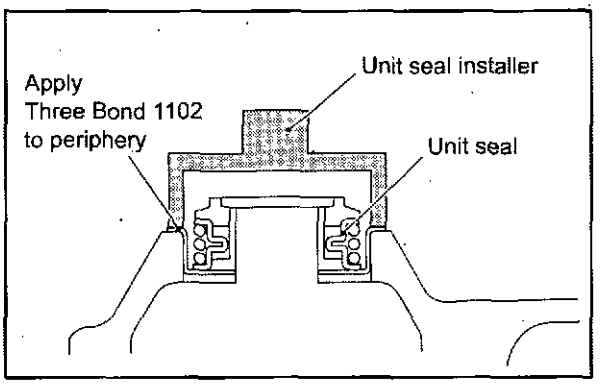
Install new O-rings and unit seal in reassembly.

### 2.9.1 Installing unit seal

(1) Apply sealant (ThreeBond 1102) to the circumference of the unit seal.

(2) Drive the unit seal into the case using a unit seal installer.

Note: Always replace the unit seal with a new one once it has been removed from the pump case.




Installing unit seal

### 2.9.2 Installing shaft

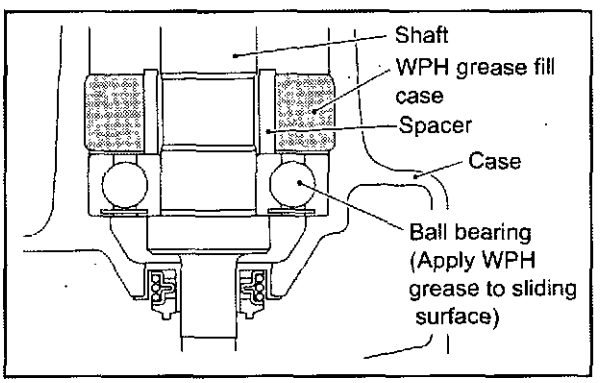
(1) Drive the ball bearing into the shaft.

Note: The ball bearing should be installed so that the shield plate is positioned on the unit seal side.

(2) Fill the ball bearing rolling section with WPH grease.

(3) Drive the shaft into the case.

(4) Install the spacer into the shaft, and fill the case with 31 g [1.09 oz.] of WPH grease.



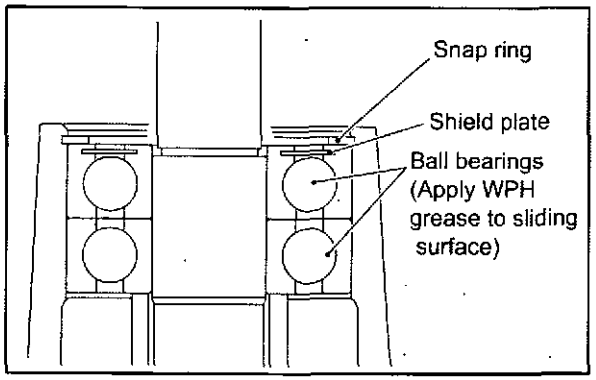

Installing shaft

### 2.9.3 Installing ball bearing

(1) Fill the ball bearing rolling section with WPH grease, and drive the ball bearing.

Note: The ball bearing with shield plate should be installed so that shield plate is positioned on the pulley side.

(2) Secure the ball bearing using a snap ring.



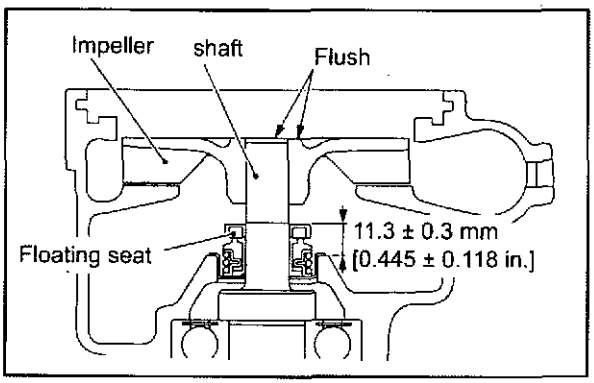

Installing ball bearing

### 2.9.4 Installing floating seat and impeller

(1) Drive the floating seat of unit seal to the mounting length specified.

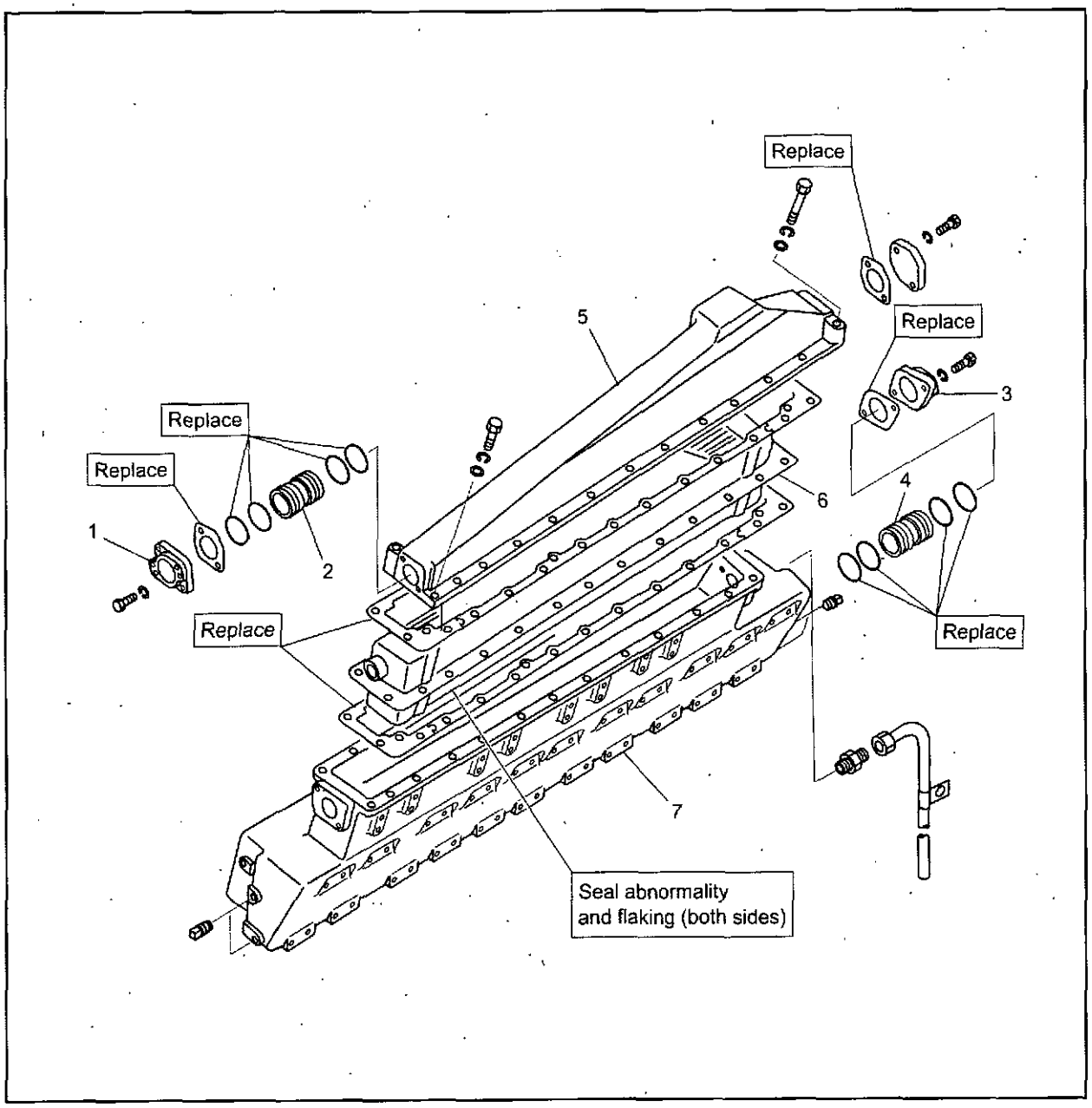
(2) Install the impeller to the shaft, making sure that end faces are flush with each other.

Note: Apply LLC solution to two locations on the float seat before installation.




Installing floating seat and imppeller

## 2.10 Disassembling and inspecting intercooler




Disassembling and inspecting intercooler

Disassembling sequence

1 Connector
2 Pipe
3 Connector
4 Pipe
5 Intercooler cover
6 Intercooler element
7 Inlet manifold

## 2.11 Inspecting intercooler

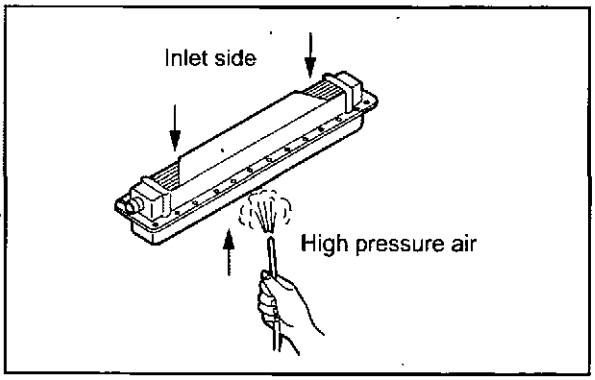
### 2.11.1 Cleaning intercooler

**⚠ CAUTION**

When handling sodium hydroxide (caustic soda) or soda lime, always use a hand protection such as rubber gloves.

(1) To remove the accumulation of dust and dirt, blow compressed air (at a pressure of 0.29 to 0.49 MPa {3 to 5 kgf/cm²} [43 to 71 psi]) through the intercooler in the opposite direction to the normal air flow. Then, inspect for corrosion and cracks.

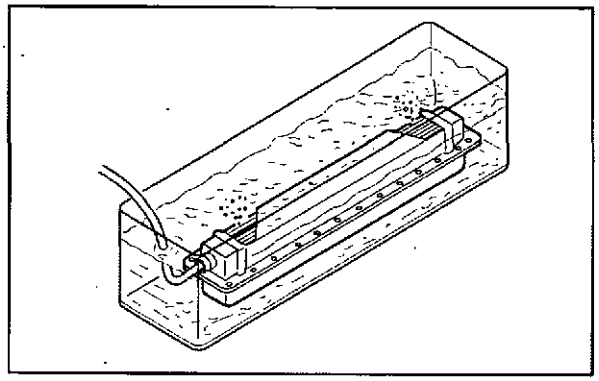
(2) Flush the coolant pipes thoroughly with water holding sodium hydroxide (caustic soda) or soda lime in solution to remove scales.




Cleaning intercooler

### 2.11.2 Inspecting intercooler for leakage

Immerse the intercooler in water. In this condition, blow compressed air (at a pressure of 0.39 MPa {4 kgf/cm²} [57 psi]) through the coolant passage and check for air leak.

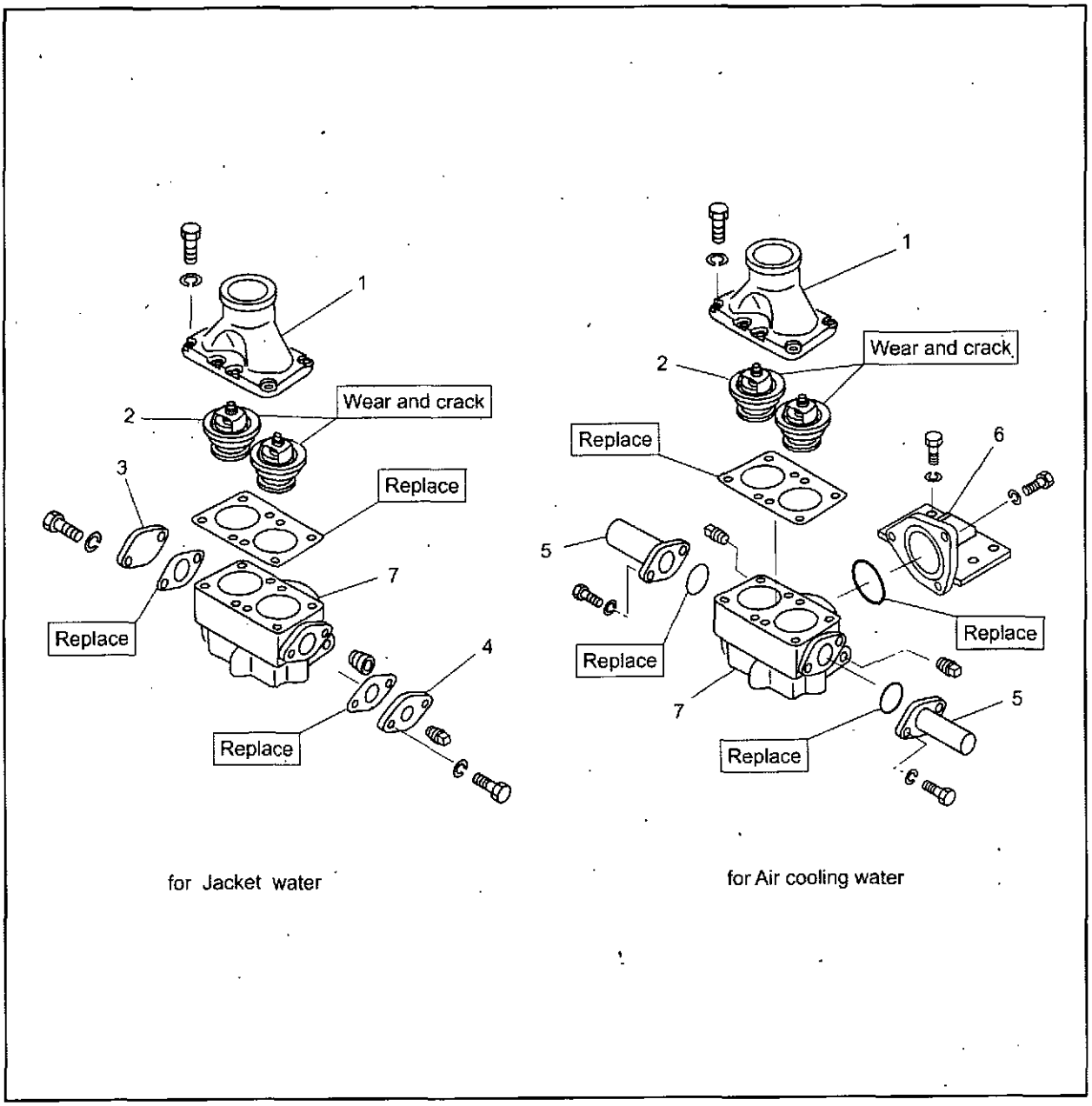


Inspecting intercooler for leakage

## 2.12 Reassembling air cooler

To reassembly, follow the disassembling sequence in reverse.

## 2.13 Disassembling and inspecting thermostat assembly




Disassembling and inspecting thermostat assembly

Disassembling sequence

1 Thermostat cover
2 Thermostat
3 Cover
4 Cover
5 Water pipe
6 Thermostat case bracket
7 Thermostat case

## 2.14 Inspecting water thermostat

**⚠ CAUTION**

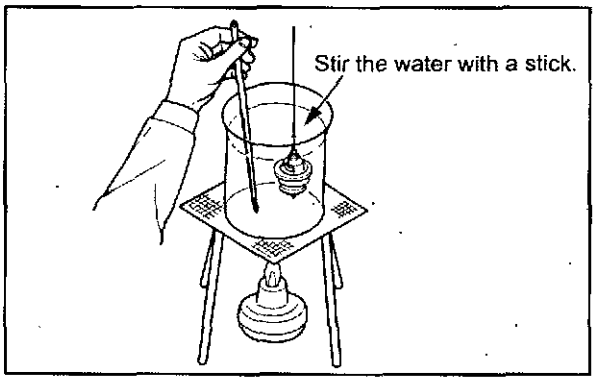
Be careful of burns or a fire when measuring temperature, as it involves a high-temperature and open flame.

To test the thermostat operation, immerse the thermostat in a container filled with water. Heat the water, while measuring the water temperature. Record the temperature at the conditions shown in the table below. If the temperatures are not within the standard range, replace the thermostat.

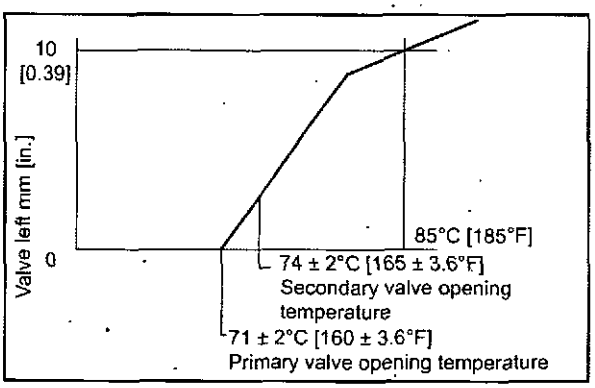
Note: (a) Stir the water in the container with a stick to ensure uniform temperature distribution.

(b) Prior to installing the thermostat, be sure to check the valve opening temperature stamped on the thermostat valve end face.

| Item | Standard |
|---|---|
| Primary valve opening temperature | 71 ± 2°C [160 ± 3.6°F] |
| Secondary valve opening temperature | 74 ± 2°C [165 ± 3.6°F] |
| Temperature at which valve lift is 10 mm [0.39 in.] or more | 85°C [185°F] |




Inspecting thermostat



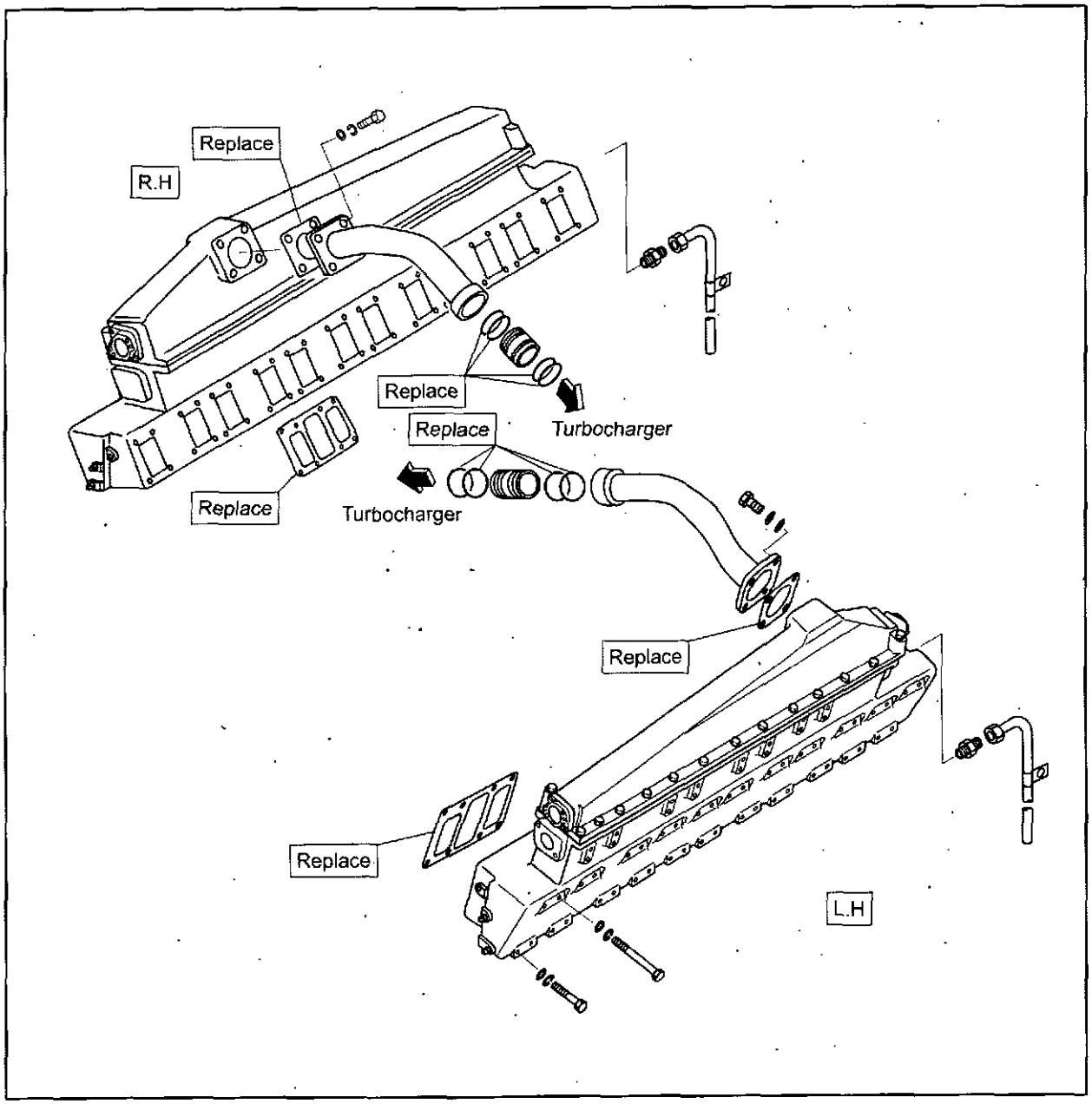

Themostat performance curve

## 2.15 Reassembling thermostat assembly

To reassembly, follow the disassembling sequence in reverse.

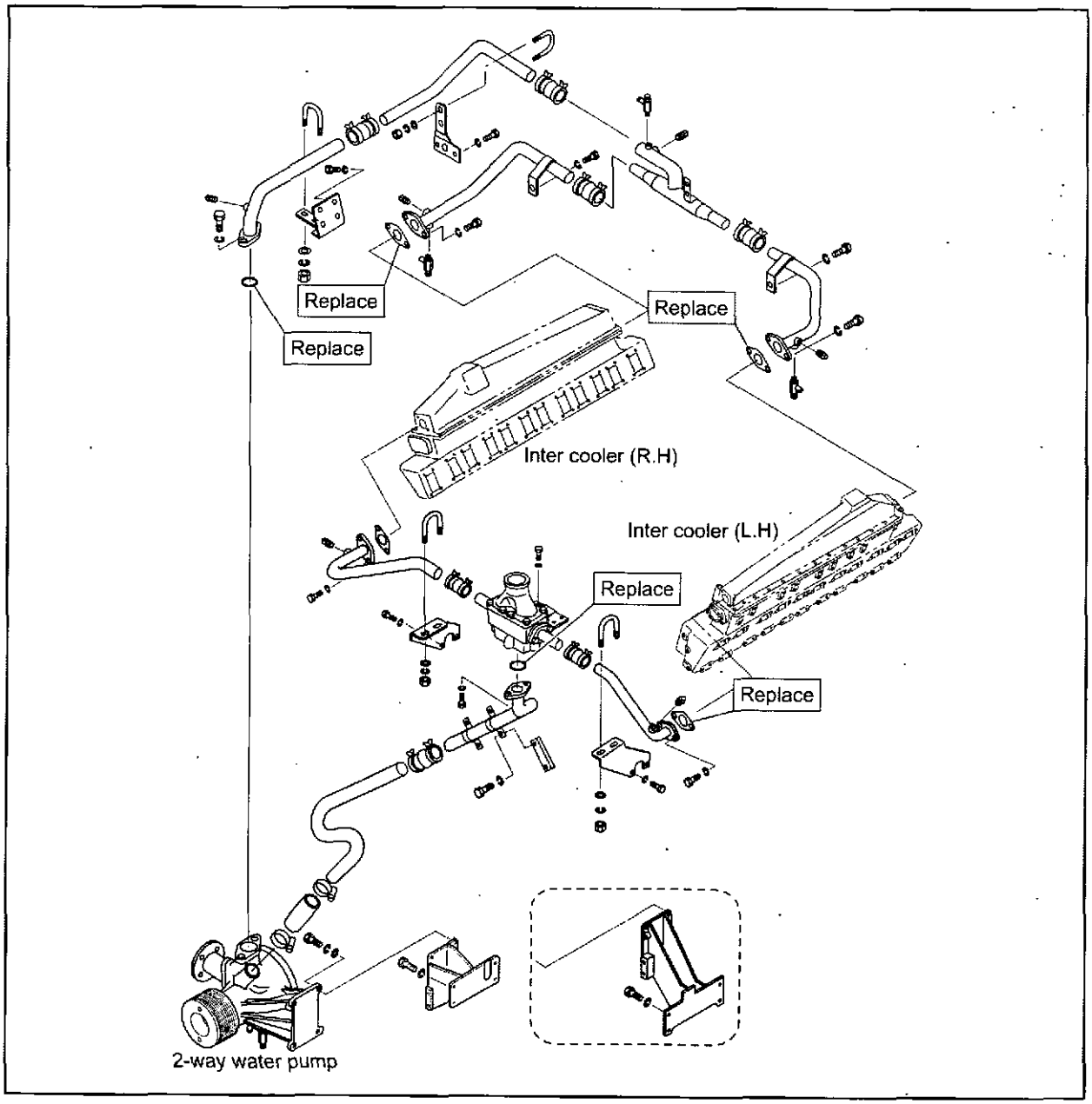
## 3. Installing cooling system

### 3.1 Installing intercooler



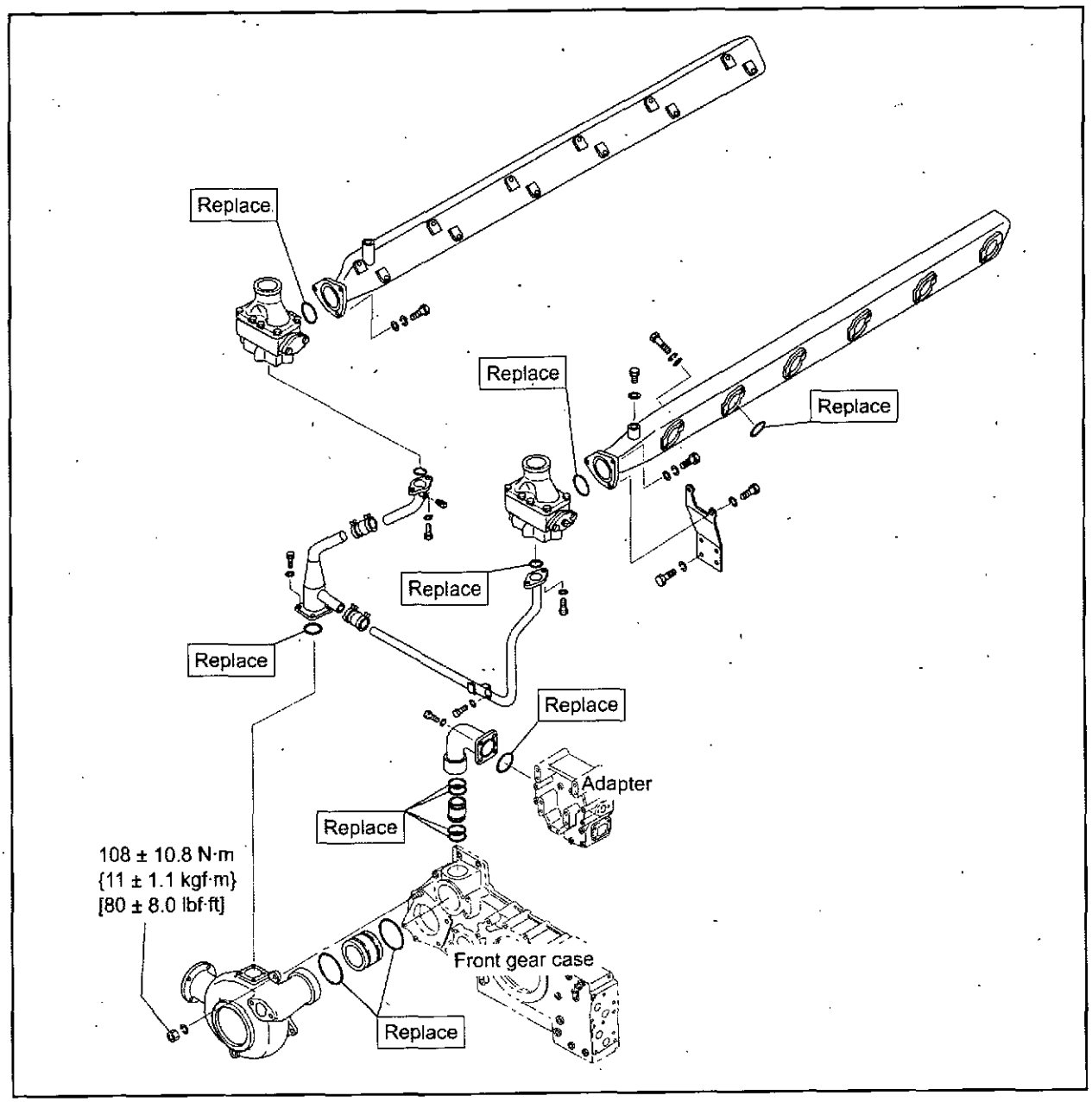

Installing intercooler

### 3.2 Installing 2-way water pump and intercooler water pipe



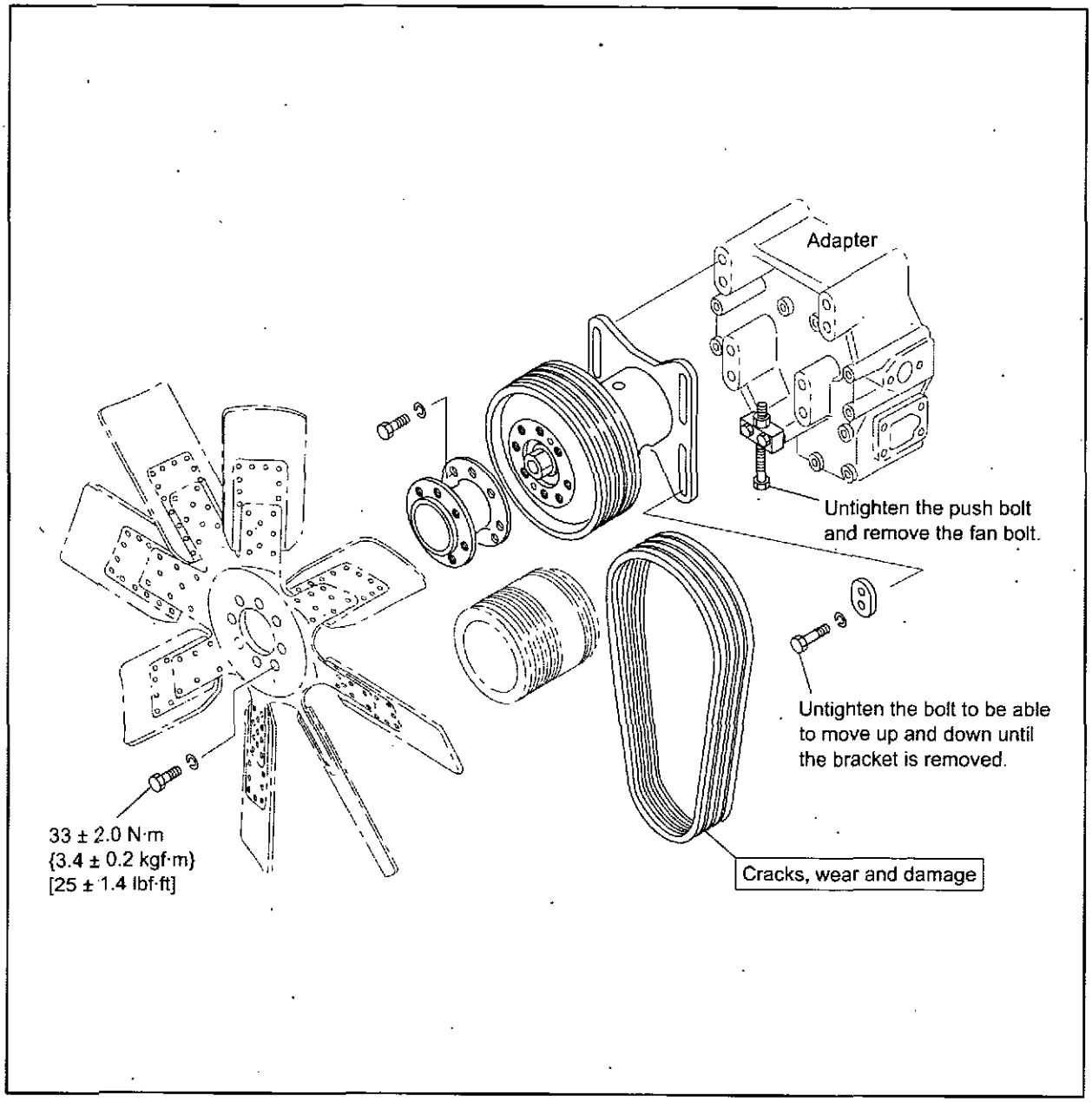

Installing 2-way water pump and intercooler water pipe

### 3.3 Installing water pump and water outlet pipe




Installing water pump and water outlet pipe

### 3.4 Installing fan and fan drive

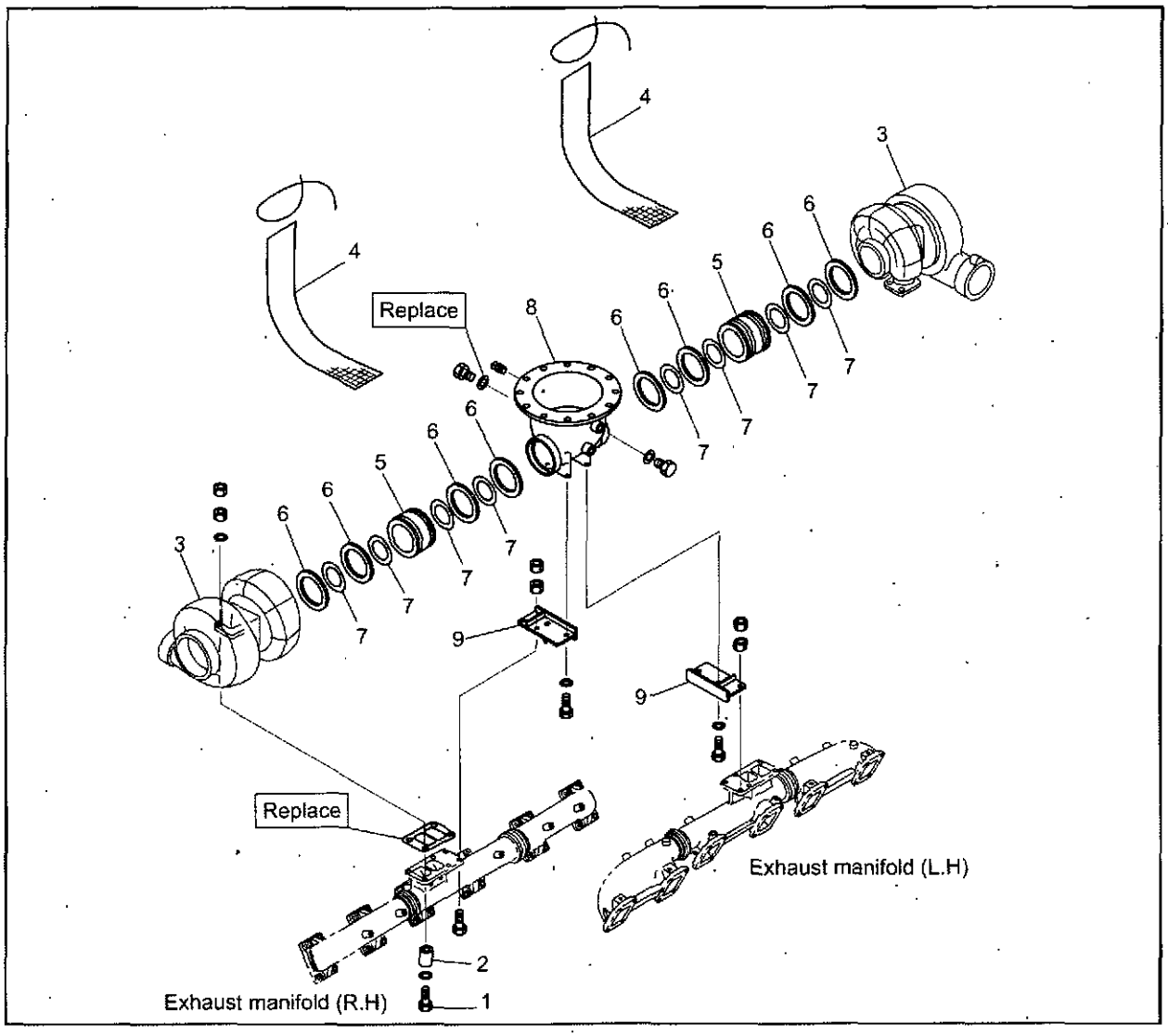



Installing fan and fan drive

# INLET AND EXHAUST SYSTEMS

# 1. Removing and inspecting inlet and exhaust system

## 1.1 Removing and inspecting turbocharger and exhaust pipe

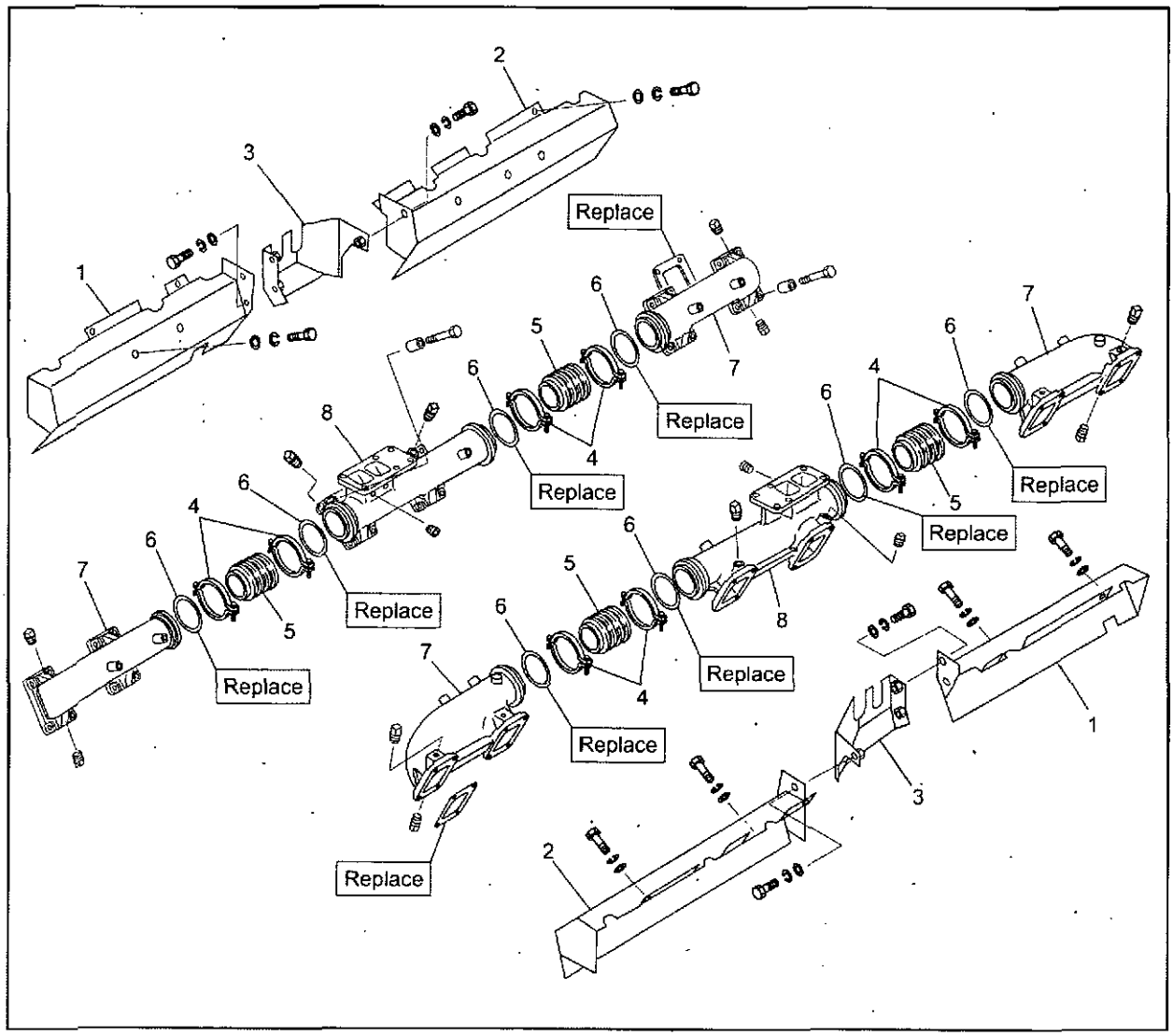



Removing and inspecting turbocharger and exhaust pipe

Removing sequence

1 Bolt
2 *Spacer*
3 Turbocharger (weight: approx. 29 kg [64 lb])
4 Heat insulator
5 Joint
6 Seal outlet ring
7 *Seal inner ring*
8 Exhaust pipe (weight: approx. 25 kg [55 lb])
9 Stay

## 1.2 Removing and inspecting exhaust manifold and insulator



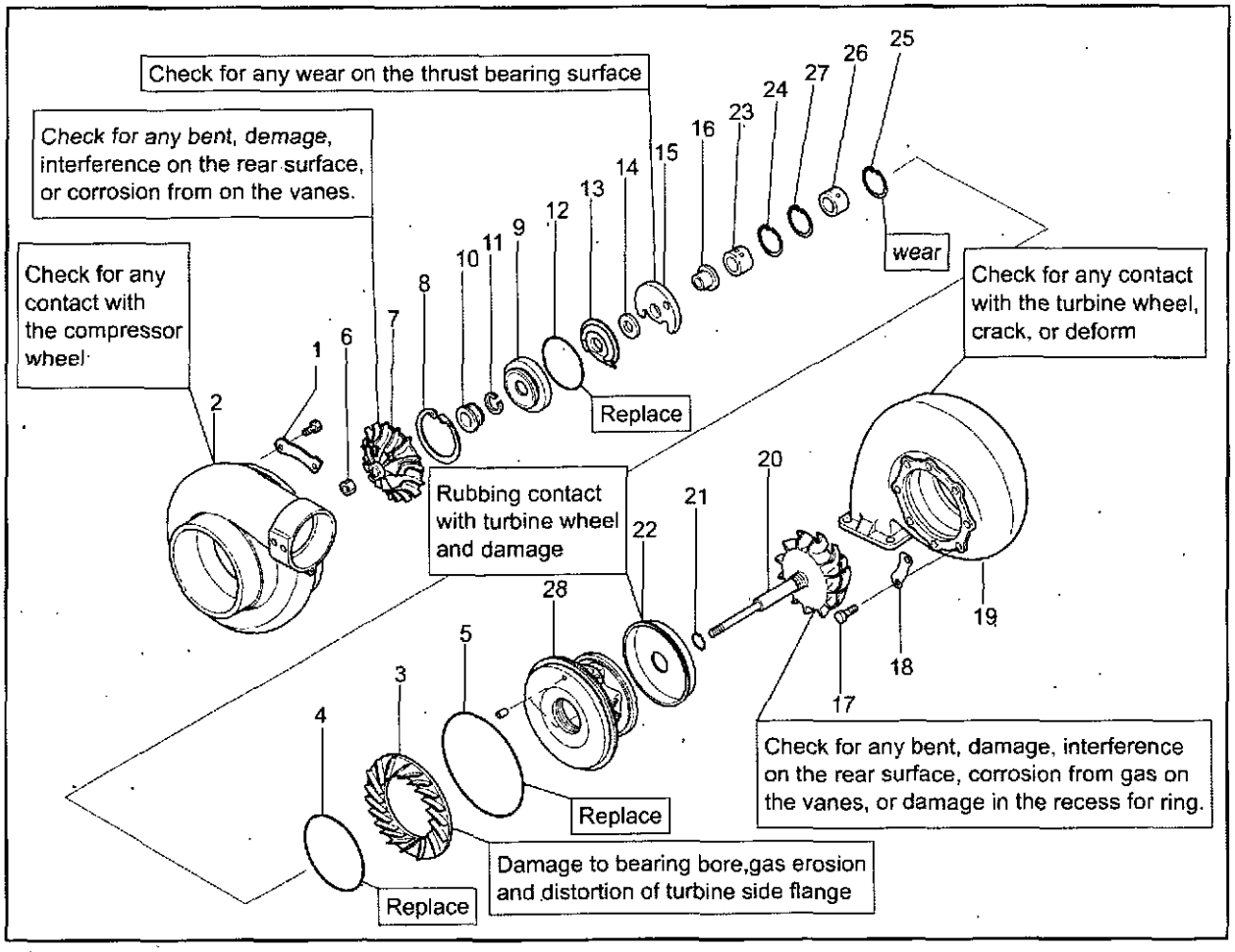

Removing and inspecting exhaust manifold and insulator

Removing sequence

1 Insulator
2 Insulator
3 Insulator
4 Coupling
5 Flexible joint
6 Joint gasket
7 Exhaust manifold
8 Exhaust manifold

## 2. Disassembling and inspecting inlet and exhaust system

### 2.1 Disassembling and inspecting turbocharger




Disassembling and inspecting turbocharger

Disassembling sequence

1 Lock plate
2 Compressor cover
3 Diffuser
4 O-ring
5 O-ring
6 Lock nut
7 Compressor wheel
8 Snap ring
9 *Insert*
10 Flinger sleeve
11 Piston ring
12 O-ring
13 Oil deflector
14 Thrust ring (compressor side)
15 Thrust bearing
16 Thrust ring (turbine side)
17 Bolt
18 Clamp plate
19 *Turbine housing*
20 Shaft & turbine wheel
21 Piston ring
22 Turbine backplate
23 Bearing (compressor side)
24 Snap ring (compressor side)
25 Snap ring (turbine side)
26 Bearing (turbine side)
27 Snap ring (turbine side)
28 Bearing housing

**CAUTION**

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

**CAUTION**

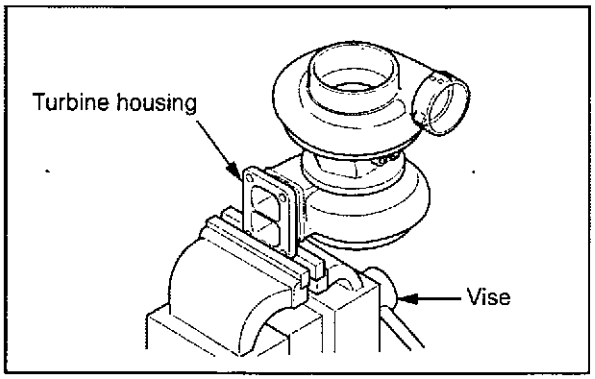
Carefully handle the compressor wheel and turbine wheel during disassembly and assembly, since vanes can easily bend when dropped or hit.

### 2.1.1 Preparing for disassembly

**⚠ CAUTION**

Firmly hold the turbine housing with the vise so as not to allow it to move or become loose during operation. However, exercise care so as not to damage the flange surface by attaching jigs on the vise.

Hold the flange of the turbine housing in a vise.




Preparing for disassembly

### 2.1.2 Removing compressor cover

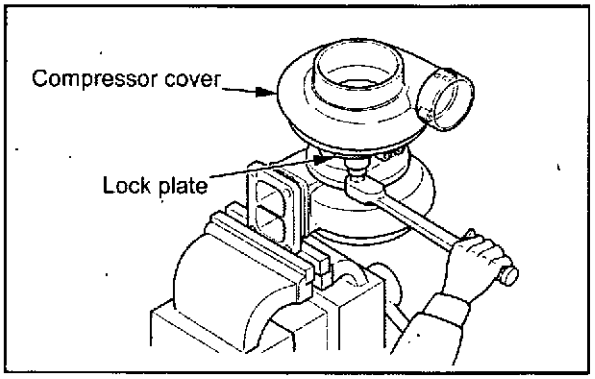
**⚠ CAUTION**

(a) Be sure to make the relationship of the compressor cover, bearing housing and turbine housing with a punch or a marker at disassembly.

(b) Be careful not to hit the compressor wheel against the compressor cover.

(1) Remove the lock plates.

(2) Lightly tap around the compressor cover with a soft-faced hammer to loosen the cover, and remove the cover.

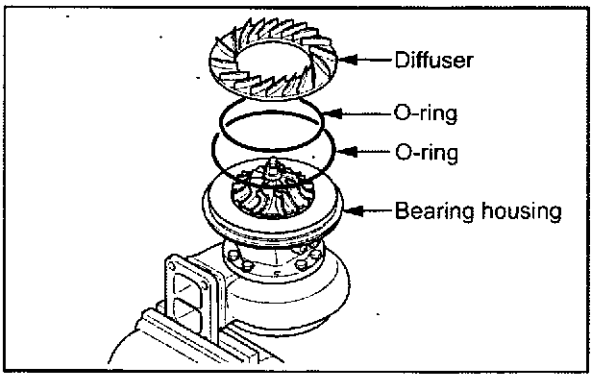



Removing compressor cover

### 2.1.3 Removing diffuser

(1) Lightly tap around the diffuser with a soft-faced hammer to remove the diffuser.

(2) Remove O-rings from the bearing housing.




Removing diffuser

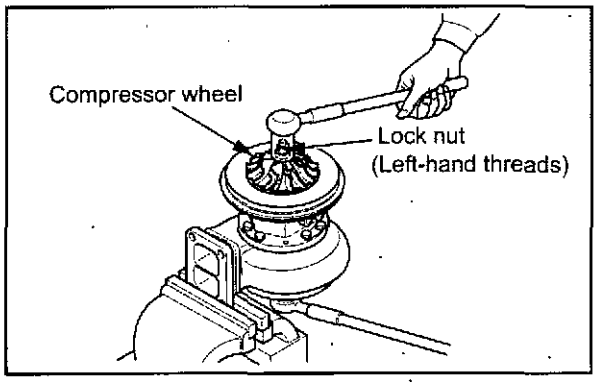
### 2.1.4 Removing compressor wheel

**⚠ CAUTION**

(a) Be careful not to hit the compressor wheel against the compressor cover.

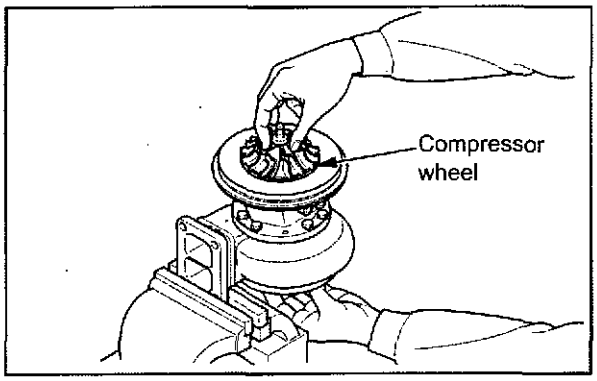
(b) Note that lock nut has left-handed threads.

(1) Hold the boss of the shaft & turbine wheel and unscrew the lock nut that holds the compressor wheel.




Removing compressor wheel (1)

(2) Hold the turbine wheel by one hand, and remove the compressor wheel by lightly turning it.



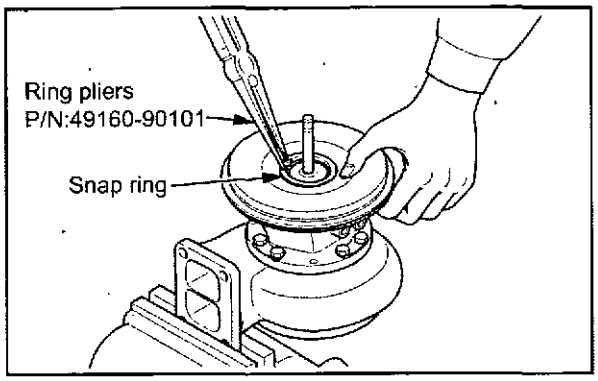

Removing compressor wheel (2)

### 2.1.5 Removing snap ring

**⚠ CAUTION**

Put a thumb on the snap ring to prevent it from flying out in case pliers lose grip.

Using the ring pliers, remove the snap ring.



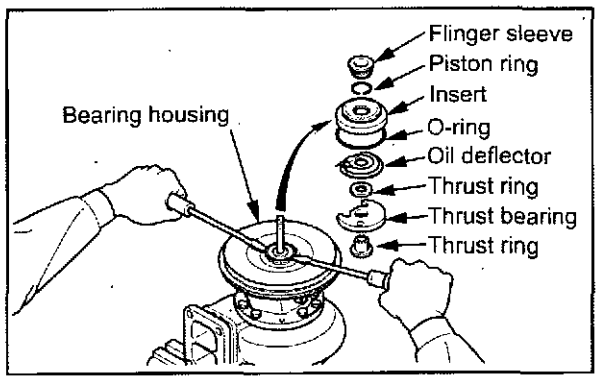

Removing snap ring

### 2.1.6 Removing insert and oil deflector

(1) Using two screwdrivers, gently pry out the insert from the bearing housing.

(2) Separate the flinger sleeve together with the piston ring from the insert.

(3) Remove the following parts from the bearing housing.
O-ring
Oil deflector
Thrust ring (compressor side)
Thrust bearing
Thrust ring (turbine side)

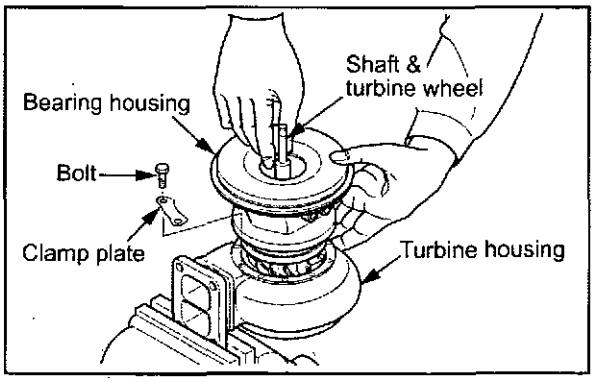



Removing insert and oil deflector

### 2.1.7 Removing shaft & turbine wheel

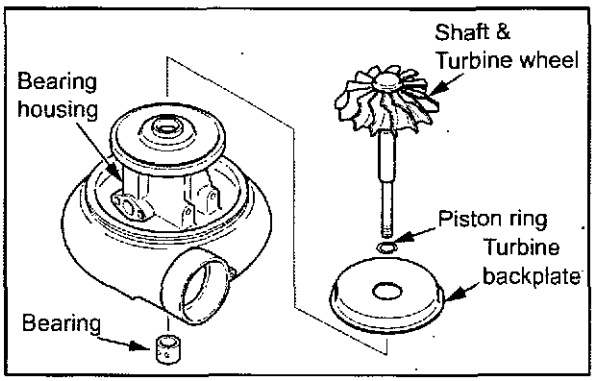
(1) Remove the bolts and clamp plates.

(2) While gripping the shaft of the shaft & turbine wheel with one hand, hold the bearing housing with the other hand and slowly remove the shaft & turbine wheel from the turbine housing.




Removing shaft & turbine wheel (1)

(3) Turn over the bearing housing (so the turbine wheel faces up), and place it on the compressor cover. Then, remove the following parts.
Shaft & turbine wheel
Piston ring
Turbine backplate
Bearing (compressor side)




Removing shaft & turbine wheel (2)

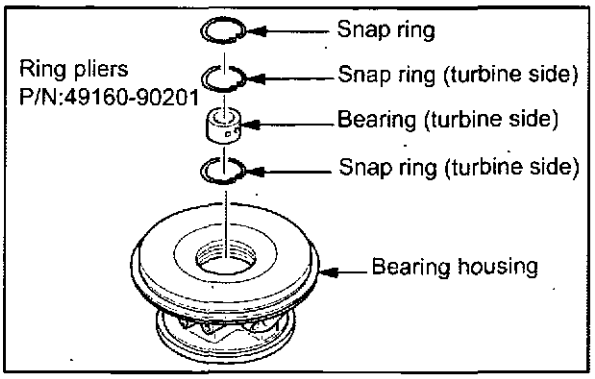
### 2.1.8 Removing snap ring and bearing

**⚠ CAUTION**

(a) Use the pliers to remove the snap ring.

(b) Carefully remove the snap ring, making sure not to damage the inside surface of the bearing housing or the seal (turbine side) of the piston ring.

Place the bearing housing on a workbench with the compressor side facing up. Then, remove the following parts.
Snap ring (compressor side)
Bearing (turbine side)
Snap ring (turbine side)




Removing snap ring and bearing

## 2.2 Cleaning turbocharger

**CAUTION**

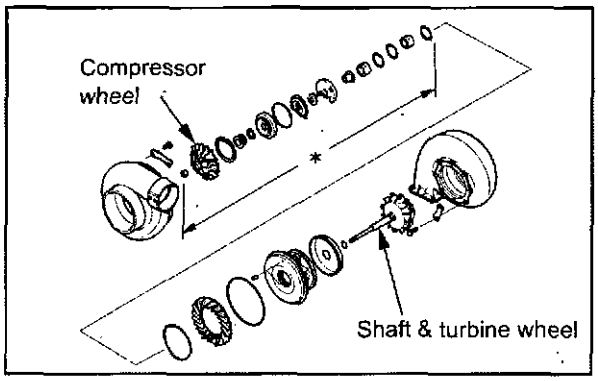
(a) If any commercial neutral detergent needs to be used, it must not have a corrosive nature.
(b) Exercise care not to damage any part.
(c) Where shot-blasting is necessary, cover the both end surfaces of the compressor wheel, and screws, shafts, and groove for ring of the turbine shaft & turbine wheel to protect their surfaces from being rugged or sore before the cleaning operation.

In maintenance workshops dedicated for turbocharger, it is popular to use a blasting equipment for cleaning the target parts. The alternative of this method is as follows:

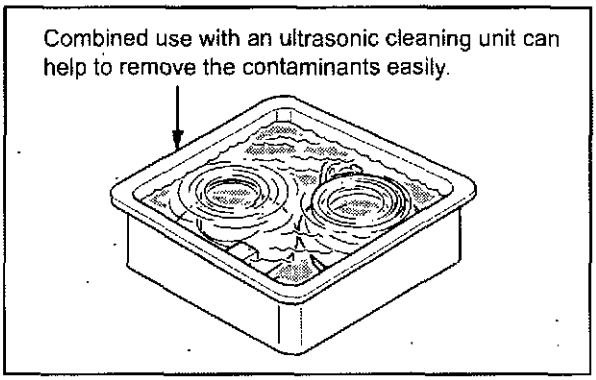
Note: On this shot blast, do not blast over such parts as included in the section marked with an * in the figure, both end surfaces of the compressor wheel, and shaft section of the shaft & turbine wheel.

(1) Visually check the part conditions before cleaning to note any burns and abrasions, which may not be observable after cleaning.
(2) Soak the disassembled parts in the inflammable solvent (e.g. Die Cleaner T-30 manufactured by Daido Chemical Industry Corp.) to remove oil contaminants and carbon attachments. However, do not soak the O-ring, thrust bearing, and other bearings.
(3) Blow a compressed air over the either inside and outside surfaces.

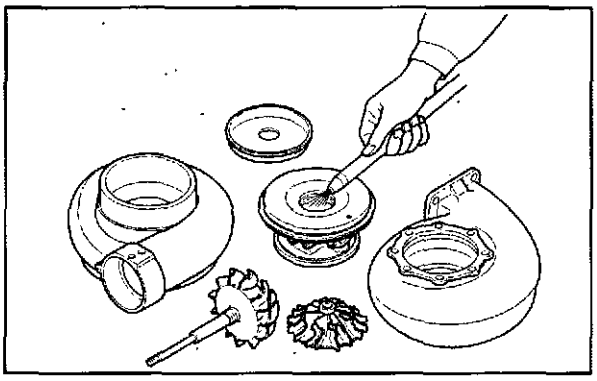
(4) Pick off the attachments using a plastic lever or bristle brush.



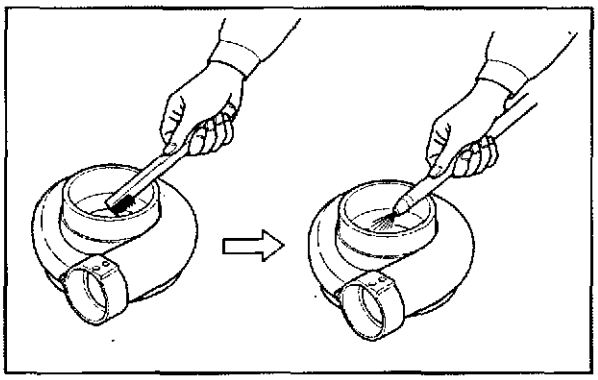

Cleaning procedure turbocharger




Cleaning turbocharger

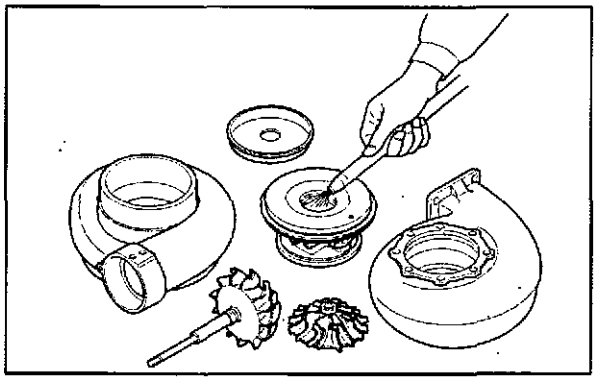


Blow compressed air onto



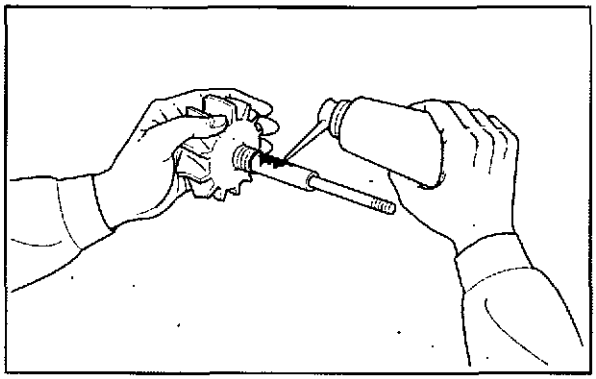
Cleaning carbon deposits thorughly

(5) Blow a clean compressed air over the inside and outside surfaces again.



Blow compressed air onto

Coat a clean engine oil over the surfaces of each sliding component. Should the screw, shaft, or ring-receiving groove be rusty, remove it with a puff, etc. Never use a file to abrade the surfaces.



Apply engine oil

## 2.3 Inspecting turbocharger

**CAUTION**

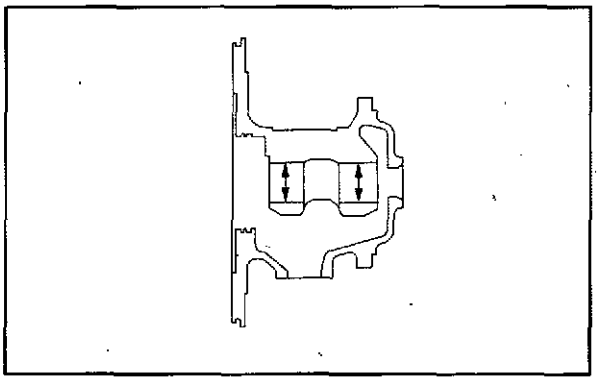
When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

### 2.3.1 Bearing housing

**Measuring inside diameter of bearing-fitted section**

If the measured diameter exceeds the service limit, replace the bearing housing.

| Item | Limit |
|---|---|
| Inside diameter of bearing-fitted housing section | 30.006 mm [1.1813 in.] |



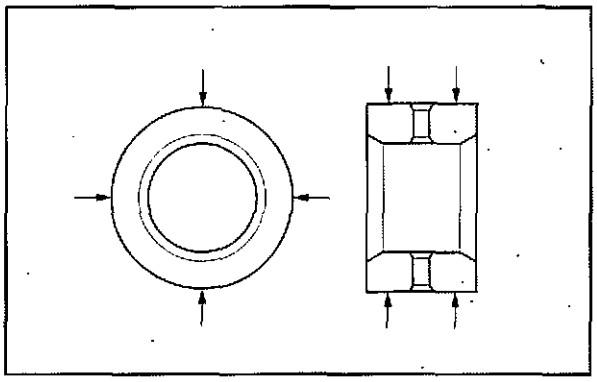
Measuring inside diameter of bearing-fitted section

### 2.3.2 *Bearing*

**(1) Measuring bearing outside diameter**

If the measured diameter is less than the service limit, replace the bearing.

| Item | Limit |
|---|---|
| Bearing outside diameter | 29.876 mm [1.1762 in.] |

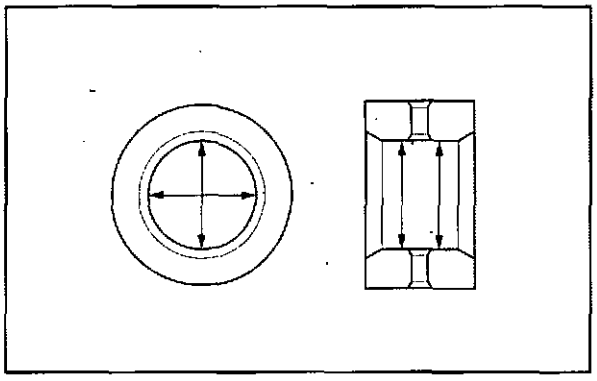


Measuring bearing outside diameter

**(2) Measuring bearing inside diameter**

If the measured diameter exceeds the service limit, replace the bearing.

| Item | Limit |
|---|---|
| Bearing inside diameter | 18.050 mm [0.7106 in.] |

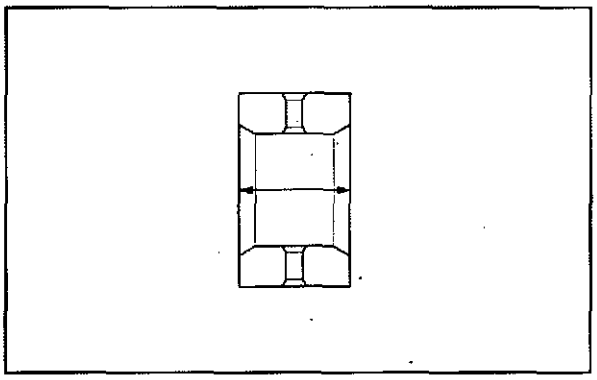


Measuring bearing inside diameter

**(3) Measuring bearing length**

If the measured length is less than the service limit, replace the bearing.

| Item | Limit |
|---|---|
| Bearing length | 17.440 mm [0.6866 in.] |



Measuring bearing length

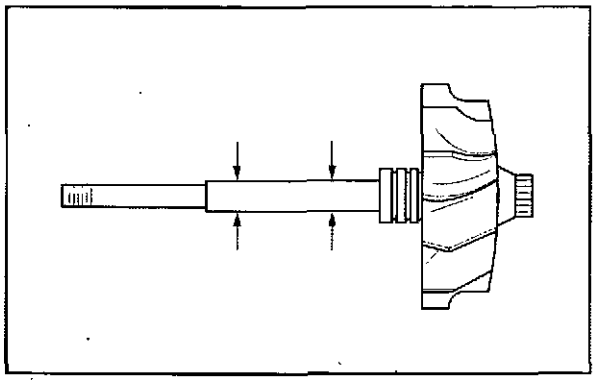
### 2.3.3 Shaft & turbine wheel

**(1) Measuring journal diameter of the shaft & turbine wheel**

If the measured diameter is less than the service limit, replace the shaft & turbine wheel.

Replace the piston ring with new one.

| Item | Limit |
|---|---|
| Shaft journal diameter | 17.996 mm [0.7085 in.] |



Measuring journal diameter of shaft and turbine wheel

**(2) Measuring shaft runout**

**⚠ CAUTION**

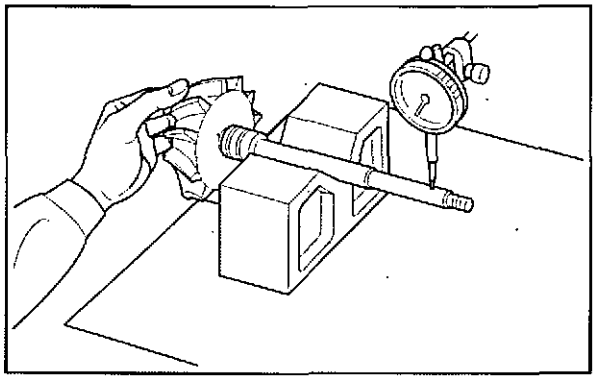
If the shaft is bent, replace. Do not attempt to correct the bend.

Set a dial gauge at a location next to the threaded section of the shaft, and measure shaft runout.

If the deviation indicated by the dial gauge exceeds the service limit, replace the shaft & turbine wheel.

If the surface of the shaft journal is rough, mount the shaft on a lathe, and gently polish the surface using #400 sandpaper and engine oil while rotating at 300 to 600 $min^{-1}$.

| Item | Limit |
|---|---|
| Shaft runout | 0.015 mm [0.0006 in.] |



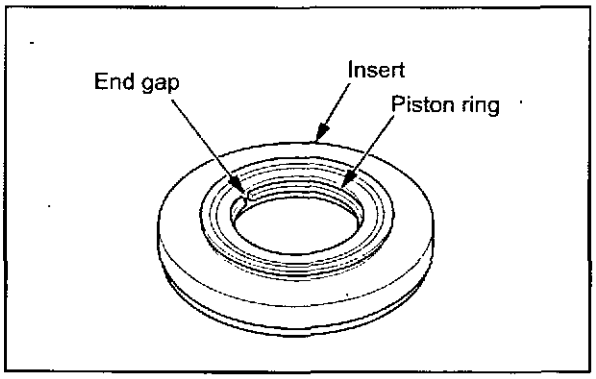
Measuring shaft runout

### 2.3.4 Inspecting insert and measuring piston ring end gap

Install a new piston ring squarely in the insert, then measure the piston ring end gap.

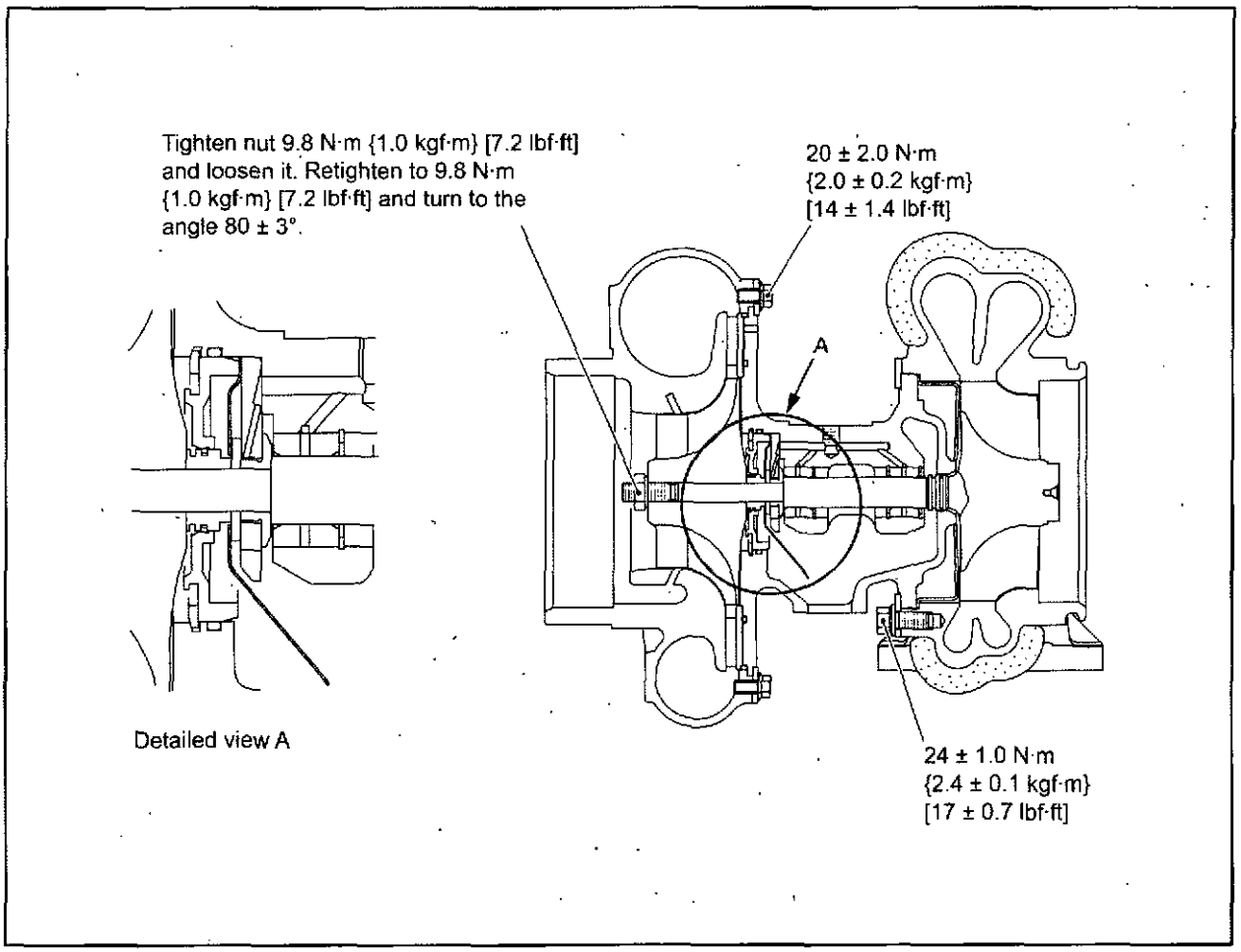
If the end gap deviates from the assembly standard, replace the insert.

| Item | Standard |
|---|---|
| Ring end gap | 0.05 to 0.25 mm [0.0020 to 0.0098 in.] |




Measuring piston ring end gap

## 2.4 Reassembling turbocharger




Reassembling turbocharger

**CAUTION**

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

**CAUTION**

Replace the following parts once disassembled.

Piston ring

*O-ring*

After installing the overhauled turbocharger on the engine, crank the engine with the starter to send lubricating oil to the moving parts in the turbocharger.

**CAUTION**

(a) If vanes are damaged or cracked, do not reuse the part.

(b) If only one vane is slightly bent or scratched, the part can reused. However, do not attempt to correct the bend.

### 2.4.1 Installing shaft & turbine wheel and bearing

**⚠ CAUTION**

(a) Use the ring pliers to install the snap ring. After installing the snap ring, rotate the ring with a finger to make sure it rotates smoothly.

(b) Apply engine oil to the outside and inside surfaces of the bearing before installation.

(c) Do not expand the piston ring excessively or twist the ends when installing on the shaft & turbine wheel.

(d) After installing the piston ring in the ring groove, apply Molykote to the ring before assembly.

(e) The piston rings on the turbine side and compressor side are identical.

(f) Do not apply excessive force without centering the shaft properly during the installation of the shaft & turbine wheel.

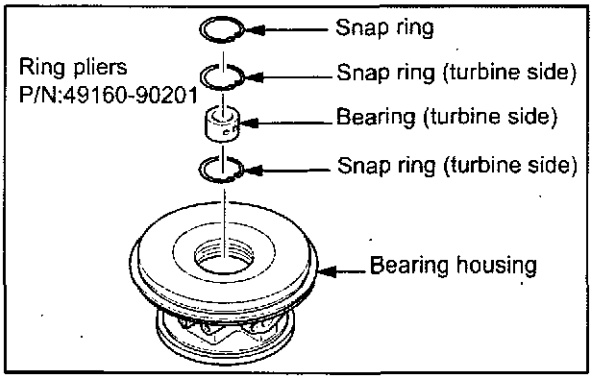
(1) Install the following parts.
Bearing housing
Snap ring (turbine side)
Bearing (turbine side)
Snap ring (compressor side)

(2) Place the bearing housing on the compressor cover, and install the turbine backplate.

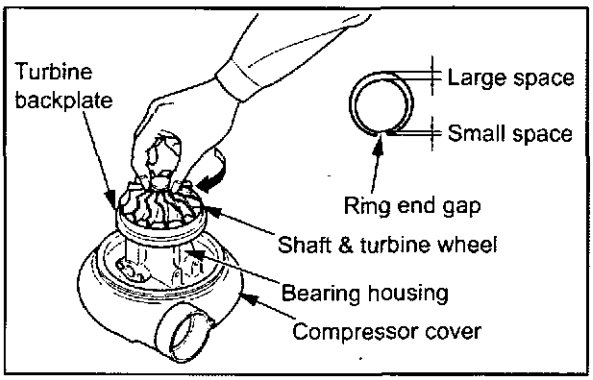
(3) Insert the piston ring into the groove on the shaft & turbine wheel.

(4) When installing the shaft & turbine wheel mounted with the piston ring in the bearing housing, position the ring on the shaft as shown in the illustration, and insert the shaft & turbine wheel while rotating.

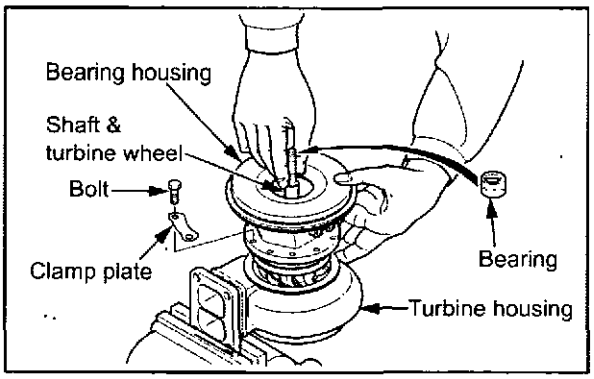
(5) After installing the shaft & turbine wheel, hold the shaft end and turn over the assembly so the compressor side faces up.
Then, install the bearing on the compressor side.
After the assembly was completed, mount the bearing housing on the turbine housing and tighten the bolts and clamp plates temporarily.




Installing shaft & turbine wheel and bearing (1)




Installing shaft & turbine wheel and bearing (2)

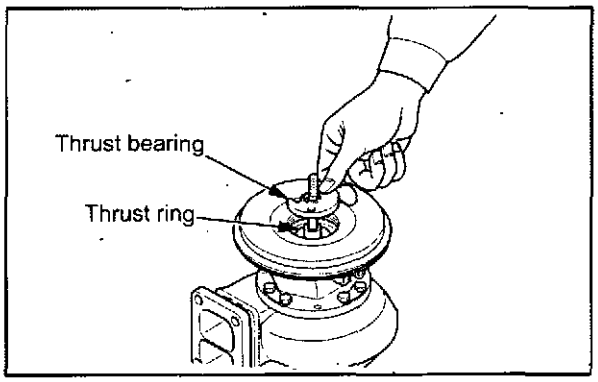



Installing shaft & turbine wheel and bearing (3)

### 2.4.2 Installing thrust bearing

Apply engine oil to both sides of the thrust ring and thrust bearing.

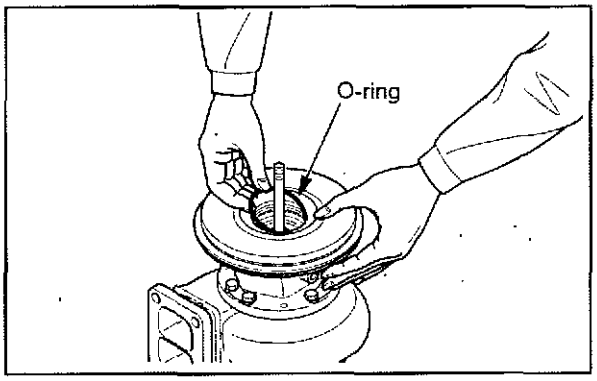
To install the thrust bearing, align the notch to the groove pin.




Installing thrust bearing

### 2.4.3 Installing O-ring

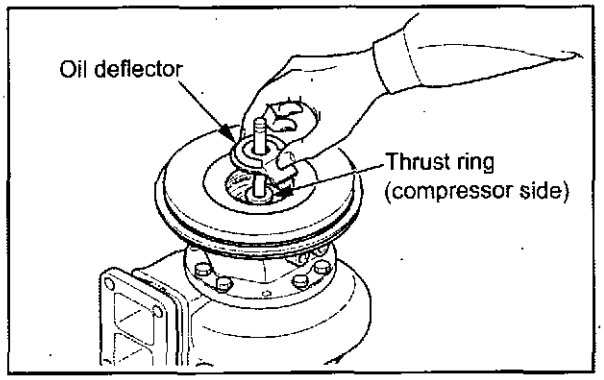
Apply grease to O-ring, and install.




Installing O-ring

### 2.4.4 Installing oil deflector

Apply engine oil to both sides of the thrust ring and install. Then, install the oil deflector with the baffle facing down.




Installing oil deflector

### 2.4.5 Reassembling insert sub-assembly

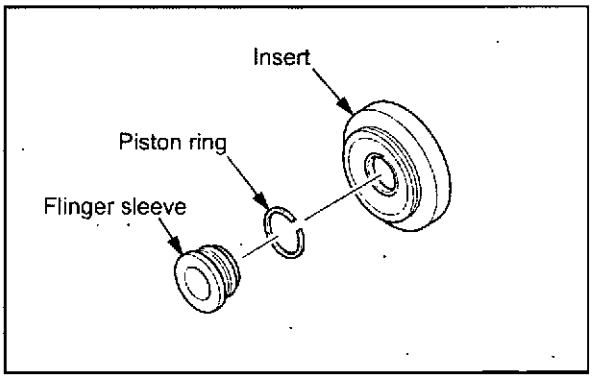
**CAUTION**

(a) Do not expand the piston ring excessively or twist the ends when installing on the finger sleeve.

(b) Apply specified sealant to the piston ring installed on the flinger sleeve, then install on the insert carefully so as to avoid piston ring damage.

(1) Install the following parts to the insert.
Flinger sleeve
Piston ring
Insert

(2) After installing the above parts, install the sub-assembly in the bearing housing.




Reassembling insert sub-assembly

### 2.4.6 Installing snap ring

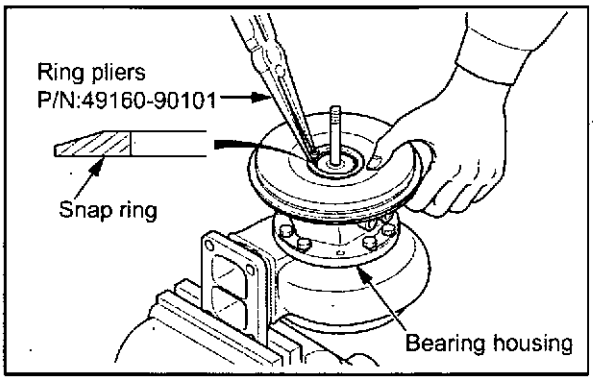
**CAUTION**

(a) Be sure to install the snap ring in the correct direction.

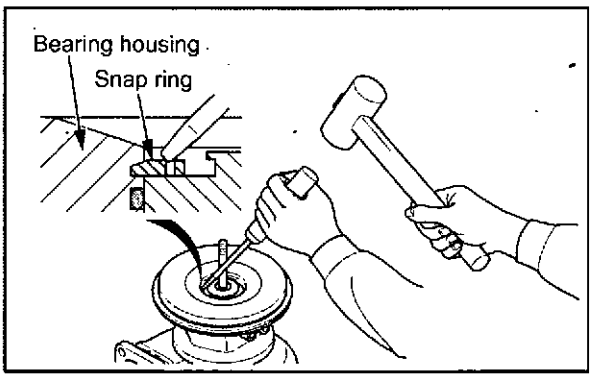
(b) Lightly drive both ends of the snap ring using a screwdriver and hammer to securely insert the ring into the groove on the bearing housing.

(c) Make sure the screwdriver does not hit the bearing housing when driving the snap ring with the screwdriver and hammer.

With the tapered face facing up, install the snap ring in the bearing housing using the pliers.




Installing snap ring (1)



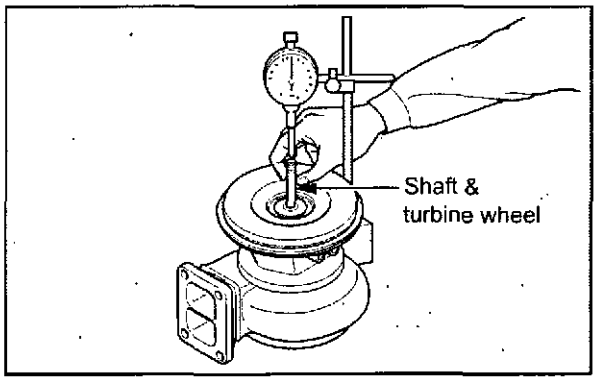

Installing snap ring (2)

### 2.4.7 Measuring clearance between shaft & turbine wheel and turbine housing

Set dial gauge on the end face of the shaft & turbine wheel. Read the dial gauge indication while moving the shaft & turbine wheel in the axial direction.

If the dial gauge indication deviates from the assembly standard, disassemble and locate the cause of the problem.

| Item | Standard |
|---|---|
| Clearance between shaft & turbine wheel and turbine housing | 0.29 to 0.91 mm [0.0114 to 0.0358 in.] |



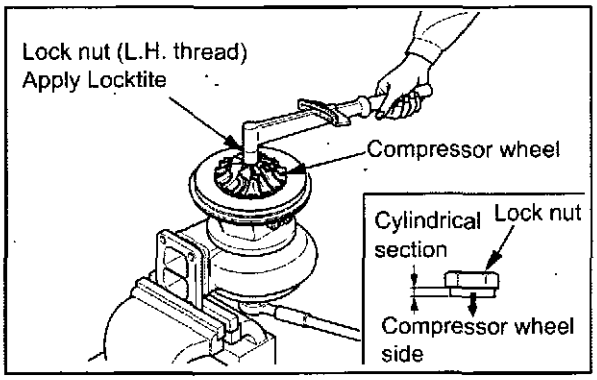

Measuring clearance between turbine wheel and turbine housing

### 2.4.8 *Installing compressor wheel*

Install the compressor wheel. Apply specified sealant to the threads of the lock nut, and tighten the nut to the specified torque.

· Lock nut tightening method

Tighten nut to 9.8 N·m {1.0 kgf·m} [7.2 lbf·ft] and loosen it. Retighten to 9.8 N·m {1.0 kgf·m} [7.2 lbf·ft] and turn to the angle 80 ± 3°.




Installing compressor wheel

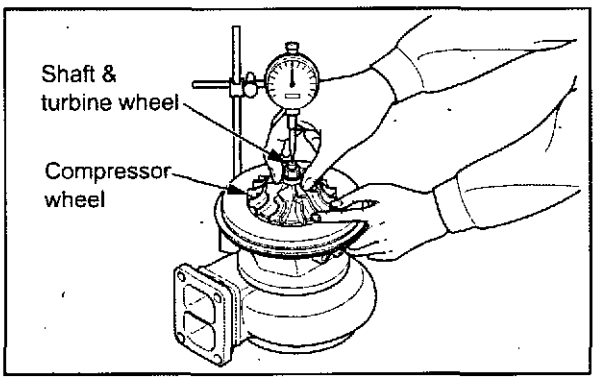
### 2.4.9 Measuring play of shaft & turbine wheel in axial direction

Set a dial gauge on the end face of the shaft & turbine wheel.

Measure the amount of play while moving the compressor wheel in the axial direction.

If the measured amount of play deviates from the standard value, disassemble and locate the cause of the problem.

| Item | Standard |
|---|---|
| Shaft & turbine wheel end play | 0.075 to 0.135 mm [0.0030 to 0.0053 in.] |




Measuring play of shaft & turbine wheel in axial direction

### 2.4.10 Measuring clearance between turbine backplate and back side of turbine wheel

**CAUTION**

Be sure to use two feeler gauges, and take the measurement at vane tips.

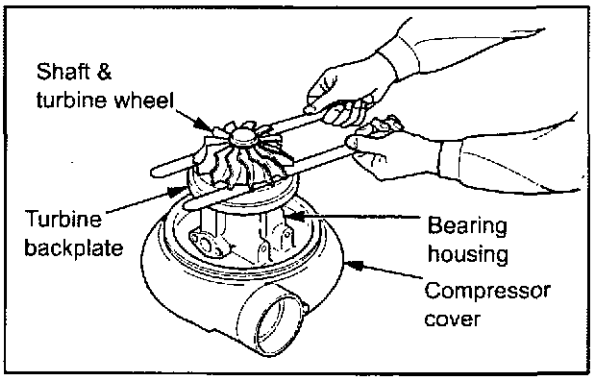
Remove the turbine housing from the bearing housing.

Install the compressor cover, and conduct the following measurement.

Using feeler gauges, measure clearance between the turbine backplate and the back side of the turbine wheel.

If the measured clearance deviates from the assembly standard, disassemble and locate the cause of the problem.

| Item | Standard |
|---|---|
| Clearance between turbine backplate and back side of turbine wheel | 0.55 to 1.15 mm [0.0217 to 0.0453 in.] |

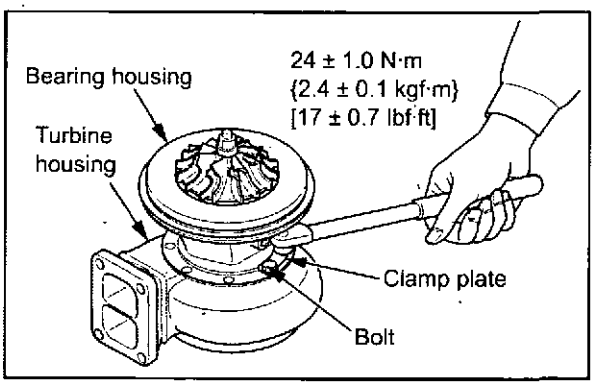



Measuring clearance between turbine backplate and back side of turbine wheel

### 2.4.11 Installing turbine housing

(1) Check the mounting direction of the turbine housing, then install on the bearing housing.

(2) Apply Moly Disulfide to the threads of the bolt, install clamp plate and tighten the bolt.

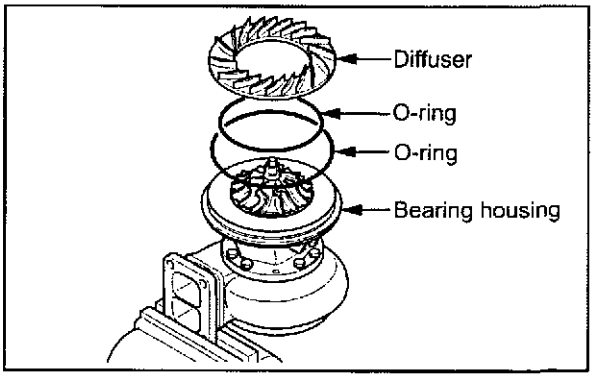



Installing turbine housing

### 2.4.12 Installing diffuser

(1) Apply grease to the O-ring and install the O-ring to the bearing housing.

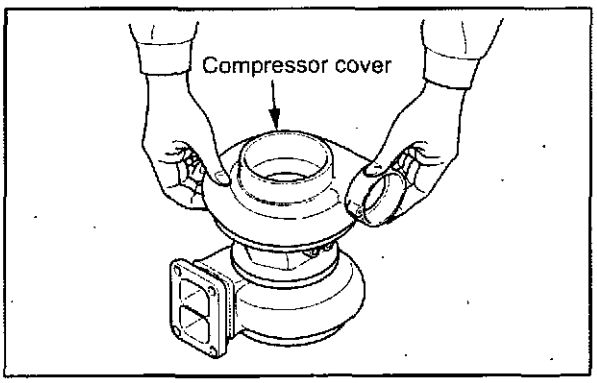
(2) Install the diffuser.




Installing diffuser

### 2.4.13 Installing compressor cover

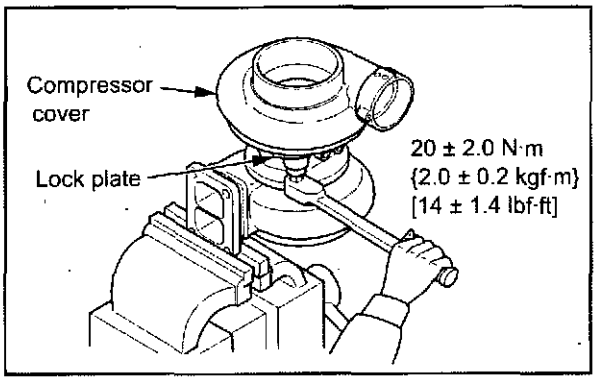
Check the mounting direction of the compressor cover, then install.




Installing compressor cover

### 2.4.14 Installing lock plate

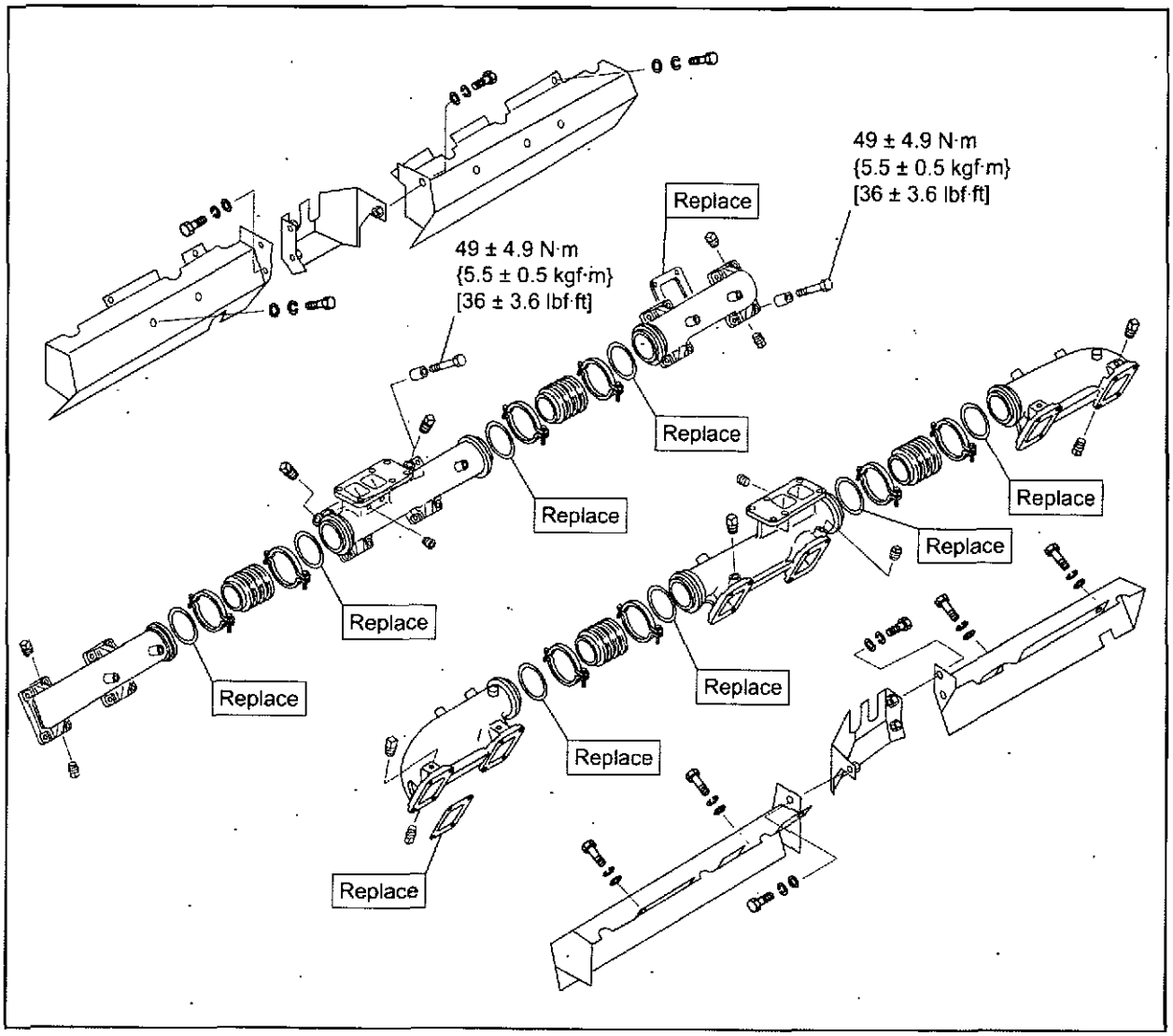
Install the lock plate and tighten the bolts to the specified torque.




Installing look plate

## 3. Installing inlet and exhaust system

### 3.1 Installing exhaust manifold and insulator

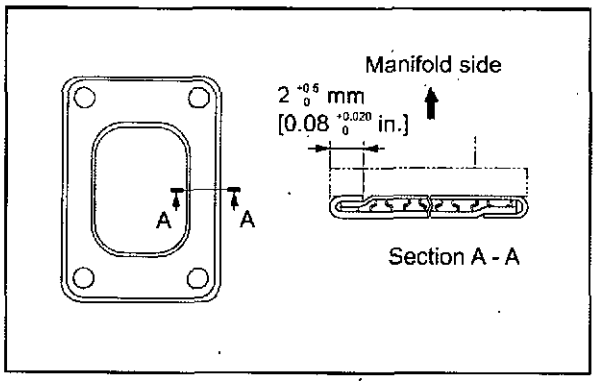



Installing exhaust manifold and insulator

**CAUTION**

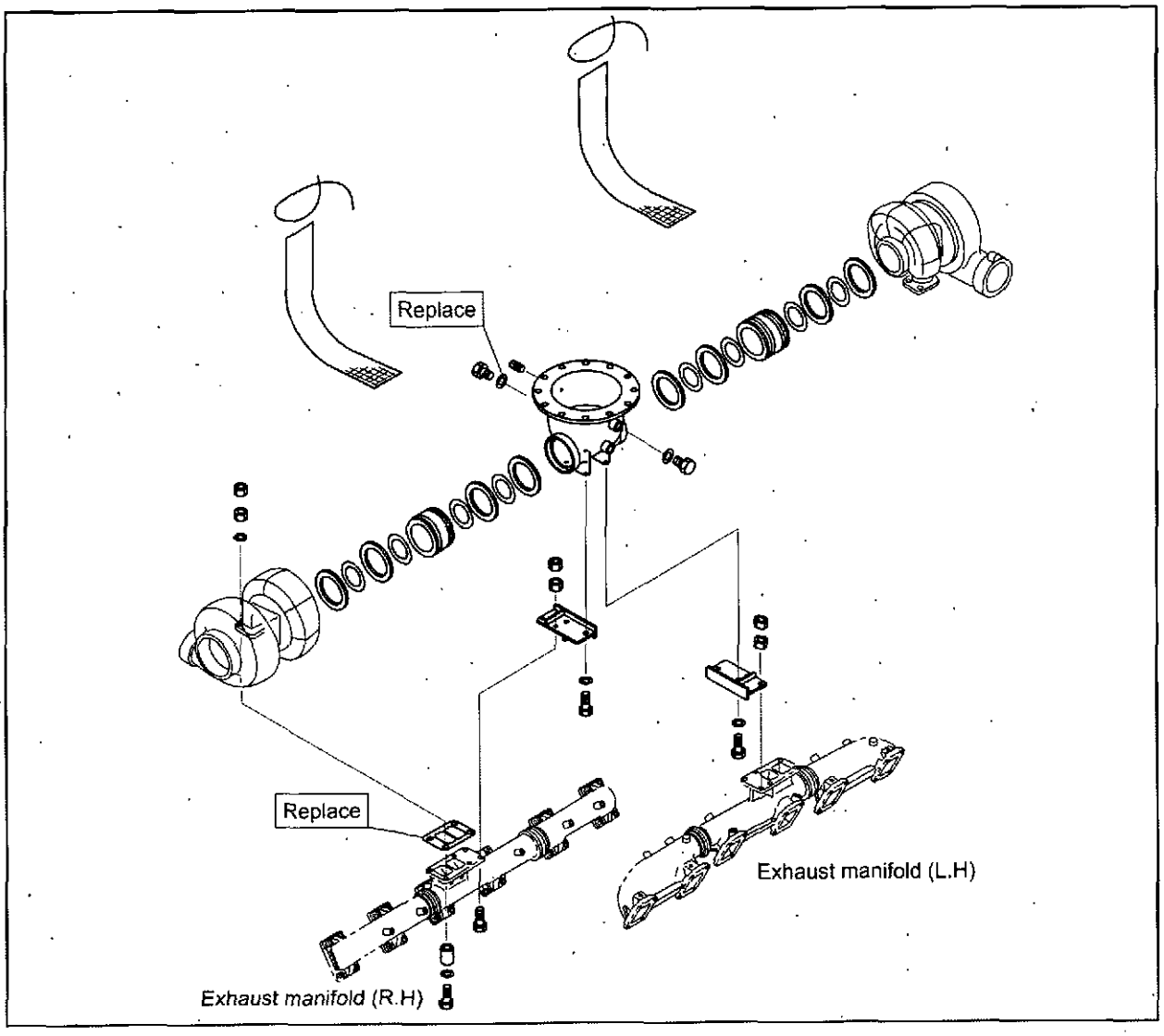
(a) Position the gasket so that the folded section faces the manifold, as shown in the illustration on the right.

(b) When installing the gasket, replace all other gaskets with new parts.




Installing exhaust manifold gasket

### 3.2 Installing turbocharger and exhaust pipe

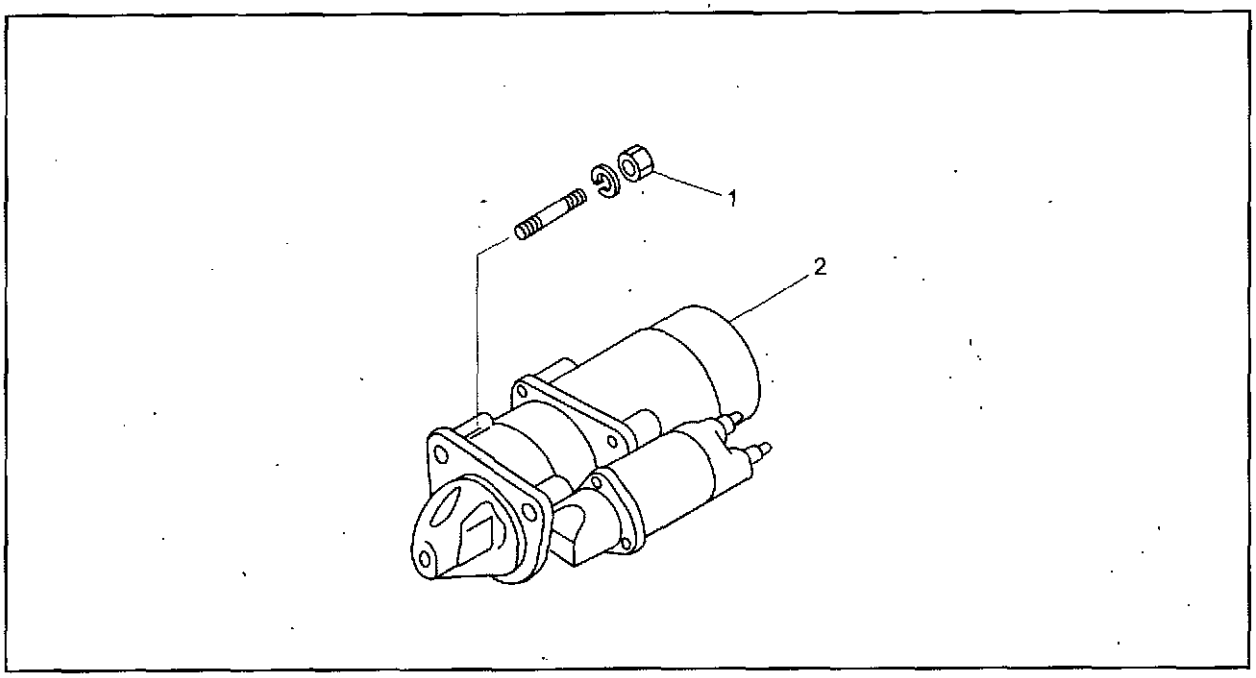



Installing turbocharger and exhaust pipe

# ELECTRICAL SYSTEM

# 1. Removing and inspecting electrical system

## 1.1 Removing starter

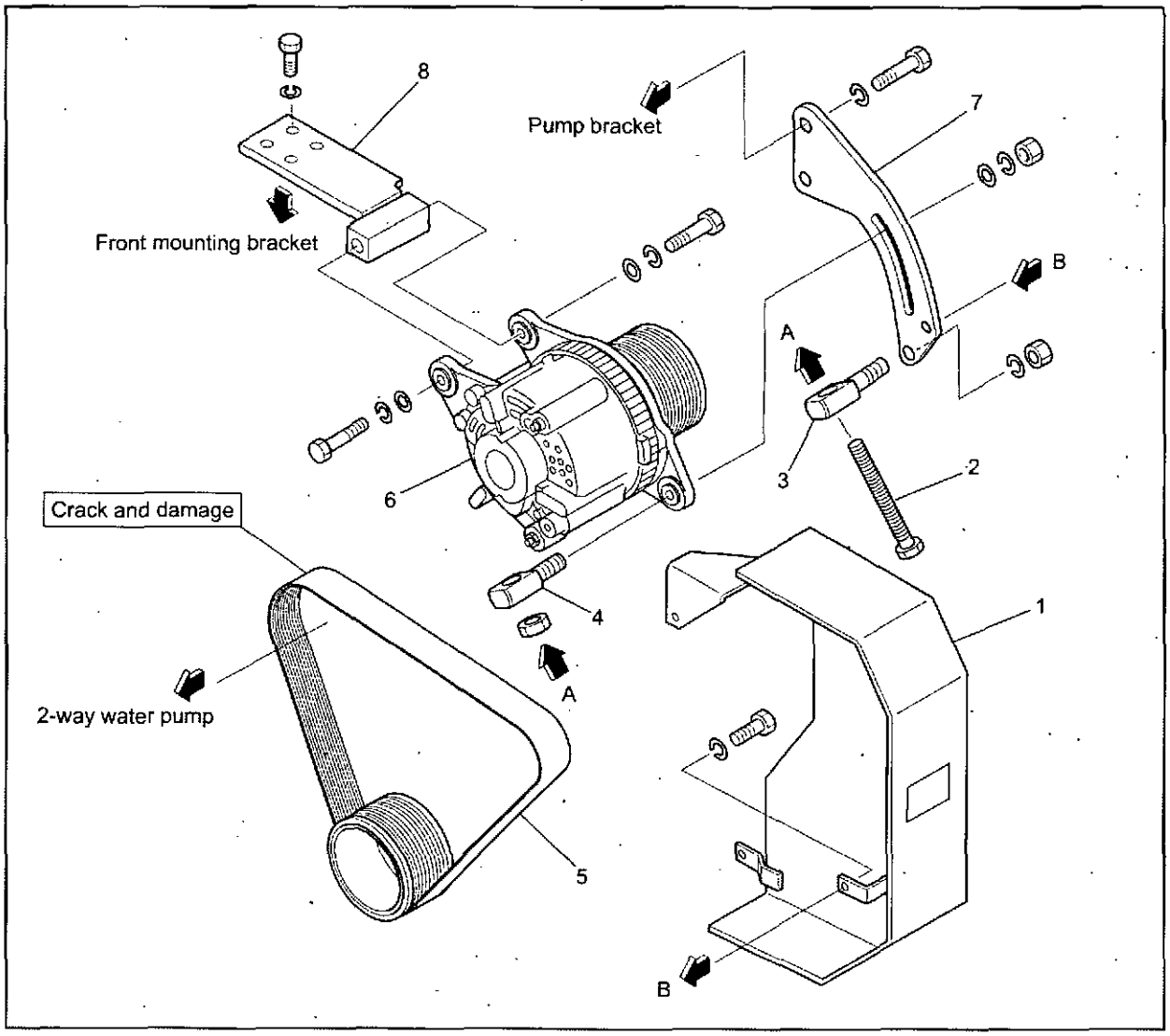



Removing starter

Removing sequence

1 Nut
2 Starter

## 1.2 Removing and inspecting alternator



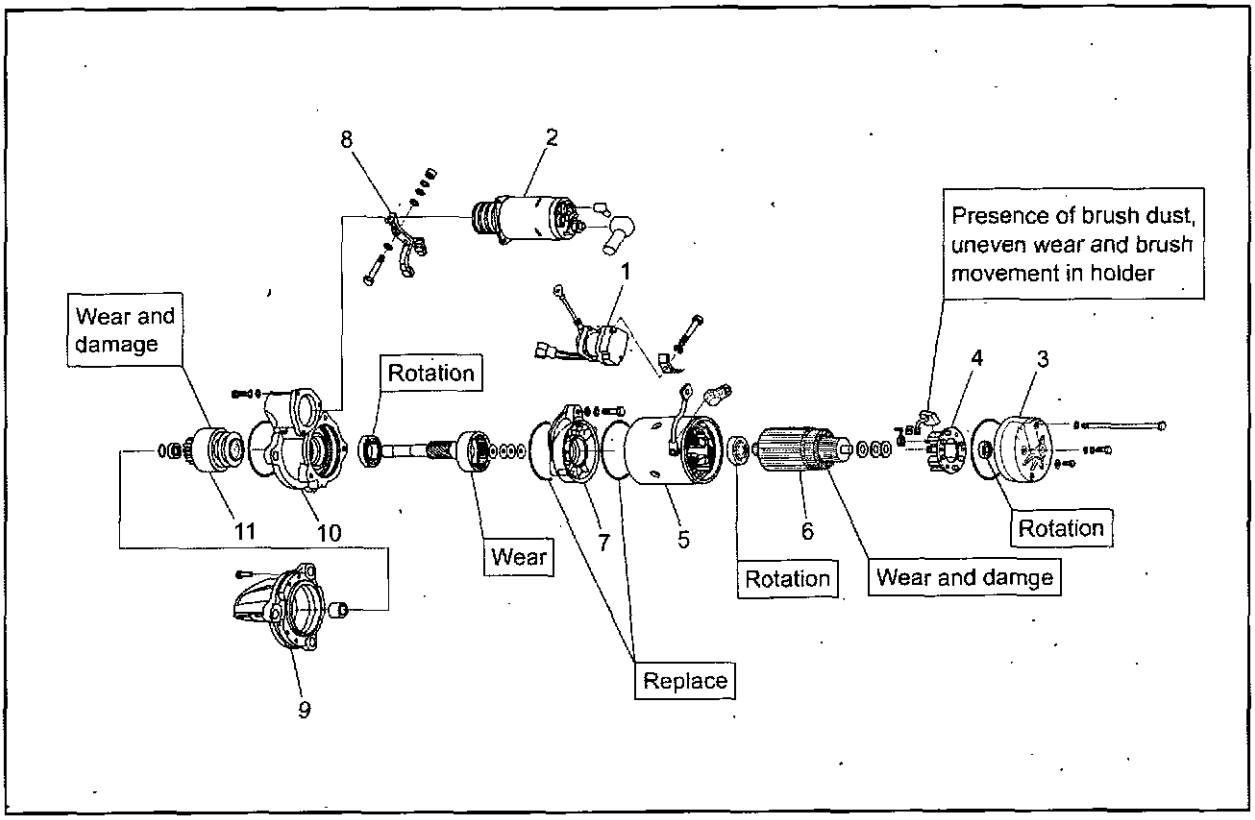

Removing and inspecting alternator

Removing sequence

1 Belt cover
2 Tension bolt
3 Tension boss
4 Tension boss
5 Alternator belt
6 Alternator
7 Adjusting plate
8 Alternator bracket

## 2. Disassembling and inspecting electrical system

### 2.1 *Disassembling and inspecting starter*




Disassembling and inspecting starter

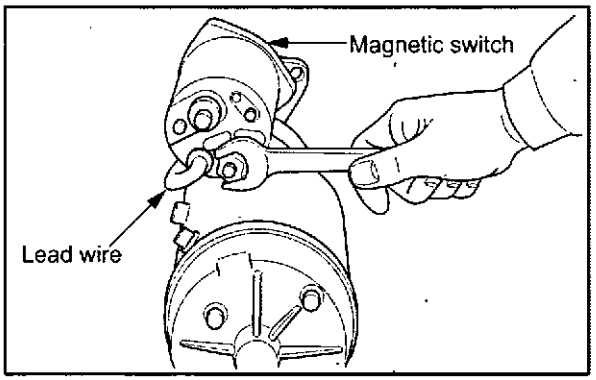
Disassembling sequence

1 Safety switch
2 Magnetic switch assembly
3 Rear bracket
4 Brush holder assembly
5 Yoke assembly
6 Armature assembly
7 Center bracket
8 Lever assembly
9 Front bracket
10 Pinion case
11 Pinion clutch assembly

### 2.1.1 Removing safety switch and magnetic switch

(1) Remove the safety switch.

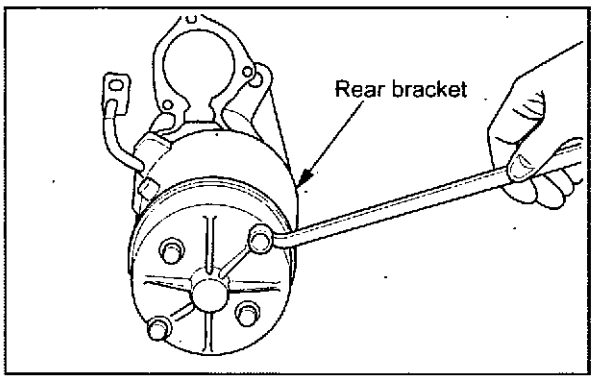
(2) Disconnect the lead wire, then dismount the magnetic switch.




Removing magnetic switch

### 2.1.2 Removing rear bracket

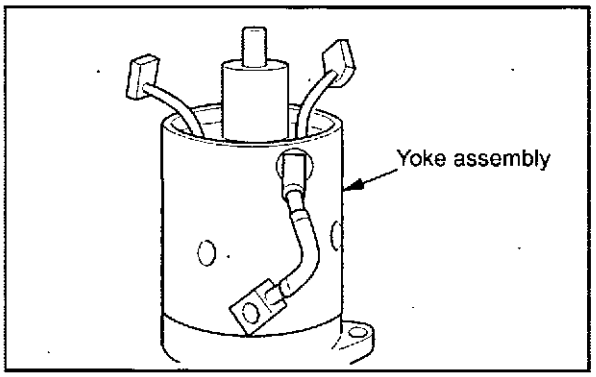
Remove the through bolts and screws of the brush holder, and then remove the rear bracket.




Removing rear bracket

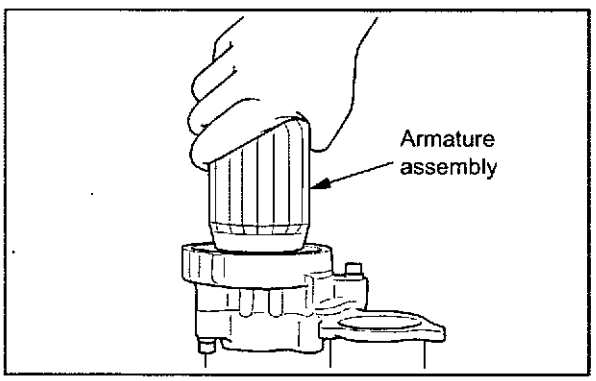
### 2.1.3 Removing armature and yoke assembly

(1) Remove the brushes from the brush holder assembly, then remove the yoke.




Removing yoke assembly

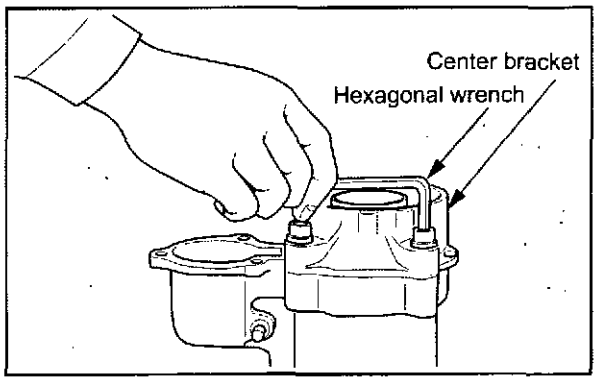
(2) Pull out the armature assembly.




Removing armature assembly

### 2.1.4 Removing center bracket

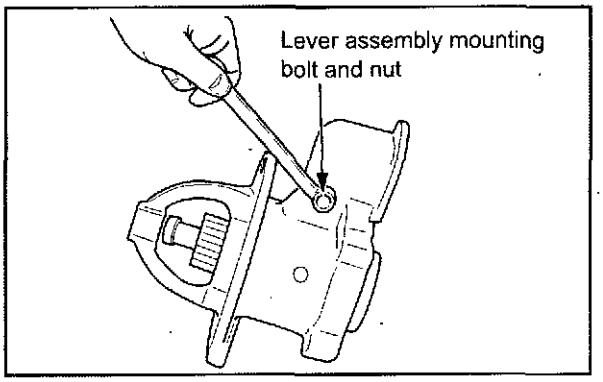
Remove the center bracket using a hexagonal wrench.




Removing center bracket

### 2.1.5 Removing pinion set

(1) Remove the lever pin, inner housing and shift lever from the pinion case.

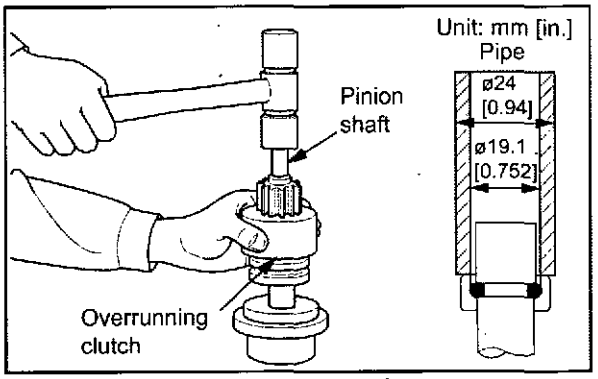



Removing lever assembly

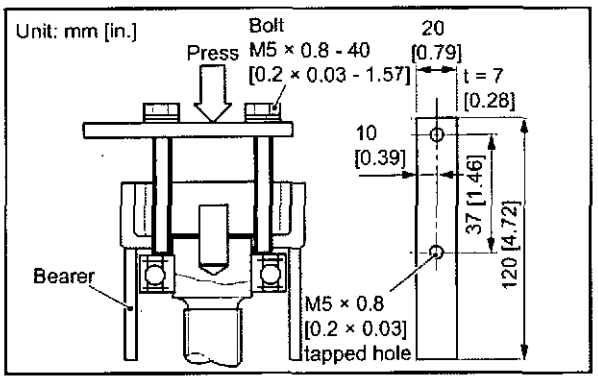
(2) Using a jig, remove the pinion stopper, then remove the overrunning clutch from the pinion shaft. Measure the outside diameter of the pinion shaft where the bearing is fitted. If the measured value is out of the standard range, replace the pinion shaft with a new one.

| | Item | Nominal | Standard | Remarks |
|---|---|---|---|---|
| Pinion shaft | Shaft diameter on rear side | ø 30 mm [1.18 in.] | 30.002 to 30.011mm [1.1812 to 1.1820 in.] | Replace pinion shaft. |
| | Clearance between shaft diameter and metal inside metal on front side | ø 19 mm [0.75 in.] | 0.045 to 0.138 mm [0.002 to 0.005 in.] | Replace pinion shaft. |

Note: To remove the shaft bearing for replacement, use a bearing puller as shown in the illustration.




Removing overrunning clutch

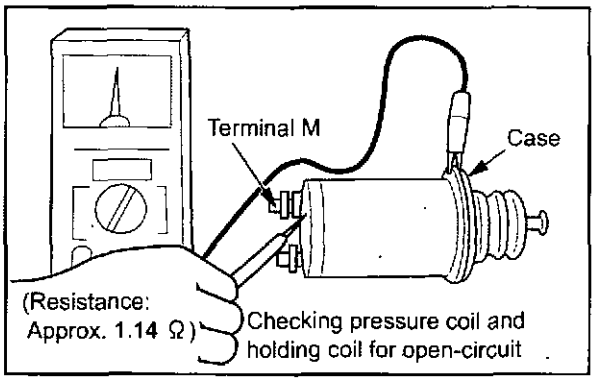



Pinion shaft bearing puller

## 2.2 Inspecting starter

### 2.2.1 Inspecting continuity of magnetic switch (between M terminal and case)

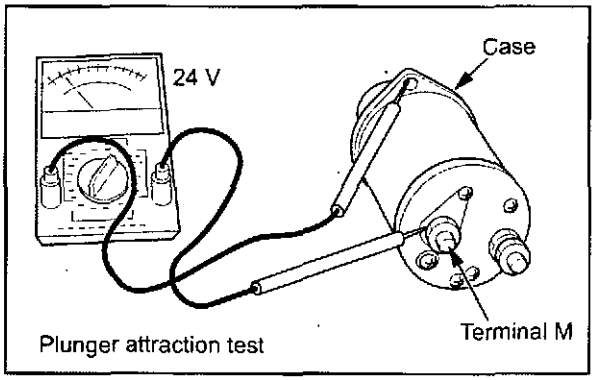
Check that there is continuity between M terminal and case. If no continuity is observed, replace the magnetic switch with a new one.




Testing magnetic switch coil

### 2.2.2 Inspecting magnetic switch function

Apply a voltage between M terminal and the case of magnetic switch. Using the other hand, push the plunger in, then release the plunger. The magnetic switch is normal if the plunger is not be attracted when the plunger is released.




Testing magnetic switch plunger

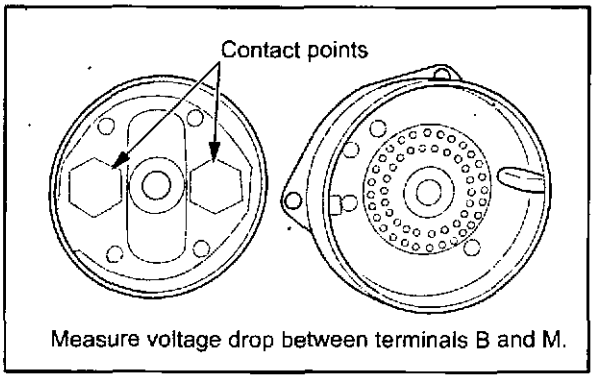
### 2.2.3 Inspecting magnetic switch contact point

**CAUTION**

Never conduct an operation test with a dismounted magnetic switch unit..

Measure the load current flowing through the starter. If the voltage drop between terminals B and M exceeds service limit, grind or replace the contact points.

Note: If the starter switch is turned to OFF during voltage measurement, the battery voltage is directly applied to the voltmeter, and damages the voltmeter. Always turn the starter switch to ON before measuring the voltage, then turn it to OFF after measuring.



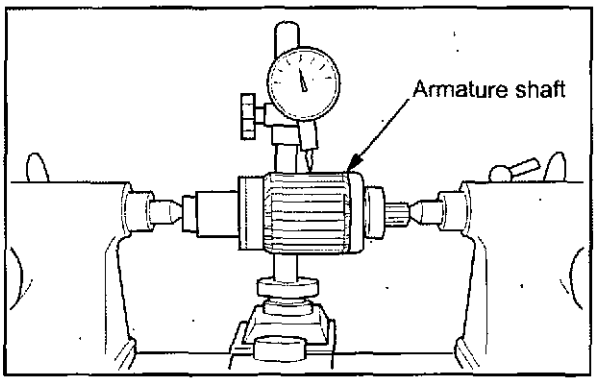

Testing magnetic switch contact point

| Item | Limit |
|---|---|
| Voltage drop between terminals B and M (per 100 A) | 0.3 V |

### 2.2.4 Measuring armature shaft runout

Using a dial gauge, measure the shaft runout. If the runout exceeds the standard, repair or replace the armature.

| Item | Standard |
|---|---|
| Armature runout | 0.10 mm [0.0039 in.] |



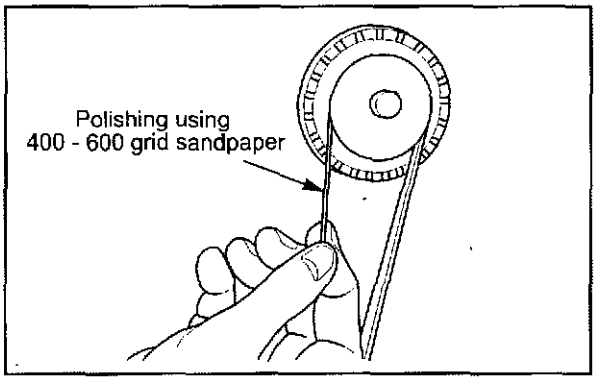

Measuring armature shaft runout

### 2.2.5 Measuring commutator radial runout

(1) Inspect the commutator surface. If the surface is rough, polish it using a 400 to 600 grit sandpaper.

(2) Measure the commutator radial runout with a dial gauge. If the measured value exceeds the limit, replace the armature with a new one.

| Item | Standard | Limit |
|---|---|---|
| Commutator runout | 0.06 mm [0.0024 in.] or less | 0.10 mm [0.0039 in.] |



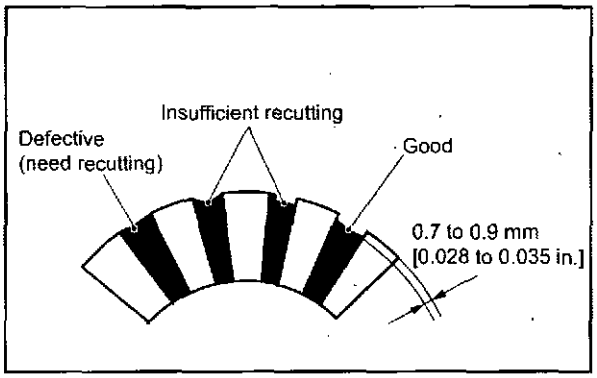

Polishing commutator surface

### 2.2.6 Measuring undercut depth

Measure the depth of undercutting between the commutator segments.

If the measured value is less than the limit, repair or replace with a new part.

| Item | Standard | Limit |
|---|---|---|
| Undercutting depth | 0.7 to 0.9 mm [0.028 to 0.035 in.] | 0.2 mm [0.008 in.] |



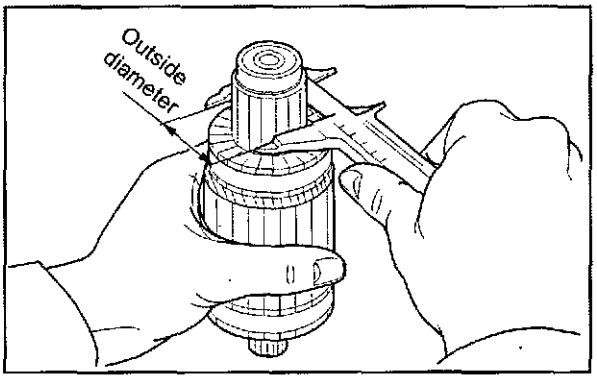

Measuring commutator undercut depth

### 2.2.7 Measuring commutator outside diameter

Measure the commutator outside diameter.

If the measured value is less than the limit, replace the armature with a new one.

| Item | Nominal | Limit |
|---|---|---|
| Commutator outside diameter | ø 43 mm [1.69 in.] | ø 42 mm [1.65 in.] |



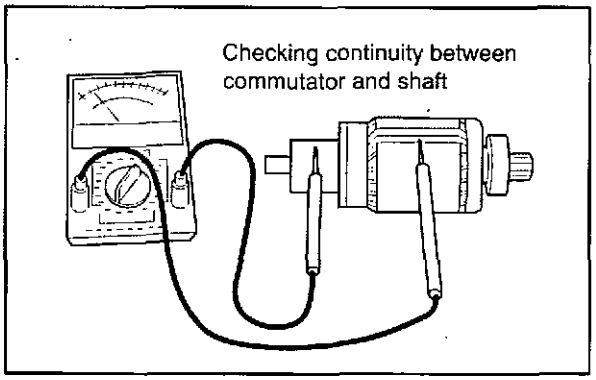

Measuring commutator outside diameter

### 2.2.8 Testing armature coil

(1) Inspect the armature coil using a growler.
Hold a piece of iron plate against the armature core. If the iron plate vibrates, replace the armature with a new one.

(2) Check that there is continuity between segments in various combinations.
If poor or no continuity is observed, replace the armature with a new one.

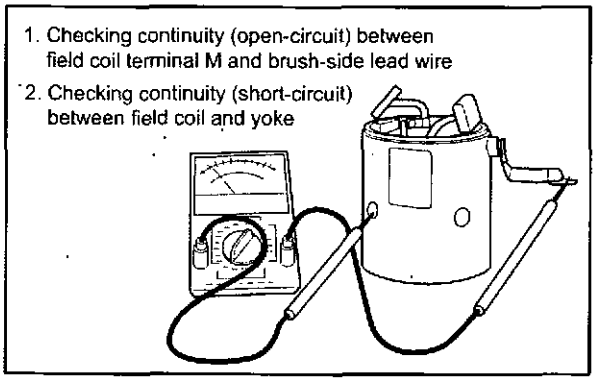
(3) Check that there is no continuity between the commutator and the shaft (core).
If any continuity is observed, replace the armature with a new one.




Testing armature coil

### 2.2.9 Inspecting continuity of yoke assembly

Check that there is continuity between M terminal of field coil and the lead wire for the brush. If no continuity is observed, replace the yoke assembly with a new one.



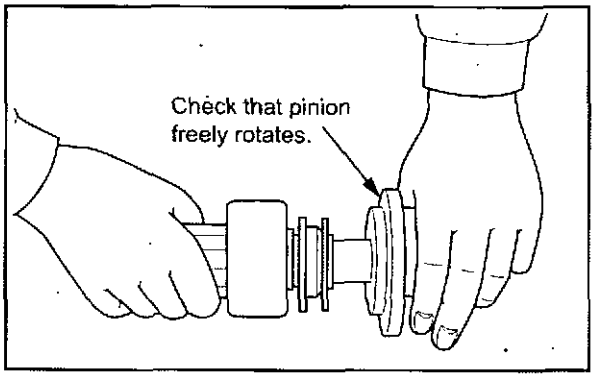

Testing field coil for open circuit

### 2.2.10 Inspecting overrunning clutch

**CAUTION**

Do not clean the overrunning clutch in wash oil.

Make sure that, when attempting to turn the overrunning clutch, it locks in one direction and rotates smoothly in the opposite direction.

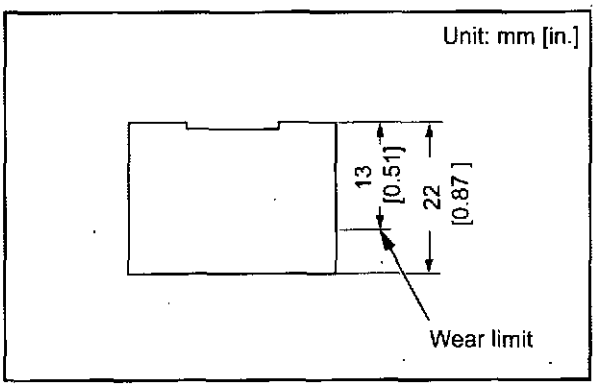



Inspecting overrunning clutch

### 2.2.11 Inspecting brushes for wear

Measure the length of the brushes. If the measured value is less than the limit, replace both the brush holder assembly and the brush assembly with new ones.

| Item | Standard | Limit |
|---|---|---|
| Brush height | 22 mm [0.87 in.] | 13 mm [0.51 in.] |




Inspecting brushes for wear

### 2.2.12 Measuring brush spring load

Using a new brush, measure the spring load at which the spring lifts from the brush. If the measured value is less than the limit, replace the spring with a new one.

| Item | Standard | Limit |
|---|---|---|
| Spring load (when brush is installed) | 39.23 to 49.03 N {4.0 to 5.0 kgf} [8.8 to 11.0 lbf] | Less than 39.23 N {4.0 kgf} [8.8 lbf] |

### 2.2.13 Inspecting safety switch

**CAUTION**

When connecting the battery, be sure to connect the battery in correct polarity.

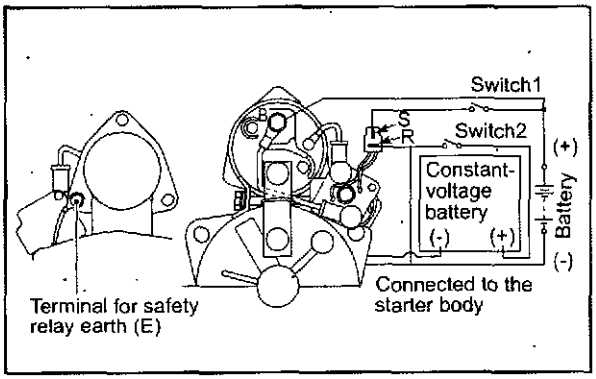
Connect the components as shown and check the operation of starter and safety switch.

(1) Connect the terminal R to the battery negative terminal.

(2) Turn on the switch and check if the starter operates (rotates).

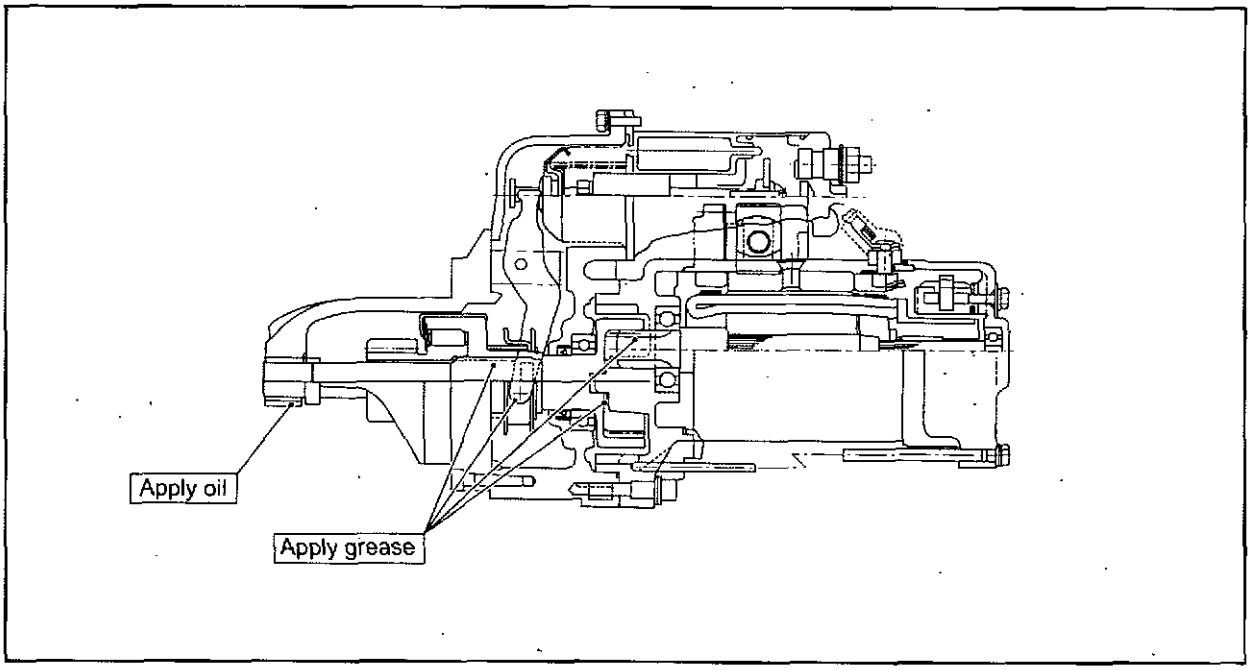
(3) While operating the starter, disconnect the terminal R from the battery negative terminal and connect the terminal R to the battery positive terminal. Check if the starter stops.

Note: On some specifications, starter stops operation when the connection to the battery negative terminal is disconnected.




Inspecting safety switch

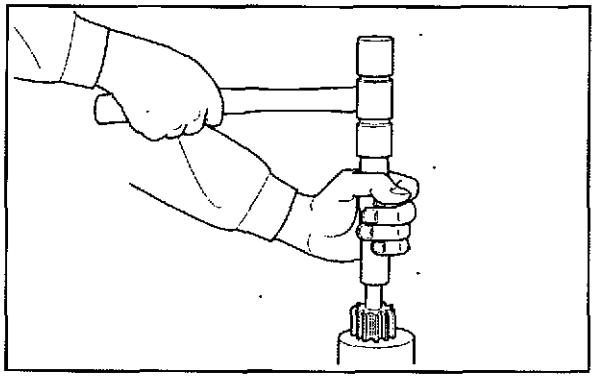
## 2.3 Reassembling starter




Reassembling starter

### 2.3.1 Installing pinion shaft

Install the center bracket, overrunning clutch and pinion stopper to the pinion shaft, and insert the shaft into position by tapping it with a soft-head mallet.

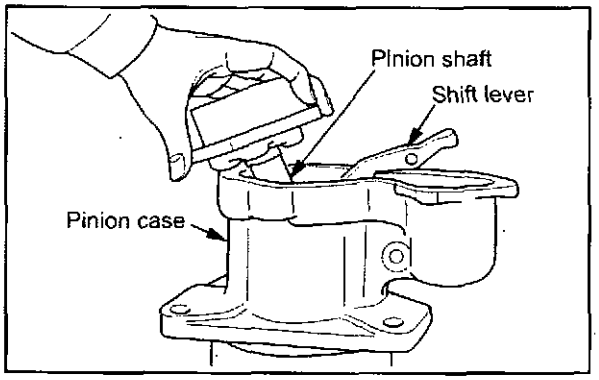


Installing pinion shaft

### 2.3.2 Installing lever and pinion shaft

(1) Install the shift lever and pinion shaft to the front bracket while aligning the mark on the shift lever with the mark on the bracket.

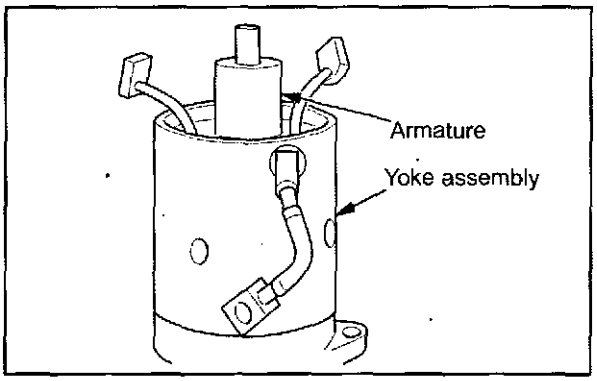
(2) Coat the internal gear of the pinion shaft with a liberal amount of Nikko Grease R.




Installing shift lever and pinion shaft

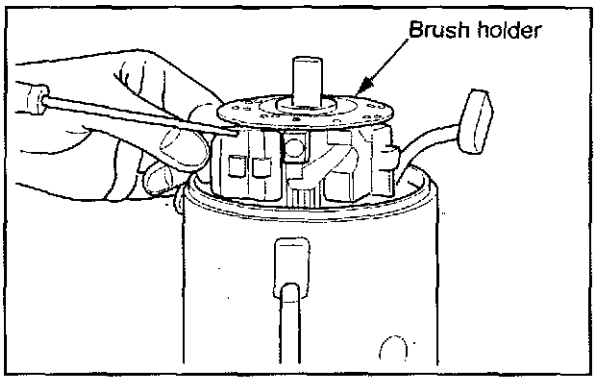
### 2.3.3 Installing armature, yoke, brush holder and brush

(1) Align the knock pin with the center bracket and reassemble the armature to the yoke.

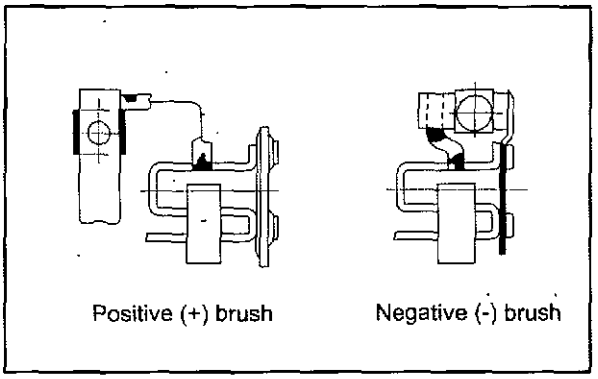



*Installing armature and yoke*

(2) Reassemble the brush holder and brushes.



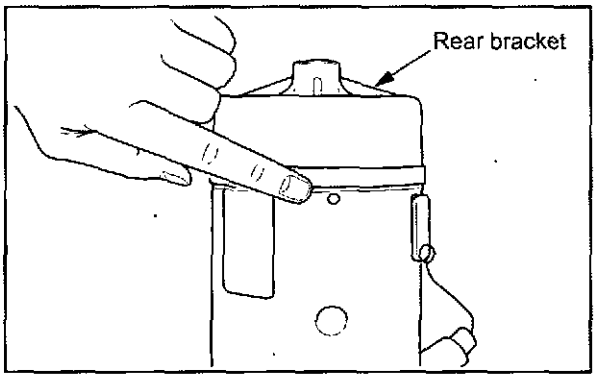

Installing brush holder and brush




Installing positive (+) and negative (-) brush

### 2.3.4 *Installing rear bracket*

Install the rear bracket to the yoke by aligning the alignment marks, secure the brush holder with the bolts, then tighten the through bolts.

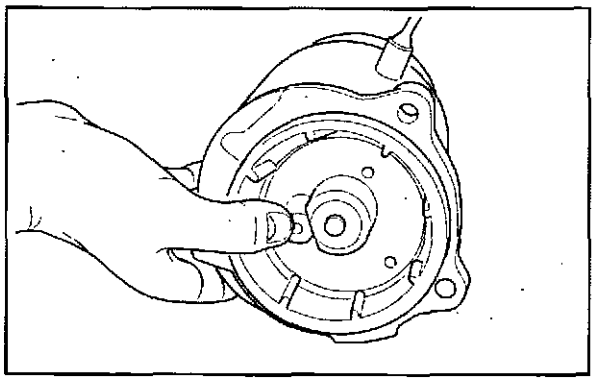



Installing rear bracket

### 2.3.5 Measuring armature end play

Measure the armature end play. If the measured value is out of tolerance, adjust the end play at the rear.

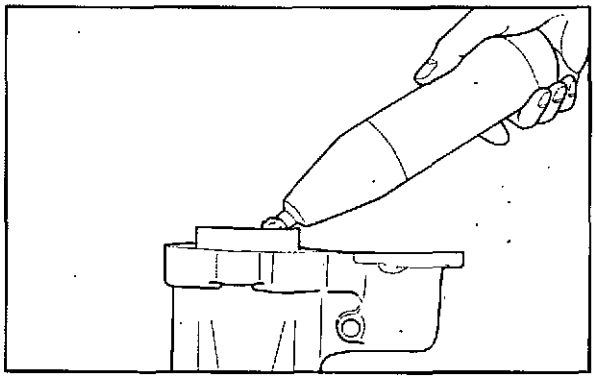
| Item | Standard |
|---|---|
| Armature end play | 0.2 to 0.6 mm [0.008 to 0.024 in.] |



Measuring armature end play

### 2.3.6 Installing pinion shaft

Coat the internal gear of the pinion shaft with a liberal amount of Nikko Grease R, and assemble the pinion shaft into position.

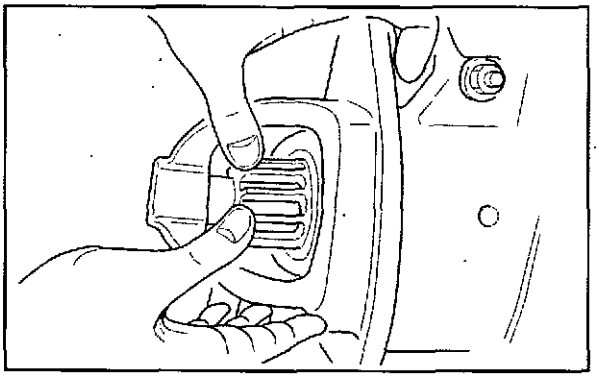


Installing pinion shaft

### 2.3.7 Measuring pinion shaft end play

Measure the pinion shaft end play. If the measurement is out of tolerance, adjust the end play at the internal gear side.

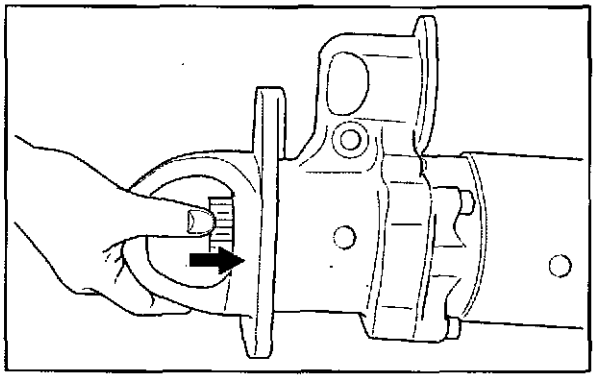
| Item | Standard |
|---|---|
| Pinion shaft end play | 0.2 to 0.6 mm [0.008 to 0.024 in.] |



Measuring pinion shaft end play

### 2.3.8 Measuring pinion gear retraction length

Apply a voltage of 24 V between terminals C and E. Connect the lead wire and supply a current between terminals M and E (for less than 1 second). After the pinion is moved, push the pinion gear and measure the pinion gear retraction length. If the measured value is not within the standard range, adjust the length using the adjust screw of the magnetic switch.

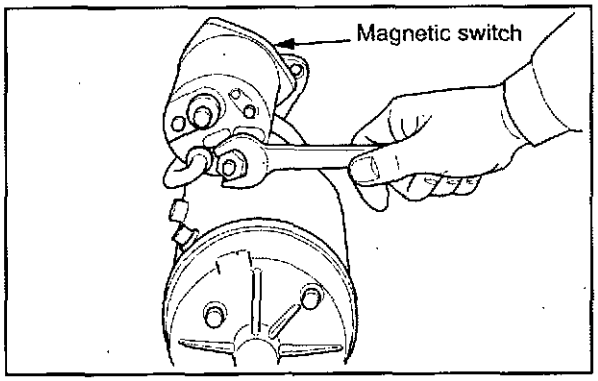


Measuring pinion gear retraction length

### 2.3.9 Installing magnetic switch

(1) Install the magnetic switch and tighten the screws.

(2) Connect the lead to the terminal M and secure it with the fixing nut.



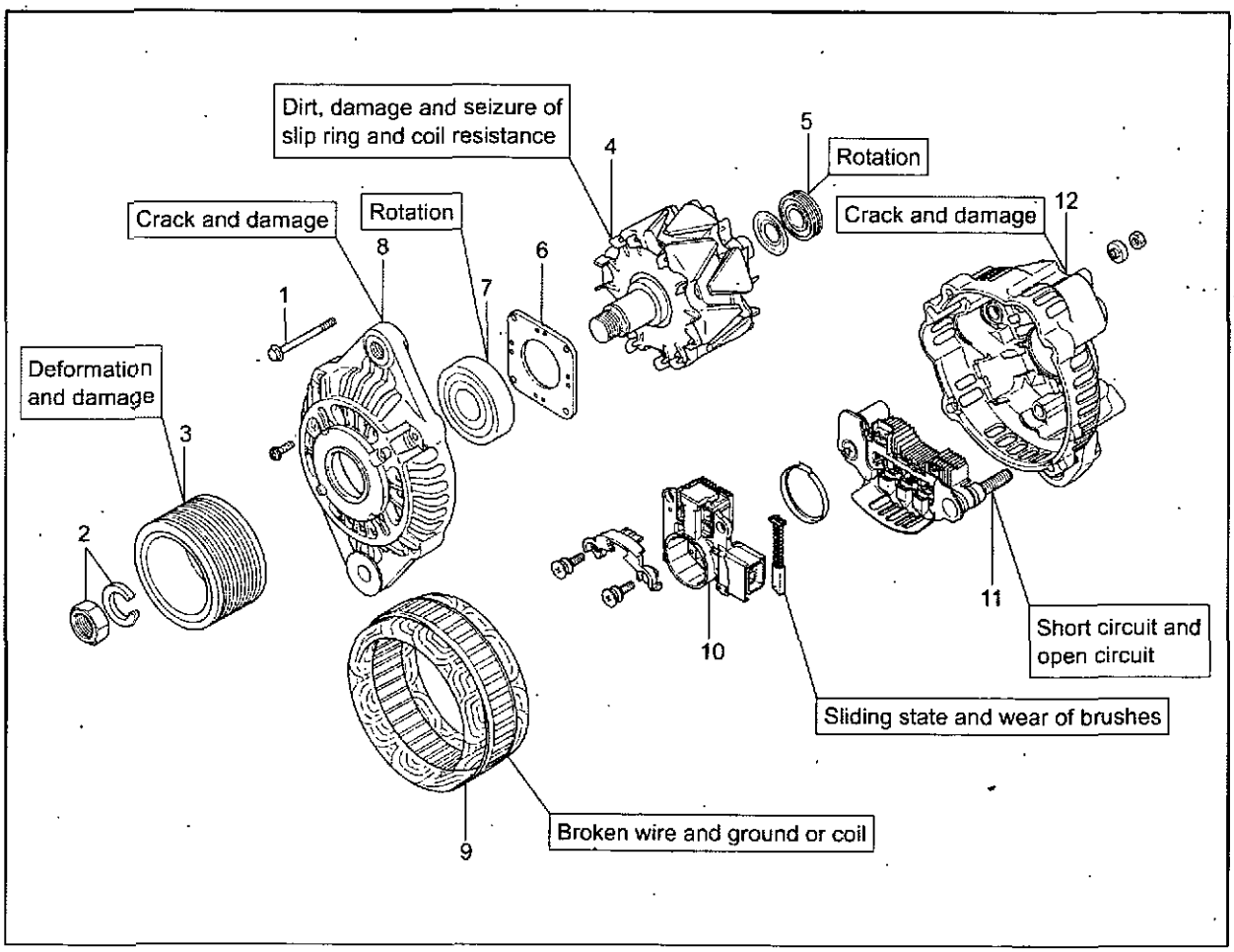

*Installing magnetic switch*

### 2.3.10 Installing safety switch

(1) Tighten the lead wire.

(2) Install the safety switch.

## 2.4 Disassembling and inspecting alternator




Disassembling and inspecting alternator

Disassembling sequence

1 Through bolt
2 Nut
3 Pulley, spacer
4 Rotor
5 Rear bearing
6 Bearing retainer
7 Front bearing
8 Front bracket
9 Stator
10 Regulator assembly
11 Rectifier assembly
12 Rear bracket

### 2.4.1 Separating front bracket from stator

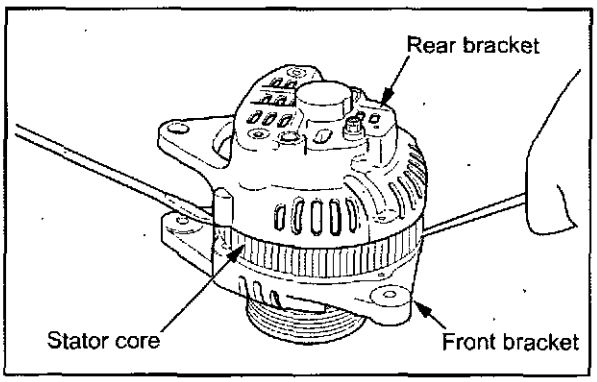
**CAUTION**

Do not disassemble the alternator unless the repair is necessary.

Do not insert the screwdrivers too deep, as it can damage the stator.

(1) Remove the through bolts.

(2) With two flat-head screwdrivers inserted between the front bracket and stator, pry them apart.




Separating front bracket from stator

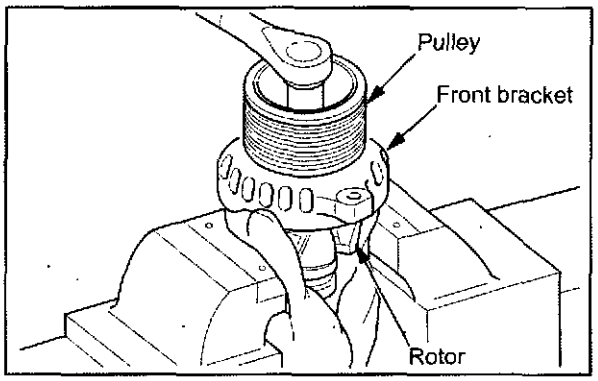
### 2.4.2 Removing pulley

**CAUTION**

When setting the rotor in a vise, be sure to hold the base of the rotor claw. Do not hold the rotor claw, as it causes damage to the claw.

(1) Apply a cloth to the rotor and set it in a vise.

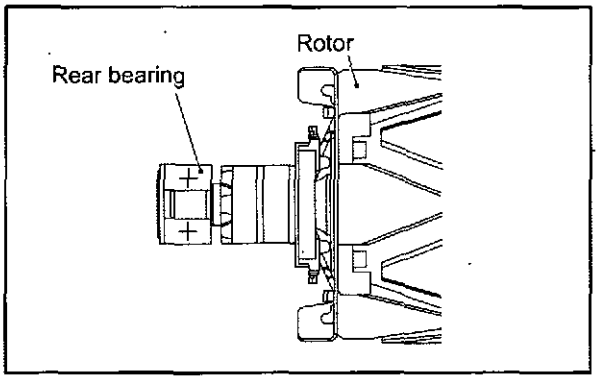
(2) Remove the pulley nut and then pull out the pulley.




Removing pulley

### 2.4.3 Removing rear bearing

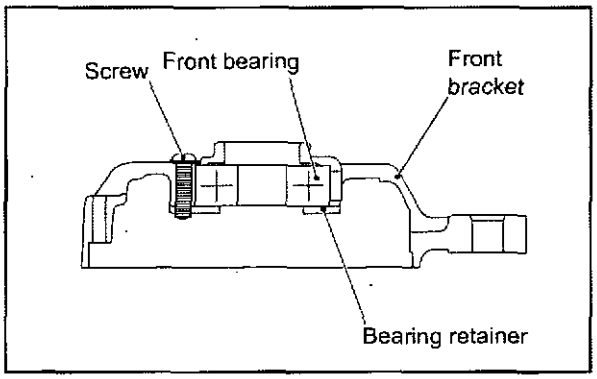
Remove the rear bearing from the rotor using a bearing puller.




Removing rear bearing

### 2.4.4 Removing front bearing

Remove the screw, and then remove the bearing retainer and front bearing from the front bracket.



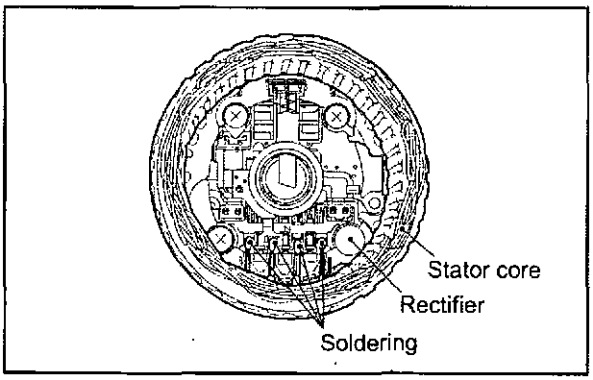

Removing front bearing

### 2.4.5 Removing stator

**CAUTION**

Unsoldering must be finished as quickly as possible. Extended heating will damage the diodes.

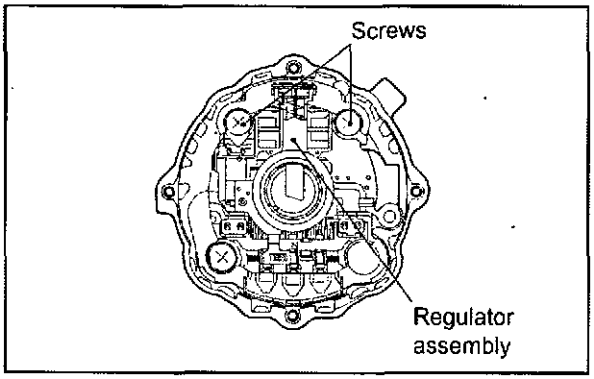
Cut off the joint of the stator and remove the stator from the rectifier.




Removing stator

### 2.4.6 Removing regulator assembly

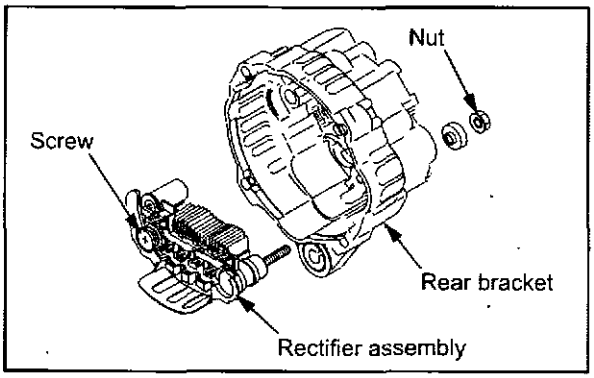
Remove the screws of the regulator assembly and then remove the regulator assembly.




Removing regulator assembly

### 2.4.7 Removing rectifier assembly

(1) Remove the screw and nut from the rectifier.
(2) Remove the rectifier assembly.



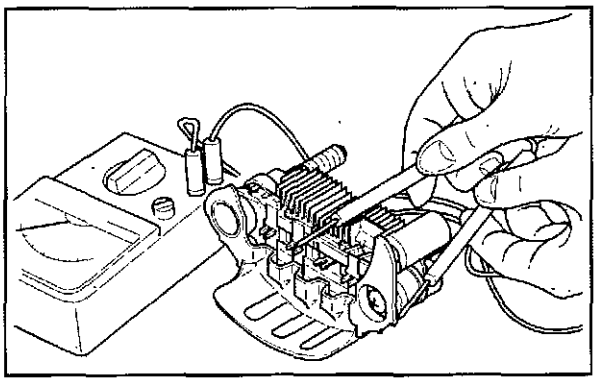

Removing rectifier assembly

## 2.5 Inspecting and repairing alternator

### 2.5.1 Inspecting rectifier

Check that diodes in a rectifier function properly. To check, measure both negative (-) and positive (+) resistance alternately twice. If both infinite negative and infinite positive resistances are observed, the diode is open-circuited. If measured value is close to 0 Ω, the diode is short-circuited. In either case, replace the rectifier with a new one.

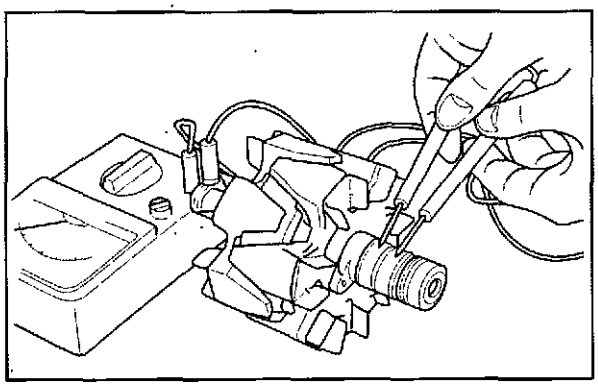
Note: Use a wide measuring range as much as possible. The current flow during test is significantly lower than the current that normally flows in the rectifier, by which the accurate resistance may not be measured using a tester, and this tendency is noticeable if the measuring range is small.



Inspecting rectifier

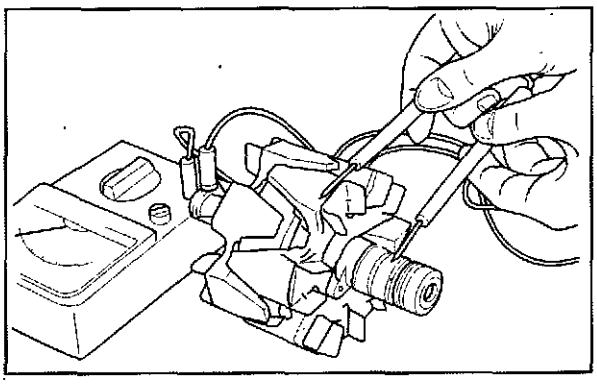
### 2.5.2 Inspecting armature

(1) Check that there is continuity between slip rings. If no continuity is observed, replace the armature with a new one.



Inspecting field coil for continuity

(2) Check that there is no continuity between the slip ring and the shaft (or the core). If continuity is observed, replace the armature with a new one.



Inspecting field coil for grounding

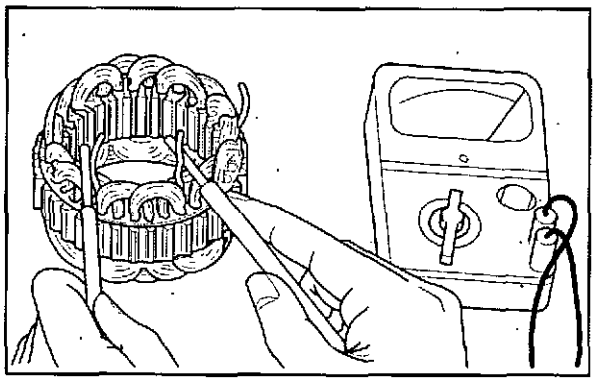
### 2.5.3 Inspecting stator

(1) Checking continuity between lead wires

Check that there is continuity between a pair of lead wires.

Also check that there is no continuity between a pair of lead wires and other pair of lead wires.

If defective, replace the stator.

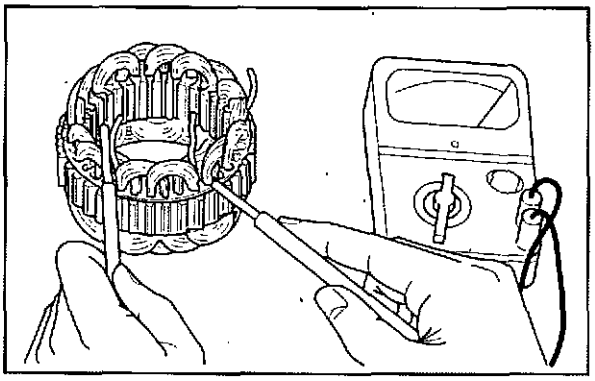


Checking continuity between lead

(2) Checking insulation between lead wire and core

Check that there is no continuity between each lead wire and the stator core. If continuity is observed, replace the stator.

Note: The core cannot be replaced as a single item.

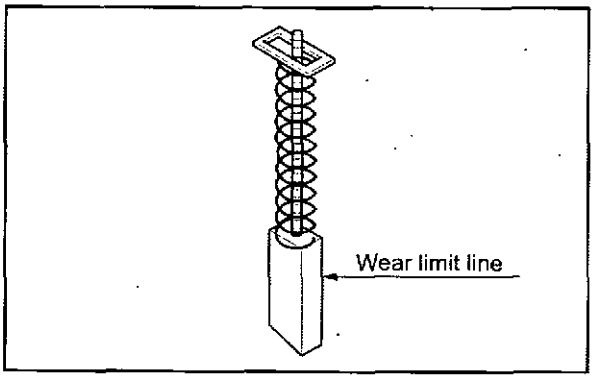


Checking grounding between the lead and the core

### 2.5.4 Inspecting brushes for wear

Measure the length of the brushes. If the measured value is less than the limit, replace both the brush holder assembly and the brush assembly with new ones.

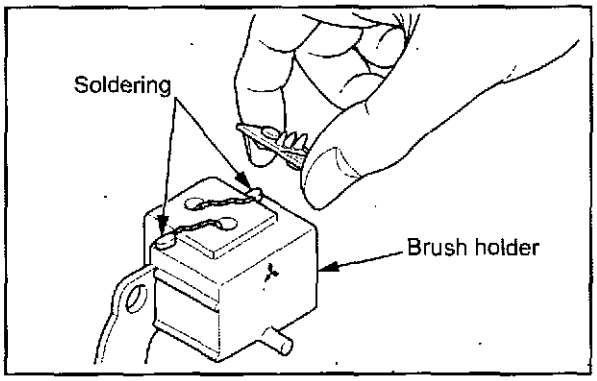
| Item | Nominal | Limit |
|---|---|---|
| Brush height | 21.5 mm [0.85 in.] | 8 mm [0.31 in.] |




Inspecting brushes

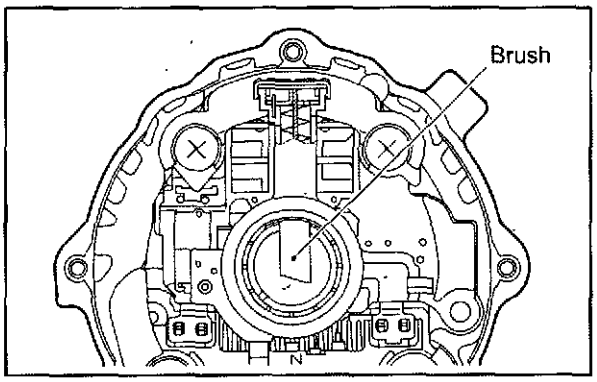
### 2.5.5 Replacing brushes

(1) To remove the brush and the spring, unsolder the brush lead.



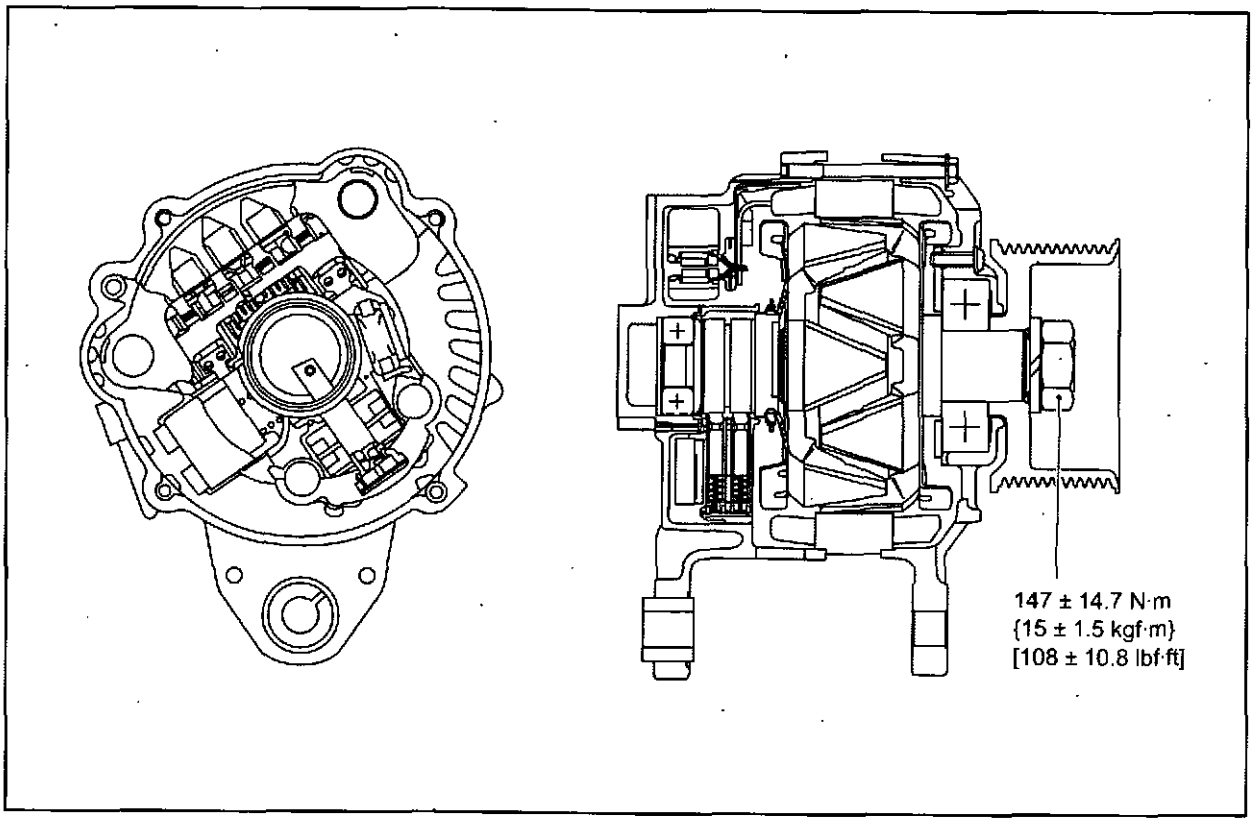

Replacing brushes

(2) To install a new brush, push the brush into the brush holder as shown in the illustration, and then solder the lead to the brush.




Installing brushes

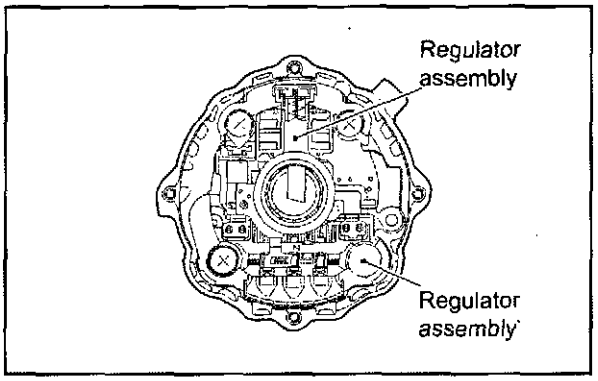
## 2.6 Reassembling alternator




Reassembling alternator

### 2.6.1 Installing rectifier assembly and regulator assembly

Install the rectifier assembly and regulator assembly on the rear bracket.



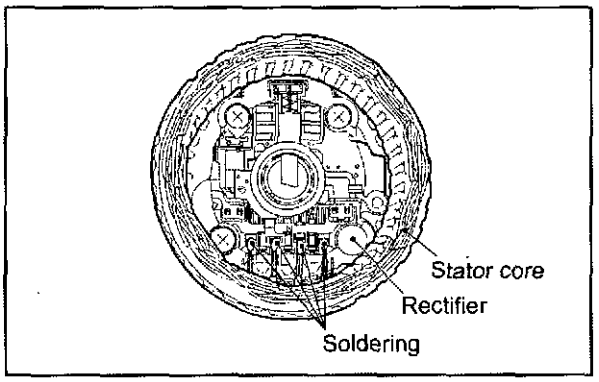

Installing rectifier assembly and regulator assembly

### 2.6.2 *Installing stator*

**CAUTION**

Soldering must be finished as quickly as possible.
Extended heating will damage the diodes.

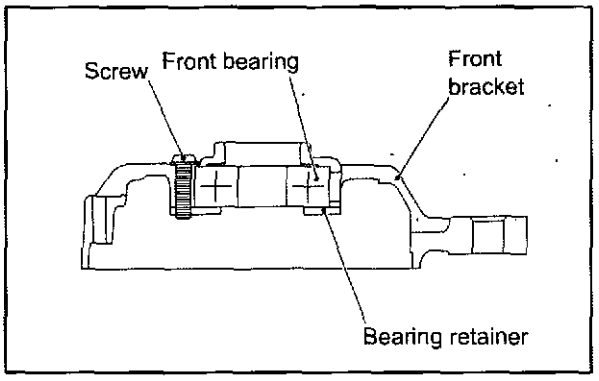
Install the stator and solder the leads of the stator to the rectifier.




Installing stator

### 2.6.3 Installing front bearing

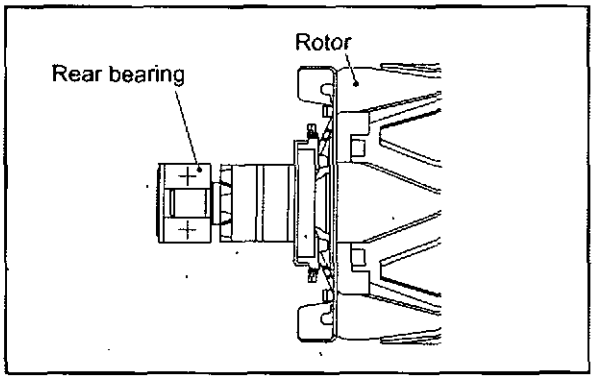
Drive the front bearing into the front bracket and secure the bearing retainer with a screw.




Installing front bearing

### 2.6.4 Installing rear bearing

Press-fit the rear bearing to the rotor.

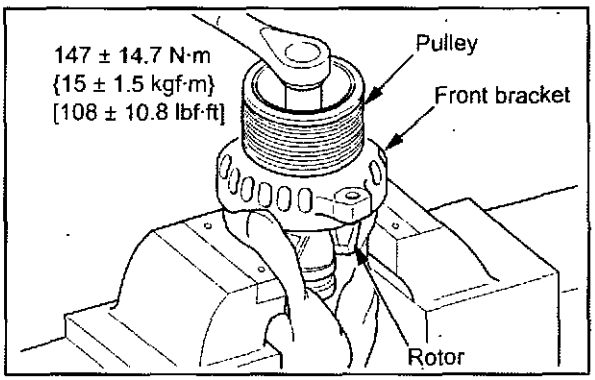



Installing rear bearing

### 2.6.5 Installing pulley

(1) Insert the rotor into the front bracket.
Apply a cloth to the rotor and set it in a vise.

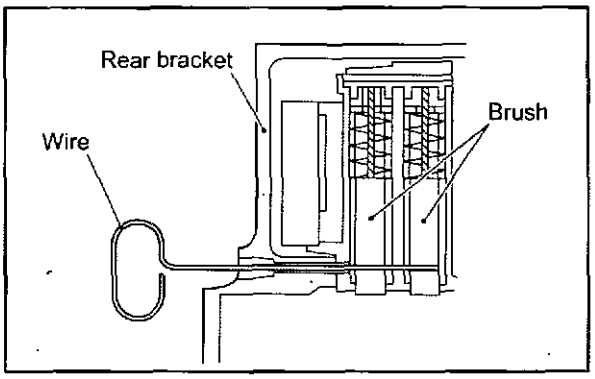
(2) Install the spacer and pulley, and secure the pulley with a nut.




Installing pulley

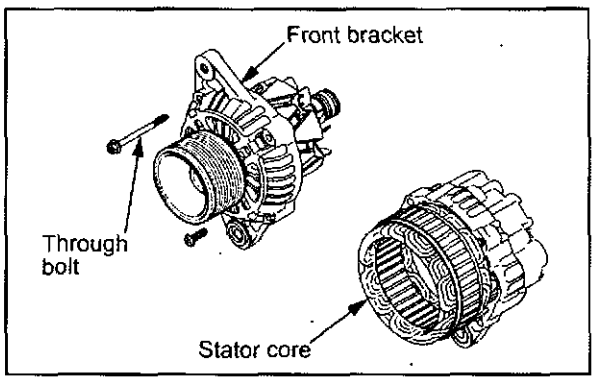
### 2.6.6 Assembling stator and front bracket

(1) When installing the rotor into the rear bracket, lift the brushes with a piece of wire inserted through the small hole in the bracket. After installation, remove the wire.




Securing brushes

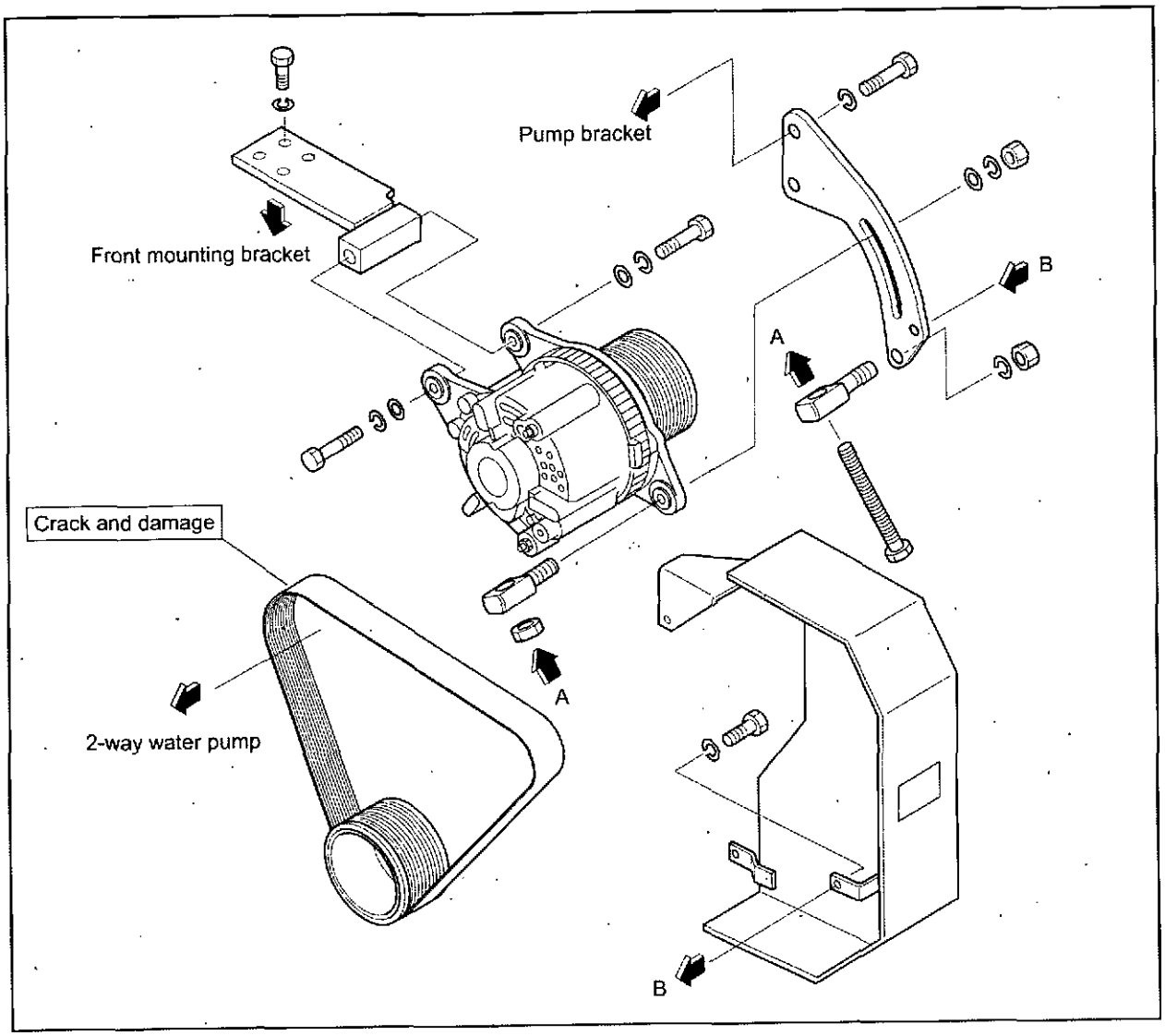
(2) Assemble the front bracket, stator and rear bracket and secure them with through bolts.




Joining stator and front bracket

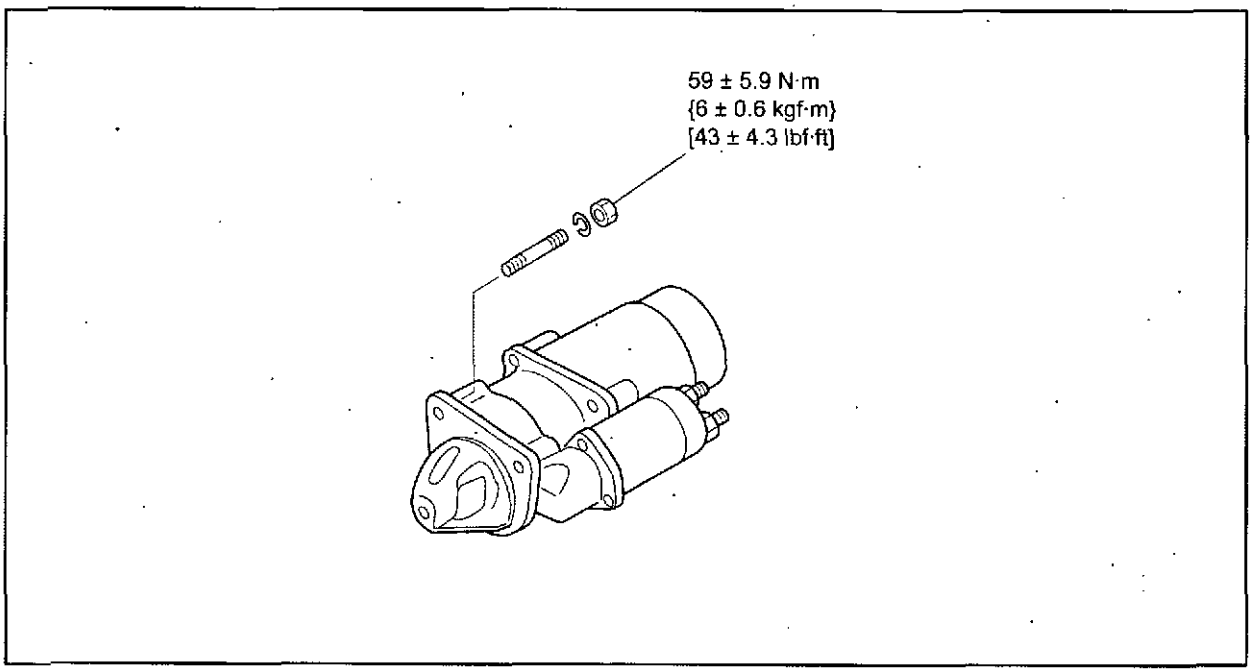
## 3. Installing electrical system

### 3.1 Installing alternator




Installing alternator

### 3.2 Installing starter




Installing starter

# ADJUSTMENT AND OPERATION

# 1. Adjusting engine

## 1.1 Inspecting and adjusting valve clearance

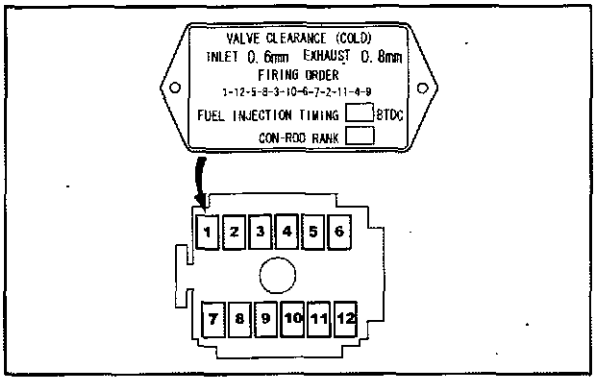
Inspect and adjust the valve clearance.

The valve clearance should be inspected and adjusted when the engine is cold.

Note: (a) The inlet values are on the left side and the exhaust values are on the right side when the cylinder head is viewed from the camshaft gear side.

(b) The valve clearance standard values are indicated on the caution plate on the No.1 cylinder rocker cover.

| Item | | Standard |
|---|---|---|
| Valve clearance | Inlet | 0.6 mm [0.024 in.] |
| | Exhaust | 0.8 mm [0.031 in.] |

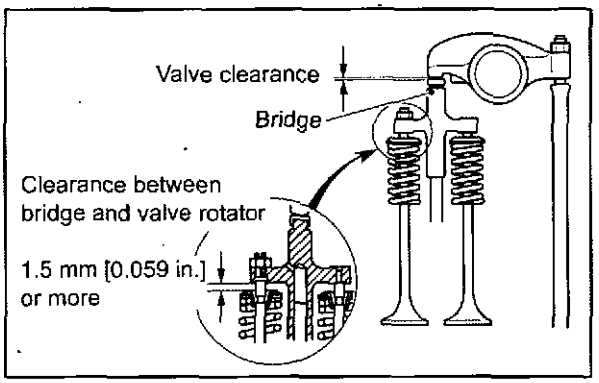



Valve clearance indication position

### 1.1.1 Inspecting clearance between bridge and valve rotator

The clearance between the bridge and the valve rotator should meet to the standard after attaining the standard height of both valves using the valve bridge.

If the clearance is not within the standard, attain the standard value by grinding the bridge bottom on the screw side.



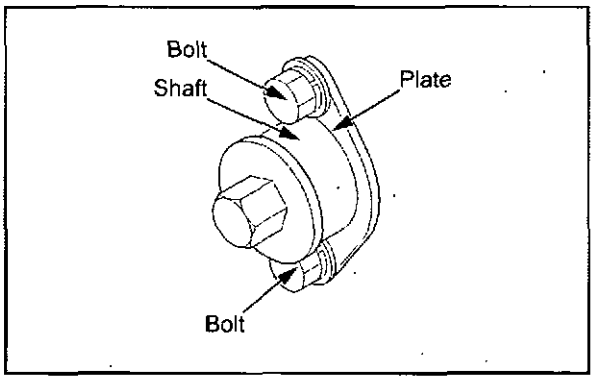

Inspecting clearance between bridge and valve rotator

### 1.1.2 Using turning gear

**⚠ WARNING**

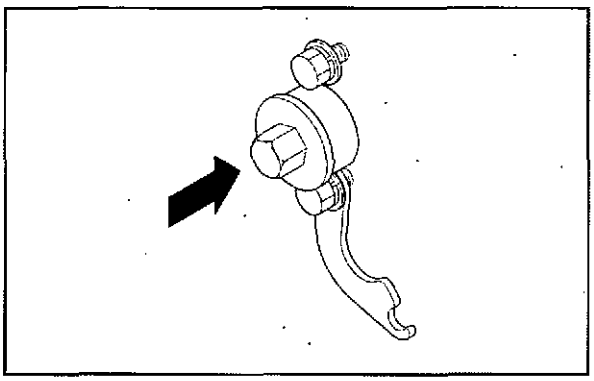
Make sure that the turning gear is at the original position when the engine is started. If the engine is started while the turning gear is depressed, it will cause not only damage the gear but could result in personal injuries.

(1) Loosen the bolts, and remove the plate from the slot of the shaft.




Using turning gear (during driving)

(2) Then push in the shaft until it engages with the ring gear.



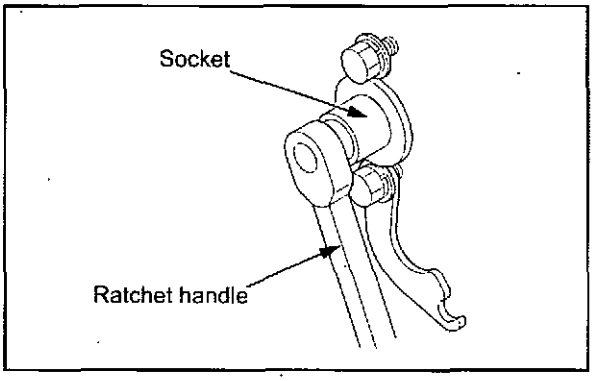
Using turning gear (when pushed)

(3) Using the socket and ratchet handle, turn the shaft. Pushing the ratchet down turns the shaft in the normal direction.

(4) After completing the turn, pull out the shaft, insert the plate into the slot of the shaft, then tighten the bolts.

**⚠ CAUTION**

Check to make sure the plate is inserted securely into the slot of the shaft.



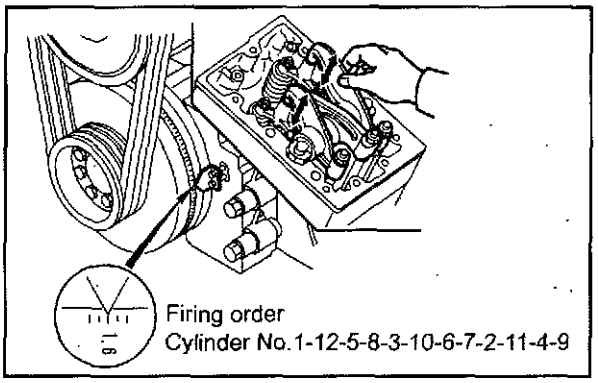

Using turning gear (when turning)

### 1.1.3 Inspecting valve clearance

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

(2) A piston is at the top dead center on compression stroke when its number that stamped on the vibration damper aligns with the pointer, and the push rods are not pushing the inlet or exhaust valves off their seats.

(3) Using feeler gauges, measure the clearance between each rocker arm and bridge cap.




Inspecting valve clearance

### 1.1.4 Adjusting both inlet and both exhaust valve heights by valve bridge

**CAUTION**

If there is no clearance between the bridge and valve rotator, the interference between them could cause the valve cotters to fall out. Be sure to provide the specified clearance.

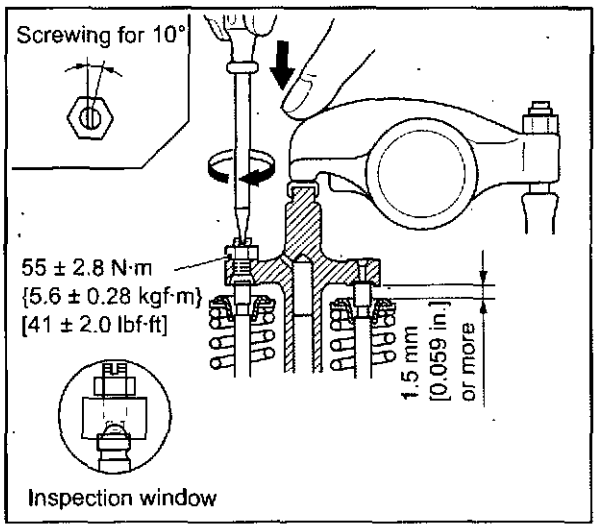
When adjusting the both inlet and both exhaust valve heights with the valve bridge, bring the piston at the top dead center on the compression stroke.

(1) Prior to the valve clearance adjustment, it is necessary to adjust the both inlet and both exhaust valve heights with the valve bridge (bringing the bridge into contact with the both inlet and both exhaust valves). If the both inlet and both exhaust valve heights are not the same, which can occur due to such conditions as valve seat wear, a clearance will be generated between the top of valve stem and the either side of bridge, resulting in the change of valve clearance.

Note: When adjusting both inlet and both exhaust valve heights using a valve bridge, be sure to bring each piston to the top dead center on the compression stroke.

(2) To adjust the valve height, loosen the rock nut and unscrew the adjusting screw.

(3) Hold the rocker arm with a finger, and slowly turn the adjusting screw until the screw contacts the top of valve stem. Then, turn the screw further, at angle of 10 degrees from the position, and tighten the rock nut.

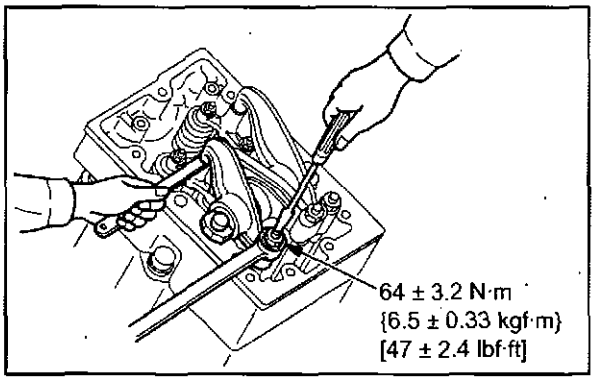



Adjusting valve height using valve bridge

### 1.1.5 Adjusting valve clearances

(1) Insert the feeler gauge of the specified thickness between the rocker arm and bridge cap, then adjust the clearance by turning the screw in either direction so that the gauge is gripped softly between the rocker arm and bridge cap.

(2) After adjusting the clearance, tighten the lock nut firmly, and inspect the clearance again.




Adjusting valve clearance

### 1.2 Bleeding air from fuel system

**⚠ WARNING**

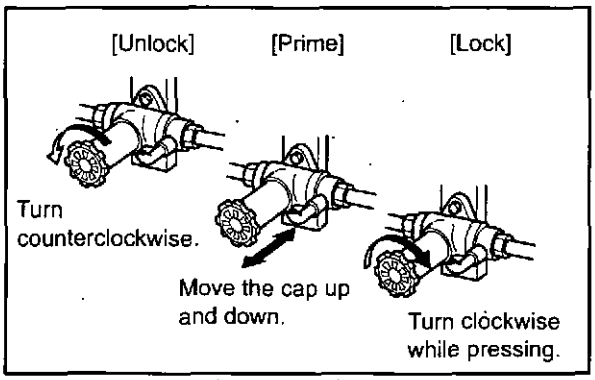
(a) Wipe off any fuel spilled from the air vent plug thoroughly with a cloth. Spilled fuel could cause fire.

(b) After bleeding air, be sure to lock priming pump cap. If the lock is not insufficient, it could cause damage to the pump and result in fire due fuel leaks. The priming pump cap must be locked in accordance with the procedure in the next page.

**CAUTION**

If all the air vent plugs are tightened before the priming pump cap is locked, fuel pressure acts on the priming pump, making it impossible to return the cap to the original position.

To bleed air from the fuel system, start at the place nearest to the fuel tank as follows: water separator → fuel filter → injection pump.




How to use priming pump

### 1.2.1 Bleeding air from fuel filter

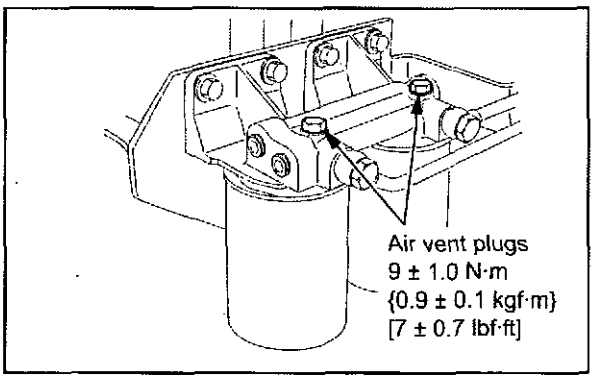
**CAUTION**

If the air vent plug, bracket threads or sealing washer is damaged, replace with a new one.

(1) Loosen the air vent plugs of the fuel filters. (approx. 1.5 turns)

(2) Unlock the priming pump cap by turning it counterclockwise, then move the cap up and down repeatedly.

(3) When fuel flowing from the vent holes no longer contains air bubbles, tighten the air vent plugs.




Bleeding air from fuel filter

### 1.2.2 Bleeding air from fuel injection pump

(1) Loosen the air vent plug and cock for the injection pump (approx. 1.5 turns).

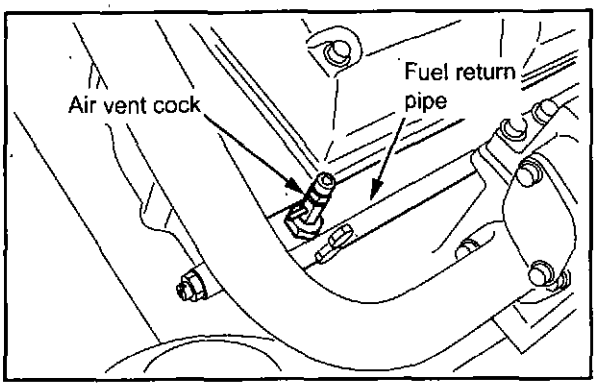
(2) Move the priming pump cap up and down repeatedly.

(3) When fuel flowing from the vent holes no longer contains air bubbles, tighten the air vent plug and cock. Before tightening the last air vent plug, lock the priming pump cap by turning it clockwise while pushing it down.

Note: (a) If all the vent plug and cock are tightened before the priming pump cap is locked, fuel pressure acts on the feed pump, making it impossible to return the cap to the original position.

(b) Wipe off fuel spilled from the vent holes thoroughly with a cloth.

(4) Turn the stay to the original position, and tighten the mounting bolt.

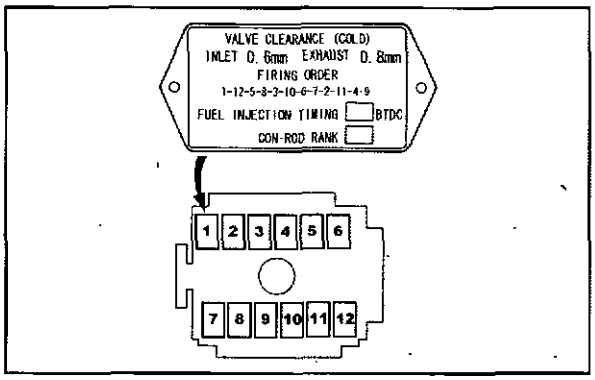



Bleeding fuel return pipe

## 1.3 Inspecting and adjusting fuel injection timing

### 1.3.1 Fuel injection timing and its indication location

Since the fuel injection timing varies depending on the engine output as well as engine speed and other specifications, be sure to check the caution plate on the No.1 rocker cover.




Injection timing and its indication location

### 1.3.2 Determining top dead center of No.1 cylinder compression stroke

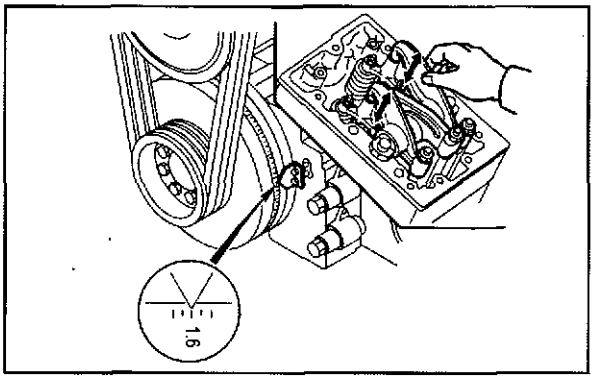
**⚠ CAUTION**

Be sure to check that #1 cylinder is on top dead center (TDC) of compression stroke, not on the TDC of the exhaust stroke.

(1) Using a ratchet handle, rotate the turning gear in the normal direction (clockwise when viewed from the front of the engine).

(2) Stop turning when the cylinder number "1" stamped on the damper is aligned with the pointer.

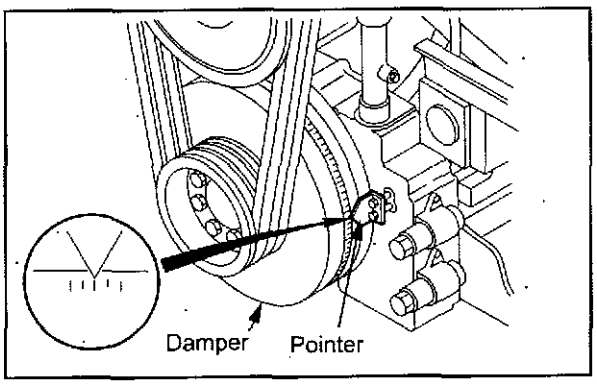
(3) Move the rocker arms of the inlet and exhaust valves for the No. 1 cylinder up and down, and make sure that the push rods are not pushing the inlet and exhaust valves off their seats.




Determining top dead center of No.1 cylinder compression stroke

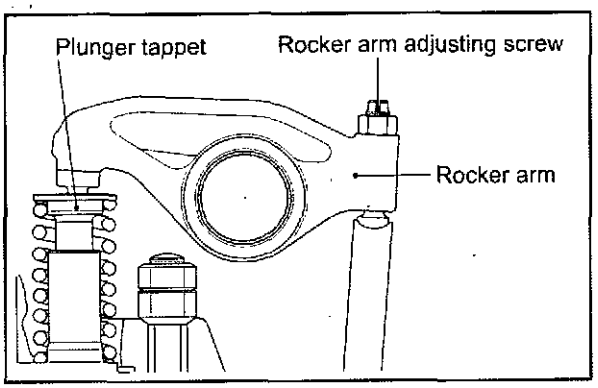
### 1.3.3 *Inspecting fuel injection timing*

(1) Rotate the engine about 60 degrees in reverse direction, then slowly rotate the engine in the forward direction until the pointer is aligned with the fuel injection timing mark (number stamped on the caution plate) on the circumference of the damper.



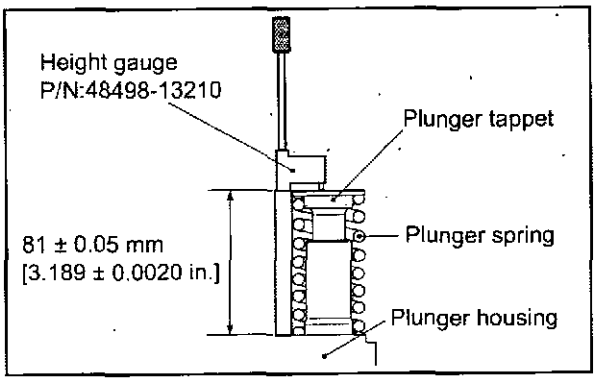

Fuel injection timing location

(2) Tighten the rocker arm adjusting screw firmly so that there is no looseness of the rocker arm.




Adjusting rocker and adjust screw

(3) Adjust the plunger tappet height between the spring seat of plunger housing and the tappet end, to the standard value when the plunger is positioned its compression top dead center. (Cam profile is base circle.)




Measuring plunger tappet height

## 1.4 Inspecting ribbed belt and adjusting belt tension

**CAUTION**

(a) If defects such as cuts or surface separations are found on ribbed belt during inspection, replace ribbed belt. Keep the belt free from oil and grease, since they can cause the belt to slip and shorten the service life.

(b) Excessive ribbed belt tension can cause rapid wear of the alternator bearing and shorten the service life of the belt. Adjust belt tension accurately by following the procedures below.

### 1.4.1 Inspecting and adjusting ribbed belt

(1) Inspect ribbed belt for defects such as wear, cuts or surface separations. If a defect is found, replace ribbed belt with a new one.

(2) Measure the belt tension. The correct tension of new belt is 1373 ± 10 N {140 ± 1.0 kgf} [309 ± 2 lbf]. The correct tension when retightening is 961 ± 5 N {98 ± 0.5 kgf} [216 ± 1 lbf].

### 1.4.2 Adjusting ribbed belt tension (Alternator side)

(1) Remove alternator front cover and ribbed belt cover.

(2) Loosen all the retaining bolts on the alternator and adjusting rod.

(3) Loosen the upper and lower lock nuts on the adjusting rod.

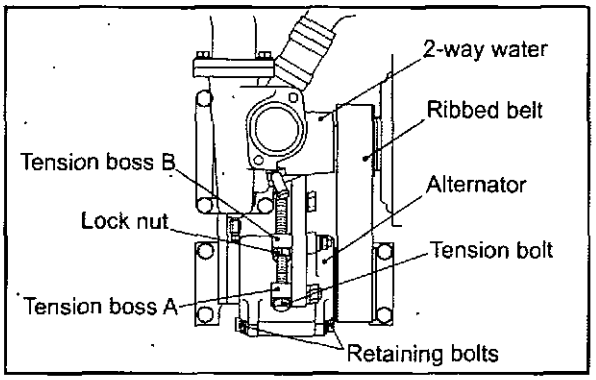
Note: The lower nut on the adjusting rod has left-hand threads.

(4) Turn the adjusting rod to adjust ribbed belt tension.

(5) After having adjusted belt tension, tighten the upper and lower lock nuts.

(6) Tighten all the retaining bolts on the alternator and adjusting rod.

(7) Reinstall belt cover and alternator front cover.




Inspecting V-belt and adjusting belt tension

## 2. Break-in operation

After the engine is overhauled, couple the engine to the dynamometer, and run the engine for break-in operation and inspection.

### 2.1 Starting up

(1) Before starting the engine, check the levels of coolant, engine oil and fuel.
*Bleed air from the fuel and cooling systems.*

(2) Stop the fuel supply, and crank the engine with the starter for about 10 seconds to lubricate the engine.

(3) Move the control lever slightly in the fuel increase direction (but not to the "full injection" position), and then turn the starter switch key to the [START] position to start the engine.

(4) After the engine is started, adjust the control lever to let the engine operate at a minimum no-load speed (low idle speed).

(5) Turn the starter switch key to the [OFF] position and make sure that the engine is stopped.

### 2.2 Inspecting engine condition after starting up

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

(1) The oil pressure must be within the specified value.

(2) The coolant temperature must be within the specified value.

(3) The engine must be free from any leakages such as oil, coolant and fuel. Pay special attention to oil leakage from the fitting face of turbocharger lube oil pipe.

(4) Check for an abnormal noise.

Note: Knocking noise will disappear as the coolant temperature rises.

(5) Check for the color of smoke and odors.

### 2.3 Break-in operation time

The relationship between the load in break-in operation and the operation time is as shown below.

| Break-in operation time | | | | |
|---|---|---|---|---|
| | Engine speed ($min^{-1}$) | | Load | Duration (min) |
| 1 | Low rotation speed | 600 to 900 | No-load | 5 |
| 2 | Medium rotation speed | 1000 to 1200 | No-load | 5 |
| 3 | High rotation speed | 1400 to rated speed | No-load | 10 |
| 4 | Rated speed | | 25 % | 10 |
| 5 | | | 50 % | 10 |
| 6 | | | 75 % | 30 |
| 7 | | | 100 % | 20 |

Note: The table above is provided solely for reference purpose. Run the engine at appropriate speed and load for the break-in operation of your engine. Be sure to perform break-in operation after overhaul or installation.

### 2.4 Inspection and adjustment after break-in operation

(1) Valve clearance adjustment

(2) Ignition timing inspection

(3) Exterior bolt and nut tightness check

## 3. Performance test (JIS standard)

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

#### 3.2.1 Operation load test

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

#### 3.2.2 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.

#### 3.2.3 Low idle test

Conduct this test to confirm that the engine can operate stably at the specified low idle speed.

### 3.3 Other inspections

Check for gas, coolant and oil leaks; 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.

#### 3.4.1 Standard atmospheric conditions:

Base temperature: 298 K (25°C) [77°F]
Total pressure: 100 kPa (750 mmHg)
Dry pressure: 99 kPa [743 mmHg]

### 3.4.2 Calculation of corrected power

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

If the applicable range of the correction formula is exceeded, indicate the corrected values and record the test conditions on the test record.

**Colculation output = Correction factor ( $\alpha_c$) × Measured brake power**

- Atmospheric conditions during test

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

  Dry atmospheric pressure($P_d$):80kPa (600mmHg) ≦ $P_d$ ≦ 110kPa (825mmHg)

  $\alpha_c=(f_a)^{f_m}$ $f_a$:Atmospheric factor $f_m$: Engine factor

- Range of correction equation use

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

  $0.9 \leqq \alpha_c \leqq 1.1$.

**Calculation of correction factor($f_a$)**

- Natural aspiration engine and engine with mechanically driven air charger

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

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

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

- Turbocharged engine with air-to-liquid cooler

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

**Calculation of engine factor ($f_m$)**

$f_m=0.036q_c-1.14$.

$q_c$:Corrected fuel supply volume

$$q_c=\frac{q}{r}$$

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

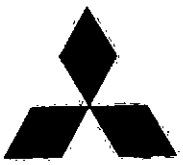
$z$=120000 (4-cycle engine)

$r$:Ratio between pressure at turbocharger or air cooler outlet and atmospheric pressure ($r$=1 for natural aspiration engine)

- Applicable range of engine factor ($f_m$)

  $37.2 \leqq q_c \leqq 65$mg/($l$-cycle)

  - $q_c \leqq 37.2$mg/($l$-cycle) : $f_m$=0.2 (constant)
  - 65mg/($l$-cycle) $\leqq q_c$ : $f_m$=1.2 (constant)



Printed in Japan

Pub. No. 99266-A3100