

SERVICE MANUAL

**MITSUBISHI
DIESEL ENGINE**

S16R-Y2PTAW

for EPA Tier2

March 2007



**MITSUBISHI
HEAVY INDUSTRIES, LTD.**

INTRODUCTION

This service manual describes the specifications and the maintenance and adjustment procedures of the S16R-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.

How to use this manual

In this service manual, the S16R-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.

CAUTION

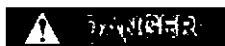
When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

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.



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



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



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:

Indicates important information or 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: $1 \text{ MPa} = 10.197 \text{ kgf/cm}^2$
- Torque: $1 \text{ N}\cdot\text{m} = 0.10197 \text{ kgf}\cdot\text{m}$
- Force: $1 \text{ N} = 0.10197 \text{ kgf}$
- Horsepower: $1 \text{ kW} = 1.341 \text{ HP} = 1.3596 \text{ PS}$
- Meter of mercury: $1 \text{ kPa} = 0.7 \text{ cmHg}$
- Meter of water: $1 \text{ kPa} = 10.197 \text{ cmH}_2\text{O} (\text{cmAq})$
- Rotational speed: $1 \text{ min}^{-1} = 1 \text{ rpm}$

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 neat 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 due to 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 using 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.

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 break the seals

To ensure proper engine operation, the fuel control link is provided with seals that protect the fuel injection volume and rotation speed settings against tampering. If these seals are broken and the settings are changed, proper operation of the engine will no longer be guaranteed, and the following problems will be expected to occur.

- Rapid wear of moving and rotating parts
- Engine troubles such as damage and seizure of engine parts
- Increased consumption of fuel and lubricating oil
- Deterioration of engine performance due to poorly balanced fuel injection volume and governor operation

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/pre-cleaner 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 your 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.

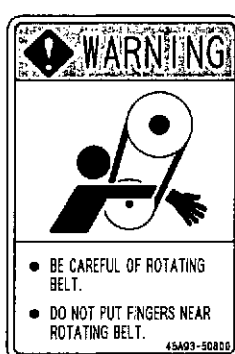
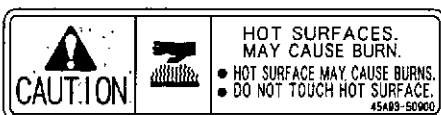
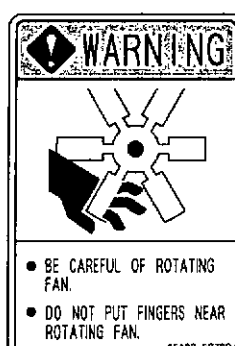
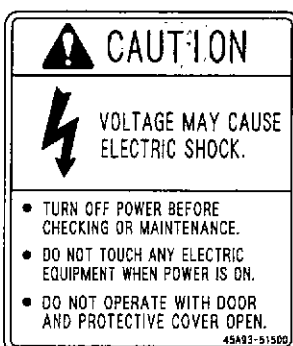
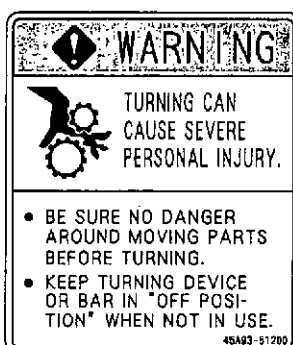
Clean or replace the warning/caution labels the description and/or illustration of which cannot be seen clearly.

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.

To obtain replacement warning labels, contact a Mitsubishi dealer.



Warning labels

GENERAL CONTENTS

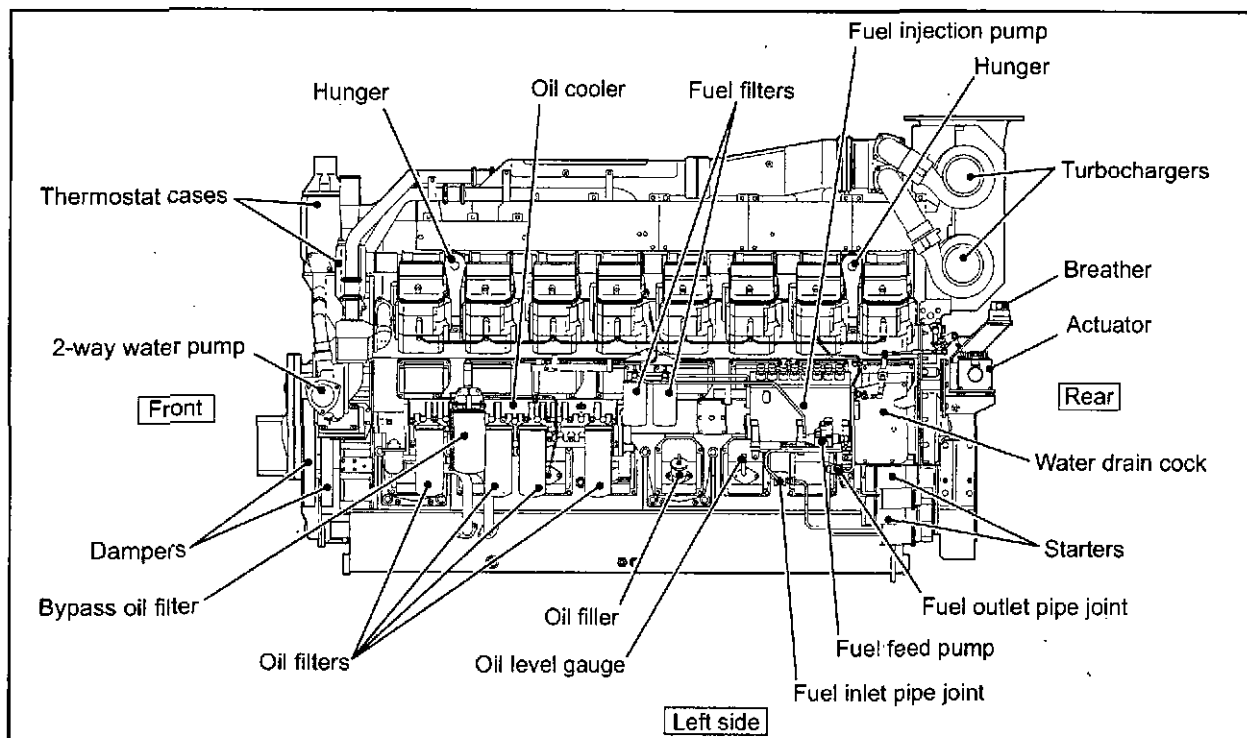
Group Name	Contents	Group No.
General	Outline Main specifications Tips on disassembling and reassembling	1
Service data	Maintenance service data Tightening torque table	2
Service tools	General tools Special tools	3
Determination overhaul	Determining overhaul timing Testing compression pressure	4
Disassembly of basic engine	Disassembling cylinder head and valve mechanism Disassembling flywheel, timing gear, camshaft Disassembling damper and front gear Disassembling cylinder liner, piston and connecting rod Disassembling crankcase, crankshaft, and main bearing	5
Inspecting and repair of basic engine	Cylinder head and valve mechanism Cylinder liner, piston and connecting rod Damper and front gear Flywheel, timing gear and camshaft Crankcase, crankshaft and main bearing	6
Reassembly of basic engine	Reassembling crankcase, crankshaft and main bearing Reassembling cylinder liner, piston and connecting rod Reassembling damper and front gear Reassembling flywheel, timing gear, camshaft, oil pan Reassembling cylinder head and valve mechanism	7
Fuel system	Removing fuel system Disassembling inspecting and reassembling fuel system Installing fuel system	8
Lubrication system	Removing lubrication system Disassembling, inspecting and reassembling lubrication system Installing lubrication system	9
Cooling system	Removing cooling system Disassembling, inspecting, and reassembling cooling system Disassembling, inspecting, and reassembling intercooler cooling system Installing cooling system	10
Inlet and exhaust systems	Air duct (intercooler-to-turbocharger) Insulator Exhaust manifold Turbocharger oil pipe Exhaust pipe Intercooler Boost sensor pipe Turbocharger	11
Electrical system	Removing electrical system Disassembling, inspecting and reassembling electrical system Reinstalling electrical system	12
Adjustment and operation	Adjusting engine Break-in operation Performance test (JIS standard)	13

GENERAL

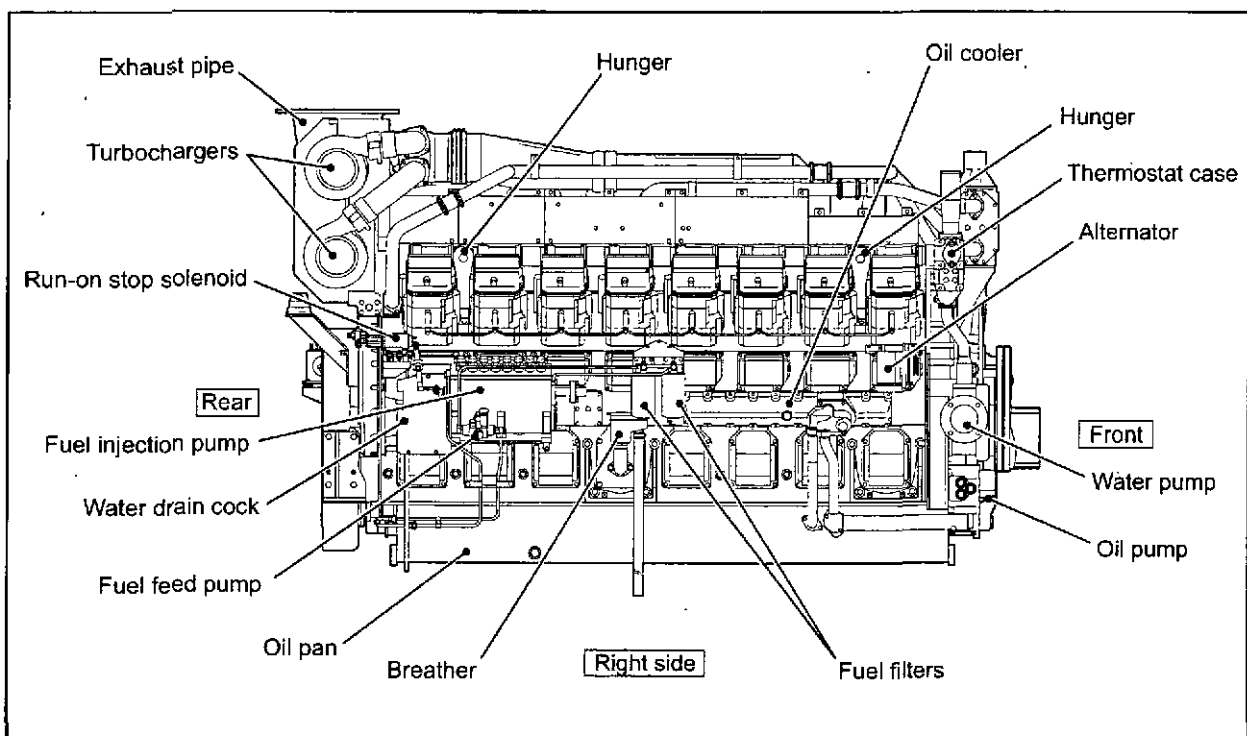
1. Outline	1-2
1.1 Outside drawings	1-2
1.2 Outline of ignition system	1-3
1.3 Outline of lubrication system	1-3
1.4 Outline of cooling system	1-4
1.5 Outline of inlet and exhaust systems	1-4
1.6 Outline of electrical system	1-5
1.7 Engine serial number location	1-6
2. Main specifications	1-7
3. Tips on disassembling and reassembling	1-10
3.1 Disassembling	1-10
3.2 Reassembling	1-10

1. Outline

1.1 Outside drawings

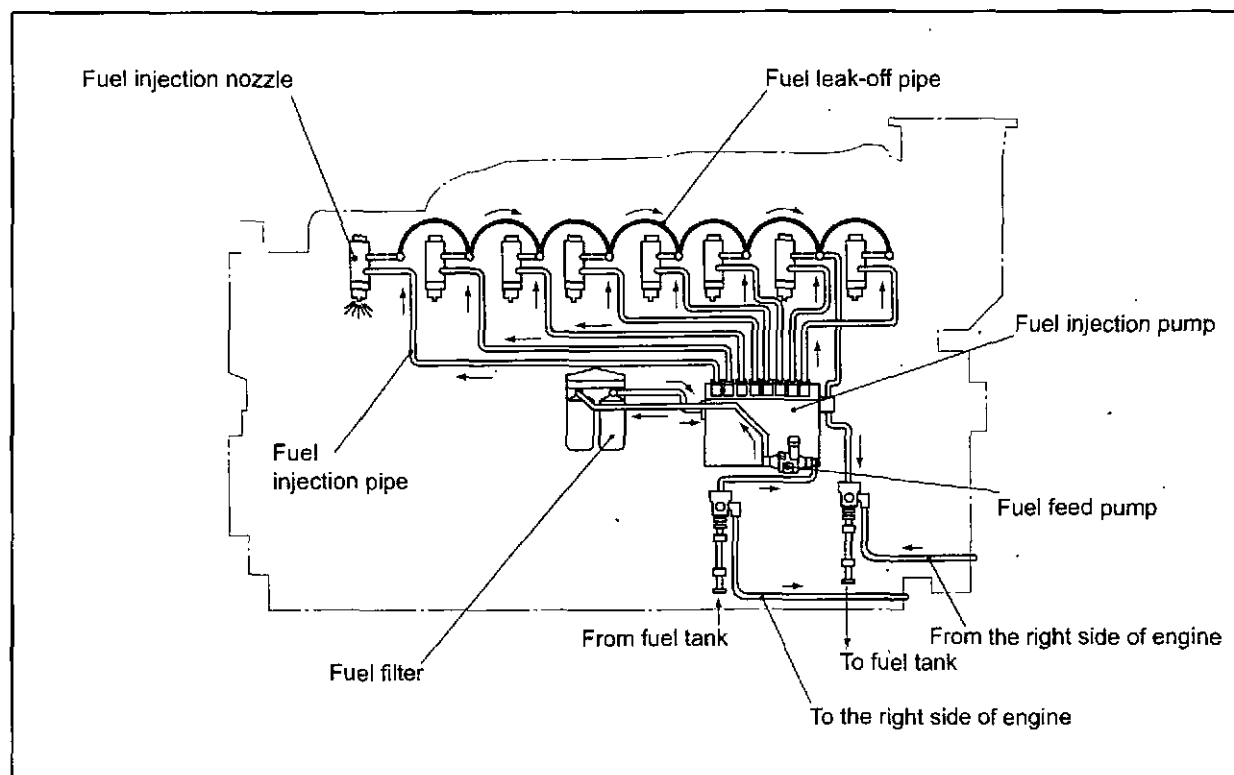


Left view of engine



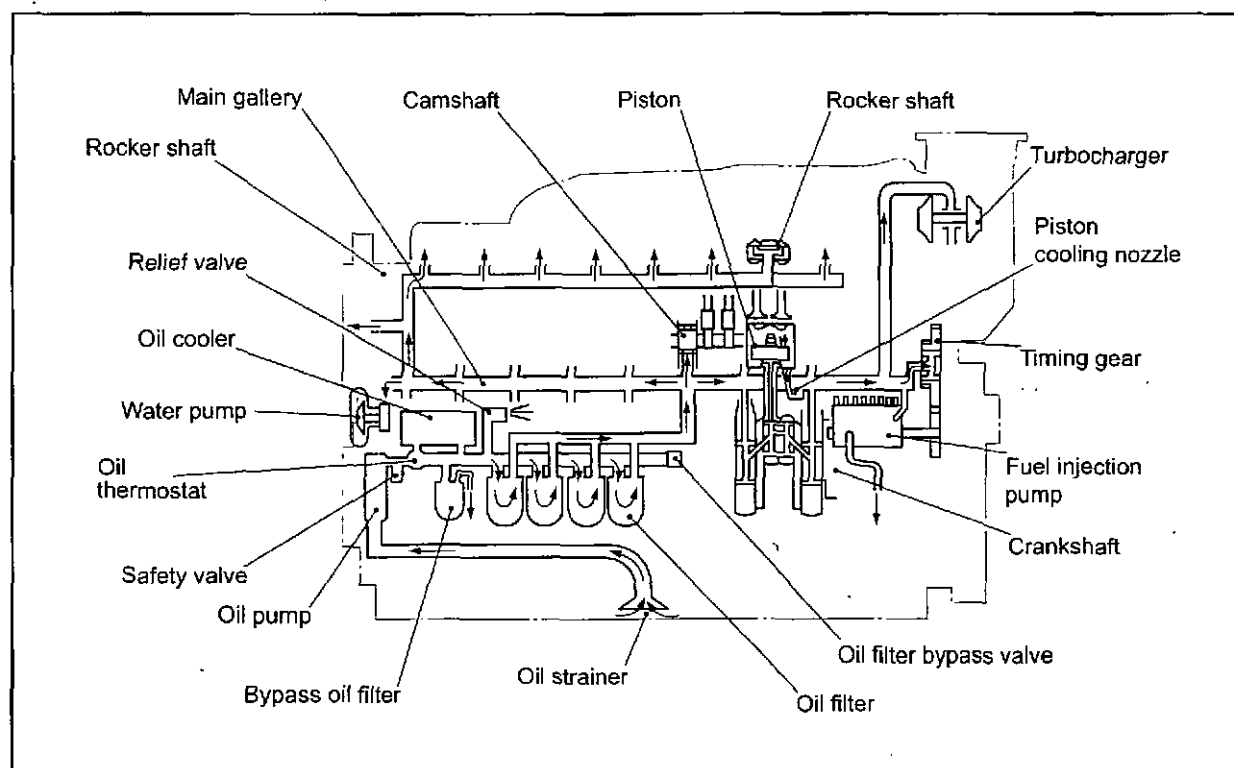
Right view of engine

1.2 Outline of ignition system



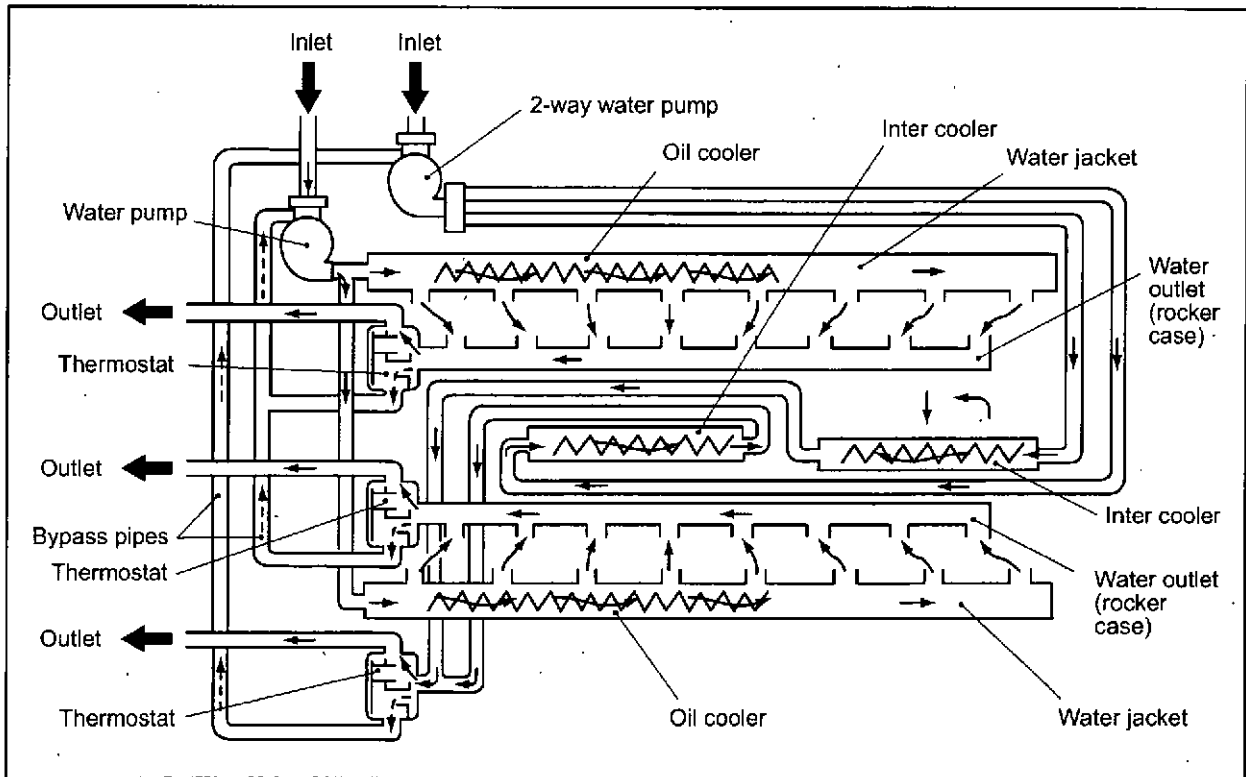
Outline of ignition system

1.3 Outline of lubrication system



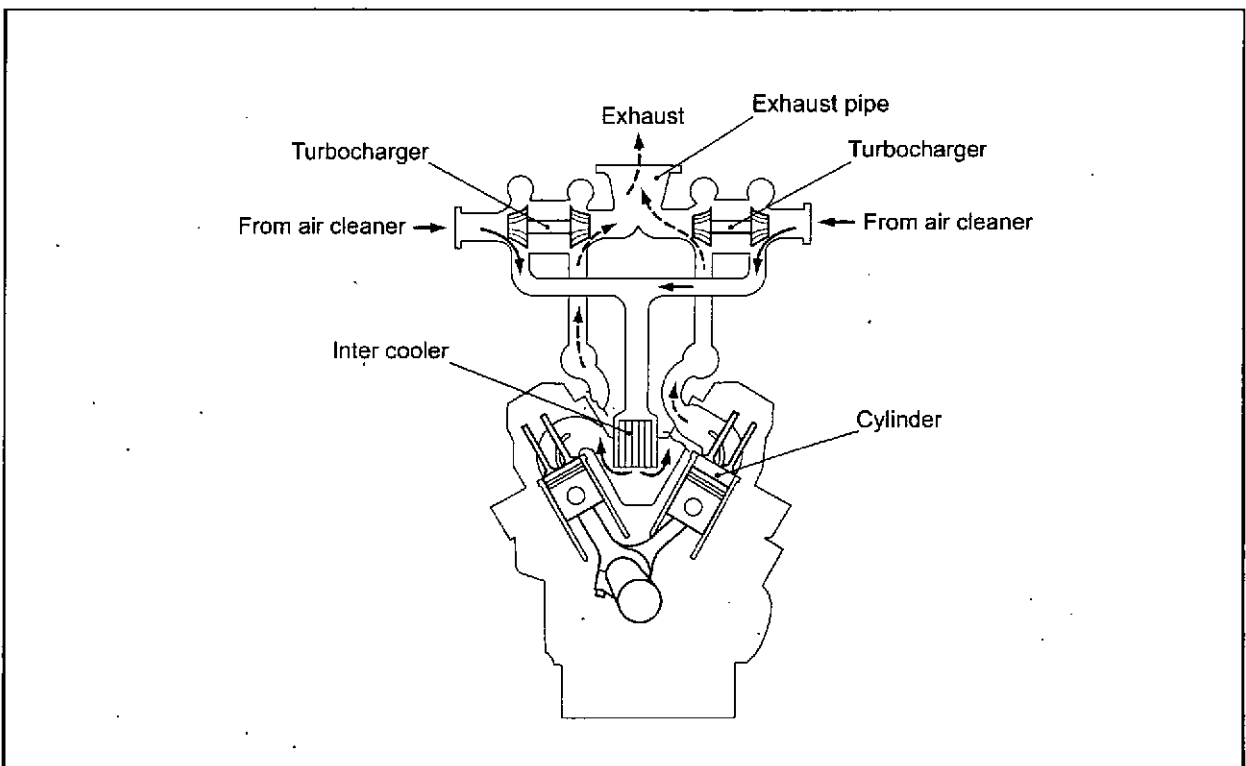
Outline of lubrication system

1.4 Outline of cooling system



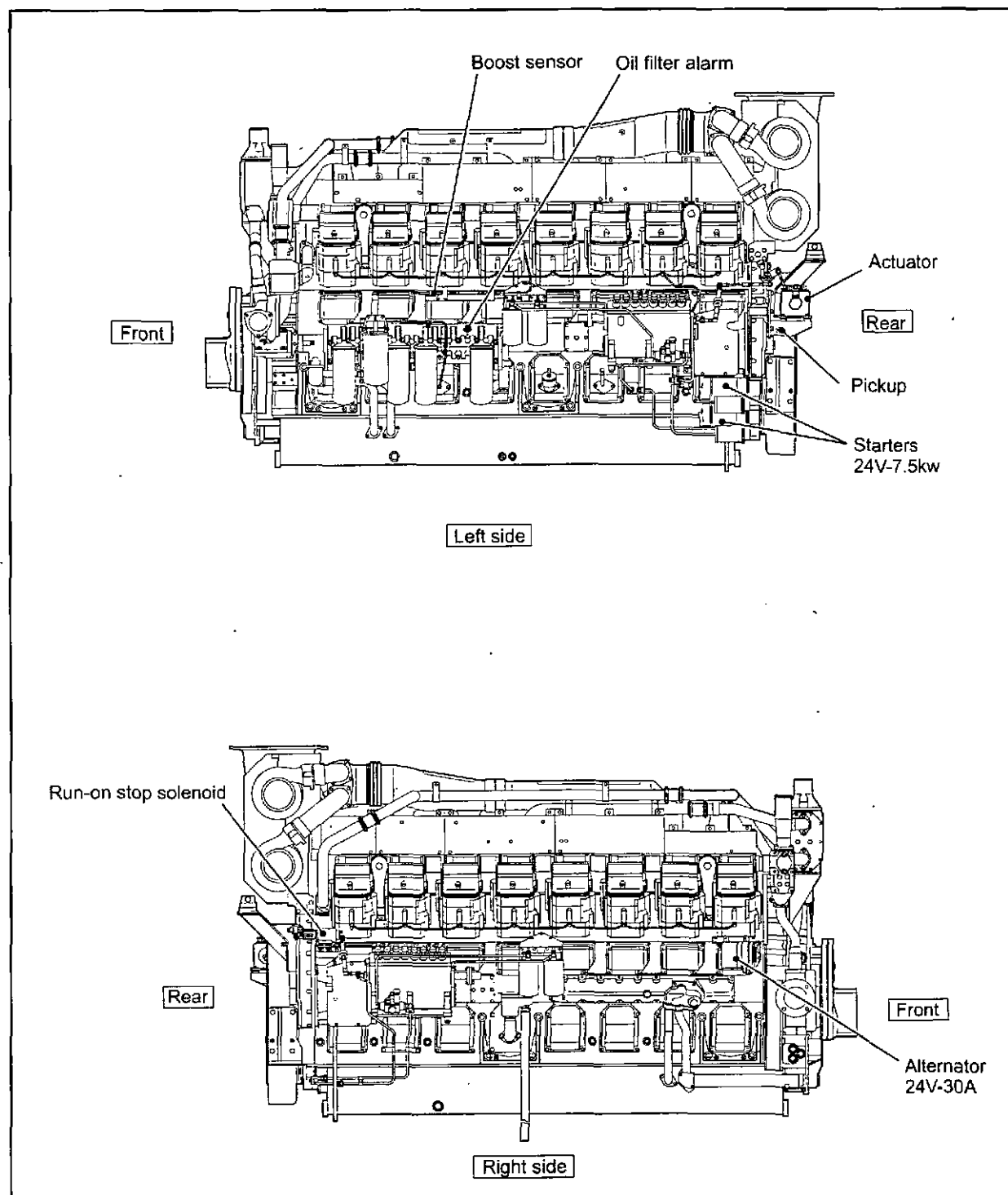
Outline of cooling system

1.5 Outline of inlet and exhaust systems



Outline of inlet and exhaust systems

1.6 Outline of electrical system

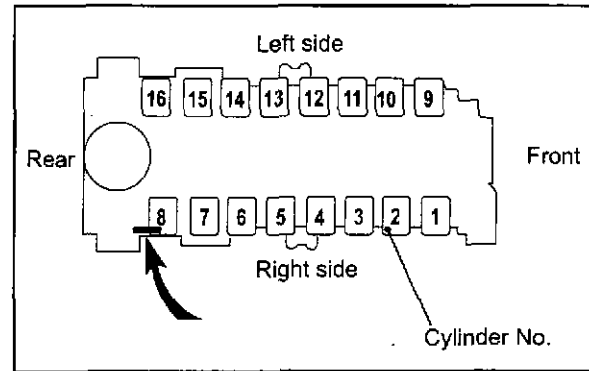


Outline of electrical system

1.7 Engine serial number location

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

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



Location of nameplate

2. Main specifications

Table 1-1 Main specifications (1 / 3)

Engine type				S16R-Y2PTAW	
Main specifications	Model			Water cooled, 4 cycle, turbocharged with air-cooled intercooler	
	No. of cylinders - cylinder arrangement			16 - V	
	Combustion type			Direct injection	
	Valve mechanism			Overhead	
	Cylinder bore × stroke			170 × 180 mm [6.70 × 7.10 in.]	
	Displacement			65.37 L [17.27 US gal.]	
	Compression ratio			14.5 : 1	
	Fuel			Diesel fuel (ASTM,D975 No.1-D, No.2-D)	
	Firing order			1 - 9 - 6 - 14 - 2 - 10 - 4 - 12 - 8 - 16 - 3 - 11 - 7 - 15 - 5 - 13	
	Rotational direction			Counterclockwise as viewed from flywheel	
	Dimensions	Length		3046 mm [119.92 in.]	
		Width		1457 mm [57.36 in.]	
		Height		1810 mm [71.26 in.]	
Dry mass			6530 kg [14396 lb.]		
Engine main part	Cylinder liner	Type		Wet type	
	Piston ring	No. of units		Compression ring: 2 Oil ring (with expander) : 1	
	Valve timing (when warm)	Inlet valve	Open	BTDC 63°	
			Close	BBDC 35°	
		Exhaust valve	Open	BBDC 53°	
			Close	ATDC 45°	
	Engine support method			6-point support	
Starting system			Starter		
Inlet and exhaust system	Turbocharger	Type		TD10	
		No. of units		4	

Table 1-1 Main specifications (2 / 3)

Engine type			S16R-Y2PTAW
Lubrication. system	Lubricating system		Forced circulation (oil pump pressure feed system)
	Engine oil		Class CD or CF oil (API service classification)
	Engine oil capacity		Approx. 230 L [60.76 U.S.gal]
	Oil pump	Type	Gear pump
		Delivery capacity	240 L [63.4 US gal.]/min (at 800 min ⁻¹ engine)
	Relief valve	Type	Piston valve type
		Valve opening pressure	0.51 ± 0.02 MPa {5.2 ± 0.2 kgf/cm ² } [74 ± 2.8 psi]
	Oil cooler	Type	Water-cooled, multi-plate type (housed in the crankcase)
		Element	13-step
	Full-flow oil filter	Type	Paper-element type (spin on)
	Bypass oil filter	Type	Paper-element type (spin on)
	Oil filter alarm	Type	Piston valve type, built in electric contact points
		Lamp lighting and valve opening pressure	0.15 ^{+0.03} ₀ MPa{1.5 ^{+0.3} ₀ kgf/cm ² } [21.3 ^{+4.27} ₀ psi]
Oil thermostat	Type	Wax type	
	Valve opening temperature	80 to 84°C [176 to 183.2°F]	
Cooling system	Cooling type		Forced-circulation water cooling by exterior pump
	Coolant capacity (engine)		170 L [44.9 US gal.] approx. (of jacket 142 L [37.5 US gal.], of Air cooler 28 L [7.4 US gal.])
	Water pump	Type	Separate type motor pump (centrifugal volute pump)
		Delivery capacity	1600 L [423 U.S.gal]/min at 1800 min ⁻¹ (engine)
	Thermostat	Type	Wax type
		Valve opening temperature	69 to 73°C [156.2 to 163.4°F]
	2-way water pump	Type	Centrifugal
		Water pressure	1793 mm Hg [24.4 mAg]
		Delivery capacity	885 L [234 U.S.gal]/min at 2996 min ⁻¹ (pump)
	2-way water pump thermostat	Type	Wax type
		Valve opening temperature	42°C [107.6°F]
	2-way water pump drive belt	Model	Ctype-V-belt (Raw edge cog NR-1)
		Manufacturer	Mitsuboshi Belting Ltd
		Outside circumference	1960 mm [77.17 in.]
	Intercooler	Core type	Multilayer fin-and plate type
Total radiation area		18.61 m ² [200.35 ft ²] × 2	

Table 1-1 Main specifications.(3 / 3)

Engine type		S16R-Y2PTAW	
Fuel system	Injection pump	Type	PS8
		Manufacturer	Mitsubishi Heavy Industries
		Plunger diameter	17 mm [0.67 in.]
		Plunger lead	Left-hand coil, both-sided 35 mm [1.38 in.] lead
		Cam lift	15 mm [0.59 in.]
	Feed pump	Model	Bosch KD22Z
		Manufacturer	Bosch Automotive systems corporation
		Theoretical delivery capacity	12 mm [0.47 in.]
	Governor	Speed control system	Woodward PROACT-2
	Injection nozzle	Type	Hole type
		Manufacturer	Bosch Automotive systems corporation
		No. of spray holes	10
		Spray hole diameter - spray angle	ϕ 0.27 mm [0.0106 in.] - 158°
		Valve opening pressure	34.3 to 34.8 MPa (350 to 355 kgf/cm ²) [4979 to 5050 psi]
	Filter	Type	Paper-element type (spin on)
Electrical system	Voltage - Polarity		24V - ground
	Starter	Manufacturer	Nikko Electric industry
		Pinion mesh type	Pinion shaft (Reduction type)
		Output	24V - 7.5 kW
		No. of starters	2
		No. of pinion tooth/ ring gear tooth	15/193
	Alternator	Type	3-phase alternating generator, Internal IC regulator
		Manufacturer	Mitsubishi Electric
		Output	24 V - 30 A
		Rated output generated speed	5000 min ⁻¹ (at 27 V, 30 A)
		Regulated voltage	28.5 $\pm$ 0.5 V
	Alternator drive belt	Model	LType-vbelt (Raw edge orange cog 38)
		Manufacturer	Mitsuboshi Belting Ltd
		Outside circumference	1000 mm [39.37 in.]

3. 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.

3.1 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.)

3.2 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	2-2
1.1 General	2-2
1.2 Engine main part.....	2-2
1.3 Inlet and exhaust system	2-7
1.4 Fuel system.....	2-8
1.5 Lubrication system.....	2-9
1.6 Cooling system	2-10
1.7 Electrical system.....	2-11
2. Tightening torque table	2-12
2.1 Tightening torque list.....	2-12
2.1.1 Engine	2-12
2.1.2 Inlet and exhaust system	2-13
2.1.3 Fuel system.....	2-14
2.1.4 Lubrication system	2-15
2.1.5 Cooling system.....	2-15
2.1.6 Electrical system	2-15
2.2 Standard bolt and nut tightening torque.	2-16
2.3 Standard eyebolt tightening torque.....	2-17
2.4 Standard union nut tightening torque.....	2-17
2.5 High-pressure fuel injection pipe tightening torque.....	2-17

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		5 to 10 % higher than rated		Faulty if lower or 15 % higher than rated	The rated rpm is stamped on the nameplate. Check governor setting.
Compression pressure		1.81 MPa {18.5 kgf/cm ² } [263 psi] minimum (at 120 min ⁻¹)		Faulty if 1.27 MPa {13 kgf/cm ² } [185 psi] or less	Oil temp 60 °C [141 °F] more
Engine oil pressure		0.49 to 0.64 MPa {5 to 6.5 kgf/cm ² } [71 to 85 psi] at rated speed		Faulty if 0.49 MPa {5 kgf/cm ² } [71 psi] or less	Oil temp. 60 to 70°C [140 to 158°F]
Valve timing	Inlet valve opens	BTDC25°	± 2° (crank angle)		With 2 mm [0.079 in.] clearance on valve side, when cold. Values are only for checking valve timing and are different from the actual ones.
	Inlet valve closes	BBDC3°			
	Exhaust valve opens	BBDC21°			
	Exhaust valve closes	ATDC7°			
Valve clearance (when cold)	Inlet valve		0.6 [0.024]		
	Exhaust valve		0.8 [0.031]		
Fuel injection timing		BTDC19°	±0.5° (crank angle)		Varies according to specifications. Refer to caution plate on No.1 rocker cover.

1.2 Engine main part

Table 2-2 Maintenance service data table - Engine main part (1 / 5)

Unit: mm [in.]

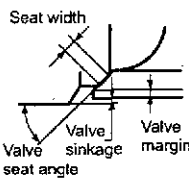
Inspection point		Nominal	Standard	Limit	Remark
Rocker	Rocker bushing inside diameter	ø 36 [1.42]	36.000 to 36.040 [1.4173 to 1.4189]	36.090 [1.4209]	
	Rocker shaft diameter	ø 36 [1.42]	35.966 to 35.991 [1.4160 to 1.4170]	35.940 [1.4150]	
Valve	Valve stem diameter	ø 10 [0.39]	9.940 to 9.960 [0.3913 to 0.3921]	9.910 [0.3902]	The same for both 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	-0.2 to 0.2 [-0.008 to 0.008]	1.0 [0.039]	
	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]	
	Cylinder head bore inside diameter and valve seat diameter	ø 60 [2.36]	(-0.070 to -0.130 [-0.0028 to -0.0051])		- (minus) indicates the interference in diameter
Inlet valve spring	Free length		73 [2.87]	71 [2.80]	
	Perpendicularity		θ = 1.5° or less Δ = 1.9 [0.075] or less Lf = 73 [2.87]	Δ = 2.2 [0.087] at the end	
	Set length / set force		66.0 / 289 to 319 N (29.45 to 32.55 kgf) [2.598 / 64.9 to 71.8 lbf]		

Table 2-2 Maintenance service data table - Engine main part (2 / 5)

Unit: mm [in.]

Inspection point			Nominal	Standard	Limit	Remark
Exhaust valve spring	Free length	Inner		90.6 [3.567]	88.12 [3.4693]	
		Outer		96.57 [3.802]	93.92 [3.6976]	
	Perpendicularity	Inner		$\theta = 2.0^\circ$ or less $\Delta = 3.2$ [0.126] or less Lf = 90.6 [3.567]	$\Delta = 3.7$ [0.146] at the end	
		Outer		$\theta = 2.5^\circ$ or less $\Delta = 4.2$ [0.165] or less Lf = 96.57 [3.8020]	$\Delta = 4.9$ [0.193] at the end	
	Set length/set force	Inner		56.0 / 137 to 152 N (14 to 15.5 kgf) [2.205 / 101.3 to 112.1 lbf]		
		Outer		62.0 / 496 to 549 N (50.6 to 56.0 kgf) [2.441 / 111.6 to 123.5 lbf]		
Valve pushrod	Runout			0.50 [0.0197] or less	0.50 [0.0197]	
Cylinder head	Flatness of gasket surface			0.03 [0.0012] or less	0.50 [0.0197]	Reface if necessary
Cylinder liners	Inside diameter		ø 170 [6.69]	170.000 to 170.040 [6.6929 to 6.6945]	170.500 [6.7126]	
	Roundness			0.02 [0.0008] or less		
	Cylindricity			0.02 [0.0008] or less		
	Perpendicularity of flange lower face to liner axle			0.03 [0.0012] or less		
	Protrusion of cylinder liner flange above gasket surface			0.11 to 0.20 [0.0043 to 0.0079]		
	Flange thickness			14.16 to 14.20 [0.5575 to 0.5591]		
	Height of cylinder liner projection			0.16 to 0.24 [0.0063 to 0.0095]		
Piston	Outside diameter		ø 170 [6.69]	169.76 to 169.80 [6.6835 to 6.6850]	169.66 [6.6795]	Measure diameter perpendicular to pin at piston skirt.
	Weight difference in one engine			20 g [0.71 oz.] or less		
	Pin bore diameter		ø 70 [2.76]	70.002 to 70.015 [2.7560 to 2.7565]	70.040 [2.7575]	
	Protrusion			0.06 to 0.65 [0.0024 to 0.0256]		
Cylinder head gasket	Thickness when tightened		1.8 [0.07]	1.77 to 1.83 [0.0697 to 0.0721]		
Piston and cylinder head	Clearance between piston top and cylinder head			1.22 to 1.95 [0.0481 to 0.0768]		
Piston ring	Gaps	No.1 compression		0.6 to 0.8 [0.024 to 0.031]	2.0 [0.079]	If gauge is not available, the general value can be obtained at the cylinder bore.
		No.2 compression		0.6 to 0.8 [0.024 to 0.031]	2.0 [0.079]	
		Oil		0.3 to 0.45 [0.012 to 0.018]	2.0 [0.079]	
Piston pin	Diameter		ø 70 [2.76]	69.987 to 70.000 [2.7554 to 2.7559]	69.970 [2.7547]	

Table 2-2 Maintenance service data table - Engine main part (3 / 5)

Unit: mm [in.]

Inspection point				Nominal	Standard	Limit	Remark
Connecting rod	Bushing inside diameter			ø 70 [2.76]	70.020 to 70.040 [2.7567 to 2.7575]	70.070 [2.7587]	
	Bend and twist				0.05/100 [0.0020/3.94] or less		
	End play			60 [2.36] × 2	0.4 to 0.9 [0.0157 to 0.0354]	1.4 [0.05516]	Difference between connecting rod width and crankpin width
	Big end bore diameter			ø 131 [5.16]	131.000 to 131.025 [5.1575 to 5.1585]	131.050 [5.1594]	To be measured in combination with caps. Roundness* : Less than 0.1 [0.004] *: (Max. value) - (Min. value)
Connecting rod bearing	Thickness of center	STD		3.000 [0.1181]	2.957 to 2.970 [0.1164 to 0.1169]	2.930 [0.1154]	Replace metals if worn out to service limit. Regrind crankpins and use undersize bearings if necessary.
		-0.25 [-0.01]		3.125 [0.1230]	3.082 to 3.095 [0.1213 to 0.1219]	3.055 [0.1203]	
		-0.50 [-0.02]		3.250 [0.1280]	3.207 to 3.220 [0.1263 to 0.1268]	3.180 [0.1252]	
		-0.75 [-0.03]		3.375 [0.1329]	3.332 to 3.345 [0.1312 to 0.1317]	3.305 [0.1301]	
		-1.00 [-0.04]		3.500 [0.1378]	3.472 to 3.485 [0.1361 to 0.1366]	3.430 [0.1350]	
Flywheel	Face runout			-	0.336 [0.0132] or less		
	Radial runout				0.130 [0.0051] or less		
Damper	Face runout				0.5 [0.020] or less	1.5 [0.059]	Replace at the initial overhaul.
	Radical runout (at periphery)				0.5 [0.020] or less	1.5 [0.059]	
Injection pump accessory drive	Bearing bore inside diameter			ø 90 [3.54]	89.987 to 90.022 [3.5428 to 3.5442]		
				ø 100 [3.94]	99.987 to 100.022 [3.9365 to 3.9379]		
	Bearing	Outside diameter	S	ø 90 [3.54]	89.985 to 90.000 [3.5427 to 3.5433]		
			L	ø 100 [3.94]	99.985 to 100.000 [3.9364 to 3.9370]		
		Inside diameter	S	ø 50 [1.97]	49.988 to 50.000 [1.9680 to 1.9685]		
			L	ø 45 [1.77]	44.988 to 45.000 [1.7712 to 1.7717]		
	Drive shaft bearing journal diameter			ø 45 [1.77]	45.002 to 45.013 [1.7717 to 1.7722]		
				ø 50 [1.97]	50.002 to 50.013 [1.9686 to 1.9690]		
Oil pump drive	Cover bearing bore inside diameter			ø 110 [4.33]	110.000 to 110.035 [4.3307 to 4.3321]		
	Plate bearing bore inside diameter			ø 110 [4.33]	109.987 to 110.022 [4.3302 to 4.3316]		
	Bearing	Outside diameter	ø 110 [4.33]	109.985 to 110.000 [4.3301 to 4.3307]			
		Inside diameter	ø 50 [1.97]	49.988 to 50.000 [1.9680 to 1.9685]			
	Gear shaft bearing bore outside diameter			ø 50 [1.97]	49.993 to 50.013 [1.9682 to 1.9690]		

Table 2-2 Maintenance service data table - Engine main part (4 / 5)

Unit: mm [in.]

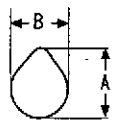
Inspection point		Nominal	Standard	Limit	Remark
Front gear	Backlash		0.12 to 0.18 [0.0047 to 0.0071]	0.50 [0.0197]	Replace gears, if necessary
	Idler gear shaft bushing inside diameter	ø 50 [1.97]	50.000 to 50.025 [1.9685 to 1.9695]	50.060 [1.9709]	Same as in the case of front oil pump idler and front fan drive idler
	Idler gear shaft diameter	ø 50 [1.97]	49.950 to 49.975 [1.9665 to 1.9675]	49.900 [1.9646]	
	Front idler gear end play		0.2 to 0.4 [0.008 to 0.016]	0.6 [0.024]	
Timing gear	Backlash		0.12 to 0.18 [0.0047 to 0.0071]	0.50 [0.0197]	
	Idler gear end play		0.3 to 0.6 [0.012 to 0.024]	1.0 [0.039]	
	Rear idler bushing inside diameter	ø 65 [2.56]	65.000 to 65.030 [2.5591 to 2.5602]	65.060 [2.5614]	
	Rear idler shaft diameter	ø 65 [2.56]	64.951 to 64.970 [2.5571 to 2.5579]	64.900 [2.5551]	
Camshaft	Cam lift (A - B)	9.300 [0.3661]	9.197 to 9.297 [0.3621 to 0.3660]	8.45 [0.3327]	
	Runout		0.10 [0.0039] or less	0.16 [0.0063]	Runout at center bushing measured with both ends supported. Repair or replace, if necessary.
	Journal diameter	ø 84 [3.31]	83.920 to 83.940 [3.3039 to 3.3047]	83.870 [3.3020]	
	Camshaft bushing inside diameter (as installed in crankcase)	ø 84 [3.31]	84.000 to 84.035 [3.3071 to 3.3085]	84.10 [3.3110]	Replace bushings and ream them, if necessary.
	End play	8 [0.3]	0.10 to 0.25 [0.0039 to 0.0098]	0.40 [0.0157]	Replace thrust bearing if necessary

Table 2-2 Maintenance service data table - Engine main part (5 / 5)

Unit: mm [in.]

Inspection point			Nominal	Standard	Limit	Remark
Crankshaft	Crankpin diameter		ø 125 [4.92]	124.930 to 124.950 [4.9185 to 4.9193]	124.890 [4.9169]	Use undersize bearing if worn down to service limit
	Crankpin journal diameter		ø 170 [6.69]	169.920 to 169.940 [6.6898 to 6.6905]	169.890 [6.6886]	
	Center to center distance between journal and crankpin		90 [3.54]	89.90 to 90.10 [3.5394 to 3.5472]		
	Parallelism between journals and crankpins			0.01 [0.0004] or less at pin length	0.03 [0.0012]	Correct
	Roundness of journals and crankpins			0.01 [0.0004] or less in diameters	0.03 [0.0012]	Correct
	Cylindricity of journals and crankpins			0.01 [0.0004] or less in diameters	0.03 [0.0012]	Correct
	Fillet radius of crankpins		R7 [0.28]	6.8 to 7 [0.2677 to 0.2756]		
	Fillet radius of journals		R8.5 [0.33]	8.3 to 8.5 [0.3270 to 0.3349]		
	Hardness of journals and crankpins			Hv>590		
	Angularity			±0°20'		
	Runout			0.08 [0.0032] or less	0.20 [0.0079]	Repair or replace, if necessary.
	End play (width between webs and thrust bearings)		67 [2.64]	(0.20 to 0.40 [0.0079 to 0.0157])	(0.50 [0.0197]) +1.18 [+0.0465] for crank shaft width	Replace thrust bearings until worn down to service limit. Use oversize thrust bearings if worn beyond limit. +0.25 [+0.01], +0.50 [+0.02], +0.75 [+0.03]
Main bearing	Thickness of center	STD	4.500 [0.1772]	4.467 to 4.480 [0.1759 to 0.1764]	4.425 [0.1742]	Replace bearings until worn down to service limit. Regrind crankpins and use undersize bearings if worn beyond service limit.
		-0.25 [-0.01]	4.625 [0.1821]	4.592 to 4.605 [0.1808 to 0.1813]	4.550 [0.1791]	
		-0.50 [-0.02]	4.750 [0.1870]	4.717 to 4.730 [0.1857 to 0.1862]	4.675 [0.1841]	
		-0.75 [-0.03]	4.875 [0.1919]	4.842 to 4.855 [0.1906 to 0.1911]	4.800 [0.1890]	
		-1.00 [-0.04]	5.000 [0.1969]	4.967 to 4.980 [0.1956 to 0.1961]	4.925 [0.1939]	
Crankcase	Gasket surface distortion			0.10 [0.0039] or less	0.20 [0.0079]	Reface if necessary.
	Main bearing bore diameter		ø 179 [7.05]	179.000 to 179.025 [7.0472 to 7.0482]	179.045 [7.0490]	
	Counter bore depth			14.00 to 14.05 [0.5512 to 0.5531]		

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]		30.006 [1.1813]	
	Bearing	Outside diameter	ø 30 [1.18]	29.876 [1.1762]	
		Bore diameter	ø 18 [0.71]	18.046 [0.7106]	
		Length	17.5 [0.689]	17.440 [0.6866]	
	Shaft & turbine wheel	Journal diameter	ø 18 [0.71]	17.996 [0.7085]	
		Shaft runout		0.015 [0.0006]	
	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		0.65 to 1.25 [0.0256 to 0.0492]		

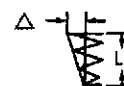
SERVICE DATA

1.4 Fuel system

Table 2-4 Maintenance service data table - Fuel system

Unit: mm [in.]

Inspection point		Nominal value	Standard	Limit	Remark
Fuel injection nozzle	Injection starting pressure	34.3 MPa {350 kgf/cm ² } [4979 psi]	34.3 to 34.8 MPa {350 to 355 kgf/cm ² } [4979 to 5050 psi]		
	Spray cone angle	158°			Check nozzle with a hand tester (at fuel oil temperature 20°C [68°F]). Replace the nozzle tip if the spray pattern is still bad after washing in clean fuel oil.
Injection pump	Overall clearance at tappet roller			0.2 [0.008]	
	Wear of contact surface between tappet and plunger			0.2 [0.008]	
	Outside diameter at contact surface of camshaft oil seal		ø 35 [1.38]	34.938 to 34.963 [1.3765 to 1.3755]	34.800 [1.3701]
	Camshaft runout			0.05 [0.0020]	0.15 [0.0059]
	Camshaft thrust clearance			0.02 to 0.06 [0.0008 to 0.0024]	
	Perpendicularity of spring	Plunger spring		Δ = 1.8 [0.071]	Lf = 70.8 [2.79]
		Delivery spring		Δ = 0.6 [0.024]	Lf = 18 [0.709]
	Sliding resistance of control rack			4.9 N {500 gf} [1.10 lb.] or less	Ensure smooth rack operation, and set rack stroke to 36 [1.42]
	Injection interval			45 ± 0.5°	Camshaft angle
	Total stroke of control rack			36 [1.42]	
Feed pump	Air tightness test		There shall be no air leakage (air bubbles) from assembly.		Plug discharge port. Apply air pressure of 0.2 MPa (2kgf/cm ²) [29 psi] to suction port and immerse in diesel fuel.
	Feed pressure		Discharge start time: 20 sec or less		
	Priming pump discharge start		No. of pumping operations: 30 strokes or less		
	Feed pump feed rate (pump at 500 min ⁻¹)		1100 cm ³ [60.4 cu.in.]/15 sec		
	Clearance between plunger and barrel		Replace plunger assembly if injection characteristics value exceeds-5% at 17 [0.669] rack position.		



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	Backlash between drive and driven gear		0.100 to 0.200 [0.0039 to 0.0079]	0.400 [0.0157]	
	Radial clearance between gear and case	ø 60 [2.36]	0.100 to 0.148 [0.0039 to 0.0058]	0.35 [0.0138]	Tip clearance
	Side clearance between gear and case	72.5 [2.85]	0.040 to 0.116 [0.0016 to 0.0046]	0.21 [0.0083]	Measure with the cover mount packing (0.04 [0.0016] thickness) removed
	Drive shaft	ø30 [1.18]	29.887 to 29.900 [1.1767 to 1.1772]	29.840 [1.1748]	
	Driven shaft		29.947 to 29.960 [1.1790 to 1.1795]	29.900 [1.1772]	
	Bushing inside diameter		30.000 to 30.021 [1.1811 to 1.1819]	30.055 [1.1833]	
Safety valve	Valve opening pressure		1.3 ± 0.13 MPa {13 ± 1.3 kgf/cm ² } [185 ± 18 psi]		
	Spring set length/load		65.8/359 N {36.6 kgf} [2.591/80.7 lbf]	65.8 /314 N {32 kgf} [2.591/70.5 lbf]	
Relief valve	Valve opening pressure		0.51 ± 0.02 MPa {5.2 ± 0.2 kgf/cm ² } [74 ± 2.9 psi]		
Oil thermostat	Temperature at which valve starts opening	82°C [180°F]	82 ± 2°C [180 ± 3.6°F]		
	Temperature at which valve lift is more than 11 [0.43] minimum		95°C [203°F]		
Bypass oil filter alarm	Lamp lighting pressure (differential pressure)		0.15 ^{+0.03} ₀ MPa {1.5 ^{+0.3} ₀ kgf/cm ² } [21 ⁺⁴ ₀ psi]		Changes of oil pressure is 6.86 kPa {0.07 kgf/cm ² } [1.00 psi] with a 1 mm [0.0394 in.] shim.
Piston cooling nozzle	Valve opening pressure		0.26 to 0.32 MPa {2.7 to 3.3 kgf/cm ² } [38 to 47 psi]		

1.6 Cooling system

Table 2-6 Maintenance service data table - Cooling system

Unit: mm [in.]

Inspection point				Nominal	Standard	Limit	Remark
Water pump	Pump case bearing bore inside diameter			ø 120 [4.72]	119.987 to 120.022 [4.7239 to 4.7253]		
	Cover bearing bore inside diameter			ø 110 [4.33]	110.005 to 110.040 [4.3309 to 4.3323]		
	Bearing	Large	Outside diameter	ø 120 [4.72]	119.985 to 120.000 [4.7238 to 4.7244]		
			Inside diameter	ø 55 [2.17]	54.985 to 55.000 [2.1648 to 2.1654]		
		Small	Outside diameter	ø 110 [4.33]	109.985 to 110.000 [4.3301 to 4.3307]		
			Inside diameter	ø 50 [1.97]	49.988 to 50.000 [1.9680 to 1.9685]		
	Diameter of shaft on which bearing inner race fitted			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]		
Vane front face clearance in pump case			1.04 [0.04]	0.58 to 1.50 [0.0228 to 0.0591]			
Thermostat	Temperature at which valve starts opening			71°C [160°F]	71 ± 2°C [160 ± 3.6°F]		Check in atmospheric pressure
	Temperature at which valve lift is more than 9 [0.35]				85°C [185°F]		
Tension pulley assembly	Tension pulley bearing bore inside diameter			ø 62 [2.44]	61.970 to 62.000 [2.4398 to 2.4409]		
	Bearing	Inside diameter		ø 25 [0.98]	24.988 to 25.000 [0.9838 to 0.9843]		
		Outside diameter		ø 62 [2.44]	61.985 to 62.000 [2.4403 to 2.4409]		
	Tension pulley bracket bearing journal diameter			ø 25 [0.98]	24.987 to 25.000 [0.9837 to 0.9843]		
2-way water pump thermostat	Temperature at which valve starts opening			42°C [108°F]	42 ± 2°C [108 ± 3.6°F]		Check in atmospheric pressure
	Temperature at which valve lift is more than 9 [0.35]				55°C [131°F]		

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 [1.69]		ø 42 [1.65]	
		Runout			0.06 [0.0024] or less	0.10 [0.0039]	
		Undercutting depth			0.7 to 0.9 [0.028 to 0.035]	0.2 [0.008]	
	Height of brush				21 to 22 [0.83 to 0.87]	13 [0.51]	
	Tension of brush spring			44.13 N {4.5 kgf} [10 lbf]	39.23 to 49.03 N {4.0 to 5.0 kgf} [9 to 11 lbf]	39.23 N {4.0 kgf} [9 lbf]	With brush installed
	Armature	Shaft diameter (rear)		ø 14 [0.55]	13.941 to 13.968 [0.5489 to 0.5499]		
		Shaft diameter (front)		ø 25 [0.98]	25.002 to 25.011 [0.9843 to 0.9847]		
		Shaft runout			0.12 [0.0047]		
	Pinion shaft	Diameter (rear)		ø 30 [1.18]	30.002 to 30.011 [1.1812 to 1.1815]		
		Diameter (front)		ø 19 [0.75]	18.90 to 18.94 [0.7441 to 0.7457]		
	Metal	Pinion		ø 19 [0.75]	19.000 to 19.033 [0.7480 to 0.7493]	0.25 [0.0098]	*Clearance between shaft and metal
	End play	Armature			0.15 to 0.75 [0.0059 to 0.0259]		
		Pinion shaft			0.2 to 0.8 [0.008 to 0.031]		
Alternator	Output current (27 V)	Rotating speed	1500 min ⁻¹		18 A or higher (at warm room temperature)		
			2500 min ⁻¹		26 A or higher (at warm room temperature)		
			5000 min ⁻¹		30 A or higher (at warm room temperature)		
	Regulator adjusting voltage (alternator 5000 min ⁻¹ , load at 5 A or lower)				28.5 ± 0.5 V		
	Field coil resistance (at 20°C [68°F])				3.8 to 4.5 Ω		
	Slip ring outside diameter				32.8 to 33.2 [1.291 to 1.307]	32.4 [1.276]	
	Brush length			21.5 [0.85]		8 [0.31]	
	Brush spring tension				3.1 to 4.3 N (320 to 440 gf) [0.70 to 0.97 lbf]	2.0 N (200 gf) [0.45 lbf]	
	Drive belt tension				10 to 15 [0.39 to 0.59]		When center of belt pressed at approx. 98 to 147 N (10 to 15 kgf) [22 to 33 lbf] 

2. Tightening torque table

2.1 Tightening torque list

2.1.1 Engine

Table 2-8 Tightening torque list - Engine

Description		Threads Dia × Pitch (mm)	Torque			Remark
			N·m	kgf·m	lbf·ft	
Cylinder head bolt		22 × 2.5	539 ± 27	55 ± 2.75	398 ± 20	[Wet] (2-step tightening method) Note (a)
Cylinder head nozzle gland (stud)		14 × 2.0	73.5 ± 4.5	7.5 ± 0.5	54.5 ± 3.6	
Rocker case		12 × 1.25	108 ± 5.4	11 ± 0.55	80 ± 4.0	
Rocker shaft		14 × 2.0	147 ± 7.4	15 ± 0.75	108 ± 5.4	
Rocker arm lock nut		12 × 1.25	64 ± 3.2	6.5 ± 0.33	47 ± 2.4	
Bridge lock nut		10 × 1.25	55 ± 2.8	5.6 ± 0.28	41 ± 2.0	
Camshaft gear		12 × 1.25	127 ± 6.4	13 ± 0.65	94 ± 4.7	
Camshaft thrust plate		12 × 1.25	59 ± 5.9	6 ± 0.6	43 ± 4.3	
Main bearing cap		24 × 3.0	588 ± 29.4	60 ± 3.0	434 ± 22	[Wet] Note (b)
Main bearing cap (side bolt)		20 × 2.5	392 ± 19.6	40 ± 2.0	289 ± 14	[Wet] Note (b)
Hanger		20 × 1.5	392 ± 19.6	40 ± 2.0	289 ± 14	
		16 × 1.5	216 ± 10.8	22 ± 1.1	159 ± 8.0	
Piston cooling nozzle		12 × 1.75	34 ± 1.7	3.5 ± 0.18	25 ± 1.3	Note (c)
Timing gear case		16 × 1.5	255 ± 12.8	26 ± 1.3	188 ± 9.4	Use hard washer
Rear plate		12 × 1.25	108 ± 5.4	11 ± 0.55	80 ± 4.0	
		16 × 1.5	216 ± 10.8	22 ± 1.1	159 ± 8.0	Use spring washer
Front mounting bracket		20 × 1.5	392 ± 19.6	40 ± 2.0	289 ± 14	
			245 ± 12.3	25 ± 1.25	181 ± 9	2 lower bolts of right side bracket.
Center mounting bracket		20 × 1.5	392 ± 19.6	40 ± 2.0	289 ± 14	
Rear mounting bracket		20 × 1.5	392 ± 19.6	40 ± 2.0	289 ± 14	
Connecting rod bearing cap		22 × 1.5	539 ± 27	55 ± 2.75	398 ± 20	[Wet] (2-step tightening method) Note (d)
Balance weight		22 × 1.5	490 ± 24.5	50 ± 2.5	362 ± 18	[Wet]
Flywheel		22 × 1.5	588 ± 29.4	60 ± 3.0	434 ± 22	[Wet]
Ring gear		10 × 1.25	59 ± 3.0	6 ± 0.3	43 ± 2.2	
Damper and crankshaft pulley		22 × 1.5	490 ± 24.5	50 ± 2.5	362 ± 18	
Rear idler shaft		20 × 1.5	392 ± 19.6	40 ± 2.0	289 ± 14	Apply Molykote.
Idler shaft thrust collar (nut)		18 × 1.5	196 ± 9.8	20 ± 1.0	145 ± 7.2	
Front gear case		12 × 1.25	59 ± 3.0	6 ± 0.3	43 ± 2.2	
		16 × 1.5	216 ± 10.8	22 ± 1.1	159 ± 8.0	
Front plate		12 × 1.25	59 ± 5.9	6 ± 0.6	43 ± 4.3	
Front idler shaft		12 × 1.25	108 ± 10.8	11 ± 1.1	80 ± 8.0	
Front idler shaft thrust plate		10 × 1.25	29 ± 2.9	3 ± 0.3	22 ± 2.2	
Bearing cover		12 × 1.25	108 ± 10.8	11 ± 1.1	80 ± 8.0	
Accessory drive	Case	12 × 1.25	108 ± 5.4	11 ± 0.55	80 ± 4.0	
	Gear (nut)	30 × 1.5	392 ± 19.6	40 ± 2.0	289 ± 14	

Note: (a) To tighten cylinder head bolts according to the angle method, follow the sequence described below.

1. Tighten to snug torque of $294 \pm 14.7 \text{ N}\cdot\text{m}$ $\{30 \pm 1.5 \text{ kgf}\cdot\text{m}\}$ $[217 \pm 11 \text{ lbf}\cdot\text{ft}]$.
2. Tighten by turning $30 \pm 1.5^\circ$.
3. Tighten by further turning $30 \pm 1.5^\circ$. (total $60 \pm 3^\circ$ turn)
4. Loosen all bolts, and tighten again according to the angle method. (tightening twice)

(b) Be sure to tighten main bearing caps and main bearing cap side bolts according to the specified sequence.

1. Tighten the main bearing cap bolts to the specified torque.
2. Tighten the right side bolts to the specified torque.
3. Tighten the left side bolts to the specified torque.

(c) Be sure to tighten piston cooling nozzle check valves to the specified torque. 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 cylinder head bolts according to the angle method, follow the sequence described below.

1. Tighten to snug torque of $245 \pm 12.25 \text{ N}\cdot\text{m}$ $\{25 \pm 1.25 \text{ kgf}\cdot\text{m}\}$ $[181 \pm 91 \text{ lbf}\cdot\text{ft}]$.
2. Tighten by turning $30 \pm 1.5^\circ$.
3. Tighten by further turning $30 \pm 1.5^\circ$. (total of $60 \pm 3^\circ$ turn)
4. Loosen all bolts, and tighten again according to the angle method. (tightening twice)

(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			Remark
		N·m	kgf·m	lbf·ft	
Air duct clamp	6 × 1.0	4.9 ± 0.49	0.5 ± 0.05	3.6 ± 0.4	T-bolt type
Exhaust manifold V-clamp (nut)	6 × 1.0	8.4 ± 0.45	0.85 ± 0.05	6.2 ± 0.3	
Exhaust pipe V-clamp	1/4 - 28 UNF	9 ± 1	0.9 ± 0.1	6.6 ± 0.7	
Exhaust manifold mounting bolt	10 × 1.5	98 ± 4.9	10 ± 0.5	72 ± 3.6	
Turbocharger compressor wheel (nut) (left-handed thread)	11 × 1.0	Note			Apply Molykote to threads.
Compressor cover	-	8.8 ± 1.0	0.9 ± 0.1	6.5 ± 0.7	Apply Molykote to threads.
Turbine housing	8 × 1.25	19.6 ± 2.0	2.0 ± 0.2	14.5 ± 1.4	

Note: Tighten nut to $9.8 \text{ N}\cdot\text{m}$ $\{1.0 \text{ kgf}\cdot\text{m}\}$ $[7.2 \text{ lbf}\cdot\text{ft}]$ then loosen. Tighten again to $9.8 \text{ N}\cdot\text{m}$ $\{1.0 \text{ kgf}\cdot\text{m}\}$ $[7.2 \text{ lbf}\cdot\text{ft}]$, then further turn $80^\circ \pm 3^\circ$.

2.1.3 Fuel system

Table 2-10 Tightening torque list - Fuel system

Description	Threads Dia × Pitch (mm)	Torque.			Remark
		N·m	kgf·m	lbf·ft	
Fuel injection pump coupling shaft	14 × 1.5	171 to 181	17.5 to 18.5	127 to 134	Tightening slip part.
Fuel injection pump laminated plate	12 × 1.25	113 to 123	11.5 to 12.5	83 to 90	Tightening twice
Fuel injection pump	12 × 1.25	108 ± 5.4	11 ± 0.55	80 ± 4.0	
Fuel injection pump bracket	12 × 1.25	108 ± 5.4	11 ± 0.55	80 ± 4.0	
Fuel injection pump flywheel (nut)	24 × 1.5	392	40	289	
Plunger assembly	12 × 1.25	78 to 83	8.0 to 8.5	58 to 61	
Deliver valve holder	30 × 1.5	235 to 255	24 to 26	174 to 188	Tightening twice
Injection pipe (nozzle and pump sides)	18 × 1.5	59 ± 10	6 ± 1	43.5 ± 7.5	
Fuel rack control lever	8 × 1.25	25 ± 1.25	2.5 ± 0.13	18 ± 0.9	Tightening twice
Fuel injection pump check valve assy	14 × 1.5	56 ± 6	5.7 ± 0.6	41 ± 4.3	
Fuel injection pump check valve self locking nut	12 × 1.25	34 ± 3.9	3.5 ± 0.4	25 ± 2.9	
Fuel injection pump deflector bolt	12 × 1.25	59	6	43	
Fuel injection pump front and rear cover	8 × 1.25	21	2.1	15	
Fuel injection pump rack set screw	8 × 1.25	21	2.1	15	
Fuel injection pump center bearing	8 × 1.25	21	2.1	15	
Fuel injection pump air vent plug	8 × 1.25	15 ± 2.0	1.5 ± 0.2	11 ± 1.4	
Fuel injection pump drain plug	12 × 1.25	21	2.1	15	
Fuel injection pump oil drain pipe eye bolt	14 × 1.5	34 ± 3.9	3.5 ± 0.4	25 ± 2.9	
Feed pump priming pump	16	41.5 ± 2.5	4.25 ± 0.25	31 ± 1.8	
Feed pump plug	16	41.5 ± 2.5	4.25 ± 0.25	31 ± 1.8	
Fuel pump adapter	24	54 ± 5	5.5 ± 0.5	61.5 ± 3.5	
Feed pump plug	26	83 ± 5	8.5 ± 0.5	61.5 ± 3.5	
Feed pump eye bolt	14	31.5 ± 2.5	3.21 ± 0.25	23.2 ± 1.8	
Fuel filter air vent plug	8 × 1.25	9 ± 1.0	0.9 ± 0.1	7 ± 0.7	
Nozzle tip retaining nut	28 × 1.5	186.5 ± 9.5	19 ± 1	137.5 ± 7.5	
Nozzle inlet connector	16 × 1.5	69 ± 4.9	7 ± 0.5	51 ± 3.6	
Nozzle holder cap nut	14 × 1.5	73.5 ± 4.9	7.5 ± 0.5	54.5 ± 3.6	Note
Nozzle holder set screw	10 × 1.5	39 ± 4.9	4 ± 0.5	29 ± 3.6	
Nozzle gland (nut)	14 × 1.5	98 ± 4.9	10 ± 0.5	72 ± 3.6	

Note: Tighten cap nut with oil applied to the top and bottom surfaces of sealing washer. Be sure to perform torque check at least 3 times.

2.1.4 Lubrication system

Table 2-11 Tightening torque list - Lubrication system

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Oil pump and water pump mounting plate	12 × 1.25	59 ± 5.9	6 ± 0.6	43 ± 4.3	
Oil pump	12 × 1.25	108 ± 10.8	11 ± 1.1	80 ± 8.0	
Oil pump cover	10 × 1.25	33 ± 3.3	3.4 ± 0.34	24 ± 2.5	
Safety valve plug	24 × 1.5	88 ± 10	9 ± 1.0	65 ± 7.2	
Safety valve assembly	32 × 2.0	74 ± 10	7.5 ± 1.0	54 ± 7.2	
Oil pan	12 × 1.25	59 ± 5.9	6 ± 0.6	43 ± 4.3	

2.1.5 Cooling system

Table 2-12 Tightening torque list - Cooling system

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Water pump	12 × 1.25	108 ± 10.8	11 ± 1.1	80 ± 8.0	
Water pump shaft pulley (nut)	30 × 1.5	392 ± 19.0	40 ± 2.0	289 ± 14	For alternator
2-way water pump pulley (nut)	24 × 1.5	245 ± 36	25 ± 3.75	181 ± 26.5	
2-way water pump pipe		22.5 ± 2.25	2.29 ± 0.23	17 ± 1.7	Coat with loctite 271
2-way water pump plug	PT 1/4	12.3 ± 2.45	1.25 ± 0.25	9 ± 1.8	

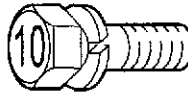
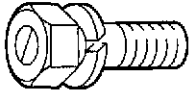
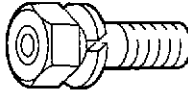
2.1.6 Electrical system

Table 2-13 Tightening torque list - Electrical system

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Starter	12 × 1.25	59 ± 5.9	6 ± 0.6	43 ± 4.3	
Alternator pulley set nut	20 × 1.5	147 ± 15	15 ± 1.5	108.5 ± 11	

2.2 Standard bolt and nut tightening torque

Table 2-14 Standard bolt and nut tightening torque

Description	Thread Dia × Pitch (mm)	Width across flats (mm) [in.]	Strength classification					
			7T			10.9		
Metric automobile screw thread								
			N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft
	M8 × 1.25	12 [0.47]	17	1.7	12	30	3.1	22
	M10 × 1.25	14 [0.55]	33	3.4	25	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	129
	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	278
	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	647
	M27 × 1.5	41 [1.61]	738	75.3	544	1328	135.5	980
Metric coarse screw thread								
			N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft
	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	200	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	911

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 $\pm 10\%$.

(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	5.8 ± 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 ± 2.9
M16 × 1.5	22 [0.87]	44 ± 5	4.5 ± 0.5	33 ± 3.6
M18 × 1.5	24 [0.94]	74 ± 5	7.5 ± 0.5	54 ± 3.6
M20 × 1.5	27 [1.06]	98 ± 10	10.0 ± 1.0	72 ± 7.2
M24 × 1.5	32 [1.26]	147 ± 15	15.0 ± 1.5	109 ± 11
M27 × 1.5	41 [1.61]	226 ± 20	23.0 ± 2.0	166 ± 15

(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

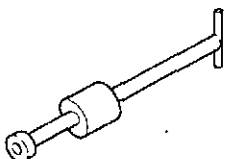
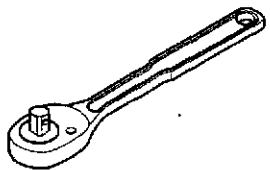
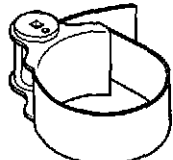
(Dry)

SERVICE TOOLS

1. General tools 3-2
2. Special tools 3-3

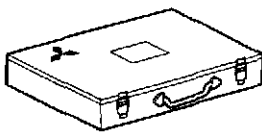
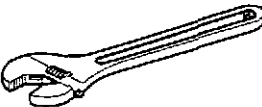
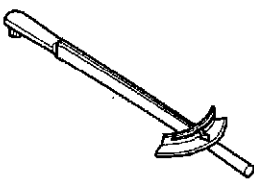
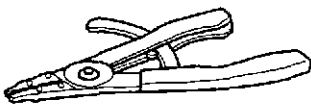
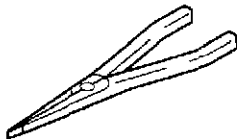
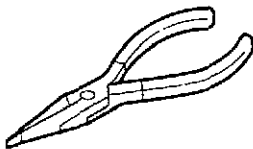
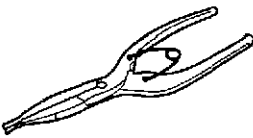
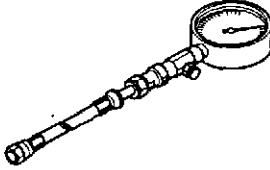
1. General tools

Table 3-1 General tools

Tool name	Part No.	Shape	Remark
Nozzle remover	33591-10101		Fuel injection nozzle removal
Ratchet handle	37191-03300		Use with socket
Oil filter wrench	32591-22100		Oil filter/fuel filter removal

2. Special tools

Table 3-2 Spécial tools(1 / 7)

Service	Tool name/Part No.	Shape	Remark
General	Tool box 49160-90501		Tool box 75 × 203 × 360 mm [2.95 × 7.99 × 14.17 in.]
	Adjustable wrench F9611-15000		Max. open width 20 mm [0.79 in.]
	Torque wrench 32191-03100		Range applicable: 0 to 539 N·m {0 to 55 kgf·m} [0 to 398 lbf·ft]
	Ring pliers 45191-08400		Snap ring removal/installation
	Ring pliers 49160-90101		Snap ring removal/installation
	Ring pliers 49160-90201		Snap ring removal/installation
	Compression gauge 49160-90301		Snap ring removal/installation
Determination of overhaul timing and test	Compression gauge 35A91-03100		Compression pressure measurement, 0 to 7 MPa {(0 to 70 kgf/cm²)} [0 to 996 psi]

SERVICE TOOLS

Table 3-2 Special tools(2 / 7)

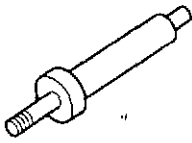
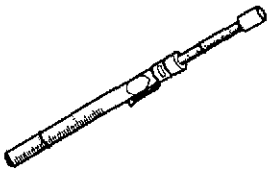
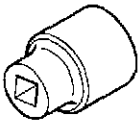
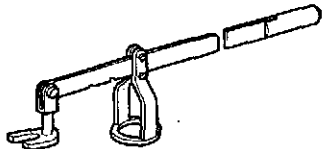
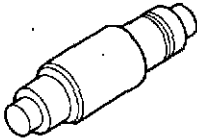
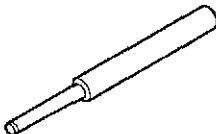
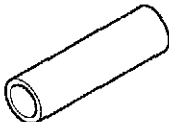
Service	Tool name/Part No.	Shape	Remark
Determination of overhaul timing and test	Gauge adapter 37591-02200		Compression pressure measurement, US/8 - 18 threads
Inspection	V-belt gauge 32591-09100		V-belt tension measurement
Removal of systems	Socket 58309-73100		Width across flats: 46 mm [1.811 in.] Shank size: 19 mm [0.75 in.]
Cylinder head, valve mechanism	Eye nut 37591-02400		Cylinder head assembly removal/installation
	Valve spring pusher 33591-04500		Inlet and exhaust valve spring removal/installation Handle plate length: 600mm [23.62 in.]
	Rocker bushing tool 37591-02600		Rocker bushing replacement
	Valve guide remover 33591-04300		Valve guide removal
	Guide & seal installer 37191-11500		Valve guide and stem seal installation

Table 3-2 Special tools(3 / 7)

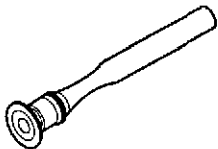
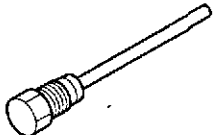
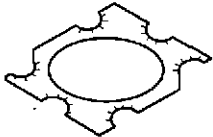
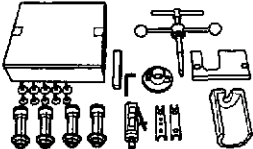
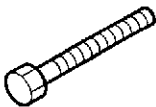
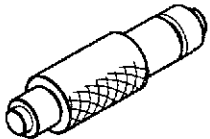
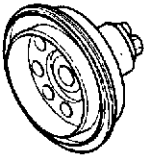
Service	Tool name/Part No.	Shape	Remark
Cylinder head, valve mechanism	Valve lapper 30091-08800		Inlet and exhaust valve lapping
	Valve seat cutter shaft 37591-06400		Valve seat correction
	Valve seat cutter 37591-06430		
	Head bolt plate 37598-08900		Angle tightening of cylinder head bolt
	Valve seat puller 32591-04200		Valve seat removal
Flywheel, timing gear and camshaft	Jack bolt 64362-68500		Flywheel removal M12 × 1.25-95 mm [3.74 in.]
	Idler bushing puller 32591-02500		Idler bushing replacement
	Rear seal installer assembly 37791-06010		Rear oil seal insertion

Table 3-2 Special tools(4 / 7)

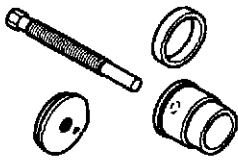
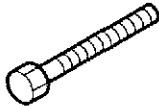
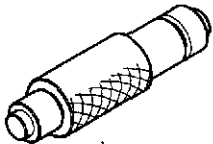
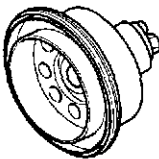
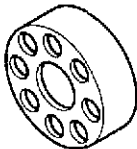
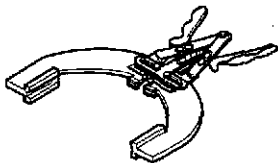
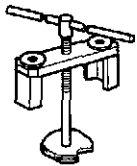
Service	Tool name/Part No.	Shape	Remark
Flywheel, timing gear and camshaft	Cam bushing tool assembly 37591-08020		Camshaft bushing press-fitting/removal
Damper and front gear	Jack bolt 64362-68500		Oil pump and water pump mounting plate removal M12 × 1.25 - 95 mm [3.74 in.]
	Idler bushing puller 32591-02500		Idler bushing replacement
	Front seal installer assembly 37591-05010		Front oil seal insertion
	Front slinger insert 37591-03900		Front slinger in insertion
Cylinder liner, piston and connecting rod	Piston remover MM321420		Piston removal M10 × 1.5 mm
	Ring expander 37191-03200		Piston ring removal/installation Applicable range: ø 101.6 to 177.8 mm [4.000 to 7.000 in.]
	Cylinder liner remover 37591-04100		Cylinder liner removal

Table 3-2 Special tools(5 / 7)

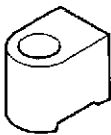
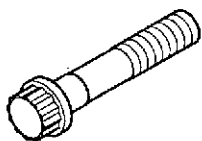
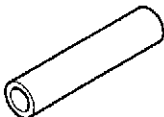
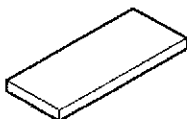
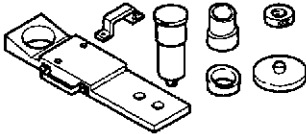
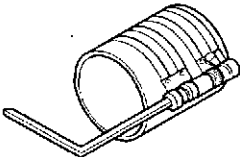
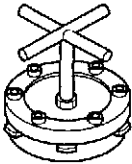
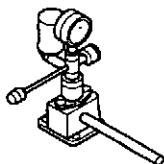
Service	Tool name/Part No.	Shape	Remark
Cylinder liner, piston and connecting rod	Liner pusher 37591-06200		Cylinder liner flange projection measurement
	Bolt 37591-06300		Cylinder liner flange projection measurement M22 × 2.5 mm
	Head bolt spacer 37598-09100		Cylinder liner flange projection measurement
	Projection plate 37598-09201		Step depth measurement
	Connecting rod bushing installer 37591-01010		Connecting rod bushing removal/installation
	Piston installer 37191-07100		Piston insertion
	Crankcase grinder 37591-07010		Crankcase step correction
Fuel injection pump	Nozzle tester 83091-03301		Fuel injection nozzle valve opening pressure measurement

Table 3-2 Special tools(6 / 7)

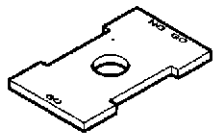
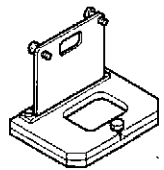
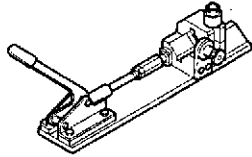
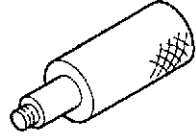
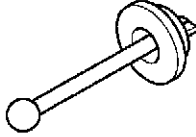
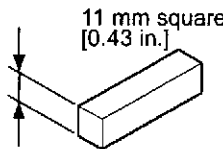
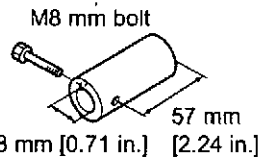
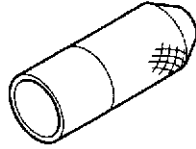
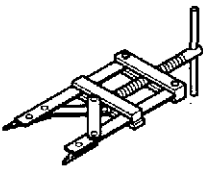
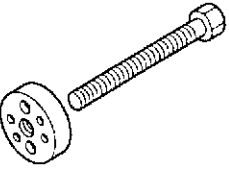
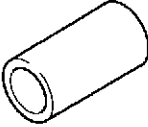
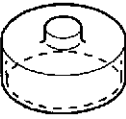
Service	Tool name/Part No.	Shape	Remark
Fuel injection pump	Injection coupling gauge 37591-06100		Fuel injection pump coupling clearance adjustment
	Pump assembling stand 48291-00100		Fuel injection pump disassembly/reassembly
	Plunger spring compression tool 48291-00200		Plunger spring removal/installation
	Plunger holder 48291-00301		Plunger spring removal/installation (8 pcs.)
	Cam thrust ejector 48291-00400		Camshaft thrust clearance measurement
	Projection plate 48291-00500	 11 mm square [0.43 in.]	Prevention of damage on pinion and rack when installing barrel
	Rack set jig 48291-00600	 M8 mm bolt 57 mm ø18 mm [0.71 in.] [2.24 in.]	Control rack assembling
	Sleeve installer 48202-09301		Striking camshaft oversize sleeve.

Table 3-2 Special tools(7 / 7)

Service	Tool name/Part No.	Shape	Remark
Water pump	Water pump pliers 37591-03100		Removal of snap ring on water pump cover
	Impeller remover 37591-03200		Water pump impeller removal M 18 × 1.5 mm
	Ring remover 37791-03400		Water pump unit seal removal
	Ring installer 37791-03300		Striking water pump unit seal
	Socket 58309-73100		Water pump shaft pulley nut removal/installation Width across flats: 46 mm [1.81 in.] Shank size: 19 mm [0.75 in.]
	Unit seal installer 37191-06300		Press-fitting of water pump unit seal ring

DETERMINATION OVERHAUL

1. Determining overhaul timing 4-2
2. Testing compression pressure 4-3

1. Determining overhaul timing

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.

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.

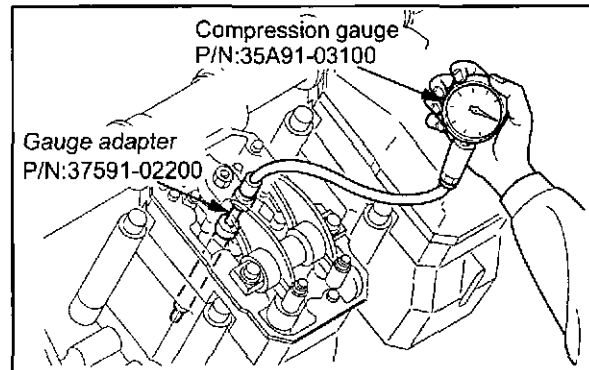
- (1) Decreased output power
- (2) Increased fuel consumption
- (3) Increased engine oil consumption
- (4) Increased blow-by gas through the breather due to worn cylinder liners and piston rings (Visually check the blow-by amount)
- (5) Increased gas leakage due to poor seating of inlet and exhaust valves
- (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 judgment.

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 for the remaining cylinder.
 - (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 injection nozzle from the cylinder head where the compression pressure is to be measured.
 - (2) Attach the compression gauge adapter 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.



Testing Compression Pressure

Item	Standard	Limit
Compression pressure	1.81 MPa {18.5 kgf/cm ² } [263 psi] or more	1.27 MPa {13 kgf/cm ² } [185 psi] or more

Note: Measure the compression pressure with the engine running at 120 min⁻¹.

DISASSEMBLY OF BASIC ENGINE

1. Disassembling cylinder head and valve mechanism 5-2
 - 1.1 Removing fuel injection nozzle 5-3
 - 1.2 Removing rocker shaft assembly and push rod 5-3
 - 1.3 Disassembling rocker shaft assembly 5-3
 - 1.4 Removing valve bridge 5-4
 - 1.5 Removing rocker case 5-4
 - 1.6 Removing cylinder head assembly 5-4
 - 1.7 Removing valve and valve spring 5-5

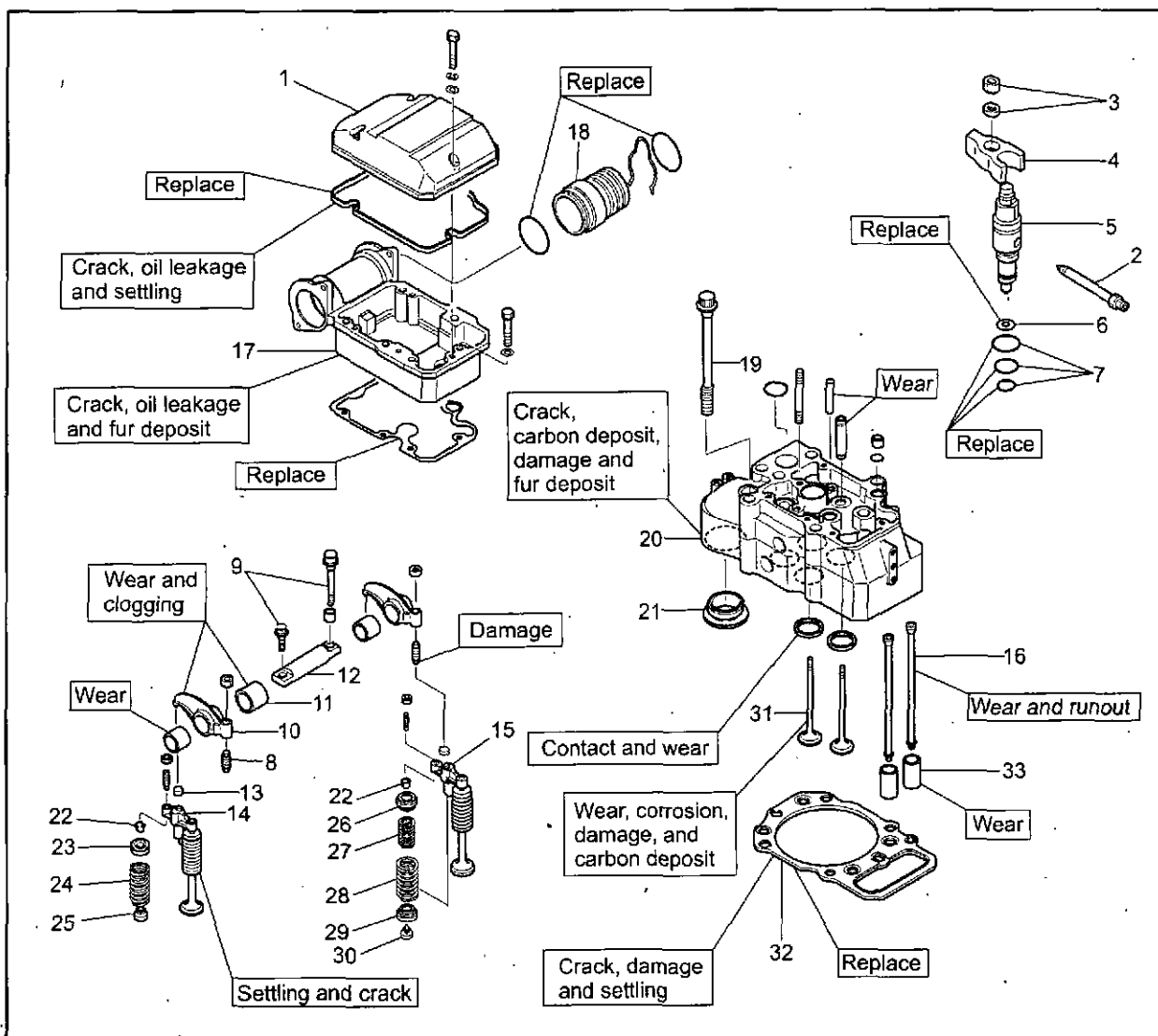
2. Disassembling flywheel, timing gear, camshaft 5-6
 - 2.1 Removing flywheel 5-7
 - 2.2 Removing idler shaft thrust collar 5-7
 - 2.3 Removing timing gear case 5-7
 - 2.4 Measuring timing gear backlash and end play 5-8
 - 2.5 Removing accessory drive (right and left) 5-8
 - 2.6 Removing idler gear 5-8
 - 2.7 Removing idler shaft 5-9
 - 2.8 Removing camshaft gear 5-9
 - 2.9 Removing camshaft 5-9

3. Disassembling damper and front gear 5-10
 - 3.1 Removing crankshaft pulley 5-11
 - 3.2 Removing damper 5-11
 - 3.3 Removing mounting plate for oil and water pumps 5-11
 - 3.4 Removing oil pump gear 5-11
 - 3.5 Removing front gear case 5-12
 - 3.6 Removing bearing cover for oil and water pumps 5-12
 - 3.7 Measuring idler gear backlash and end play 5-12
 - 3.8 Removing idler gear on the front side 5-12
 - 3.9 Removing idler shaft on the front side 5-13

4. Disassembling cylinder liner, piston and connecting rod 5-14
 - 4.1 Removing connecting rod cap 5-15
 - 4.2 Removing carbon deposits from the upper part of cylinder liner 5-15
 - 4.3 Removing piston 5-16
 - 4.4 Removing piston ring 5-16
 - 4.5 Removing piston pin and piston 5-17

5. Disassembling crankcase, crankshaft and main bearing 5-18
 - 5.1 Turning over crankcase 5-19
 - 5.2 Removing main bearing cap 5-19
 - 5.3 Removing crankshaft 5-19
 - 5.4 Removing piston cooling nozzle 5-20

1. Disassembling cylinder head and valve mechanism



Disassembling cylinder head and valve mechanism

Disassembling sequence

- | | | |
|--------------------------|---|-------------------------|
| 1 Rocker cover | 12 Rocker shaft | 23 Valve rotator |
| 2 Fuel inlet connector | 13 Bridge cap | 24 Valve spring |
| 3 Nut and washer | 14 Valve bridge (inlet) | 25 Stem seal |
| 4 Nozzle gland | 15 Valve bridge (exhaust) | 26 Double rotator |
| 5 Fuel injection nozzles | 16 Push rod | 27 Valve spring (inner) |
| 6 Gasket | 17 Rocker case | 28 Valve spring (outer) |
| 7 O-ring | 18 Water outlet connector | 29 Lower retainer |
| 8 Adjusting screw | 19 Cylinder head bolt | 30 Stem seal |
| 9 Bolt | 20 Cylinder head (weight: approx. 35 kg [77.16 lb]) | 31 Valve |
| 10 Rocker | 21 Inlet port packing | 32 Cylinder head gasket |
| 11 Spacer | 22 Valve cotter | 33 Tappet |

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 fuel injection nozzle

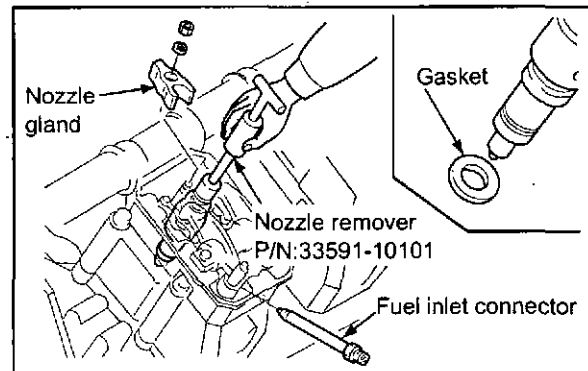
CAUTION

When removing a nozzle holder, wipe dust off the nozzle assembly, and prevent dust from entering the cylinder head when the nozzle holder is removed. Keep the nozzle and the fuel inlet connector together, and handle the nozzle with care to avoid damage to the nozzle tip.

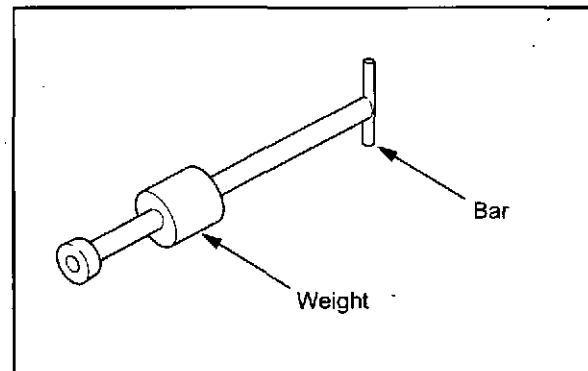
CAUTION

When removing the nozzle assembly using a nozzle remover, be careful not to get caught your fingers between the nozzle remover weight, bar and the plate.

- (1) Remove the fuel inlet connector and nozzle gland.
- (2) Using the nozzle remover, pull out the nozzle holder.
- (3) Remove the remaining gasket from inside the cylinder head.



Removing fuel injection nozzle



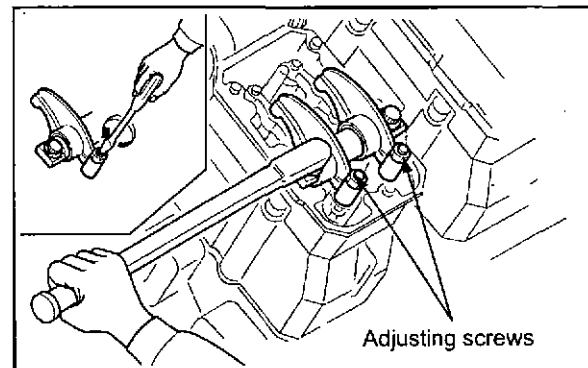
Nozzle remover

1.2 Removing rocker shaft assembly and push rod

- (1) Loosen the adjusting screw on each rocker arm.
- (2) Unscrew the rocker shaft mounting bolts, and dismount the rocker arm assemblies.

Note: Remove the rocker arm assembly together with mounting bolts, and keep them together.

- (3) Remove the push rod.



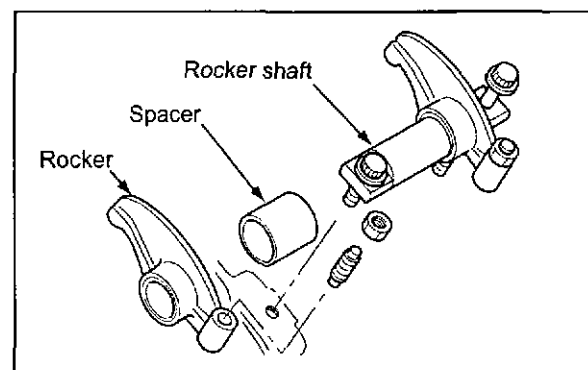
Removing rocker shaft assembly

1.3 Disassembling rocker shaft assembly

Disassemble the rocker shaft assembly.

Note: Be sure to arrange the parts in order during disassembly. Keep the original combination of rocker arm and shaft assembly, and when reassembling, make sure to install them in their original positions to restore the same clearance between the rocker shaft and arms.

Do not remove the rocker bushing unless it is defective or its inside diameter exceeds the limit.

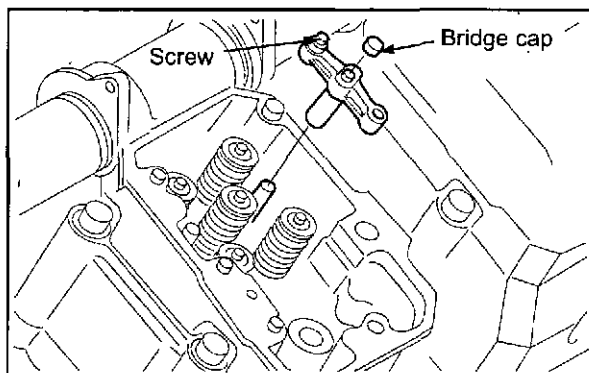


Disassembling rocker shaft assembly

1.4 Removing valve bridge

Remove the valve bridge and bridge cap.

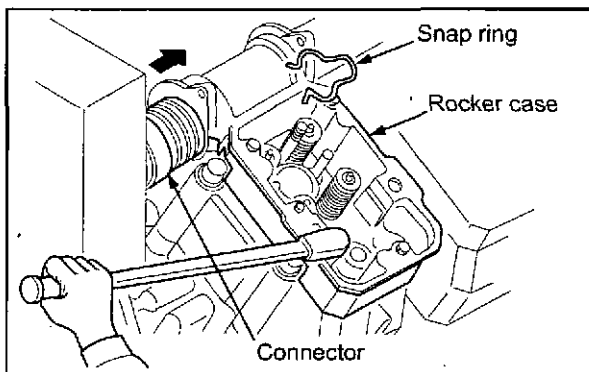
Note: Be careful not to drop bridge caps into the crankcase through the pushrod holes.



Removing valve bridge

1.5 Removing rocker case

- (1) Remove the snap ring from the water outlet connector, and slide the connector toward the snap ring groove.
- (2) Unscrew the rocker case mounting bolts, and dismount the rocker case from the cylinder head.



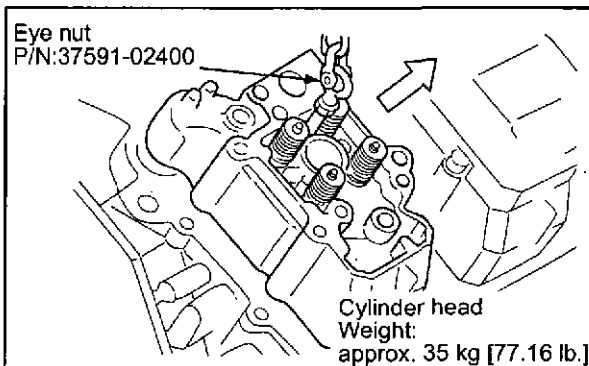
Removing rocker case

1.6 Removing cylinder head assembly

CAUTION

When removing the cylinder head gasket, be careful not to damage the cylinder head or crankcase surface by tools such as a screwdriver.

- (1) Remove cylinder head bolts.
- (2) Remove the cylinder head by lifting it up using the eye bolt, as dowel pins are used to hold the cylinder heads in position.
- (3) Remove the cylinder head gasket.

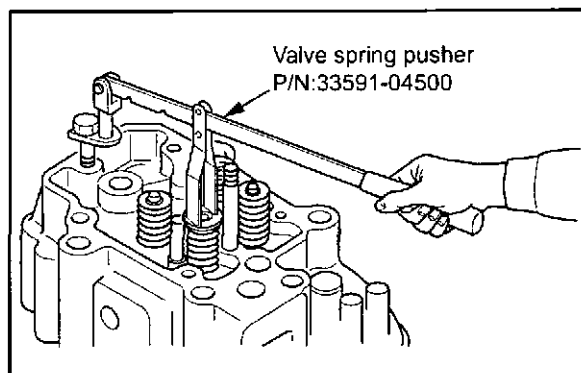


Removing cylinder head assembly

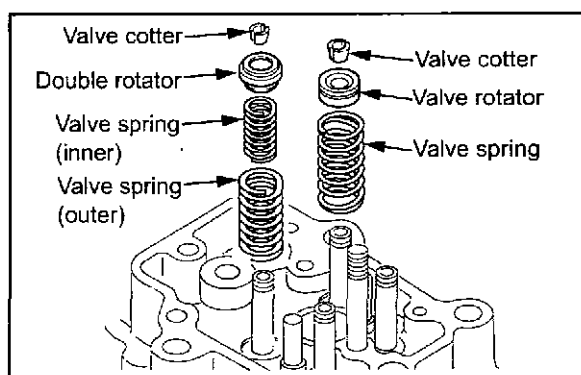
1.7 Removing valve and valve spring

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.

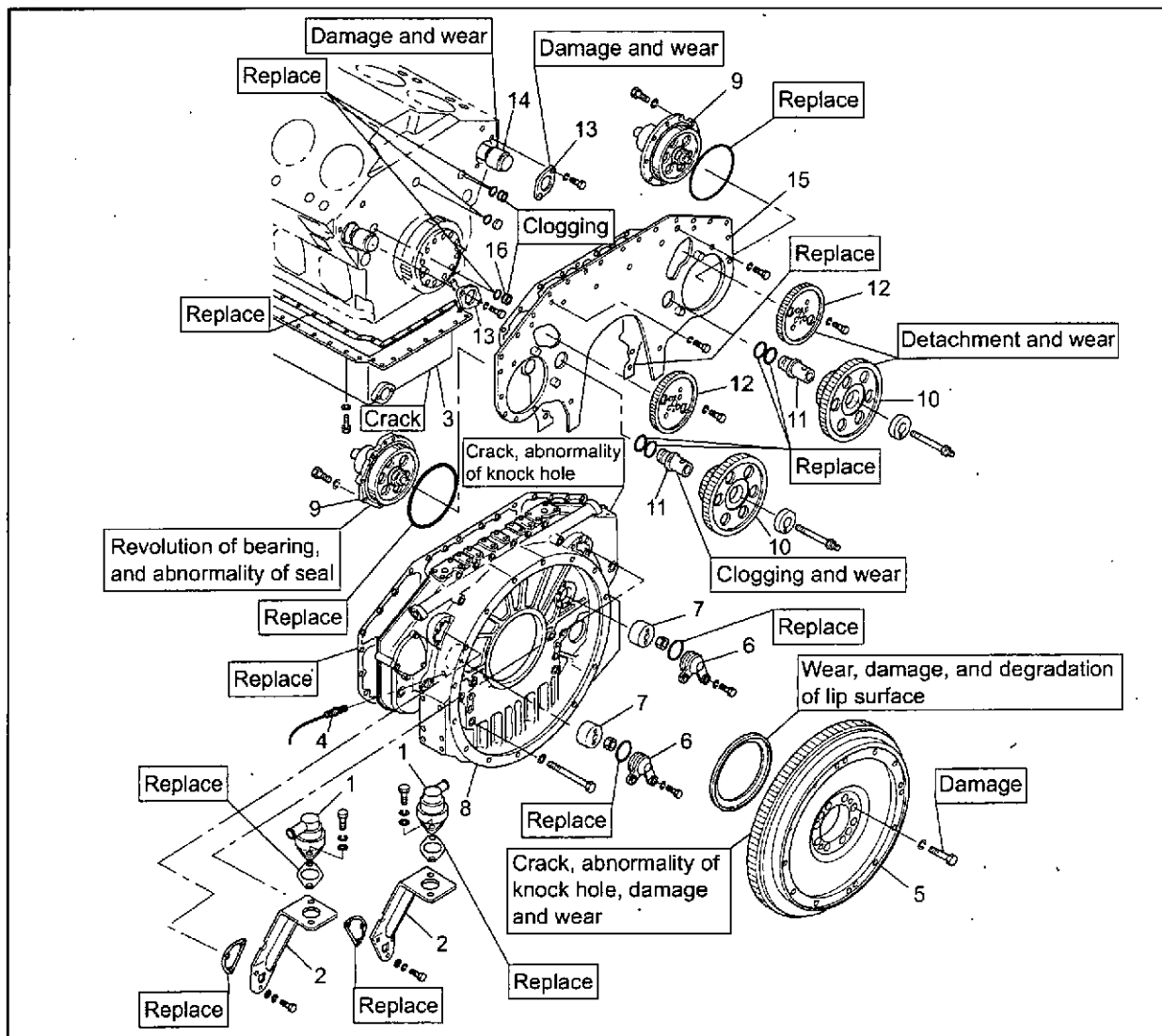


Removing valve and valve spring (1)



Removing valve and valve spring (2)

2. Disassembling flywheel, timing gear, camshaft



Disassembling flywheel, timing gear, camshaft

Disassembling sequence

- | | |
|--|--|
| 1 Breather | 10 Idler gear |
| 2 Breather pipe | 11 Idler shaft |
| 3 Oil pan | 12 Camshaft gear |
| 4 Pickup | 13 Thrust plate |
| 5 Flywheel (weight: approx. 140 kg [308.64 lb.]) | 14 Camshaft (weight: approx. 50 kg [110.23 lb.]) |
| 6 Cover | 15 Rear plate |
| 7 Idler shaft thrust collar | 16 Nozzle plate |
| 8 Timing gear case, oil seal (weight: approx. 150 kg [330.69 lb.]) | |
| 9 Fuel injection pump and feed pump accessory drive
(Refer to the pages of fuel system for disassembly, inspection and assembly.) | |

CAUTION

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

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

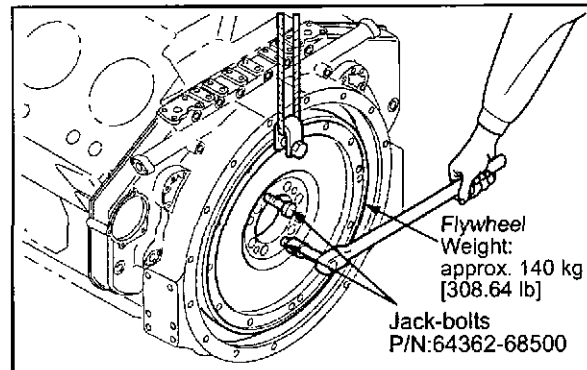
2.1 Removing flywheel

⚠ 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

- (a) Be sure to remove the pickups before removing the flywheel.
 - (b) Use jack bolts with convex and round ends. Do not use jack bolts with sharp edge, as they may cause damage to the surface of crankshaft.
- (1) Attach a lifting sling to the flywheel to prevent from falling out.
 - (2) Remove the flywheel mounting bolts.
 - (3) Screw two jack bolts evenly into bolt holes, and remove the flywheel.

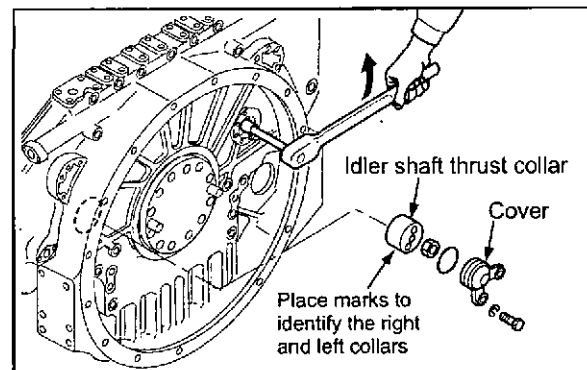


Removing flywheel

2.2 Removing idler shaft thrust collar

- (1) Unscrew the cover mounting bolts, and dismount the cover.
- (2) Unscrew the idler thrust collar mounting bolts located on the rear end of the timing gear case. Before removing the collar, mark the collar to ensure correct position at assembly.
- (3) Screw bolts into the holes of thrust collar, and pull out the thrust collar.

Note: Mark each collar right and left to ensure correct position so that the same backlash and end play can be restored at assembly.



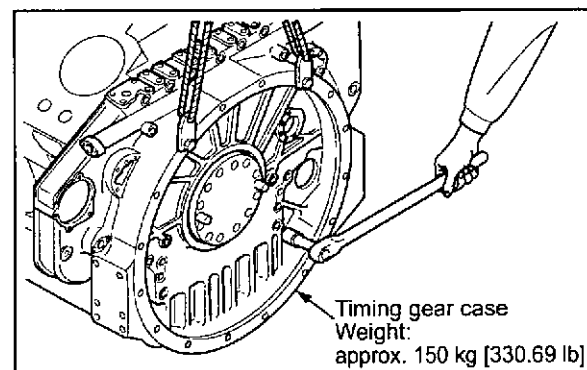
Removing idler shaft thrust collar

2.3 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.

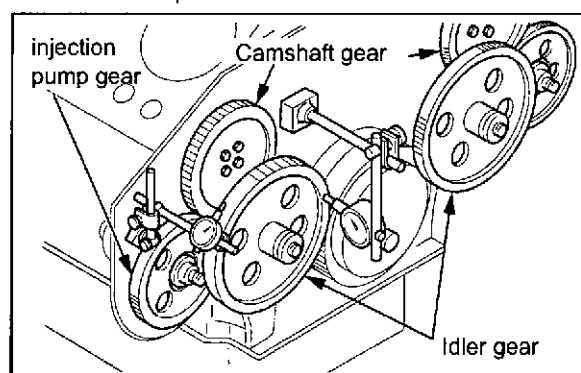
- (1) Attach a lifting sling to the the timing gear case to prevent it from falling out.
- (2) Remove the timing gear case mounting bolts.
- (3) While lifting and supporting the timing gear case, remove the timing gear case by sliding it out until the gear case is disengaged from the dowel pins. Be careful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



Removing timing gear case

2.4 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.



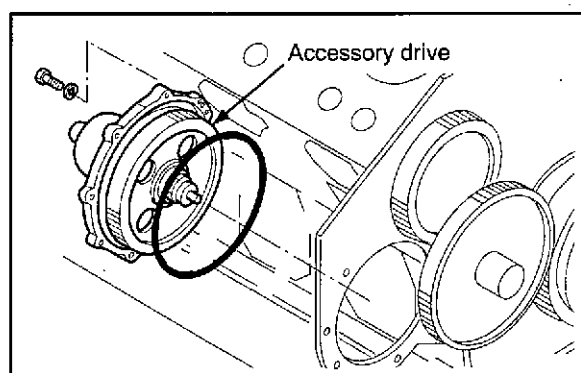
Measuring timing gear backlash and end play

2.5 Removing accessory drive (right and left)

Unscrew the mounting bolts of the injection pump drive case, and dismount the accessory pump drive. Be careful not to damage the gear teeth.

(See the "Fuel System" section for disassembly, inspection and reassembly.)

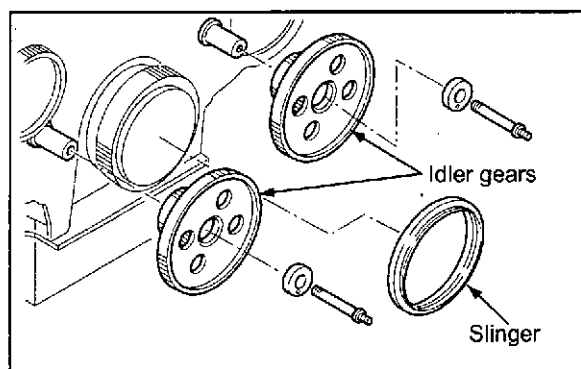
Note: Before removing the left-side accessory drive case, dismount the cam cover of the No.16 cylinder.



Removing accessory drive (right and left side)

2.6 Removing idler gear

- (1) Remove the crankshaft slinger.
- (2) Remove the idler gears (right and left).

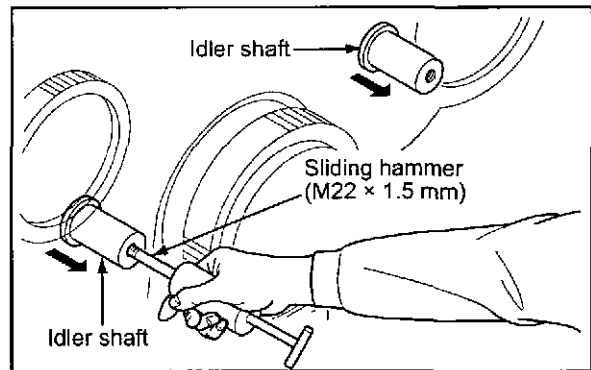


Removing idler gear

2.7 Removing idler shaft

Do not remove the idler shafts unless repair or replacement is necessary.

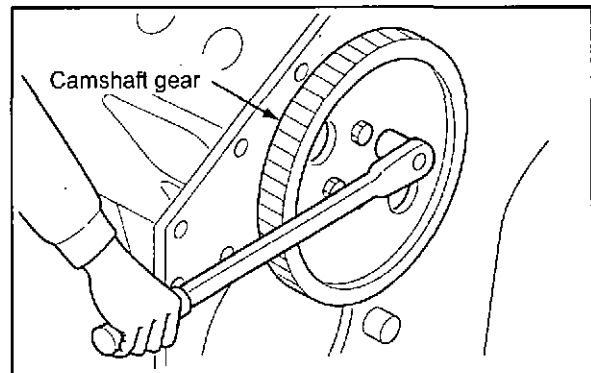
For dismantling, attach a sliding hammer to the extraction hole of the idler shaft, and pull out the idler shaft.



Removing idler shaft

2.8 Removing camshaft gear

Unscrew the camshaft gear mounting bolts, and remove the camshaft gears.



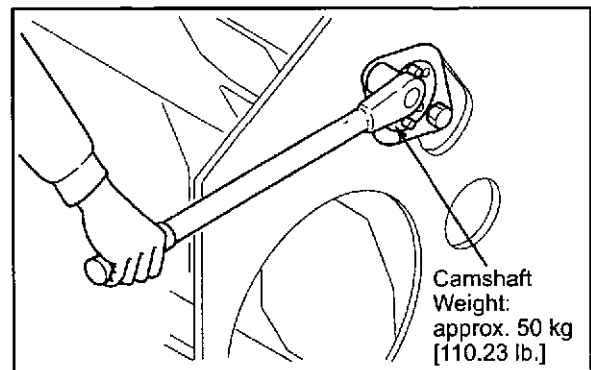
Removing camshaft gear

2.9 Removing camshaft

CAUTION

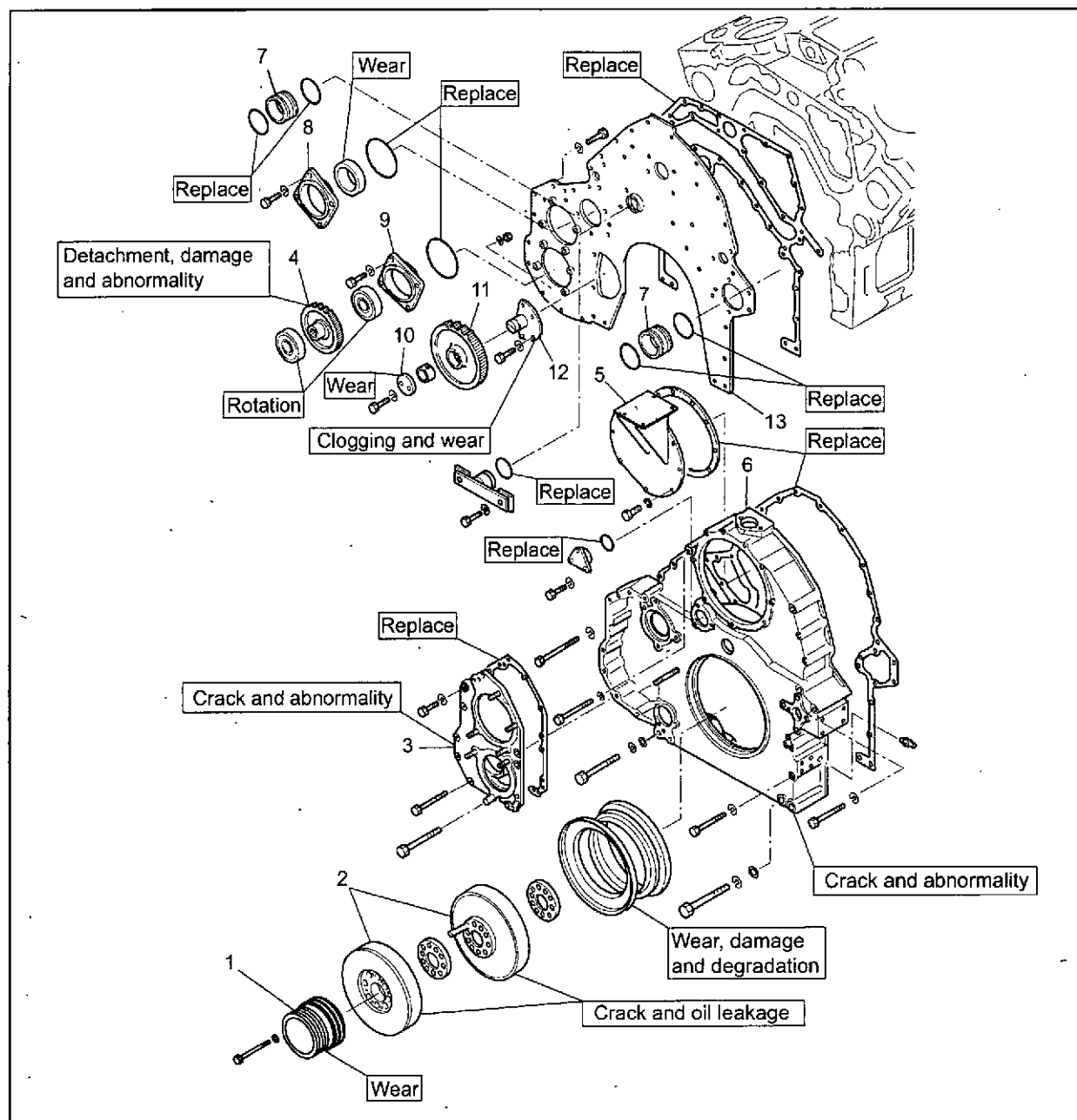
To prevent damage to the cam surfaces and bushings of the camshaft, support the camshaft with a bar inserted through the side cover mounting section when removing the camshaft.

Unscrew the thrust plate mounting bolts, and remove the camshaft from the crankcase.



Removing camshaft

3. Disassembling damper and front gear



Disassembling damper and front gear

Disassembling sequence

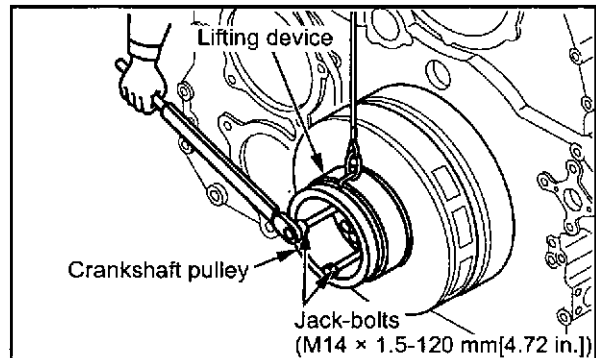
- | | |
|---|---|
| 1 Crankshaft pulley | 8 Water pump bearing cover |
| 2 Damper
(weight: approx. 50 kg [110.23 lb.] on the front side and
approx. 56 kg [123.46 lb.] on the rear side) | 9 Oil pump bearing cover |
| 3 Plate | 10 Thrust plate |
| 4 Oil pump gear | 11 Idler gear |
| 5 Thermo case bracket | 12 Idler shaft |
| 6 Front gear case (weight: approx. 70 kg [154.32 lb]) | 13 Front plate (weight: approx. 25 kg [55.11 lb]) |
| 7 Water coupling | |

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.

- (1) To prevent the crankshaft pulley from falling, attach a lifting device.
- (2) Unscrew the crankshaft pulley mounting bolt.
- (3) Screw two jack bolts evenly into bolt holes, and remove the crankshaft pulley.



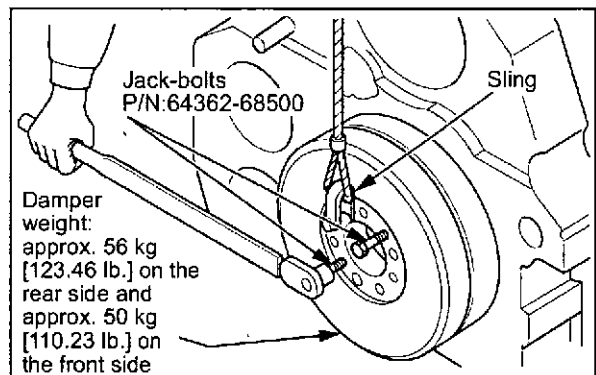
Removing crankshaft pulley

3.2 Removing damper

CAUTION

Use the jack-bolts with convex and round ends. Do not use the jack-bolts with sharp angles as they may cause damage to the surface of spacer

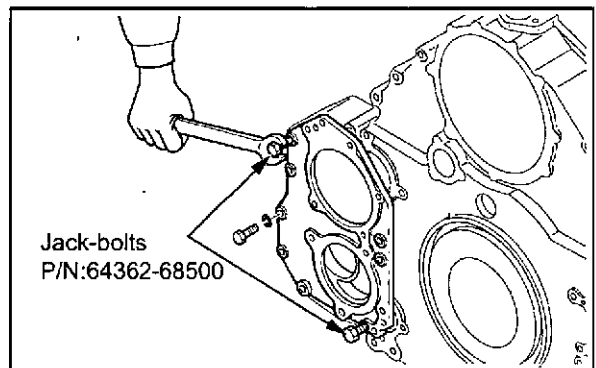
- (1) To support the damper to prevent it from falling attach a sling to the damper and unscrew the damper mounting bolts.
- (2) Screw two jack-bolts evenly into bolt holes, and remove the damper.



Removing damper

3.3 Removing mounting plate for oil and water pumps

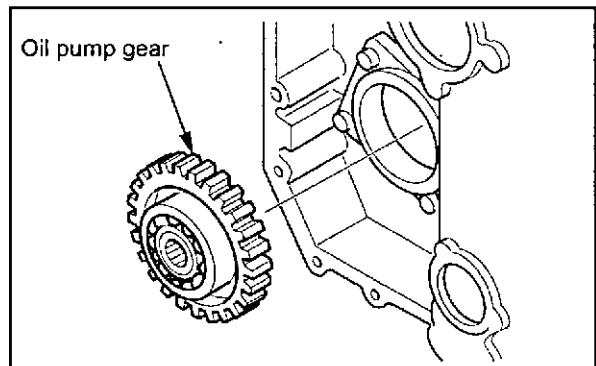
Unscrew the mounting bolts of the plate, and dismount the plate by evenly screwing two jack bolts (special tool) into the bolt holes of plate.



Removing mounting plate for oil pump and water pump

3.4 Removing oil pump gear

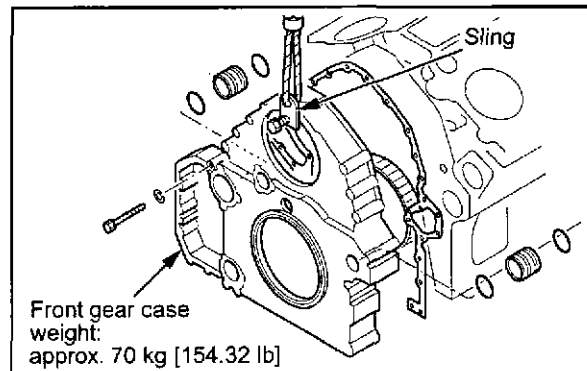
Pull out the oil pump gear together with the bearing.



Removing oil pump gear

3.5 Removing front gear case

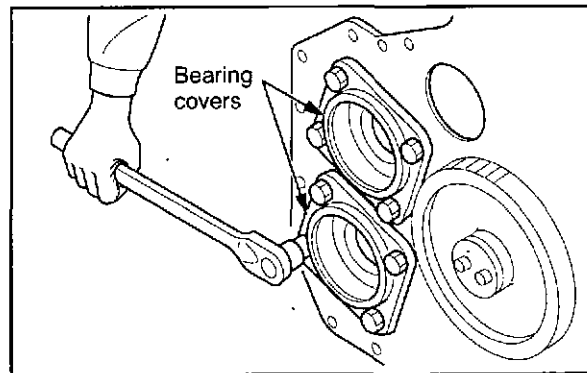
- (1) Attach a sling to the front gear case.
- (2) Unscrew the front gear mounting bolts, and dismount the front gear case by suspending and pulling it out until the gear case is disengaged from the dwell pins. When removing the gear case, be careful not to damage the oil seal or bend the pointer by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



Removing front gear case

3.6 Removing bearing cover for oil and water pumps

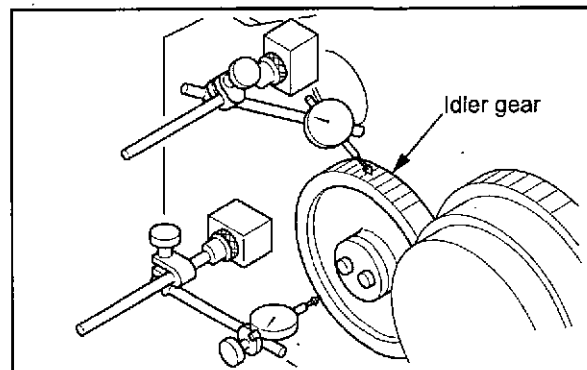
Unscrew the bearing cover mounting bolts, and dismount the bearing cover.



Removing water pump bearing cover

3.7 Measuring idler gear backlash and end play

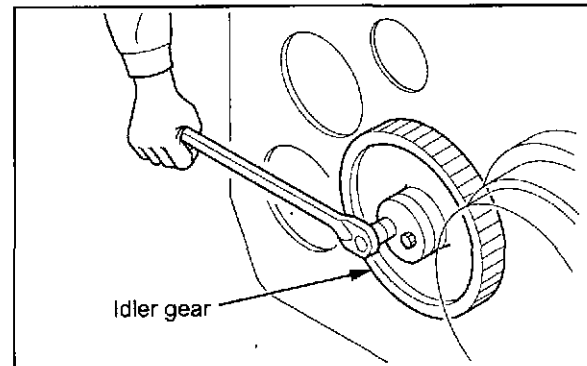
Measure the backlash and the end play of the front idler gear, and make a note of them to use as a reference for parts replacement.



Measuring idler gear backlash and end play

3.8 Removing idler gear on the front side

Unscrew the thrust plate mounting bolts, and dismount the idler gear.



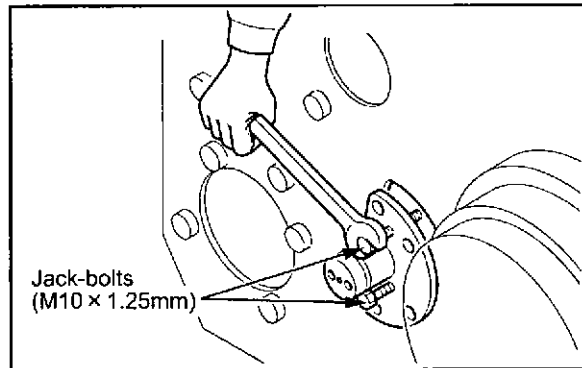
Removing idler gear on the front side

3.9 Removing idler shaft on the front side

CAUTION

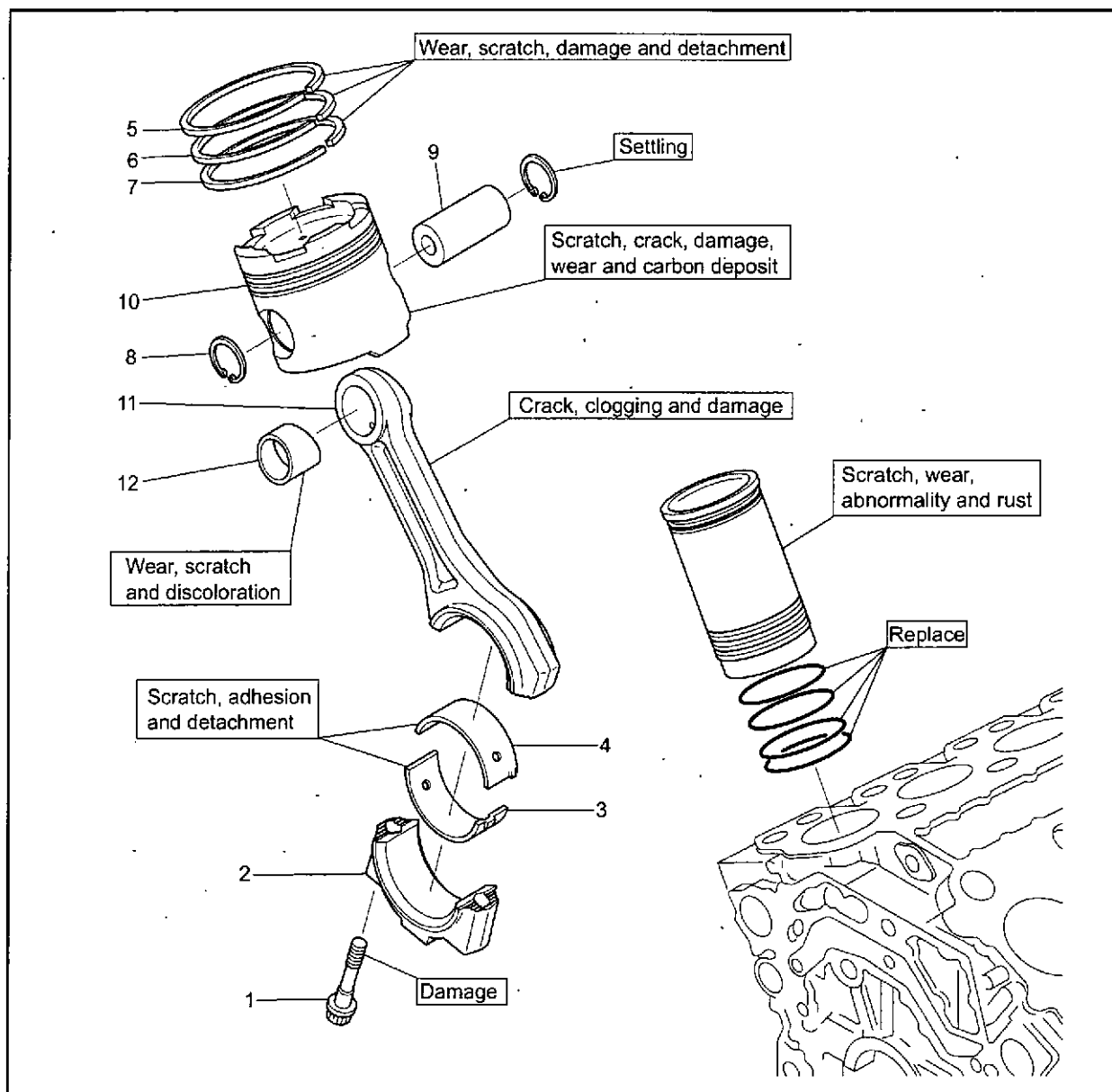
Use jack bolts with convex and round end. Do not use jack bolts with sharp edge, as they could cause damage to the surface of crankcase.

Do not remove the idler shaft unless it is necessary. To remove the idler shaft, unscrew the mounting bolts, and screw two jack bolts evenly into the bolt holes, and pull out the shaft.



Removing idler shaft on the front side

4. Disassembling cylinder liner, piston and connecting rod



Disassembling cylinder liner, piston and connecting rod

Disassembling sequence

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

CAUTION

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

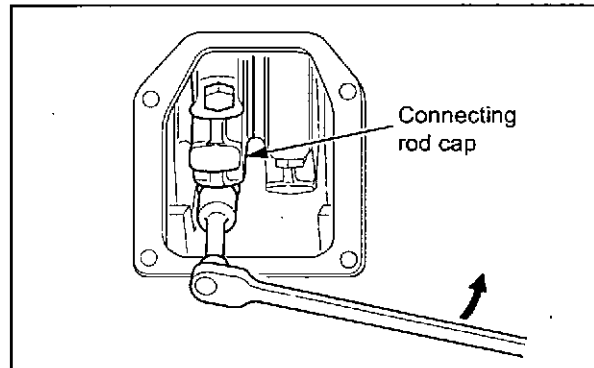
Unless our designated parts are used, the exhaust emission regulations cannot be met.

4.1 Removing connecting rod cap

Remove the connecting rod bolts through the inspection door on the side of the crankcase, and remove the connecting rod cap and connecting rod bearings.

Note: (a) Be careful not to drop the connecting rod bearings into the oil pan, as it could cause damage.

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



Removing connecting rod cap

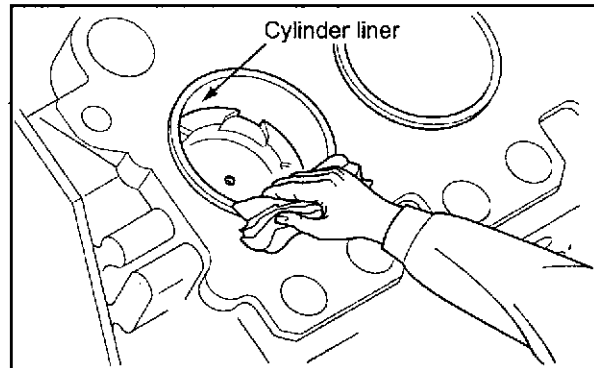
4.2 Removing carbon deposits from the upper part of cylinder liner

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 Removing piston

⚠ CAUTION

When pulling out the piston and the connecting rod from the cylinder liner, be careful not to damage the cylinder liner by the swing of the connecting rod. When you hold the connecting rod with your hands to prevent it from swinging, pay attention to the position of hands, and be careful not to hurt yourself by the swing of the connecting rod.

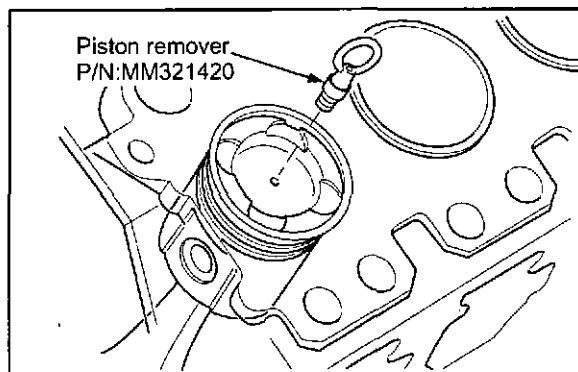
CAUTION

- (a) When pulling out the piston, be careful not to drop the upper connecting rod bearing. If the upper connecting rod drops, it causes damage to the cylinder liner and the crankshaft.
- (b) When removing piston, take care not to damage the inner surface of the cylinder by the connecting rod.
- (c) Stop the crankshaft from rotating while removing pistons, as the crankshaft tends to rotate when pistons inside cylinders get fewer.

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



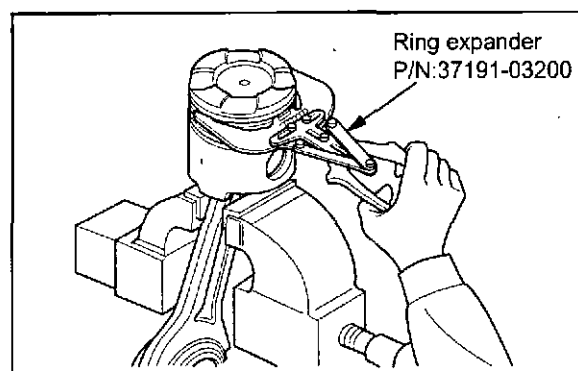
Removing piston

4.4 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.

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



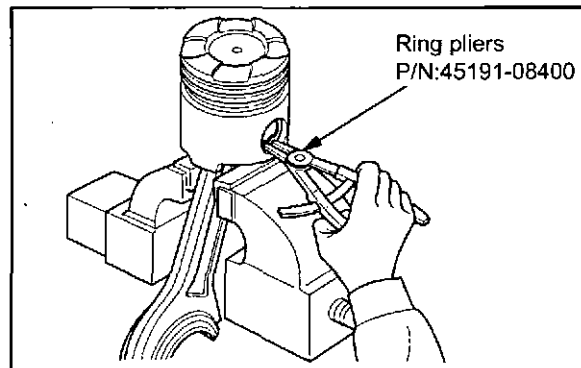
Removing piston ring

4.5 Removing piston pin and piston

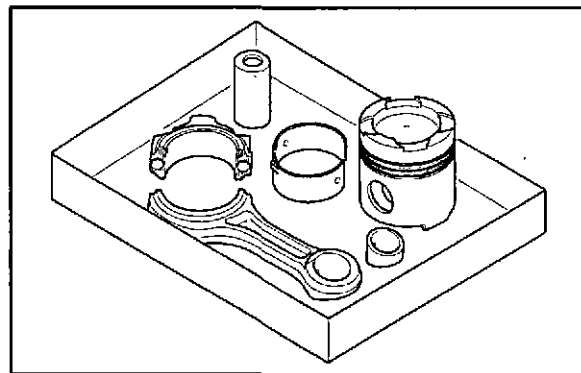
- (1) Clamp the connection rod in a vise.
- (2) Using the ring pliers, remove the snap ring.
- (3) Remove the piston pin, and separate the piston from the connecting rod.

Note: (a) Do not hit the piston with a hammer directly.

- (b) Heat the piston with a piston heater or in hot water if the piston pin is stubborn.

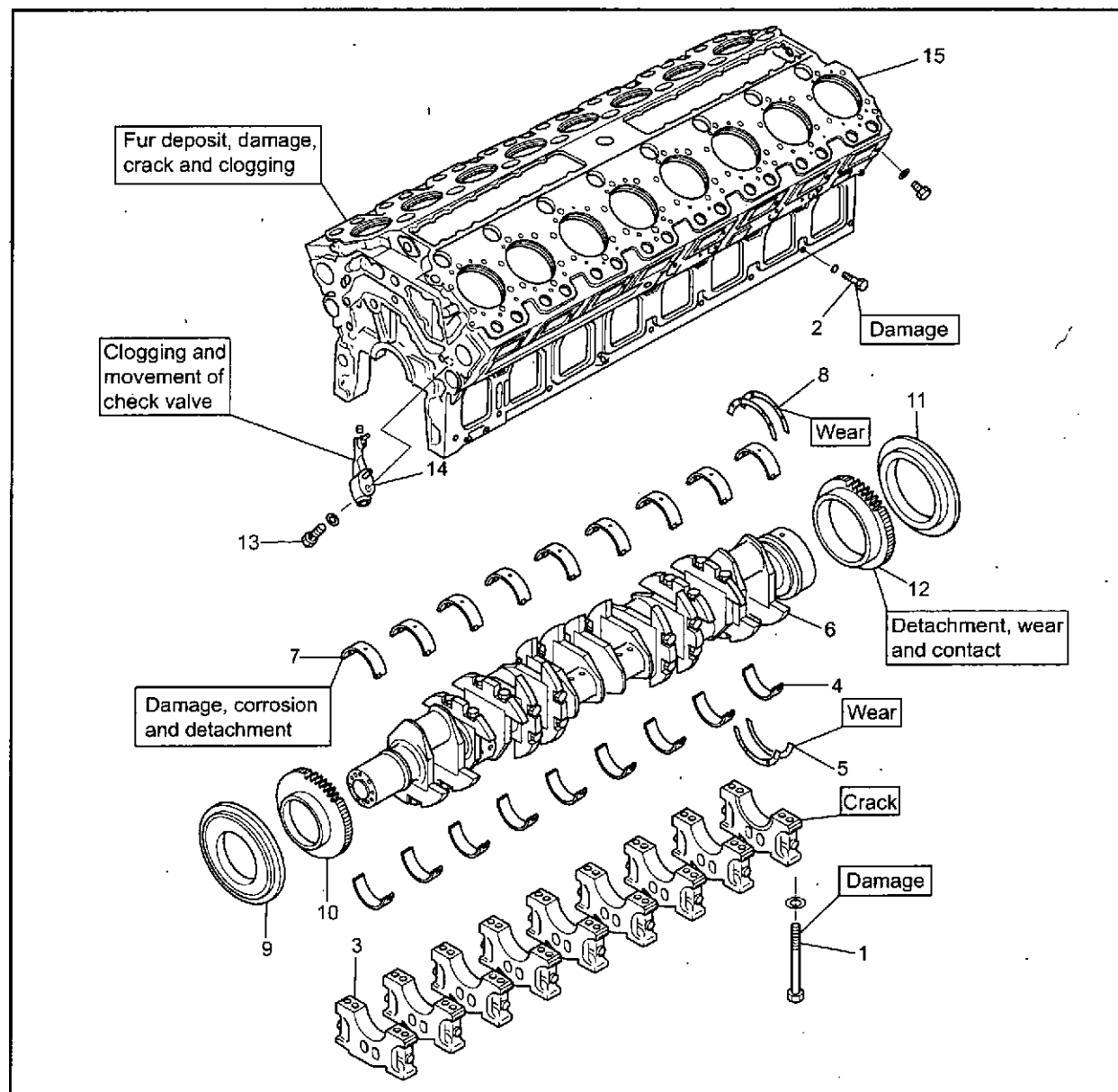


Removing piston pin and piston



Storage after removing piston

5. Disassembling crankcase, crankshaft and main bearing



Disassembling crankcase, crankshaft and main bearing

Disassembling sequence

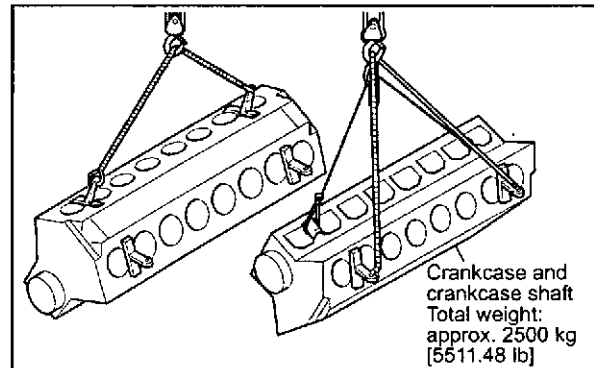
- | | | |
|-------------------------|---|--|
| 1 Main bearing cap bolt | 6 Crankshaft
(weight: 650 kg [1432.98 lb]) | 11 Slinger (rear) |
| 2 Side bolt | 7 Main bearing (upper) | 12 Crankshaft gear (rear) |
| 3 Main bearing cap | 8 Thrust plate | 13 Eye bolt |
| 4 Main bearing (lower) | 9 Slinger (front) | 14 Piston cooling nozzle |
| 5 Thrust plate | 10 Crankshaft gear (front) | 15 Crankcase
(weight: 1850 kg [4078.49 lb]) |

5.1 Turning over crankcase

Place the crankcase on a turn table and turn it around.

When a turn table is not available, use a wood block or a cloth to place the crankcase on it to prevent the crankcase from damage, and using a crane and wire ropes, raise the crankcase and lay it on the wood block with its side faced downwards.

Then, changing the positions of the wire ropes, turn over the crankcase.



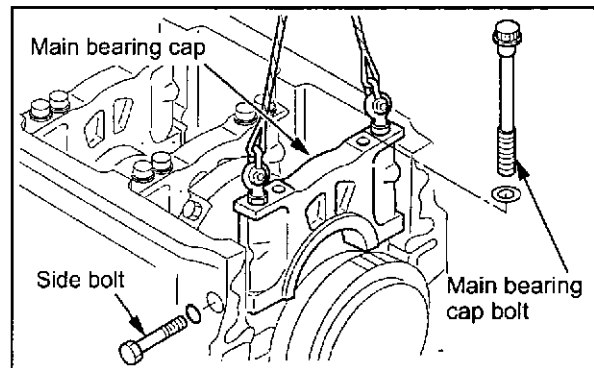
Turning over crankcase

5.2 Removing main bearing cap

CAUTION

When lifting the main bearing cap away from the crankcase, be careful to not 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.

- (1) Unscrew the main bearing cap bolts and the side bolts, and remove the main bearing cap using a cap remover or a crane (eye bolt M27×1.5 mm).
- (2) Remove the main bearing cap by taking care not to damage the thrust plate attached to the cap No. 9.



Removing main bearing cap

5.3 Removing crankshaft

CAUTION

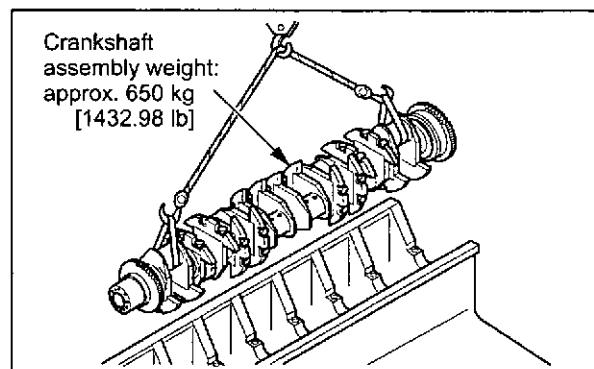
Remove the upper thrust plate on the front side first, otherwise the front upper thrust plate will fall off onto the crankcase when removing the the crankshaft.

When placing the crankshaft onto a pallet or other stands, be careful to not 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

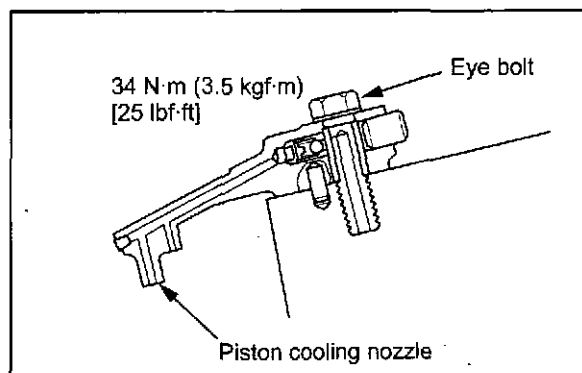
5.4 Removing piston cooling nozzle

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. Cylinder head and valve mechanism 6-3
 - 1.1 Measuring rocker bushing inside diameter and rocker shaft outside diameter..... 6-3
 - 1.2 Replacing rocker bushing 6-3
 - 1.3 Measuring valve stem outside diameter and valve guide inside diameter 6-3
 - 1.4 Replacing valve guide and stem seal 6-4
 - 1.5 Inspecting valve face 6-4
 - 1.6 Refacing valve face..... 6-5
 - 1.7 Refacing valve seat..... 6-5
 - 1.8 Replacing valve seat inserts 6-6
 - 1.9 Lapping valve and valve seat..... 6-7
 - 1.10 Measuring perpendicularity and free length of valve spring..... 6-8
 - 1.11 Inspecting bridge, cotter and rotator 6-9
 - 1.12 Inspecting tappet..... 6-9
 - 1.13 Measuring pushrod runout..... 6-9
 - 1.14 Measuring distortion of cylinder head bottom face 6-10
2. Cylinder liner, piston and connecting rod..... 6-11
 - 2.1 Measuring cylinder liner inside diameter 6-11
 - 2.2 Measuring cylinder liner flange protrusion 6-11
 - 2.2.1 When cylinder liner is not replaced 6-12
 - 2.2.2 When cylinder liner is replaced 6-12
 - 2.2.3 Measuring height of cylinder liner top ridge 6-13
 - 2.2.4 Inserting shim under cylinder liner flange. 6-13
 - 2.3 Replacing cylinder liner..... 6-14
 - 2.4 Visual inspection of piston 6-14
 - 2.5 Measuring piston outside diameter 6-15
 - 2.6 Measuring clearance between piston ring groove and piston ring 6-15
 - 2.7 Measuring piston pin bore diameter..... 6-16
 - 2.8 Measuring piston protrusion..... 6-16
 - 2.9 Measuring piston ring end gap..... 6-17
 - 2.10 Measuring piston pin outside diameter .. 6-17
 - 2.11 Measuring connecting rod bushing inside diameter 6-18
 - 2.12 Replacing connecting rod bushing 6-18
 - 2.13 Inspecting connecting rod bend and twist 6-19
 - 2.14 Inspecting connecting rod bearing 6-19
 - 2.15 Measuring connecting rod end play 6-19
 - 2.16 Weight difference of connecting rod assembly in one engine 6-20
 - 2.17 Measuring connecting rod big end bore diameter and circularity..... 6-20
 - 2.18 Inspecting serrated portion of connecting rod big end..... 6-20
 - 2.19 Measuring connecting rod bearing thickness 6-21
3. Damper and front gear..... 6-22
 - 3.1 Inspecting damper..... 6-22
 - 3.2 Measuring front gear backlash..... 6-22
 - 3.3 Inspecting outside diameter and inside diameter of oil pump drive bearing-fitted section..... 6-23
 - 3.4 Measuring idler bushing inside diameter and idler shaft outside diameter..... 6-23
 - 3.5 Measuring idler gear end play..... 6-23
 - 3.6 Replacing idler bushing..... 6-24
4. Flywheel, timing gear and camshaft 6-25
 - 4.1 Measuring flywheel face and radial runouts 6-25
 - 4.2 Measuring backlash of timing gear 6-25
 - 4.3 Measuring idler bushing inside diameter and idler shaft outside diameter..... 6-25
 - 4.4 Measuring idler gear end play..... 6-26
 - 4.5 Replacing idler bushing..... 6-26
 - 4.6 Measuring cam lift..... 6-26
 - 4.7 Measuring camshaft runout..... 6-26
 - 4.8 Measuring camshaft journal outside diameter..... 6-27
 - 4.9 Measuring camshaft bushing inside diameter..... 6-27
 - 4.10 Measuring camshaft end play 6-27
 - 4.11 Replacing camshaft bushing..... 6-28
 - 4.11.1 Removing camshaft bushing 6-28
 - 4.11.2 Installing camshaft bushing 6-28
5. Crankcase, crankshaft and main bearing 6-29
 - 5.1 Measuring crankshaft crankpin and journal outside diameters..... 6-29
 - 5.2 Grinding crankshaft..... 6-29
 - 5.3 Measuring crankshaft end play 6-30
 - 5.4 Measuring crankshaft runout..... 6-30
 - 5.5 Replacing oil seal slinger 6-31
 - 5.5.1 Removing oil seal slinger..... 6-31
 - 5.5.2 Installing oil seal slinger..... 6-31
 - 5.6 Replacing crankshaft gear 6-32
 - 5.6.1 Removing crankshaft gear..... 6-32
 - 5.6.2 Installing crankshaft gear..... 6-32
 - 5.7 Inspecting main bearing surface 6-32

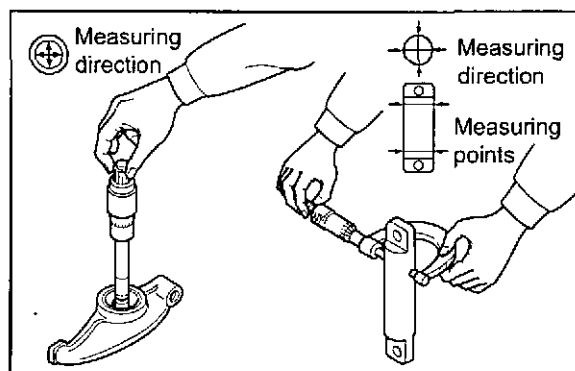
- 5.8 Measuring thickness of
main bearing shell..... 6-33
- 5.9 Replacing main bearing 6-33
- 5.10 Measuring distortion of
crankcase top surface..... 6-34
- 5.11 Measuring inside diameter of
main bearing housing..... 6-34

1. 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.

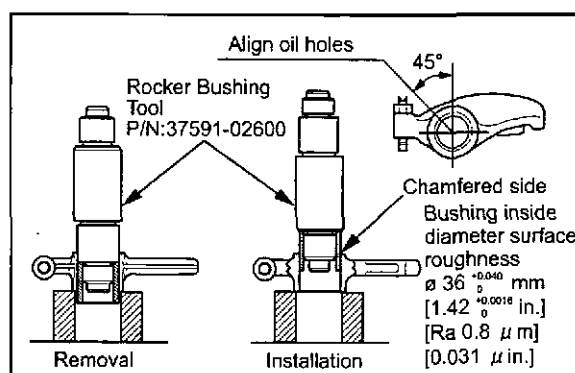
Item	Nominal	Standard	Limit
Rocker bushing inside diameter	ø 36 mm [1.42 in.]	36.000 to 36.040 mm [1.4173 to 1.4189 in.]	36.090 mm [1.4209 in.]
Rocker shaft diameter	ø 36 mm [1.42 in.]	35.966 to 35.991 mm [1.4160 to 1.4170 in.]	35.940 mm [1.4150 in.]



Measuring rocker bushing inside diameter and rocker shaft outside 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.

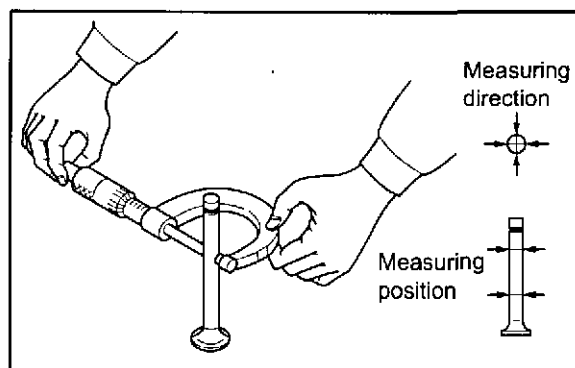


Replacing rocker bushing

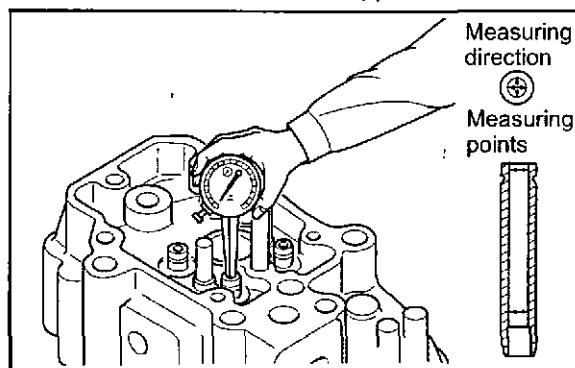
1.3 Measuring valve stem outside diameter and valve guide inside diameter

Measure the valve stem diameter and valve guide inside diameter. If the limit is exceeded, replace with new parts.

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 outside diameter



Measuring valve guide inside diameter

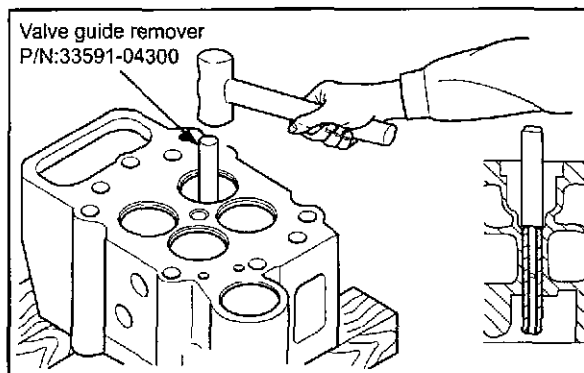
1.4 Replacing valve guide and stem seal

CAUTION

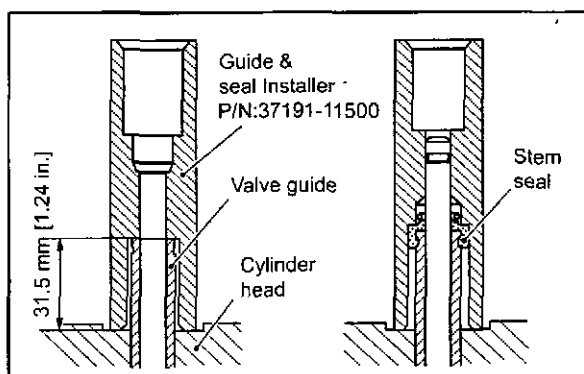
- (a) The valve guide must be inserted to the specified depth. Be sure to use the guide/stem seal installer when press-fitting the valve guide.
- (b) Do not apply oil or liquid gasket to the stem seal inside that comes in contact with the valve guide.
- (c) Always replace the stem seal with a new one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

- (1) Drive out the valve guide using the valve guide remover.
- (2) Using the guide and 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.



Driving out valve guide



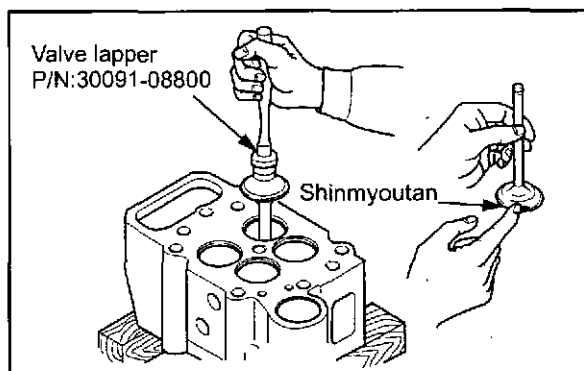
Press-fitting valve guide and stem seal

1.5 Inspecting valve face

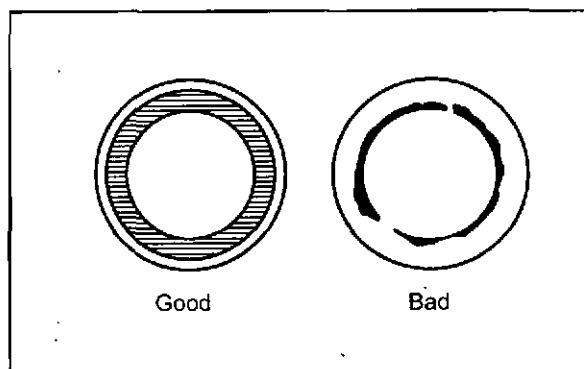
Apply a thin coat of Shinmyoutan or equivalent lead-free coloring paste on the valve face, and strike the valve face against the valve seat using a valve lapper to check for contact condition. If the contact is not even, or any defects are found, or if the limit is exceeded, reface or replace the valve.

Note: (a) Inspect the valve face when the valve guide has been 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.

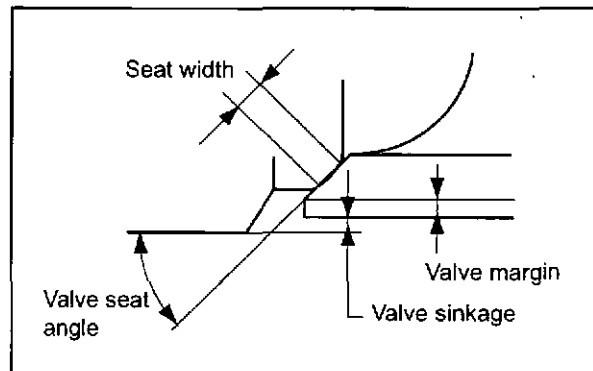


Inspecting valve face



Valve and valve seat contact

Item		Standard	Limit
Valve seat	Valve seat angle	30° (nominal value)	
	Valve sinkage	-0.2 to 0.2 mm [-0.008 to 0.008 in.]	1.0 mm [0.039 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.]



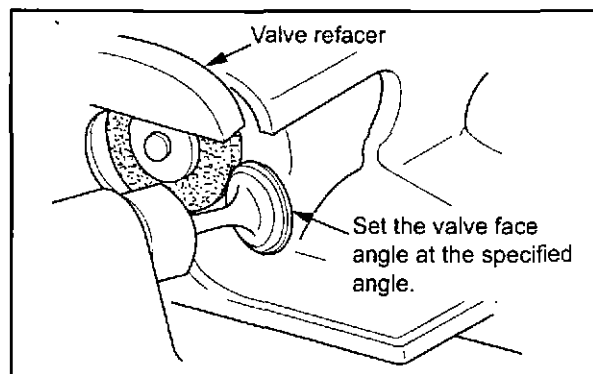
Valve contact with seat

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 do not meet the specified values, replace the valve with a new one.



Refacing valve face

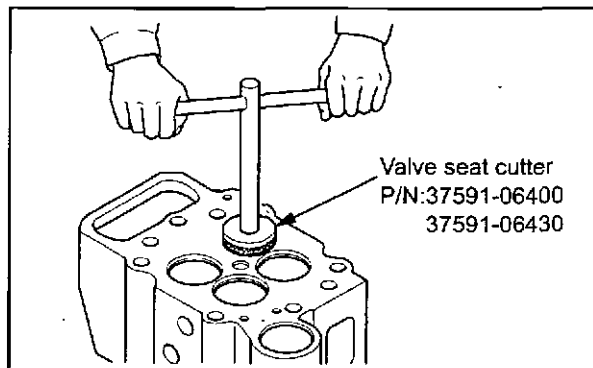
1.7 Refacing valve seat

- (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.

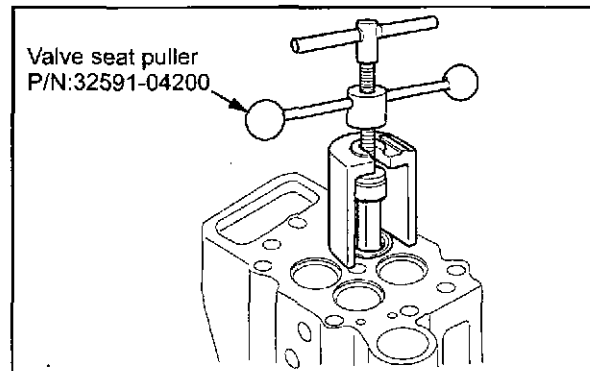


Refacing valve seat

1.8 Replacing valve seat inserts

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

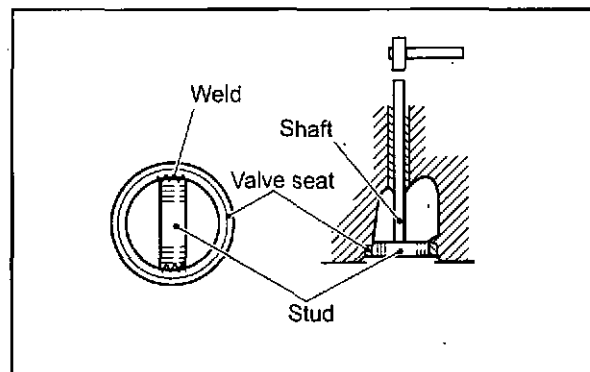
Note: Be careful not to damage the machined surface of cylinder head when removing the valve seat.



Removing valve seat (using valve seat puller)

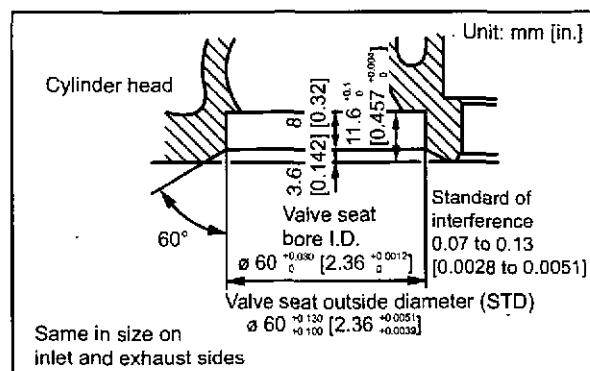
- (2) To remove the valve seat, weld a stud to the valve seat as illustrated. Then, insert a rod into the valve guide hole from the top of the cylinder head, and press out the valve seat with the rod.

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



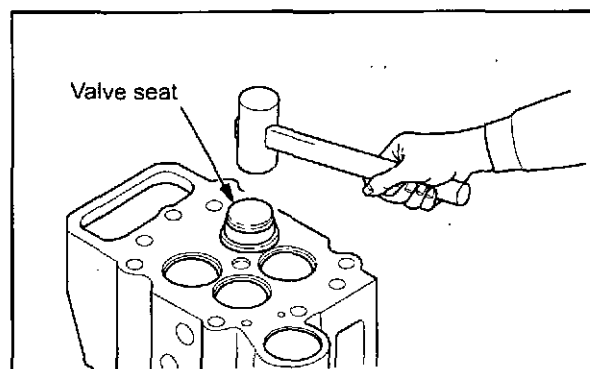
Removing valve seat

- (3) Before inserting a new valve seat, measure the cylinder head bore diameter and valve seat outside diameter to make sure the interference meets the specified value.



Valve seat fitting bore

- (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 valve seat caulking tool.



Installing valve seat

Selecting valve seat

Select an oversize seat of part No. 37501-04200 when the interference is 0.04 to 0.13 mm [0.0016 to 0.0051 in.], and select an oversize seat of part No. 37501-04300 when the interference is 0.01 to 0.13 mm [0.0004 to 0.0051 in.].

Note: Avoid using a valve seat inappropriate for the interference. An inappropriate valve seat may fall off during operation or cause cracks in the cylinder head.

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.

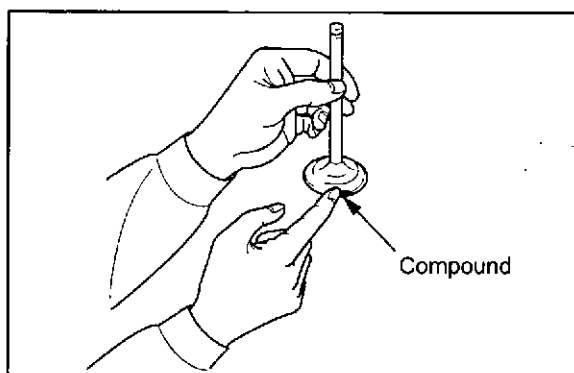
- (c) Use medium-grain compound (120 to 150 mesh) for initial lapping, then use fine-grain compound (200 mesh or finer) for finishing.

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

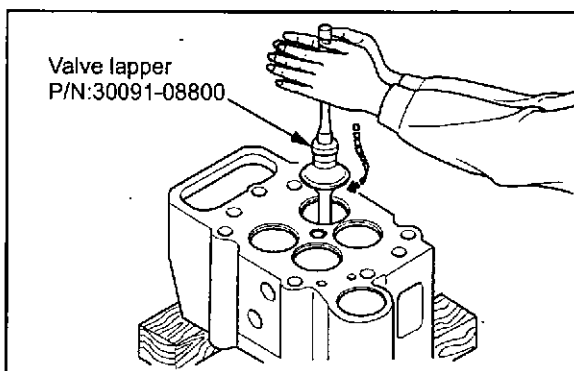
- (3) Wash off the compound using diesel fuel.

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

- (5) Check valve-to-seat contact.



Coating valve with lapping compound

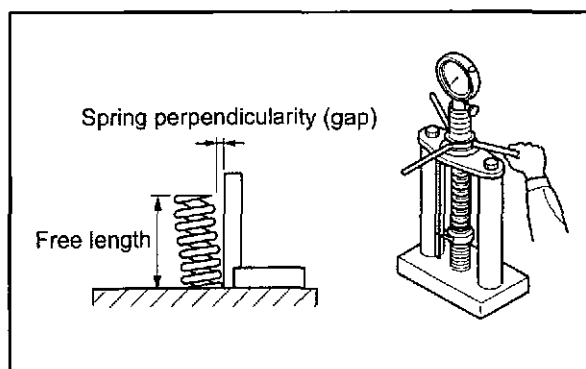


Lapping valve against valve seat

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.

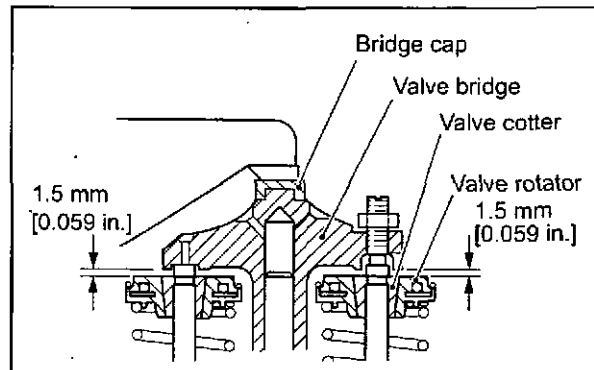
Item			Standard	Limit
Inlet valve spring	Free length		73 mm [2.87 in.]	71 mm [2.80 in.]
	Perpendicularity		 $\theta = 1.5^\circ$ or less Δ (gap) = 1.9 mm [0.075 in.] or less $L_f = 73$ mm [2.87 in.]	$\Delta = 2.2$ mm [0.087 in.] over entire length
	Mounting length/force		66.0 mm/289 to 319 N {29.45 to 32.55 kgf} [2.598 in./64.9 to 71.8 lbf]	
Exhaust valve spring	Free length	Inner	90.6 mm [3.567 in.]	88.12 mm [3.4693 in.]
		Outer	96.57 mm [3.802 in.]	93.92 mm [3.6976 in.]
	Perpendicularity	Inner	 $\theta = 2.0^\circ$ or less Δ (gap) = 3.2 mm [0.126 in.] or less $L_f = 90.6$ mm [3.567 in.]	$\Delta = 3.7$ mm [0.146 in.] over entire length
		Outer	 $\theta = 2.5^\circ$ or less Δ (gap) = 4.2 mm [0.165 in.] $L_f = 96.57$ mm [3.8020 in.]	$\Delta = 4.9$ mm [0.193 in.] over entire length
	Mounting length/force	Inner	56.0 mm/137 to 152 N {14 to 15.5 kgf} [2.205 in./101.3 to 112.1 lbf]	
		Outer	62.0 mm/496 to 549 N {50.6 to 56.0 kgf} [2.441 in./111.6 to 123.5 lbf]	



Measuring perpendicularity and free length of spring

1.11 Inspecting bridge, cotter and rotator

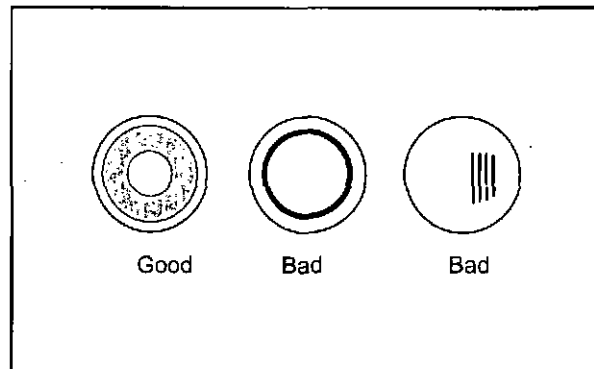
- (1) After having adjusted valve heights using valve bridge screws, measure the clearance between the valve bridge and the rotator. If the clearance is less than the standard, replace the valve with a new one to secure the standard clearance.
- (2) Check the bridge cap for wear. If it is significantly worn out, replace the bridge cap.
- (3) Check the valve rotator for rotation. If any defect is found, replace the valve rotator.



Inspecting clearance between valve bridge and cotter or rotator

1.12 Inspecting tappet

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

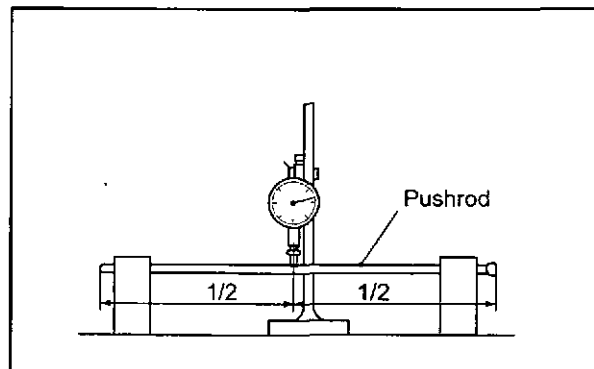


Contact surface of tappet and cam

1.13 Measuring pushrod runout

Measure the runout of pushrod. If the standard value is exceeded, replace the push rod.

Item	Standard	Limit	Remark
Pushrod runout	0.50 mm [0.0197 in.] or less	0.50 mm [0.0197 in.]	Total indicated reading (TIR)



Measuring push rod runout

1.14 Measuring distortion of cylinder head bottom face

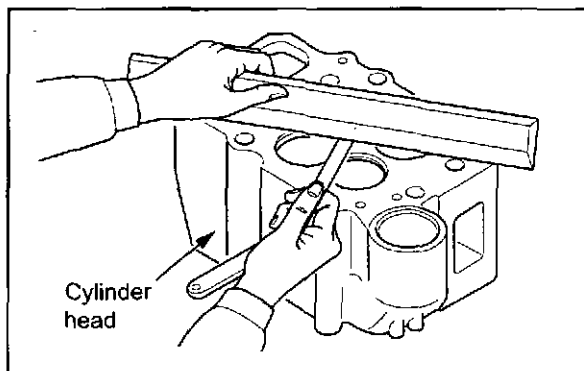
CAUTION

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
Distortion of cylinder head bottom surface	0.03 mm [0.0012 in.] or less	0.50 mm [0.0197 in.]



Measuring distortion of cylinder head bottom face

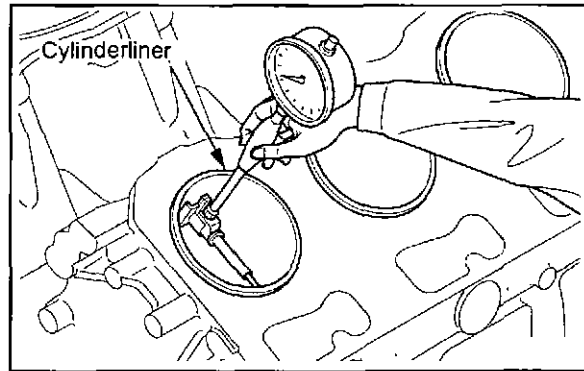
2. Cylinder liner, piston and connecting rod

2.1 Measuring cylinder liner inside diameter

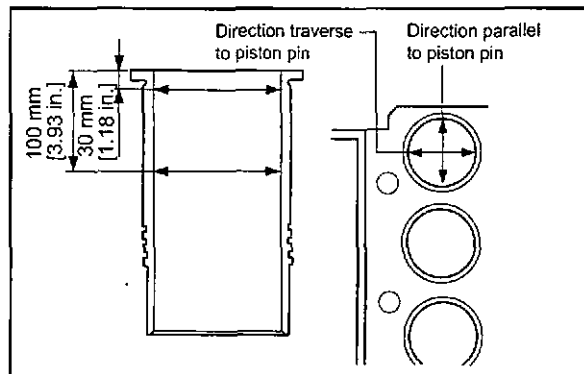
Measure the inside diameter of the cylinder liners at two levels each, i.e., upper (with much stepped wear) and middle levels, in both directions parallel to and perpendicular to the piston pin direction.

Replace the cylinder liner if the limit is exceeded.

Item	Nominal	Standard	Limit
Cylinder liner Bore diameter	ø 170 mm [6.69 in.]	170.000 to 170.040 mm [6.6929 to 6.6945 in.]	170.500 mm [6.7126 in.]
Cylinder liner Roundness		0.02 mm [0.0008 in.] or less	
Cylinder liner Cylindricity		0.02 mm [0.0008 in.] or less	
Cylinder liner Perpendicularity of flange bottom sur- face to cylinder liner		0.03 mm [0.0012 in.] or less	



Measuring cylinder liner inside diameter



Measuring cylinder liner dimension

2.2 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.

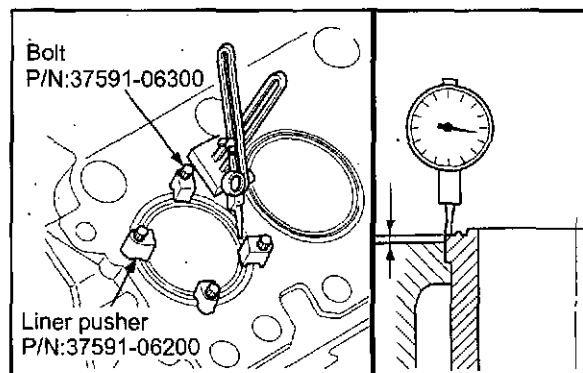
Item	Standard
Cylinder liner flange protrusion	0.11 to 0.20 mm [0.0043 to 0.0079 in.]

2.2.1 When cylinder liner is not replaced

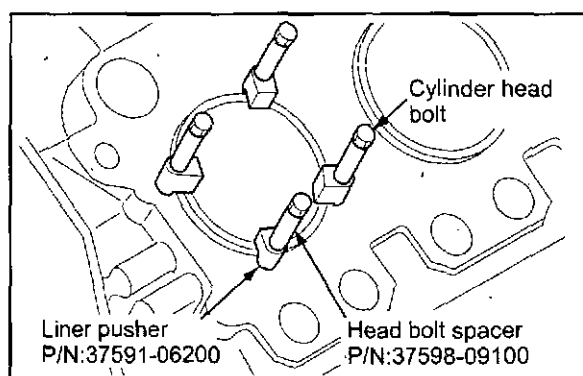
- (1) Make sure that the top surface of crankcase and the upper end of cylinder liner are clean before measurement.
- (2) Attach the liner holders on equally spaced 4 locations of the cylinder liner upper rim and tighten the bolts of the holders evenly to press the cylinder liner against the crankcase 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 (1)

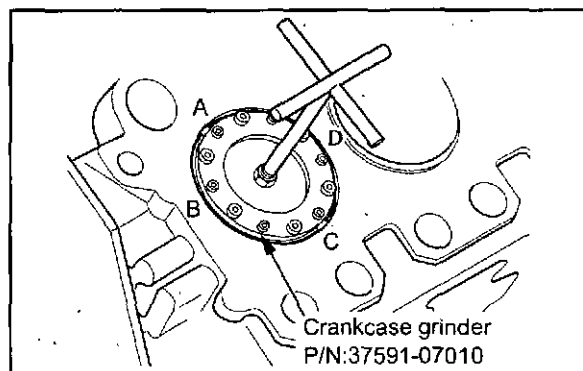


Measuring cylinder liner collar protrusion (2)

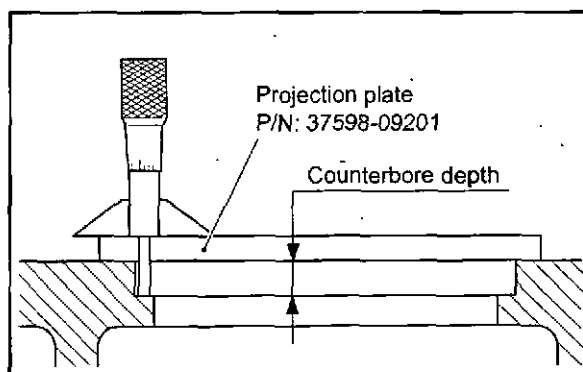
2.2.2 When cylinder liner is replaced

- (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.].
- (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 projection plate (standard: 15 mm [0.59 in.]) with a micrometer, and subtract the projection plate thickness from the measured crankcase counterbore depth to obtain the actual counterbore depth from the top surface of the crankcase.

Item	Standard
Crankcase counterbore depth	14.00 to 14.05 mm [0.5512 to 0.5531 in.]



Correcting crankcase counterbore depth



Measuring crankcase counterbore depth

- (6) Measure the thickness of the cylinder liner flange with a micrometer.

Item	Standard
Thickness of cylinder liner flange	14.16 to 14.20 mm [0.5575 to 0.5591 in.]

- (7) Calculate the cylinder liner flange protrusion by subtracting the counterbore depth from the thickness of the cylinder liner flange.
- (8) If the calculated value is smaller than the standard, place a shim of an appropriate thickness under the cylinder liner flange.

2.2.3 Measuring height of cylinder liner top ridge

- (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.

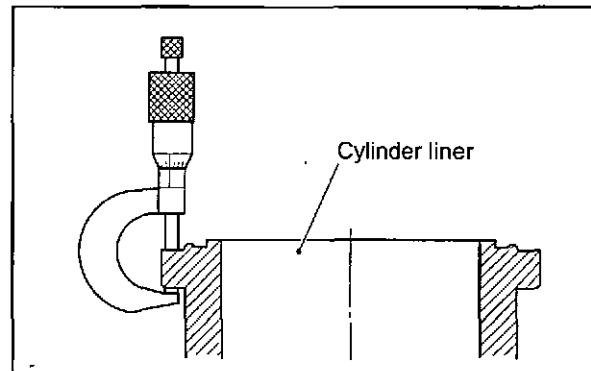
Item	Standard
Height of cylinder liner top ridge	0.16 to 0.24 mm [0.0063 to 0.0094 in.]

2.2.4 Inserting shim under cylinder liner flange

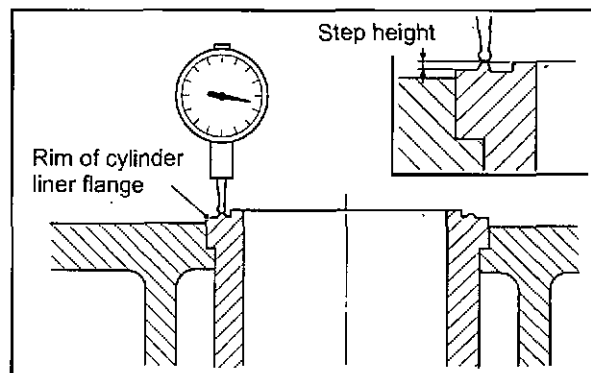
Pull out the cylinder liner, and insert a shim between the cylinder liner and the crankcase.

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.

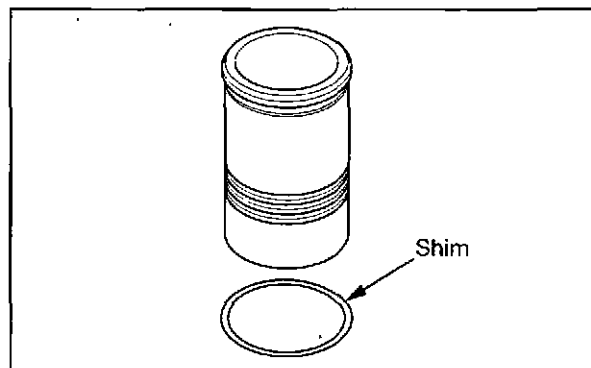
Shim thickness	Part No.
0.05 mm [0.0020 in.]	37507-02510
0.10 mm [0.0039 in.]	37507-02500
0.15 mm [0.0059 in.]	37507-02520



Thickness of cylinder liner collar



Measuring height of cylinder liner top ridge



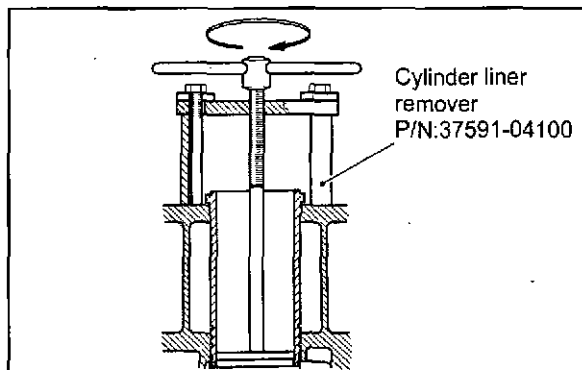
Inserting shim under cylinder liner flange

2.3 Replacing cylinder liner

CAUTION

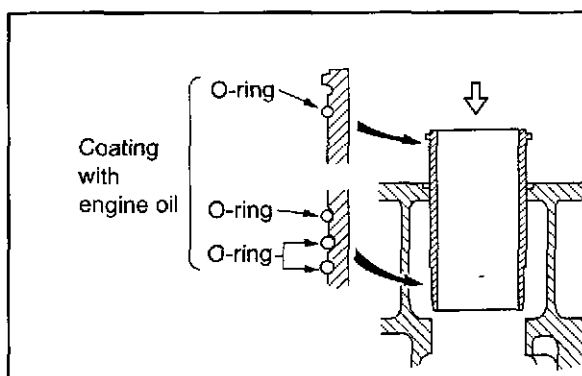
Apply engine oil to the O-rings to prevent them from twisting.

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



Removing cylinder liner

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

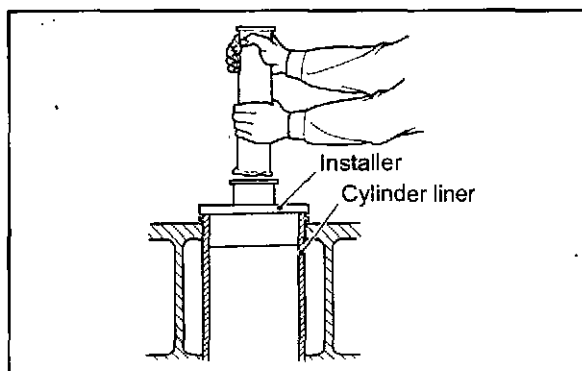


Attaching O-ring to cylinder liner

- (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.

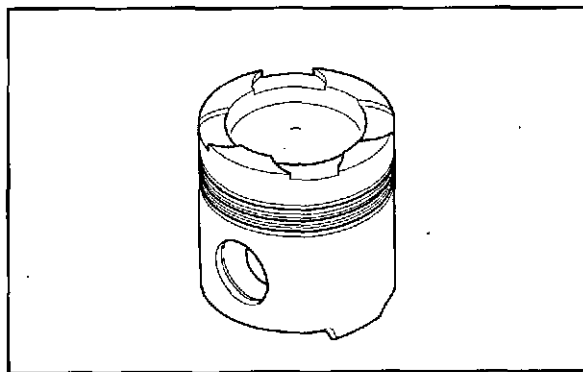
- (b) Check the cylinder liner flange protrusion from the crankcase top surface.



Driving in cylinder liner

2.4 Visual inspection of piston

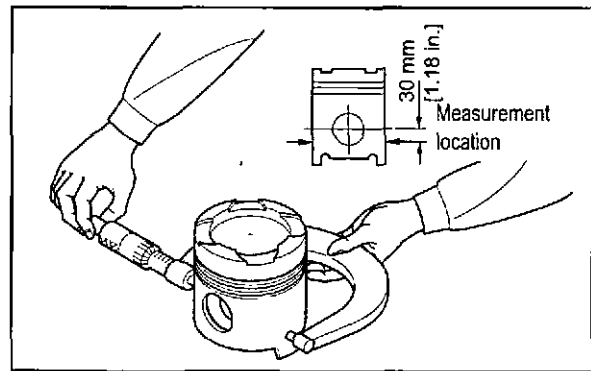
Check the combustion surface of the piston and the piston pin bore. If any defect is found, replace the piston with a new one.



Visual inspection of piston

2.5 Measuring piston outside diameter

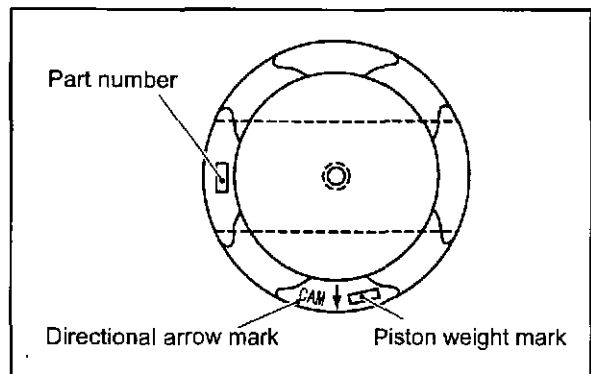
- (1) Measure the piston outside diameter of the piston skirt at right angles to the piston pin. If it is less than the limit, replace the piston with a new piston. When replacing piston, be sure to select a piston so that the piston weight difference in one engine is kept within the permissible range.



Measuring piston outside diameter

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

Item	Nominal	Standard	Limit
Piston outside diameter	ϕ 170 mm [6.69 in.]	169.76 to 169.80 mm [6.6835 to 6.6850 in.]	169.66 mm [6.6795 in.]
Weight difference	-	20 g [0.71 oz.] or less in one engine	



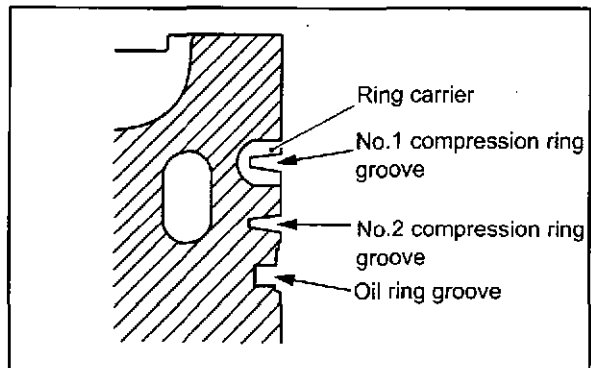
Piston weight stamp location

2.6 Measuring clearance between piston ring groove and piston ring

CAUTION

Remove carbon deposits from pistons and check the piston ring grooves over 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 faulty or damaged, replace the ring.
- (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.

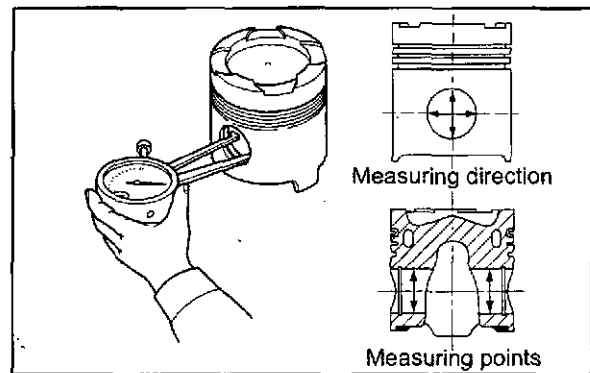


Inspecting piston ring groove

2.7 Measuring piston pin bore diameter

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	ϕ 70 mm [2.76 in.]	70.002 to 70.015 mm [2.7560 to 2.7565 in.]	70.040 mm [2.7575 in.]



Measuring piston pin bore diameter

2.8 Measuring piston protrusion

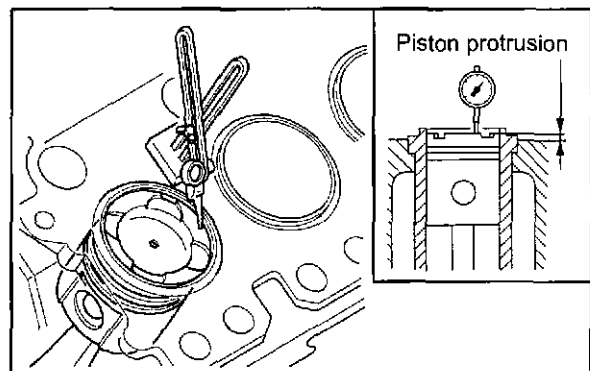
CAUTION

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 as follows: If the measurement does not conform to the standard, the clearances between various parts concerned must be checked.

- (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

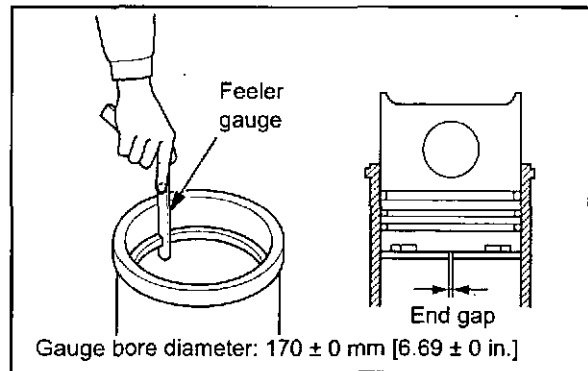
Item	Standard
Piston protrusion	0.06 to 0.65 mm [0.0024 to 0.0256 in.]
Thickness when tightened (cylinder head gasket)	1.77 to 1.83 mm [0.0697 to 0.0720 in.]
Clearance between piston and cylinder head	1.22 to 1.95 mm [0.0480 to 0.0768 in.]

2.9 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	0.6 to 0.8 mm [0.024 to 0.031 in.]	
	Oil	0.3 to 0.45 mm [0.012 to 0.018 in.]	



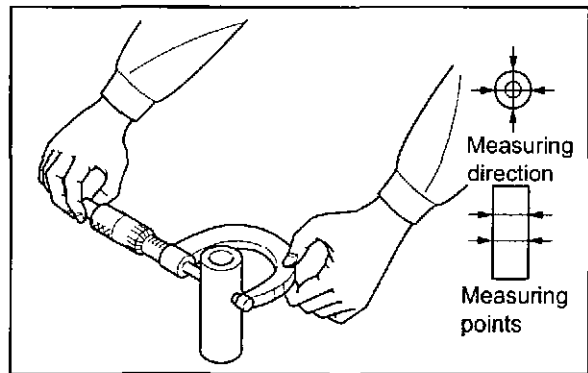
Measuring piston ring end gap

2.10 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 part.

Item	Nominal	Standard	Limit
Piston pin outside diameter	ø 70 mm [2.76 in.]	69.987 to 70.000 mm [2.7554 to 2.7559 in.]	69.970 mm [2.7547 in.]

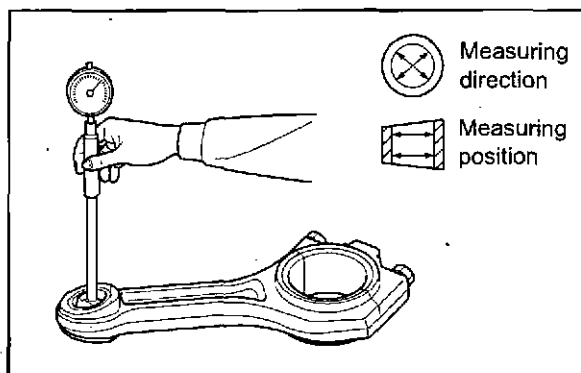


Measuring piston pin outside diameter

2.11 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 70 mm [2.76 in.]	70.020 to 70.040 mm [2.7567 to 2.7575 in.]	70.070 mm [2.7587 in.]

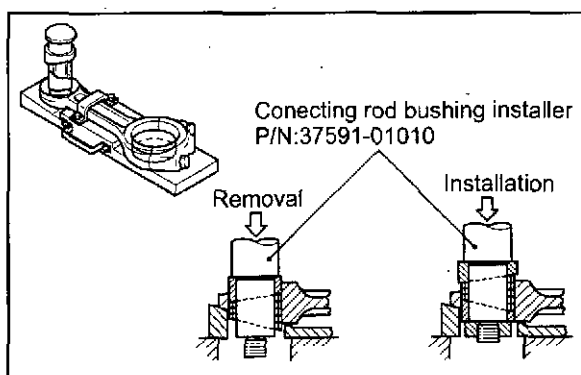


Measuring connecting rod bushing inside diameter

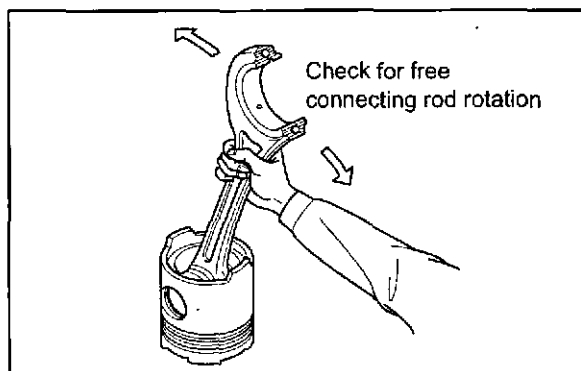
2.12 Replacing connecting rod bushing

Use a connecting rod bushing installer to replace the connecting rod bushing.

- (1) With the bushing joints oriented as shown in the illustration, align the oil hole of bushing with the oil hole of connecting rod, and press-fit the connecting rod bushing into the connecting rod.
- (2) After press-fitting, insert the piston pin, and make sure the connecting rod and piston rotate freely without rattling.



Replacing connecting rod bushing



Inspecting connecting rod fitting

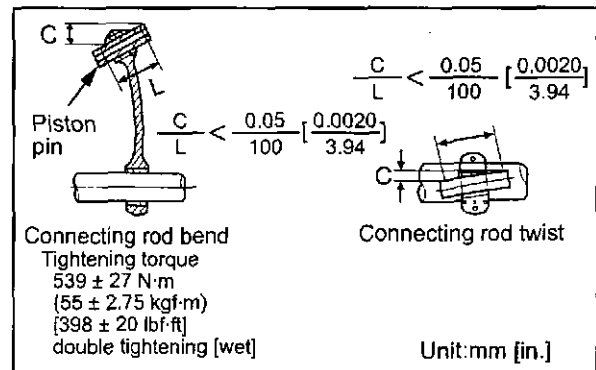
2.13 Inspecting connecting rod bend and twist

- (1) Measure C and L as shown in the illustration to check the connecting rod bend and twist. If the measured value deviates from the standard value, straighten the connecting rod with a press.
If the limit is exceeded, replace the connecting rod.
- (2) In general, a connecting rod aligner is used to check bend and twist.

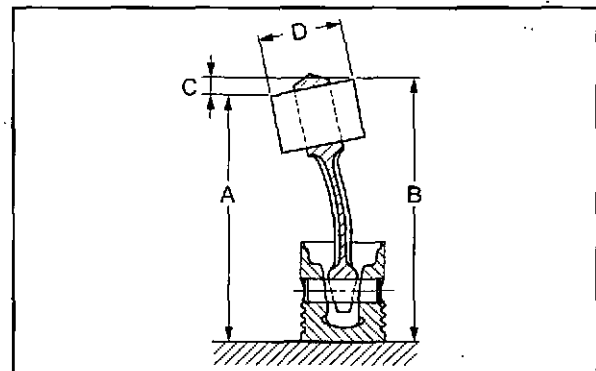
Note: Before checking bend, tighten the connecting rod cap to the specified torque.

- (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



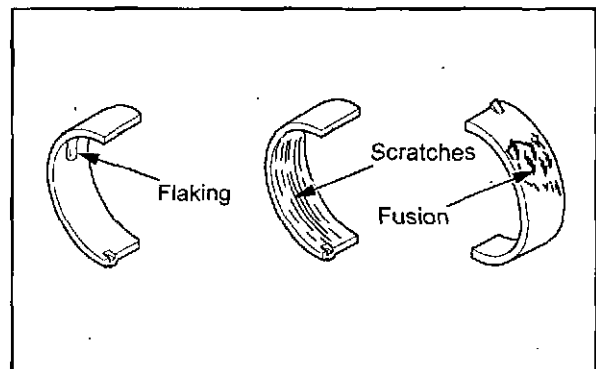
Inspecting connecting rod bend and twist



Measuring connecting rod bend

2.14 Inspecting connecting rod bearing

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

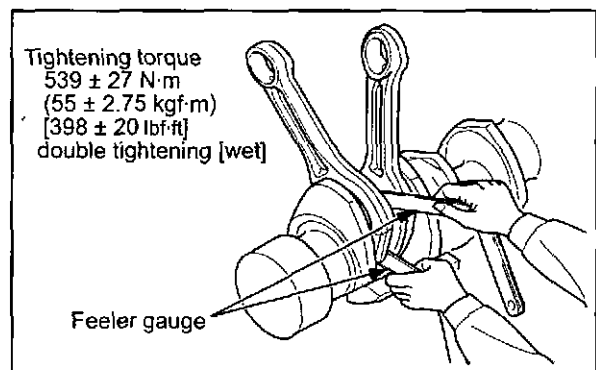


Inspecting connecting rod bearing

2.15 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.

Item	Nominal	Standard	Limit
Connecting rod end play (Connecting rod width and crankpin width)	60 mm [2.36 in.] × 2	0.4 to 0.9 mm [0.016 to 0.035 in.]	1.4 mm [0.055 in.]

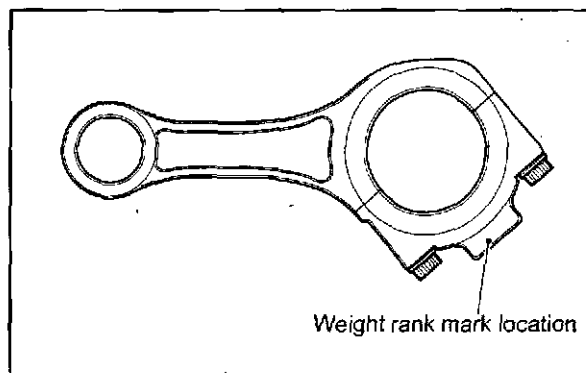


Measuring connecting rod end play

2.16 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
C	14050 g [496 oz.]
D	14200 g [501 oz.]



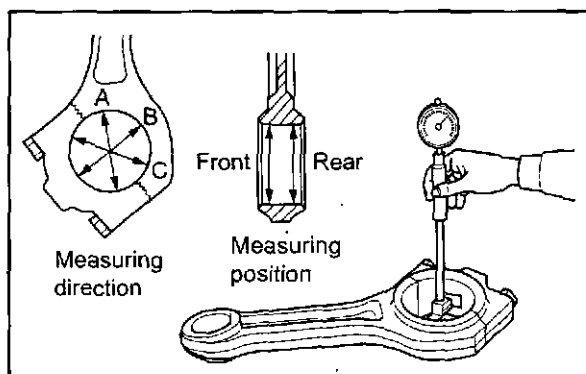
Weight rank stamp location on connecting rod

2.17 Measuring connecting rod big end bore diameter and circularity

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.

Replace if the limit is exceeded.

Item	Nominal	Standard	Limit	Roundness Limit
Connecting rod big-end bore diameter	ϕ 131 mm [5.16 in.]	131.000 to 131.025 mm [5.1575 to 5.1585 in.]	131.050 mm [5.1594 in.]	0.1 mm [0.004 in.]



Measuring connecting rod big end bore diameter

2.18 Inspecting serrated portion of connecting rod big end

Check the serrated portion of the connecting rod big end by using magnetic particle test. If any defect is found, replace the connecting rod assembly.

2.19 Measuring connecting rod bearing thickness

Measure the thickness of each bearing shell at its center.

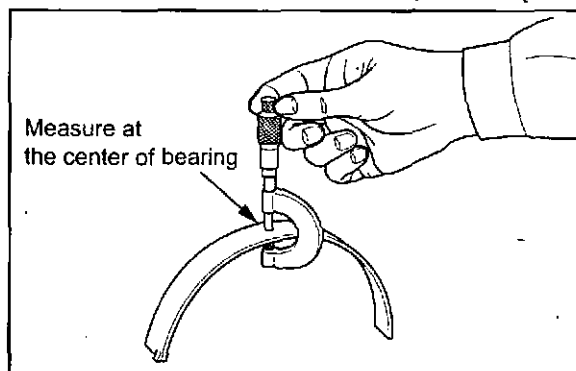
If the measurement exceeds the limit, replace both upper and lower bearing shells as a set.

Note: Replacement bearings are available in four undersizes:

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

[-0.01, -0.02, -0.03 in. and -0.04 in.].

Item		Nominal	Standard	Limit
Connecting rod bearing thickness	STD	3.000 mm [0.1181 in.]	2.957 to 2.970 mm [0.1164 to 0.1169 in.]	2.930 mm [0.1154 in.]
	-0.25 mm [-0.01 in.]	3.125 mm [0.1230 in.]	3.082 to 3.095 mm [0.1213 to 0.1219 in.]	3.055 mm [0.1203 in.]
	-0.50 mm [-0.02 in.]	3.250 mm [0.1280 in.]	3.207 to 3.220 mm [0.1263 to 0.1268 in.]	3.180 mm [0.1252 in.]
	-0.75 mm [-0.03 in.]	3.375 mm [0.1329 in.]	3.332 to 3.345 mm [0.1312 to 0.1317 in.]	3.305 mm [0.1301 in.]
	-1.00 mm [-0.04 in.]	3.500 mm [0.1378 in.]	3.457 to 3.470 mm [0.1361 to 0.1366 in.]	3.430 mm [0.1350 in.]



Measuring main bearing thickness

3. Damper and front gear

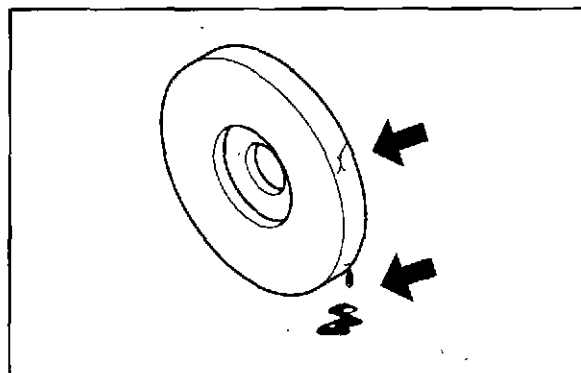
3.1 Inspecting damper

- (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.

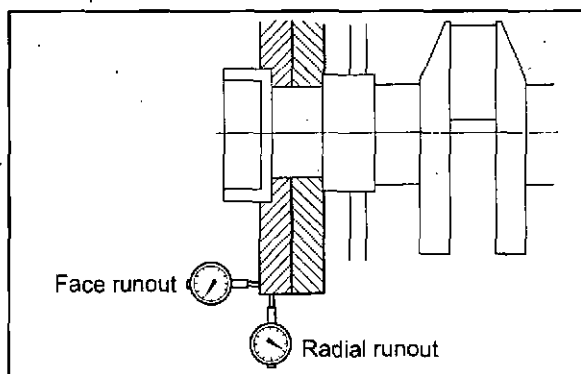
If any defect is found, replace the damper.

- (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

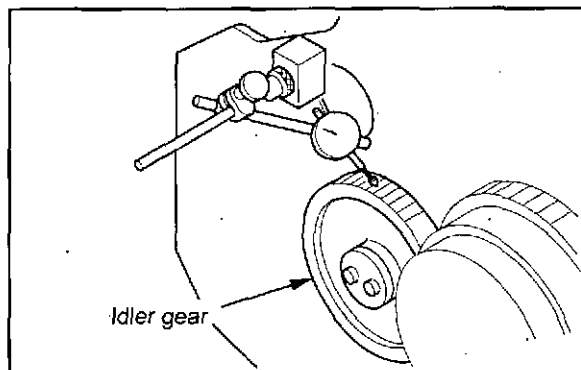


Measuring of face and radial runout damper

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 idler gear backlash	0.12 to 0.18 mm [0.0047 to 0.0071 in.]	0.50 mm [0.0197 in.]



Measuring front gear backlash

3.3 Inspecting outside diameter and inside diameter of oil pump drive bearing-fitted section

Rotate each bearing to check for smooth rotation. If the rotation is not smooth, replace the bearing.

Check the fitting condition between the bearing and the oil pump bearing cover. If either of these parts is badly worn, replace it.

Check the fitting condition between the bearing and the plate. If either of these parts is badly worn, replace it.

Check the fitting condition between the bearings and the oil pump gear. If any of these parts is badly worn, replace it.

Item		Nominal	Standard
Cover bearing bore inside diameter		ø 110 mm [4.33 in.]	110.000 to 110.035 mm [4.3307 to 4.3321 in.]
Bearing fitting bore in plate		ø 110 mm [4.33 in.]	109.987 to 110.022 mm [4.3302 to 4.3316 in.]
Bearing	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.]
Gear shaft bearing bore outside diameter		ø 50 mm [1.97 in.]	49.993 to 50.013 mm [1.9682 to 1.9690 in.]

3.4 Measuring idler bushing inside diameter and idler shaft outside diameter

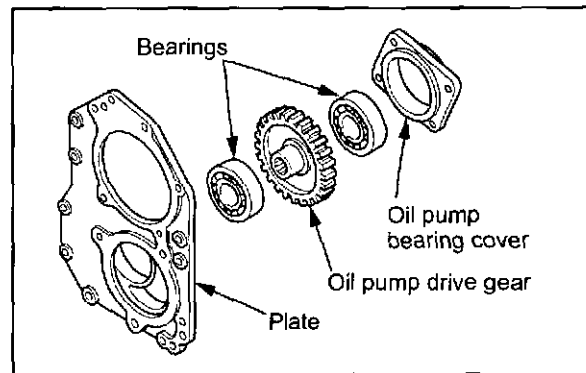
Measure the idler bushing inside diameter and the idler shaft outside diameter. If the inside diameter exceeds the limit, replace the idler bushing, and if the outside diameter is smaller than the limit, replace the idler shaft.

Item	Nominal	Standard	Limit
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.]
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.]

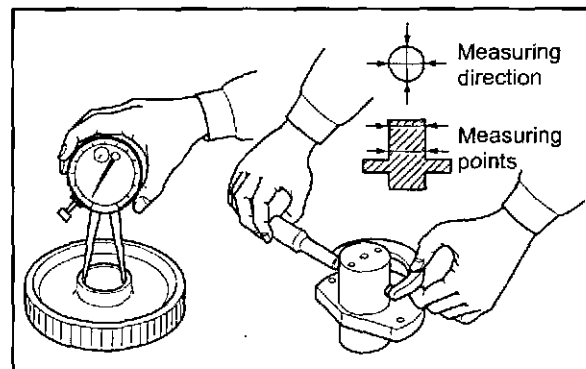
3.5 Measuring idler gear end play

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

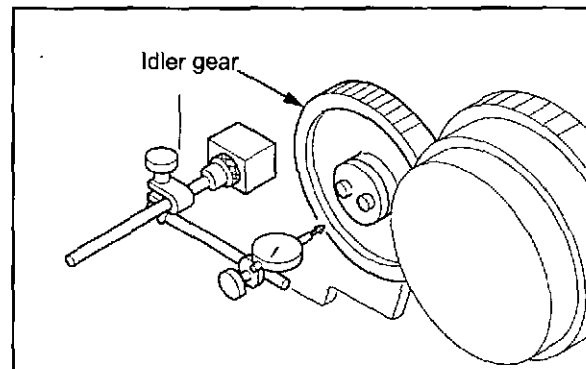
Item	Standard	Limit
Idler gear end play	0.20 to 0.40 mm [0.0079 to 0.0157 in.]	0.60 mm [0.0236 in.]



Outside diameter and inside diameter of oil pump drive bearing-fitted sections



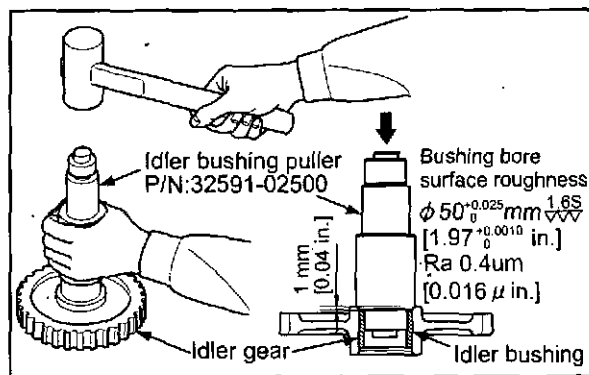
Measuring idler bushing inside diameter and idler shaft outside diameter



Measuring idler gear end play

3.6 Replacing idler bushing

- (1) Use the idler bushing puller to replace idler bushing.
- (2) After the bushing is fitted in the 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.



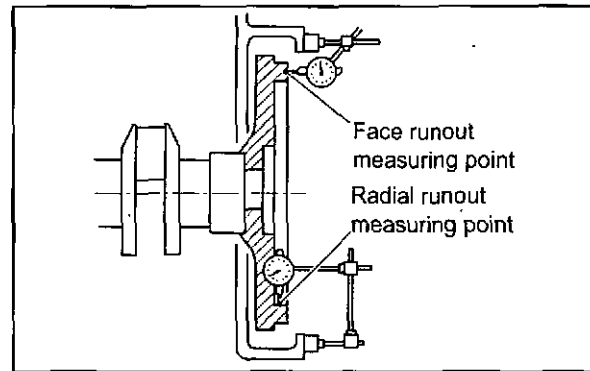
Replacing idler bushing (front side)

4. Flywheel, timing gear and camshaft

4.1 Measuring flywheel face and radial runouts

Measure the runouts of the flywheel in the installed condition. If any of the measurements exceeds the standard, check the flywheel for loosened bolts and foreign matter accumulation on the mounting face.

Item	Standard
Face runout	0.336 mm [0.0132 in.] or less
Radial runout	0.130 mm [0.0051 in.] or less

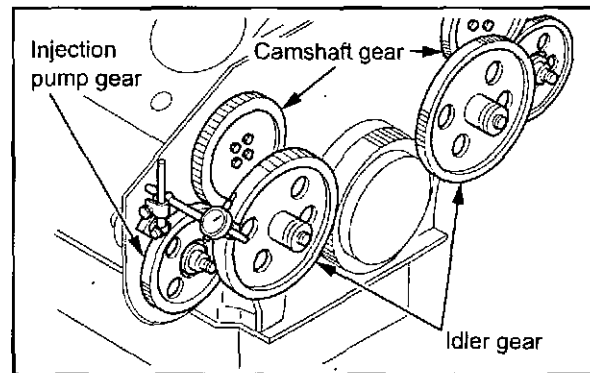


Measuring face and radial runout of flywheel

4.2 Measuring backlash of timing gear

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
Backlash	0.12 to 0.18 mm [0.0047 to 0.0071 in.]	0.50 mm [0.0197 in.]

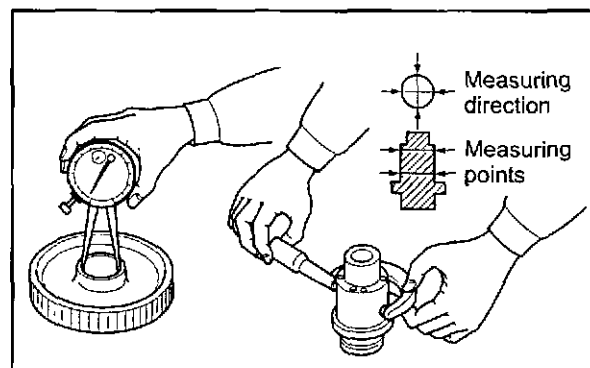


Measuring backlash of timing gear

4.3 Measuring idler bushing inside diameter and idler shaft outside diameter

Measure the idler bushing inside diameter and the idler shaft outside diameter. If the inside diameter exceeds the limit, replace the idler bushing, and if the outside diameter is smaller than the limit, replace the idler shaft.

Item	Nominal	Standard	Limit
Rear idler bushing inside diameter	ø 65 mm [2.56 in.]	65.000 to 65.030 mm [2.5591 to 2.5602 in.]	65.060 mm [2.5614 in.]
Rear idler shaft outside diameter	ø 65 mm [2.56 in.]	64.951 to 64.970 mm [2.5571 to 2.5579 in.]	64.900 mm [2.5551 in.]

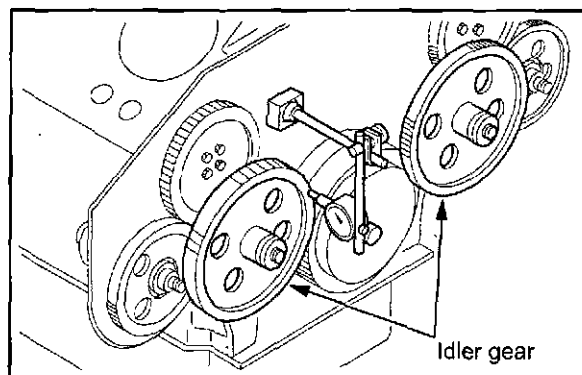


Measuring rear idler bushing inside diameter and shaft diameter

4.4 Measuring idler gear end play

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

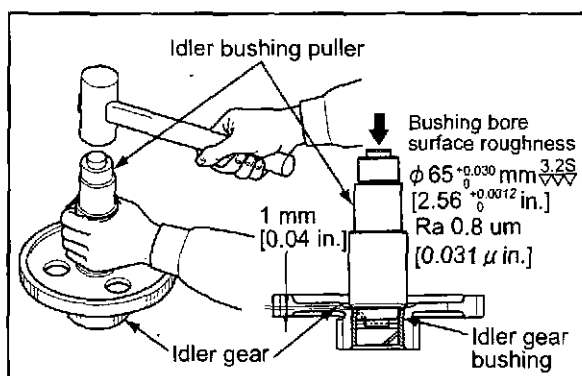
Item	Standard	Limit
Idler gear end play	0.3 to 0.6 mm [0.0118 to 0.0236 in.]	1.0 mm [0.0394 in.]



Measuring idler gear end play

4.5 Replacing idler bushing

- (1) Use the idler bushing puller to replace idler bushing.
- (2) After the bushing is fitted in the 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.

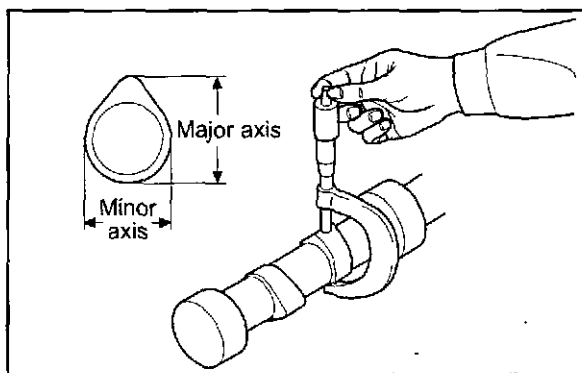


Replacing idler bushing (rear side)

4.6 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)	9.197 to 9.297 mm [0.3621 to 0.3660 in.]	8.45 mm [0.3327 in.]



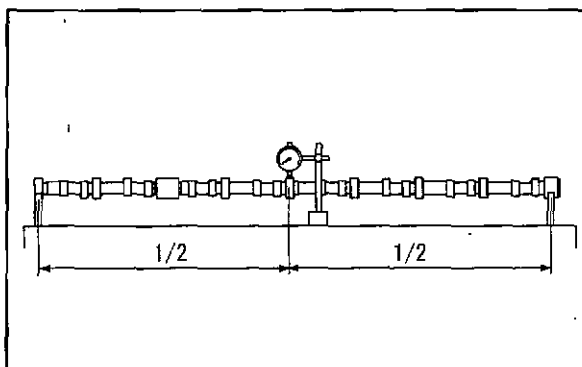
Measuring cam lift

4.7 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.]

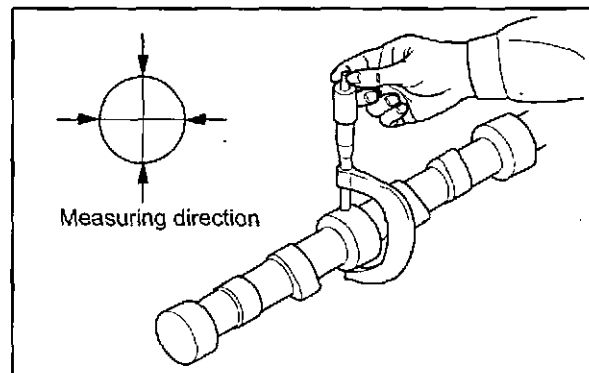


Measuring camshaft runout

4.8 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 84 mm [3.31 in.]	83.920 to 83.940 mm [3.3039 to 3.3047 in.]	83.870 mm [3.3020 in.]

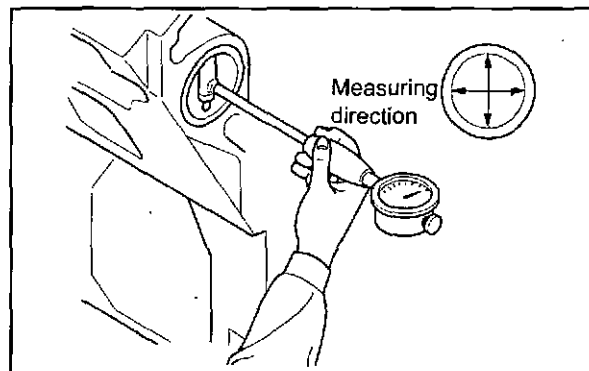


Measuring camshaft journal outside diameter

4.9 Measuring camshaft bushing inside diameter

With the camshaft bushings installed in the crankcase, measure the inside diameters using a cylinder gauge. If the limit is exceeded, replace the bushing with a new one.

Item	Nominal	Standard	Limit
Camshaft bushing inside diameter	ø 84 mm [3.31 in.]	84.000 to 84.035 mm [3.3071 to 3.3085 in.]	84.100 mm [3.3110 in.]

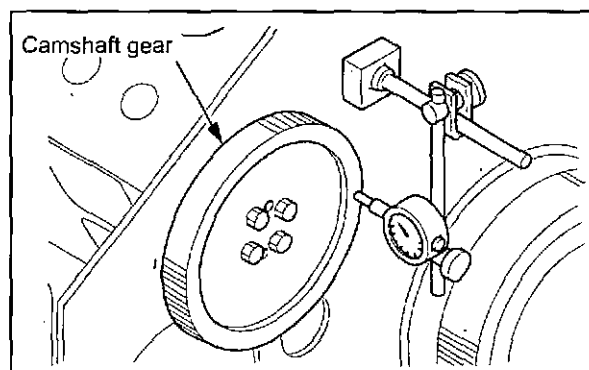


Measuring camshaft bushing inside diameter

4.10 Measuring camshaft end play

Measure the camshaft end play with the camshaft gear attached. Replace the thrust plate with a new one if the limit is exceeded.

Item	Standard	Limit
Camshaft end play	0.10 to 0.25 mm [0.0039 to 0.0098 in.]	0.40 mm [0.0157 in.]

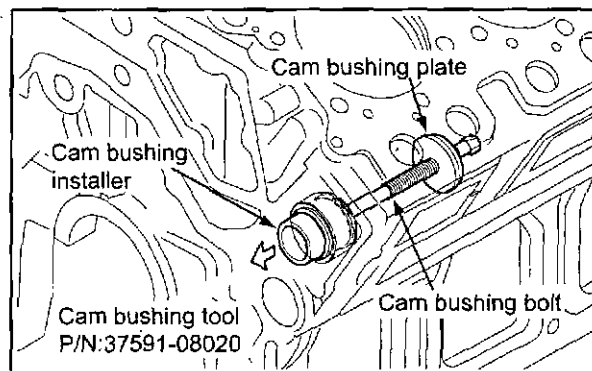


Measuring camshaft end play

4.11 Replacing camshaft bushing

4.11.1 Removing camshaft bushing

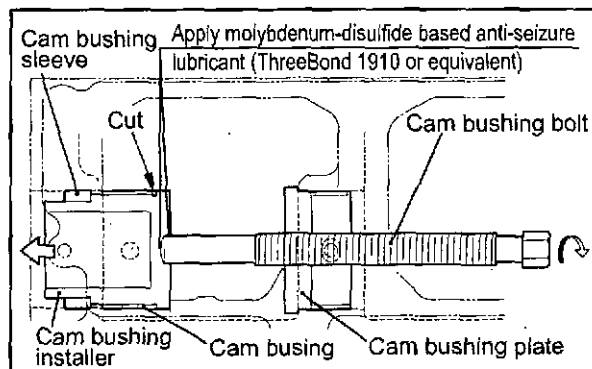
- (1) Set the cam bushing installer and cam bushing plate into the positions appropriate for removing the bushing.
- (2) Set the cam bushing bolt by screwing it into the cam bushing plate.
- (3) Apply molybdenum-disulfide base anti-seizure lubricant (ThreeBond 1910 or equivalent) to the tip of the cam bushing bolt (the portion that will touch the cam bushing installer).
- (4) Screw in the cam bushing bolt to push the cam bushing installer and force out the camshaft bushing.



Removing camshaft bushing

4.11.2 Installing camshaft bushing

- (1) Insert the cam bushing installer into the camshaft bushing and install the cam bushing sleeve.
- (2) Face the cut of the camshaft bushing upward and set the camshaft bushing in the camshaft fitting bore while aligning the hole in the camshaft bushing with the hole in the crankcase.
- (3) Set the cam bushing plate and cam bushing bolt as shown in the illustration.
- (4) Apply molybdenum-disulfide based anti-seizure lubricant (ThreeBond 1910 or equivalent) to the tip of the cam bushing bolt (the portion that will touch the cam bushing installer).

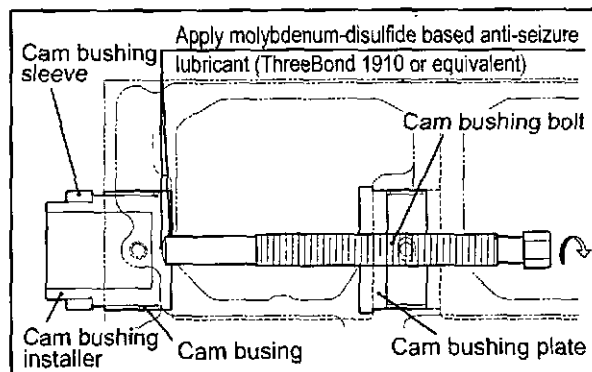


Installing camshaft bushing (beginning of installation)

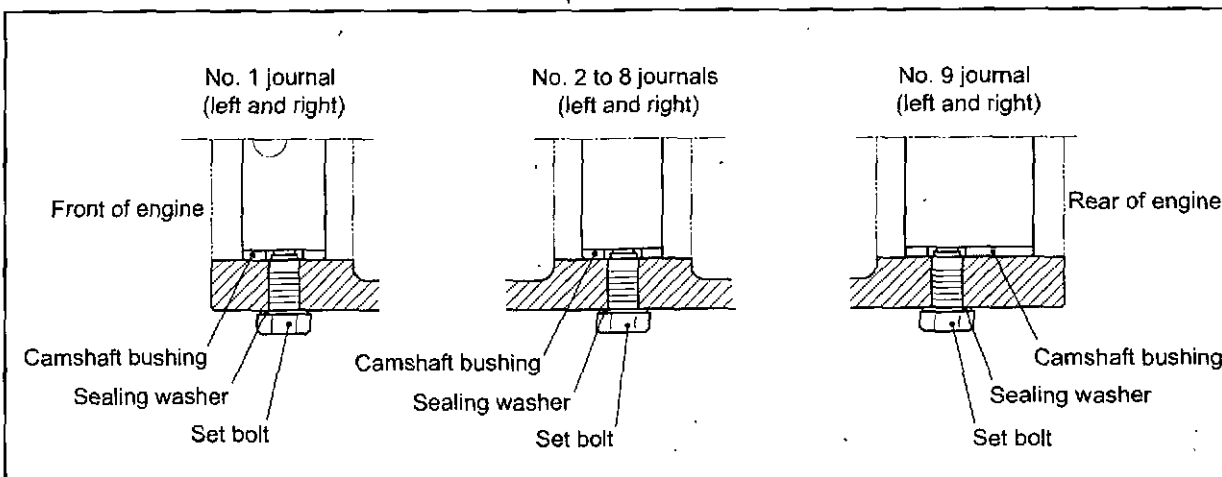
- (5) Screw in the cam bushing bolt to push the cam bushing installer and force the camshaft bushing into position.

Note: Force the camshaft bushing while aligning the hole in the crankcase and the hole in the camshaft bushing.

- (6) Install the sealing washer and set bolt to hold the camshaft bushing in position.



Installing camshaft bushing (set)



Camshaft journal and bushing type

5. 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 measurement exceeds the limit, grind the pin or journal to match the diameter with the next undersize bearing.
- (2) Determine the out-of-roundness and the out-of-cylindricity (taper) based on the outside diameter measurements.
- (3) If the limit is exceeded on a crankshaft in which -1.00 mm [-0.0394 in.] undersize bearings are already used, replace the crankshaft with a new one.

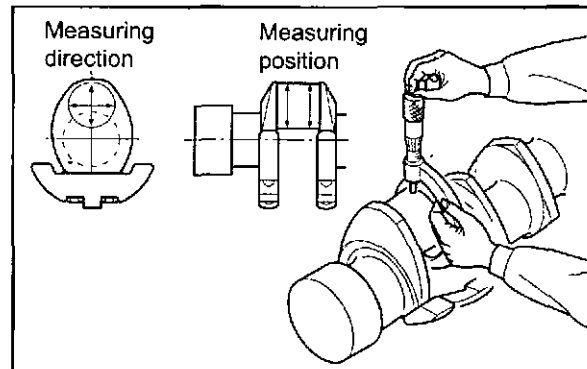
Item		Nominal	Standard	Limit
Crankpin diameter		ø 125 mm [4.92 in.]	124.930 to 124.950 mm [4.9185 to 4.9193 in.]	124.890 mm [4.91692 in.]
Crank journal diameter		ø 170 mm [6.69 in.]	169.920 to 169.940 mm [6.6898 to 6.6905 in.]	169.890 mm [6.6886 in.]
Distance between centers of journal and crankpin		90 mm [3.54 in.]	89.90 to 90.10 mm [3.5394 to 3.5472 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.]
	Roundness		Diameter difference 0.01 mm [0.0004 in.] or less	0.03 mm [0.0012 in.]
	Cylindricity		Diameter difference 0.01 mm [0.0004 in.] or less	0.03 mm [0.0012 in.]
	Fillet radius	Pin	R7 [0.28 in.]	6.8 to 7.0 mm [0.2677 to 0.2756 in.]
		Journal	R8.5 [0.33 in.]	8.3 to 8.5 mm [0.3270 to 0.3349 in.]
	Hardness		Hv>590	
	Surface accuracy		Ra 0.2 µm [0.008 µin.]	
Angular deviation between pins			± 0° 20'	

5.2 Grinding crankshaft

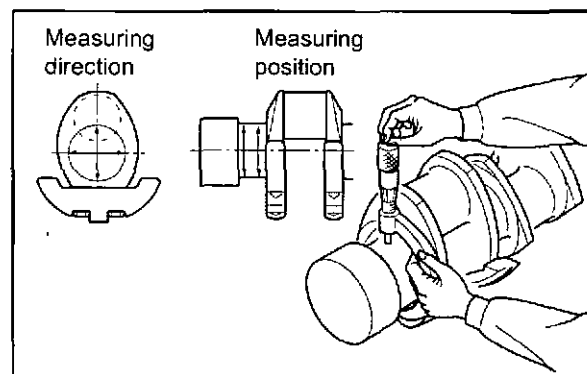
Grind the crankshaft journals (or pins) to the diameter matching the inside diameter of the next undersize main (or connecting) bearing. By doing so, the fitness check with an actual bearing can be omitted.

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.



Measuring crankpin diameter



Measuring crankshaft journal outside diameter

Undersize grinding dimension of crankshaft

Grin parts	Under-size	Finishing dimension	Roundness	Cylindricity
Crankpin diameter	0.25 mm [0.01 in.]	124.68 to 124.70 mm [4.9087 to 4.9094 in.]	Diameter difference 0.01 mm [0.0004 in.] or less	Diameter difference 0.02 mm [0.0008 in.] or less
	0.50 mm [0.02 in.]	124.43 to 124.45 mm [4.8988 to 4.8996 in.]		
	0.75 mm [0.03 in.]	124.18 to 124.20 mm [4.8890 to 4.8898 in.]		
	1.00 mm [0.04 in.]	123.93 to 123.95 mm [4.8791 to 4.8799 in.]		
Journal diameter	0.25 mm [0.01 in.]	169.67 to 169.69 mm [6.6799 to 6.6807 in.]	Diameter difference 0.01 mm [0.0004 in.] or less	Diameter difference 0.02 mm [0.0008 in.] or less
	0.50 mm [0.02 in.]	169.42 to 169.44 mm [6.6701 to 6.6709 in.]		
	0.75 mm [0.03 in.]	169.17 to 169.19 mm [6.6602 to 6.6610 in.]		
	1.00 mm [0.04 in.]	168.92 to 168.94 mm [6.6504 to 6.6512 in.]		

5.3 Measuring crankshaft end play

- (1) Check 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 even after a new thrust plate is 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	0.20 to 0.40 mm [0.0079 to 0.0157 in.]	0.50 mm [0.0197 in.]

Oversize	Used on one side	Used on both sides	Tolerance
+0.25 mm [0.01 in.] O.S.	67.25 mm [2.6476 in.]	67.50 mm [2.6575 in.]	$\begin{matrix} +0.03 \\ 0 \\ -0.0012 \end{matrix}$ mm $\begin{bmatrix} 0.0012 \\ 0 \end{bmatrix}$ in.
+0.50 mm [0.02 in.] O.S.	67.50 mm [2.6575 in.]	68.00 mm [2.6772 in.]	
+0.75 mm [0.03 in.] O.S.	67.75 mm [2.6673 in.]	68.50 mm [2.6968 in.]	

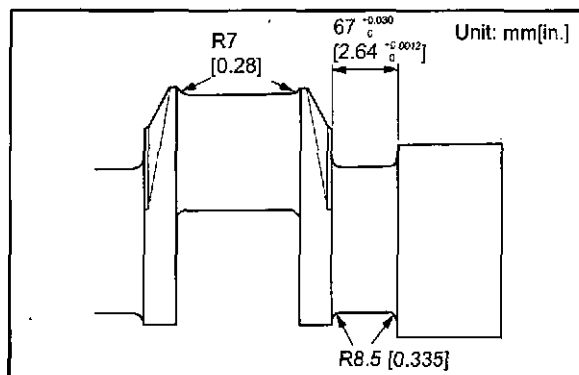
5.4 Measuring crankshaft runout

Support the crankshaft at the front and rear journals with V-blocks, and measure the crankshaft deflection (radial runout at the center journal) using a dial gauge. If the runout deviates from the standard only slightly, correct by grinding the crankshaft. If the runout is a little large, straighten the crankshaft using a press.

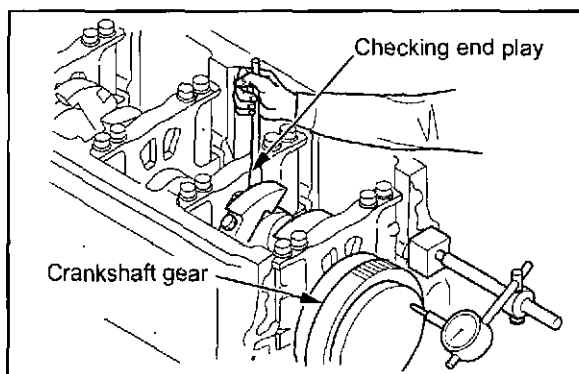
If the limit is exceeded, replace the crankshaft.

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

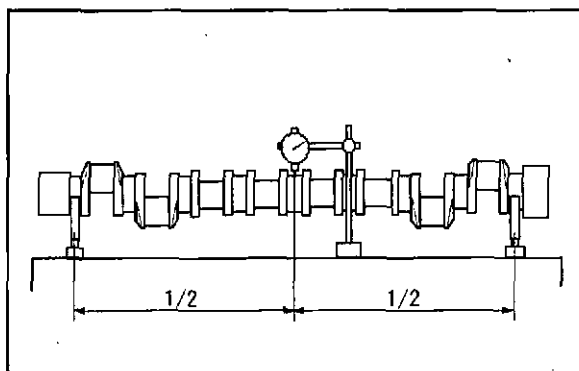
Item	Standard	Limit
Crankshaft runout (TIR)	0.08 mm [0.0031 in.] or less	0.20 mm [0.0079 in.]



Measuring thrust bearing journal length



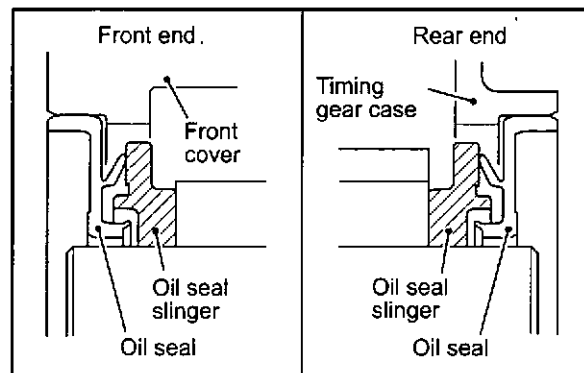
Measuring crankshaft end play



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.

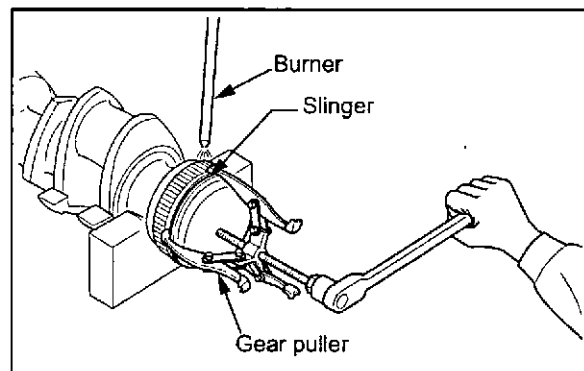


Replacing oil seal slinger

5.5.1 Removing oil seal slinger

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

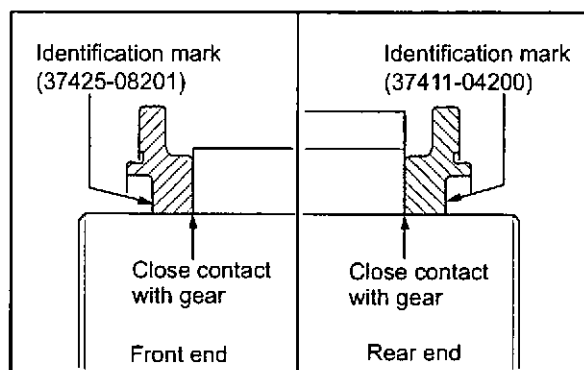
Note: Do not heat the slinger for longer than necessary.



Removing oil seal slinger

5.5.2 Installing oil seal slinger

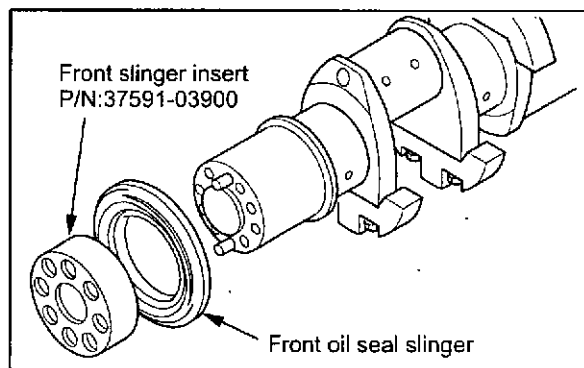
Identify the front slinger and the rear slinger, and pay attention to the installation directions.



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.



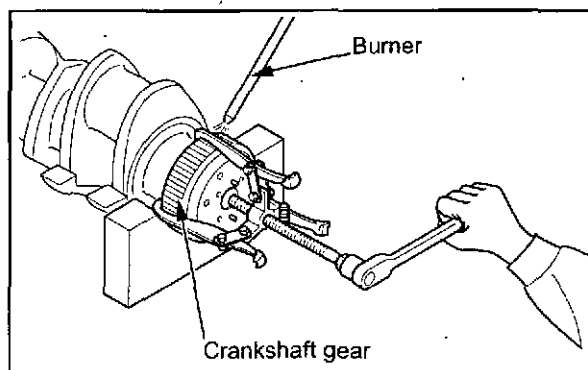
Installing oil seal slinger (2)

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.



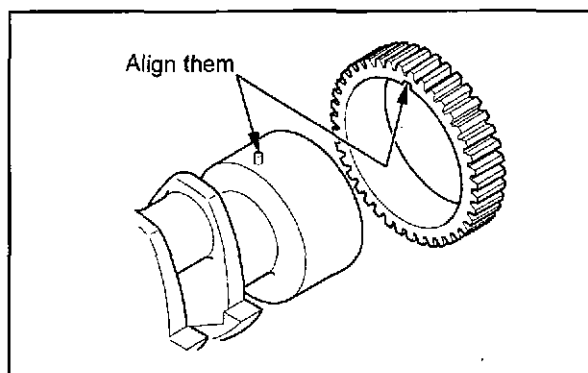
Removing crankshaft gear

5.6.2 Installing crankshaft gear

CAUTION

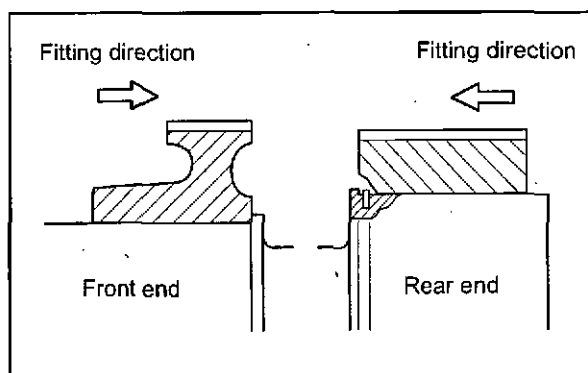
- (a) Install the crankshaft gear until it comes into contact with the crankshaft flange.
- (b) Be sure to install the gear in the correct orientation.

- (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

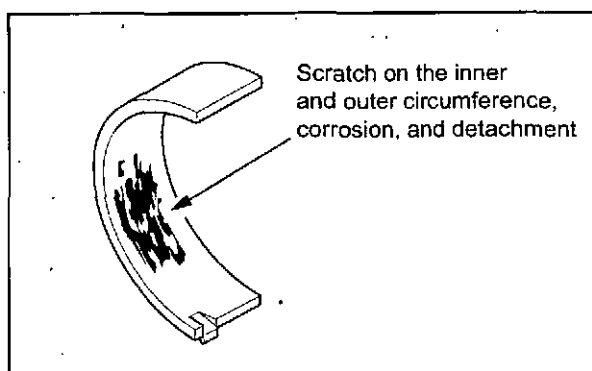
Item	Front side	Rear side
Interference of crankshaft diameter and inside diameter of the crankshaft gear	0.106 to 0.171 mm [0.0042 to 0.0067 in.]	0.274 to 0.358 mm [0.0108 to 0.0141 in.]



Fitting direction of crankcase

5.7 Inspecting main bearing surface

Check the inside surface of each main bearing shell for abnormal contact, scratches and corrosion resulting from foreign matter intrusion, and coating delamination. 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

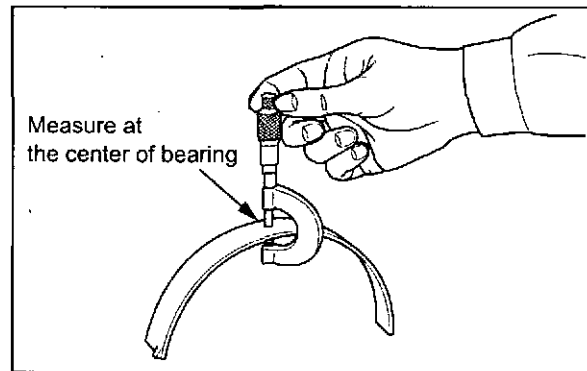
5.8 Measuring thickness of main bearing shell

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.

Item	Nominal	Standard	Limit
STD	4.500 mm [0.1772 in.]	4.467 to 4.480 mm [0.1759 to 0.1764 in.]	4.425 mm [0.1742 in.]
-0.25 mm [-0.01 in.]	4.625 mm [0.1821 in.]	4.592 to 4.605 mm [0.1808 to 0.1813 in.]	4.550 mm [0.1791 in.]
-0.50 mm [-0.02 in.]	4.750 mm [0.1870 in.]	4.717 to 4.730 mm [0.1857 to 0.1862 in.]	4.675 mm [0.1841 in.]
-0.75 mm [-0.03 in.]	4.875 mm [0.1919 in.]	4.842 to 4.855 mm [0.1906 to 0.1911 in.]	4.800 mm [0.1890 in.]
-1.00 mm [-0.04 in.]	5.000 mm [0.1969 in.]	4.967 to 4.980 mm [0.1956 to 0.1961 in.]	4.925 mm [0.1939 in.]

Main bearing thickness at center

Note: Four bearing undersizes are available: -0.25, -0.50, -0.75 and -1.00 mm [-0.01, -0.02, -0.03 and -0.04 in.].



Measuring main bearing thickness

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 distortion of crankcase top surface

CAUTION

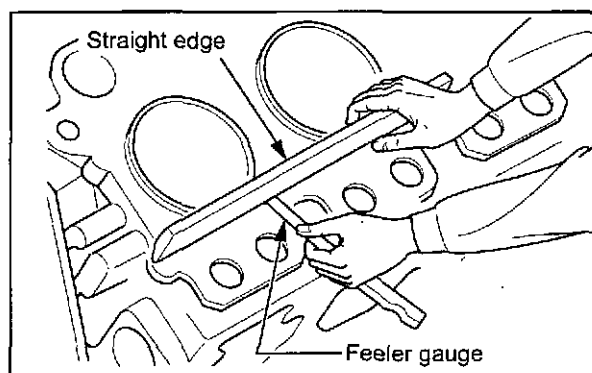
Refacing of cylinder head should be kept to an absolute minimum.

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	0.10 mm [0.0039 in.] or less	0.20 mm [0.0079 in.]

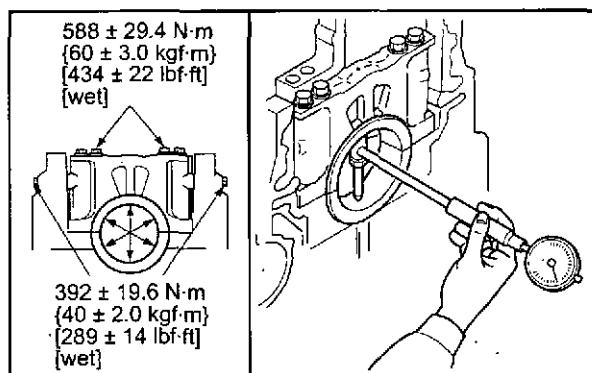


Measuring distortion of crankcase top surface

5.11 Measuring inside diameter of main bearing housing

- (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	$\phi 179$ mm [7.05 in.]	179.000 to 179.025 mm [7.0472 to 7.0482 in.]	179.045 mm [7.0490 in.]



Measuring main bearing fitting bore

REASSEMBLY OF BASIC ENGINE

1. Reassembling crankcase, crankshaft and main bearing	7-2	4.14 Installing oil pan	7-17
1.1 Installing main bearing	7-2	5. Reassembling cylinder head and valve mechanism	7-18
1.2 Installing thrust plates	7-2	5.1 Installing inlet and exhaust valve	7-18
1.3 Installing crankshaft	7-2	5.2 Installing tappet	7-18
1.4 Installing main bearing cap	7-3	5.3 Applying liquid gasket	7-19
1.5 Installing main bearing cap bolts	7-3	5.4 Installing cylinder head gasket	7-19
1.6 Measuring crankshaft end play	7-4	5.5 Installing cylinder head assembly	7-20
2. Reassembling cylinder liner, piston and connecting rod	7-5	5.6 Tightening cylinder head bolt	7-20
2.1 Reassembling piston and connecting rod	7-5	5.6.1 2-step tightening method	7-20
2.2 Installing piston ring	7-5	5.6.2 Angle tightening method	7-20
2.3 Preparation for Installing Pistons	7-6	5.7 Installing rocker case	7-21
2.4 Installing connecting rod bearing upper shell	7-6	5.8 Installing bridges and bridge cap	7-21
2.5 Installing piston	7-7	5.9 Installing rocker shaft assembly	7-21
2.6 Installing connecting rod cap	7-8	5.10 Inspecting valve timing	7-22
3. Reassembling damper and front gear	7-10	5.11 Installing fuel injection nozzle assembly	7-22
3.1 Installing front plate	7-10	5.12 Adjusting valve clearance	7-22
3.2 Installing idler shaft	7-10		
3.3 Installing idler gear	7-10		
3.4 Installing bearing cover of oil and water pump	7-10		
3.5 Installing front gear case and pointer	7-11		
3.6 Installing oil pump gear and oil pump/water pump mounting plate	7-12		
3.7 Installing damper and crankshaft pulley	7-12		
4. Reassembling flywheel, timing gear, camshaft, oil pan	7-13		
4.1 Installing rear plate	7-13		
4.2 Turning engine	7-13		
4.3 Installing idler shaft	7-13		
4.4 Installing camshaft	7-14		
4.5 Installing camshaft gear	7-14		
4.6 Installing idler gear	7-14		
4.7 Installing fuel injection pump accessory drive (right and left side)	7-15		
4.8 Inspecting and adjusting timing gear after installation	7-15		
4.8.1 Inspecting backlash and end play	7-15		
4.9 Installing timing gear case	7-16		
4.10 Installing rear oil seal	7-16		
4.11 Installing idler shaft thrust collar	7-16		
4.12 Installing flywheel	7-17		
4.13 Installing pickup	7-17		

1. Reassembling crankcase, crankshaft and main bearing

1.1 Installing main bearing

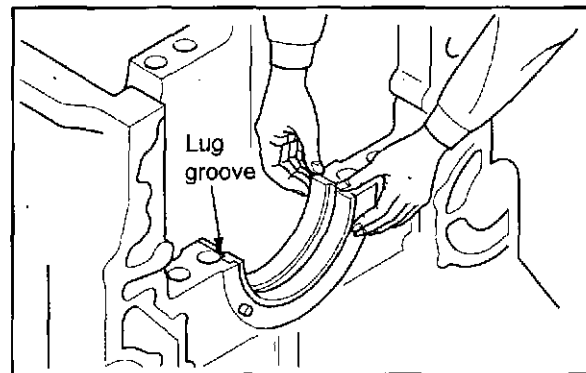
CAUTION

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

- (1) Press the upper main bearing into position by aligning its lug to the lug groove on the crankcase.

Note: The oil hole of the main bearing is aligned with the oil hole of the crankcase by installing the upper main bearing in alignment with the lug groove.

- (2) Apply a small amount of engine oil to each bearing.



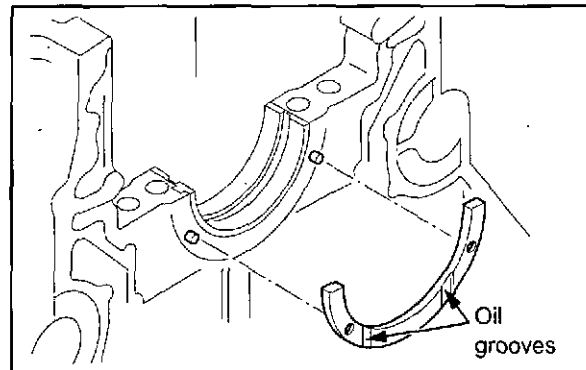
Installing main bearing

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

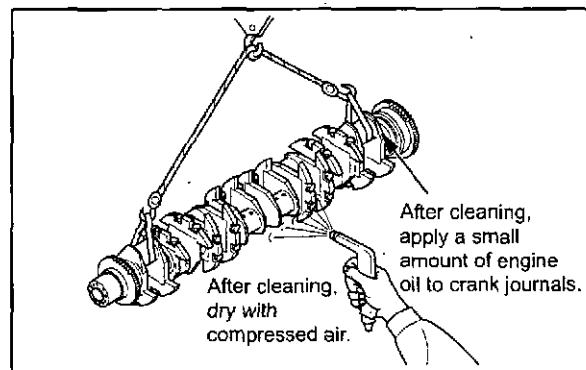
1.3 Installing crankshaft

- (1) Check to ensure that the main bearing upper shells fitted in the crankcase bores have their inner periphery (surface contacting 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 with cloth belts or pads applied on the supporting points.

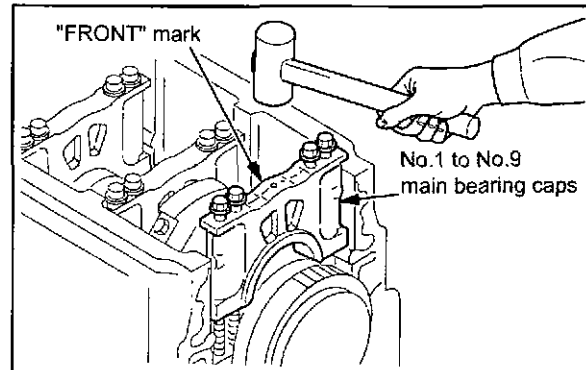


Installing crankshaft

1.4 Installing main bearing cap

- (1) Fit the main bearing (lower half) to each main bearing cap.
- (2) Install the thrust plate to the rearmost bearing cap, making sure that the oil groove side is facing toward the outside of the cap.
- (3) From the front of the engine toward the back, bearing numbers are stamped on the bearing caps. Install the caps according to the numbers, and the "FRONT" mark on the each cap facing to the front of the engine.
- (4) Coat the threads of the bearing cap bolts with engine oil, and tighten the bolts temporarily.
- (5) Use a soft-head mallet to drive in the bearing caps evenly.

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



Installing main bearing cap

1.5 Installing main bearing cap bolts

CAUTION

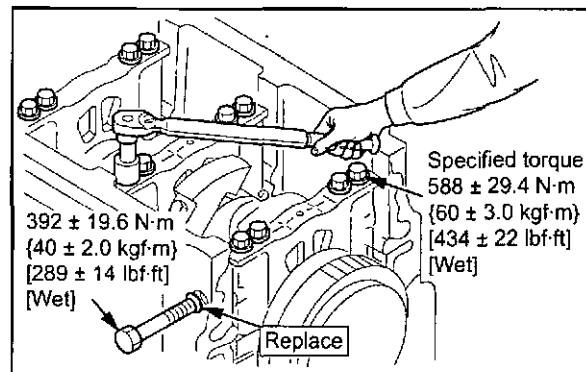
Be sure to observe the specified tightening sequence when installing the main bearing cap bolts and side bolts.

- (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.

- (3) Tighten the main bearing cap bolts and side bolts to the specified bolts. 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

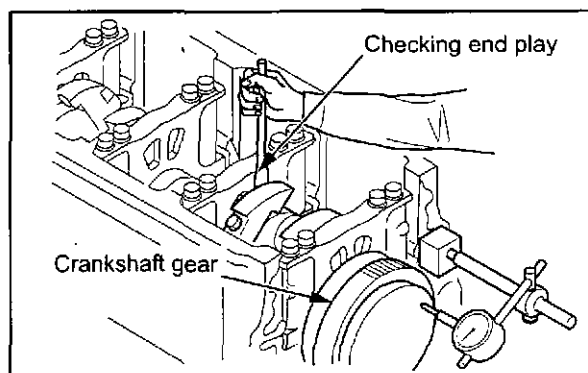
1.6 Measuring crankshaft end play

Attach a dial gauge to the end of the crankshaft to measure the end play.

If the end play deviates from the standard value, loosen the main bearing cap bolts and retighten.

Make sure that the camshaft turns freely.

Item	Standard	Limit
Crankshaft end play	0.20 to 0.40 mm [0.0079 to 0.0157 in.]	0.50 mm [0.0197 in.]



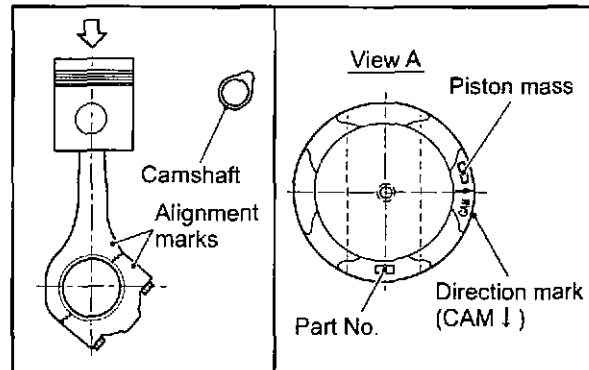
Measuring crankshaft end play

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.

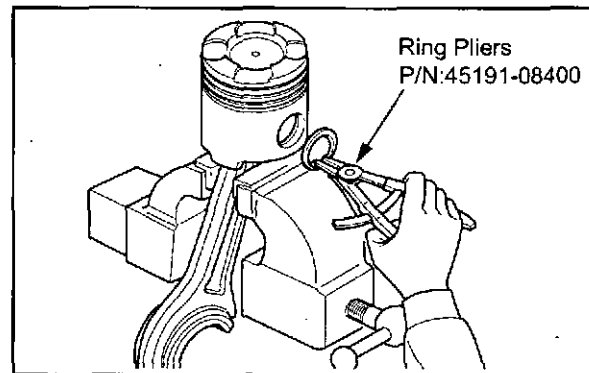
Note: The pistons and piston pins are assembled to each other in clearance fit. However, the piston pins are more easily inserted into the pistons if the pistons are warmed up with a heater or in hot water.



Reassembling 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 in the groove.

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



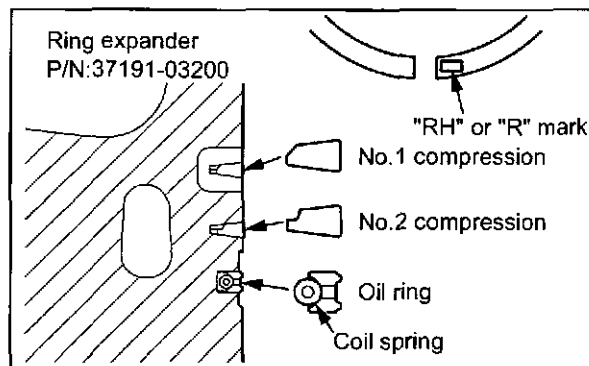
Reassembling piston and connecting rod

2.2 Installing piston ring

CAUTION

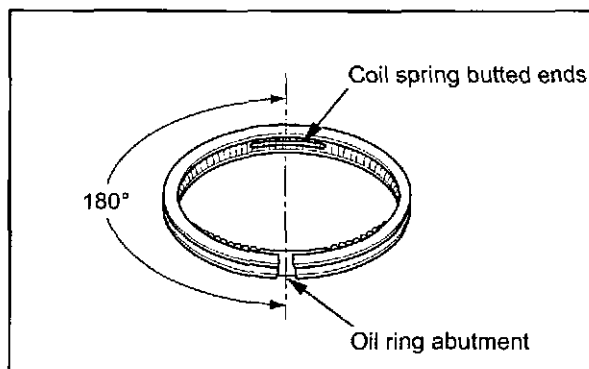
- (a) The No.1 ring and No.2 compression ring are marked "RH", and oil ring is marked "R" near the end gap on the side. Install the rings with these marks facing up.
- (b) If the rings are faced in the wrong direction, it will result in excessive oil consumption or an engine seizing.

- (1) Using the ring expander, install the piston rings to the piston.



Piston and piston ring arrangement

- (2) Install the oil ring with its end gap positioned at 180° to the coil spring joint, as shown in the diagram.

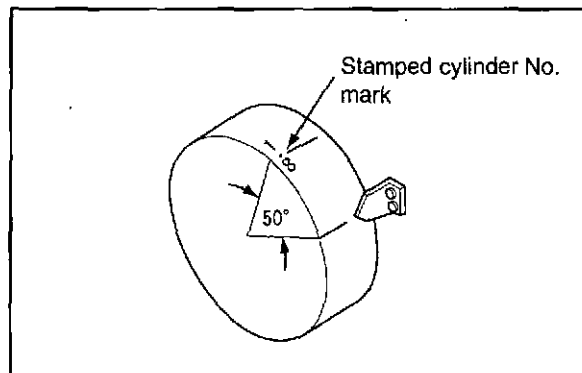


Installing oil ring and coil spring

2.3 Preparation for Installing Pistons

(1) For the right bank

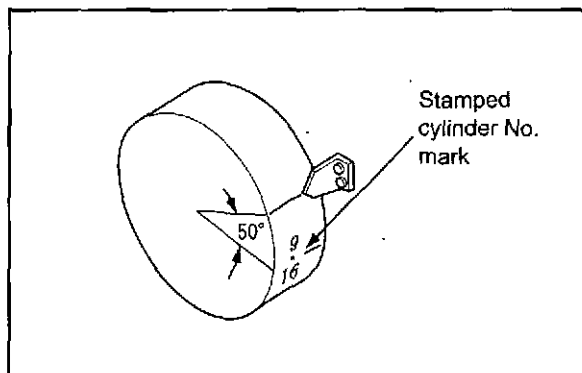
To facilitate piston installation, temporarily install the damper and the pointer. Turn the crankshaft in the normal turning direction to bring the stamped mark of the installing cylinder number to the position approximately 50° before top dead center.



Preparation before installing piston in right-bank cylinder

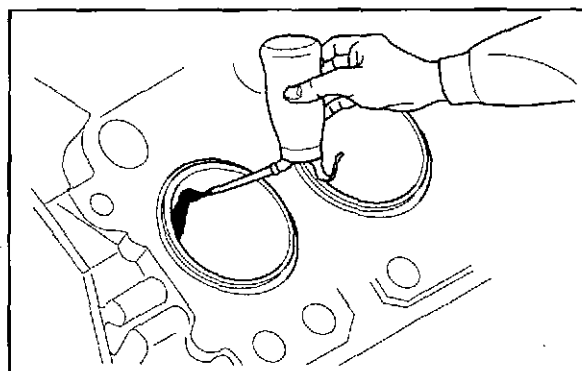
(2) For the left bank

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 before 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.



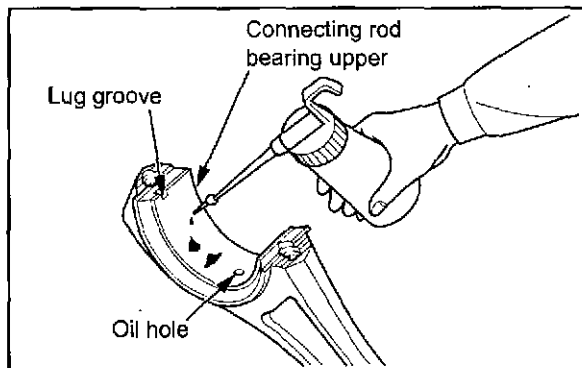
Preparation for installing piston

2.4 Installing connecting rod bearing upper shell

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. Ensure that the oil hole of the bearing is in alignment with the oil hole of the connecting rod.



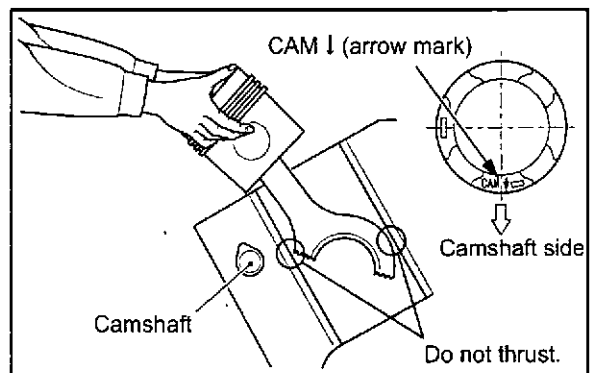
Installing connecting rod bearing upper

2.5 Installing piston

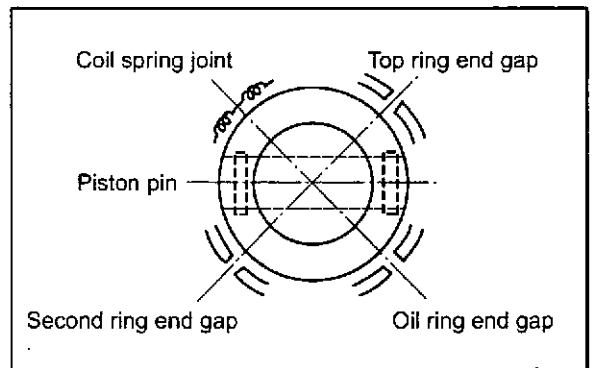
- (1) Place the connecting rod in the cylinder liner, and carefully rest the piston on top of the crankcase.

CAUTION

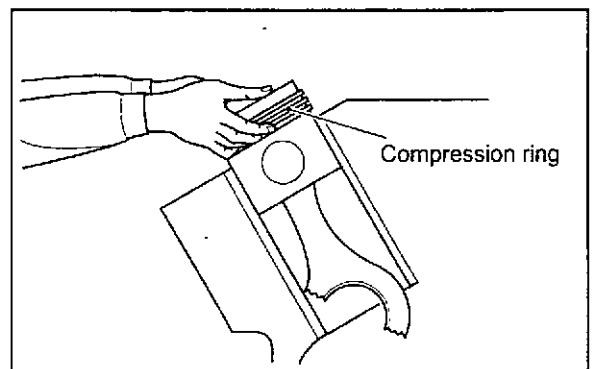
- (a) Make sure that the mark in the top of the piston is facing toward the front of the engine when installing.
 - (b) As you install the piston, make sure that the connecting rod does not come into contact with the piston cooling nozzle by checking it through the inspection window provided on the side of crankcase.
 - (c) Do not turn the piston.
- (2) Apply engine oil to the piston rings. Then, place the end gap of the individual piston rings respectively at one of equally spaced four positions, avoiding such on the diagonal in the same direction as the piston pin and on the diagonal at right angles to it.



Installing piston (1)

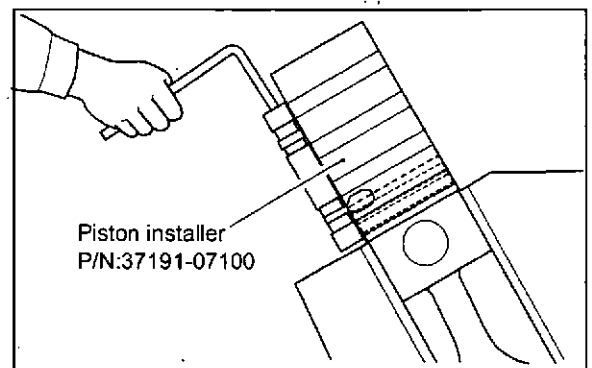


Installing piston (2)



Installing piston (3)

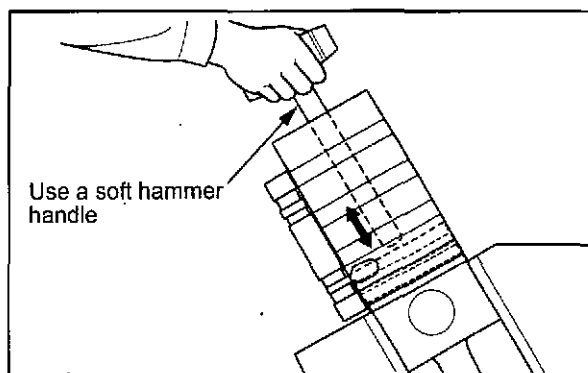
- (4) Revalidate that the piston ring end gaps are positioned correctly. Apply engine oil to the piston rings. Lubricate the inside surface of the piston installer with engine oil. Clamp the piston rings with the piston installer.



Installing piston (4)

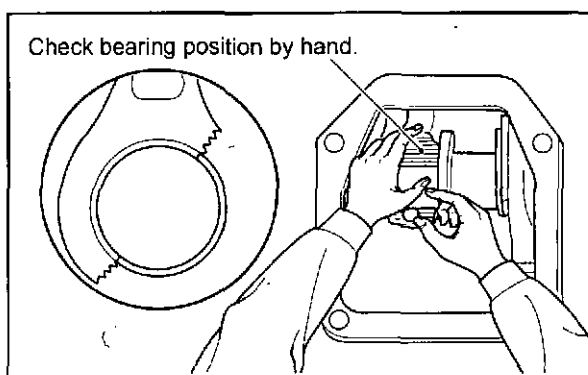
- (5) Insert piston into cylinder liner and tap the piston head with a soft-head hammer to install.

If the piston is stubborn, move the connecting rod big end back and forth through the inspection window on the side face of crankcase.



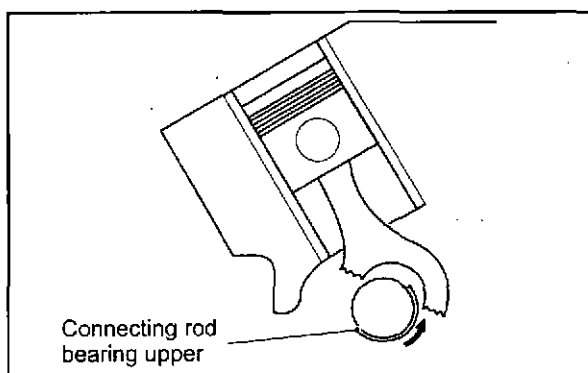
Installing piston (5)

- (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)

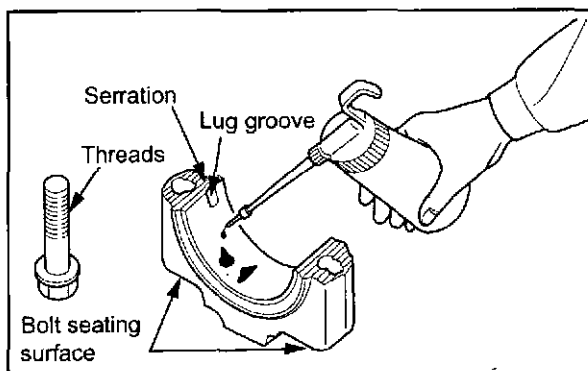
- (7) If the upper half of the bearing is off the connecting rod big-end, turn the crankshaft to make a space between the connecting rod big-end and crankpin, and insert the bearing into position while sliding it along the crankpin surface.



Installing piston (7)

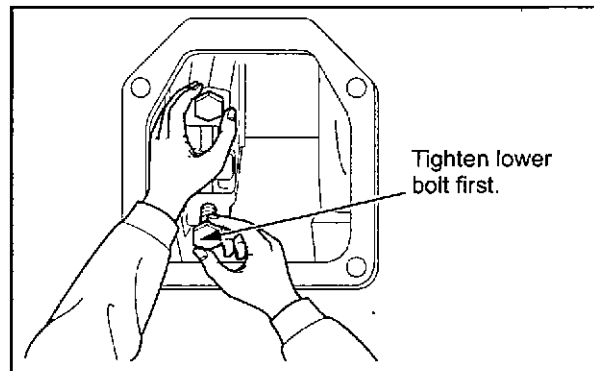
2.6 Installing connecting rod cap

- (1) Check that the mating mark on the bearing cap and the mating mark on the connecting rod are on the same side and in alignment, then install the connecting rod bearing cap to the connecting rod.
- (2) Apply engine oil to the bearing cap bolt threads and seating surface, and the inside surface of the connecting rod bearing lower shell.

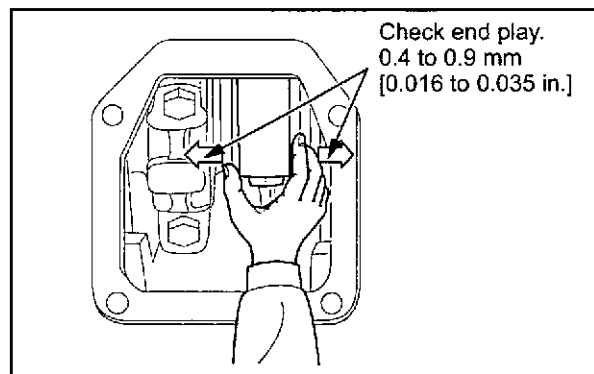


Installing connecting rod cap (1)

- (3) Check that the mating mark on the bearing cap and the mating 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 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.
- (5) With bolts temporarily tightened, measure the end play of the connecting rod using feeler gauge. Make sure the clearance is equal on the top and bottom sides of the crankpin.
- (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.

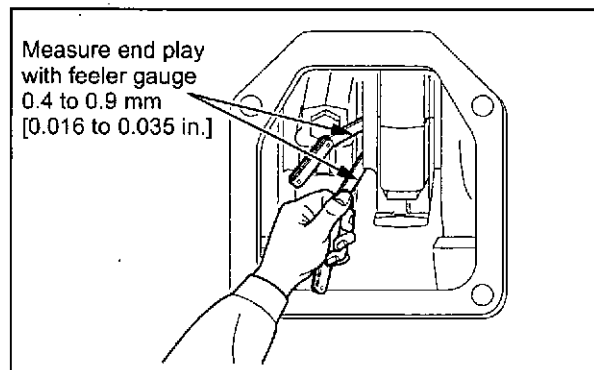


Installing connecting rod cap (2)



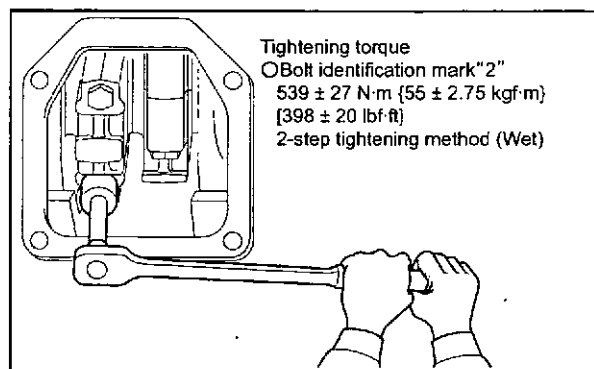
Installing connecting rod cap (3)

- (7) With bolts temporarily tightened, measure the end play of the connecting rod using feeler gauge. Make sure the clearance is equal on the top and bottom sides of the crankpin.



Installing connecting rod cap (4)

- (8) 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.

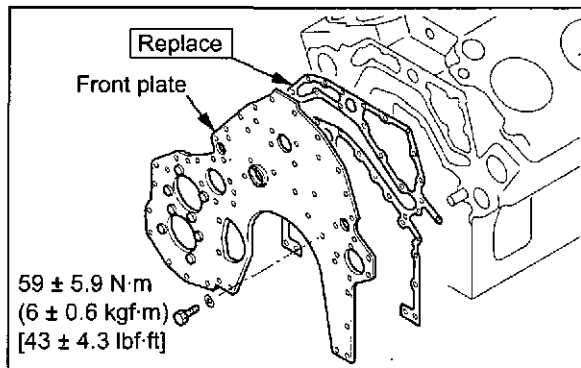


Installing connecting rod cap (5)

3. Reassembling damper and front gear

3.1 Installing front plate

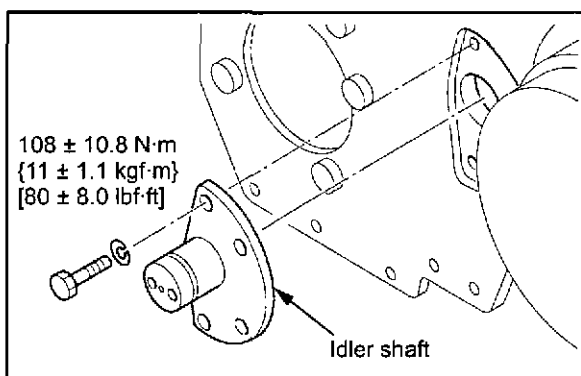
- (1) Apply sealant (Heldite) to the front plate mounting surface of the crankcase, then attach the packing in place. Apply the same sealant to the packing and install the front plate.
- (2) Replace the dowel pins if they are worn or the front plate is replaced.
- (3) Check that the lower end of the front plate is flush with the bottom surface of the crankcase. Cut off any excess packing neatly.



Installing front plate

3.2 Installing idler shaft

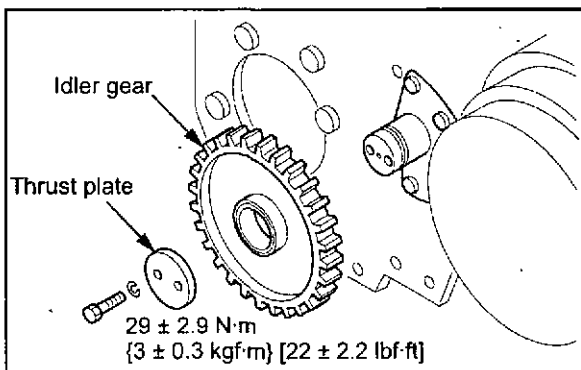
- (1) Drive the idler shaft into position using a guide bolt.
- (2) Tighten the idler shaft mounting bolts to the specified torque.



Installing idler shaft

3.3 Installing idler gear

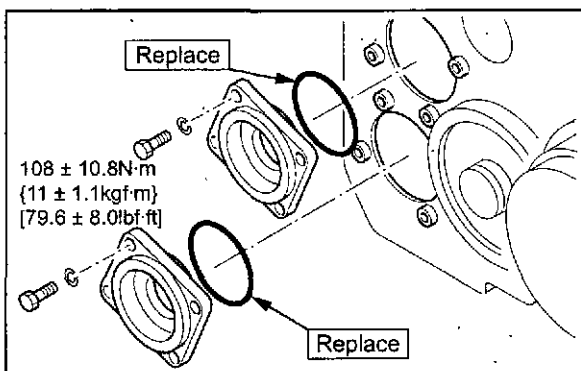
- (1) Apply engine oil to the idler gear shaft.
- (2) Install the idler gear with all match marks on it aligned with the marks on the other gears.
- (3) Install the thrust plate with its hole matching the pin of idler gear shaft.
- (4) Tighten the thrust plate bolt to the specified torque.
- (5) Move the idler gear back and forth, and make sure there is end play.



Installing idler gear

3.4 Installing bearing cover of oil and water pump

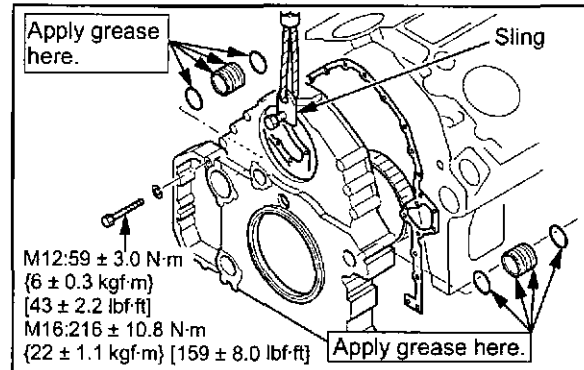
Install the bearing covers into the front plate, and tighten the cover mounting bolts to the specified torque.



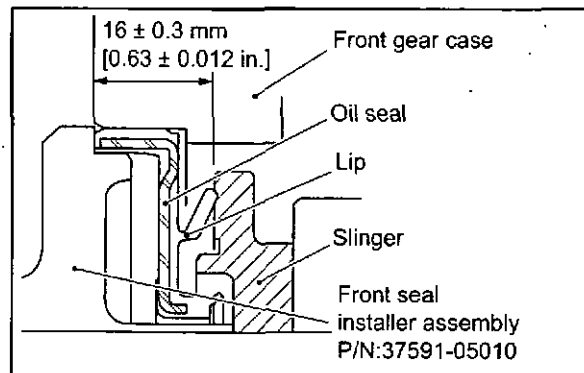
Installing front bearing cover

3.5 Installing front gear case and pointer

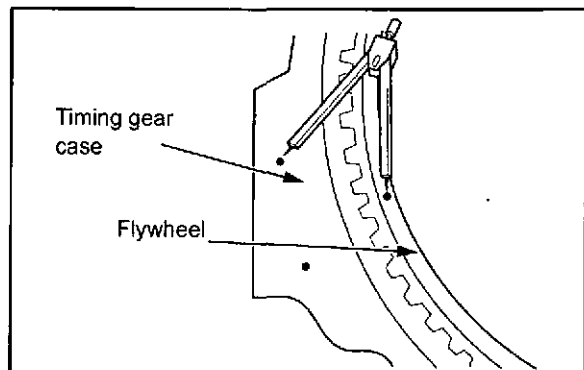
- (1) Apply sealant (ThreeBond 1211) to the surface of the crankcase to which each front gear case packing is fitted, then fit the packing in place. Apply the same sealant to each packing and install the front gear case.
- (2) Before installing the front gear case, fit the crankcase and gear case water couplings in the crankcase and apply grease O-rings and O-ring holes. Then, install the gear case using care not to damage the O-rings.
- (3) Replace the dowel pins if they are worn out or the cover is replaced.
- (4) Tighten the case mounting bolts evenly to the specified torque.
- (5) Check that the lower end of the front gear case is flush with the bottom of the crankcase. Cut off any excess packing neatly.
- (6) Install the oil seal in the front gear case.
- (7) Apply engine oil to the lip of the oil seal.
- (8) Using the special tool front seal installer assembly, install the oil seal into the illustrated position relative to the slinger.
- (9) 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 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 (also No. 8).



Installing front gear case



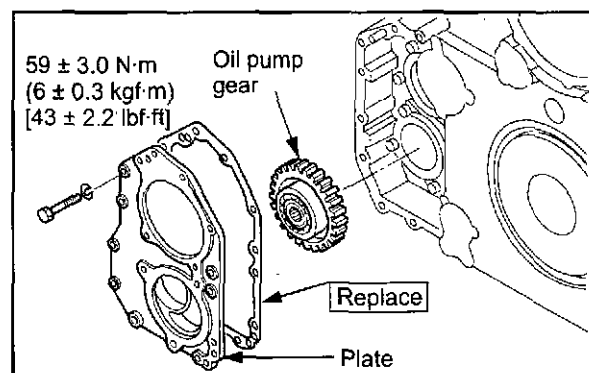
Installing oil seal and slinger



When pointer was removed or dislocated accidentally

3.6 Installing oil pump gear and oil pump/water pump mounting plate

- (1) Fit the oil pump gear into place.
- (2) Install the mounting plate and tighten bolts to the specified torque.

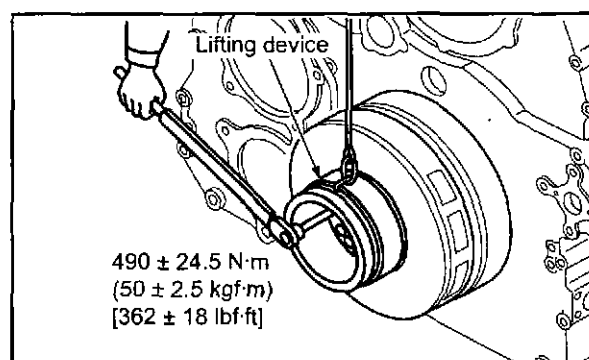


Installing oil pump gear and plate

3.7 Installing damper and crankshaft pulley

Tighten the damper mounting bolts to the specified torque.

- (1) Install the damper and crankshaft pulley to the tip of crankshaft.
- (2) Tighten the mounting bolts to the specified torque.



Installing damper and crankshaft pulley

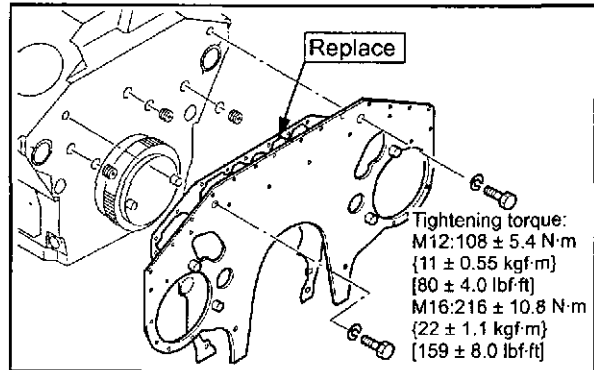
4. Reassembling flywheel, timing gear, camshaft, oil pan

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.

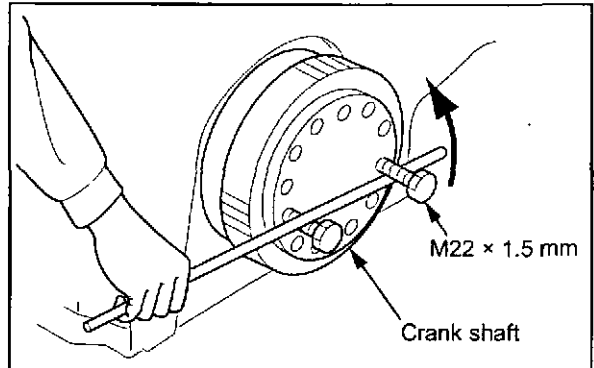
- (3) Make sure that the rear plate bottom is flush with the crankcase bottom. If the packing is protruding, cut off the excess neatly.



Installing rear plate

4.2 Turning engine

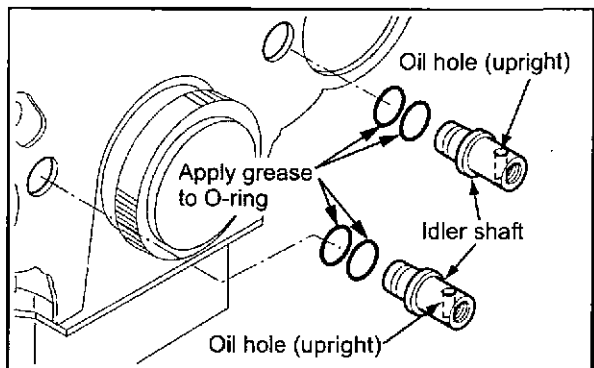
- (1) Install two bolts in the flywheel mounting holes of the crankshaft.
- (2) Turn the crankshaft with a bar using the bolts to bring the No. 1 cylinder at the top dead center.



Turning engine

4.3 Installing idler shaft

Fit the O-rings onto each idler shaft. Apply grease to the O-rings, and install the idler shafts into the crankcase. Make sure that the oil holes in the idler shafts are upright.



Installing idler shaft

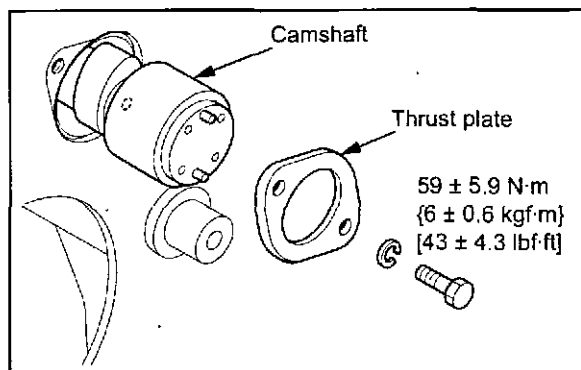
4.4 Installing camshaft

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) Insert the camshaft into the crankcase, then install the thrust plate.
- (2) Tighten the thrust plate mounting bolts to the specified torque.
- (3) Make sure that each camshaft rotates freely.

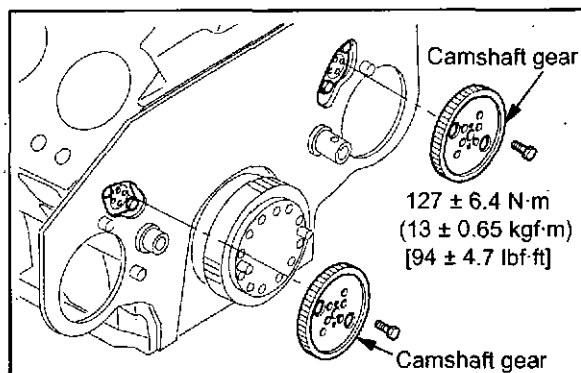
Note: Install the right camshafts to the right side. Do not mix-up the right and left camshafts.



Installing camshaft

4.5 Installing camshaft gear

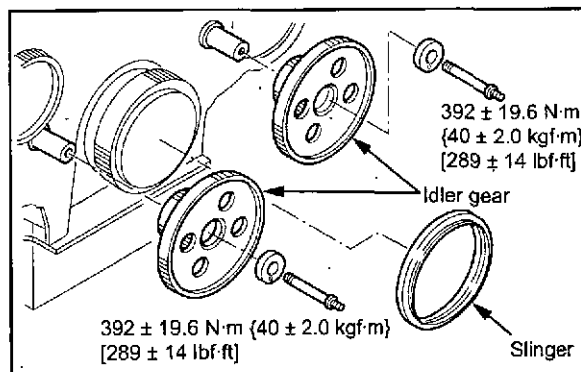
- (1) Install each camshaft gear by aligning its hole with the dowel pin on the camshaft.
- (2) Tighten the camshaft gear mounting bolts to the specified torque.
- (3) After installing the camshaft gear, make sure the camshaft rotates freely.



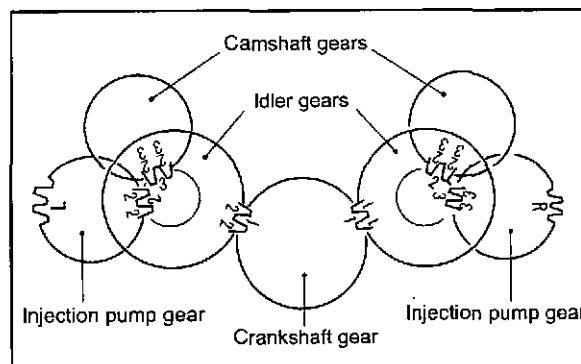
Installing camshaft gear

4.6 Installing idler gear

- (1) Apply engine oil to the idler gear shaft.
- (2) Install the idler gear with all match marks on it aligned with the marks on the other gears.
- (3) Install the thrust plate with its hole matching the pin of idler gear shaft.
- (4) Tighten the thrust plate bolt to the specified torque.
- (5) Move the idler gear back and forth, and make sure there is end play.



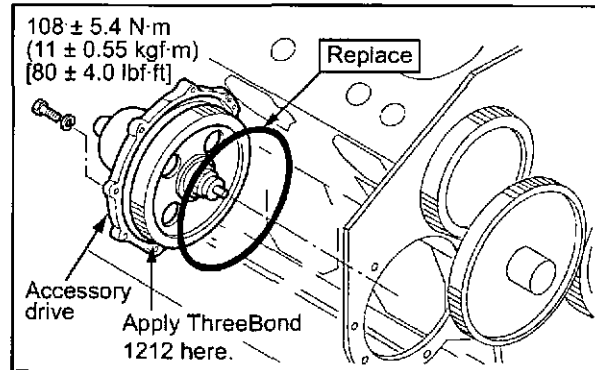
Installing rear idler gear



Timing gear train (view from flywheel side, reassembly timing gear at top dead center of No.1 piston)

4.7 Installing fuel injection pump accessory drive (right and left side)

- (1) Fit the O-ring and the gasket to the mounting surface of drive case. Apply thin coat of ThreeBond 1212 to the flange surface.
- (2) While aligning the mating mark with the mark on the idler gear, install the accessory drive on the rear plate.
- (3) Tighten the drive case mounting bolts to the specified torque.



Installing fuel injection pump accessory drive (right and left side)

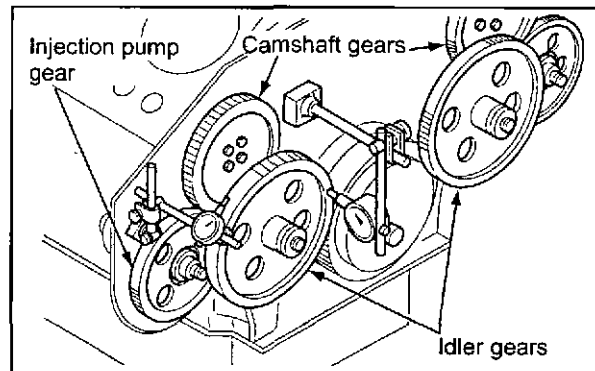
4.8 Inspecting and adjusting timing gear after installation

Be sure to inspect and adjust the timing gear when the timing gear has been reassembled.

4.8.1 Inspecting backlash and end play

After installing the timing gears, be sure to inspect and adjust the backlash and end play between gears.

Item	Standard	Limit
Backlash	0.12 to 0.18 mm [0.0047 to 0.0071 in.]	0.50 mm [0.0197 in.]
Idler gear end play	0.3 to 0.6 mm [0.012 to 0.024 in.]	1.0 mm [0.039 in.]
Camshaft end play	0.10 to 0.25 mm [0.0039 to 0.0098 in.]	0.40 mm [0.0157 in.]



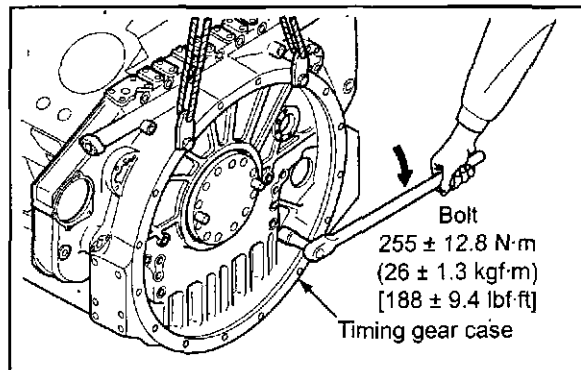
Measuring timing gear backlash and end play

4.9 Installing timing gear case

- (1) Apply sealant ThreeBond 1211 (P/N: 37594-01300) to the timing gear case mounting surface of the rear plate, then place the packing in position.
- (2) Apply the same sealant to the packing, then install the gear case.

Note: Replace the dowel pins if they are worn or if the case is replaced.

- (3) Tighten the case mounting bolts evenly to the specified torque.
- (4) Carefully cut off any excess packing extruding from the crankcase bottom face.

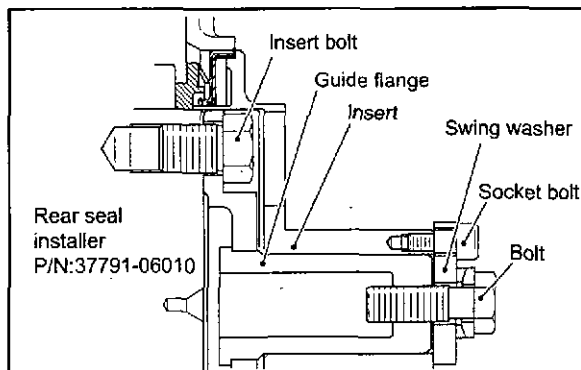


Installing timing gear case

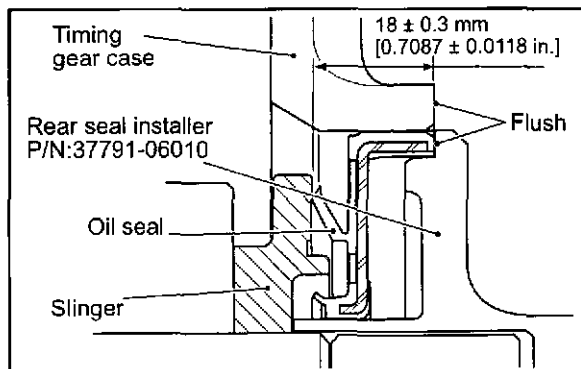
4.10 Installing rear oil seal

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 it to the guide.
- (3) Tighten the bolt mounted on the installer to insert 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.



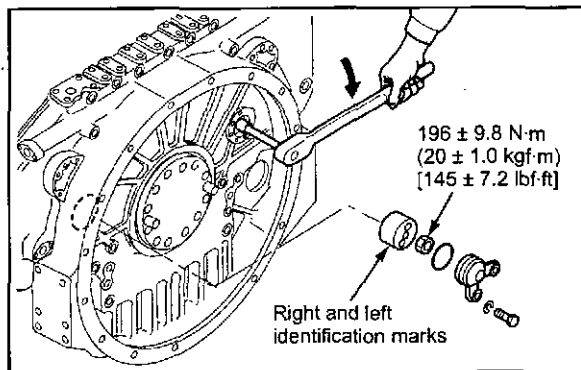
Installing rear oil seal (1)



Installing rear oil seal (2)

4.11 Installing idler shaft thrust collar

Fit the idler shaft thrust collar in place and tighten the mounting bolts to the specified torque.



Installing idler shaft thrust collar

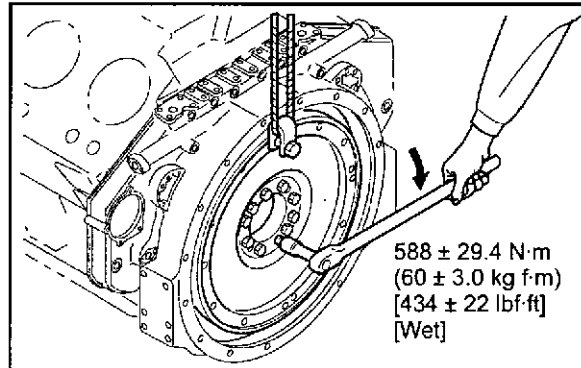
4.12 Installing flywheel

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.

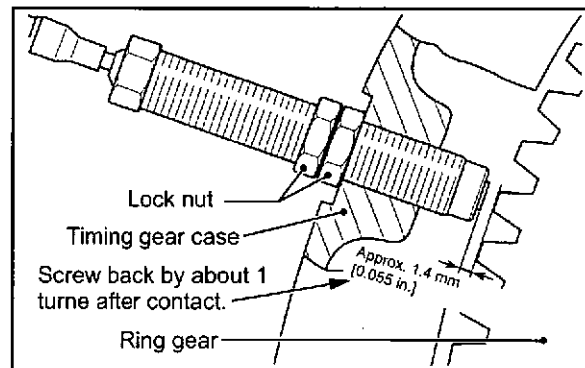
Item	Standard
Face runout	0.336 mm [0.0132 in.] or less
Radial runout	0.130 mm [0.0051 in.] or less



Installing flywheel

4.13 Installing pickup

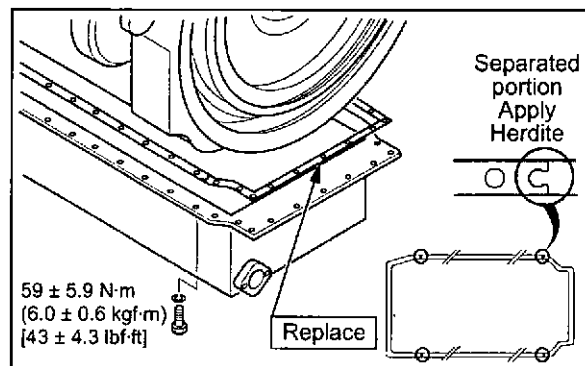
- (1) Turn the crankshaft so that the ring gear tooth tip is positioned at the center of the pickup mounting hole.
- (2) Insert the pickup into the hole slowly and carefully by hand.
- (3) When the tip of pickup comes into contact with the ring gear tooth tip, loosen the pickup so that the clearance to the ring gear meets the standard.
- (4) Secure the pickup with the locknut.



Installing pickup

4.14 Installing oil pan

- (1) Install new upper and lower gaskets in place. Apply sealant (Heldite) at each joint of gasket to prevent oil leaks, as the upper and lower gaskets are split type gaskets.
- (2) Install the oil pipe and oil strainer to the under plate.
- (3) Before assembling, apply sealant (ThreeBond 1211) to the upper mounting surface of the under plate.
- (4) Install the under plate and oil pan in place and tighten the mounting bolts to the specified torque.

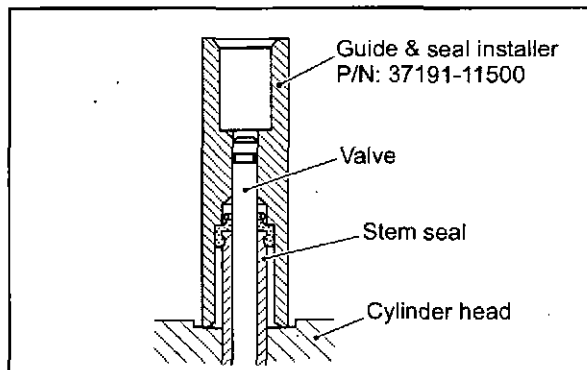


Installing oil pan

5. Reassembling cylinder head and valve mechanism

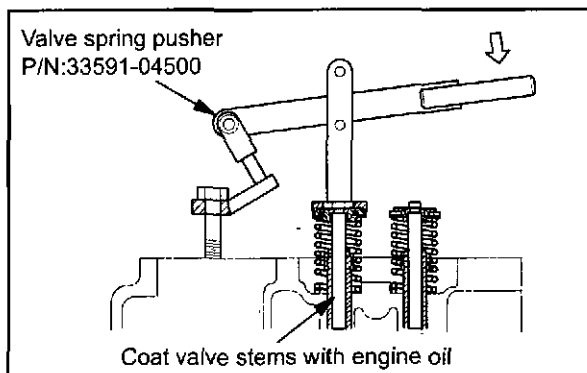
5.1 Installing inlet and exhaust valve

- (1) Insert the valve, with engine oil applied to its stem, into the valve guide.
- (2) Install the valve spring and rotator on the valve guide. *Fit the valve cotters into position using the valve spring pusher*

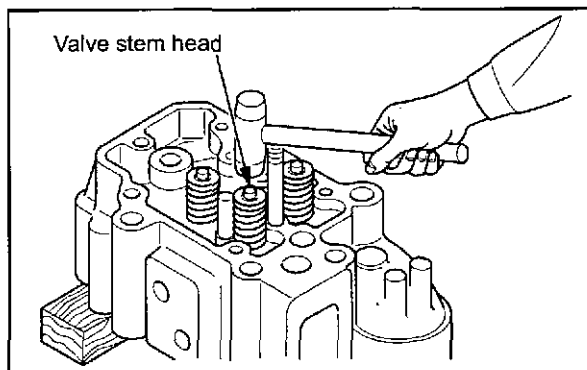


Installing stem seal

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



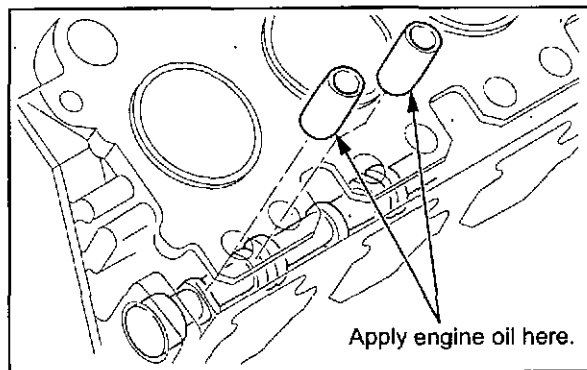
Installing inlet valve (1)



Installing inlet valve (2)

5.2 Installing tappet

Coat the periphery of tappets with engine oil, insert them into the tappet holes and place them gently on the camshafts.



Installing tappet

5.3 Applying liquid gasket

CAUTION

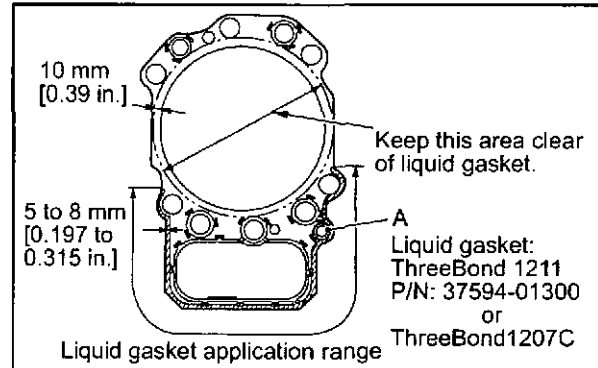
- (a) Do not apply liquid gasket more than necessary. Too much liquid gasket may come into contact with O-rings, and cause deformation of O-rings. When applying gasket to portions A and B, in particular, take utmost care since there is little clearance to the O-rings.
- (b) Keep the perimeter of the 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 application ranges are as illustrated at right.

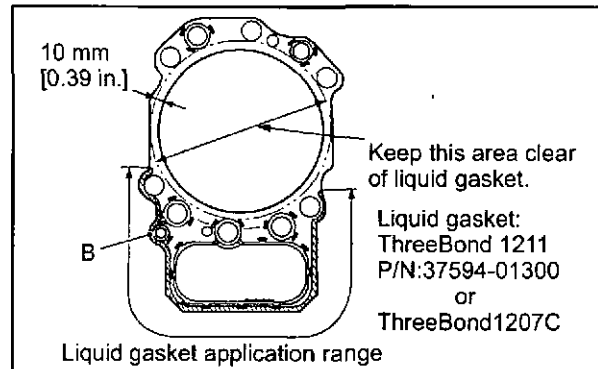
Note: After applying liquid gasket, install the cylinder head as soon as possible, as the gasket will be dried up readily.

5.4 Installing cylinder head gasket

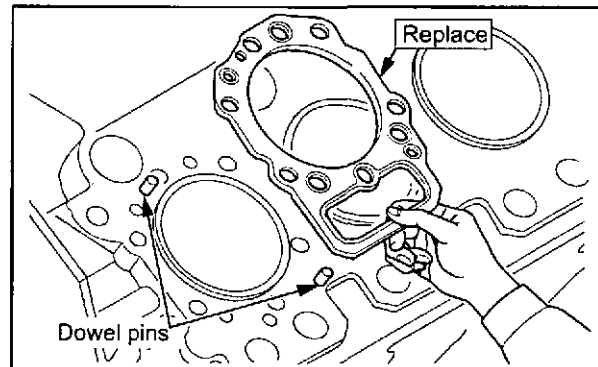
- (1) Wipe off oil, grease and other stains from the cylinder head bottom surface and the crankcase upper surface with a shop towel.
- (2) Install the cylinder head gasket that has been coated with liquid gasket onto the crankcase with the dowel pin and the hole in alignment.



Applying liquid gasket (head-facing side)



Applying liquid gasket (crankcase side)

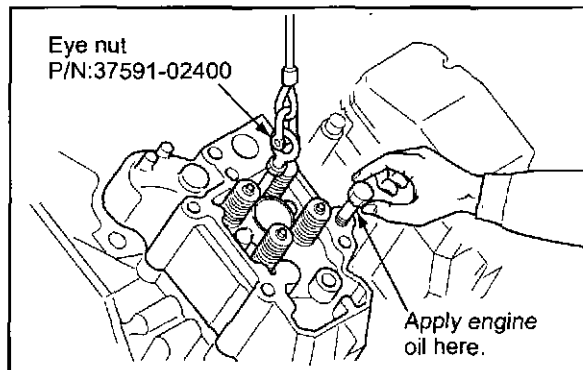


Installing cylinder head gasket

5.5 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) Install the eye nut to the stud bolt, 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

5.6 Tightening cylinder head bolt

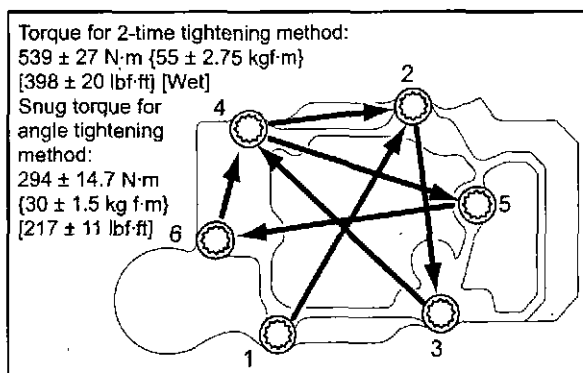
The tightening of cylinder head bolts can be accomplished in two ways, i.e., 2-step tightening method and angle tightening method.

5.6.1 2-step tightening method

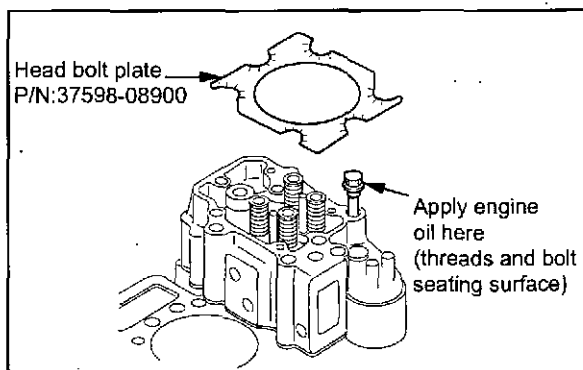
- (1) Tighten the cylinder head bolts to the specified torque in the illustrated order.
- (2) Loosen all the tightened bolts, then retighten them in the same way as above.

5.6.2 Angle tightening method

- (1) Place the head bolt plate on the cylinder head.
- (2) Tighten the cylinder head bolts to snug torque (initial torque) in the indicated sequence.
- (3) The head bolt plate has graduations at 30° intervals. Place a reference mark on each head bolt.
- (4) Tighten each bolt in the indicated sequence by turning $30 \pm 1.5^\circ$.
- (5) Then, tighten again in the indicated sequence by turning $30 \pm 1.5^\circ$ (total of $60 \pm 3^\circ$).
- (6) Loosen all bolts, and tighten again according to this angle method. (2-step tightening method)



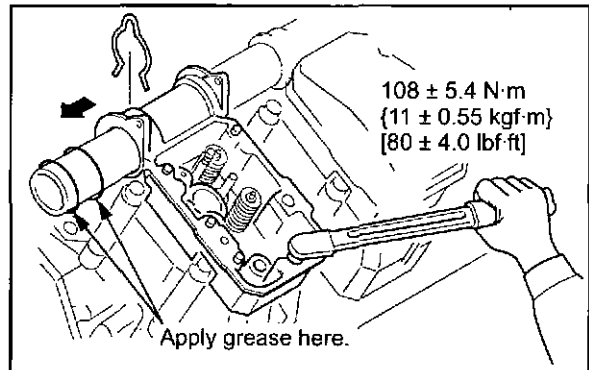
Tightening cylinder head bolt



Angle tightening method

5.7 Installing rocker case

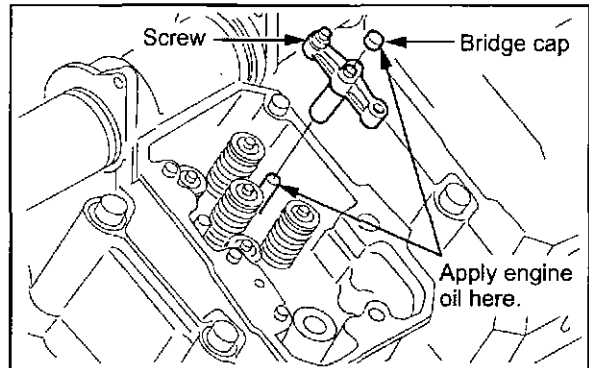
- (1) Insert the water outlet connector fully into the rocker case.
- (2) Install the rocker case by aligning its holes with the dowel pins.
- (3) Tighten the rocker case mounting bolts to the specified torque.
- (4) Insert the water outlet connector by sliding it from the next rocker case after coating the O-rings with grease. Secure it with the snap ring.



Installing rocker case

5.8 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.

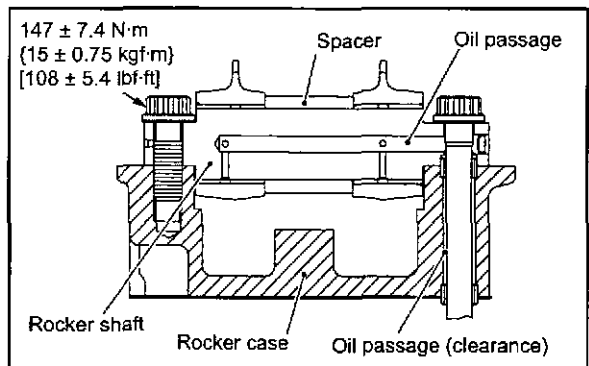


Installing bridge and bridge cap

5.9 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) Install the spacer to the rocker shaft, and mount the rocker arms on both sides.
 - (2) Align the pin hole of the rocker shaft with the positioning pin, and install the rocker shaft assembly to the rocker case.
 - (3) Tighten the rocker shaft assembly mounting bolts to the specified torque.

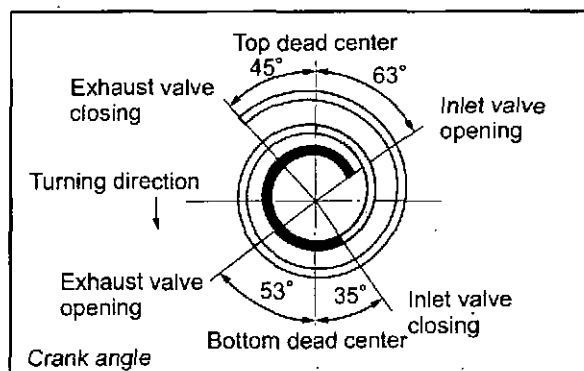


Installing rocker shaft assembly

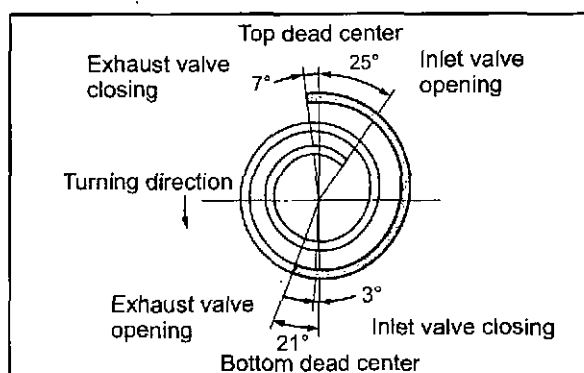
5.10 Inspecting valve timing

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) Check to verify 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.].
- (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 timing diagram (in warm state)



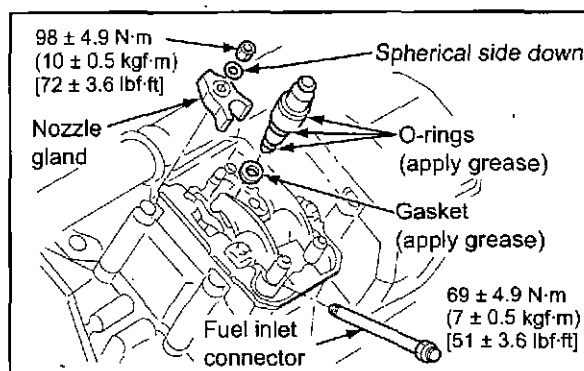
Valve timing diagram with 2mm [0.08in.] clearance added to valve (in cold state)

5.11 Installing fuel injection nozzle assembly

- (1) Disconnect the fuel inlet connector from the fuel injection nozzle assembly.
- (2) Install the three O-rings to the fuel injection nozzle, and coat the surface with grease.
- (3) Apply a small amount of grease to the gasket, install the gasket to the fuel injection nozzle, then, while observing the center of the connector mounting hole, insert the fuel injection nozzle assembly into the cylinder head.
- (4) Tighten the fuel inlet connector to the specified torque.
- (5) Tighten the nozzle gland mounting nut to the specified torque.

Note: (a) When tightening the fuel inlet connector, be sure to maintain equal distances from the cylinder head.

- (b) Be sure to install the gaskets when installing the fuel injection nozzle assemblies.



Installing fuel injection nozzle

5.12 Adjusting valve clearance

Adjust the valve clearance.

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

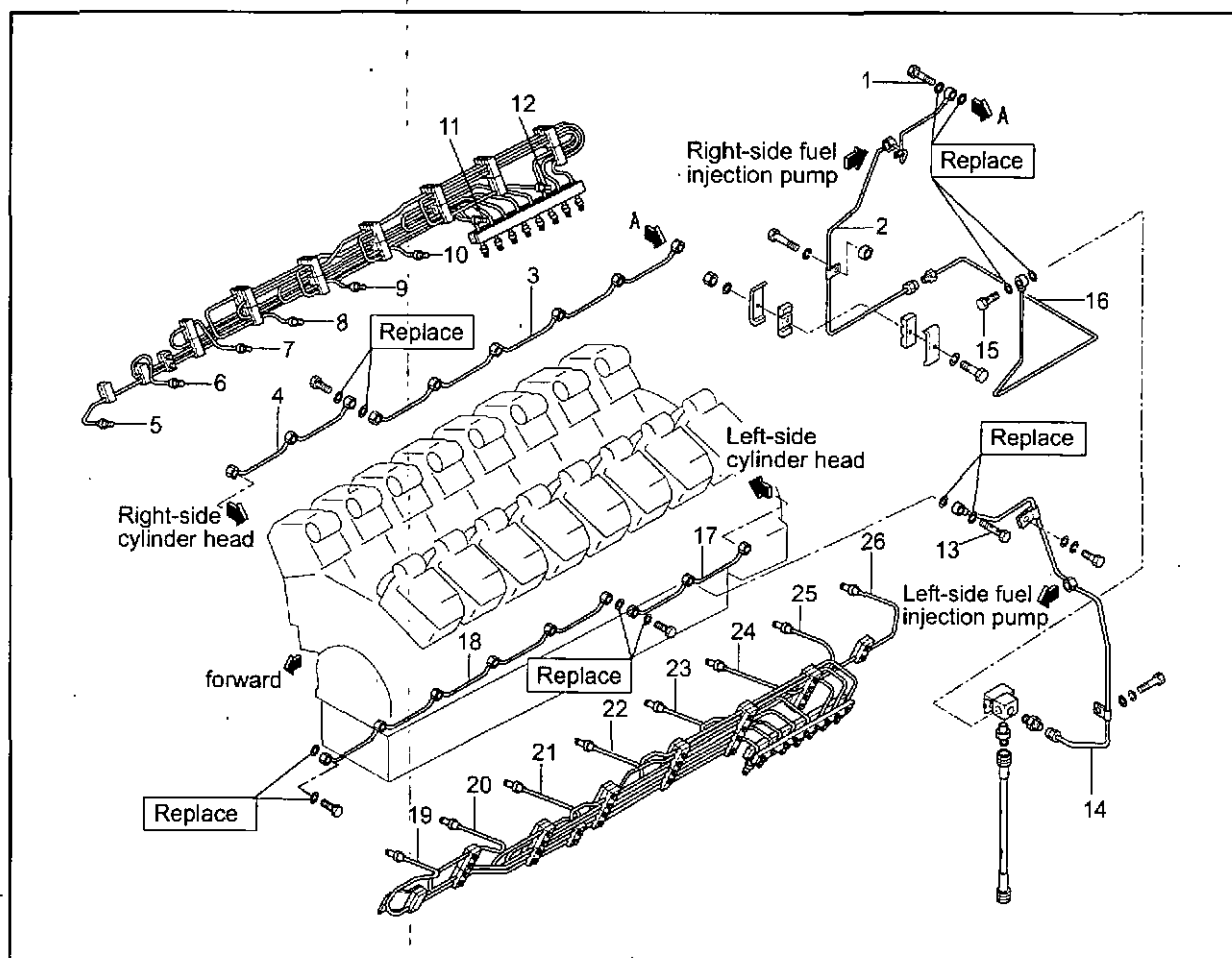
FUEL SYSTEM

1. Removing fuel system.....8-3 1.1 Removing and inspecting fuel injection pipes and fuel leak-off pipe8-3 1.2 Removing and inspecting fuel pipe..... 8-4 1.3 Removing and inspecting fuel control link 8-5 1.4 Removing and inspecting actuator..... 8-6 1.5 Removing and inspecting stop solenoid .. 8-7 1.6 Removing and inspecting fuel injection pump 8-8 2. Disassembling inspecting and reassembling fuel system8-9 2.1 Disassembling and inspecting fuel filter... 8-9 2.2 Reassembling fuel filter..... 8-10 2.3 Disassembling and inspecting fuel injection nozzle8-11 2.4 Inspecting and adjusting fuel injection start pressure8-12 2.5 Inspecting fuel spray pattern of fuel injection nozzle8-12 2.6 Cleaning and exchange at defective injection 8-13 2.6.1 Removing nozzle tip..... 8-13 2.6.2 Cleaning and inspecting nozzle tip.....8-13 2.7 Reassembling fuel injection nozzle..... 8-14 2.8 Disassembling and inspecting fuel injection pump8-15 2.8.1 Preparing fuel injection pump disassembly8-16 2.8.2 Disassembling rack set cap 8-16 2.8.3 Disassembling spring case 8-16 2.8.4 Disassembling return spring.....8-17 2.8.5 Disassembling coupling assembly and fuel feed pump8-17 2.8.6 Disassembling delivery valve 8-17 2.8.7 Disassembling plunger assembly.....8-18 2.8.8 Disassembling controller rack 8-18 2.8.9 Disassembling tappet.....8-18 2.8.10 Disassembling camshaft 8-19 2.8.11 Disassembling rear cover.....8-19 2.8.12 Disassembling plunger assembly.....8-20 2.9 Inspecting fuel injection pump..... 8-21 2.9.1 Inspecting plunger barrel.....8-21 2.9.2 Inspecting delivery valve.....8-21 2.9.3 Inspecting tappet.....8-21 2.9.4 Inspecting bearing.....8-22 2.9.5 Inspecting valve holder 8-22 2.9.6 Inspecting pump case 8-22 2.9.7 O-ring and bellow on each unit 8-22 2.9.8 Inspecting camshaft 8-22	2.9.9 Inserting oversize sleeve to camshaft 8-23 2.9.10 Inspecting plunger spring and delivery valve spring8-24 2.10 Reassembling fuel injection pump 8-24 2.10.1 Installing bearing and front cover 8-25 2.10.2 Installing camshaft and center bearing.... 8-25 2.10.3 Installing rear cover 8-26 2.10.4 Measuring thrust clearance of camshaft.. 8-26 2.10.5 Installing tappet roller assembly 8-26 2.10.6 Installing tappet 8-27 2.10.7 Reassembling plunger assembly..... 8-27 2.10.8 Installing controller rack..... 8-28 2.10.9 Positional relationship between plunger and barrel8-29 2.10.10 Removing plunger assembly 8-30 2.10.11 Measuring control rack sliding resistance8-31 2.10.12 Reassembling delivery valve..... 8-31 2.10.13 Reassembling bellow 8-31 2.10.14 Reassembling fuel feed pump..... 8-32 2.10.15 Reassembling flywheel..... 8-32 2.10.16 Reassembling coupling assembly 8-32 2.10.17 Reassembling controller rack return spring8-34 2.11 Adjusting fuel injection pump 8-35 2.11.1 Adjusting pre-stroke (injection timing) 8-35 2.11.2 Adjusting injection interval 8-36 2.11.3 Adjusting injection volume 8-36 2.12 Disassembling and inspecting fuel injection pump8-37 2.13 Reassembling fuel feed pump..... 8-38 2.14 Fuel feed pump test 8-39 2.14.1 Fuel feed pump air-tightness test 8-39 2.14.2 Fuel feed pump fuel feeding pressure test8-39 2.14.3 Priming pump suction capacity test 8-39 2.14.4 Fuel feed pump fuel feed rate test..... 8-39 2.15 Disassembling and inspecting fuel injection pump accessory drive8-40 2.16 Inspecting outer and inner diameters of fuel injection pump accessory drive bearing engagement section8-41 2.17 Reassembling fuel injection pump accessory drive8-41 3. Installing fuel system 8-42 3.1 Installing fuel injection pump 8-42 3.2 Installing stop solenoid..... 8-47 3.3 Installing actuator..... 8-48 3.3.1 Installing and adjusting actuator link..... 8-49 3.4 Adjusting and confirming working of stop solenoid
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- noid (RUN-ON)8-51
- 3.4.1 Adjusting stop solenoid (RUN-ON) 8-51
- 3.4.2 Adjusting solenoid (RUN-ON) working inspection8-51
- 3.5 Re-adjusting adjusting bolt..... 8-51
- 3.6 Installing fuel control link..... 8-52
- 3.7 Installing fuel filter and fuel pipe..... 8-53
- 3.8 Installing fuel injection pipe and fuel leak pipe
8-54

1. Removing fuel system

1.1 Removing and inspecting fuel injection pipes and fuel leak-off pipe



Removing and inspecting fuel injection pipes and fuel leak-off pipe

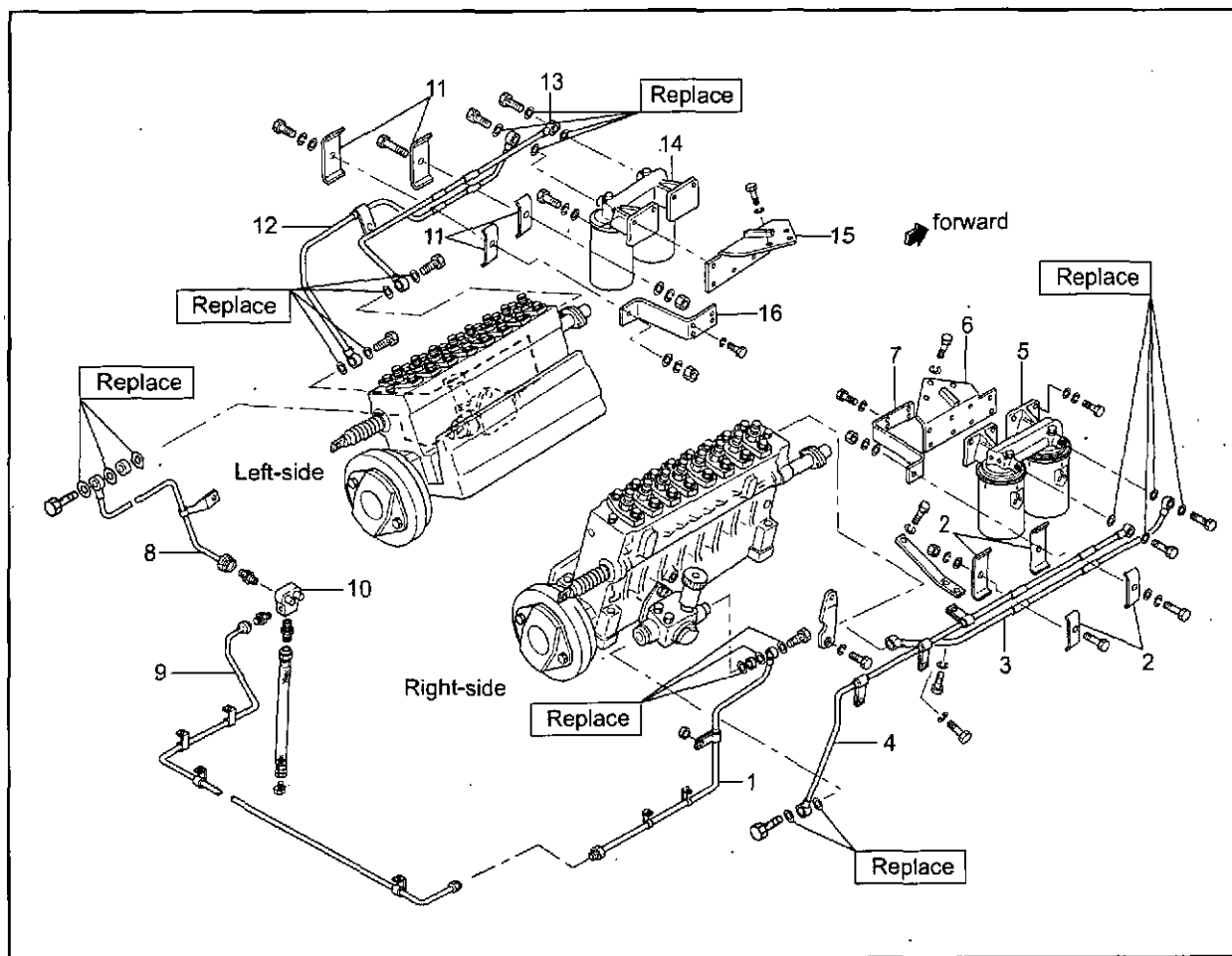
Removing sequence

- | | |
|------------------------------|-------------------------------|
| 1 Eye bolt | 14 Left-side leak pipe |
| 2 Right-side leak pipe | 15 Eye bolt |
| 3 Right-side leak-off pipe | 16 Leak pipe |
| 4 Right-side leak-off pipe | 17 Left-side leak-off pipe |
| 5 No. 1 fuel injection pipe | 18 Left-side leak-off pipe |
| 6 No. 2 fuel injection pipe | 19 No. 9 fuel injection pipe |
| 7 No. 3 fuel injection pipe | 20 No. 10 fuel injection pipe |
| 8 No. 4 fuel injection pipe | 21 No. 11 fuel injection pipe |
| 9 No. 5 fuel injection pipe | 22 No. 12 fuel injection pipe |
| 10 No. 6 fuel injection pipe | 23 No. 13 fuel injection pipe |
| 11 No. 7 fuel injection pipe | 24 No. 14 fuel injection pipe |
| 12 No. 8 fuel injection pipe | 25 No. 15 fuel injection pipe |
| 13 Eye bolt | 26 No. 16 fuel injection pipe |

CAUTION

Cover the openings on the injection pipe, nozzle inlet connector and injection pipe to prevent dust from entering the fuel system.

1.2 Removing and inspecting fuel pipe

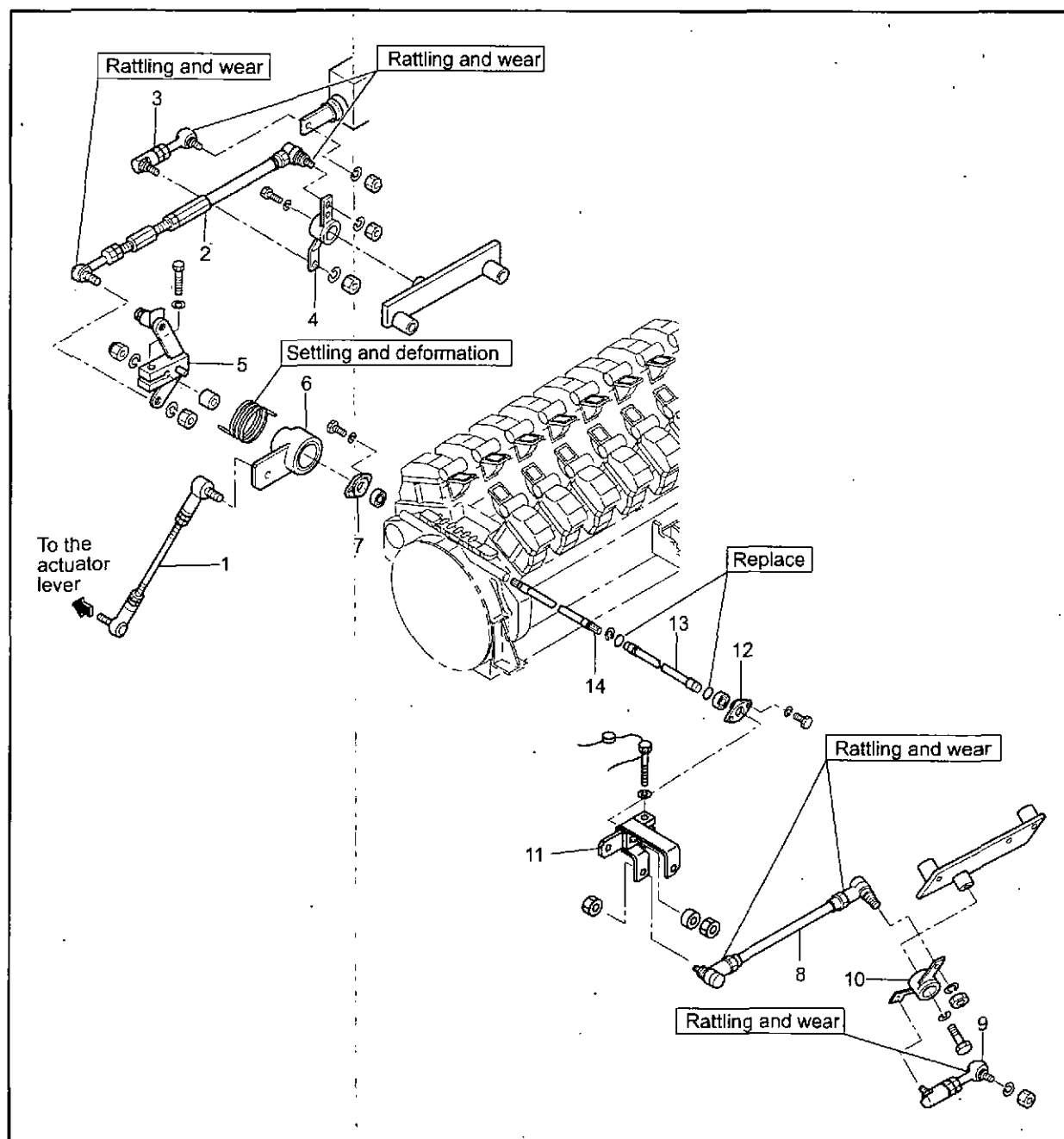


Removing and inspecting fuel pipe

Removing sequence

- | | |
|------------------------|-------------------------|
| 1 Right side fuel pipe | 9 Fuel pipe |
| 2 Clamp | 10 Connector |
| 3 Right-side fuel pipe | 11 Clamp |
| 4 Right-side fuel pipe | 12 Left-side fuel pipe |
| 5 Fuel filter assembly | 13 Left-side fuel pipe |
| 6 Fuel filter bracket | 14 Fuel filter assembly |
| 7 Pipe stay | 15 Fuel filter bracket |
| 8 Left-side fuel pipe | 16 Pipe stay |

1.3 Removing and inspecting fuel control link



Removing and inspecting fuel control link

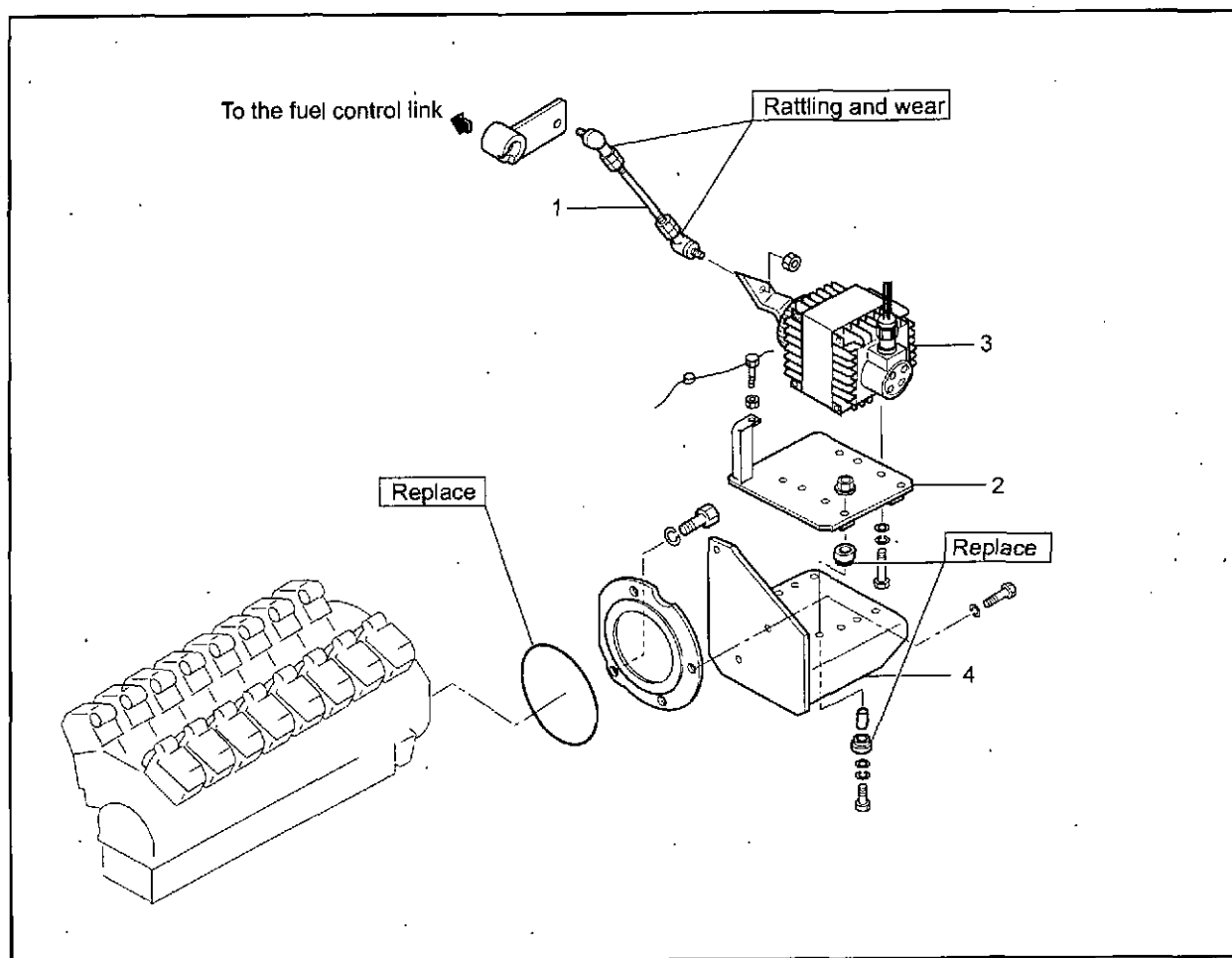
Removing sequence

- 1 Link
- 2 Left-side link
- 3 Left-side link
- 4 Left-side lever
- 5 Stop lever

- 6 Left-side lever
- 7 Bearing cover
- 8 Right-side link
- 9 Right-side link
- 10 Right-side lever

- 11 Right-side lever
- 12 Bearing cover
- 13 Pipe
- 14 Control shaft

1.4 Removing and inspecting actuator

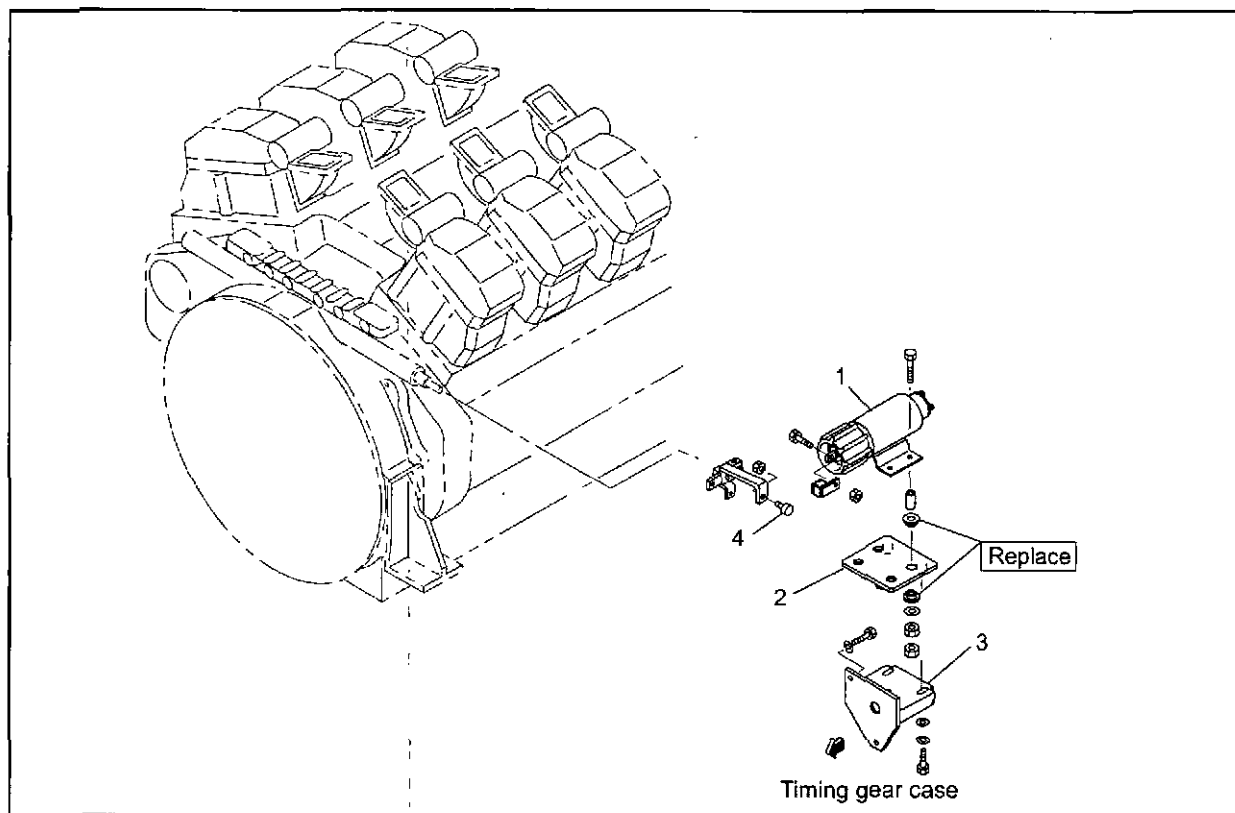


Removing and inspecting actuator

Removing sequence

- | | |
|-----------------|-------------------|
| 1 Link | 3 Actuator |
| 2 Protect-plate | 4 Protect-bracket |

1.5 Removing and inspecting stop solenoid



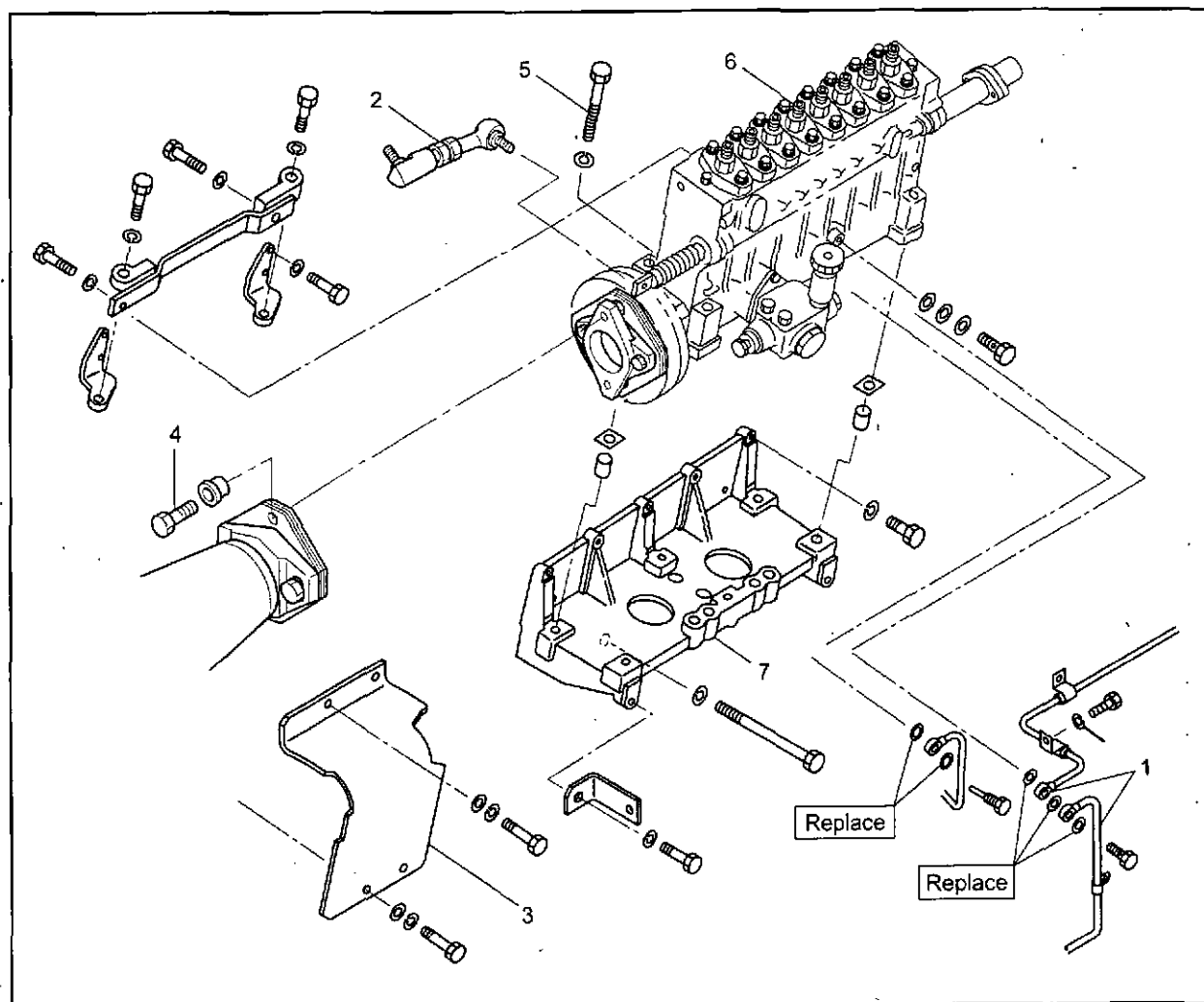
Removing sequence

- 1 Run-on solenoid
- 2 Solenoid plate

Removing and inspecting stop solenoid

- 3 Bracket
- 4 Follower

1.6 Removing and inspecting fuel injection pump



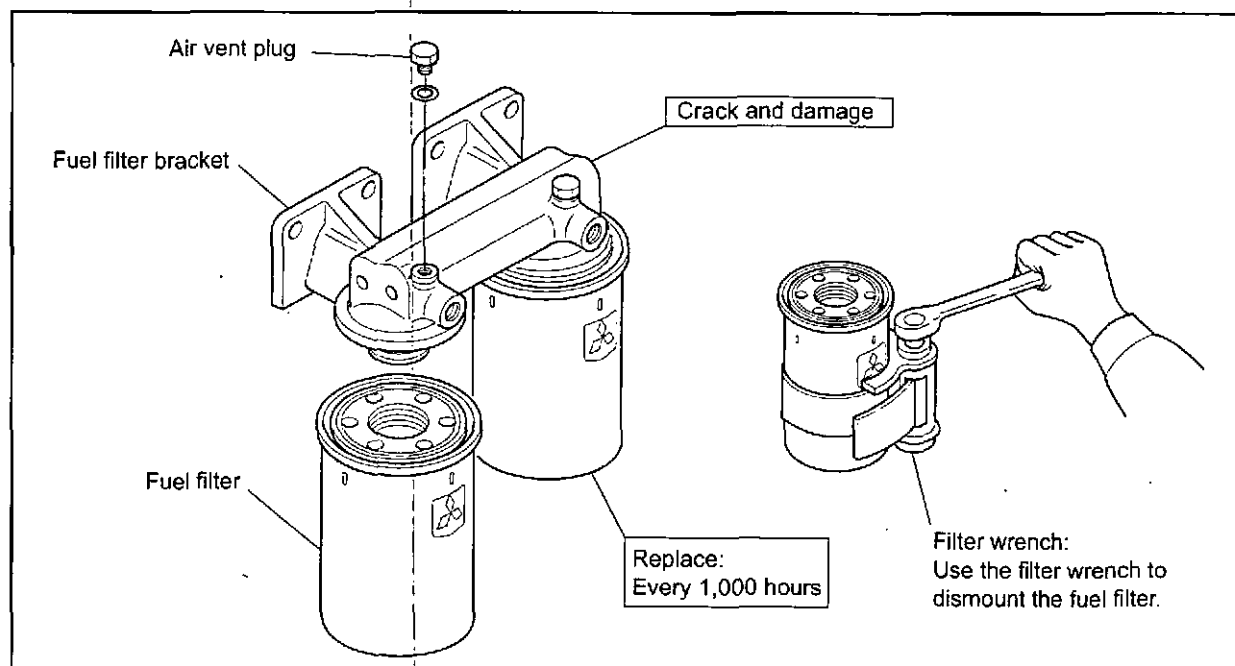
Removing and inspecting fuel injection pump

Removing sequence

- | | |
|----------------------|---|
| 1 Lubricant oil pipe | 5 Pump mounting bolt |
| 2 Link | 6 Fuel injection pump (mass: 60 kg [132.28 lb]) |
| 3 Coupling cover | 7 Fuel injection pump bracket |
| 4 Connecting bolt | |

2. Disassembling inspecting and reassembling fuel system

2.1 Disassembling and inspecting fuel filter



Disassembling and inspecting fuel filter

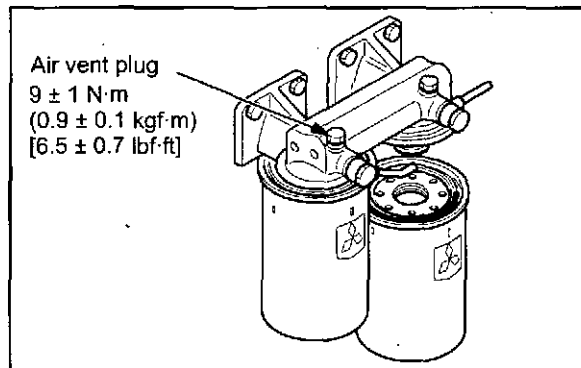
2.2 Reassembling fuel filter

⚠ WARNING

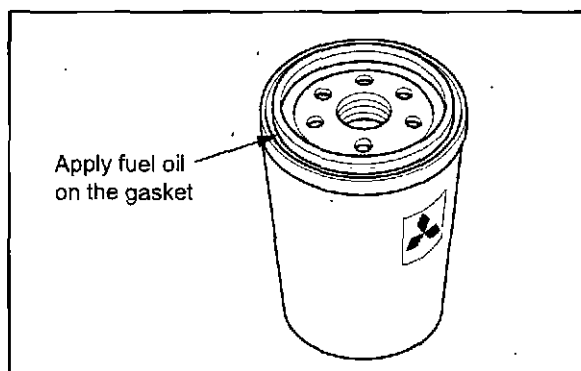
Confirm that there is no flame when handling fuel. Wipe off any spilled fuel to prevent a fire.

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 confirm 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) Confirm 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.

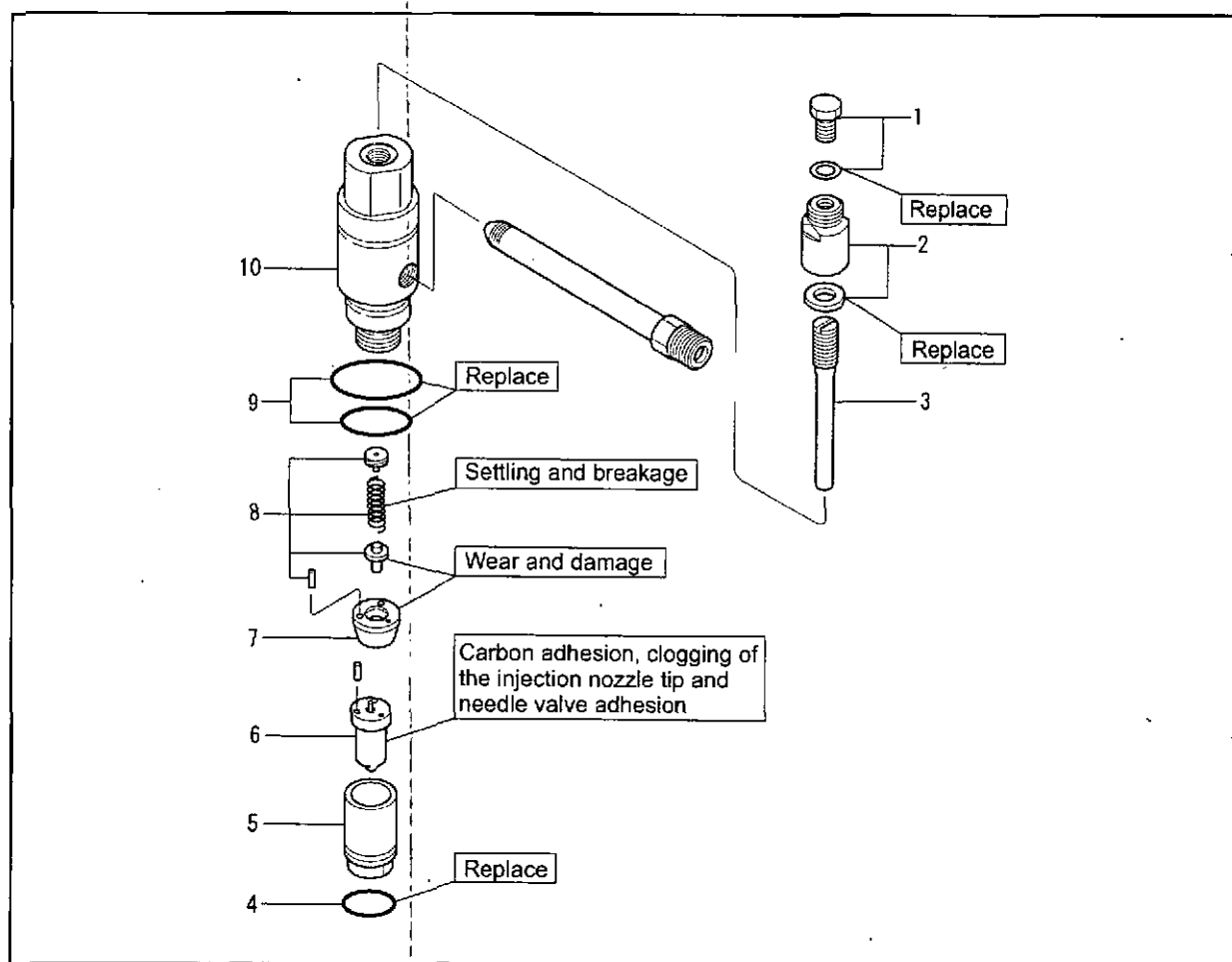


Fuel filter assembly



Fuel filter

2.3 Disassembling and inspecting fuel injection nozzle



Disassembling and inspecting fuel injection nozzle

Disassembling sequence

- | | |
|--------------------------------|--|
| 1 Set screw and sealing washer | 6 Nozzle tip |
| 2 Cap nut and sealing washer | 7 Spacer |
| 3 Adjusting screw | 8 Push rod, nozzle spring, spring seat |
| 4 O-ring | 9 O-ring |
| 5 Retaining nut | 10 Nozzle holder |

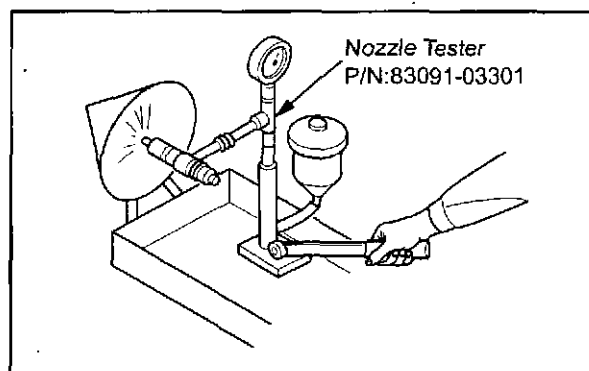
2.4 Inspecting and adjusting fuel injection start pressure

CAUTION

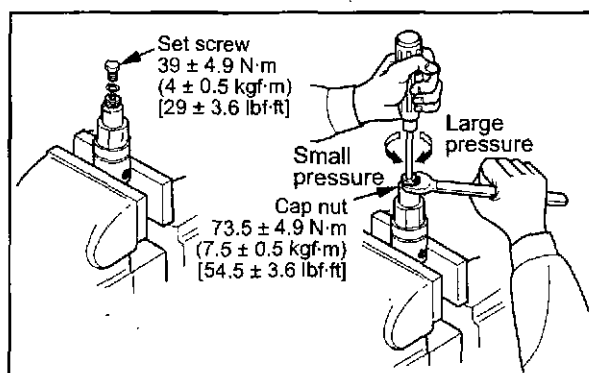
Never touch the injection nozzle tip during nozzle injection test.

- (1) Mount the nozzle on the nozzle tester.
- (2) Push down the handle at a speed of once a second and read the pressure when injection starts. Make adjustment if it is outside the standard.
- (3) To adjust the injection start pressure, remove the set screw on the nozzle holder, loosen the cap nut and turn the adjusting screw with a driver.
- (4) After adjustment, tighten the cap nut and set screw with the specified torque.
- (5) After tightening the set screw, check if the injection start pressure is within the standard again.

Item	Nominal value	Standard
Valve opening pressure	34.3MPa (350 kgf/cm ²) [4979 psi]	34.3to 34.8 MPa (350 to 355 kgf/cm ²) [4979 to 5050 psi]



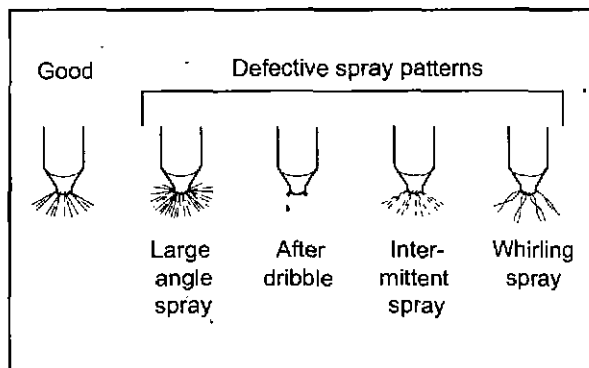
Inspecting fuel injection start pressure



Adjusting fuel injection start pressure

2.5 Inspecting fuel spray pattern of fuel injection nozzle

- (1) When adjusting the nozzle opening pressure using the nozzle tester, check for nozzle hole condition, and fuel spray pattern.
- (2) Checking points of fuel spray are as follows:
 - Fuel is injected from all spray holes simultaneously.
 - Fuel is injected conically at the specified spray angle.
 - Fuel is injected in a spray of fine droplets.
 - Fuel is injected without after-dribbling.
- (3) If spray condition is faulty, clean or replace the nozzle tip.



Inspecting fuel injection nozzle spray condition

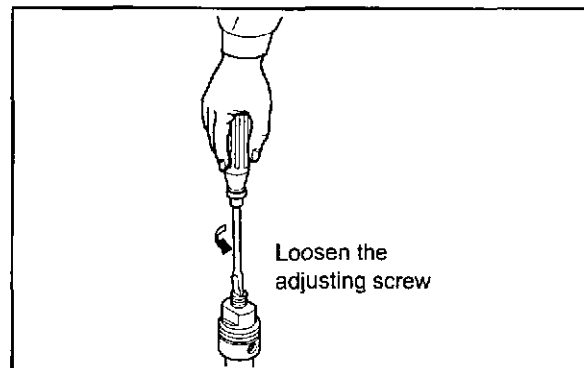
2.6 Cleaning and exchange at defective injection

2.6.1 Removing nozzle tip

CAUTION

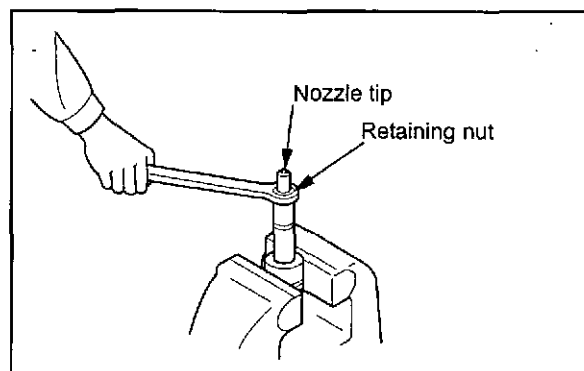
Be careful not to hit the nozzle tip.

- (1) First remove the cap nut and loosen the adjusting screw with a driver, as the spring pressure is applied to the nozzle tip. (Loosen the screw until it can be loosened by hand.)



Removing nozzle tip (1)

- (2) Remove the retaining nut and take out the nozzle tip.



Removing nozzle tip (2)

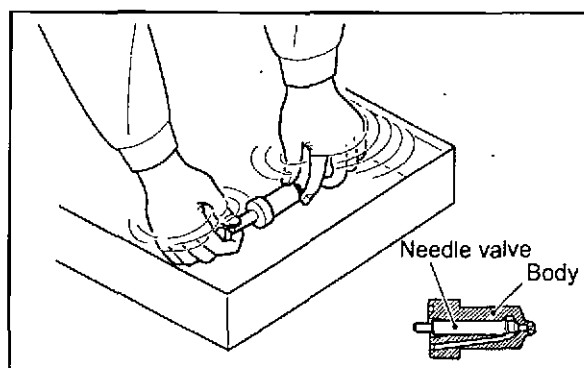
2.6.2 Cleaning and inspecting nozzle tip

- (1) Clean the needle valve and body of the nozzle tip in a clean wash oil.
- (2) After cleaning, assemble the needle valve and the body in a clean gas oil.

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

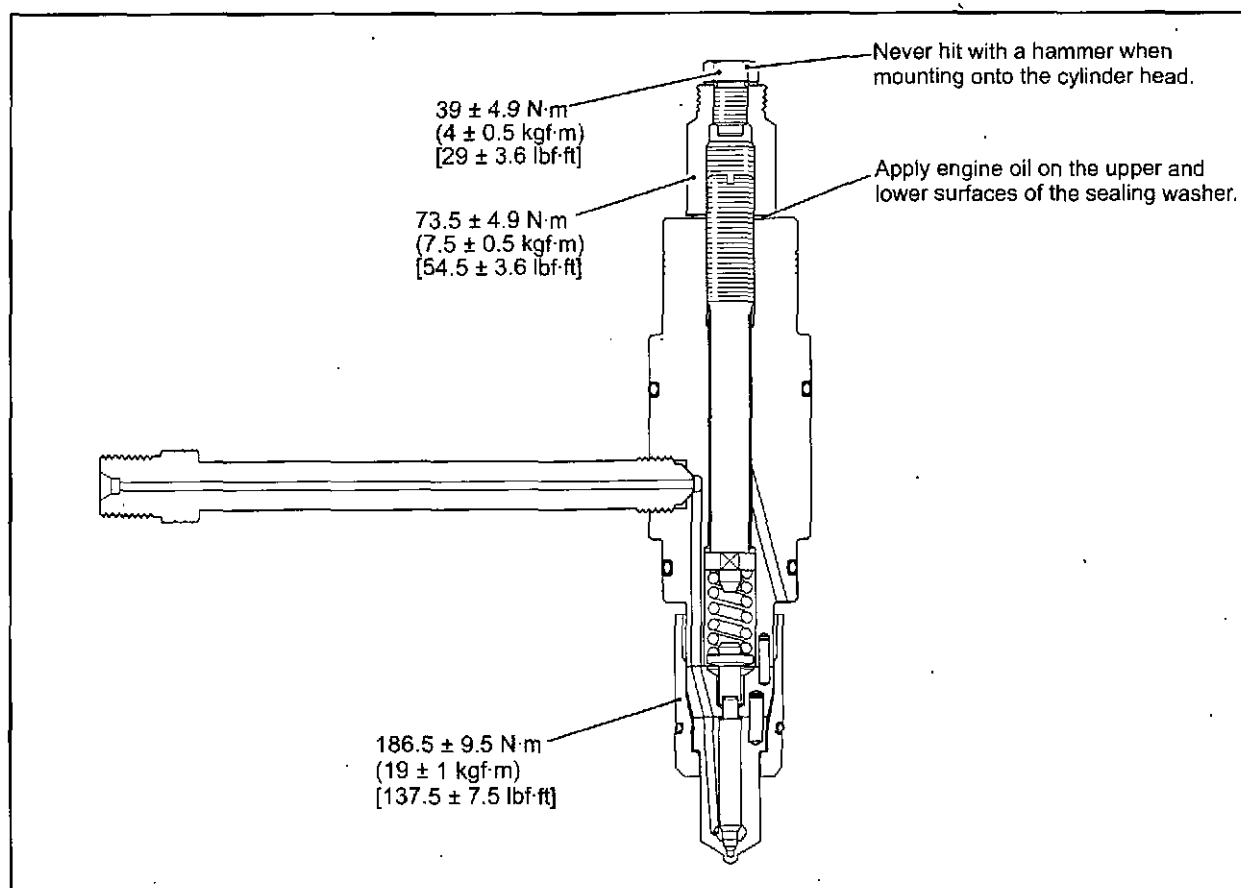
- (3) Tighten the nozzle tip tightening retainer nut to the specified torque.
- (4) If the spray pattern is still faulty after cleaning and adjusting, change the nozzle tip with a new one.

Note: New nozzle tips are coated with vaseline to prevent from rusting. Wash it off in a clean gas oil before installation.



Cleaning and mounting nozzle tip

2.7 Reassembling fuel injection nozzle



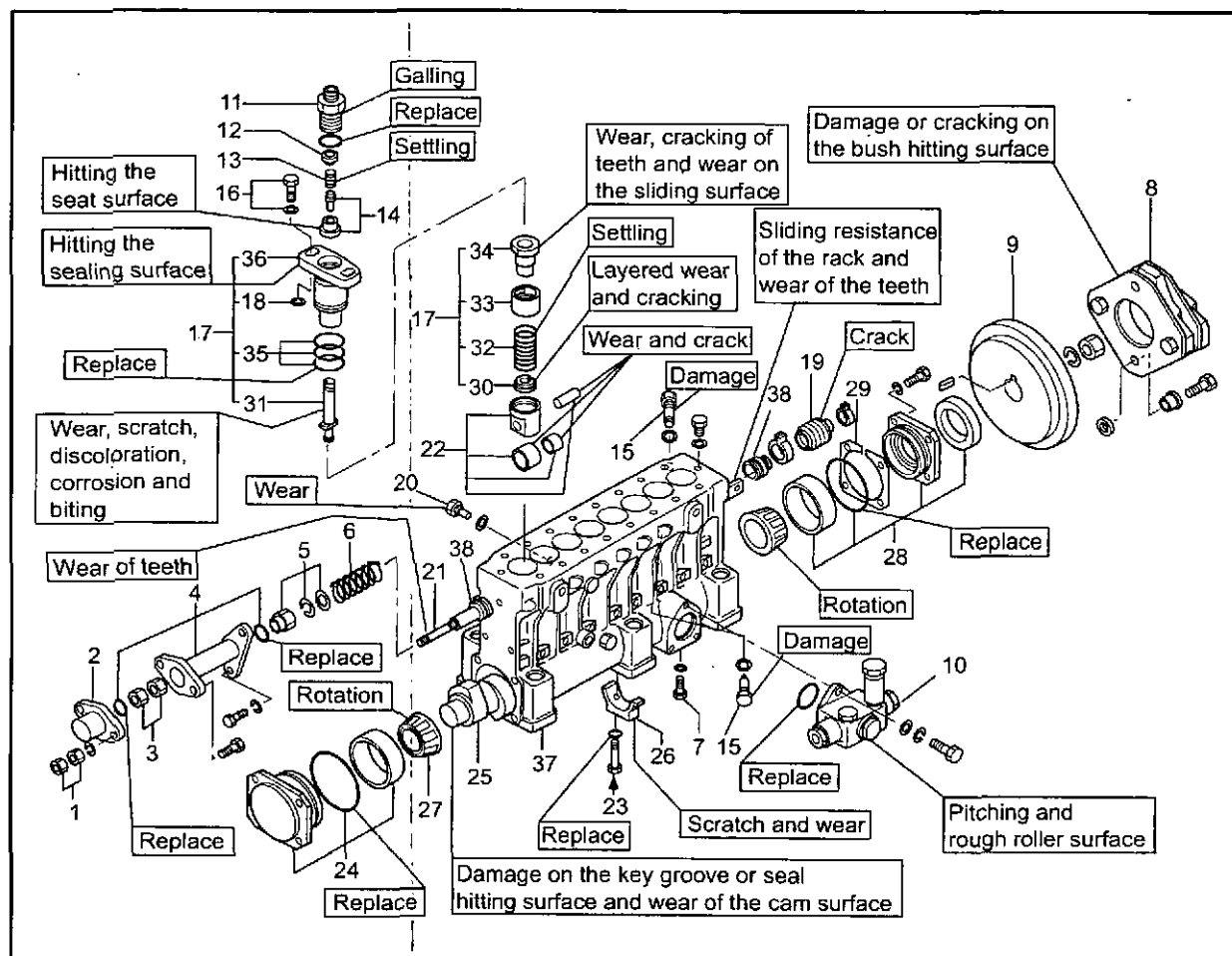
Reassembling fuel injection nozzle

Note: When putting the nozzle tip in the nozzle holder, make sure that the tip locating pin enters its hole in the holder.

CAUTION

Be sure to tighten the retaining nut to the specified torque. Excessive tightening torque on the retaining nut can hinder smooth movement of the needle and result in abnormal exhaust smoke or needle sticking.

2.8 Disassembling and inspecting fuel injection pump



Disassembling and inspecting fuel injection pump

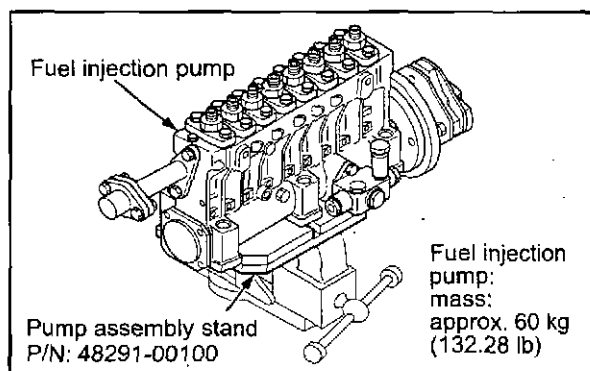
Disassembling sequence

- | | | |
|--------------------------------------|-------------------------------------|---|
| 1 Self-locking nut, tamper-proof nut | 15 Defector bolt | 28 Rear cover, oil seal, bearing outer race |
| 2 Rack set cap | 16 Barrel bolt, washer | 29 Shim |
| 3 Jam nut | 17 Plunger assembly | 30 Lower spring seat |
| 4 Spring case | 18 Barrel shim | 31 Plunger |
| 5 Self-locking nut | 19 Bellows | 32 Plunger spring |
| 6 Return spring | 20 Set screw | 33 Upper spring seat |
| 7 Drain plug | 21 Controller rack | 34 Pinion |
| 8 Coupling | 22 Tappet | 35 O-ring |
| 9 Flywheel | 23 Bolt | 36 Barrel |
| 10 Fuel feed pump | 24 Front cover, bearing outer racer | 37 Pump case |
| 11 Valve holder | 25 Camshaft | 38 Rack bush |
| 12 Spring seat | 26 Center bearing | |
| 13 Delivery valve spring | 27 Bearing inner race | |
| 14 Delivery valve assembly | | |

2.8.1 Preparing fuel injection pump disassembly

CAUTION

- (a) When the fuel injection pump is hoisted with a crane, etc., prevent falling and do not stand under the crane.
 - (b) When cleaning the fuel injection pump with cleaning oil, never have any fire around.
 - (c) At using the compressed air, wear protection glasses and protection gear.
- (1) Clean the outer surface of the fuel injection pump.
 - (2) Mount the fuel injection pump on the pump assembly stand.
 - (3) Remove the drain plug at the bottom of the fuel injection pump and drain the engine oil.



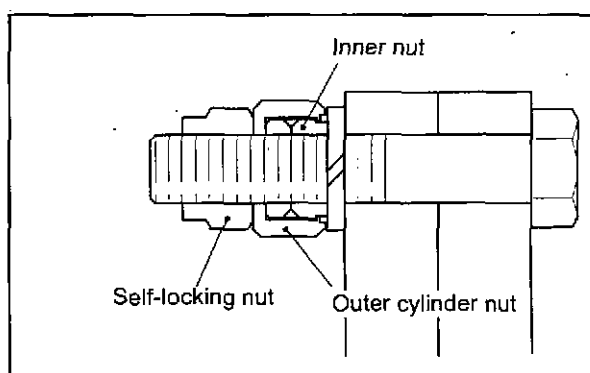
Preparing fuel injection pump disassembly

2.8.2 Disassembling rack set cap

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.

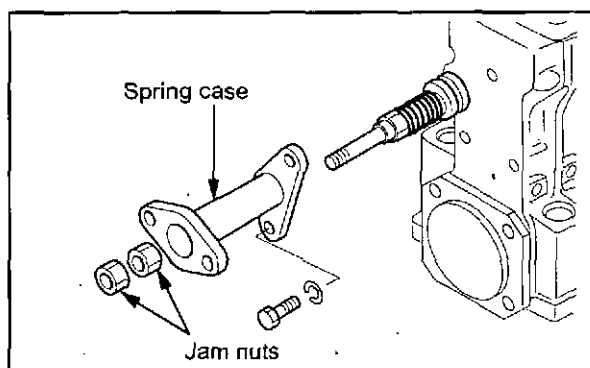
- (1) The damper-proof nut has a dual structure which turns freely and is difficult to remove.
- (2) To remove, cut the outer cylinder nut and turn the inner nut.
- (3) Remove the rack set cap.



Disassembling rack set cap

2.8.3 Disassembling spring case

Remove 2 jam nuts and take out the spring case.



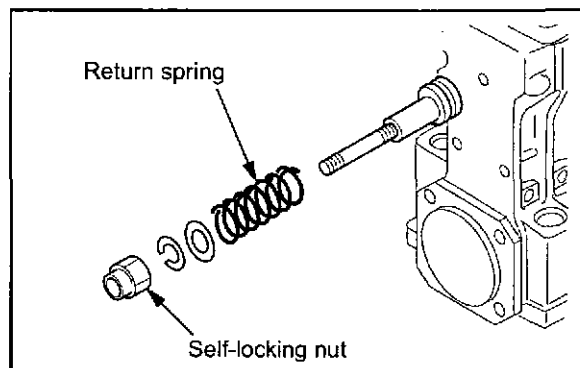
Disassembling spring case

2.8.4 Disassembling return spring

CAUTION

Do not re-use the self-locking nut.

Remove the self-locking nut and take out the return spring.

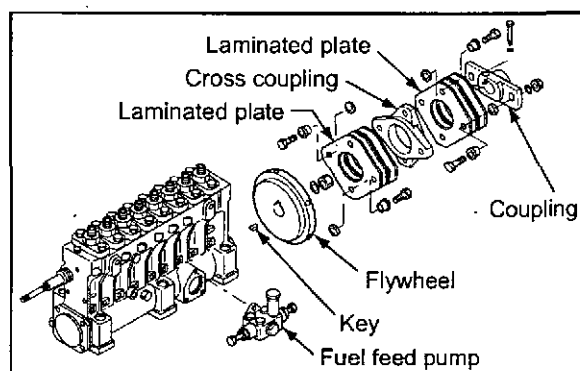


Disassembling return spring

2.8.5 Disassembling coupling assembly and fuel feed pump

- (1) Remove the laminated plate mounting bolt and take out the coupling kit.
- (2) Remove the jam nut and take out the flywheel.
- (3) Remove the fuel feed pump.

Note: At removing the flywheel mounting nut, insert a turning bar in the turning bar hole on the outer surface of the flywheel and stop the flywheel rotation.



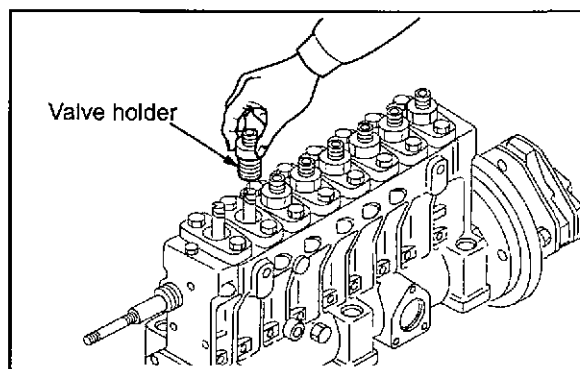
Disassembling coupling assembly and fuel feed pump

2.8.6 Disassembling delivery valve

CAUTION

- (a) Keep away from flame when handling light oil.
- (b) Keep the matching of the delivery valve with valve sheet in clean light oil.
- (c) Never change the matching of the delivery valve and valve sheet.

Remove the valve holder and take out the spring sheet, delivery valve spring, delivery valve and valve sheet.



Disassembling delivery valve

2.8.7 Disassembling plunger assembly

⚠ CAUTION

- Before disassembling, always mount the Plunger Holder.
- Friction of the O-ring combined in the barrel may sustain the plunger spring in a compressed state and the barrel may not come out automatically.
- If impact is given to the barrel in this condition, the plunger spring force is rapidly released, causing the barrel to spring out, and your finger may be caught between the barrel bolt and barrel or suffer other unexpected injuries.

CAUTION

Be sure to remove the deflector before removing the plunger assembly. If the plunger assembly is removed without removing the deflector bolt first, damage will result in the deflector bolt and plunger assembly.

- Position the cam at the bottom dead center in the cylinder from which the plunger assembly is removed.
- Remove the deflector bolt from the pump case.
- Screw the plunger holder in the threaded hole on the upper end of the plunger.
- Loosen two barrel bolts alternately, and lift the plunger assembly and remove.

2.8.8 Disassembling controller rack

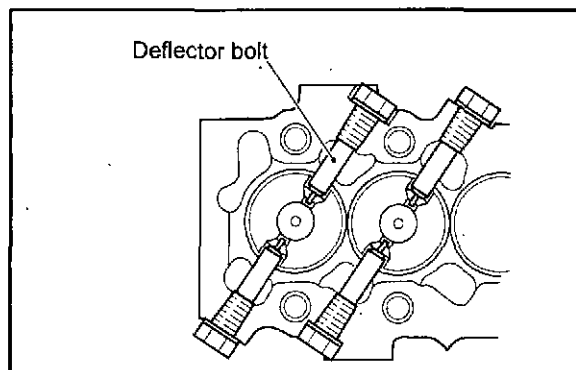
- Dislodge the bellows from grooves of the controller rack and rack bushing installed in the pump case, and remove the bellows.
- Remove the set screw from the back side of the pump case, and pull out the controller rack.

Note: (a) Confirm that the removed set screw is not cracked with color inspection, magnetic deep injury method, etc.

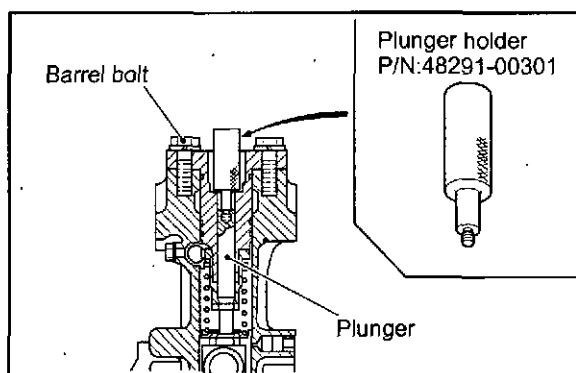
- Do not remove the rack bush unless it is necessary.

2.8.9 Disassembling tappet

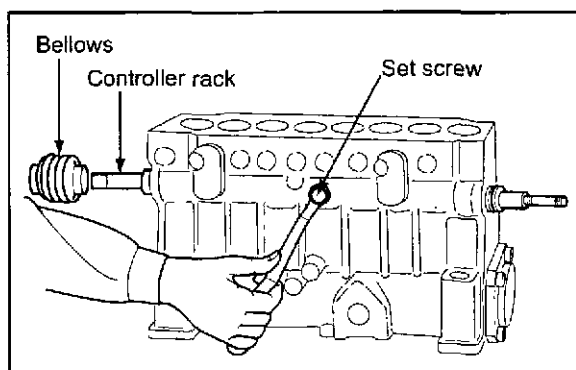
Hook a wire to two small holes (4 mm [0.16 in.] dia.) on the upper side of the tappet, and pull out the tappet.



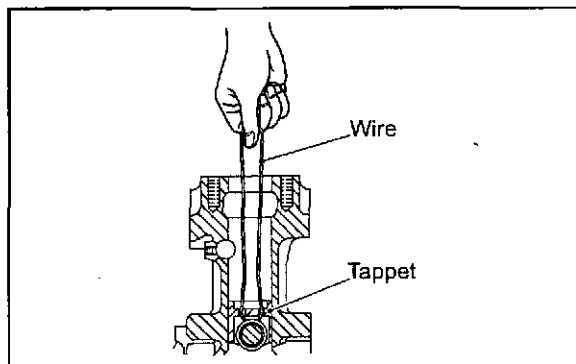
Disassembling deflector bolt



Disassembling plunger assembly



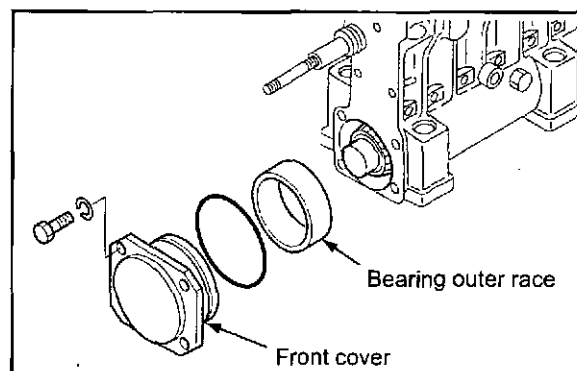
Disassembling controller rack



Disassembling tappet

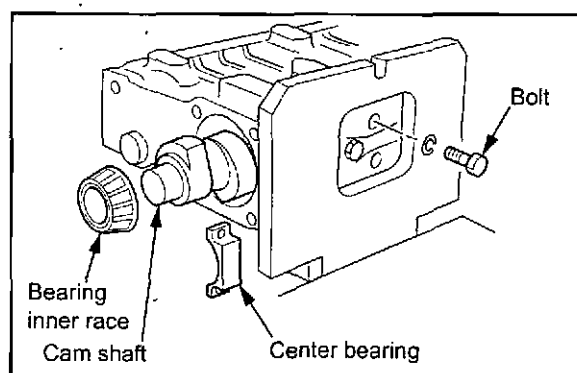
2.8.10 Disassembling camshaft

- (1) Unscrew four front cover mounting bolts, and remove the front cover and bearing outer race.



Disassembling camshaft (1)

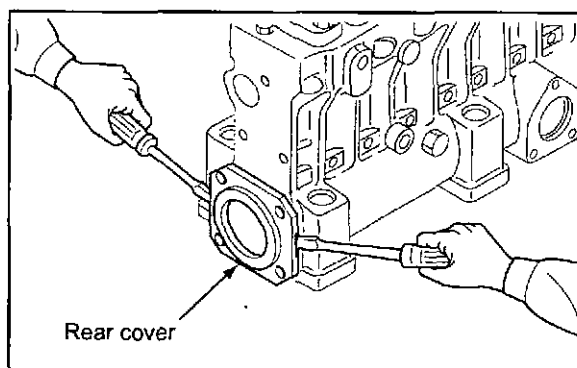
- (2) Tilt the pump case sideways, and remove two center bearing mounting bolts.
- (3) Strike the camshaft on the drive-side end with a soft hammer to remove the camshaft and center bearing.
- (4) Remove the bearing inner races from both ends of the camshaft.



Disassembling camshaft (2)

2.8.11 Disassembling rear cover

- (1) Remove four rear cover mounting bolts.
- (2) Insert the tips of screwdrivers into the notch located on the side of the rear cover, and pry out. Remove the shim.



Disassembling rear cover

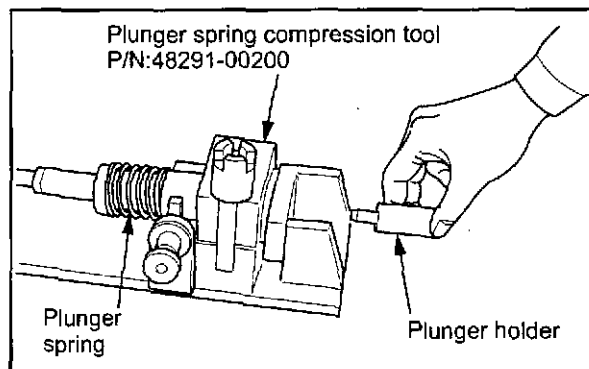
2.8.12 Disassembling plunger assembly

CAUTION

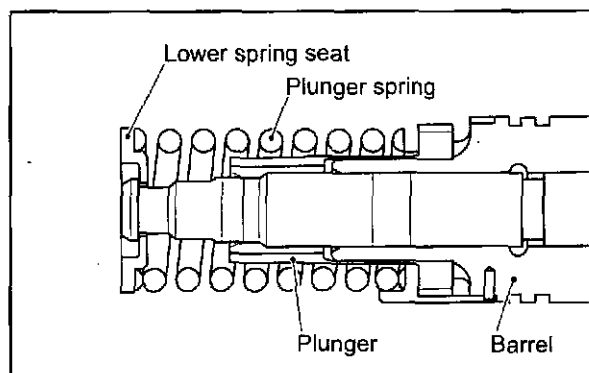
- (a) Keep flames away when using light oil.
- (b) Handle plungers carefully to prevent damage and scratches.
- (c) Place the removed plungers in a tray with clean light oil in it, making sure to arrange them in order to ensure correct reassembly.
- (d) Do not swap the original combinations of plungers and barrels.

- (1) Mount the plunger assembly on the plunger spring compression tool.
- (2) Press the knob on the jig to compress the plunger spring, then remove the plunger holder.
- (3) Loosen the compression of the plunger spring gradually, and remove the lower spring seat, plunger and plunger spring from the barrel.
- (4) Remove the barrel from the plunger spring compression tool, and take out the upper spring seat, pinion and O-ring.

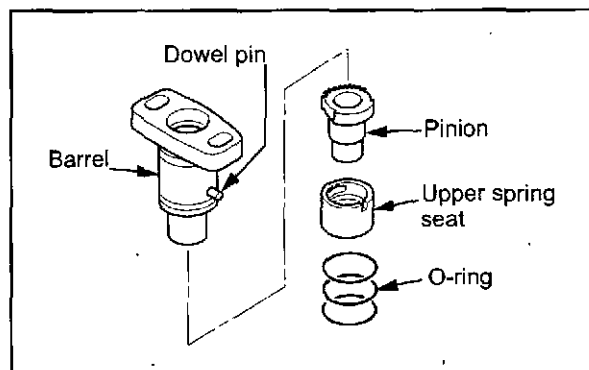
Note: Do not pull out the knock pin.



Disassembling plunger assembly (1)



Disassembling plunger assembly (2)



Disassembling plunger assembly (3)

2.9 Inspecting fuel injection pump

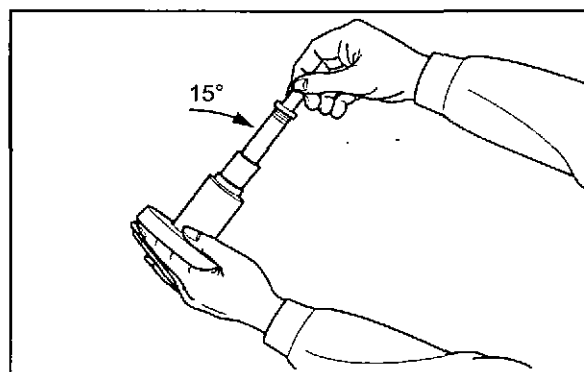
⚠ CAUTION

Keep flames away when using light oil.

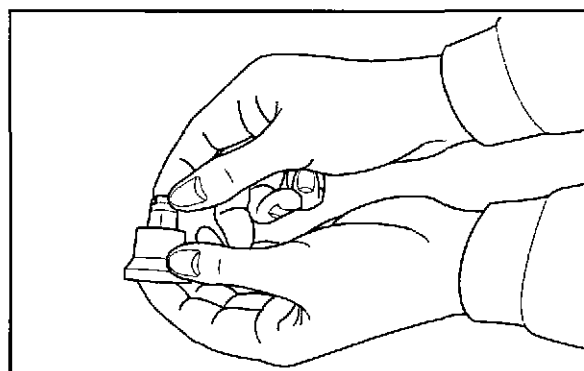
Wash each part with clean gasoline or diesel fuel without disarranging the order, and check them carefully for wear, scratches and damage. If a part is found to be non-reusable, replace with a new part. Always use new gaskets, new O-rings and new oil seals in reassembly.

2.9.1 Inspecting plunger barrel

- (1) Check for any wear, damages or discoloration of the plunger lead part and the tip.
- (2) After cleaning with clean light oil, tilt by around 15° as shown in the figure, pull up the plunger by 30 to 35 mm [1.1811 to 1.3780 in.] and inspection if it will smoothly slide down by its own weight. Turn the plunger to change the position and inspection a few times.
- (3) If the dropping speed is fast or if the fall is disrupted, exchange the plunger and the barrel with new ones.



Inspecting plunger for smooth movement



Inspecting delivery valve for smooth movement

2.9.2 Inspecting delivery valve

- (1) Check for damages on the valve sheet surface and the piston and inspect the sealing surface with the barrel.
- (2) After cleaning with clean light oil, pull up the valve and check if it smoothly slides down to the valve sheet surface.
- (3) If the fall is disrupted, exchange the delivery valve and valve sheet with new ones.

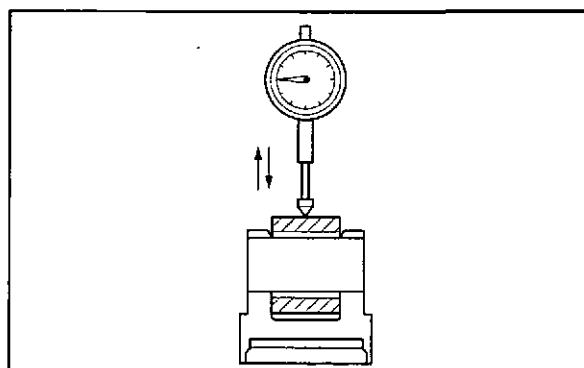
2.9.3 Inspecting tappet

- (1) Check for peeling, local wear, damages, etc. on the tappet roller, roller bearing and tappet pin surface.
- (2) Inspect the spacing between the tappet, tappet roller, roller bearing and tappet pin. If above the tolerance, exchange with new ones.

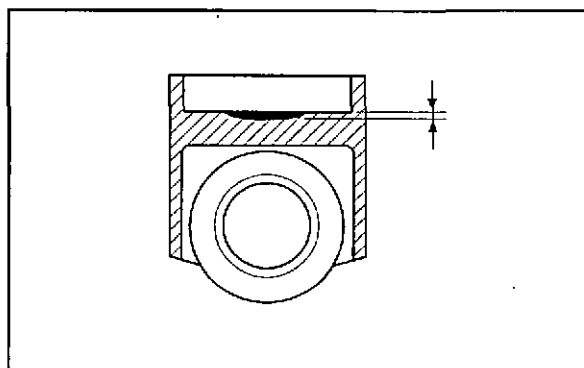
Item	Limit
Overall clearance at tappet roller	0.2 mm [0.008 in.]

- (3) Check for wear on the plunger hitting surface of the tappet. If above the tolerance, exchange with new ones.

Item	Limit
Wear of contact surface between tappet and plunger	0.2 mm [0.008 in.]



Measuring overall clearance of tappet roller



Inspecting wear of tappet

2.9.4 Inspecting bearing

Check for any peeling on the surface, gloss and noise. If damaged, exchange it.

2.9.5 Inspecting valve holder

- (1) Check for any damage on the high pressure valve and delivery valve or sealing surface.
- (2) Any damage on the sealing surface would cause fuel leakage. Exchange it.

2.9.6 Inspecting pump case

Check for any damage, dent, cracks or breakage on the surface. If damaging to the function, exchange it.

2.9.7 O-ring and bellow on each unit

After disassembling, exchange them regardless of the condition.

2.9.8 Inspecting camshaft

- (1) Inspect the play between the key and the key groove, damage on the tapered parts, peeling on the cam surface, local wear and damages. If any damage is found, exchange it.
- (2) Hold both ends of the shaft with V blocks and measure the runout at the center bearing slide part on the shaft with a dial gauge. If above the tolerance, correct it with pressing or exchange it.

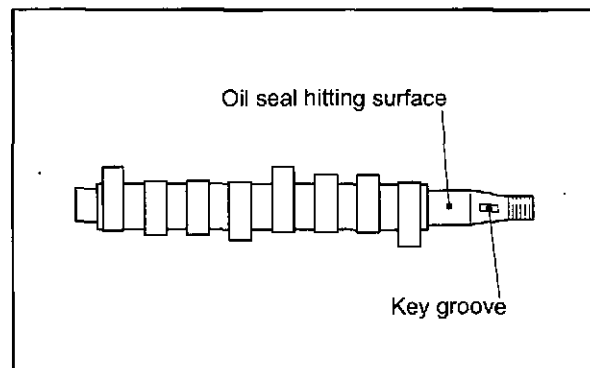
Item	Standard	Limit
Camshaft runout	0.05 mm [0.0020 in.]	0.15 mm [0.0059 in.]

- (3) Check for wear on the oil seal hitting surface. If under the standard, insert an oversize sleeve.

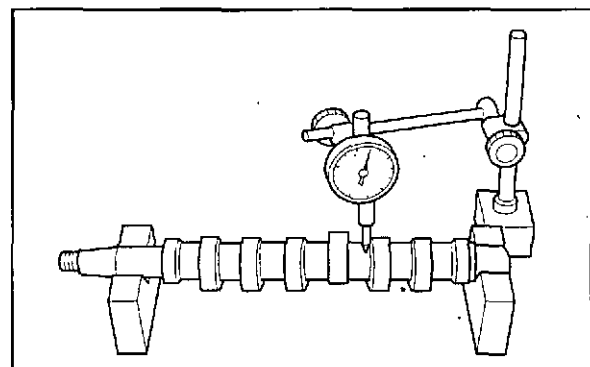
Note: (a) Assemble the bearing inner race before inserting the oversize sleeve.

- (b) Note that the bearing inner race cannot be assembled after inserting the oversize sleeve.

Item	Call value	Standard	Limit
Outer diameter at contact surface of camshaft oil seal	ø 35 mm [1.38 in.]	34.938 to 34.963 mm [1.3755 to 1.3765 in.]	34.800 mm [1.3701 in.]



Inspecting camshaft outer surface



Measuring camshaft runout

2.9.9 Inserting oversize sleeve to camshaft

(1) Clean the old sealing surface and remove any burrs of the camshaft.

(2) Lock the camshaft on a vise.

(3) Apply Three Bond No. 1215 (not necessary when Three Bond 2084B is used) on the oversize sleeve insertion part on the camshaft and assemble it to the camshaft with the flange of the oversize sleeve first.

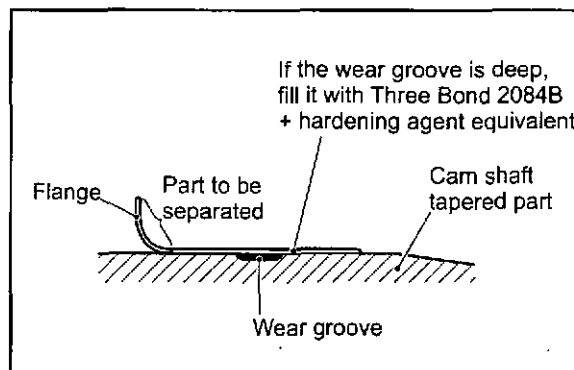
Note: If the wear groove of the camshaft is deep, fill the groove with powdered metal epoxy type filler (Three Bond 2084B + hardening agent equivalent) and insert the oversize sleeve before it hardens.

(4) Insert the oversize sleeve with the sleeve installer.

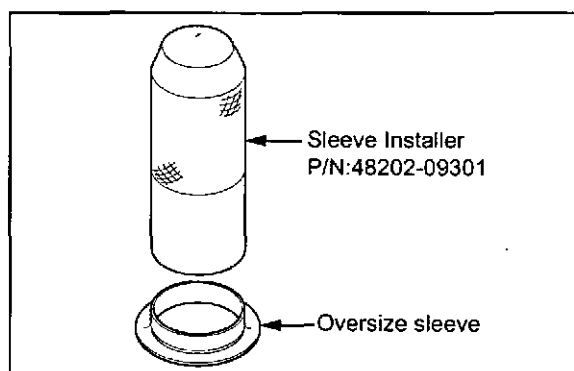
Note: Use a wooden or equivalent hammer and hit the sleeve installer carefully if needed.

(5) Make sure that the mounting position sufficiently covers the groove but does not go over the tapered part on the camshaft.

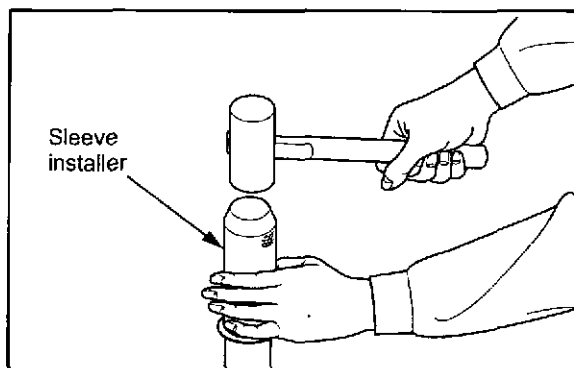
(6) After assembly, remove the flange of the oversize sleeve by placing the cutter at the cut guide and remove it in a rolling motion.



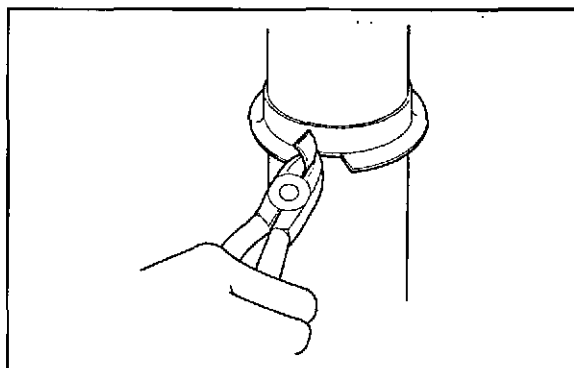
Oversize sleeve cross section



Sleeve installer



Hammering oversize sleeve

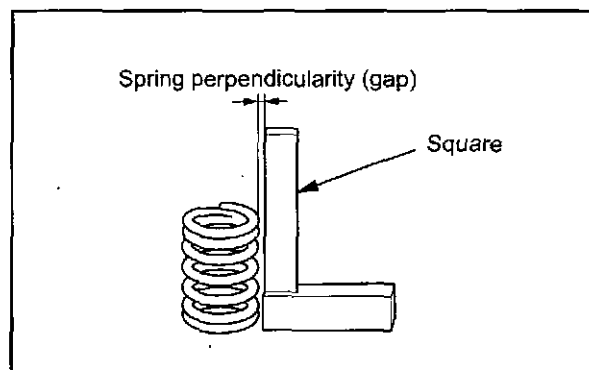


Removing flange of the oversize sleeve

2.9.10 Inspecting plunger spring and delivery valve spring

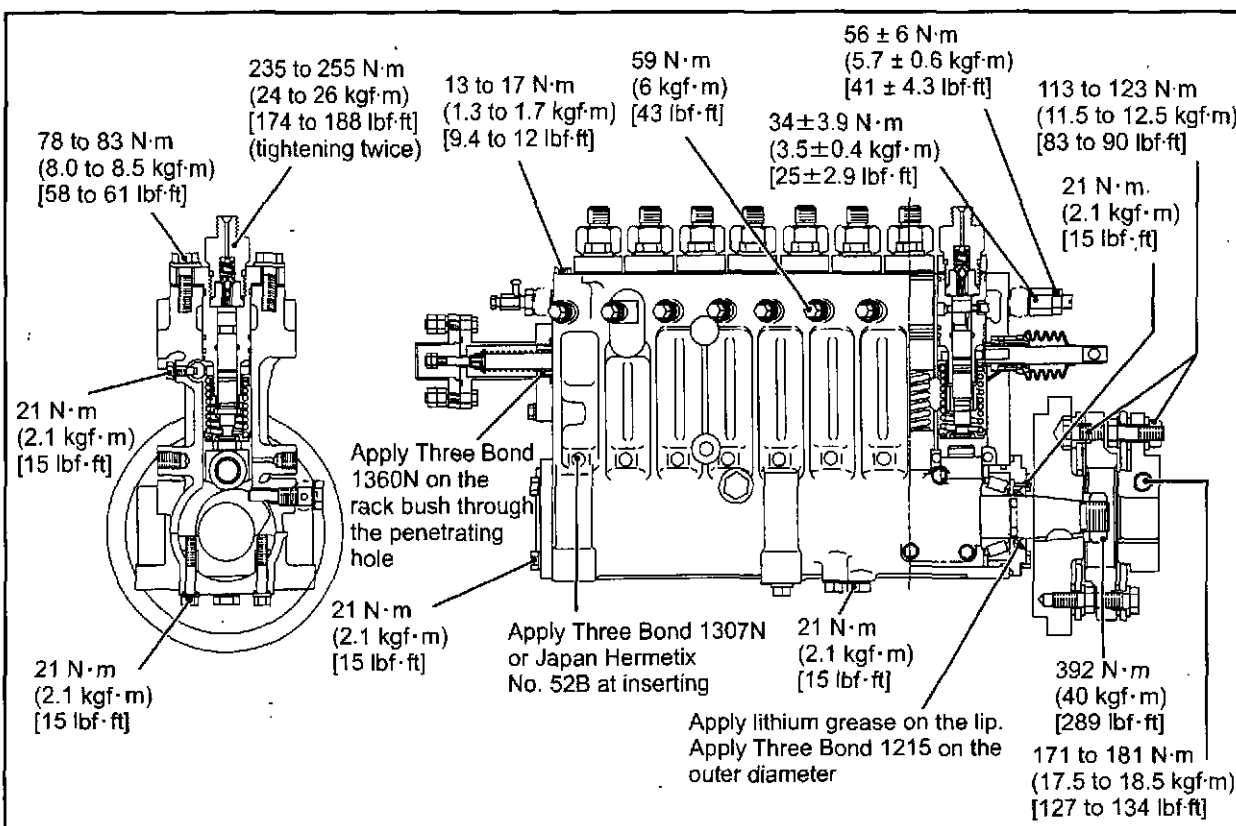
- (1) Check for damages and rust on the surface.
- (2) Measure the gap at the upper end of the spring with a square and obtain the right angle. If it is beyond the limit, exchange it.

Item		Limit
Perpendicularity	Plunger spring	1.8 mm [0.071 in.]
	Delivery valve spring	0.6 mm [0.024 in.]



Measuring spring perpendicularity

2.10 Reassembling fuel injection pump



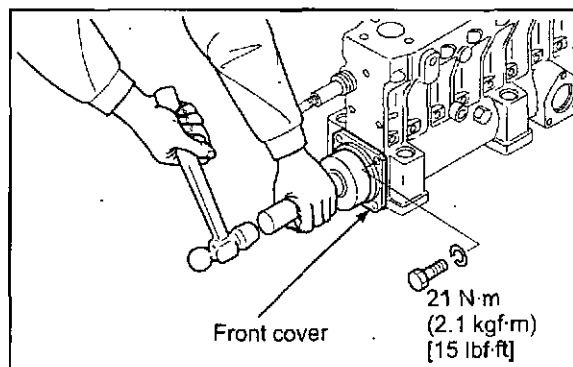
Reassembling fuel injection pump

CAUTION

At assembling damper roof, give precision adjustment with a bench test after assembling the fuel injection pump to the engine.

2.10.1 Installing bearing and front cover

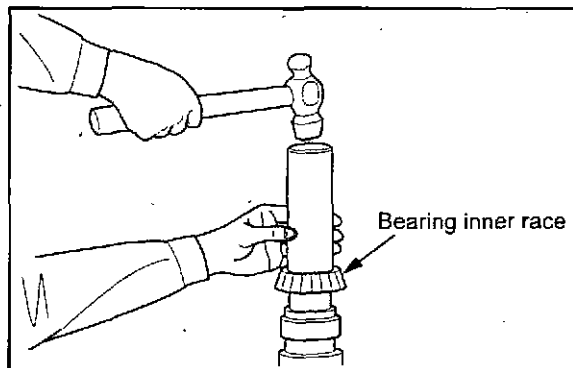
- (1) Install the O-ring and bearing outer race to the front cover.
- (2) Hammer in the front cover to the pump case.
- (3) Tighten the front cover mounting bolt with the specified torque.



Installing bearing and front cover

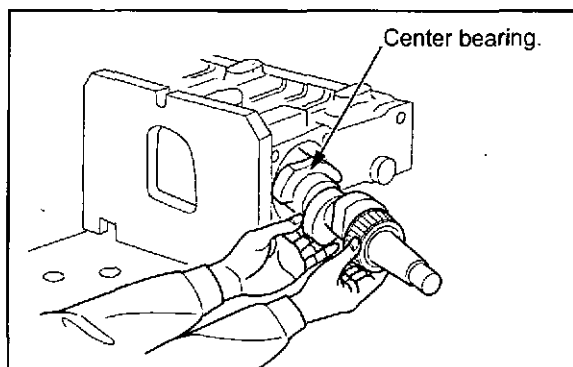
2.10.2 Installing camshaft and center bearing

- (1) Hammer in the bearing inner race to the both ends of the camshaft.



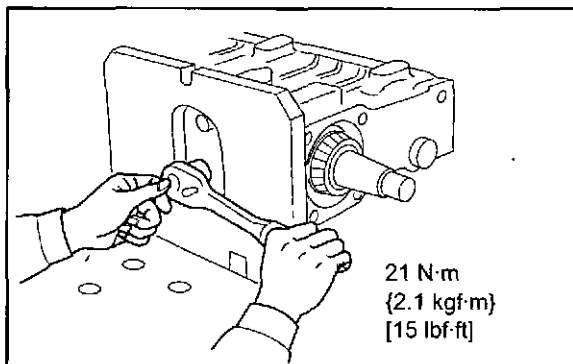
Installing camshaft and center bearing (1)

- (2) Turn the pump case sideways.
- (3) Install the center bearing on the camshaft and insert it to the pump case.



Installing camshaft and center bearing (2)

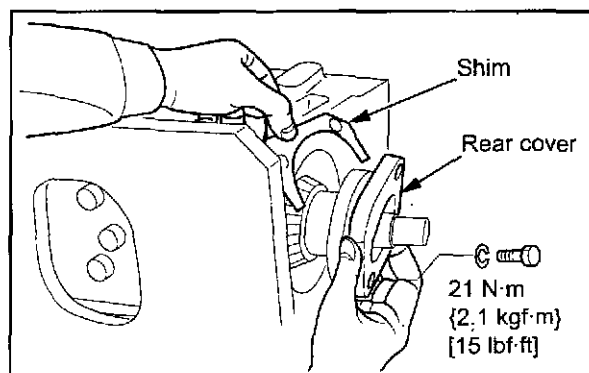
- (4) Slowly turn the camshaft, match the bolt hole of the center bearing and the bolt hole of the pump case, and tighten the mounting bolt with the specified torque.



Installing camshaft and center bearing (3)

2.10.3 Installing rear cover

- (1) Install the bearing outer race to the rear cover.
- (2) Install the O-ring and shim to the rear cover and assemble it to the pump case. Apply engine oil or grease to the O-ring. Apply lithium grease on the lip of the oil seal and Three Bond 1215 on the outer diameter. If the oversize sleeve was used to repair the camshaft, apply engine oil or grease to the tip of the oversize sleeve.
- (3) Tighten the rear cover mounting bolt with the specified torque.



Installing rear cover

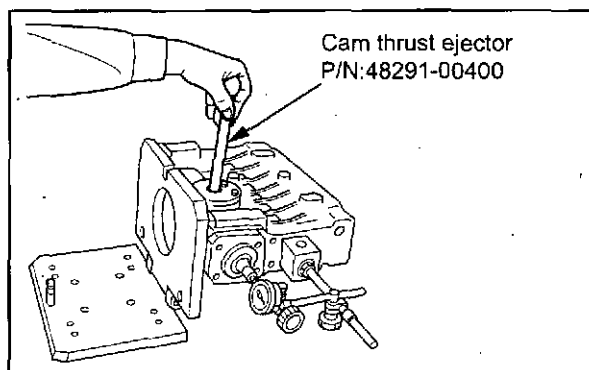
2.10.4 Measuring thrust clearance of camshaft

- (1) Set a dial gauge on the edge of the camshaft and measure the clearance with the cam thrust ejector.

Item	Standard
Camshaft thrust clearance	0.02 to 0.06 mm [0.0008 to 0.0024 in.]

- (2) If the clearance is outside the standard, use shims to make adjustment.
- (3) Turn the camshaft and confirm that it rotates smoothly.

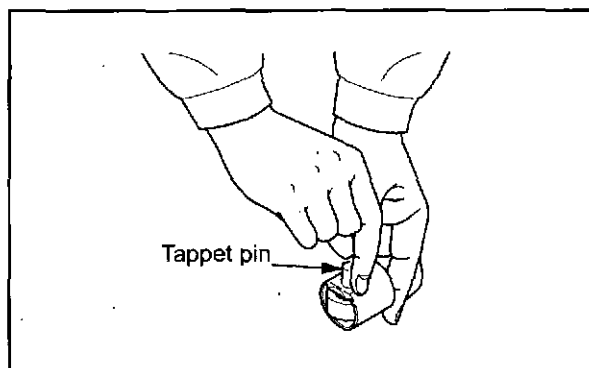
Shim parts number	Thickness
48202-14100	0.50 mm [0.0197 in.]
48202-14200	0.10 mm [0.0039 in.]
48202-14300	0.15 mm [0.0059 in.]
48202-14400	0.30 mm [0.0118 in.]



Measuring thrust clearance of camshaft

2.10.5 Installing tappet roller assembly

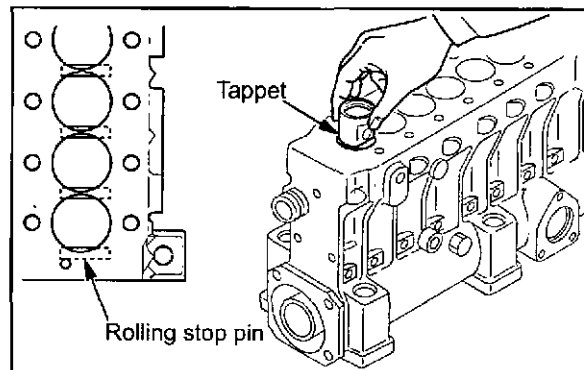
- (1) Insert the tappet roller and roller bearing in the tappet in advance, and insert the tappet pin.
- (2) Apply engine oil to all parts.
- (3) After assembly, confirm that the roller rotates lightly without a snag.



Installing tappet roller assembly

2.10.6 Installing tappet

Position so that the chipped part of the tappet securely inserts the rolling stop pin, and gently insert the tappet into the pump case.

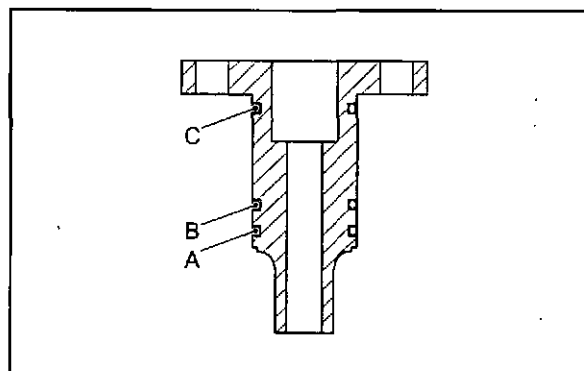


Installing tappet

(1) Assemble three O-rings to the barrel.

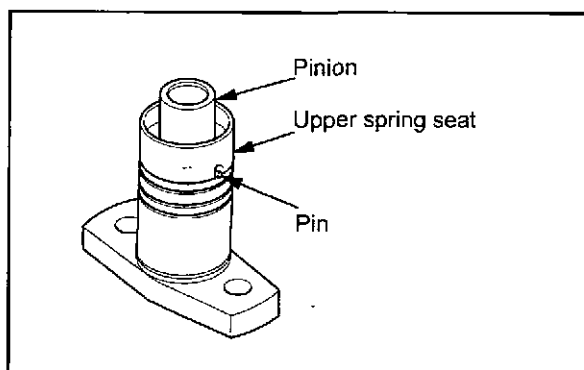
Note: (a) Always use new O-rings.

(b) At assembling the O-rings, always apply grease to prevent damage to the O-rings and assemble in the order of A, B and C.



Reassembling plunger assembly (1)

(2) Lightly hammer in the pinion and upper spring seat to the barrel. Match the chipped parts of the hammered pin and the upper spring seat.

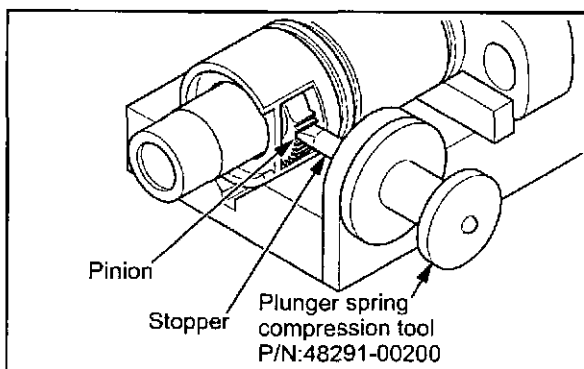


Reassembling plunger assembly (2)

(3) Lock the barrel, pinion and upper spring seat assembly on the special tool plunger spring compression tool.

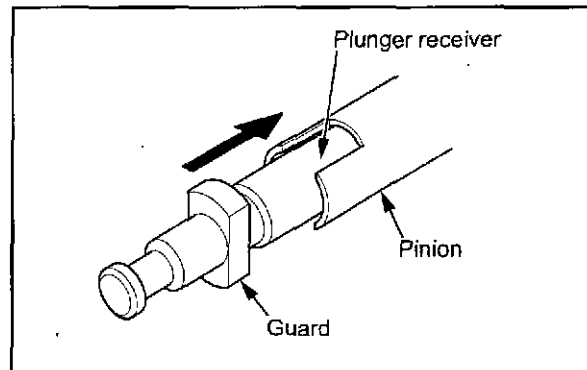
(4) Insert a stopper at the part where one tooth is omitted on the pinion to prevent wrong assembly with the rack.

Note: When you look at the pinion from the window on the upper spring seat, the part with one tooth removed is placed at the center.



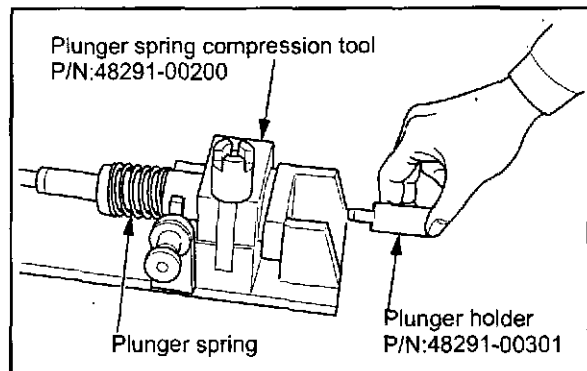
Reassembling plunger assembly (3)

- (5) Match the phases of the plunger receiver on the pinion and the plunger guard with a driver.



Reassembling plunger assembly (4)

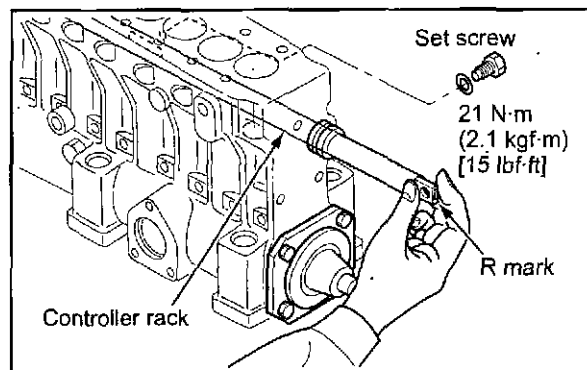
- (6) Push down the plunger spring compression tool and insert the plunger into the plunger receiver on the pinion.
(7) Push in the plunger holder to the screw part on the plunger head.



Reassembling plunger assembly (5)

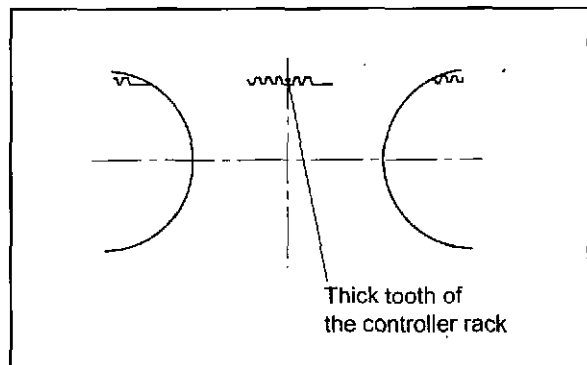
2.10.8 Installing controller rack

- (1) Insert the controller rack into the pump case so that the R mark at the edge is positioned on the driving side and tighten the set screw with the specified torque.



Installing controller rack (1)

- (2) Look through the cylinder at the top of the pump case and move the controller rack so that the thick tooth of the controller rack (three times thicker than other teeth's to prevent wrong assembling) is placed at the center of the cylinder in the pump case.

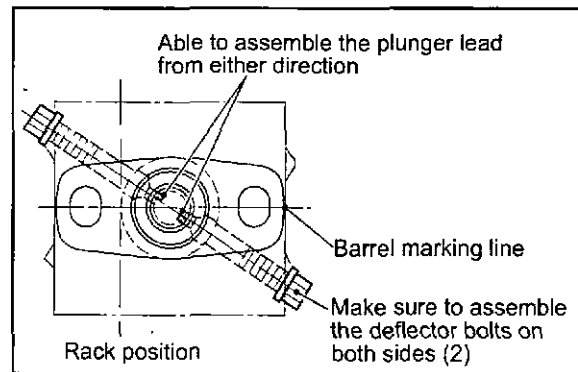


Installing controller rack (2)

2.10.9 Positional relationship between plunger and barrel

CAUTION

Pay attention to the positions of the lead and the gear of the pinion and install them as shown in the figure on the right.



Assembling two-side lead plunger

2.10.10 Removing plunger assembly

CAUTION

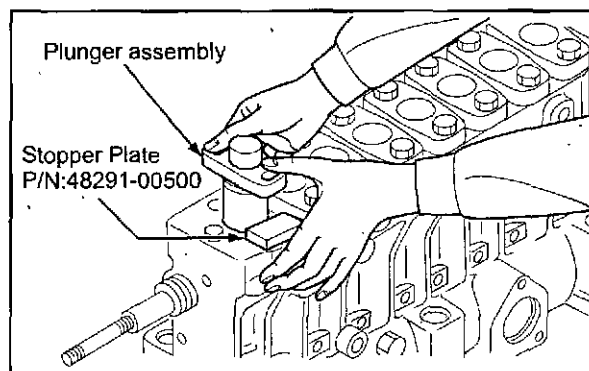
In each cylinder, insert barrel shims of the same thickness, one in front and one in back. (Do not use two or more shims at one location.) If the shim thickness varies in the front and back of a cylinder, the rack may not move smoothly, causing hunting and other problems.

- (1) Position the cam at the bottom dead center in the cylinder to which the plunger assembly is installed.
- (2) Place the stopper plate on top of the pump case to prevent damage to the pinion and control rack during the installation of the plunger assembly.

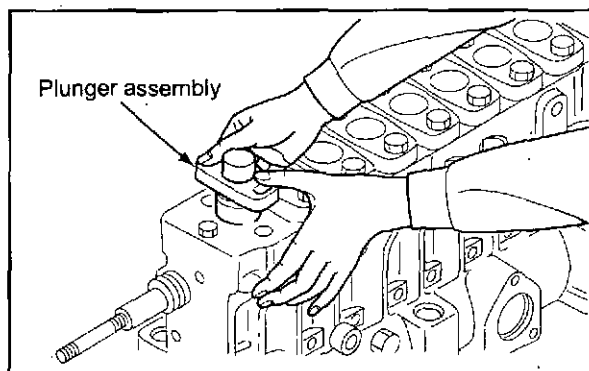
Note: If the stopper plate is not used during plunger assembly installation, the teeth on the pinion hit the teeth on the rack, causing rough edges that hinder smooth rack movement.

- (3) Hold the flange of the barrel with both hands and press down the plunger assembly until the bottom side of the flange contacts the stopper plate.
- (4) Remove the stopper plate, and slowly lower the plunger assembly to search the correct meshing. Do not apply excessive force to press down the plunger assembly. If the plunger assembly is jammed, turn the flange by jiggling back and forth, then press down.
- (5) Insert standard barrel shims (thickness: 1.0 mm [0.0394 in.]) under each barrel flange, and align the standard mark on the barrel flange with the matching mark on the pump case.
- (6) Install washers on the barrel bolts, and screw the bolts snug. Then using a torque wrench, tighten the bolts progressively and evenly to the specified torque.
- (7) Remove the plunger holder. Check to make sure the control rack slides and strokes smoothly.

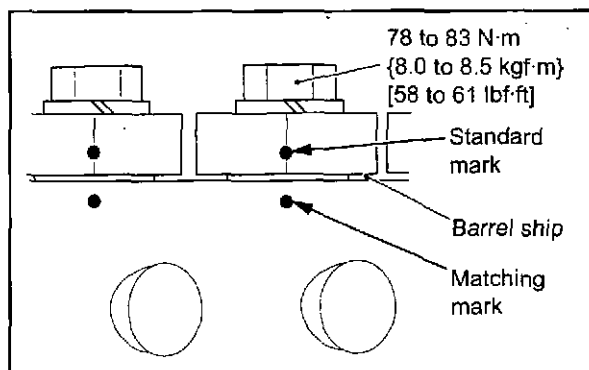
Note: Move the rack after installing each plunger assembly to make sure it moves smoothly (sliding resistance: 4.9 N {500 gf} [1.10 lbf] or less). At the same time, check to make sure the total rack stroke is 36 mm [1.42 in.].



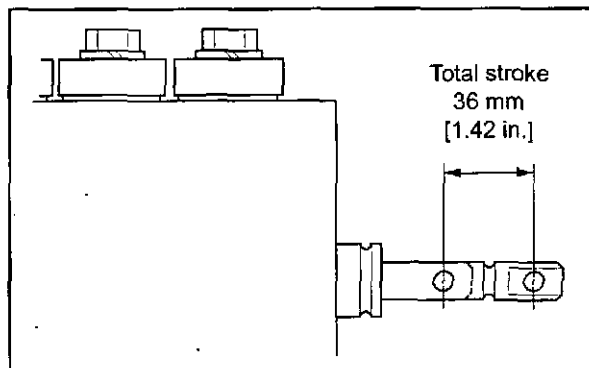
Reassembling plunger assembly (1)



Reassembling plunger assembly (2)



Reassembling plunger assembly (3)



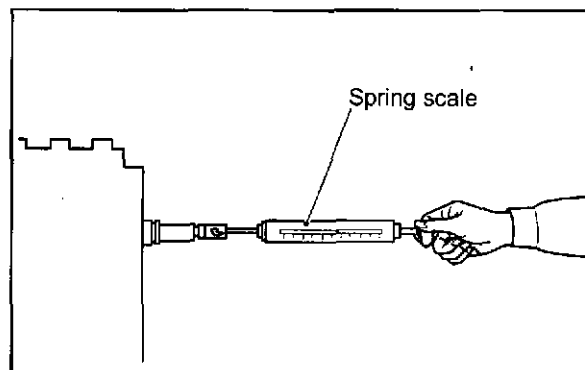
Reassembling plunger assembly (4)

2.10.11 Measuring control rack sliding resistance

- (1) After the pump assembly is completed, attach a spring scale to the control rack and make sure the control rack moves smoothly over the entire stroke.

Item	Standard
Control rack sliding resistance	4.9 N {500 gf} [1.10 lbf] or less

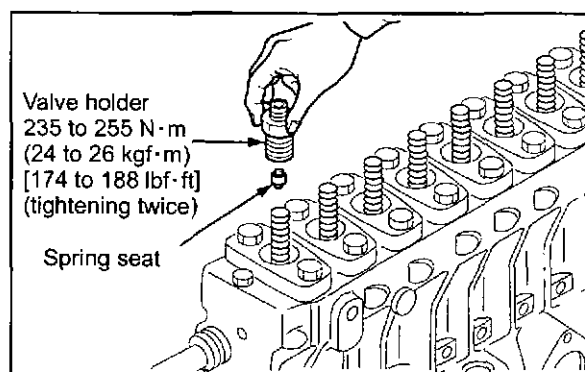
- (2) After making sure the rack sliding resistance is lower than the standard value, install the deflector bolts on the pump case and tighten.



Measuring control rack sliding resistance

2.10.12 Reassembling delivery valve

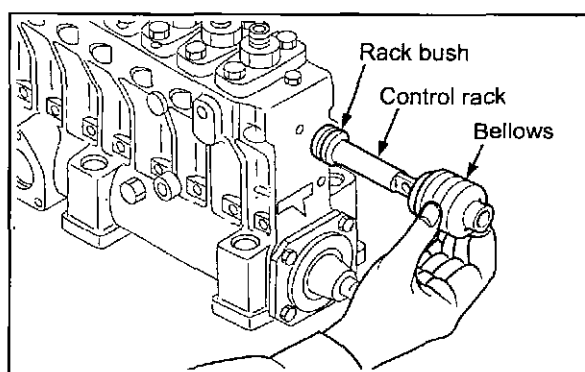
- (1) In each barrel, install spring seat and valve holder in that order.
- (2) Apply grease to a new O-ring to prevent O-ring from damage, then install the O-ring on each valve holder.
- (3) Tighten the valve holders to the specified torque.



Reassembling delivery valve

2.10.13 Reassembling bellows

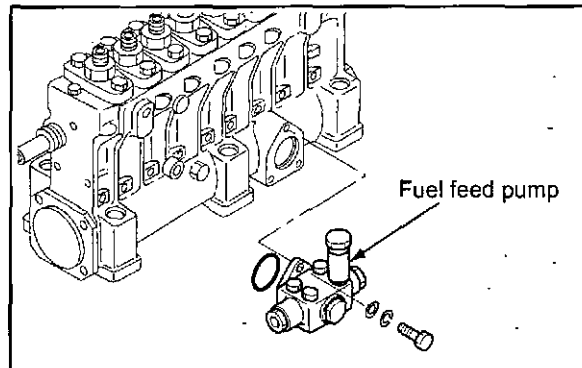
- (1) Insert the protrusions on the bellows into the grooves on the control rack and rack bushing and install the bellows. To prevent damage to the bellows, apply engine oil or grease inside the bellows.
- (2) Install the bellows band.



Reassembling bellows

2.10.14 Reassembling fuel feed pump

- (1) Assemble the fuel feed pump into the injection pump.
- (2) Tighten the fuel feed pump mounting bolt.



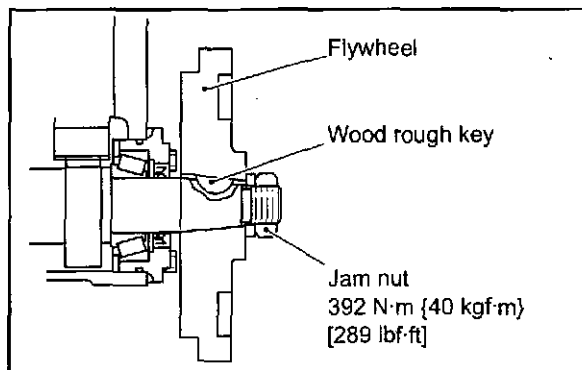
Reassembling fuel feed pump

2.10.15 Reassembling flywheel

- (1) Hammer in the wood rough key.

Note: There may be rattling with the wood rough key depending on the size of the key groove on the camshaft. In this event, deform the side of the wood rough key with a punch and then press it in (so that it will not fall off by its own weight).

- (2) Assemble the flywheel matching the wood rough key on the camshaft and tighten the jam nut with the specified torque.



Reassembling flywheel

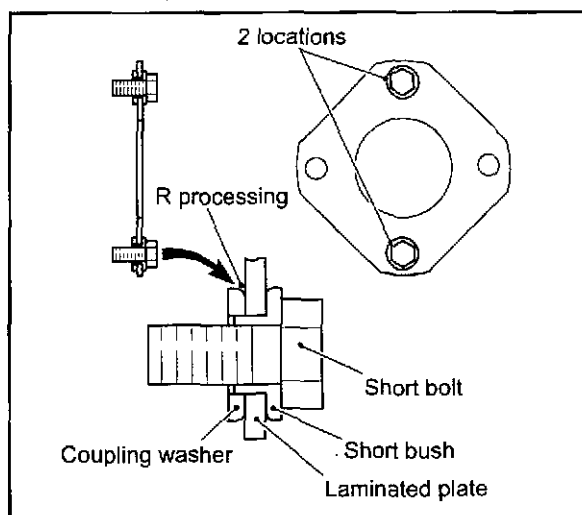
2.10.16 Reassembling coupling assembly

CAUTION

- (a) If the direction of the coupling washer is wrong, it would crack the laminated plate.
- (b) If the laminated plate cracks, the bolt may break causing a serious accident.

- (1) Assemble the short bush, short bolt and coupling washer to the diagonal positions (2) on the laminated plate.

Note: Make sure that the surface with R processing at the outer diameter edge on the coupling washer faces the laminated plate side.

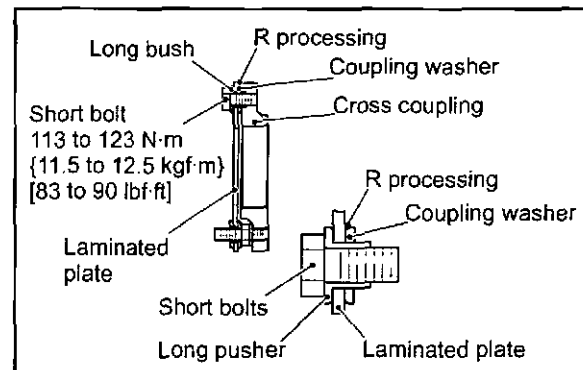


Reassembling coupling assembly (1)

- (2) Paying attention to prevent falling of the short bolt or coupling washer assembled into the laminated plate, assemble the laminated plate with the long bush and coupling washer in 2 remaining locations into the cross coupling. Tighten the short bolt with the specified torque.

Note: (a) The surface of the R processing on the edge of the outer diameter of the coupling washer must face the laminated plate.

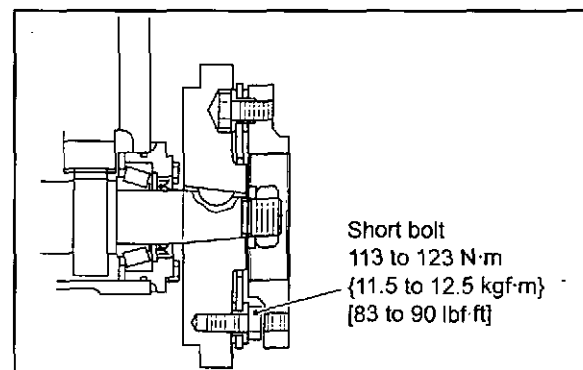
- (b) Use a spanner type torque wrench to tighten the short bolt.



Reassembling coupling assembly (2)

- (3) Tighten the laminated plate assembled with the cross coupling to the flywheel with 2 short bolts with the specified torque.

Note: Pay attention to prevent falling of the coupling washer while tightening the short bolts.

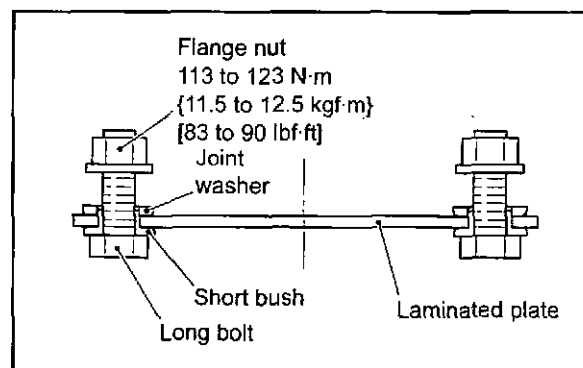


Reassembling coupling assembly (3)

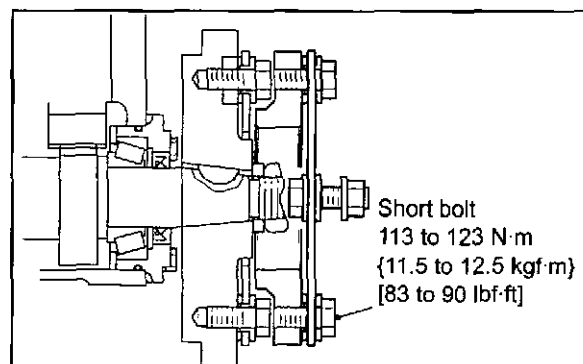
- (4) Assemble the short bush, long bolt and coupling washers to the diagonal positions (2) of the other laminated plate, and lightly tighten the flange nut to prevent falling.

Note: The surface with the R processing on the edge of the outer diameter of the coupling washer must face the laminated plate.

- (5) Assemble the laminated plate to the coupling on the driving side with the coupling wide washer. Tighten the flange nut with the specified torque.



Reassembling coupling assembly (4)



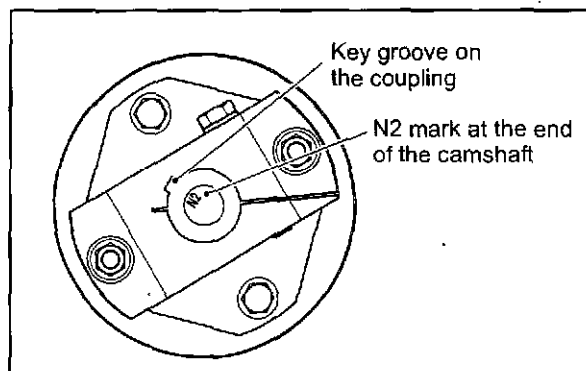
Reassembling coupling assembly (5)

- (6) Match the long bush with a washer at the remaining 2 locations on the laminated plate and assemble the laminated plate to the cross coupling with a short bolt. Tighten the short bolt with the specified torque.

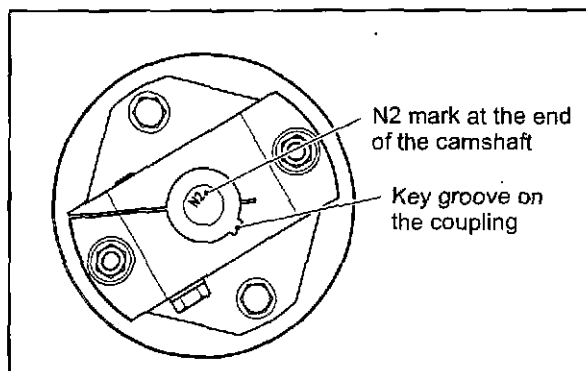
Note: The surface with the R processing on the edge of the outer diameter of the coupling washer must face the laminated plate.

CAUTION

- (a) The marking at the edge of the camshaft and the key groove on the coupling should be positioned as shown in the figure at assembling.
- (b) The coupling could be assembled at 180° in reverse by mistake. Confirm the correct assembling to prevent time lag in injection.



Reassembling position of camshaft and coupling (view from rear end of drive side) (RH)



Reassembling position of camshaft and coupling (view from rear end of drive side) (LH)

2.10.17 Reassembling controller rack return spring

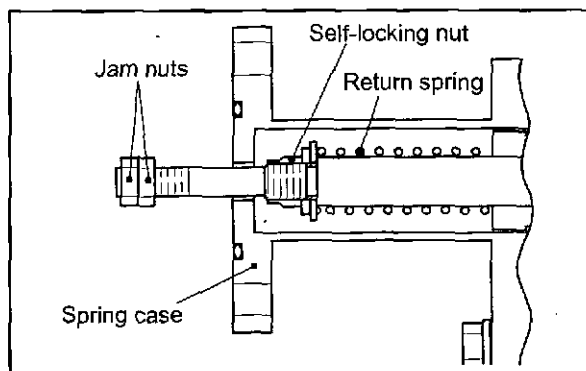
CAUTION

Two jam nuts must be mounted at the controller rack maximum injection position at the tip of the controller rack. After assembling the injection pump into the engine, make adjustment at a bench test. If the injection pump is not assembled in the correct order, it would not work correctly.

- (1) Mount the return spring, plane washer and spring washer to the controller rack and tighten with the new self-locking nut.

Note: After tightening with the self-locking nut, caulk the cylinder section.

- (2) Assemble the spring case.



Reassembling controller rack return spring

2.11 Adjusting fuel injection pump

After reassembling the fuel injection pump, make adjustments using a pump tester.

2.11.1 Adjusting pre-stroke (injection timing)

- (1) Remove all the deflector bolts from the pump case.
- (2) Remove the valve holder from cylinder No.1 (counter-drive side), then remove the spring seat, valve spring and delivery valve.
- (3) Set the measuring tip of a dial depth gauge on the head of the plunger. Rotate the camshaft by hand to bring the plunger to the bottom dead center by reading the indication on the depth gauge. Set the depth gauge indicator to "0".
- (4) Turn the camshaft in the normal operating direction until the dial depth gauge indicates 3.7 mm [0.146 in.].
- (5) With the camshaft in this position, check to make sure the pointer on the pump case and the "0" mark line on the flywheel. If they are not aligned, stamp a new line on the flywheel at the pointer position.
- (6) Point a flashlight from the top of the pump case, and look through the deflector bolt hole and check the position of the upper end of the plunger.

Note: When conducting this work, pull out the rack by 25 mm [0.98 in.] or more as the retard plunger is used.

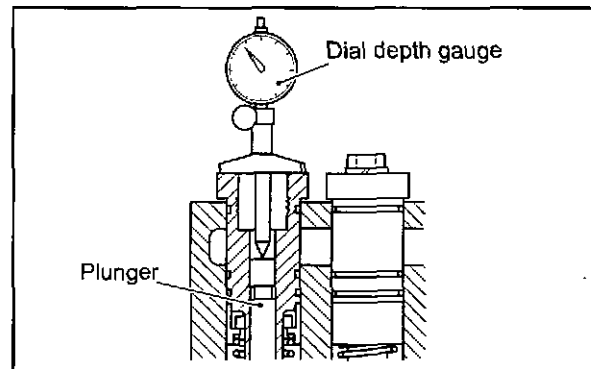
CAUTION

Use one shim of the same thickness in each side of a cylinder. Do not use two or more shims to adjust the thickness.

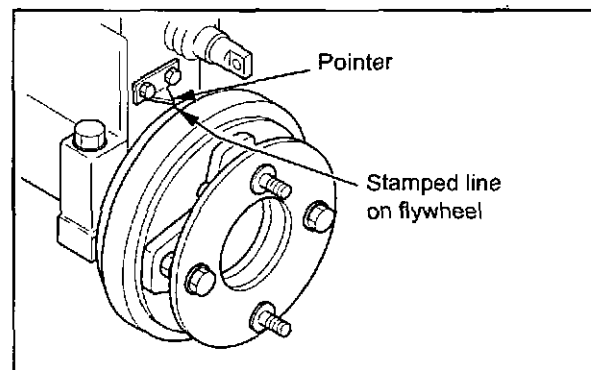
- (7) Rotate the camshaft until the upper of the plunger closes the barrel suction hole. With the camshaft in this position, the pointer should align with the stamped line on the flywheel. If not, change the shims so the pointer aligns with the line.

Increase of shim thickness → Retards injection timing

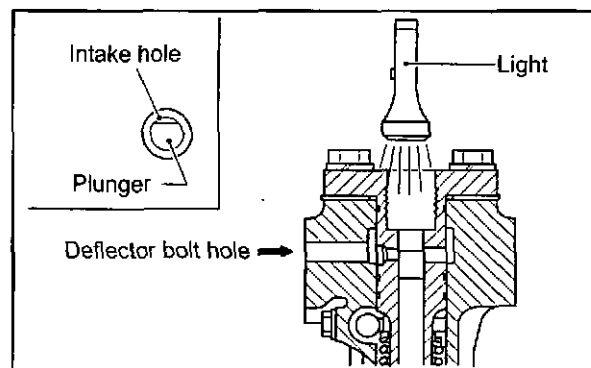
Decrease of shim thickness → Advances injection timing



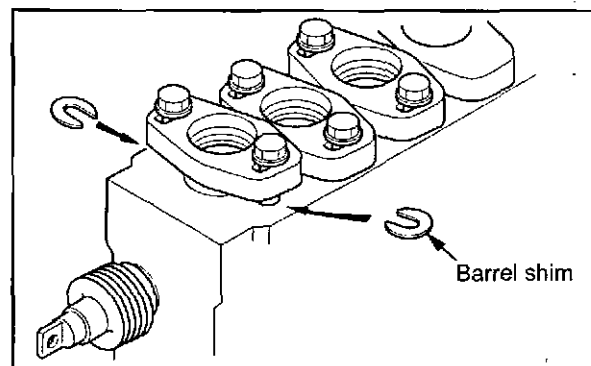
Adjusting prestroke (1)



Adjusting prestroke (2)



Adjusting prestroke (3)



Adjusting prestroke (4)

2.11.2 Adjusting injection interval

- (1) For cylinder No.2 and subsequent cylinders, use the injection start timing of cylinder No.1 as the reference point and check the injection start intervals on the angle scale on the pump tester according to the injection sequence.
- (2) If the injection intervals deviate from the specification, make adjustment by adjusting the thickness of the barrel shims in the same way for pre-stroke adjustment.

Item	Standard
Injection start intervals	45 ± 0.5°

2.11.3 Adjusting injection volume

CAUTION

Keep flames away when using light oil.

- (1) Install a fuel hose and the specified fuel pipe fuel injection nozzle to the fuel injection pump.
- (2) Make adjustment with the following conditions.
 - test fuel: JIS Class 2 light oil
 - test fuel temperature: 40±10 °C [104 ± 18°F]
 - Feed pressure: 0.3±0.05 MPa {3 ± 0.5 kgf/cm²} [42.7 ± 7.1 psi]
- (3) Check the control rack "0" position.
- (4) Set the pump to the specified rotation speed, and secure the control rack at the specified position.
- (5) To adjust the injection volume, loosen barrel bolts and slowly turn the barrel.
- (6) After adjustment, tighten the barrel bolts alternately to the specified torque.
- (7) Also adjust the injection volume so that deviations among cylinders conform to the standard value.

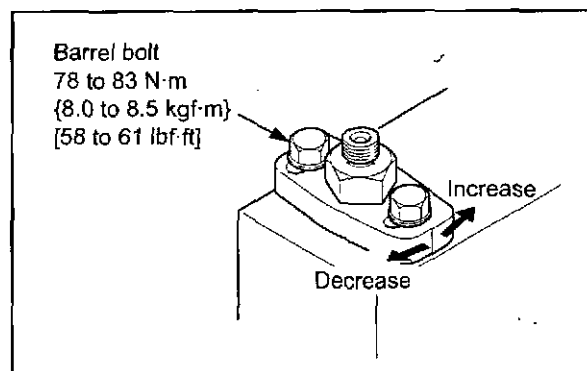
· Deviation in volume (+) = $\frac{\text{Maximum injection volume} - \text{Average injection volume of all cylinders}}{\text{Average injection volume of all cylinders}}$

· Deviation in volume (-) = $\frac{\text{Minimum injection volume} - \text{Average injection volume of all cylinders}}{\text{Average injection volume of all cylinders}}$

· Deviation in rate (+) = $\frac{\text{Maximum injection volume} - \text{Average injection volume}}{\text{Average injection volume}} \times 100$

· Deviation in rate (-) = $\frac{\text{Minimum injection volume} - \text{Average injection volume}}{\text{Average injection volume}} \times 100$

Types of barrel shims	
Part No.	Thickness
48202-04500	0.8 ± 0.02 mm [0.032 ± 0.0008 in.]
48202-04600	0.9 ± 0.02 mm [0.035 ± 0.0008 in.]
48202-04700	1.0 ± 0.02 mm [0.039 ± 0.0008 in.]
48202-04800	1.1 ± 0.02 mm [0.043 ± 0.0008 in.]
48202-04900	1.2 ± 0.02 mm [0.047 ± 0.0008 in.]

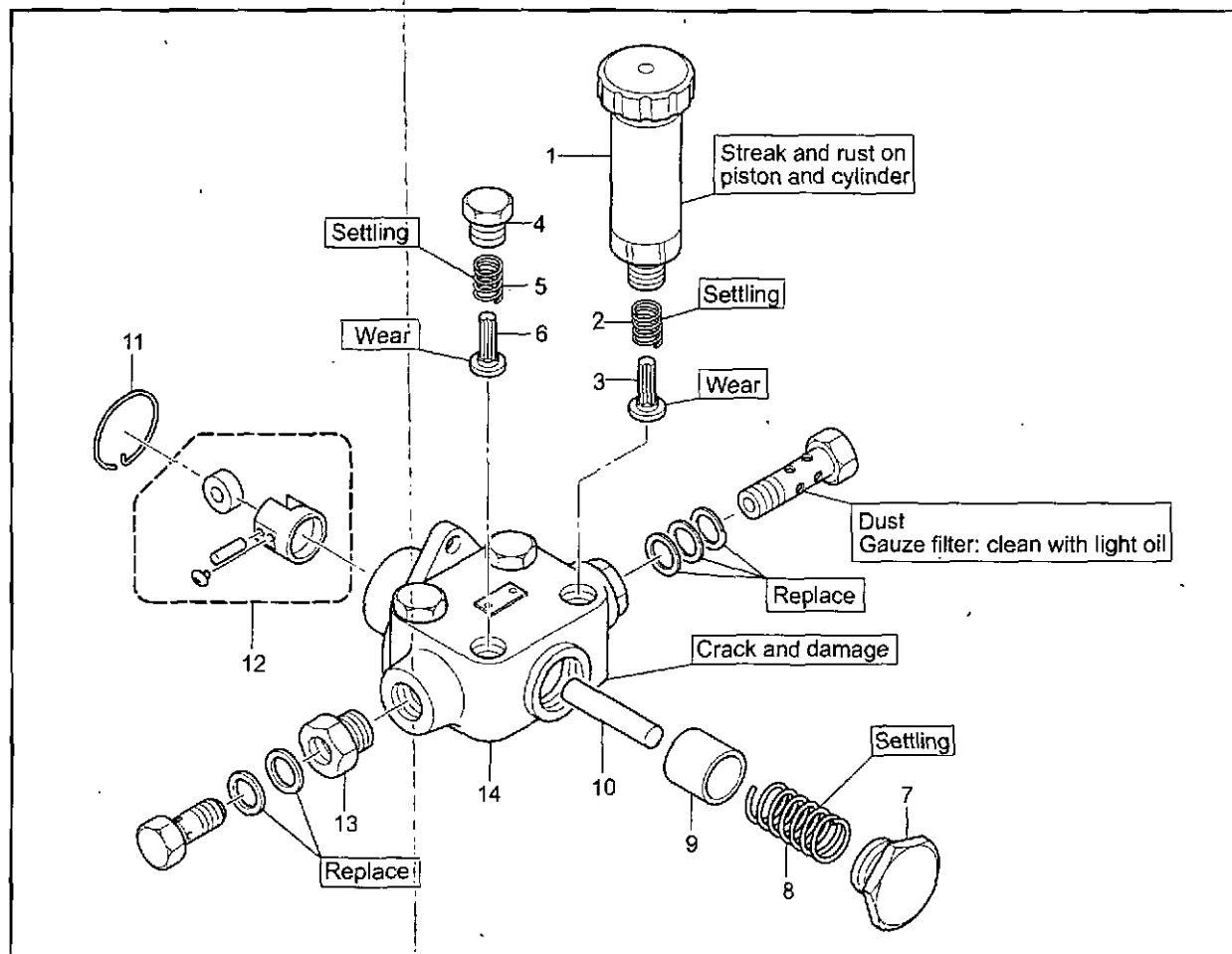


Adjusting injection volume

Deviation is as follows.

Pump speed	Rack position	Deviation in rate
300 min ⁻¹	11.5 mm [0.45 in.]	± 75%
900 min ⁻¹	7.5 mm [0.30 in.]	± 10%
900 min ⁻¹	18.5 mm [0.73 in.]	± 5%

2.12 Disassembling and inspecting fuel injection pump



Disassembling and inspecting fuel injection pump

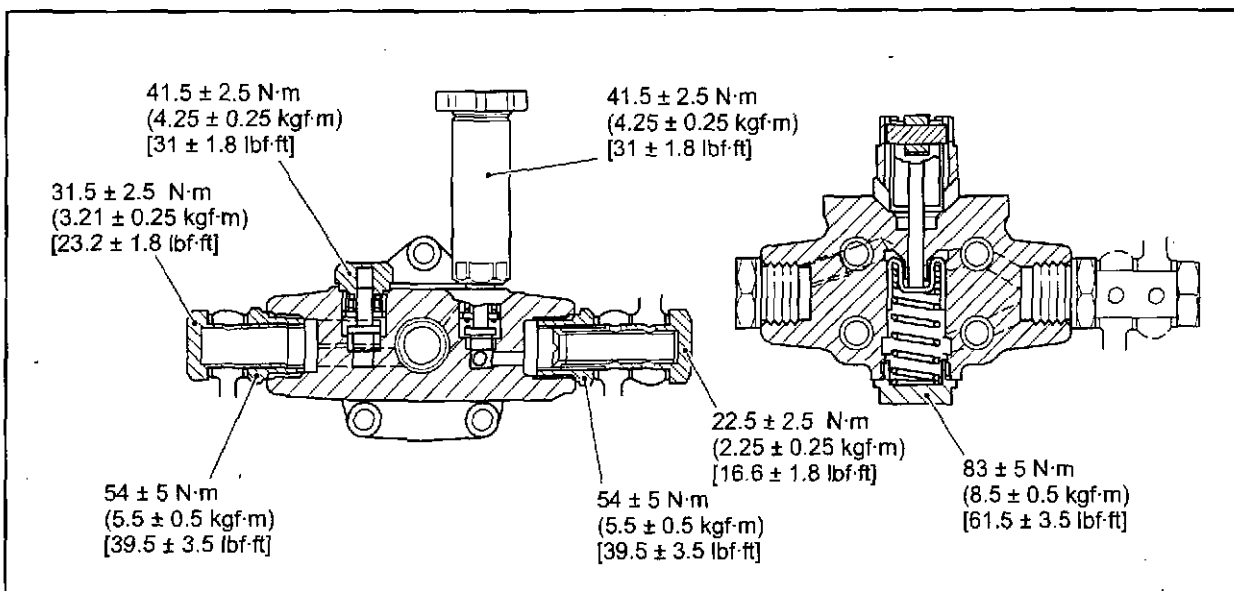
Disassembling sequence

- | | | |
|----------------|-------------|-----------------|
| 1 Priming pump | 6 Valve | 11 Snap ring |
| 2 Spring | 7 Plug | 12 Tappet |
| 3 Valve | 8 Spring | 13 Adapter |
| 4 Plug | 9 Piston | 14 Pump housing |
| 5 Spring | 10 Push rod | |

CAUTION

- Keep flames away when handling light oil.
- Disassembling while the gauze filter is clogged would twist and break the filter. Remove as much dust as possible before and use a driver for disassembling.

2.13 Reassembling fuel feed pump



Reassembling fuel feed pump

2.13.1 Tightening priming cap

WARNING

- If the priming pump cap is not tight enough, the screw inside would wear by the vibration of the engine, causing the priming pump cap to shoot out and the fuel to leak.
- If it is too tight (over 120°), on the other hand, the head of the priming pump would break and cause the head packing to stick out. Make sure to tighten at the correct angle ($90 \pm 10^\circ$).

CAUTION

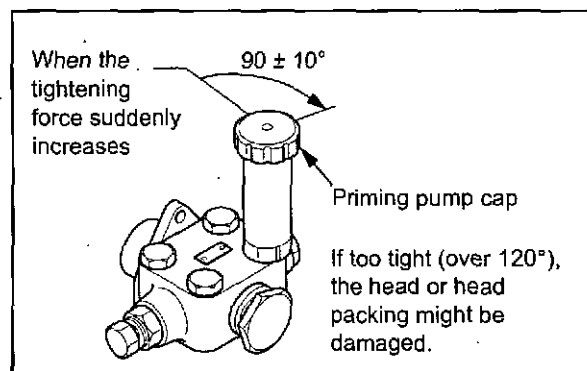
- When the head packing sticks out, confirm that the packing is not damaged, loosen the air removal plug on the fuel injection pump and re-tighten it.
- If the head packing is cut, exchange the priming pump or fuel feed pump.

- Gently tighten the priming cap by hand until the tightening force suddenly increases.

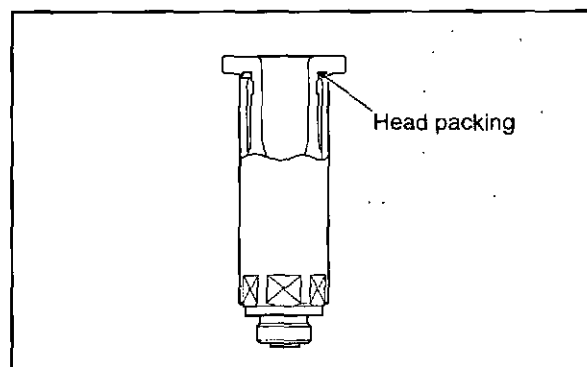
Note: Mark the priming cap at the above state to make the next step easier.

- Tighten it with a wrench to $90 \pm 10^\circ$.

After tightening, confirm that the head packing of the priming pump is not sticking out.



Tightening priming cap



Cross-section of priming pump

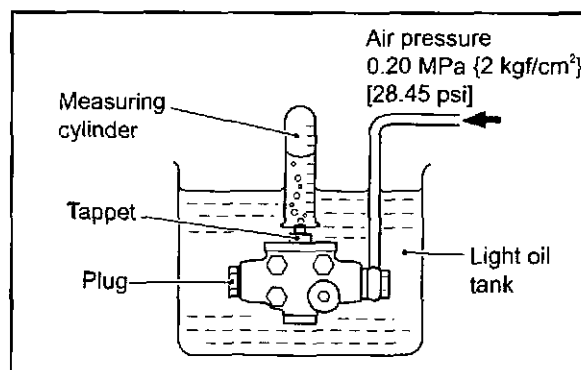
2.14 Fuel feed pump test

CAUTION

Keep flames away when handling light oil.

2.14.1 Fuel feed pump air-tightness test

Immerse the fuel feed pump in light oil, apply a plug at the outlet, and confirm that no leaking occurs when air pressure is applied from the intake at 0.20 MPa {2 kgf/cm²} [28.45 psi].



Fuel feed pump air-tightness test

2.14.2 Fuel feed pump fuel feeding pressure test

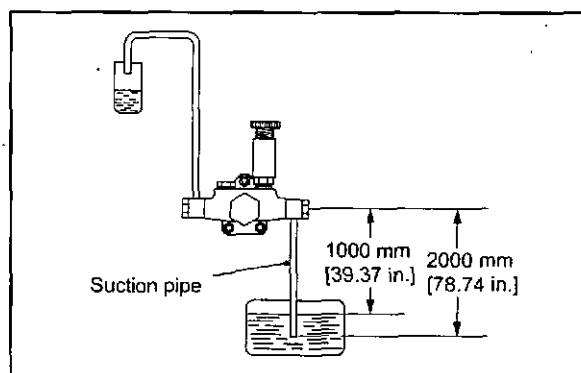
Testing conditions

Fuel pipe: Outside diameter ϕ 15 mm [0.6 in.], Inside diameter ϕ 13 mm [0.5 in.], Length 2000 mm [78.74 in.]

Suction height: 1000 mm [39.4 in.]

Cam lift: 12 mm [0.47 in]/revolution

Drive the pump in the above testing condition, and measure the discharge start time.



Fuel feed pump fuel feeding pressure test

2.14.3 Priming pump suction capacity test

- (1) Discharge fuel completely from the pump in the testing conditions described in (2.14.2).
- (2) Operate the priming pump by hand at a rate of 60 to 100 strokes per minute, and count the number of pumping operations required for fuel to reach the pump.

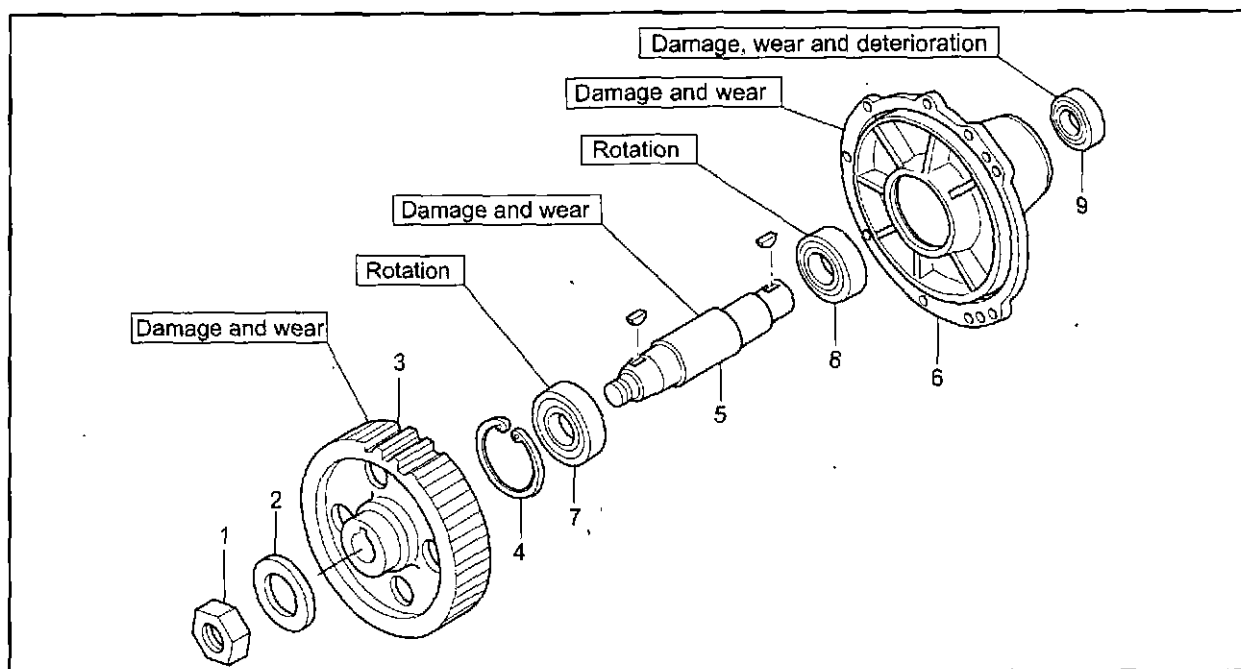
Item	Standard
Priming pump discharge start	No. of pumping operations 30 strokes or less

2.14.4 Fuel feed pump fuel feed rate test

Open the valve on the discharge side in the testing conditions described in (2.14.3). Then, operate the pump and measure the amount of fuel fed during the first 15 seconds.

Item	Standard
Feed pump feed rate (pump at 500 min ⁻¹ , 15 sec.)	1100 cm ³ [67.13 cu.in.] or more

2.15 Disassembling and inspecting fuel injection pump accessory drive



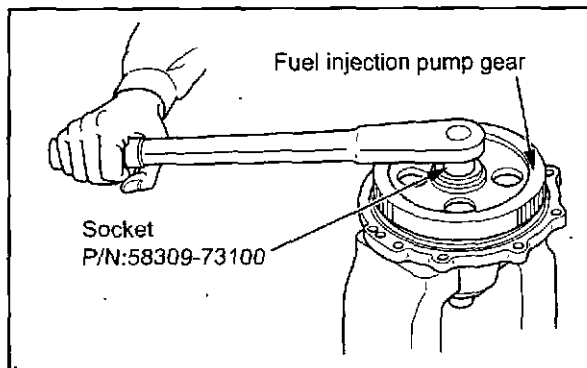
Disassembling and inspecting fuel injection pump accessory drive

Disassembling sequence

- | | | |
|-----------------------|---------------|------------|
| 1 Nut | 4 Snap ring | 7 Bearing |
| 2 Washer | 5 Drive shaft | 8 Bearing |
| 3 Injection pump gear | 6 Drive case | 9 Oil seal |

2.15.1 Removing injection pump gear

Using the socket, remove the nut.



Removing fuel injection pump gear

2.16 Inspecting outer and inner diameters of fuel injection pump accessory drive bearing engagement section

Turn the bearing and if the turning is not smooth, exchange the bearing.

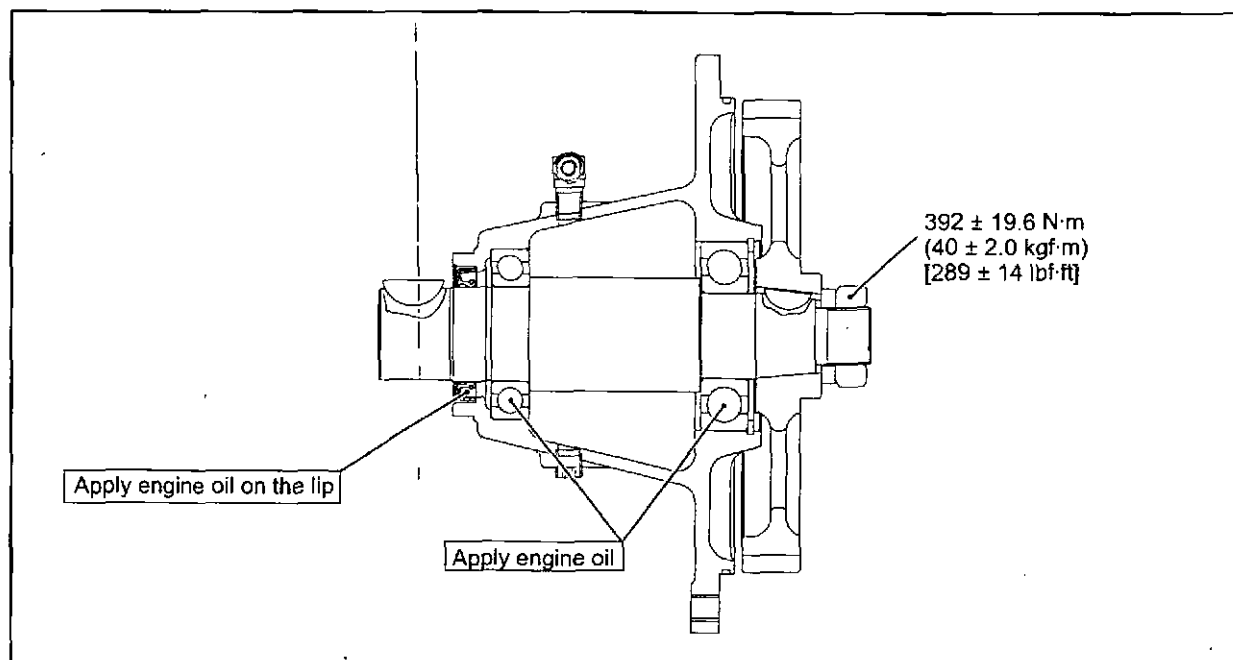
Inspect the engagement section of the drive shaft and the bearing and if heavy wear is found, exchange it.

Inspect the engagement section of the drive case and the bearing and if heavy wear is found, exchange it.

Inspect the drive shaft and oil seal, and if any defect is found, exchange them.

Item			Nominal	Standard
Bearing bore inside diameter			ø 90 mm [3.54 in.]	89.987 to 90.022 mm [3.5428 to 3.5442 in.]
			ø 100 mm [3.94 in.]	98.987 to 100.022 mm [3.9365 to 3.9379 in.]
Bearing	Outside diameter	S	ø 90 mm [3.54 in.]	89.985 to 90.000 mm [3.5427 to 3.5433 in.]
		L	ø 100 mm [3.94 in.]	99.985 to 100.000 mm [3.9364 to 3.9370 in.]
	Inside diameter	S	ø 50 mm [1.97 in.]	49.988 to 50.000 mm [1.9680 to 1.9685 in.]
		L	ø 45 mm [1.77 in.]	4.4988 to 45.000 mm [1.7712 to 1.7717 in.]
Drive shaft bearing journal diameter			ø 45 mm [1.77 in.]	45.002 to 45.013 mm [1.7717 to 1.7722 in.]
			ø 50 mm [1.97 in.]	50.002 to 50.013 mm [1.9686 to 1.9690 in.]

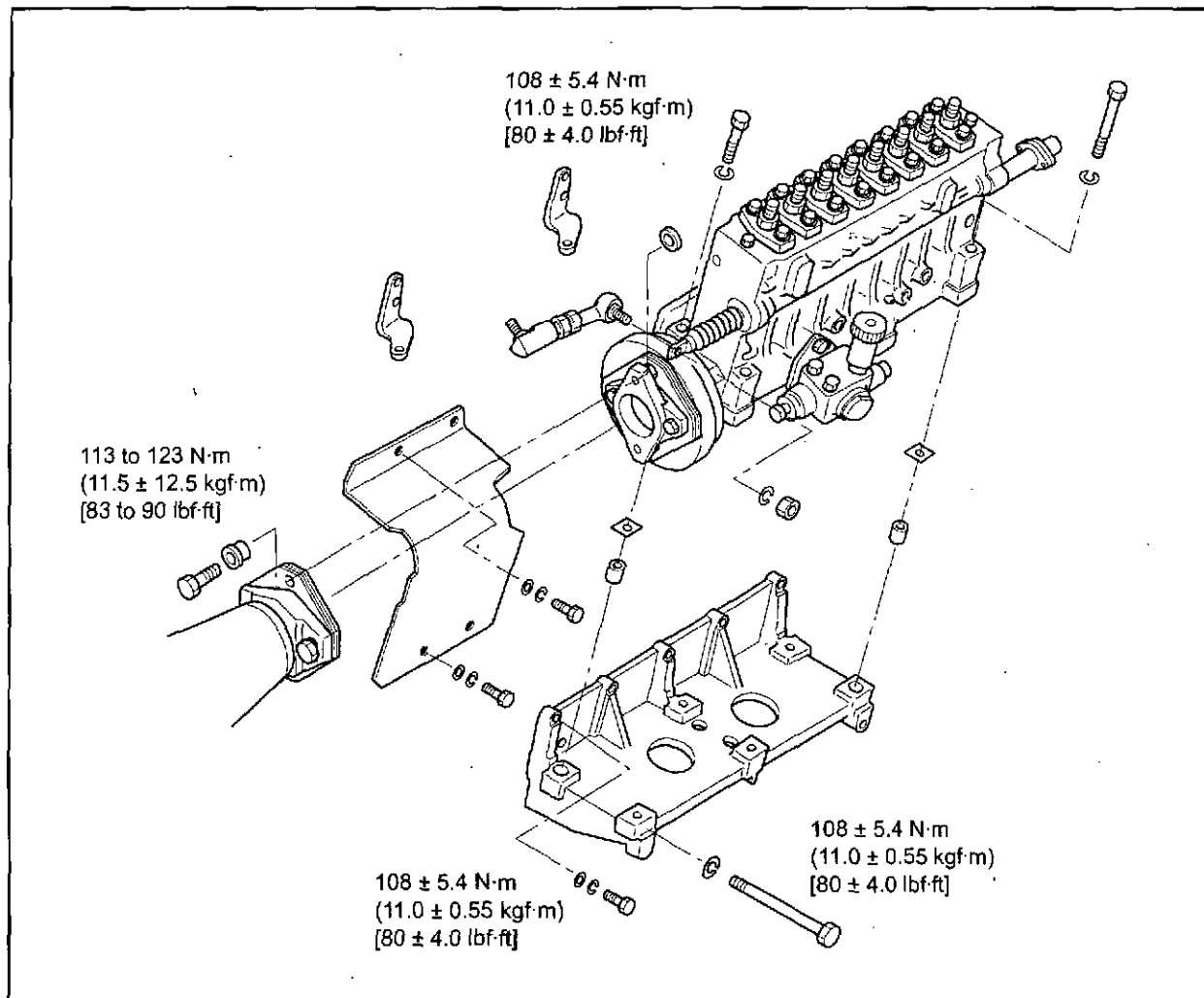
2.17 Reassembling fuel injection pump accessory drive



Reassembling fuel injection pump accessory drive

3. Installing fuel system

3.1 Installing fuel injection pump

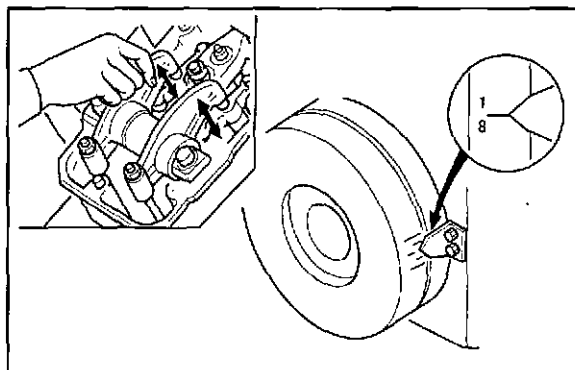


Installing fuel injection pump

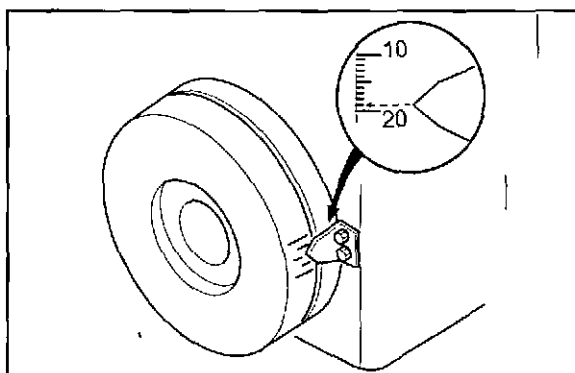
3.1.1 Checking fuel injection timing

- (1) Turn the engine until the line mark for the No. 1 cylinder on the damper is aligned with the pointer.
- (2) Move the lockers of the inlet and exhaust valve on the No. 1 cylinder and verify that the push rod does not push up the inlet and the exhaust valves.
- (3) Reversely turn the engine by about 60° and stop turning.
- (4) Slowly turn the engine to the normal direction and align the pointer on the engine with the standard fuel injection timing on the damper circumference.

Note: The fuel injection timing is indicated on the plate on the locker cover of No. 1 cylinder. Check it in advance.



No.1 cylinder compression top dead center inspection



Fuel injection timing

3.1.2 Reassembling coupling on driving side

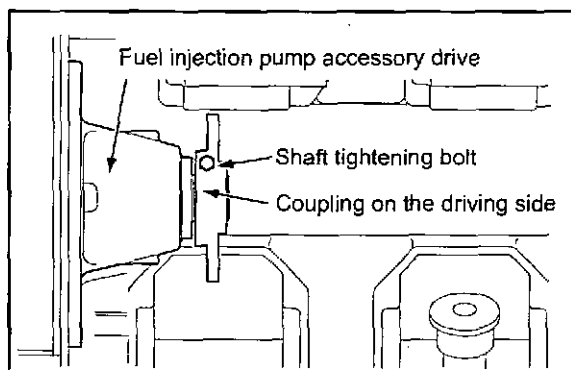
CAUTION

- (a) Clean the joint surfaces of the coupling and laminated plate, and washers and bolt around the joint area with a clean cloth to prevent dust entering between the joint surfaces.
- (b) If dust gets into the joint surface, the coupling may slip causing a time lag in the injection timing, or the coupling could be damaged.

Assemble the coupling on the driving side in the fuel injection pump to the drive shaft of the fuel injection pump accessory drive.

Keep the shaft tightening bolt loose at this time.

Note: Keep the shaft tightening bolt loose even when the coupling on the pump driving side is not disassembled from the fuel injection pump accessory drive.



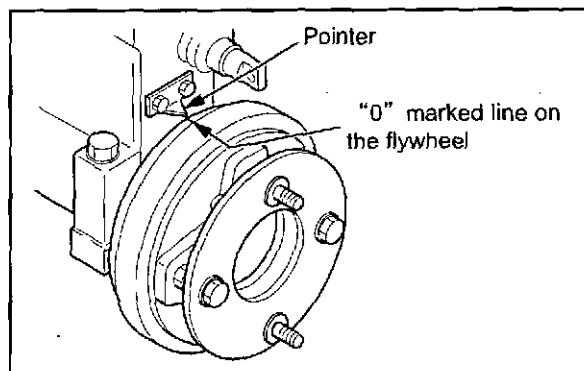
Reassembling coupling on driving side

3.1.3 Checking before assembling fuel injection pump

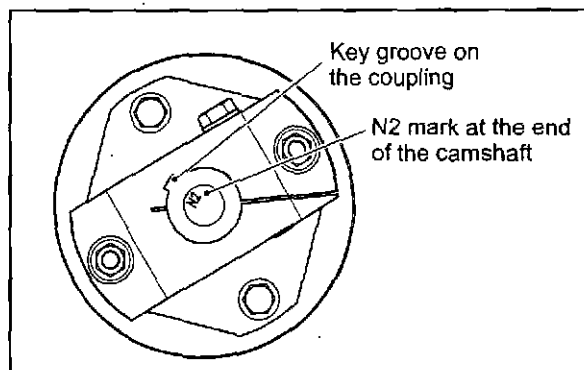
CAUTION

- (a) Check that the marks on the coupling on the driving side and on the camshaft edge of the pump are positioned as shown in the illustration on the right, and if not, correct it.
- (b) If the coupling on the driving side is assembled at the position 180° from the correct position, the injection timing would lag. Verify the correct position of marks.

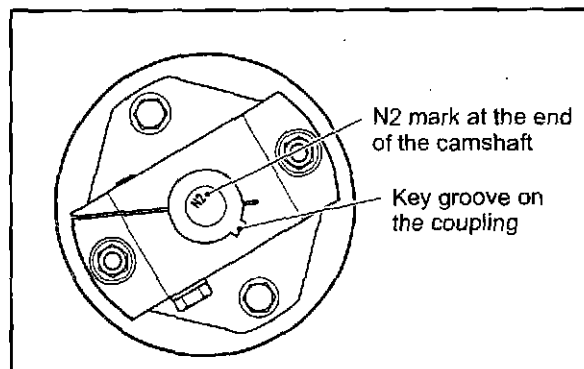
Before installing the fuel injection pump to the engine, align the pointer on the pump case with the "0" mark line on the flywheel.



Position matching with the pointer and marked line



Reassembling position of camshaft and coupling
(view from rear and of drive side) (RH)



Reassembling position of camshaft and coupling
(view from rear and of drive side) (LH)

3.1.4 Reassembling fuel injection pump

- (1) Suspend and lower the fuel injection pump to the bracket and temporarily tighten the mounting bolt.

CAUTION

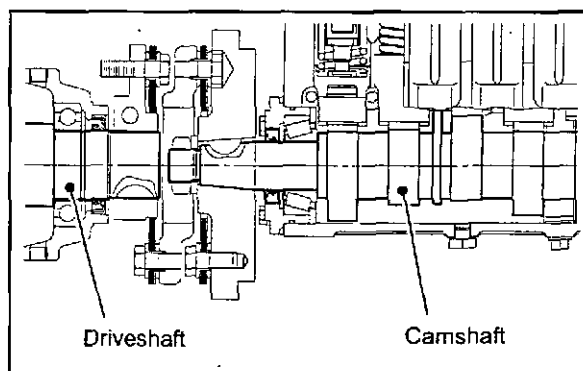
If the center runout exceeds $\phi 0.5$ mm [0.020 in.] TIR, the coupling and the laminated plate may break, and their scattering pieces could cause injuries.

- (2) Adjust the center runout of the camshaft and drive shaft to $\phi 0.5$ mm or less [0.0197 in.] TIR (Total Indicator Reading).
- (3) After adjusting the center runout, tighten the mounting bolt to the specified torque.
- (4) Connect the fuel system pipe and the fuel injection feed pipe.
- (5) Pour the specified oil to the full level from the oil pipe mounting port of the fuel injection pump, and connect the oil pipe.

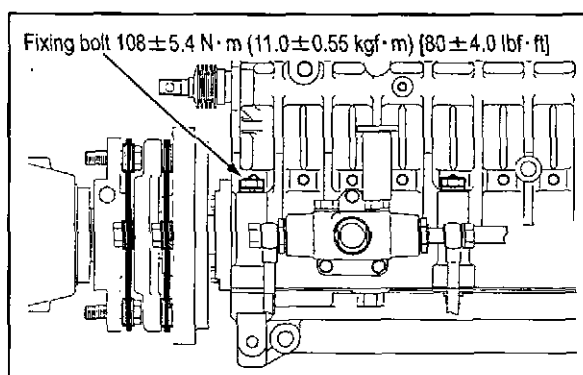
CAUTION

The flange nuts (2 places) on the connecting bolt should be loosened once after tightening to the specified torque, and retightened to the specified torque. If the laminated plate is warped after tightening nuts, loosen and retighten.

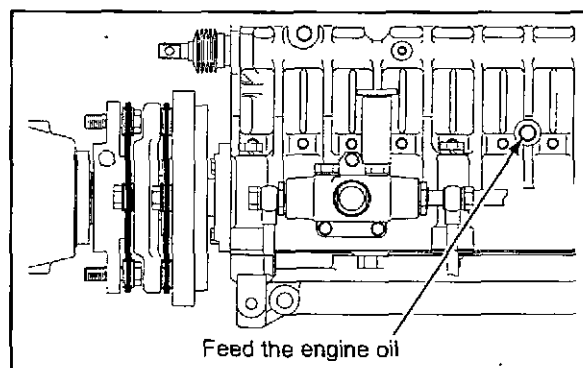
- (6) Install coupling washers and flange nuts to the connecting bolts (2 places) and tighten the flange nuts to the specified torque.



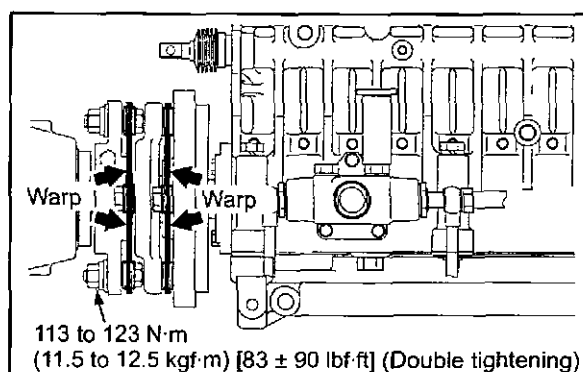
Shaft center run-out adjustment



Reassembling fuel injection pump



Engine oil feeding (intake hole on oil pipe)



Tightening the connecting bolt

3.1.5 Adjusting clearance between flywheel and coupling

CAUTION

Evenly tighten the bolts on the coupling with the specified torque.

Dust and oil caught between the tightening surfaces would cause unstable shaft power. Make sure they are clean.

Too much or too little tightening torque would cause various malfunctions or lead to a lag on the injection timing.

Set the clearance between the flywheel and the coupling using the injection coupling gauge.

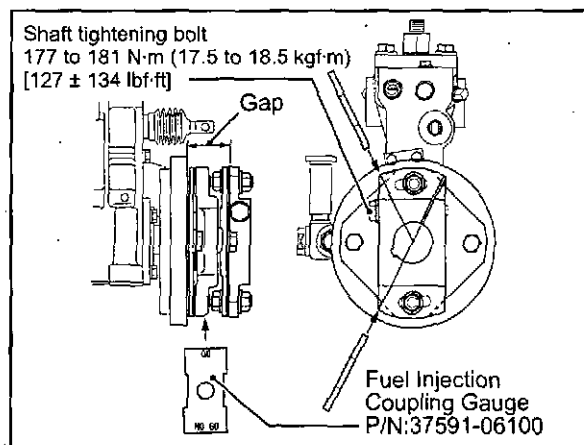
- (1) Insert the GO side of the gauge into the clearance between the flywheel and the coupling.
- (2) Tighten the shaft tightening bolt with the specified torque.
- (3) Verify that the NO GO side of the gauge cannot be inserted in the clearance while the GO side can be inserted.

In this state, the clearance between the flywheel and the coupling is the set value 49 ± 0.25 mm [1.93 ± 0.0098 in.].

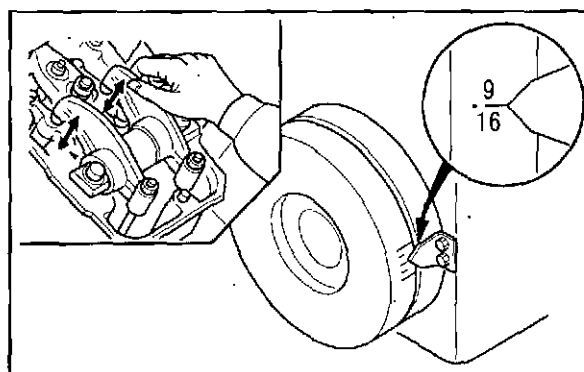
- (4) If the above state cannot be achieved with the gauge inserted, loosen the shaft tightening bolt, and set the clearance all over again.

3.1.6 Installing fuel injection pump (left side)

- (1) For the left side fuel injection pump, match the markings No. 9 and No. 16 on the damper with the pointers. Confirm that the No. 9 cylinder is at the compression top dead center by the inlet and exhaust valves on the No. 9 cylinder.
- (2) Match the injection timing in the same manner for the right side pump, assemble the fuel injection pump and assemble the pipes and control link.

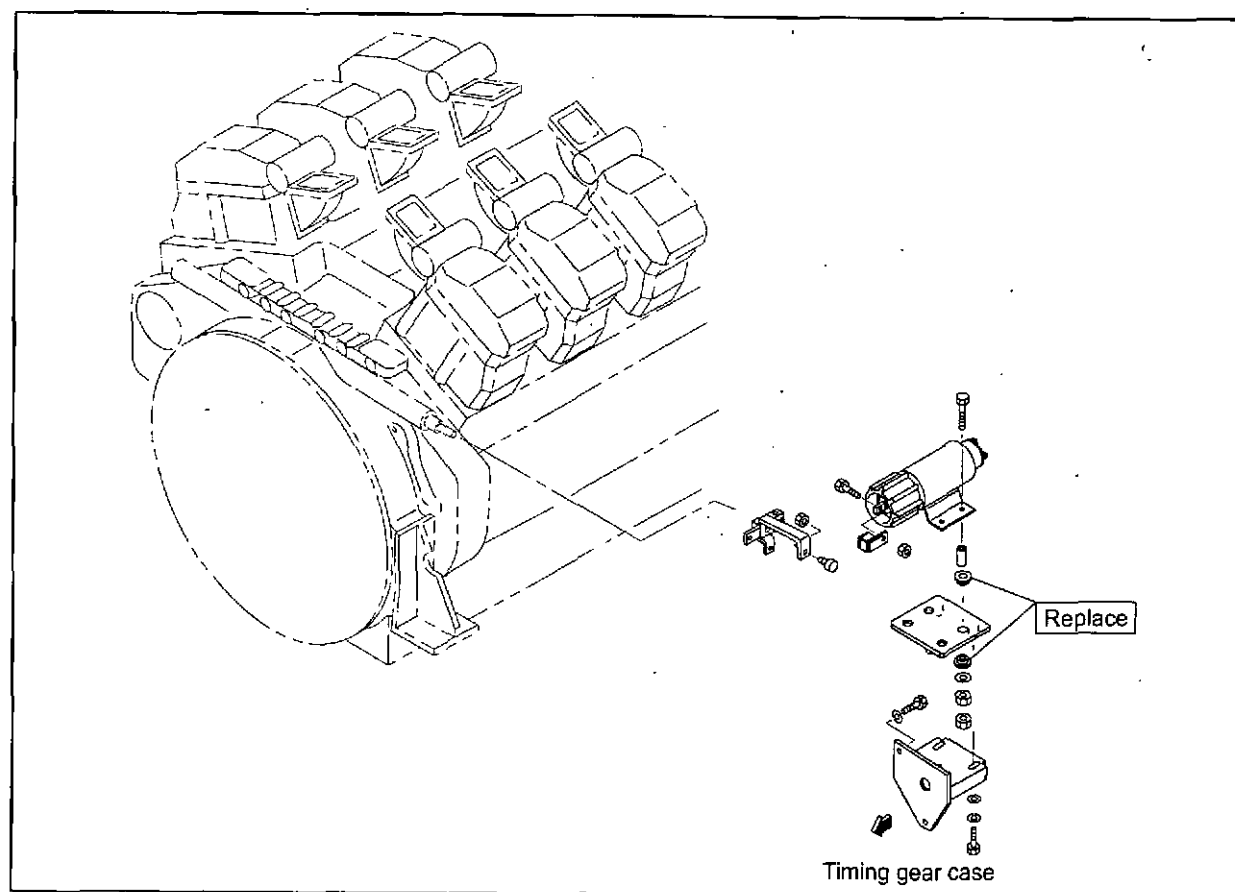


Adjusting clearance of flywheel and coupling



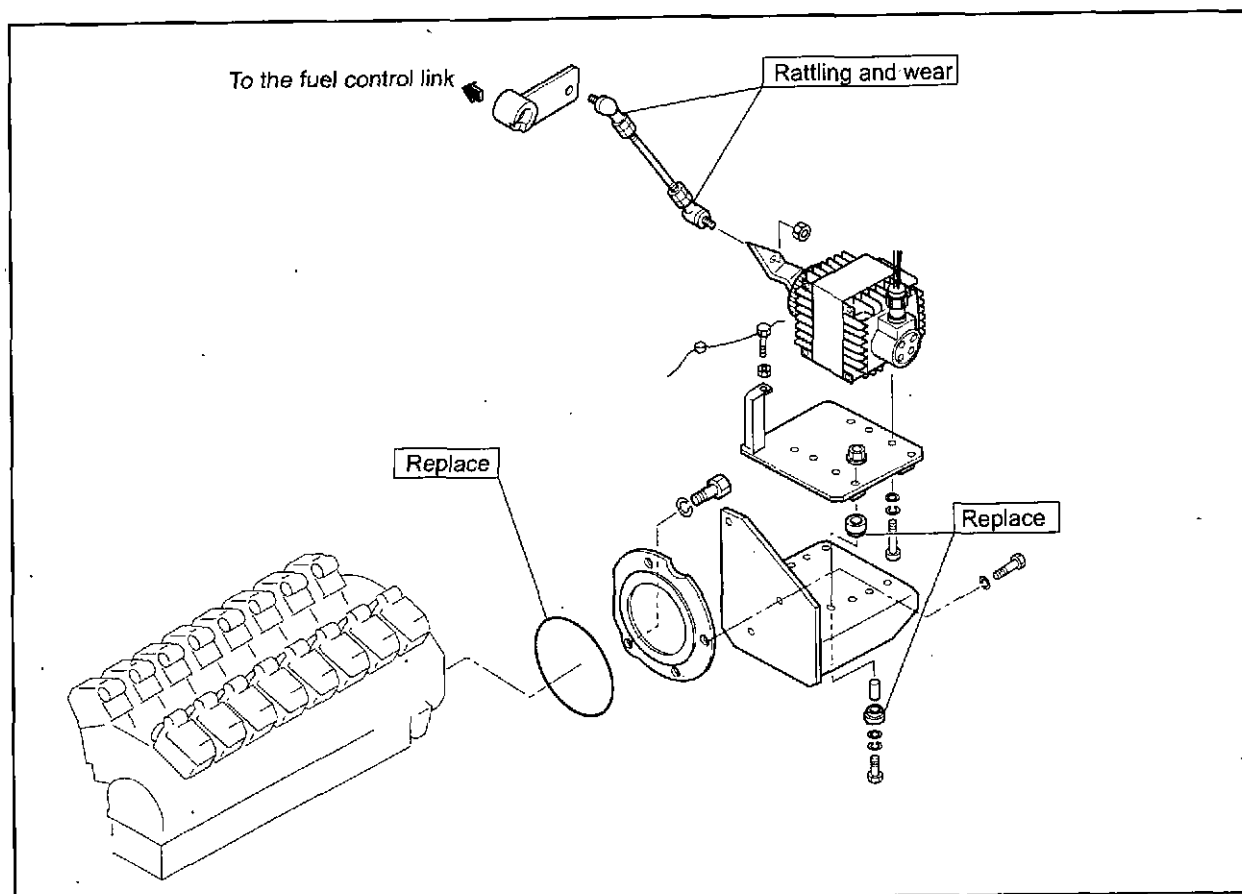
Assembling fuel injection pump (left)

3.2 Installing stop solenoid



Installing stop solenoid

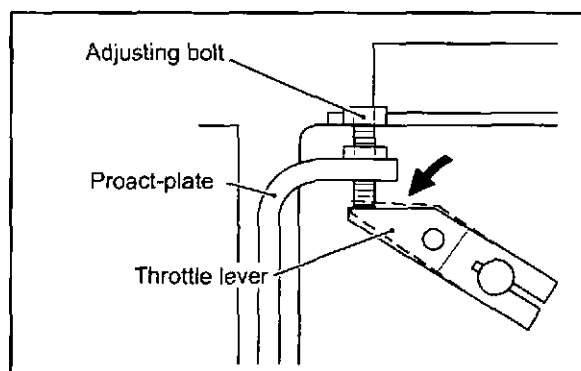
3.3 Installing actuator



Installing actuator

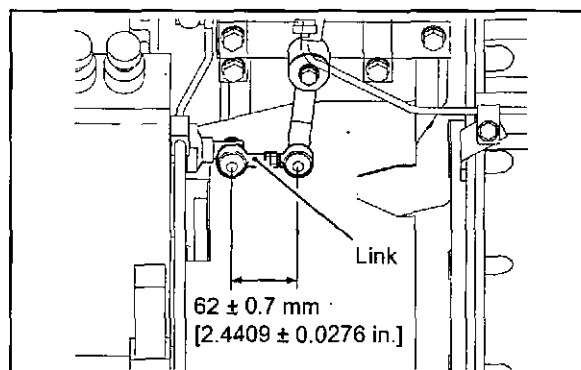
3.3.1 Installing and adjusting actuator link

- (1) Install the adjustment bolt to the proact-plate. Tighten further so that the throttle lever is horizontal when the tip of the adjustment bolt contacts the throttle lever.



Installing and adjusting actuator link (1)

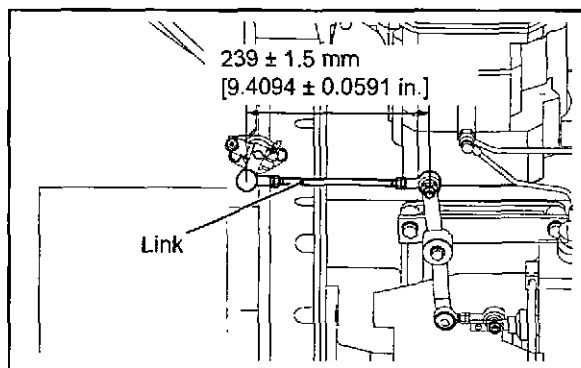
- (2) Install the right and left bank links so that the assembly length is $62 \pm 0.7 \text{ mm}$ [$2.4409 \pm 0.0276 \text{ in.}$].



Installing and adjusting actuator link (2)

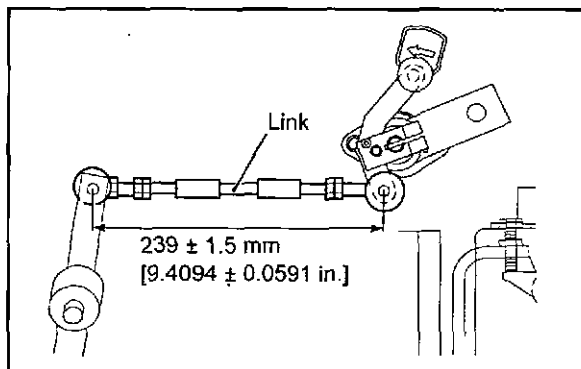
- (3) Install the right bank link.

Note: The link is fixed length link, the same at $239 \pm 1.5 \text{ mm}$ [$9.4094 \pm 0.0591 \text{ in.}$].

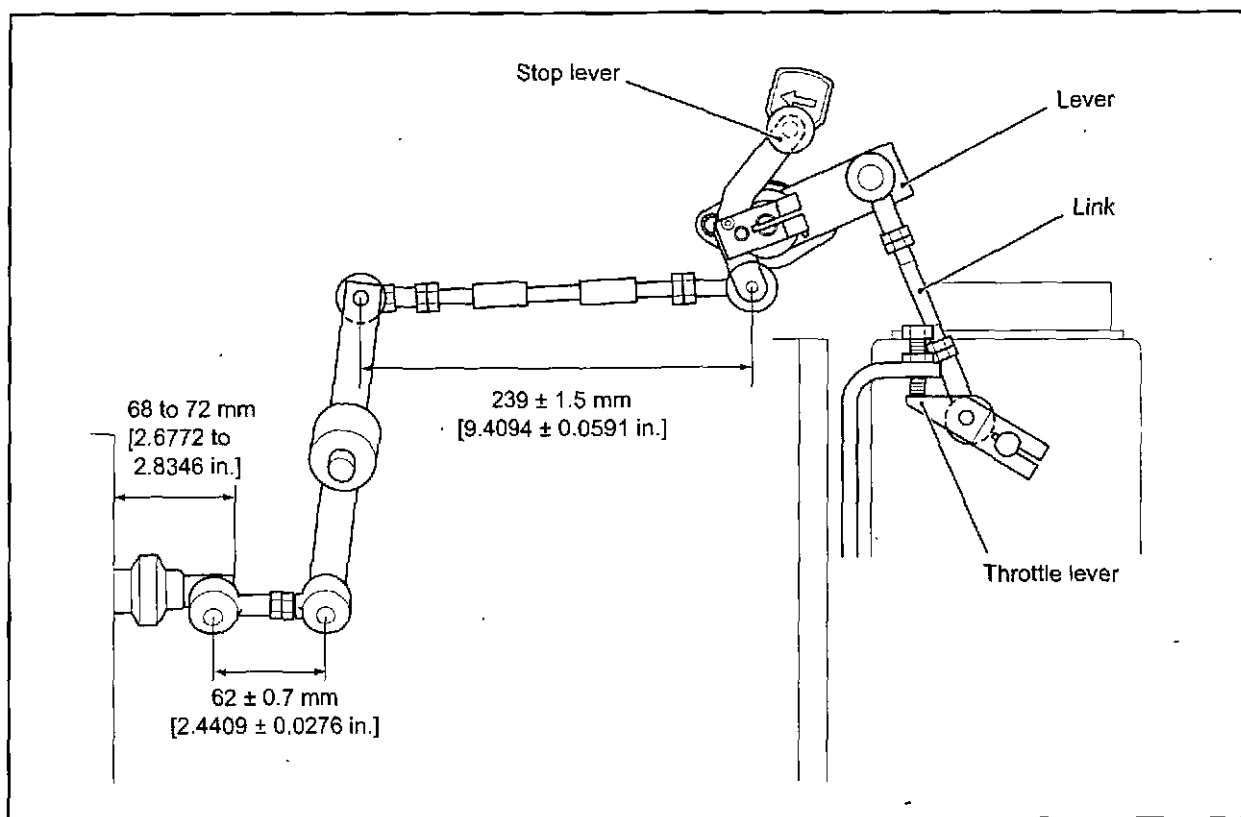


Installing and adjusting actuator link (3)

- (4) Adjust the left bank link is $239 \pm 1.5 \text{ mm}$ [$9.4094 \pm 0.0591 \text{ in.}$] as in the right side and install it.



Installing and adjusting actuator link (4)



Installing and adjusting actuator link (5)

- (5) Connect the link to the throttle lever and the lever.

Adjust the link so that the distance between the tip of the injection pump rack and the edge of the pump case is $68 \text{ to } 72 \text{ mm}$ [$2.6772 \text{ to } 2.8346 \text{ in.}$].

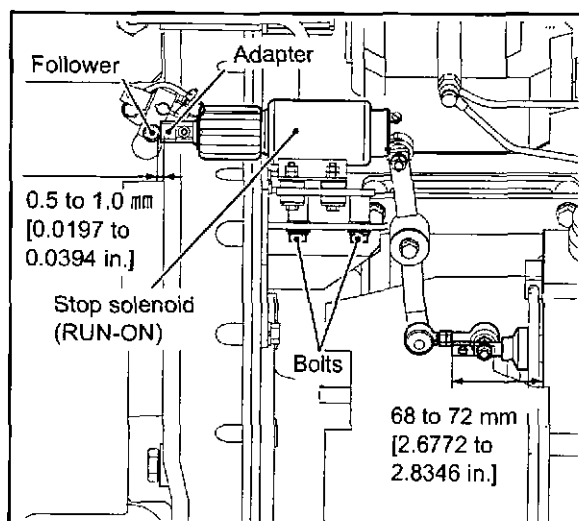
Note: The screw engagement margin of the rod and the ball joint must be 8 mm [0.3152 in.] on both ends.

- (6) Confirm that the rack stroke is around 2 mm [0.08 in.] when the stop lever is maximally pulled to the stop side.

3.4 Adjusting and confirming working of stop solenoid (RUN-ON)

3.4.1 Adjusting stop solenoid (RUN-ON)

- (1) Turn off the stop solenoid (stretched).
- (2) Loosen bolt of bracket.
- (3) Make adjustment so that the gap between the follower and the adapter is 0.5 to 1.0 mm [0.0197 to 0.0394 in.].
- (4) Tighten bolt.



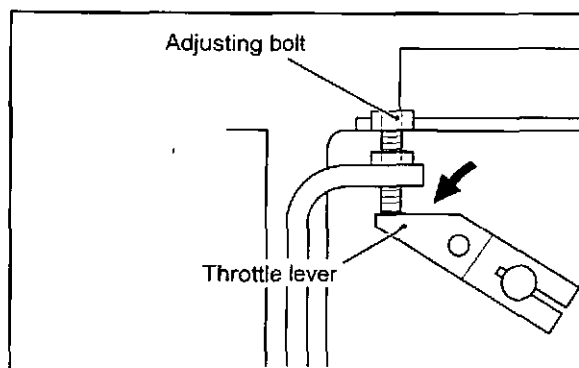
Adjusting and confirming working of stop solenoid (RUN-ON)

3.4.2 Adjusting solenoid (RUN-ON) working inspection

- (1) Turn on the stop solenoid (sucking).
- (2) Run the engine in high idling.
- (3) Turn off the stop solenoid (stretched).
- (4) Confirm that the engine stops completely.
- (5) After the engine stops completely, check to make sure the distance between the rack end surface and pump case end surface is 68 to 72 mm [2.6772 to 2.8346 in.] on both banks.

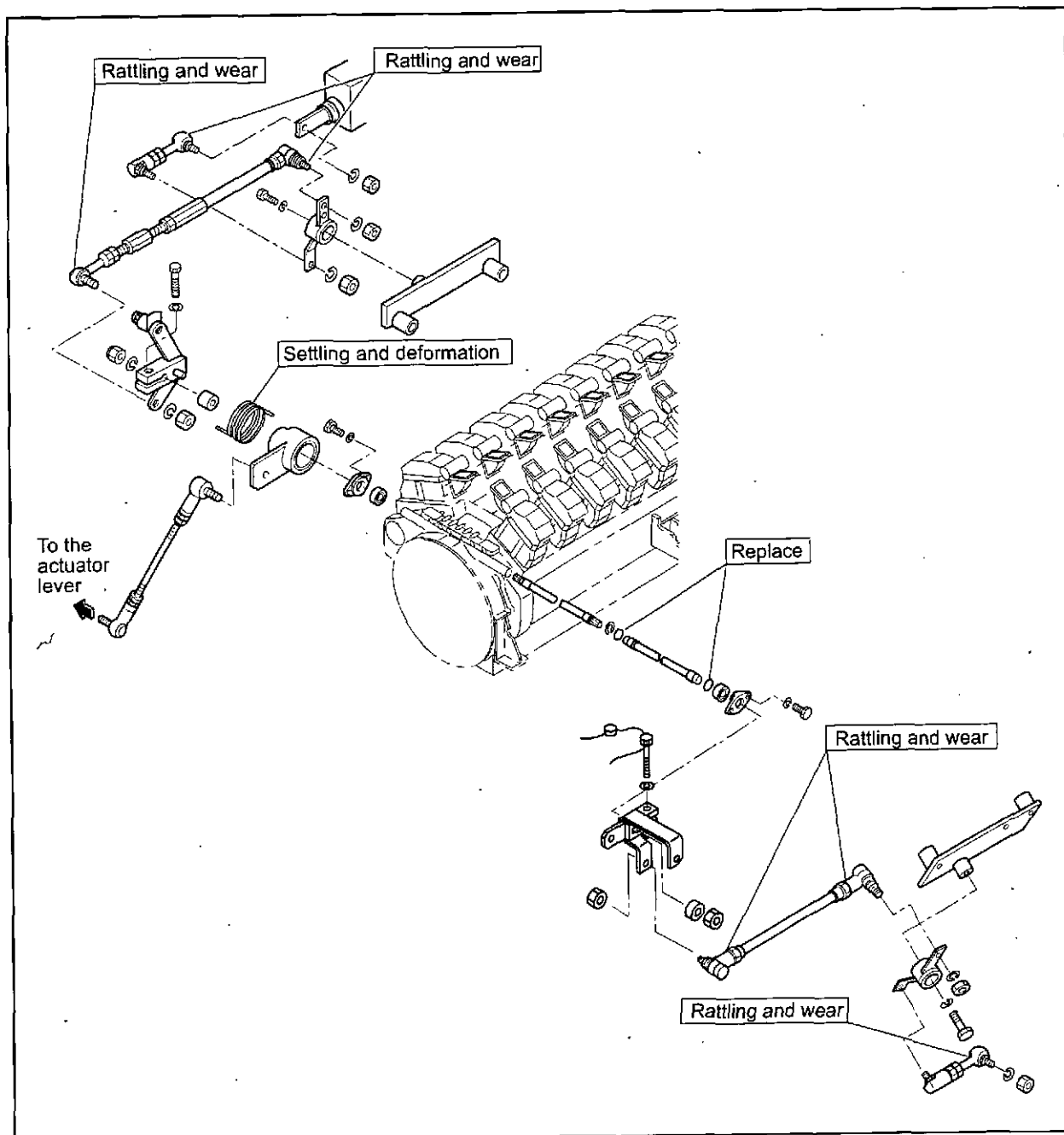
3.5 Re-adjusting adjusting bolt

After adjustment of the stop solenoid, a gap is generated between the adjusting bolt and the throttle lever. Tighten the adjusting bolt until it contacts the throttle lever.



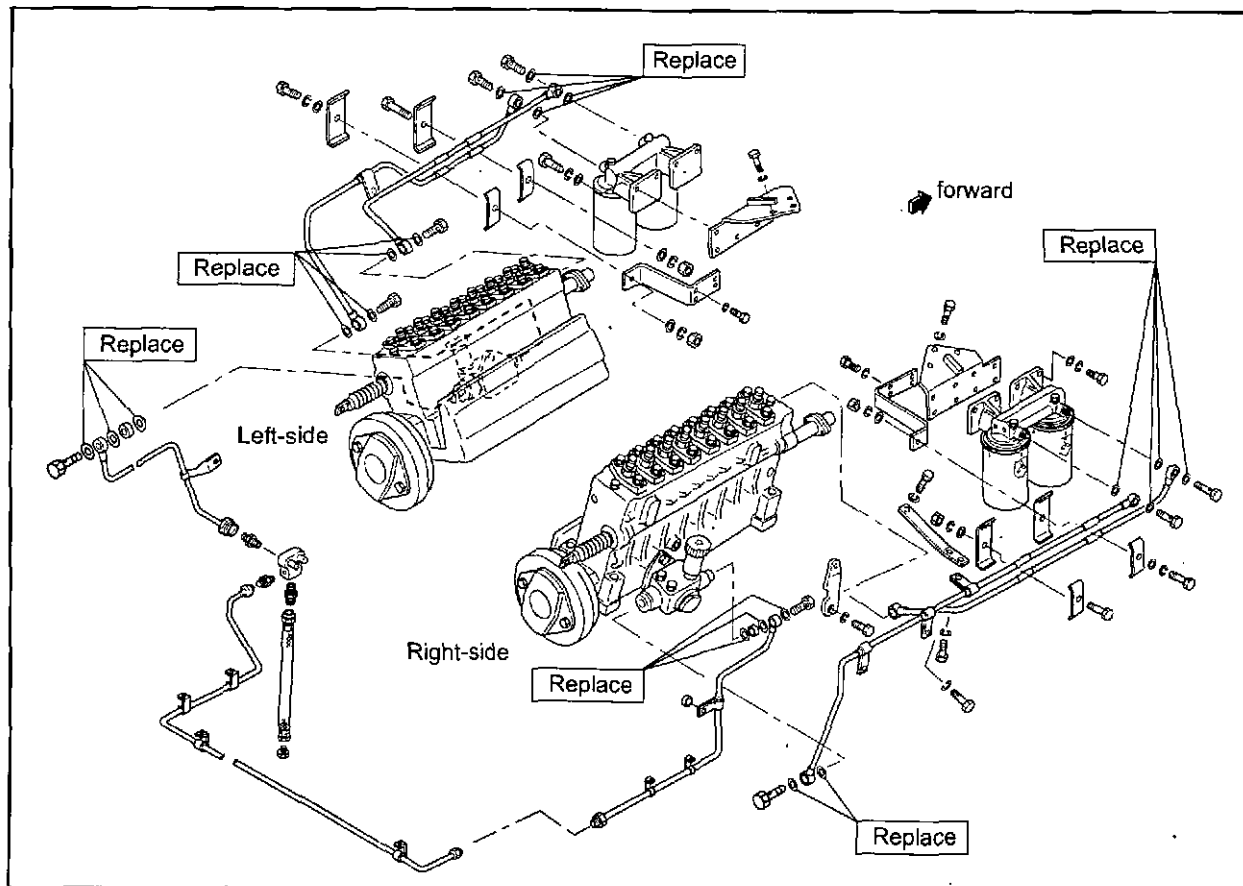
Re-adjusting adjusting bolt

3.6 Installing fuel control link



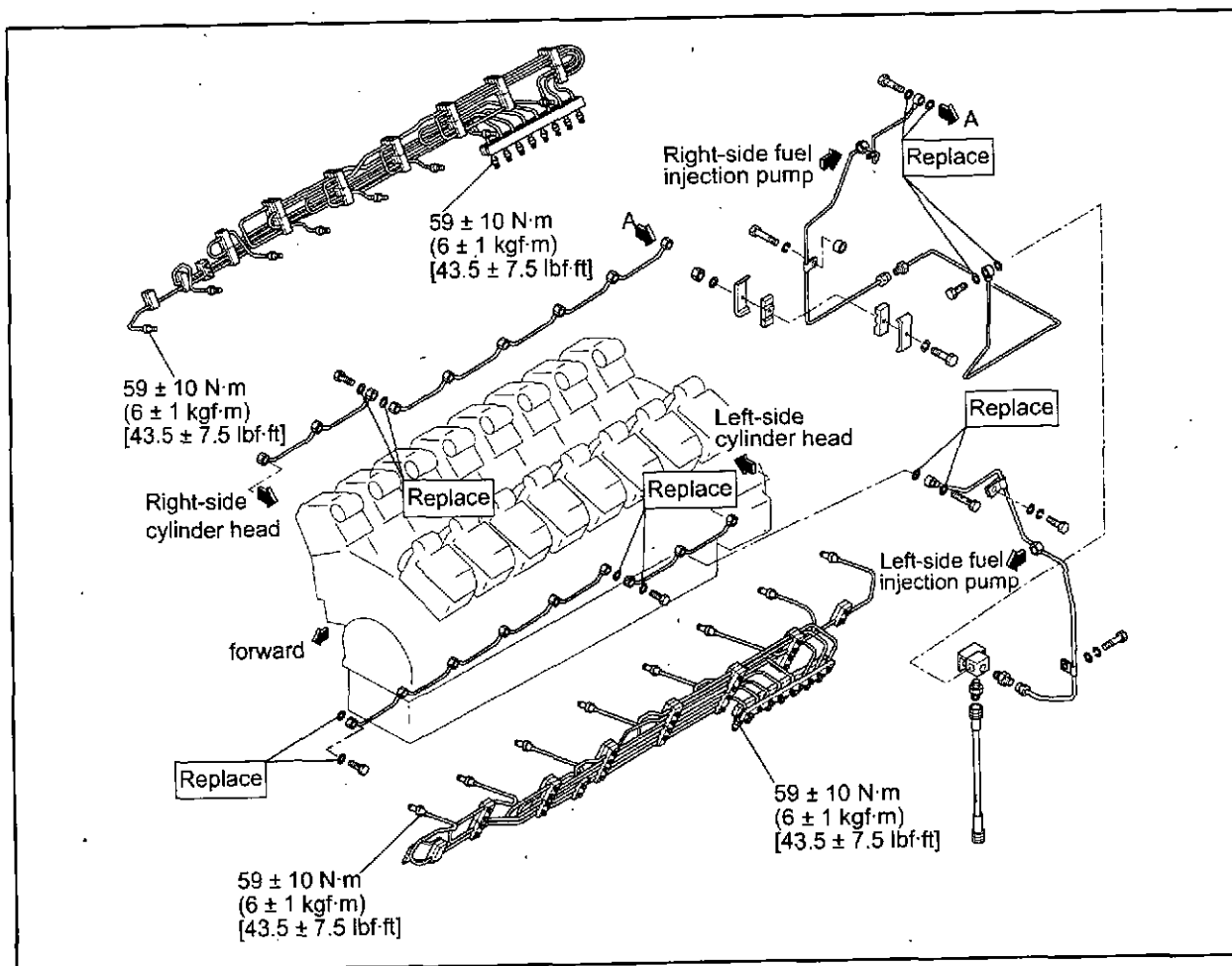
Installing fuel control link

3.7 Installing fuel filter and fuel pipe



Installing fuel filter and fuel pipe

3.8 Installing fuel injection pipe and fuel leak pipe



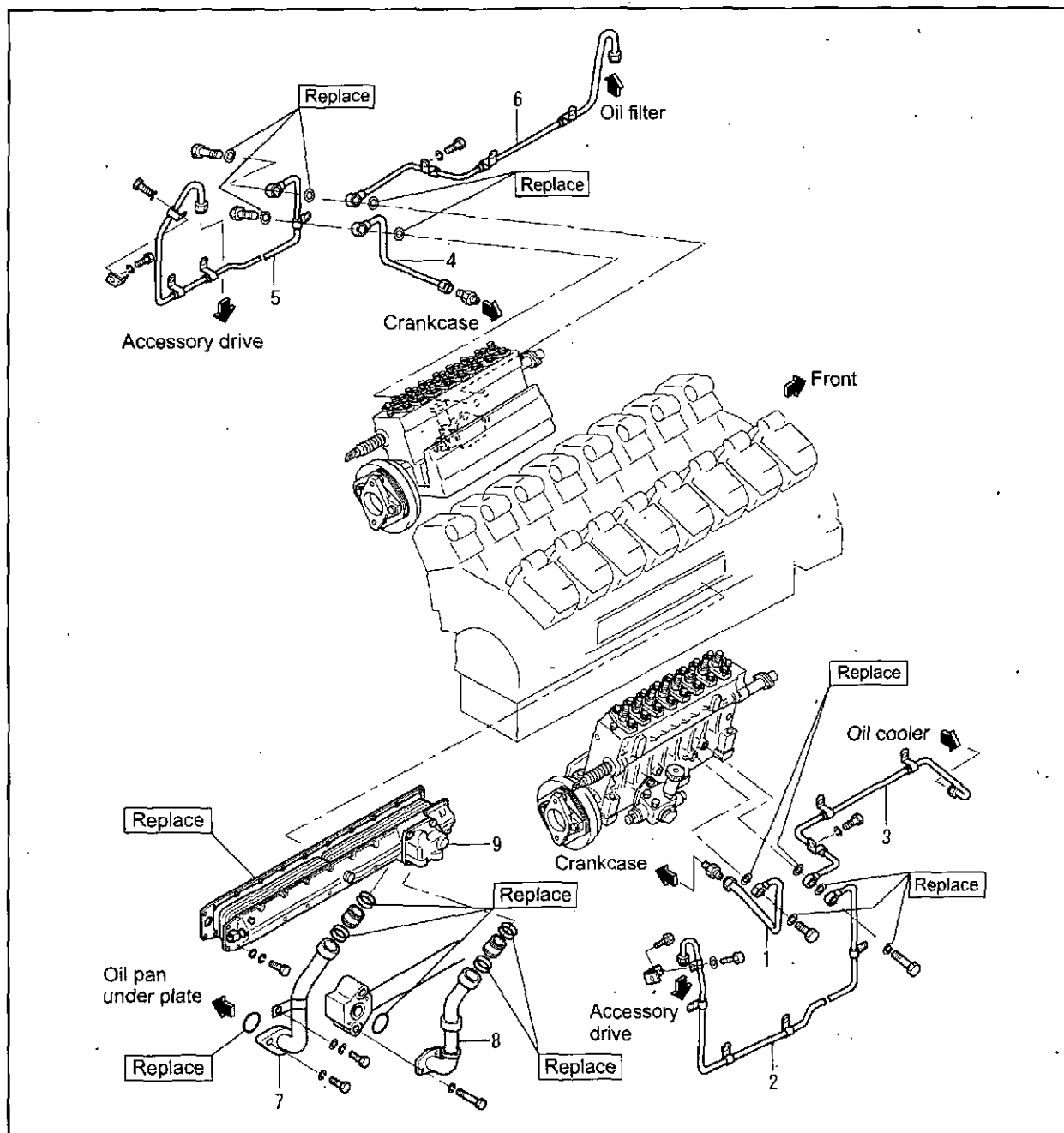
Installing fuel injection pipe and fuel leak pipe

LUBRICATION SYSTEM

1. Removing lubrication system 9-2
 - 1.1 Removing and inspecting oil cooler and oil pipe for fuel injection pump 9-2
 - 1.2 Removing and inspecting by-pass filter ... 9-3
 - 1.3 Removing and inspecting oil pump, oil filter and oil pan 9-4
2. Disassembling, inspecting and reassembling lubrication system 9-5
 - 2.1 Disassembling and inspecting oil pump and safety valve 9-5
 - 2.2 Inspecting oil pump and safety valve 9-6
 - 2.2.1 Measuring base tangent length of drive and driven gears 9-6
 - 2.2.2 Measuring side clearance between gears and case 9-6
 - 2.2.3 Measuring end clearance between gears and case 9-6
 - 2.2.4 Measuring drive and driven gear shaft outside diameters and bushing inside diameter 9-6
 - 2.2.5 Inspecting oil pump safety valve spring 9-7
 - 2.3 Reassembling oil pump and safety valve. 9-7
 - 2.4 Disassembling and inspecting oil filter, oil filter alarm, relief valve, left-side oil cooler and oil thermostat 9-8
 - 2.5 Inspecting oil filter, oil filter alarm, relief valve, left-side oil cooler and oil thermostat 9-9
 - 2.5.1 Inspecting oil filter 9-9
 - 2.5.2 Inspecting oil filter alarm 9-9
 - 2.5.3 Measuring relief valve pressure 9-9
 - 2.5.4 Inspecting oil cooler 9-10
 - 2.5.5 Inspecting oil thermostat 9-10
 - 2.5.6 Reassembling oil filter, oil filter alarm, relief valve, left-hand oil cooler and oil thermostat 9-11
 - 2.6 Disassembling and inspecting right-side oil cooler and oil thermostat 9-12
 - 2.7 Inspecting right-side oil cooler and oil thermostat 9-12
 - 2.8 Reassembling oil cooler and oil thermostat 9-12
3. Installing lubrication system 9-13
 - 3.1 Installing oil pump, oil filter and oil pan .. 9-13
 - 3.2 Installing by-pass filter 9-14
 - 3.3 Installing oil cooler and oil pipe for fuel injection pump 9-15

1. Removing lubrication system

1.1 Removing and inspecting oil cooler and oil pipe for fuel injection pump

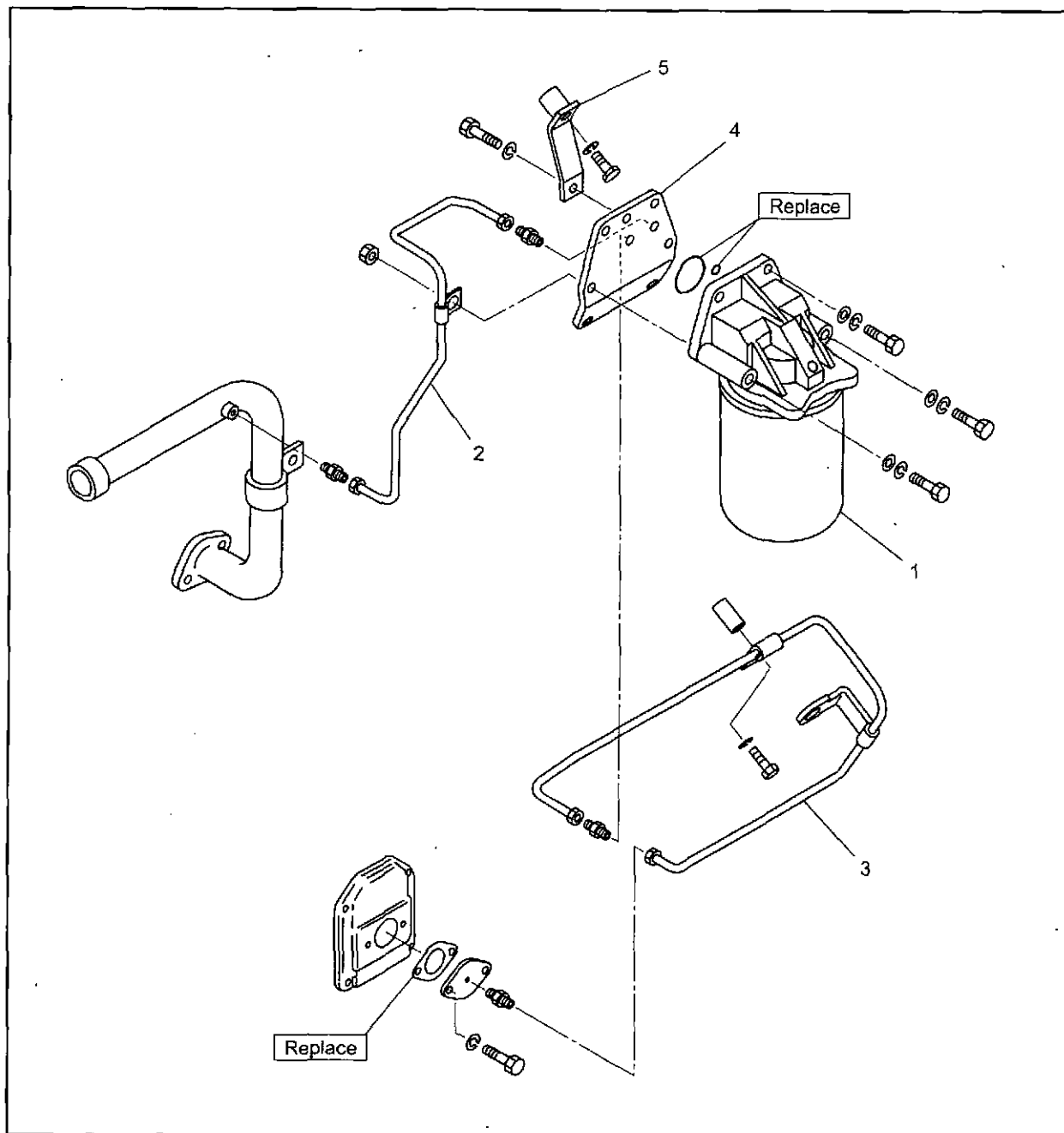


Removing and inspecting oil cooler and oil pipe for fuel injection pump

Removing sequence

- | | | |
|-------------------------|------------------------|--|
| 1 Right-hand drain pipe | 4 Left-hand drain pipe | 7 Oil pipe |
| 2 Right-hand oil pipe | 5 Left-hand oil pipe | 8 Oil pipe |
| 3 Right-hand oil pipe | 6 Left-hand oil pipe | 9 Oil cooler (weight: approx. 21 kg [46.3 lb]) |

1.2 Removing and inspecting by-pass filter

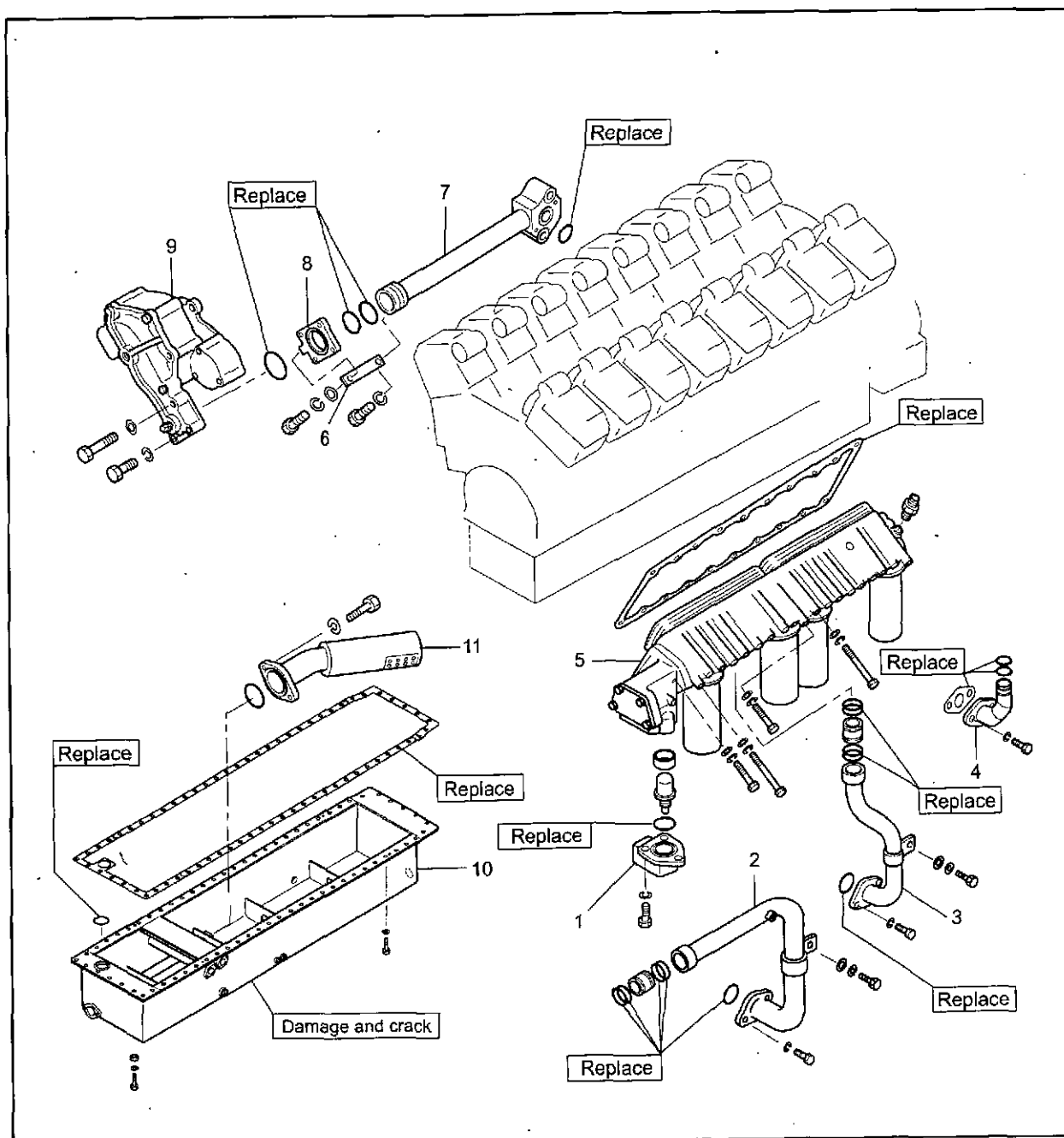


Removing and inspecting by-pass filter

Removing sequence

- | | |
|-------------------|--------------------------|
| 1 By-pass filter | 4 By-pass filter bracket |
| 2 Inlet oil pipe | 5 Bracket stay |
| 3 Outlet oil pipe | |

1.3 Removing and inspecting oil pump, oil filter and oil pan



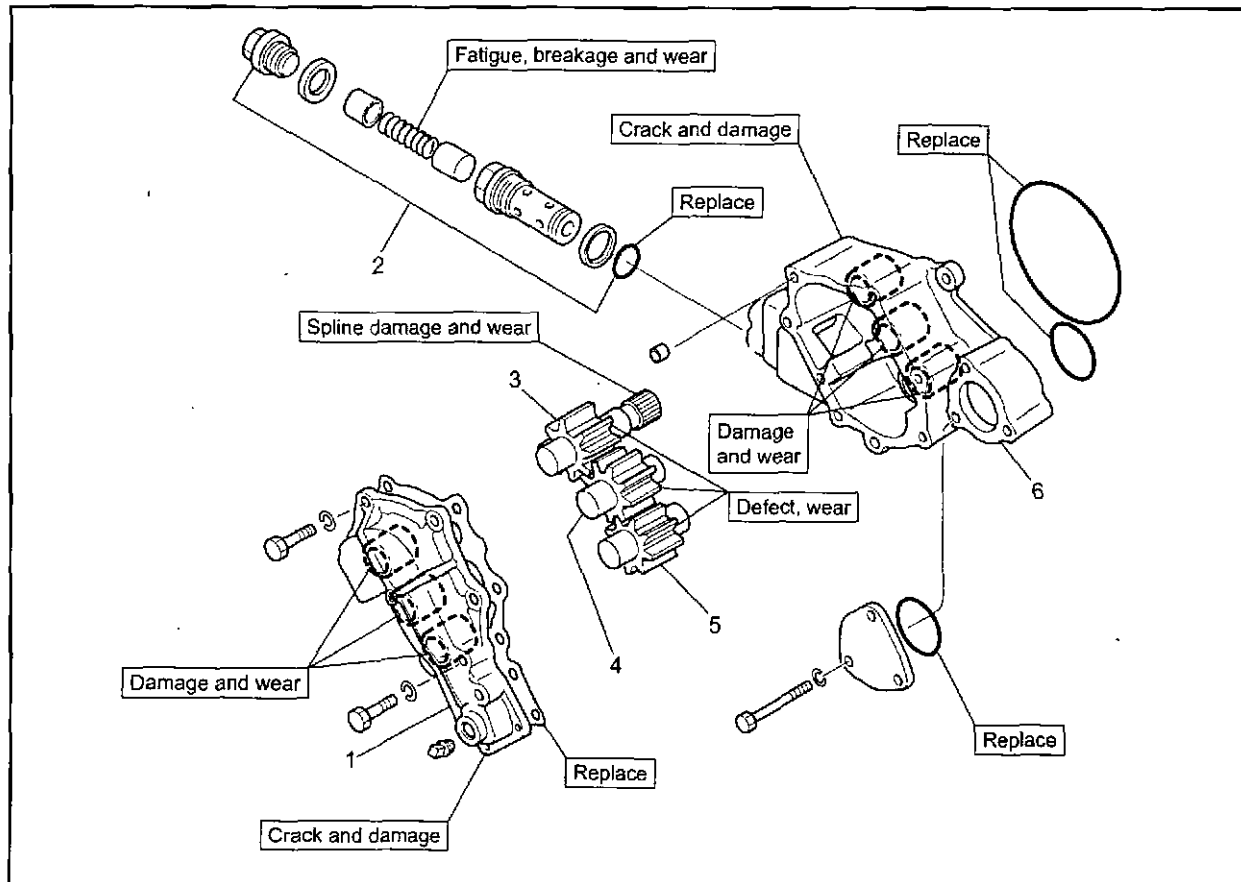
Removing and inspecting oil pump; oil filter and oil pan

Disassembling sequence

- | | |
|--|---|
| 1 Connector | 7 Oil pipe |
| 2 Oil pipe | 8 Connector |
| 3 Oil pipe | 9 Oil pump
(weight: approx. 26kg [57.32 lb]) |
| 4 Oil pipe | 10 Oil pan |
| 5 Oil filter assembly
(weight: approx. 40kg [88.18 lb]) | 11 Oil strainer assembly |
| 6 Stay | |

2. Disassembling, inspecting and reassembling lubrication system

2.1 Disassembling and inspecting oil pump and safety valve



Disassembling and inspecting oil pump and safety valve

Disassembling sequence

- | | | |
|-------------------------|---------------|-----------------|
| 1 Oil pump cover | 3 Drive gear | 5 Driven gear |
| 2 Safety valve assembly | 4 Driven gear | 6 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
Backlash between drive and driven gears	0.100 to 0.200 mm [0.0039 to 0.0079 in.]	0.400 mm [0.0157 in.]

2.2.2 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
Side clearance between gear teeth and case bore	0.100 to 0.148 mm [0.0039 to 0.0058 in.]	Tip clearance 0.350 mm [0.0138 in.]

2.2.3 Measuring end clearance between gears and case

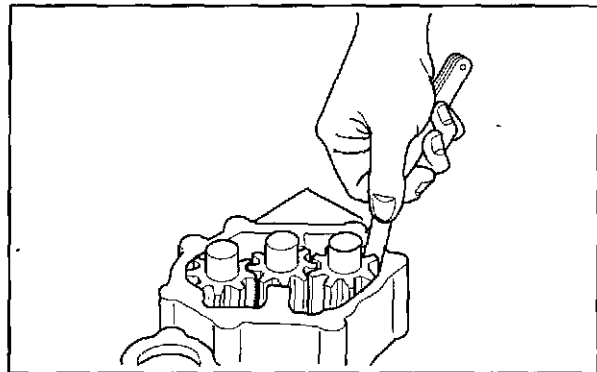
Measure the end clearance between gear width and case depth. If the limit is exceeded, replace gears/case with a new one.

Item	Standard	Limit
End clearance between gear width and case depth	0.040 to 0.116 mm [0.0016 to 0.0046 in.]	0.210 mm [0.0083 in.]

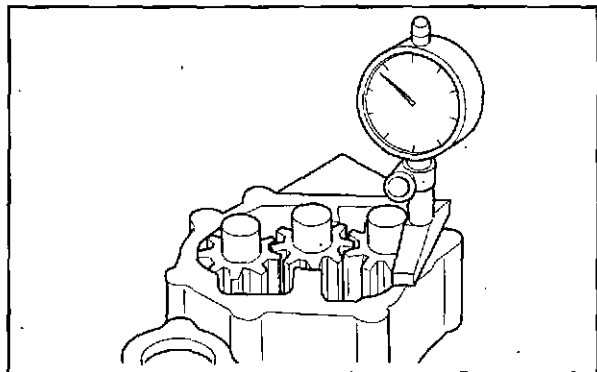
2.2.4 Measuring drive and driven gear shaft outside diameters and bushing inside diameter

- (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
Drive shaft diameter		29.887 to 29.900 mm [1.1767 to 1.1772 in.]	29.840 mm [1.1748 in.]
Driven shaft diameter	ø 30 mm [1.18 in.]	29.947 to 29.960 mm [1.1790 to 1.1795 in.]	29.900 mm [1.1772 in.]
Bushing inside diameter		30.000 to 30.021 mm [1.1811 to 1.1819 in.]	30.055 mm [1.1833 in.]



Measuring side clearance between gears and case

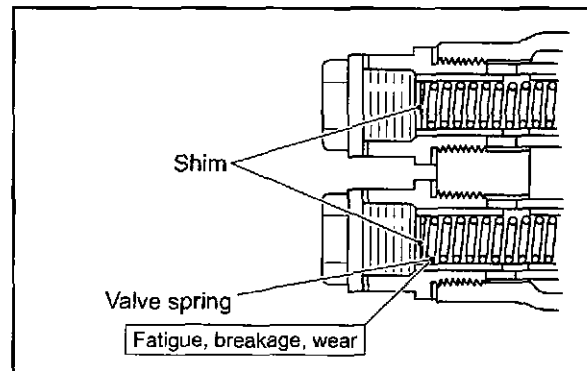


Measuring end clearance between gears and case

2.2.5 Inspecting oil pump safety valve spring

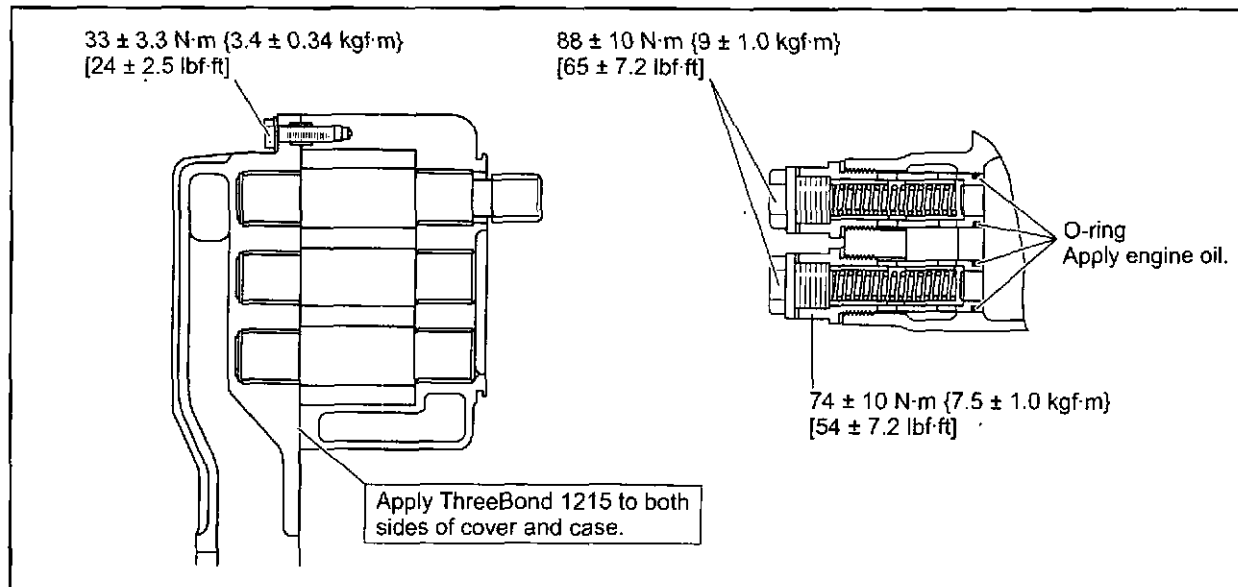
Inspect oil pump safety valve spring for settling and damage. If significant settling, wear, or damage is found, replace the safety valve spring.

Item	Standard	Limit
Safety valve spring installation length/load	65.8 mm/359 N {36.6 kgf} [2.591 in./80.7 lbf]	65.8 mm/314 N {32.0 kgf} [2.591 in./70.5 lbf]



Inspecting oil pump safety valve spring

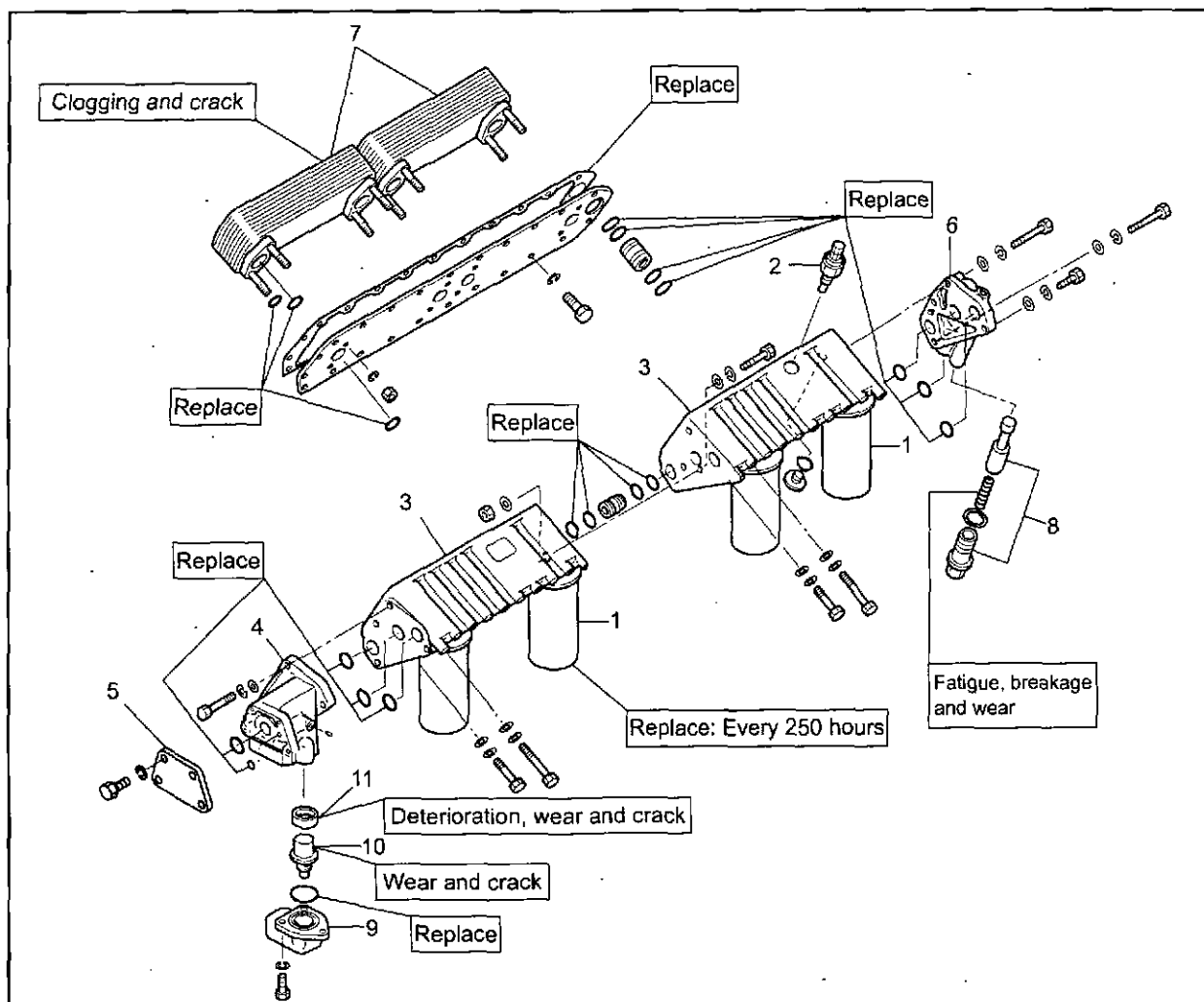
2.3 Reassembling oil pump and safety valve



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 oil filter, oil filter alarm, relief valve, left-side oil cooler and oil thermostat



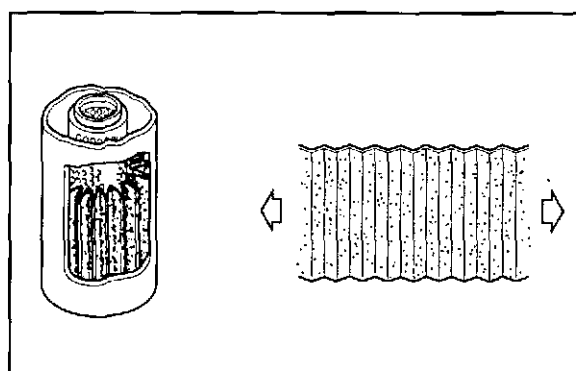
Disassembling and inspecting oil filter, oil filter alarm, relief valve, left-side oil cooler and oil thermostat
Disassembling sequence

- | | | |
|--------------------------------|-------------------------|--------------------|
| 1 Full flow oil filter element | 5 Filter cover | 9 Connector |
| 2 Oil filter alarm | 6 Adapter (B) assembly | 10 Oil thermostat |
| 3 Filter bracket assembly | 7 Oil cooler element | 11 Thermostat seal |
| 4 Adapter (A) assembly | 8 Relief valve assembly | |

2.5 Inspecting oil filter, oil filter alarm, relief valve, left-side oil cooler and oil thermostat

2.5.1 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.

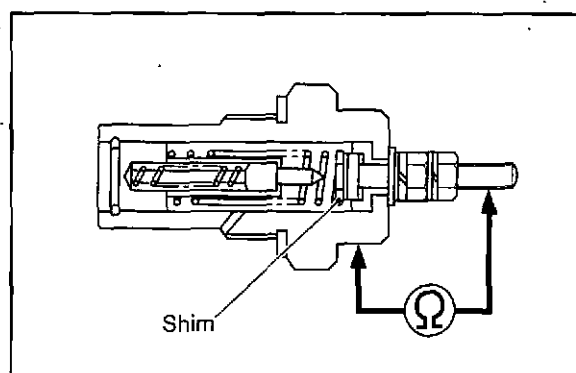


Inspecting oil filter

2.5.2 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	$0.15 \begin{smallmatrix} +0.03 \\ 0 \end{smallmatrix} \text{ MPa}$
	$\{1.5 \begin{smallmatrix} +0.3 \\ 0 \end{smallmatrix} \text{ kgf/cm}^2\}$
	$[21.34 \begin{smallmatrix} +4.27 \\ 0 \end{smallmatrix} \text{ psi}]$



Inspecting oil filter alarm

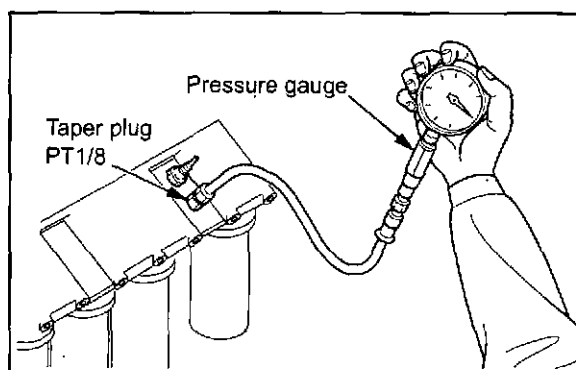
2.5.3 Measuring relief valve pressure

- (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 cap.

A shim with a thickness of 5 mm [0.20 in.] changes the relief valve pressure by approximately 0.1 MPa {1 kgf/cm²} [14.23 psi].

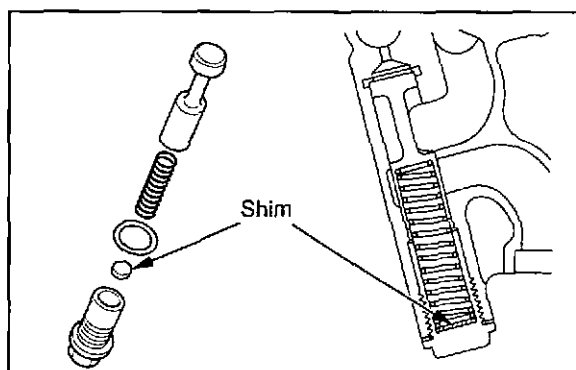
Note: when the oil temperature is low, the oil pressure may rise above the set pressure, but it returns to the set pressure as the oil temperature rises.

- (5) If the pressure does not change even after installing the adjusting shim, replace the relief valve and spring.



Measuring relief valve pressure

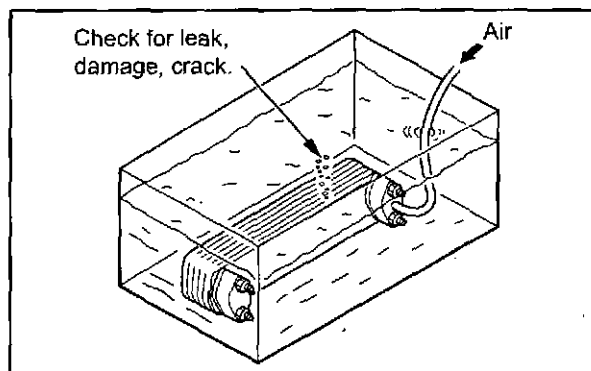
Item	Standard
Set pressure (at rated. speed)	$0.49 \text{ to } 0.64 \text{ MPa } \{5 \text{ to } 6.5 \text{ kgf/cm}^2\}$ $[71.13 \text{ to } 92.46 \text{ psi}]$
Relief valve opening pressure	$0.51 \pm 0.02 \text{ MPa } \{5.2 \pm 0.2 \text{ kgf/cm}^2\}$ $[74 \pm 2.9 \text{ psi}]$



Installing shim for relief valve adjustment

2.5.4 Inspecting oil cooler

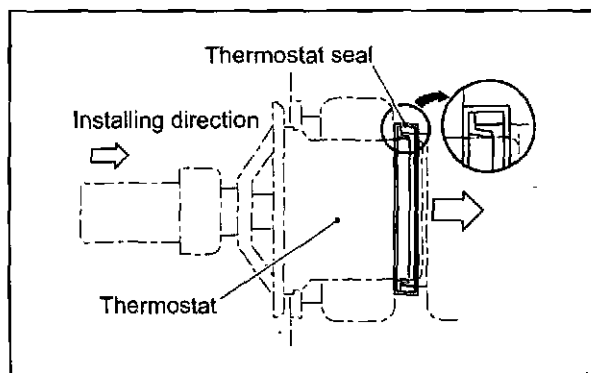
Check oil passages in the element by blowing through them with compressed air of 1.47 MPa {15 kgf/cm²} [213 psi] for damage and cracks. If any leakage or damage is found, replace the element with new one.



Inspecting oil cooler

2.5.5 Inspecting oil thermostat

- (1) Inspect the oil thermostat seal for deterioration and cracks. If defects are found, replace the seal.
- (2) The seal installation direction is as shown in the illustration.

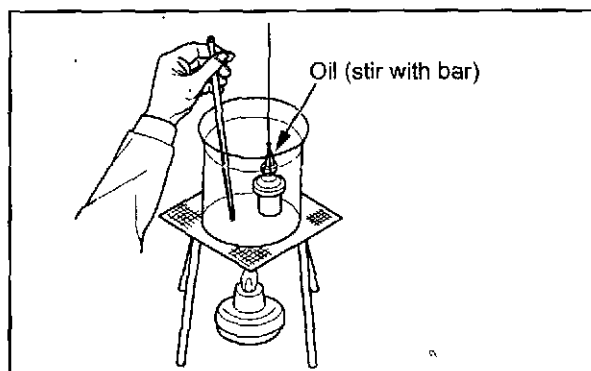


Inspecting oil cooler

- (3) To test the oil thermostat operation, immerse the thermostat in a container filled with engine oil, and heat the oil while measuring the oil temperature. Record the temperature at which the valve opens and the temperature at which the valve lift becomes 11 mm [0.43 in.] or more. If the measured temperature does not fall within the standard range, replace the oil thermostat.

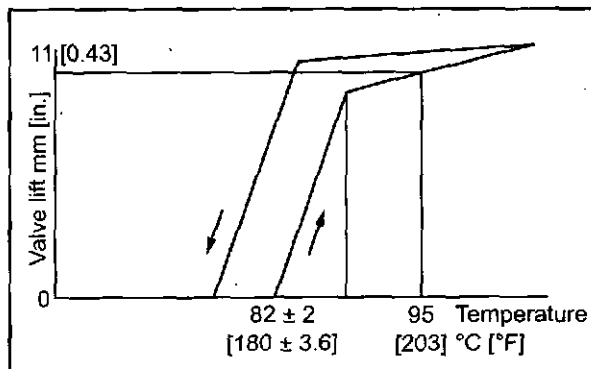
Note: (a) Stir the oil in the container with a bar to ensure uniform temperature distribution.

- (b) When installing the thermostat, be sure to check the valve opening temperature indication stamp on the valve side face of the thermostat.



Inspecting oil cooler

Item	Standard
Temperature at which valve starts opening	82 ± 2°C [180 ± 3.6°F]
Temperature at which valve lift is 11 mm [0.43 in.] or more	95°C [203°F]



Inspecting oil cooler

2.5.6 Reassembling oil filter, oil filter alarm, relief valve, left-hand oil cooler and oil thermostat

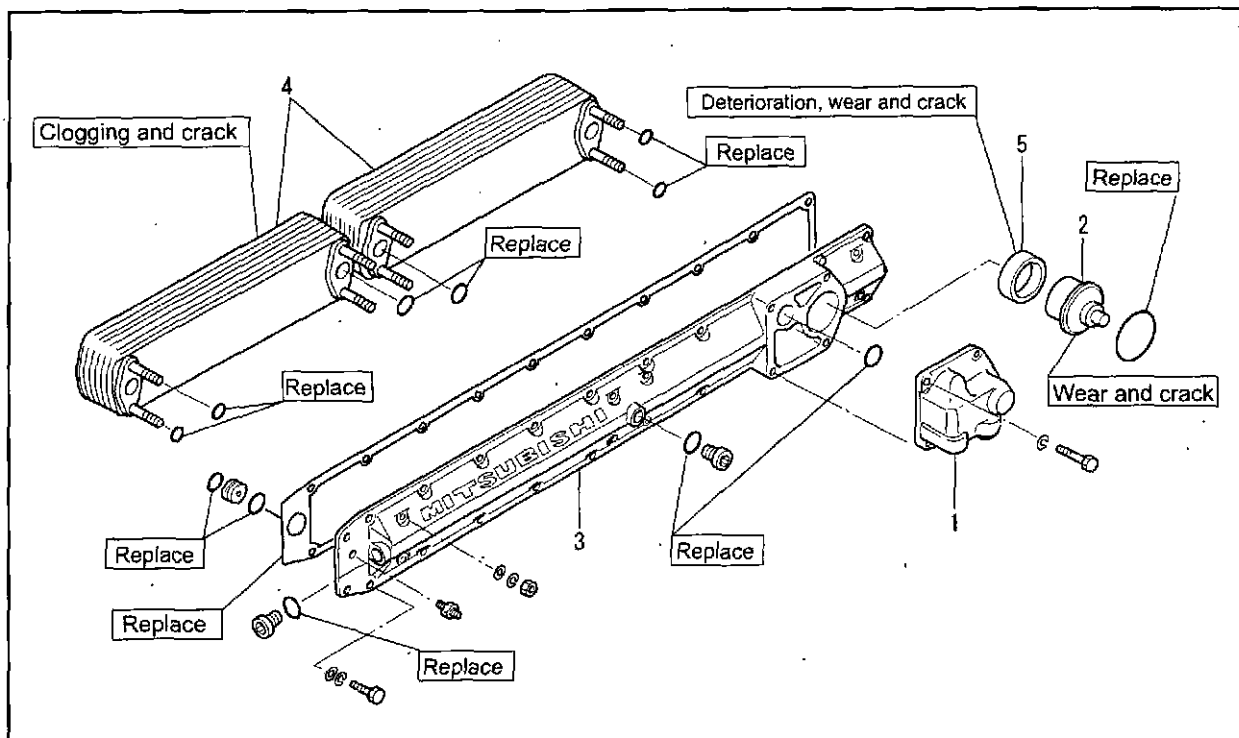
 CAUTION

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) Thoroughly clean oil passages with a wash oil, and dry the cleaned parts with compressed air.
- (3) Mount the bracket prior to installing the cartridge oil filter.
- (4) 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.)

2.6 Disassembling and inspecting right-side oil cooler and oil thermostat



Disassembling and inspecting right-side oil cooler and oil thermostat

Disassembling sequence

- | | | |
|------------------|----------------------|-------------------|
| 1 Connector | 3 Oil cooler cover | 5 Thermostat seal |
| 2 Oil thermostat | 4 Oil cooler element | |

2.7 Inspecting right-side oil cooler and oil thermostat

Inspect the right-side oil cooler and oil thermostat in the same manner as the left-side oil cooler and oil thermostat. Replace defective parts if any.

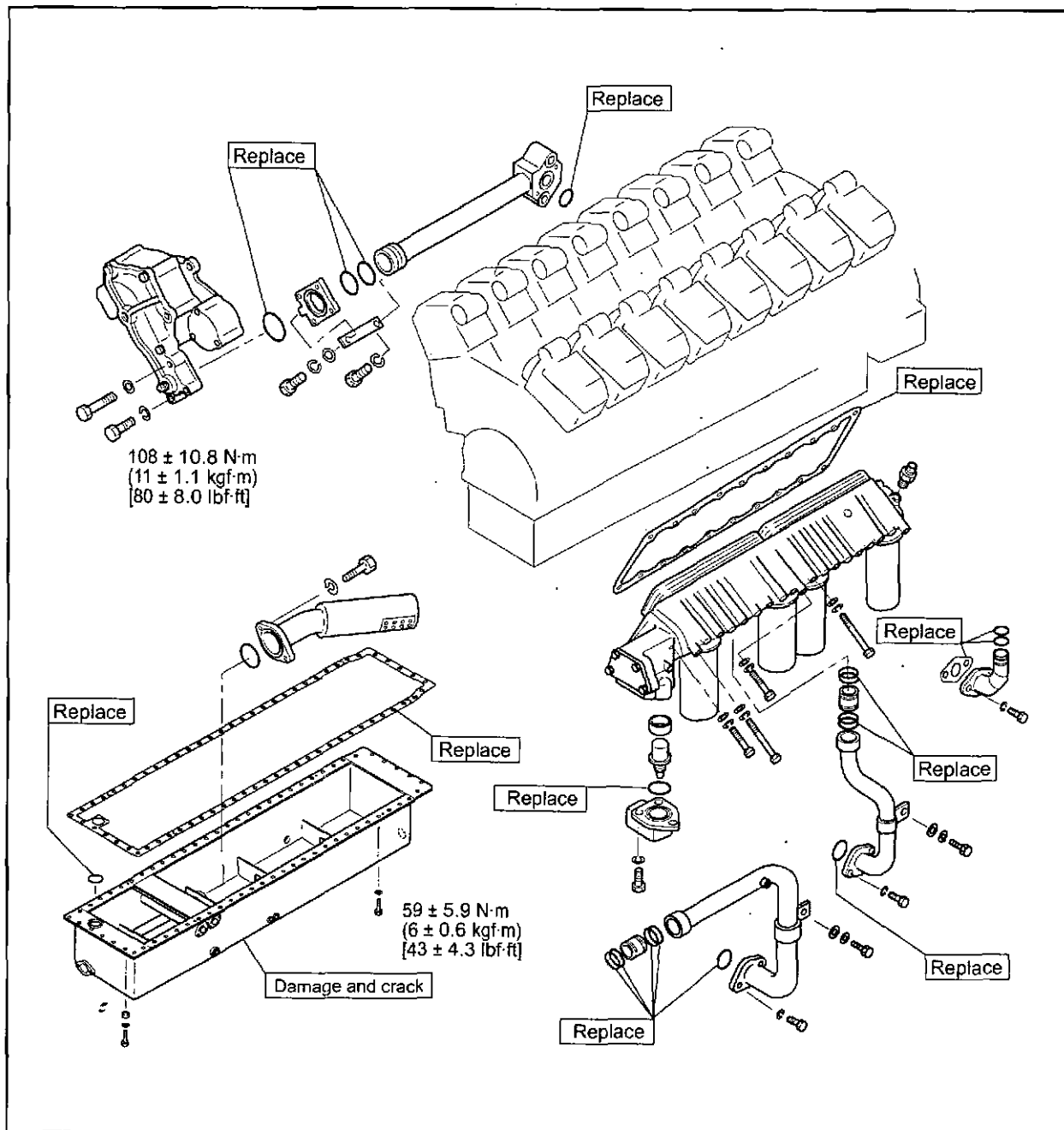
2.8 Reassembling oil cooler and oil thermostat

To reassemble, follow the disassembly sequence in reverse.

- (1) Use new packings and O-rings during reassembly.
- (2) Thoroughly clean oil passages using a wash oil, and dry the cleaned parts with compressed air.

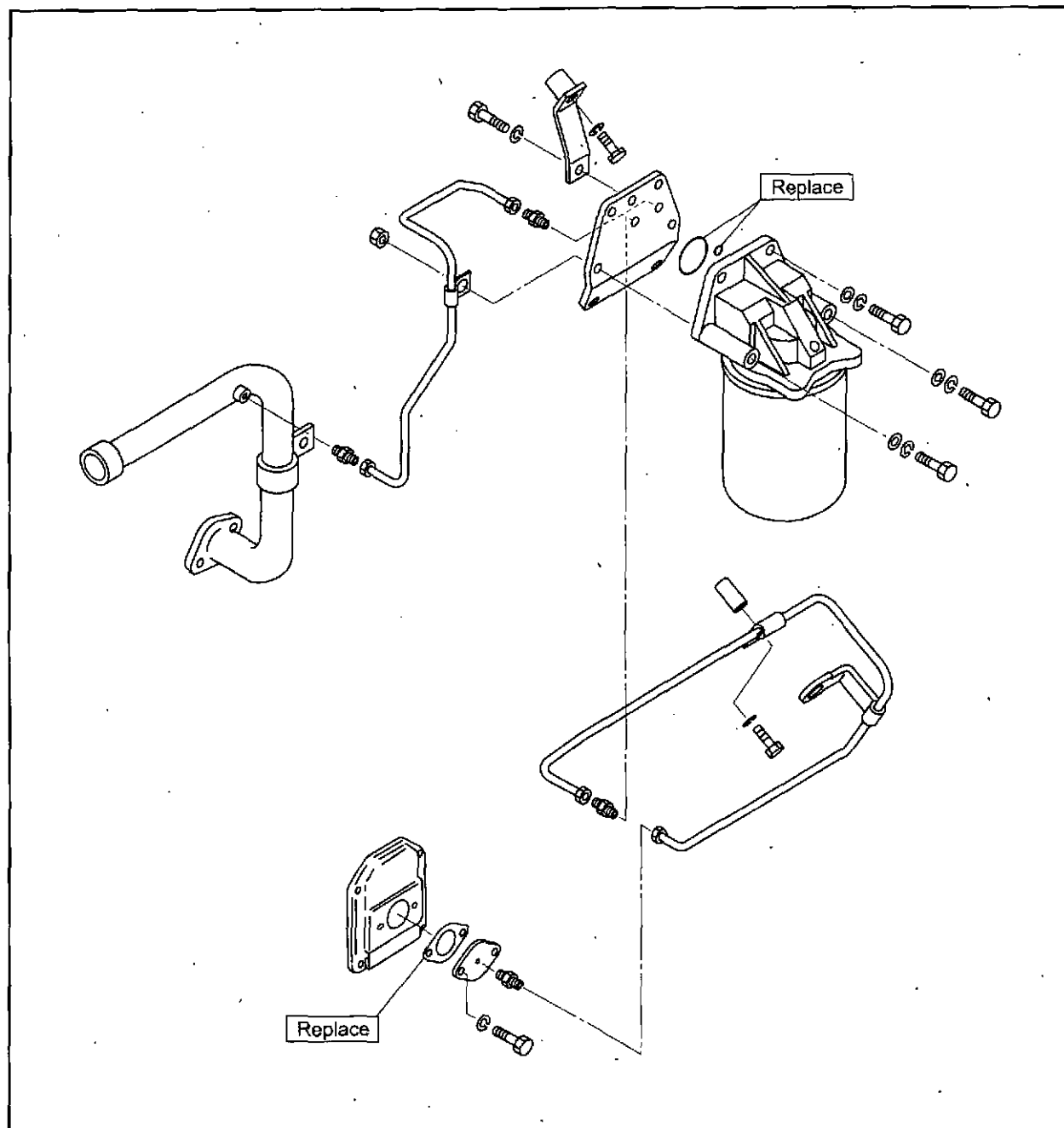
3. Installing lubrication system

3.1 Installing oil pump, oil filter and oil pan



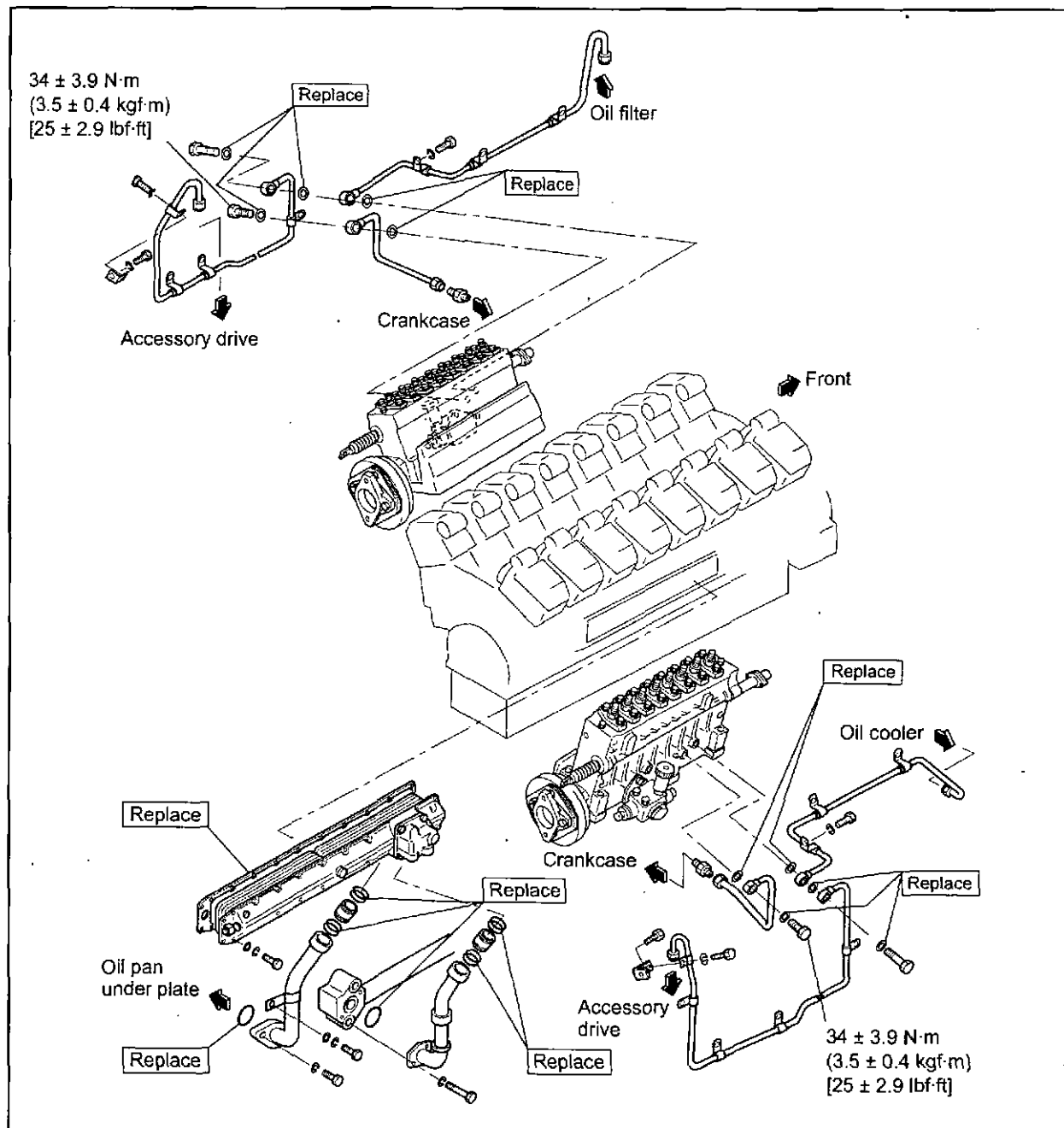
Installing oil pump, oil filter and oil pan

3.2 Installing by-pass filter



Installing by-pass filter

3.3 Installing oil cooler and oil pipe for fuel injection pump



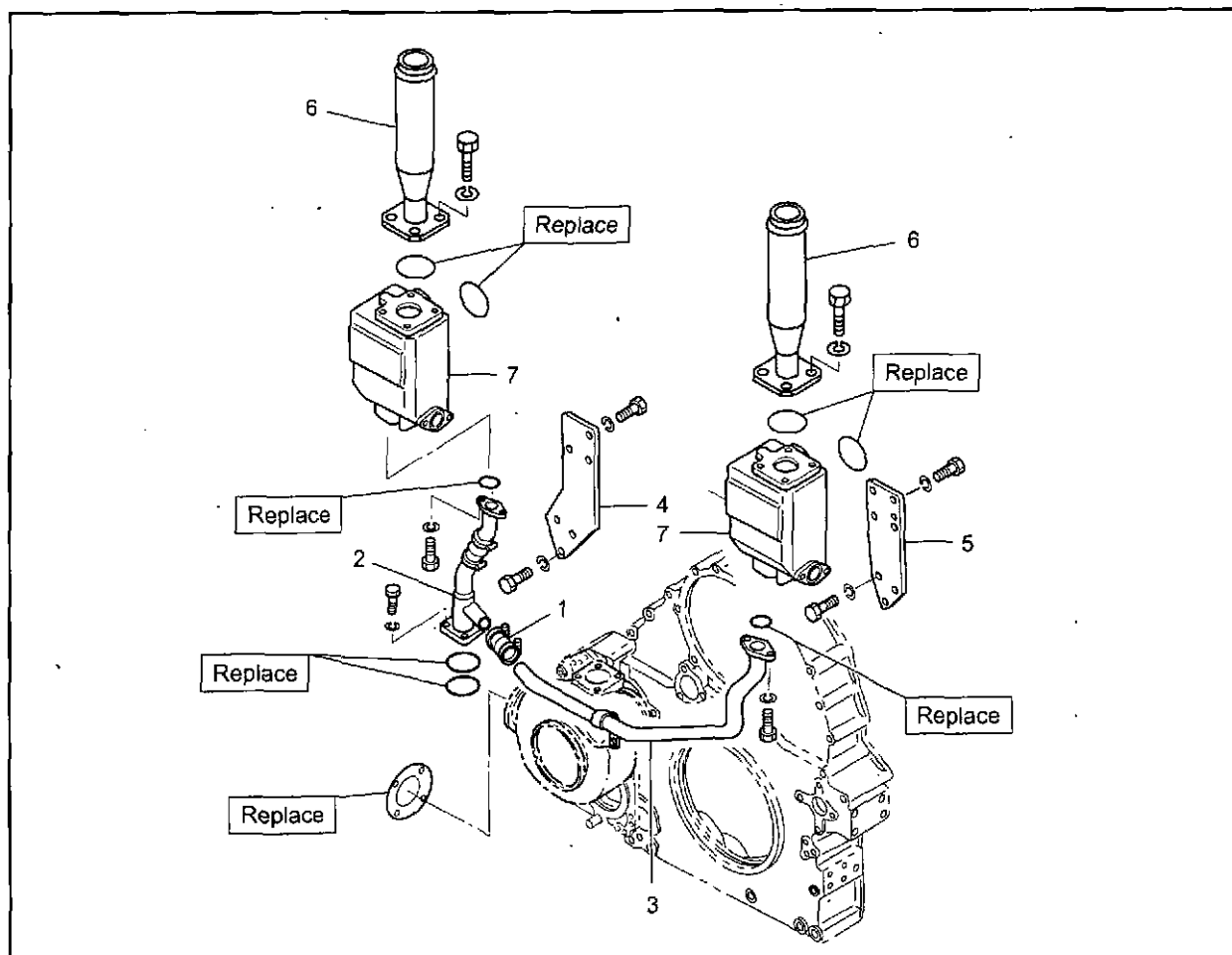
Installing oil cooler and oil pipe for fuel injection pump

COOLING SYSTEM

1. Removing cooling system 10-2
 - 1.1 Removing and inspecting thermostat case and water pipe 10-2
 - 1.2 Removing and inspecting 2-way water pipe (intercooler cooling system) 10-3
 - 1.3 Removing and inspecting water pump... 10-4
 - 1.4 Removing and inspecting 2-way water pump and tension pulley 10-5
2. Disassembling, inspecting, and reassembling cooling system 10-6
 - 2.1 Disassembling and inspecting water pump 10-6
 - 2.1.1 Inspecting dummy water pump mounted on engine 10-7
 - 2.1.2 Removing impeller 10-7
 - 2.1.3 Removing water pump gear and water pump shaft 10-8
 - 2.2 Inspecting fresh water pump 10-8
 - 2.3 Reassembling water pump 10-9
 - 2.4 Disassembling thermostat 10-12
 - 2.5 Inspecting water thermostat 10-12
3. Disassembling, inspecting and reassembling intercooler cooling system 10-13
 - 3.1 Disassembling and inspecting 2-way water thermostat 10-13
 - 3.2 Inspecting water thermostat 10-13
 - 3.3 Disassembling and inspecting tension pulley assembly 10-14
 - 3.4 Inspecting tension pulley assembly 10-14
 - 3.5 Reassembling tension pulley assembly 10-14
4. Installing cooling system 10-15
 - 4.1 Installing 2-way water pump and tension pulley 10-15
 - 4.2 Installing water pump 10-16
 - 4.3 Installing 2-way water pipe (intercooler cooling system) 10-17
 - 4.4 Installing thermostat case and water pipe 10-18

1. Removing cooling system

1.1 Removing and inspecting thermostat case and water pipe

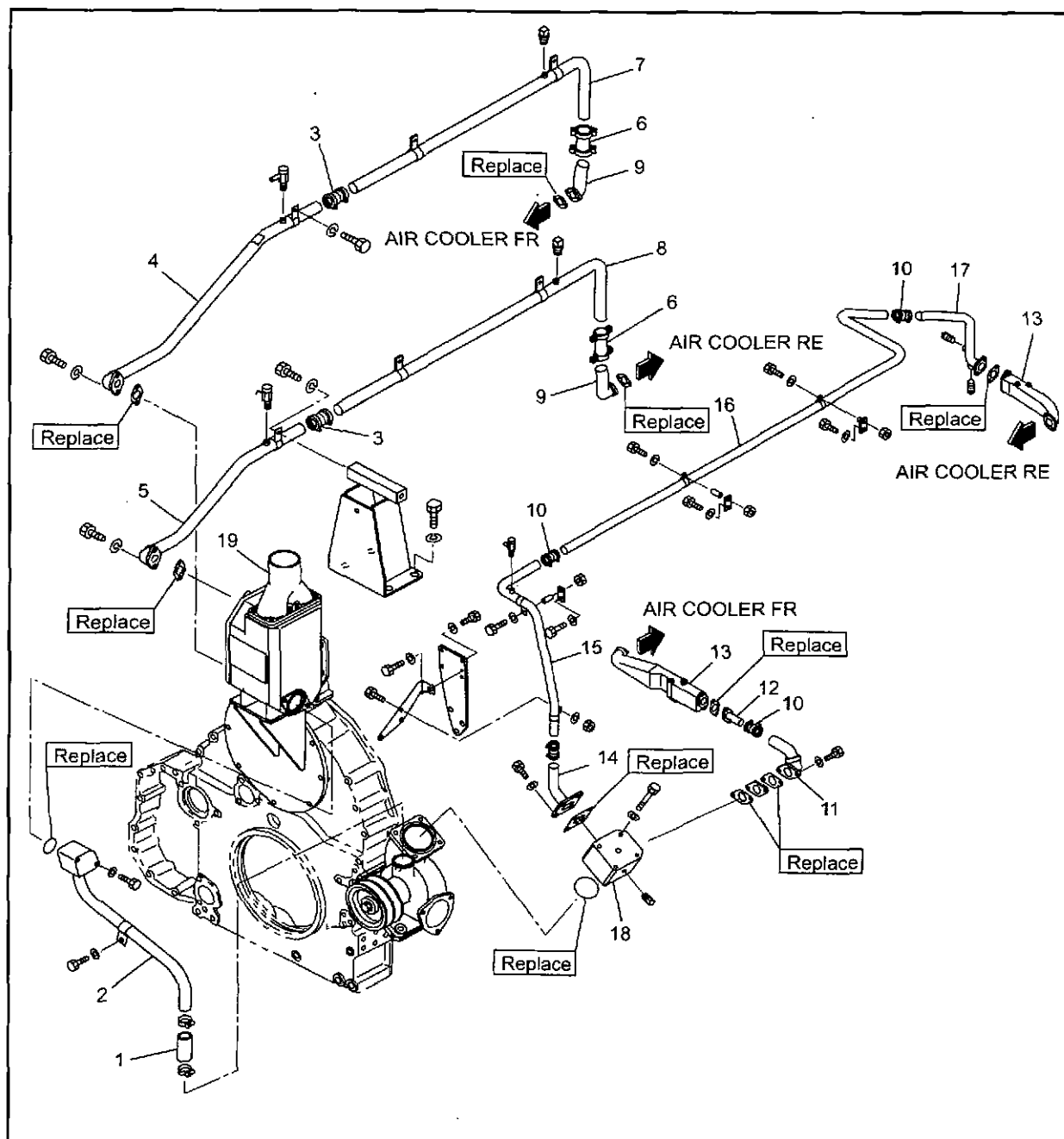


Removing and inspecting thermostat case and water pipe

Removing sequence

- | | |
|----------------------------|-----------------------------|
| 1 Coupling | 5 Thermostat bracket, right |
| 2 Bypass water pipe | 6 Water pipe |
| 3 Bypass water pipe | 7 Thermostat case |
| 4 Thermostat bracket, left | |

1.2 Removing and inspecting 2-way water pipe (intercooler cooling system)

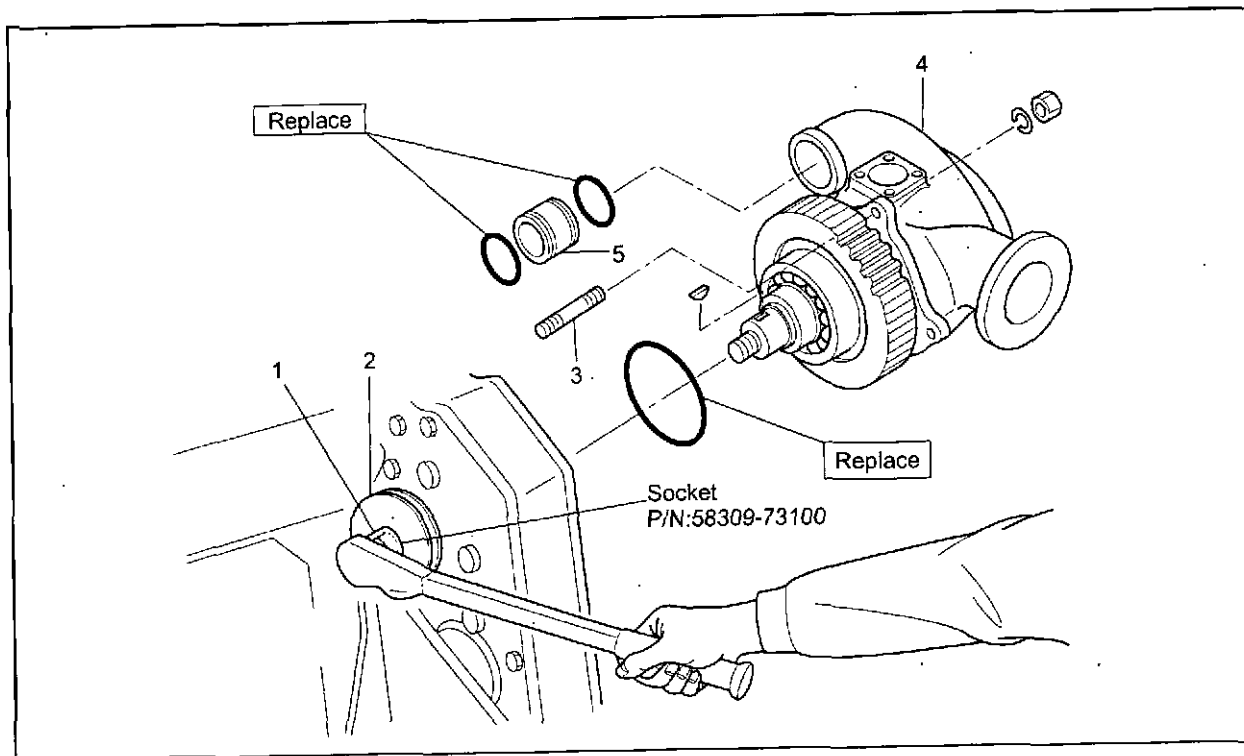


Removing and inspecting 2-way water pipe (intercooler cooling system)

Removing sequence

- | | | |
|---------------|--------------------|--------------------|
| 1 Rubber hose | 8 Water pipe | 15 Water pipe |
| 2 Bypass pipe | 9 Water pipe | 16 Water pipe |
| 3 Coupling | 10 Coupling | 17 Water pipe |
| 4 Water pipe | 11 Water pipe | 18 Coupling |
| 5 Water pipe | 12 Water pipe | 19 Thermostat case |
| 6 Coupling | 13 Water connector | |
| 7 Water pipe | 14 Water pipe | |

1.3 Removing and inspecting water pump

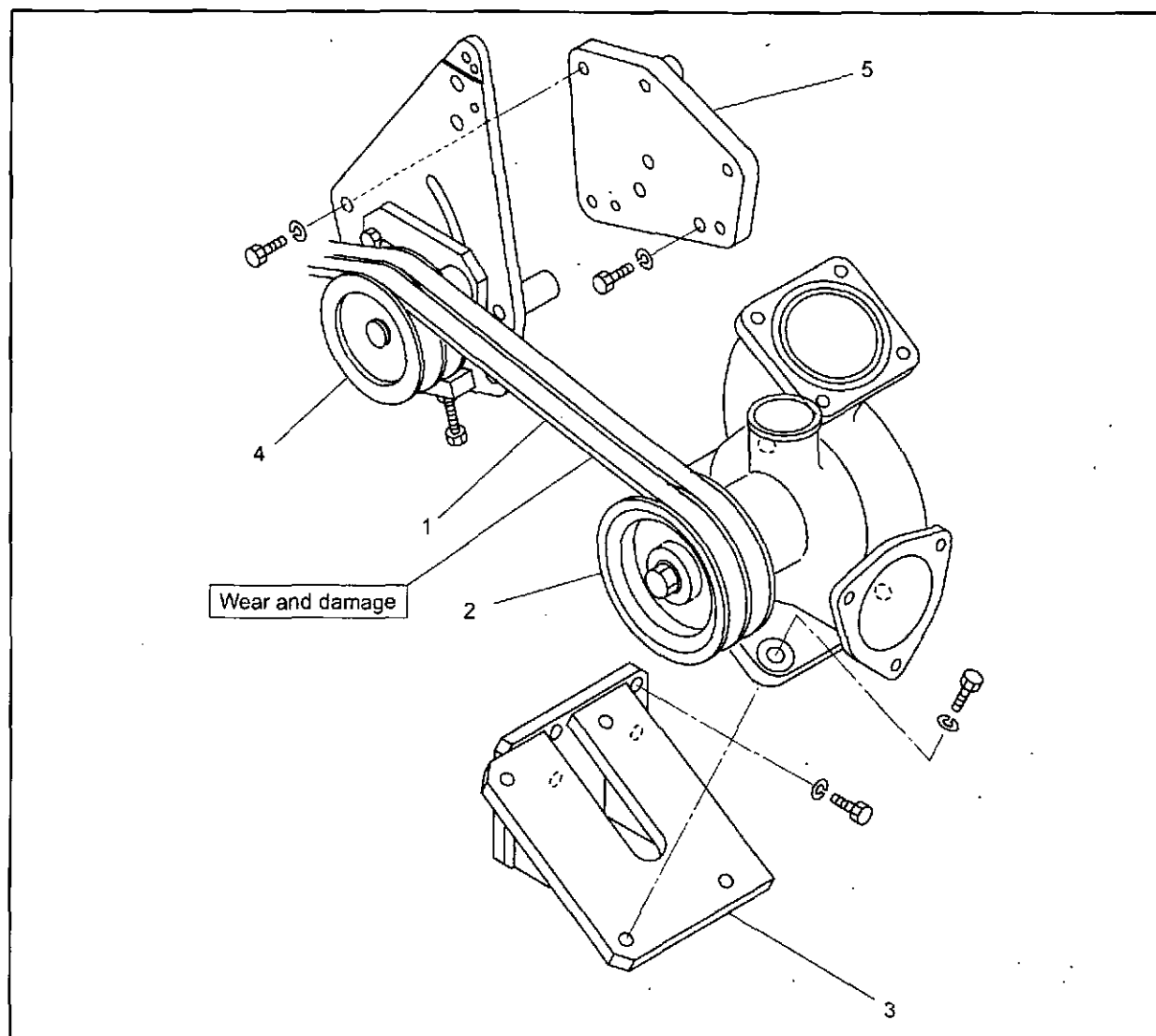


Removing and inspecting water pump

Removing sequence

- | | | |
|----------|--|---------|
| 1 Nut | 3 Stud | 5 Joint |
| 2 Pulley | 4 Water pump (weight: approx. 40 kg [88 lb]) | |

1.4 Removing and inspecting 2-way water pump and tension pulley



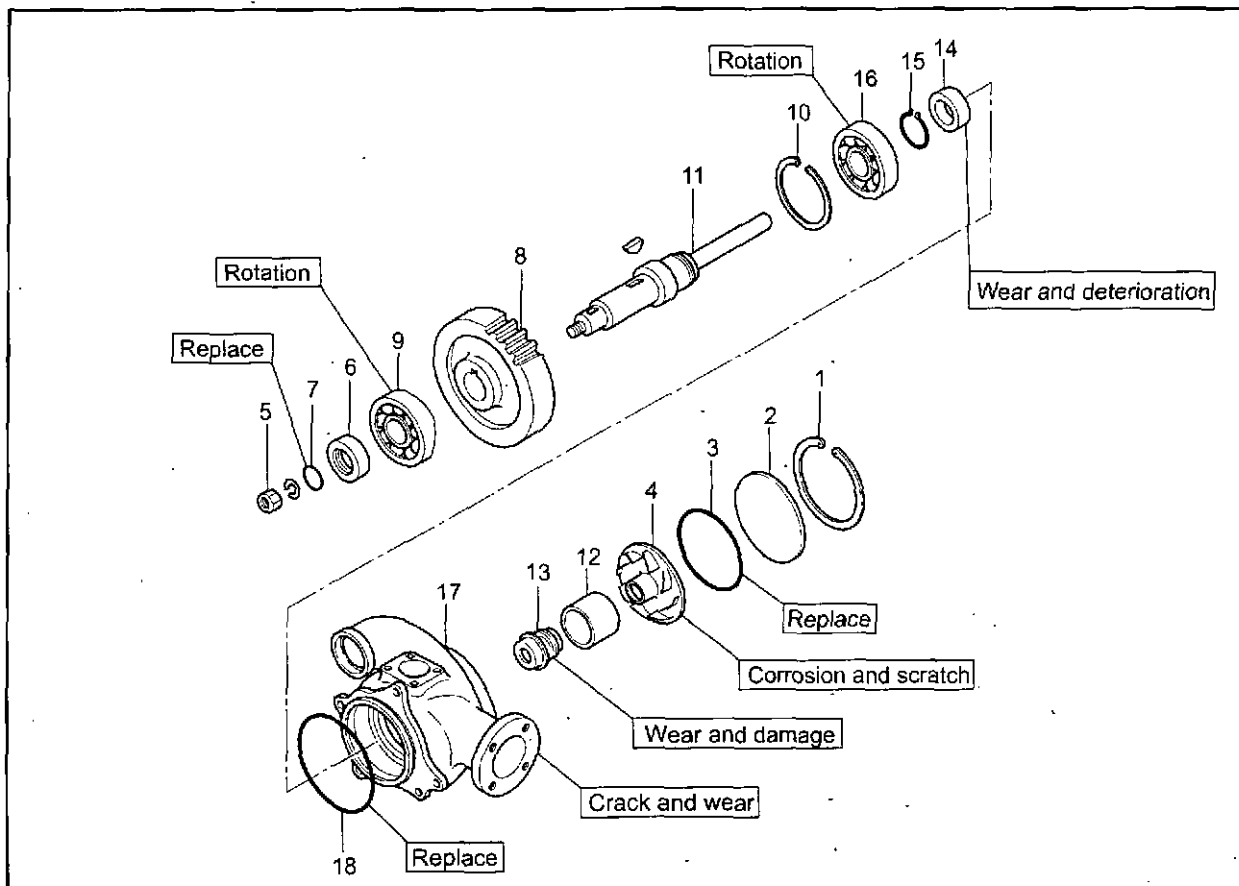
Removing and inspecting 2-way water pump and tension pulley

Removing sequence

- | | |
|--------------------|---------------------------|
| 1 V-belt | 4 Tension pulley assembly |
| 2 2-way water pump | 5 Tension plate |
| 3 Bracket | |

2. Disassembling, inspecting, and reassembling cooling system

2.1 Disassembling and inspecting water pump



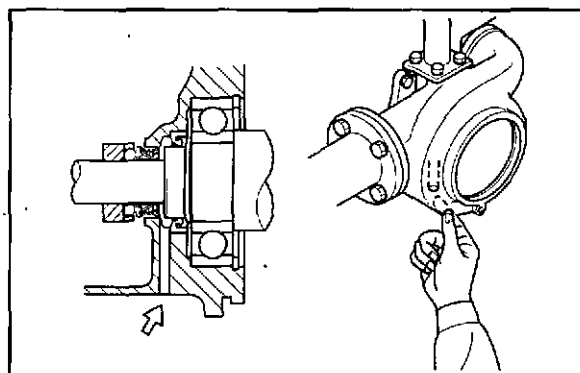
Disassembling and inspecting water pump

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 |

2.1.1 Inspecting dummy 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, the plug is defective. If oil is present, the oil seal is defective.



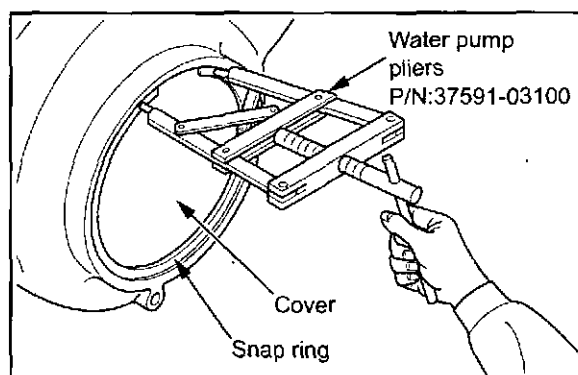
Inspecting water pump as mounted

2.1.2 Removing impeller

CAUTION

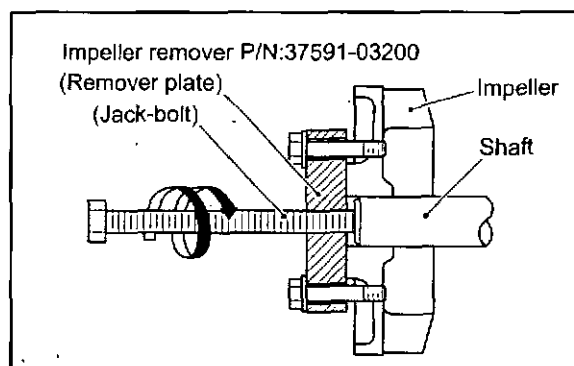
Be careful not to damage the water pump shaft, impeller, etc. when removing impeller from the shaft.

- (1) Using the water pump pliers, remove the snap ring that holds the cover in position, then dismount the cover.



Removing water pump cover

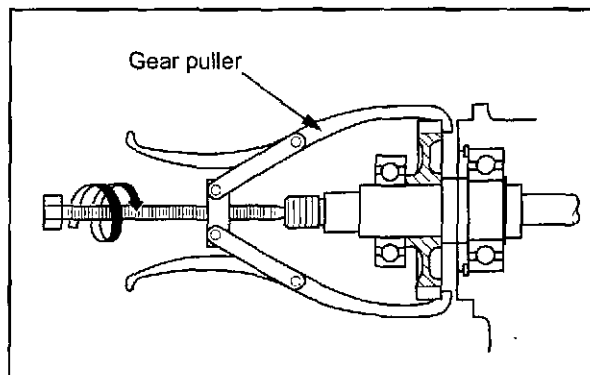
- (2) Using the impeller remover, pull out the impeller.



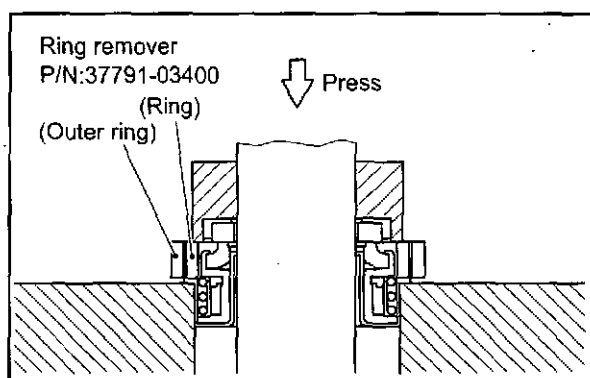
Removing water pump impeller

2.1.3 Removing water pump gear and water pump shaft

- (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 drawing.
- (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 and water pump shaft



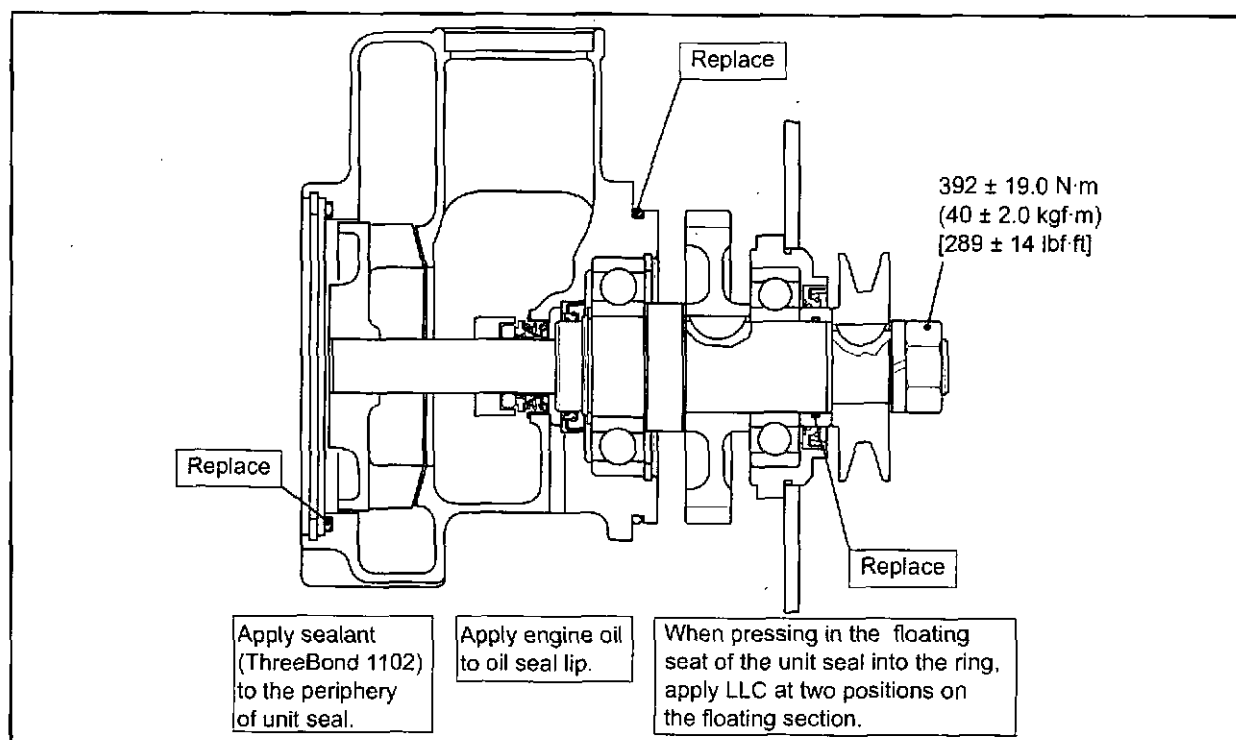
Removing water pump shaft

2.2 Inspecting fresh 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
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			.104 mm [0.0409 in.]	0.58 to 1.50 mm [0.0228 to 0.0591 in.]

2.3 Reassembling water pump

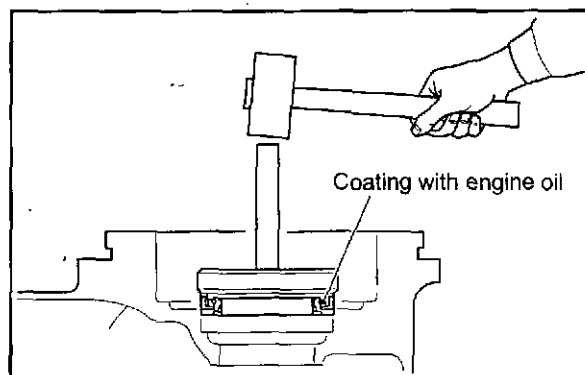


Reassembling water pump

Install new O-rings, oil seals and unit seals in reassembly.

2.3.1 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.

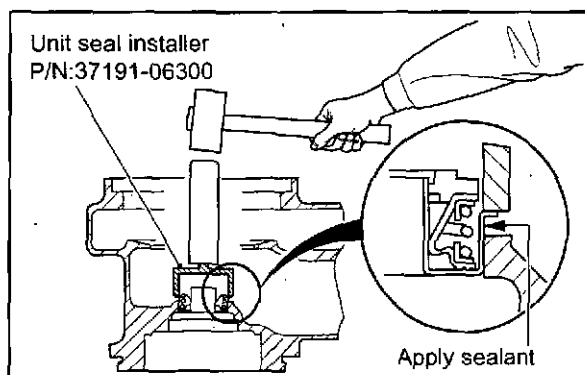


Installing water pump oil seal

2.3.2 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.

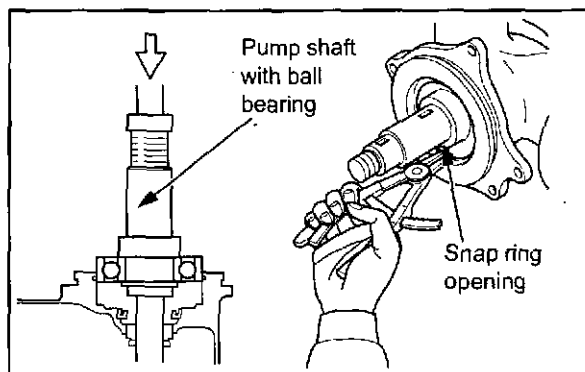


Installing unit seal

2.3.3 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.

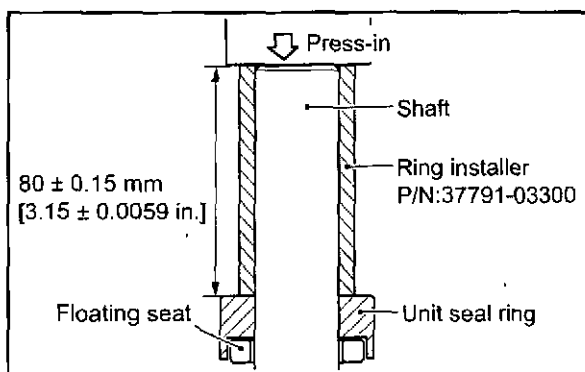


Striking in impeller side ball bearing

2.3.4 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.

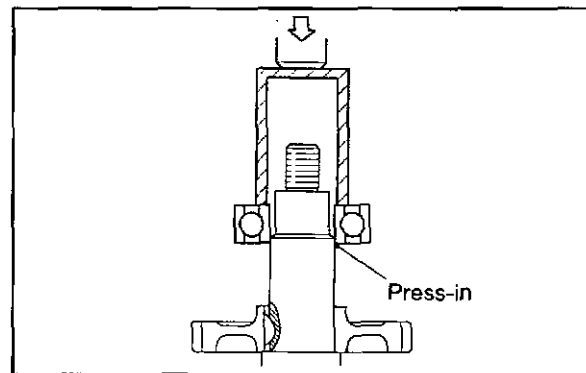
Note: When pressing in the floating seat of the unit seal into the ring, apply LLC at two positions on the floating section.



Reassembling unit seal ring

2.3.5 Installing ball bearing on the nut side

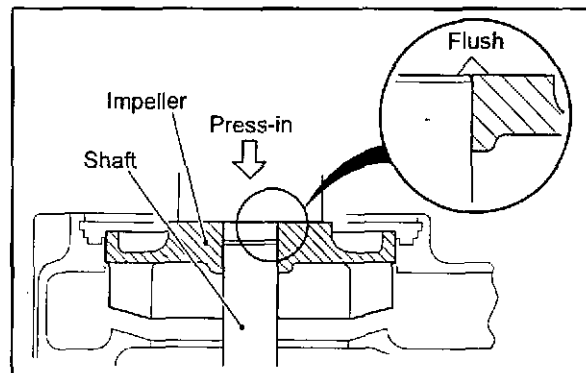
Install the gear into the shaft while aligning its key with keyway. Press in the ball bearing at the nut end using a press.



Striking in nut side ball bearing

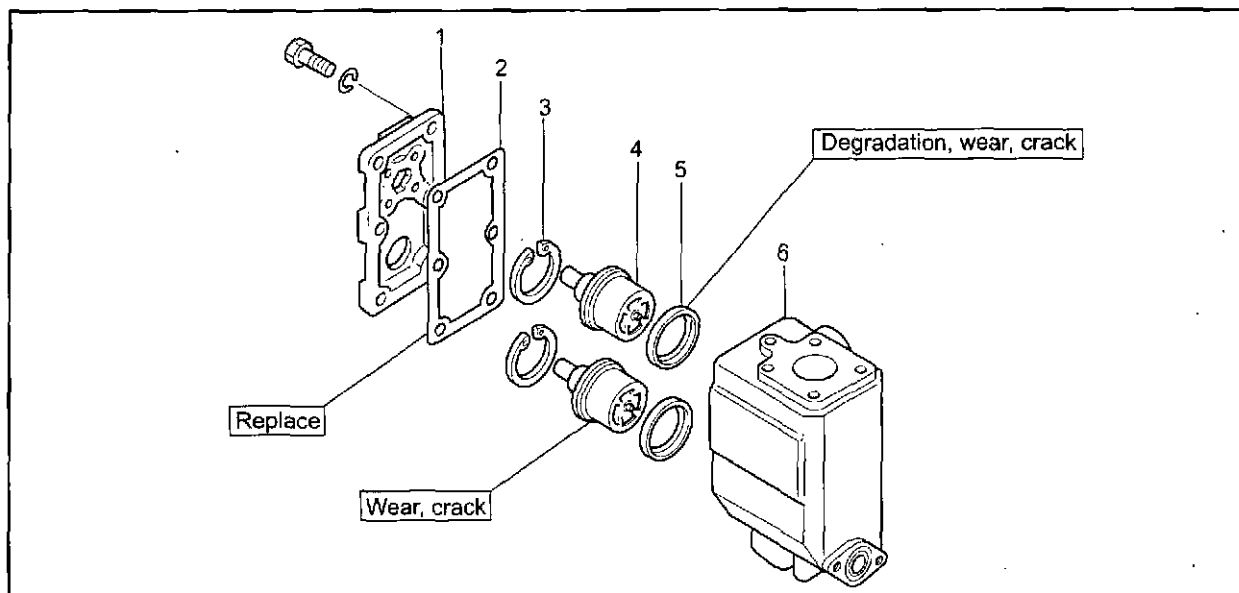
2.3.6 Press-fitting water pump impeller

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

2.4 Disassembling thermostat



Disassembling thermostat

Disassembling sequence

- | | | |
|--------------------|--------------|-------------------|
| 1 Thermostat cover | 3 Snap ring | 5 Thermostat seal |
| 2 Packing | 4 Thermostat | 6 Thermostat case |

2.5 Inspecting water thermostat

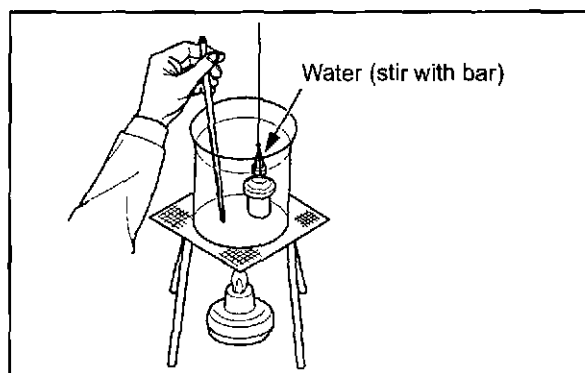
CAUTION

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.

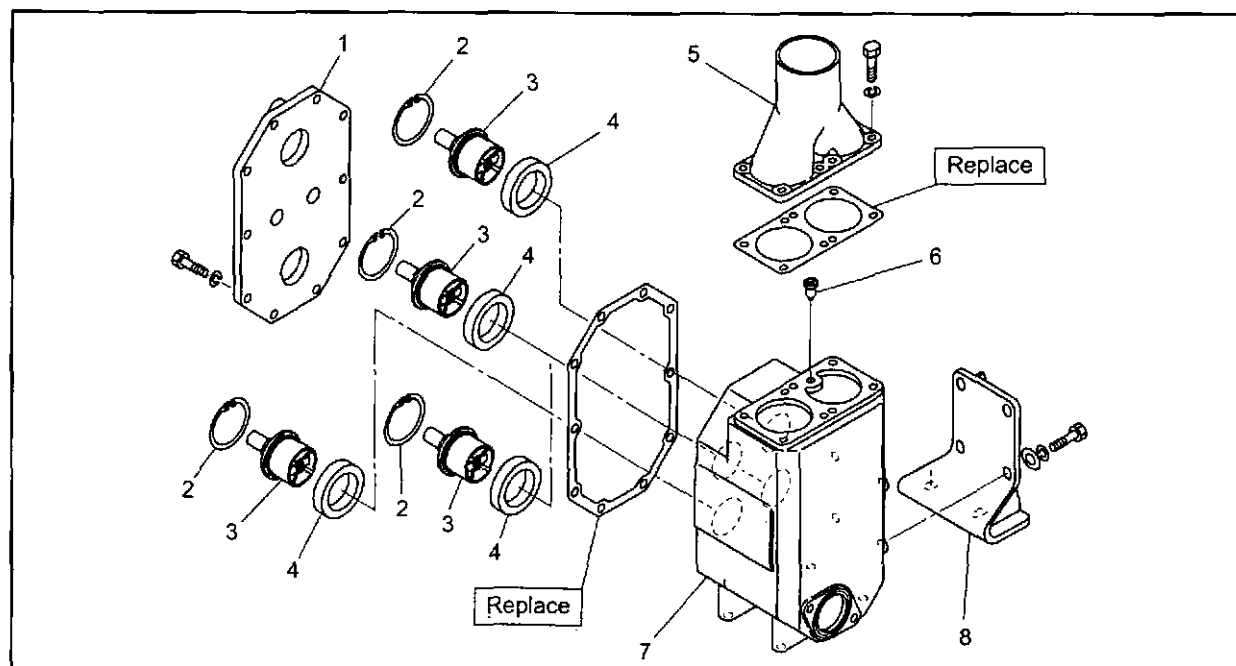


Inspecting water thermostat

Item	Standard
Temperature at which valve starts opening	71 ± 2°C [160 ± 3.6°F]
Temperature at which valve lift is 9 mm [0.35 in.] or more	85°C [185°F]

3. Disassembling, inspecting and reassembling intercooler cooling system

3.1 Disassembling and inspecting 2-way water thermostat



Disassembling and inspecting 2-way water thermostat

Disassembling sequence

- | | | |
|--------------------|-------------------|-------------------|
| 1 Thermostat cover | 4 Thermostat | 7 Packing |
| 2 Packing | 5 Thermostat seal | 8 Jiggle valve |
| 3 Snap ring | 6 Pipe | 9 Thermostat case |

3.2 Inspecting water thermostat

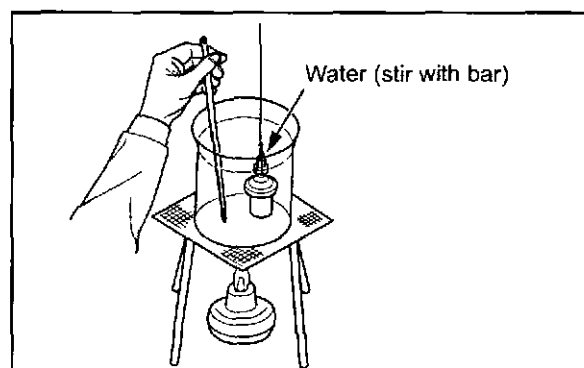
CAUTION

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.

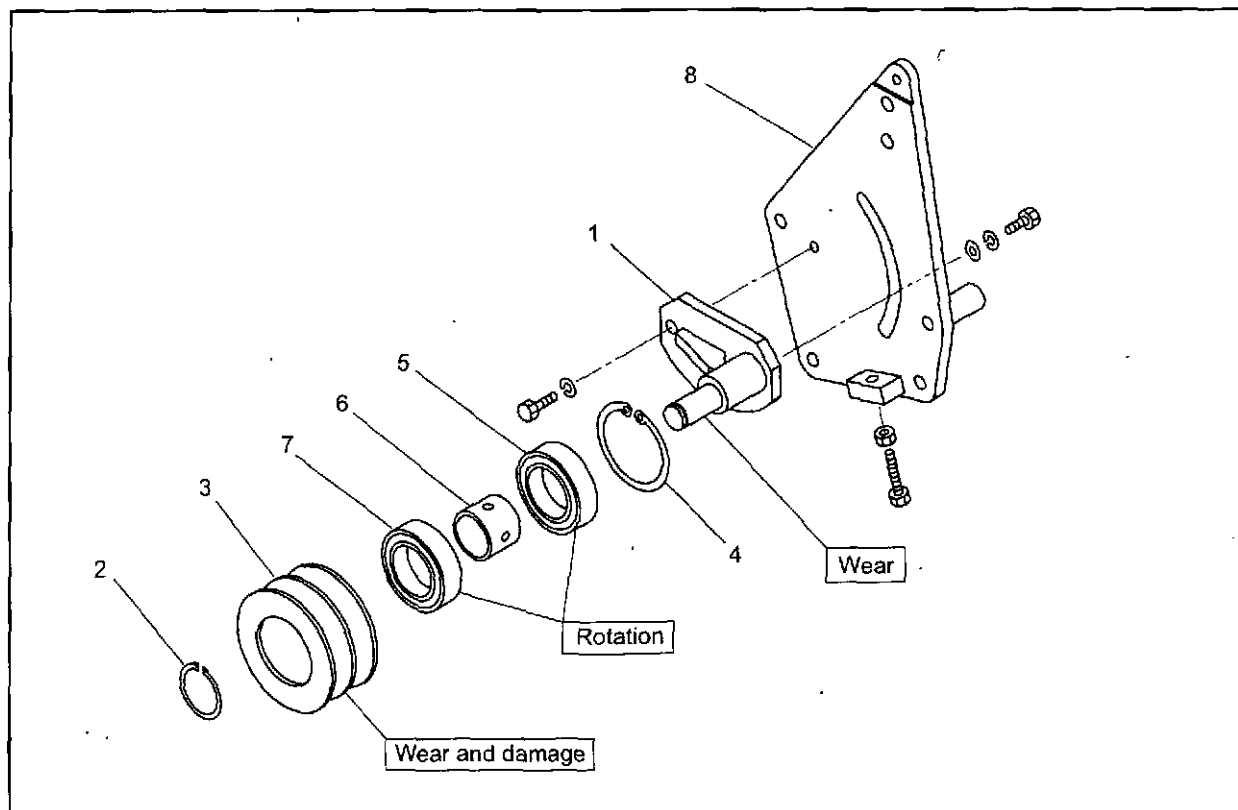
(b) Prior to installing the thermostat, be sure to check the valve opening temperature stamped on the thermostat valve end face.



Inspecting water thermostat

Measurement item	Thermostat 42
Temperature at which valve starts opening	42 ± 2°C [108 ± 3.6 °F]
Temperature at which valve lift is 9 mm [0.35 in.] or more	55°C [131°F]

3.3 Disassembling and inspecting tension pulley assembly



Disassembling and inspecting tension pulley assembly

Disassembling sequence

- | | |
|--------------------------|-------------------|
| 1 Tension pulley bracket | 5 Ball bearing |
| 2 Snap ring | 6 Spacer |
| 3 Tension pulley | 7 Ball bearing |
| 4 Snap ring | 8 Tension bracket |

3.4 Inspecting tension pulley assembly

Measure the diameter of ball bearing fitting sections of the shaft setting on the tension pulley bracket and measure the tension pulley bearing bore diameter.

If they are damaged or worn excessively, replace the ball bearing and shaft or tension pulley.

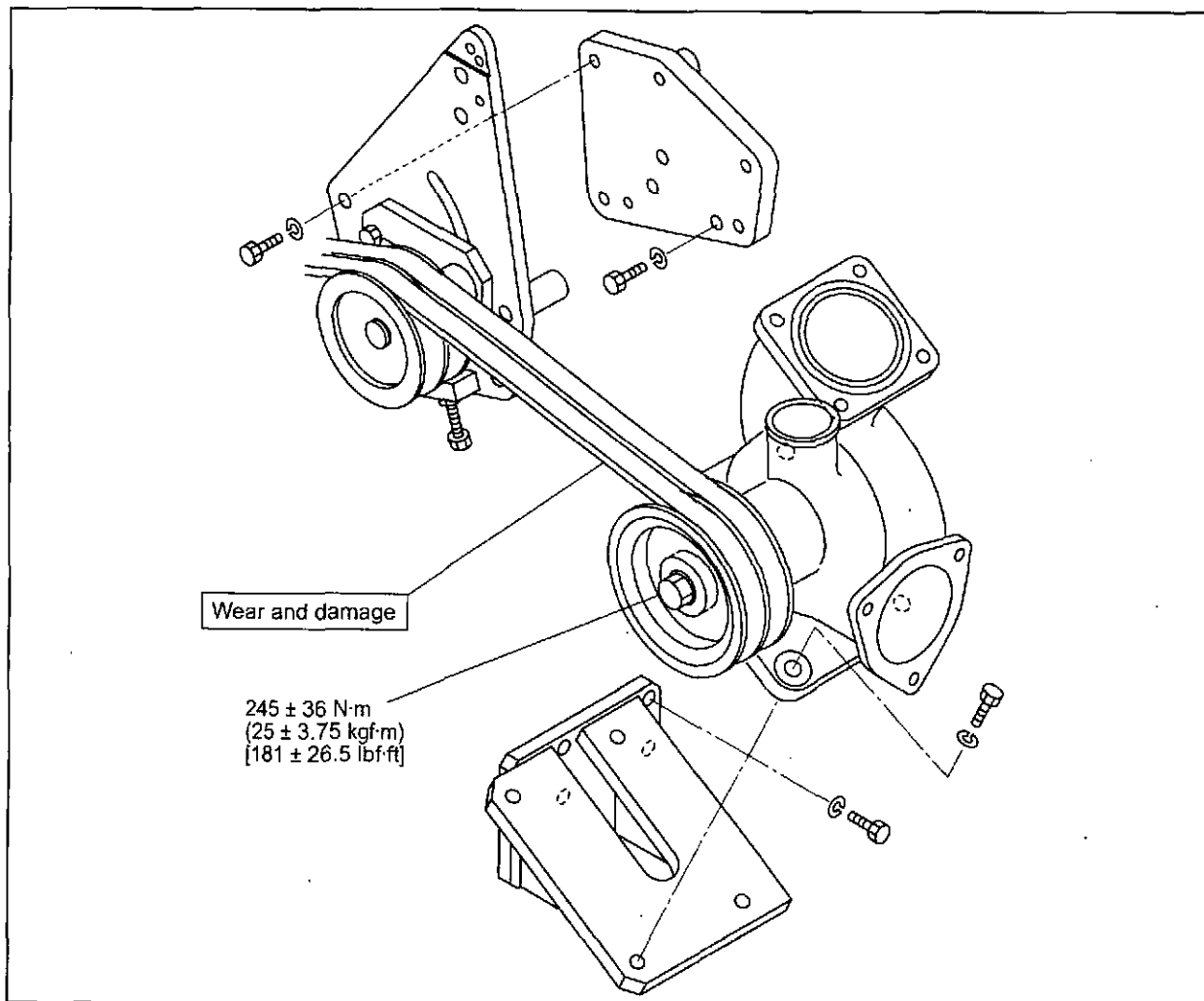
Item		Nominal	Standard
Tension pulley bearing bore inside diameter		ø 60 mm [2.44 in.]	61.970 to 62.000 mm [2.4398 to 2.4409 in.]
Bearing	Inside diameter	ø 25 mm [0.98 in.]	24.988 to 25.000 mm [0.9838 to 0.9843 in.]
	Outside diameter	ø 62 mm [2.44 in.]	61.985 to 62.000 mm [2.4403 to 2.4409 in.]
Outside diameter of shaft on which bearing is fitted		ø 25 mm [0.98 in.]	24.987 to 25.000 mm [0.9837 to 0.9843 in.]

3.5 Reassembling tension pulley assembly

To reassemble, follow the disassembly sequence in reverse.

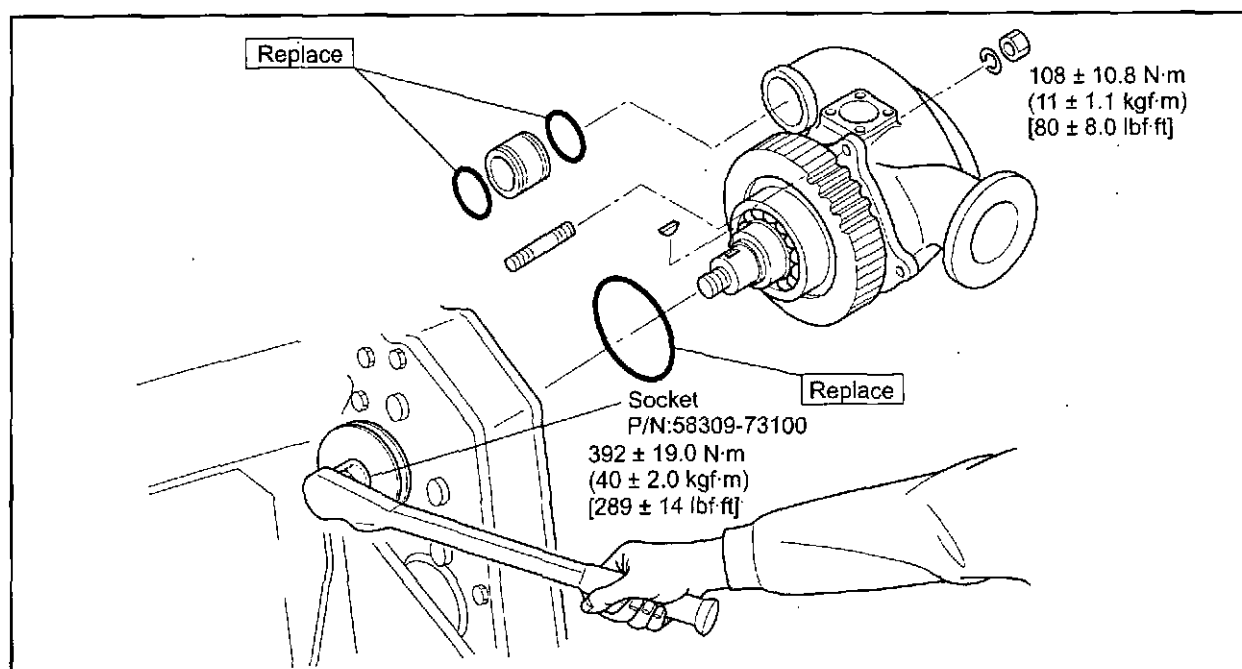
4. Installing cooling system

4.1 Installing 2-way water pump and tension pulley



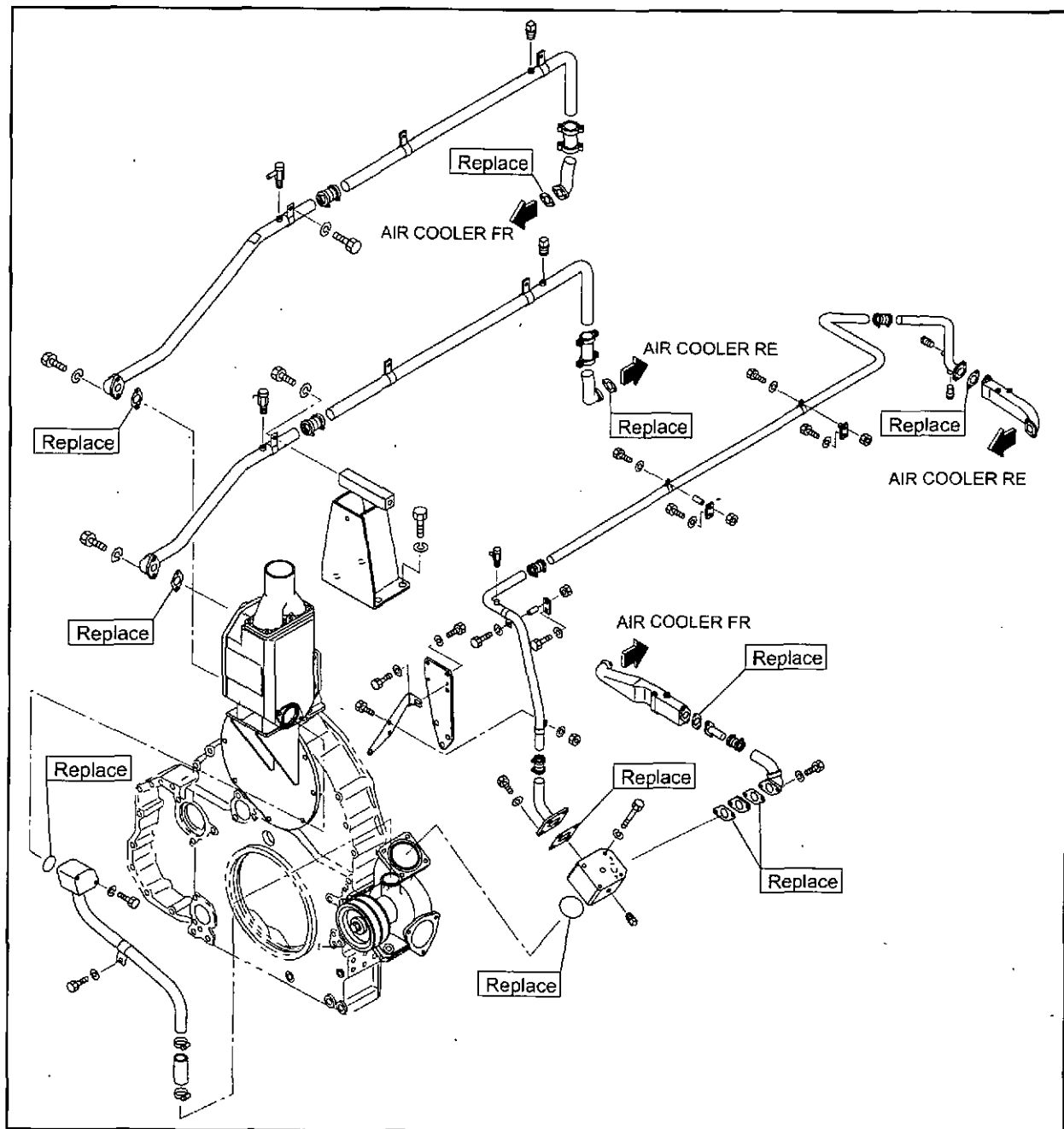
Installing 2-way water pump and tension pulley

4.2 Installing water pump



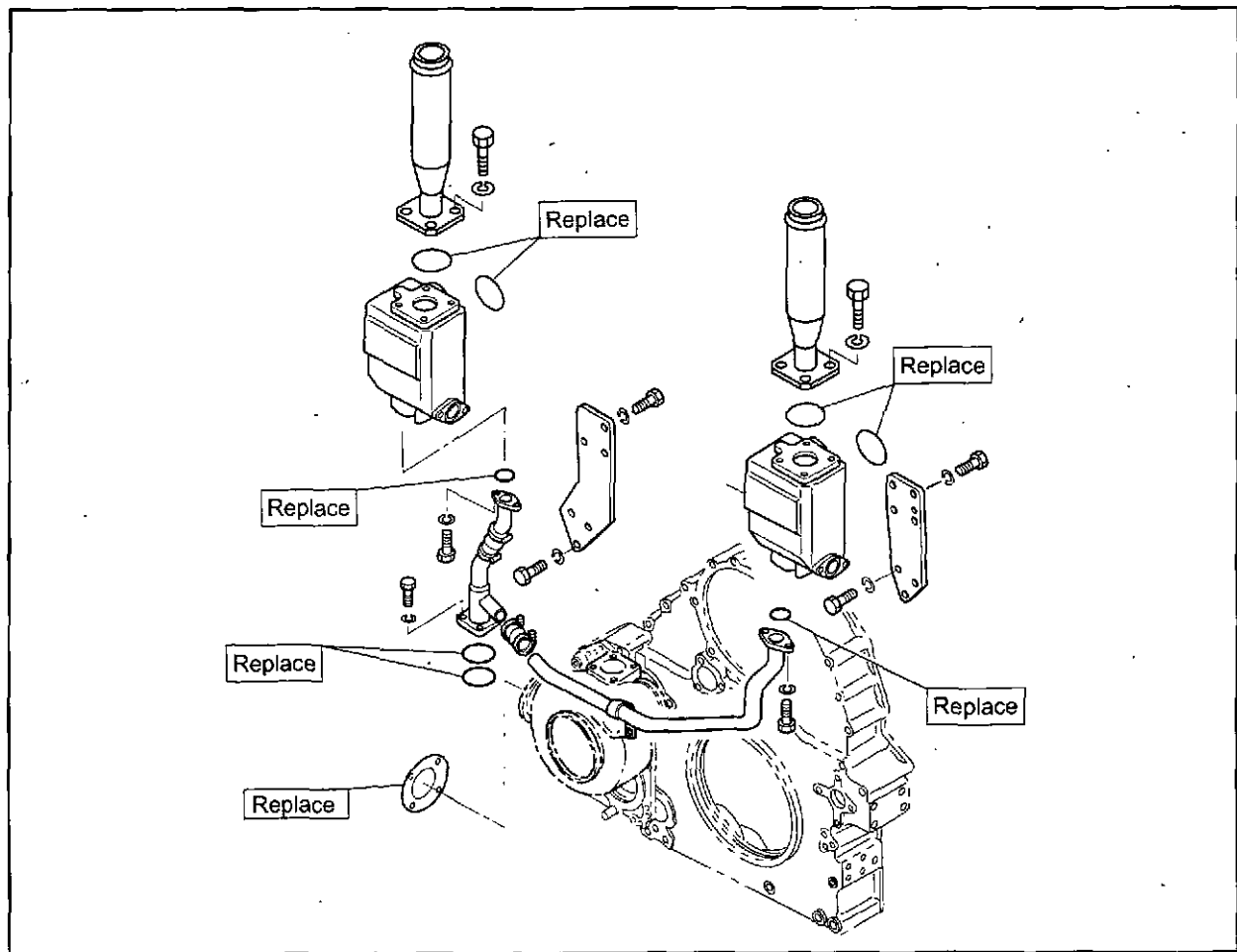
Installing water pump

4.3 Installing 2-way water pipe (intercooler cooling system)



Installing 2-way water pipe (intercooler cooling system)

4.4 Installing thermostat case and water pipe



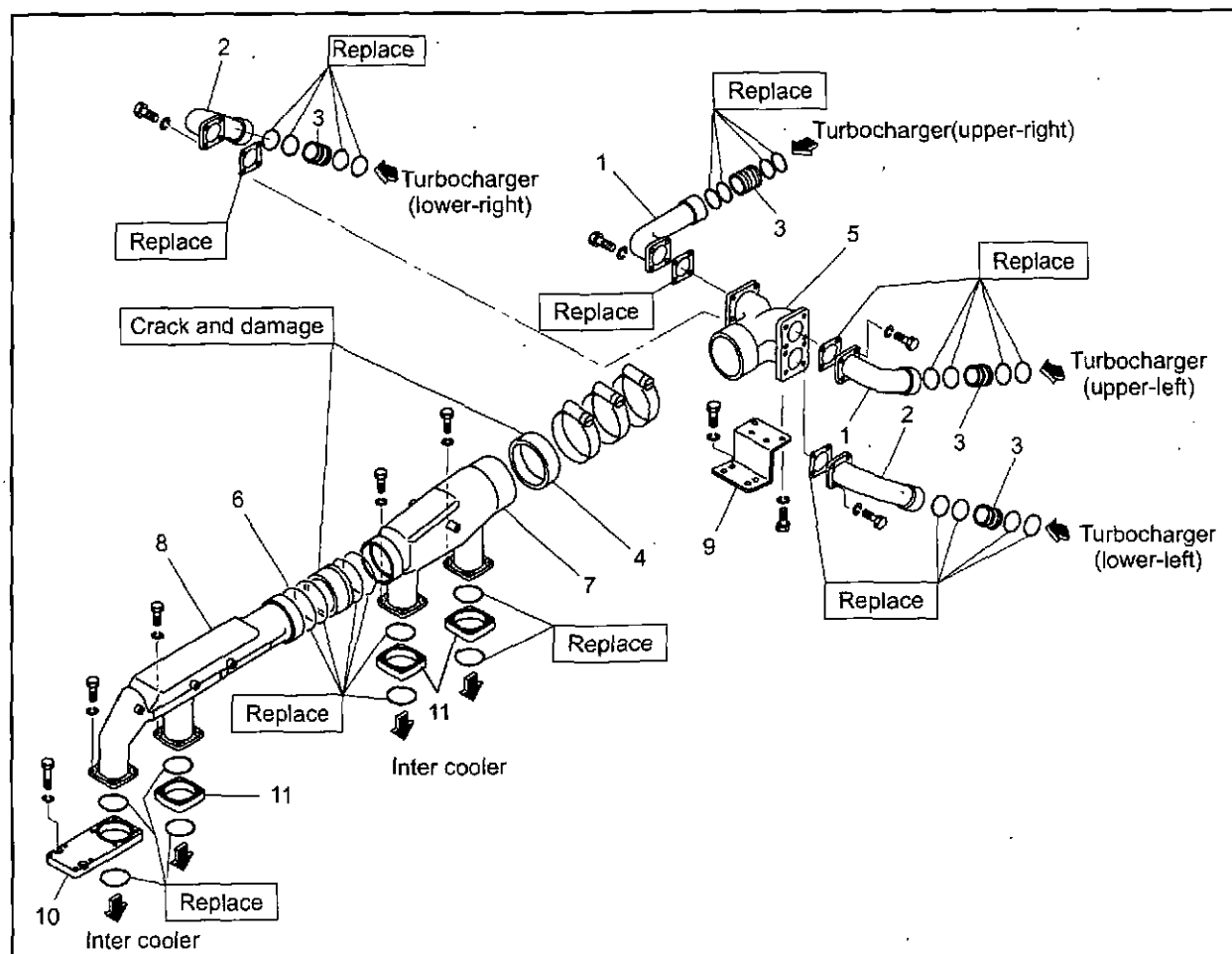
Installing thermostat case and water pipe

INLET AND EXHAUST SYSTEMS

1. Air duct (intercooler-to-turbocharger) 11-2 1.1 Disassembling and inspecting air duct... 11-2 1.2 Reassembling air duct 11-2 2. Insulator 11-3 2.1 Disassembling and inspecting insulator. 11-3 2.2 Reassembling insulator..... 11-3 3. Exhaust manifold..... 11-4 3.1 Disassembling and inspecting exhaust manifold 11-4 3.2 Reassembling exhaust manifold..... 11-5 4. Turbocharger oil pipe 11-6 4.1 Disassembling and inspecting turbocharger oil pipe 11-6 4.2. Reassembling turbocharger oil pipe 11-6 5. Exhaust pipe 11-7 5.1 Disassembling and inspecting exhaust pipe 11-7 5.2 Reassembling exhaust pipe..... 11-7 6. Intercooler 11-8 6.1 Disassembling and inspecting intercooler11-8 6.2 Cleaning intercooler 11-9 6.3 Inspecting intercooler for leakage 11-9 6.4 Reassembling air duct 11-9 7. Boost sensor pipe 11-10 7.1 Disassembling and inspecting boost sensor pipe 11-10 7.2 Reassembling turbocharger oil pipe 11-10 8. Turbocharger..... 11-11 8.1 Disassembling and inspecting turbocharger..... 11-11 8.1.1 Removing turbine housing 11-12 8.1.2 Removing compressor cover 11-12 8.1.3 Removing compressor wheel..... 11-13 8.1.4 Removing snap ring 11-13 8.1.5 Removing insert and oil deflector 11-13 8.1.6 Removing V-clamp..... 11-14 8.1.7 Removing shaft & turbine wheel 11-14 8.1.8 Removing snap ring and bearing 11-14 8.2 Cleaning..... 11-15 8.3 Inspecting turbocharger 11-17 8.3.1 Bearing housing 11-17	8.3.2 Bearing 11-17 8.3.3 Shaft & turbine wheel 11-18 8.4 Reassembling turbocharger 11-19 8.4.1 Installing shaft & turbine wheel and bearing..... 11-20 8.4.2 Installing thrust bearing 11-21 8.4.3 Installing O-ring 11-21 8.4.4 Installing oil deflector 11-21 8.4.5 Reassembling insert sub-assembly 11-22 8.4.6 Installing snap ring..... 11-22 8.4.7 Measuring clearance between shaft & turbine wheel and turbine housing..... 11-23 8.4.8 Installing compressor wheel 11-23 8.4.9 Measuring play of shaft & turbine wheel in axial direction 11-23 8.4.10 Measuring clearance between turbine backplate and back side of turbine wheel11-24 8.4.11 Installing compressor cover..... 11-24 8.4.12 Installing lock plate 11-24 8.4.13 Installing turbine housing..... 11-25
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1. Air duct (intercooler-to-turbocharger)

1.1 Disassembling and inspecting air duct



Air duct (intercooler-to-turbocharger)

Disassembling sequence

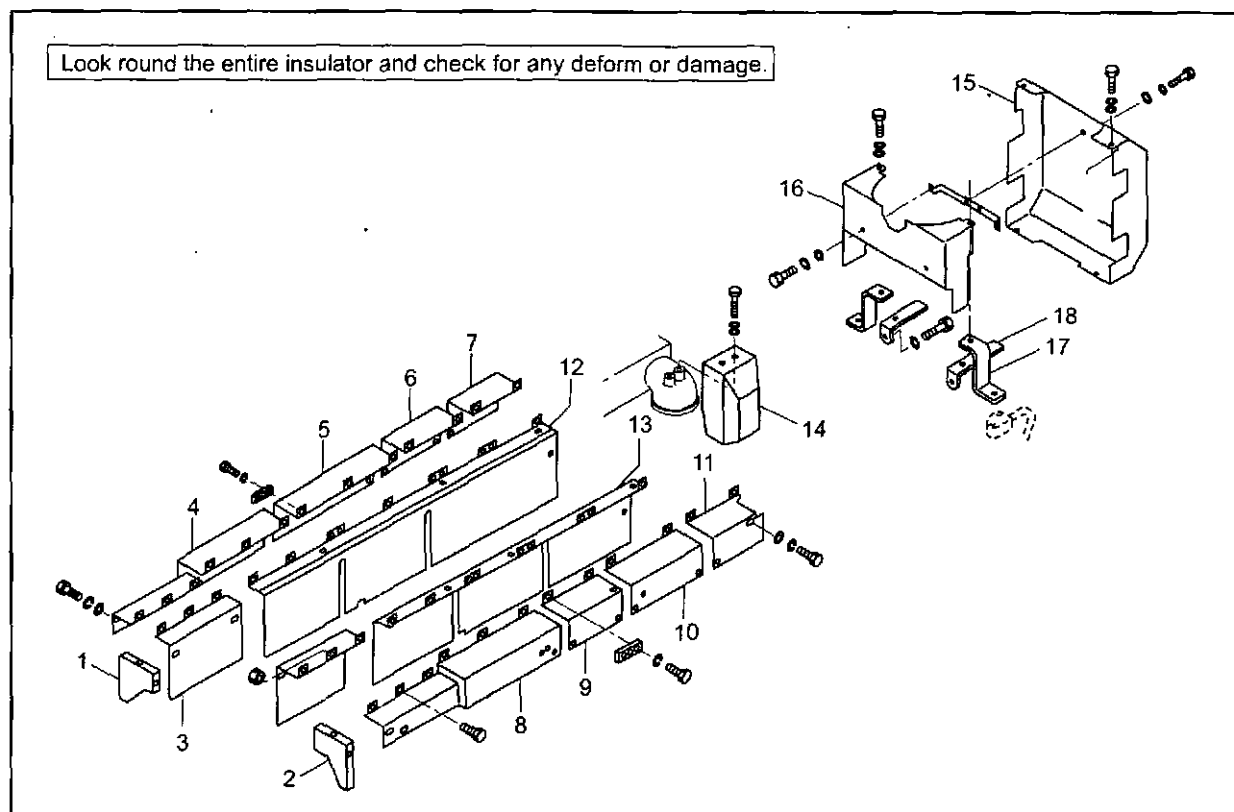
- | | | |
|---------------|------------------|-----------------|
| 1 Air duct | 5 Air duct | 9 Air duct stay |
| 2 Air duct | 6 Rubber hose | 10 Spacer |
| 3 Connector | 7 Rear air duct | 11 Spacer |
| 4 Rubber hose | 8 Front air duct | |

1.2 Reassembling air duct

To reassemble, follow the disassembly sequence in reverse.

2. Insulator

2.1 Disassembling and inspecting insulator



Disassembling and inspecting insulator

Disassembling sequence

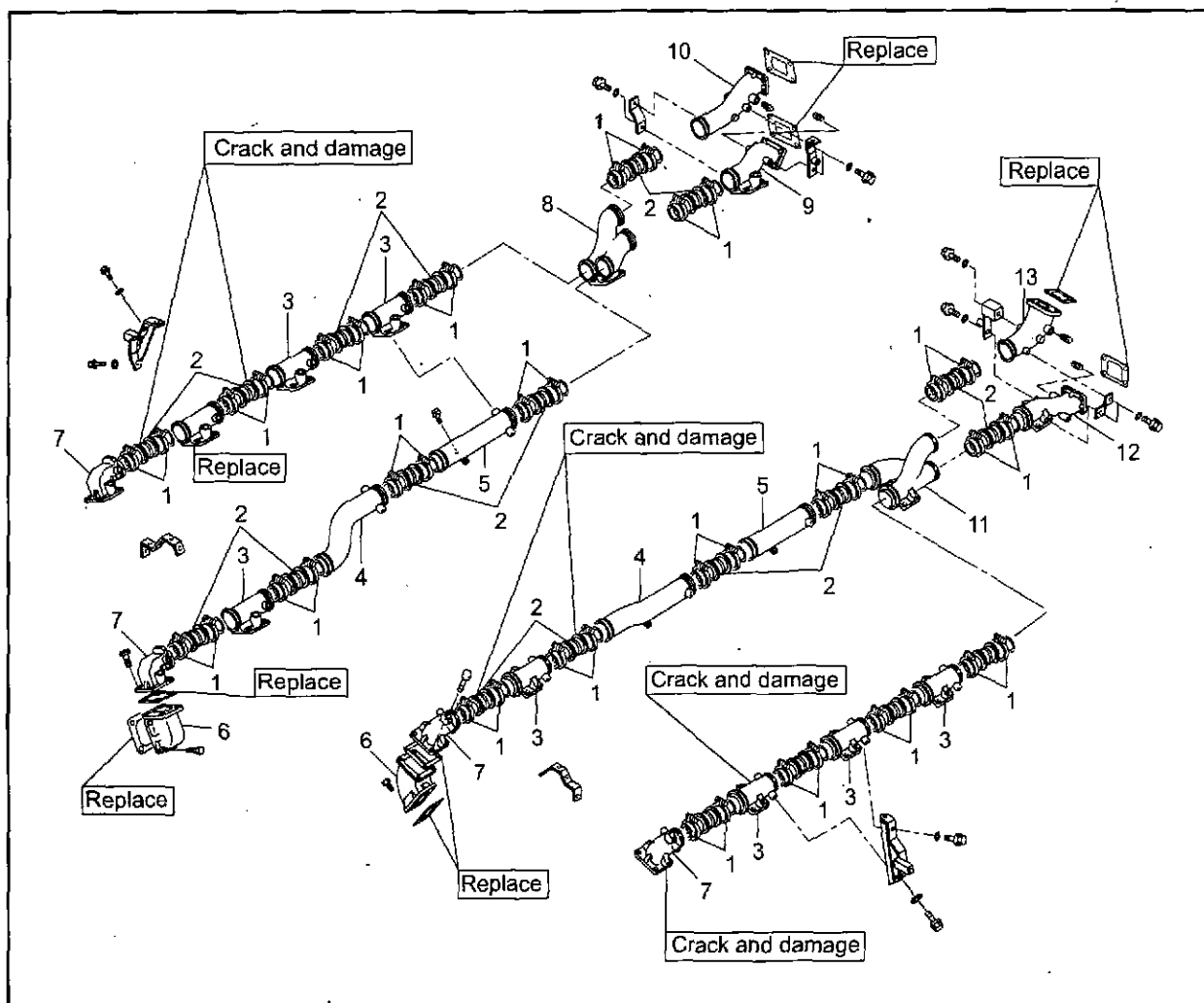
- | | |
|--------------------------------|---------------------------------|
| 1 Front cover (right side) | 10 Rear insulator (left side) |
| 2 Front cover (left side) | 11 Rear insulator (left side) |
| 3 Front insulator | 12 Rear insulator (right side) |
| 4 Front insulator (right side) | 13 Rear insulator (left side) |
| 5 Rear insulator (right side) | 14 Insulator |
| 6 Rear insulator (right side) | 15 Turbocharger insulator |
| 7 Rear insulator (right side) | 16 Turbocharger front insulator |
| 8 Front insulator (left side) | 17 Insulator stay |
| 9 Rear insulator (left side) | 18 Plate |

2.2 Reassembling insulator

To reassemble, follow the disassembly sequence in reverse.

3. Exhaust manifold

3.1 Disassembling and inspecting exhaust manifold



Disassembling and inspecting exhaust manifold

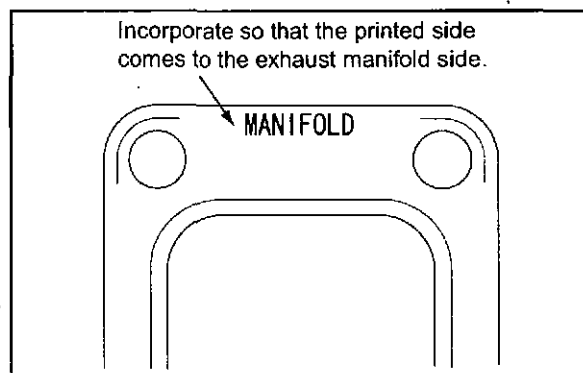
Disassembling sequence

- | | | |
|--------------------|---------------------|---------------------|
| 1 Coupling assy | 6 Connector | 11 Exhaust manifold |
| 2 Flexible joint | 7 Exhaust manifold | 12 Exhaust manifold |
| 3 Exhaust manifold | 8 Exhaust manifold | 13 Exhaust manifold |
| 4 Exhaust manifold | 9 Exhaust manifold | |
| 5 Exhaust manifold | 10 Exhaust manifold | |

3.2 Reassembling exhaust manifold

To reassemble, follow the disassembling sequence in reverse observing the followings:

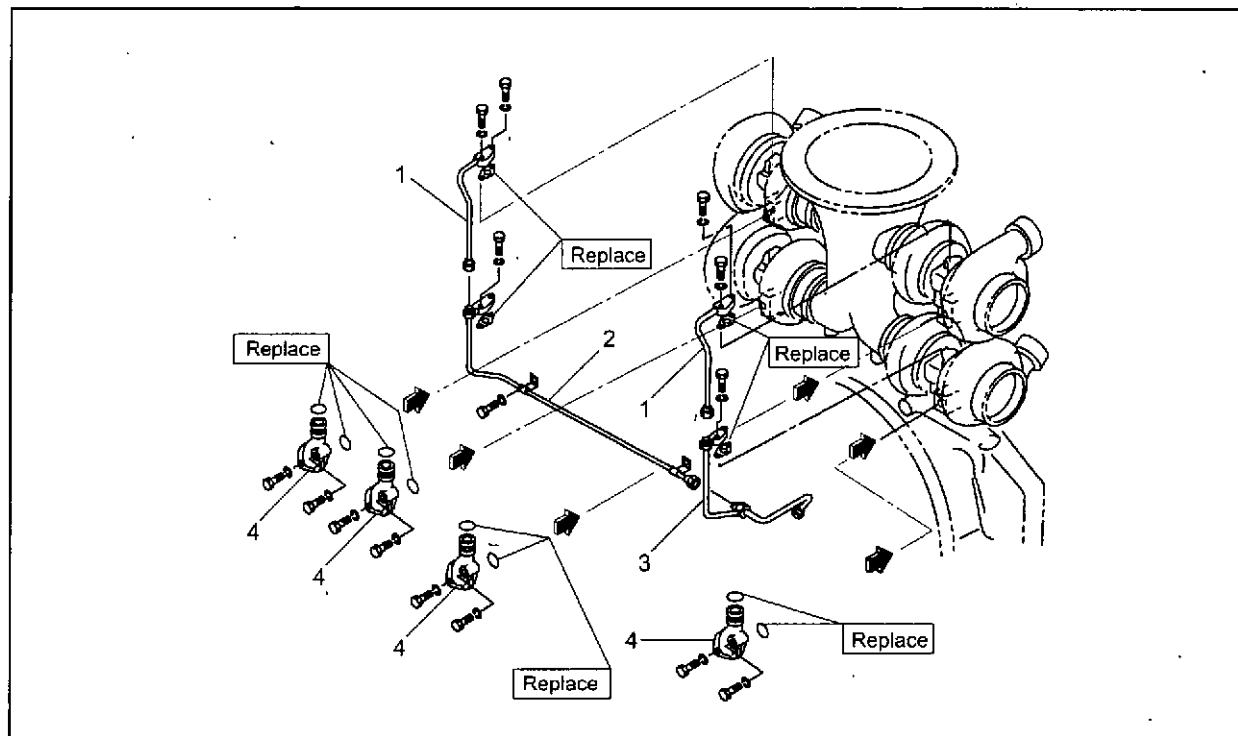
- Note: (a) Attach the exhaust gasket such that the side having letters stamped is oriented to the exhaust manifold.
- (b) When reassembling the exhaust manifold, always replace all pieces of the exhaust gasket with new ones.



Reassembling exhaust manifold

4. Turbocharger oil pipe

4.1 Disassembling and inspecting turbocharger oil pipe



Disassembling and inspecting turbocharger oil pipe

Disassembling sequence

1 Oil pipe

2 Oil pipe

3 Oil pipe

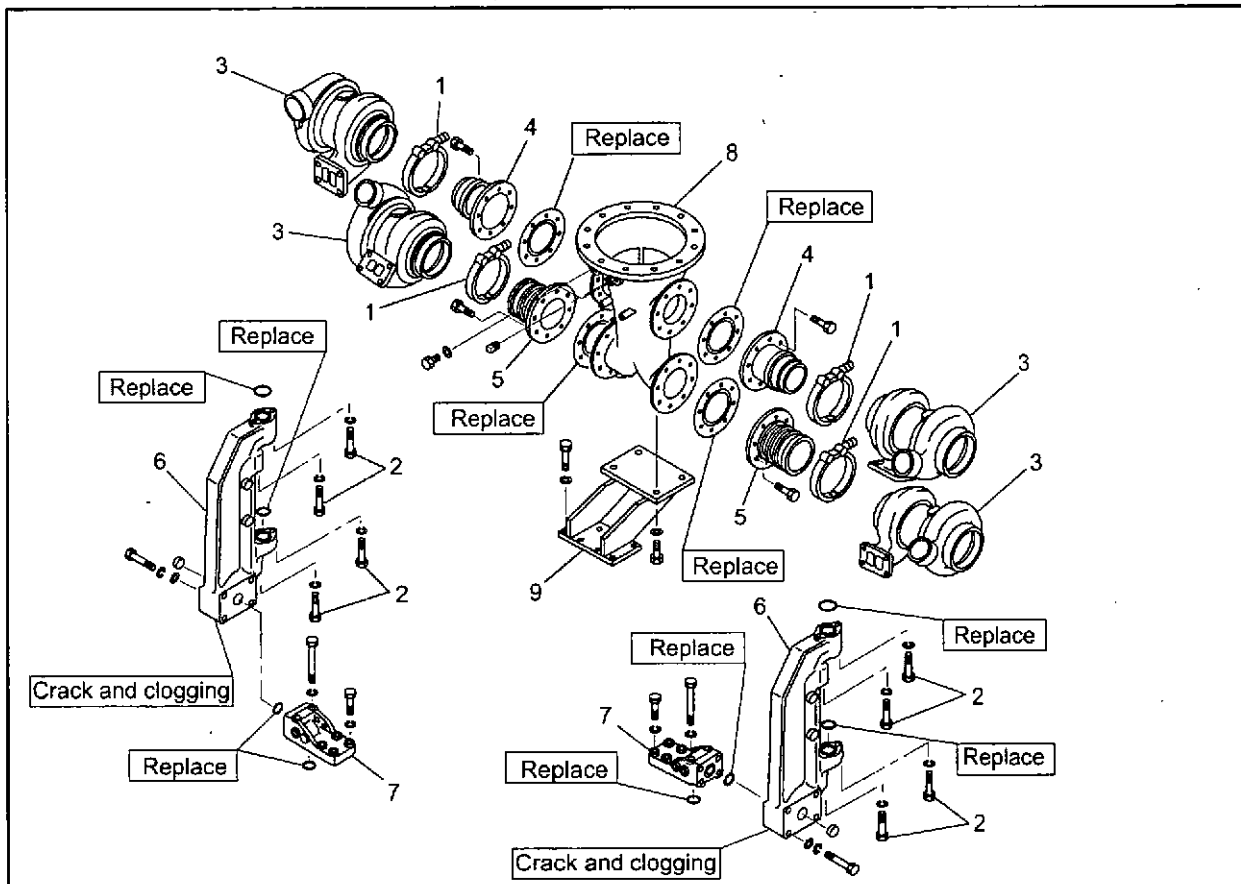
4 Drain connector

4.2 Reassembling turbocharger oil pipe

To reassemble, follow the disassembly sequence in reverse.

5. Exhaust pipe

5.1 Disassembling and inspecting exhaust pipe



Disassembling and inspecting exhaust pipe

Disassembling sequence

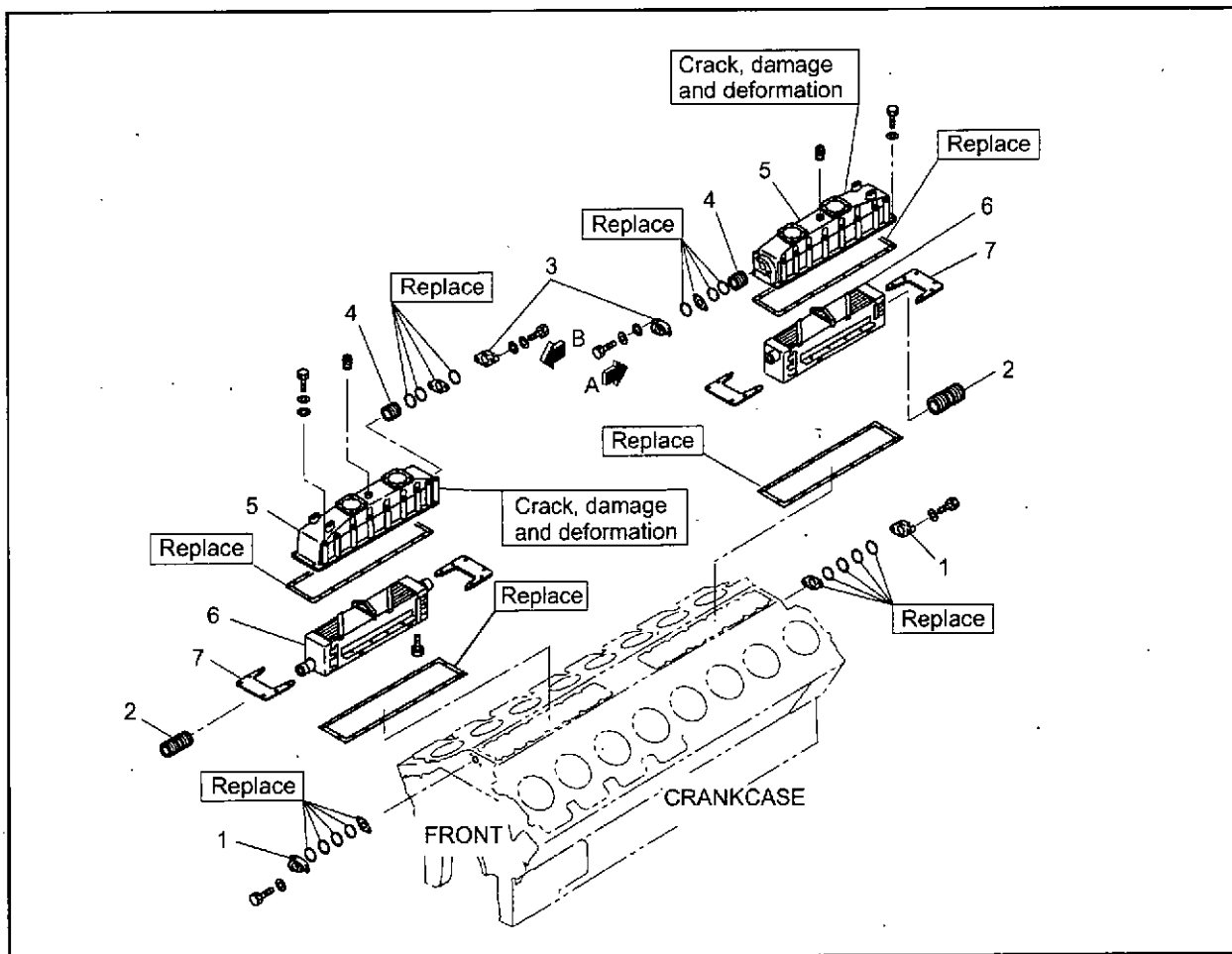
- | | | |
|----------------|------------------------|------------------------|
| 1 V-clamp | 4 Exhaust joint | 7 Turbocharger bracket |
| 2 Bolt | 5 Exhaust joint | 8 Exhaust pipe |
| 3 Turbocharger | 6 Turbocharger bracket | 9 Exhaust pipe bracket |

5.2 Reassembling exhaust pipe

To reassemble, follow the disassembly sequence in reverse.

6. Intercooler

6.1 Disassembling and inspecting intercooler



Disassembling and inspecting intercooler

Disassembling sequence

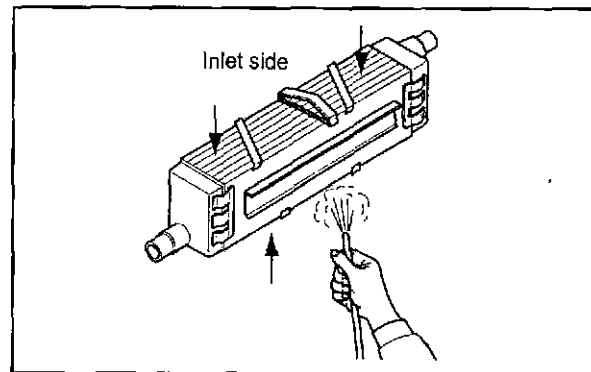
- | | |
|--------------------|--|
| 1 Connector | 5 Intercooler cover |
| 2 Intercooler pipe | 6 Intercooler element (weight: approx. 40kg [88.18 lb.]) |
| 3 Connector | 7 Plate |
| 4 Pipe | |

6.2 Cleaning intercooler

CAUTION

When handling sodium hydroxide (caustic soda) or soda lime, always use a hand protection such as rubber gloves.

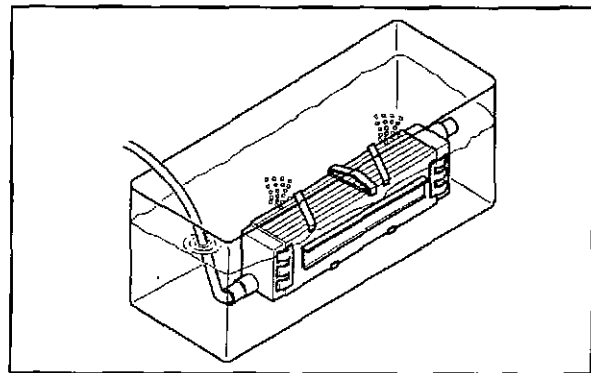
- (1) To remove the accumulation of dust and dirt, blow compressed air (at a pressure of 0.29 to 0.49 MPa {3 to 5 kgf/cm²} [43 to 71 psi]) through the intercooler in the opposite direction to the normal air flow. Then, inspect for corrosion and cracks.
- (2) Flush the coolant pipes thoroughly with water holding sodium hydroxide (caustic soda) or soda lime in solution to remove scales.



Cleaning intercooler

6.3 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.



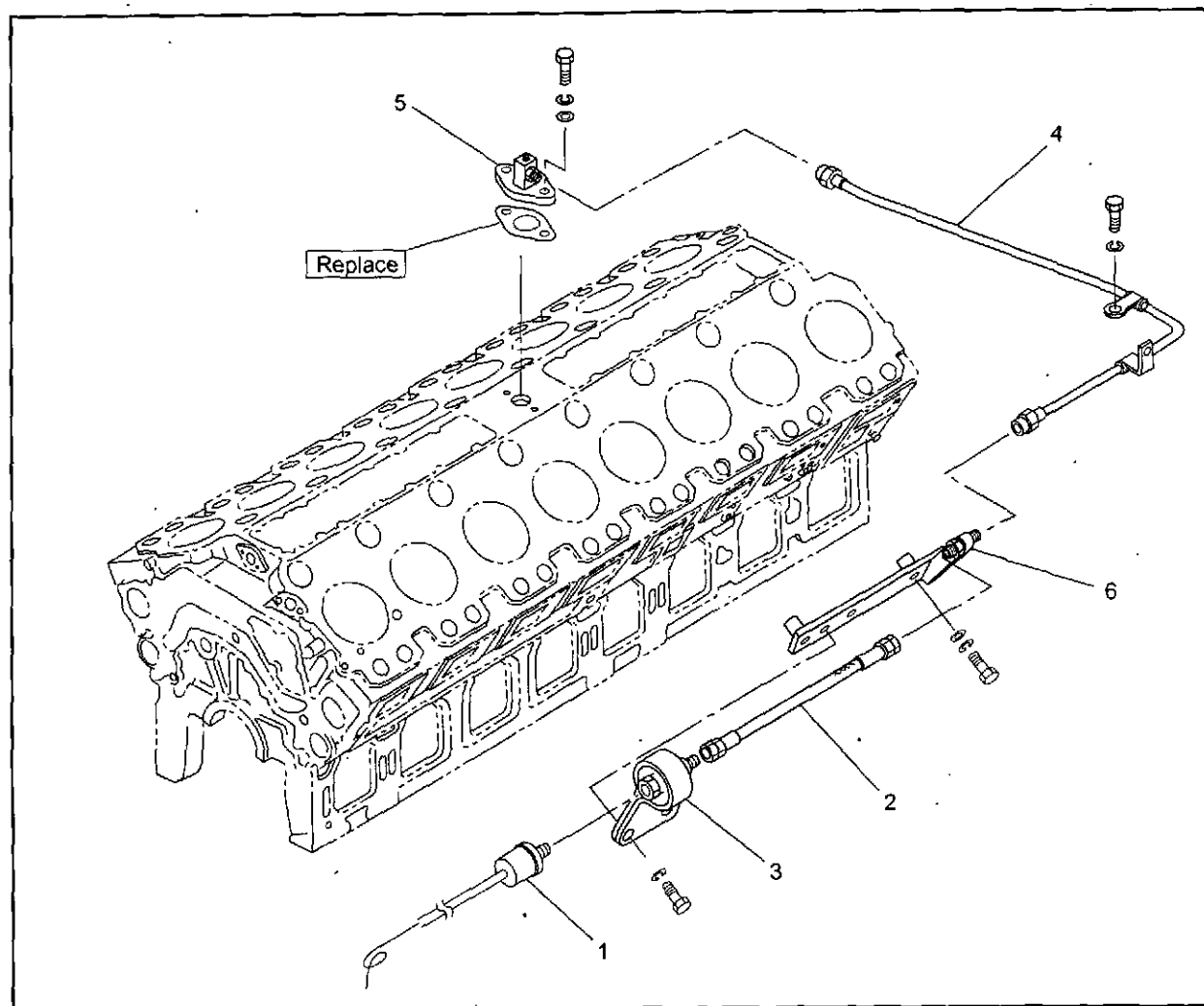
Inspecting intercooler for leakage

6.4 Reassembling air duct

To reassemble, follow the disassembly sequence in reverse.

7. Boost sensor pipe

7.1 Disassembling and inspecting boost sensor pipe



Disassembling and inspecting boost sensor pipe

Disassembling sequence

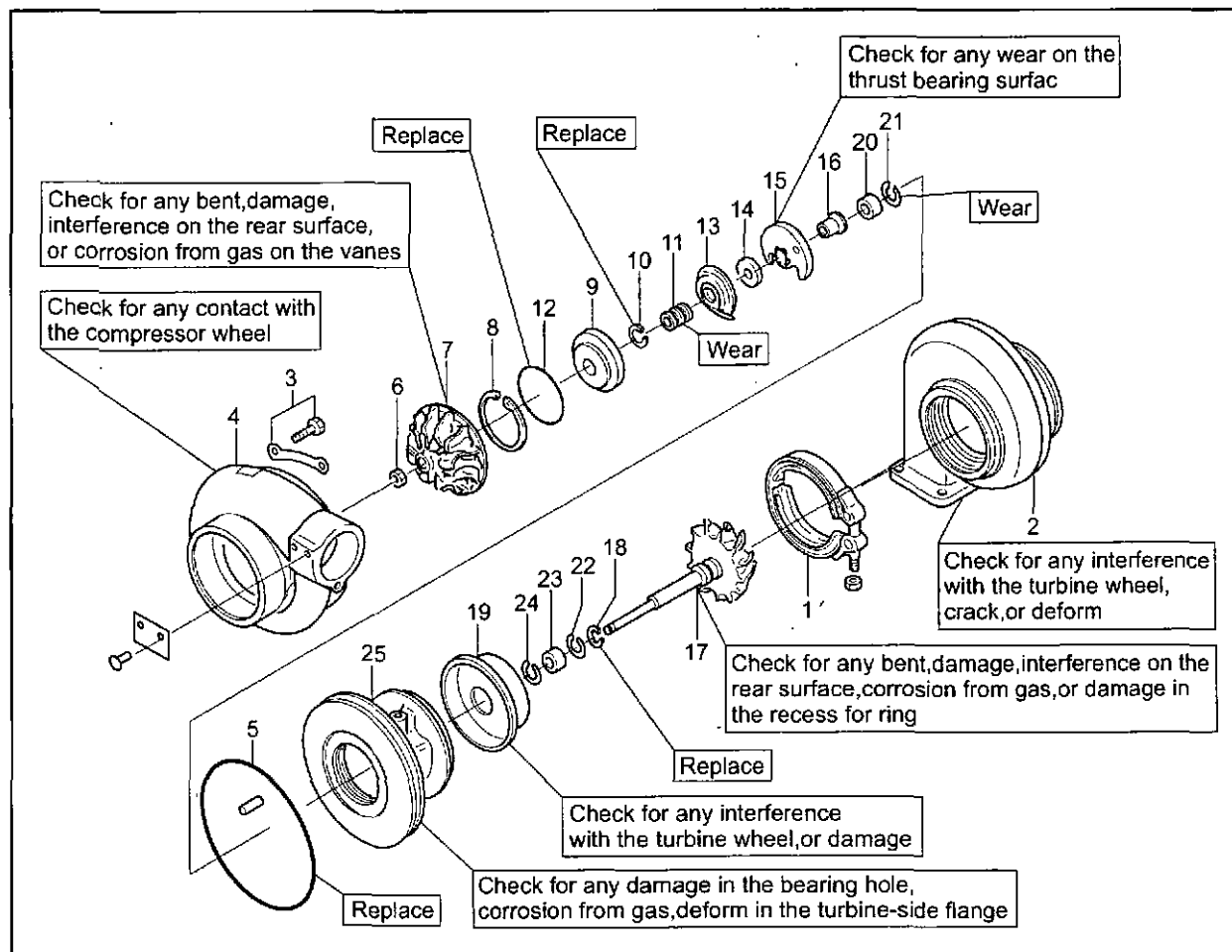
- | | |
|------------------|------------------------|
| 1 Boost sensor | 4 Boost pipe |
| 2 Flexible pipe | 5 Cover |
| 3 Pressure mount | 6 Boost sensor bracket |

7.2 Reassembling turbocharger oil pipe

To reassemble, follow the disassembly sequence in reverse.

8. Turbocharger

8.1 Disassembling and inspecting turbocharger



Disassembling and inspecting turbocharger

Disassembling sequence

- | | | | |
|--------------------|----------------------------------|-------------------------------|--------------------|
| 1 V-clamp | 8 Snap ring | 15 Thrust bearing | 22 Snap ring |
| 2 Turbine housing | 9 Insert | 16 Thrust ring (turbine side) | 23 Bearing |
| 3 Lock plate | 10 Piston ring | 17 Shaft & turbine wheel | 24 Snap ring |
| 4 Compressor cover | 11 Flinger sleeve | 18 Piston ring | 25 Bearing housing |
| 5 O-ring | 12 O-ring | 19 Turbine backplate | |
| 6 Lock nut | 13 Oil deflector | 20 Bearing | |
| 7 Compressor wheel | 14 Thrust ring (compressor side) | 21 Snap ring | |

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

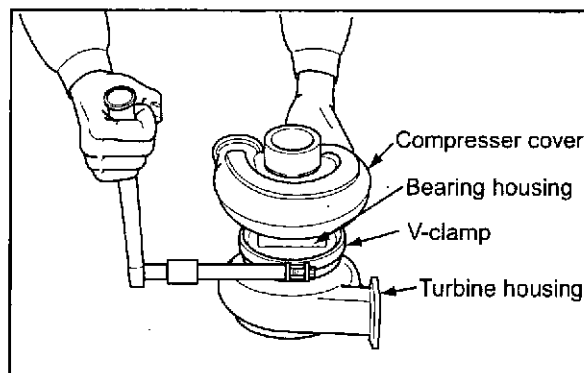
Carefully handle the compressor wheel and turbine wheel during disassembly and assembly, since vanes can easily bend when dropped or hit.

8.1.1 Removing turbine housing

CAUTION

Since it is important to ensure proper positioning of compressor cover, bearing housing and turbine housing in reassembly, be sure to place alignment marks with a punch or marker.

- (1) Use the box wrench to reduce the tension of the V-clamp.
- (2) Remove V-clamp and turbine housing from turbocharger.



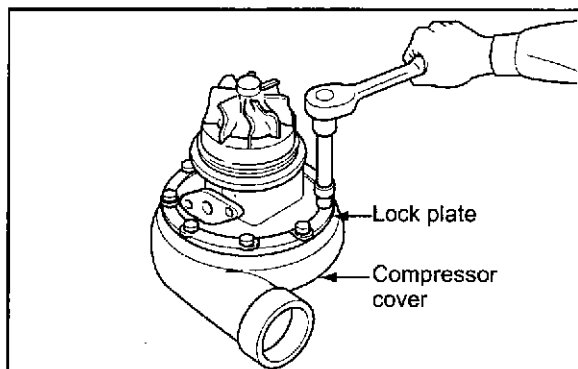
Preparing for disassembly

8.1.2 Removing compressor cover

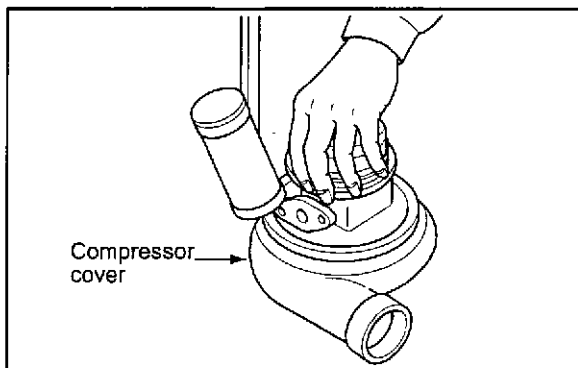
CAUTION

Be careful not to hit the compressor wheel against the compressor cover.

- (1) Place the turbocharger on a work bench with the compressor cover facing down. Unscrew bolts, and remove lock plate.
- (2) Lightly tap the entire periphery of compressor cover with a soft hammer, and remove the compressor cover. Remove O-ring from the bearing housing.



Removing compressor cover (1)

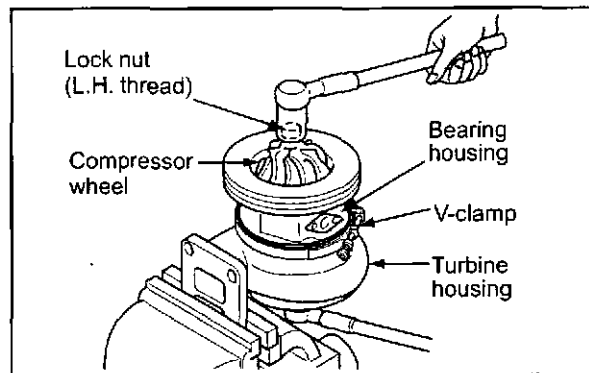


Removing compressor cover (2)

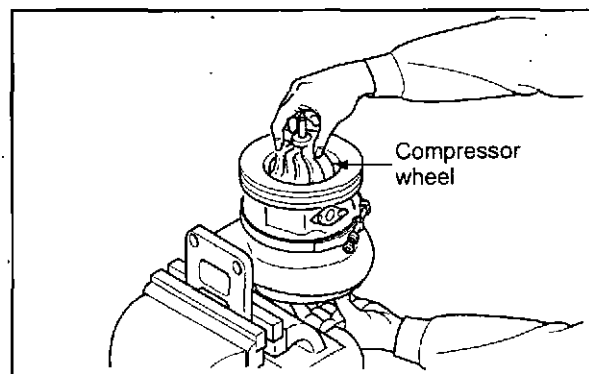
8.1.3 Removing compressor wheel

⚠ 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.
 - (2) Hold the turbine wheel by one hand, and remove the compressor wheel by *lightly turning it*.



Removing compressor wheel (1)



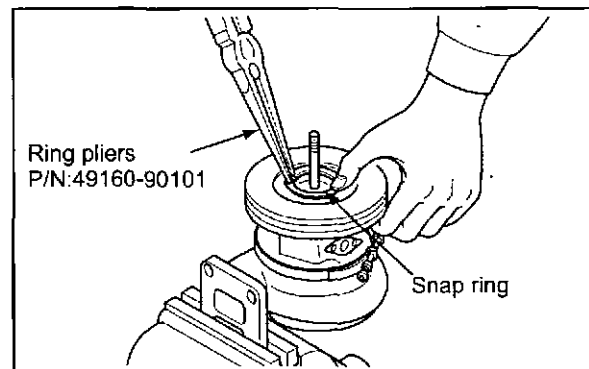
Removing compressor wheel (2)

8.1.4 Removing snap ring

⚠ CAUTION

Put a thumb on the snap ring to prevent it from flying out in case pliers lose grip.

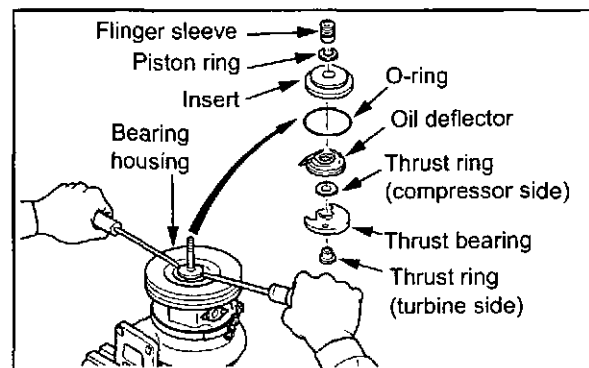
Using the ring pliers, remove the snap ring.



Removing snap ring

8.1.5 Removing insert and oil deflector

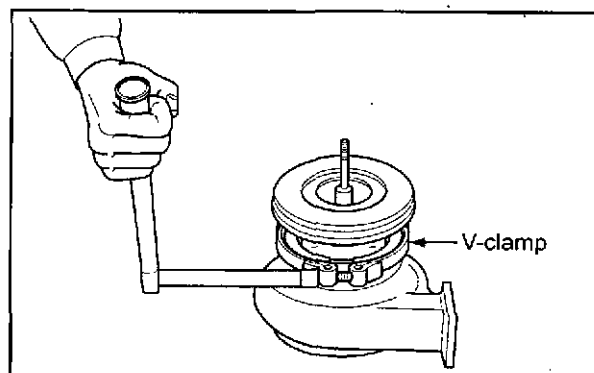
- (1) Using two screwdrivers, gently pry out the insert from the bearing housing.
- (2) Separate the flinger sleeve together with the piston ring from the insert.
- (3) Remove the following parts from the bearing housing.
 - O-ring
 - Oil deflector
 - Thrust ring (compressor side)
 - Thrust bearing
 - Thrust ring (turbine side)



Removing insert and oil deflector

8.1.6 Removing V-clamp

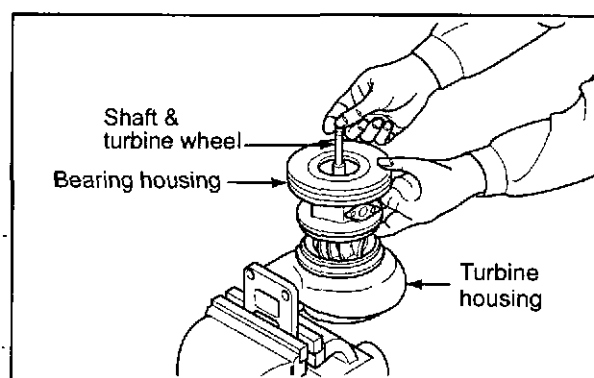
Loosen the V-clamp with a socket wrench, and dislodge the V-clamp from its clamping position.



Removing V-clamp

8.1.7 Removing shaft & turbine wheel

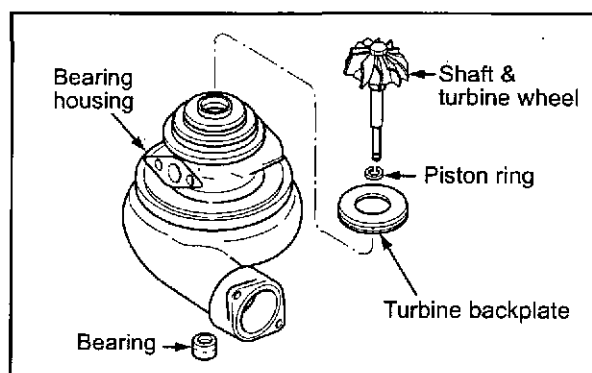
- (1) While gripping the shaft of the shaft & turbine wheel with one hand, hold the bearing housing with the other hand and slowly remove the shaft & turbine wheel from the turbine housing.



Removing shaft & turbine wheel (1)

- (2) 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)

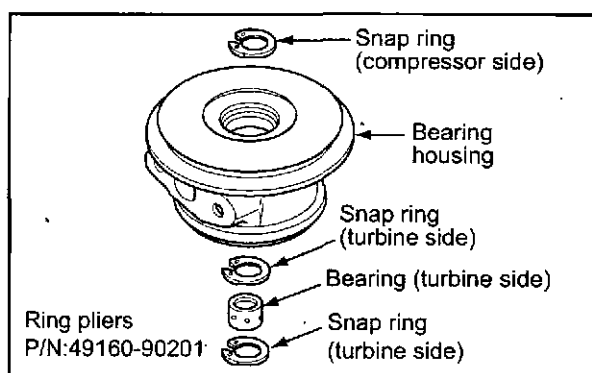
8.1.8 Removing snap ring and bearing

CAUTION

- (a) Use the ring 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

8.2 Cleaning

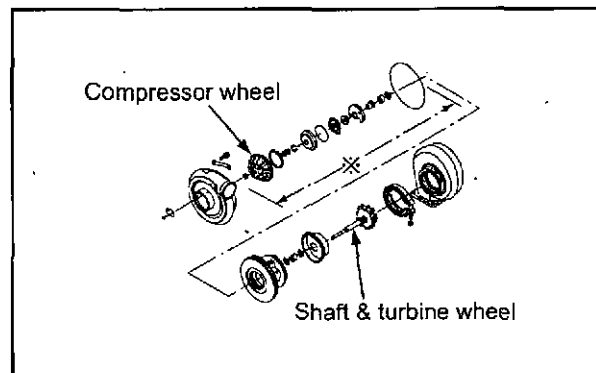
CAUTION

- (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:

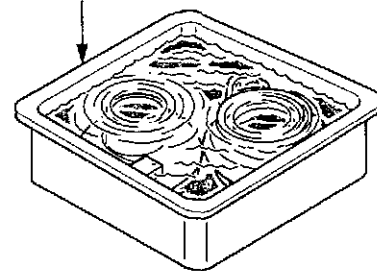
Note: On this shot blast do not blast over such parts as included in the section marked with an * in the figure, both end surfaces of the Compressor Wheel, and shaft section of the Shaft & Turbine Wheel.

- (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.

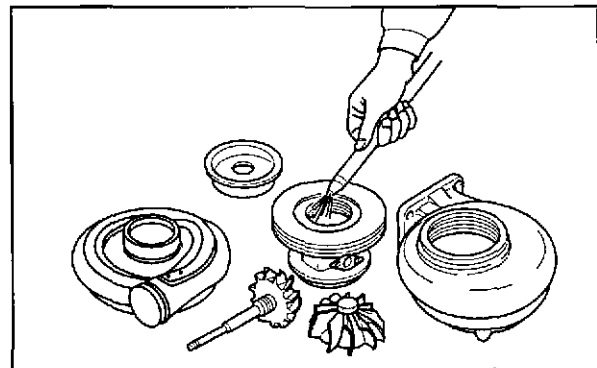


Cleaning procedure of turbocharger

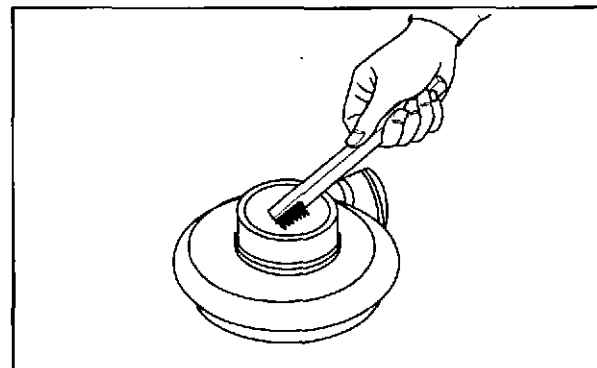
Combined use with an ultrasonic cleaning unit can help to remove the contaminants easily.



Cleaning turbocharger

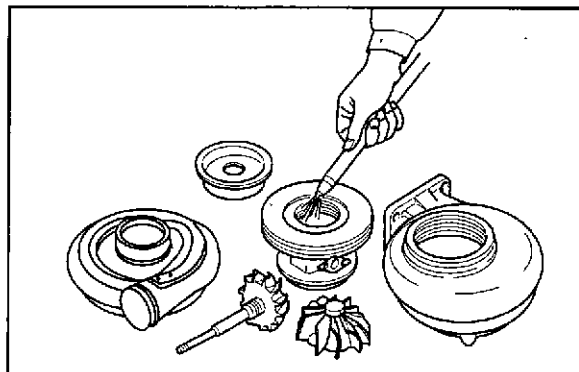


Blowing of compressed air



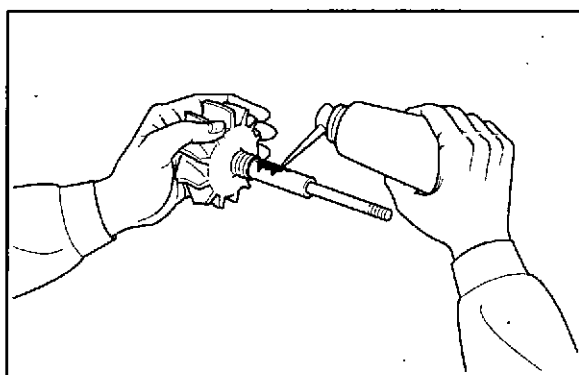
Cleaning of the attachments

- (5) Blow a clean compressed air over the inside and outside surfaces again.



Blowing of compressed air

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

8.3 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.

8.3.1 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.]

8.3.2 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.]

(2) Measuring bearing inside diameter

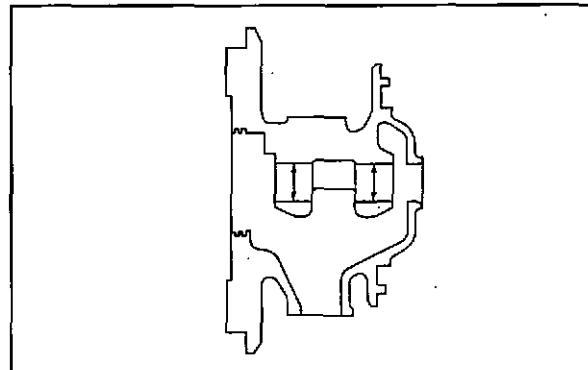
If the measured diameter exceeds the service limit, replace the bearing.

Item	Limit
Bearing inside diameter	18.046 mm [0.7105 in.]

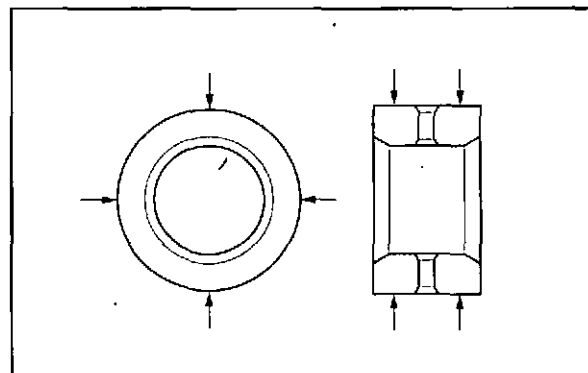
(3) Measuring bearing length

If the measured length is less than the service limit, replace the bearing.

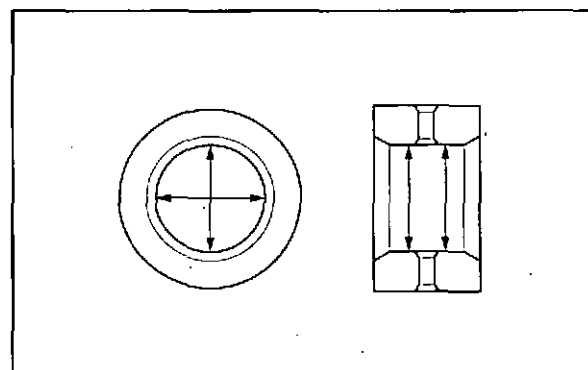
Item	Limit
Bearing length	17.440 mm [0.6866 in.]



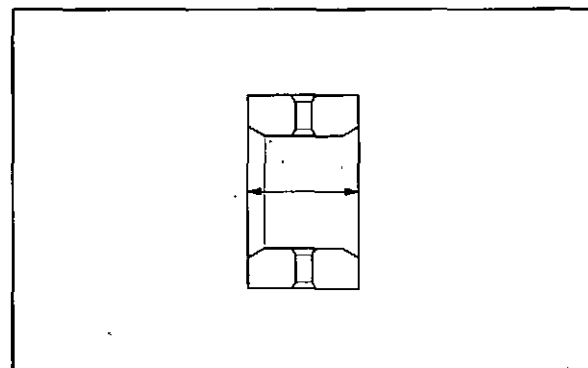
Measuring inside diameter of bearing-fitted section



Measuring bearing outside diameter



Measuring bearing inside diameter



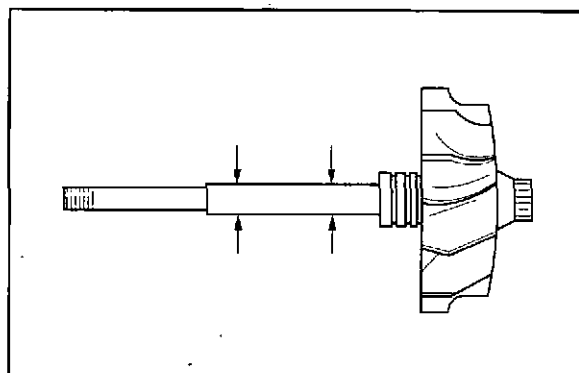
Measuring bearing length

8.3.3 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 the shaft & turbine wheel

(2) Measuring shaft runout

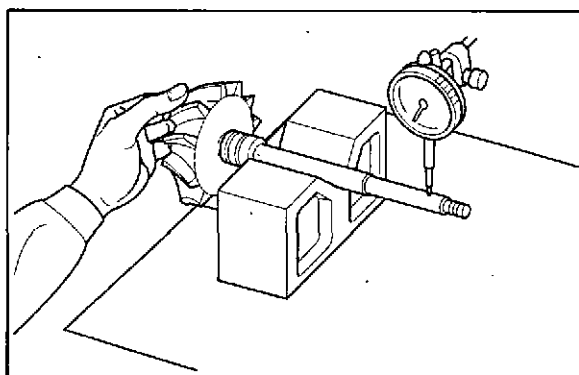
CAUTION

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.



Measuring shaft runout

Item	Limit
Shaft runout	0.015 mm [0.0006 in.]

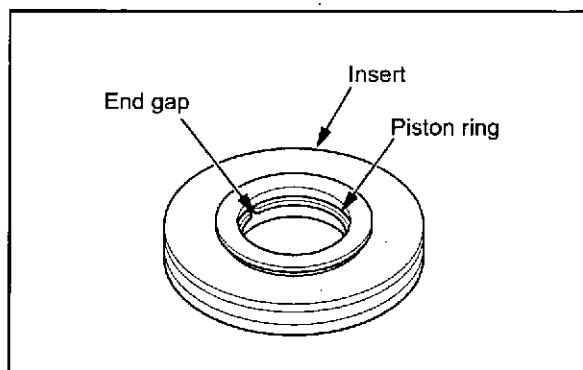
8.3.4 Insert

Measuring piston ring end gap

Install a new piston ring squarely in the insert, then measure the piston ring end gap.

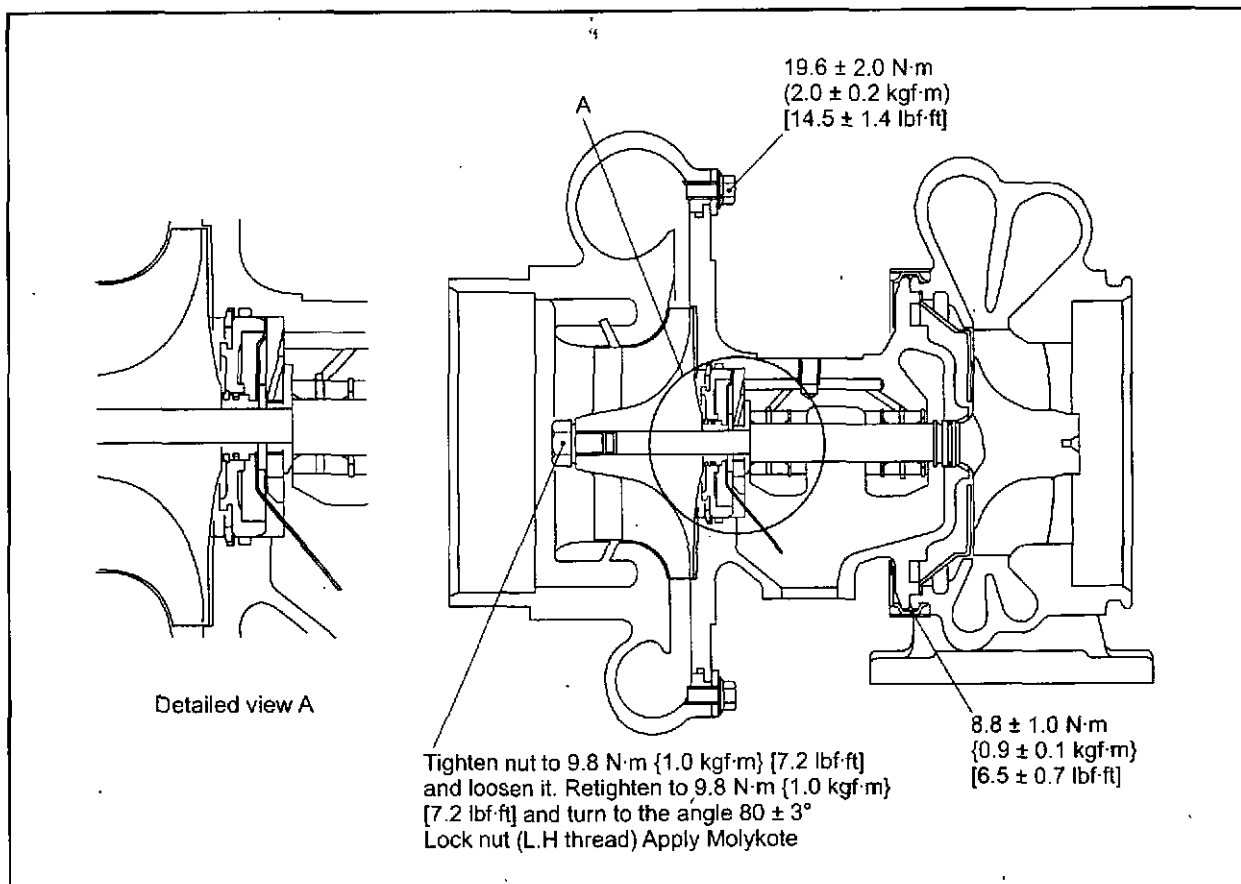
If the end gap deviates from the assembly standard, replace the insert.

Item	Standard
Ring end gap	0.05 to 0.25 mm [0.0020 to 0.0098 in.]



Measuring piston ring end gap

8.4 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

- If vanes are damaged or cracked, do not reuse the part.
- If only one vane is slightly bent or scratched, the part can be reused. However, do not attempt to correct the bend.

8.4.1 Installing shaft & turbine wheel and bearing

CAUTION

- 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.
- Apply engine oil to the outside and inside surfaces of the bearing before installation.
- Do not expand the piston ring excessively or twist the ends when installing on the shaft & turbine wheel.
- After installing the piston ring in the ring groove, apply Molykote to the ring before assembly.
- The piston rings on the turbine side and compressor side are identical.
- Do not apply excessive force without centering the shaft properly during the installation of the shaft & turbine wheel.

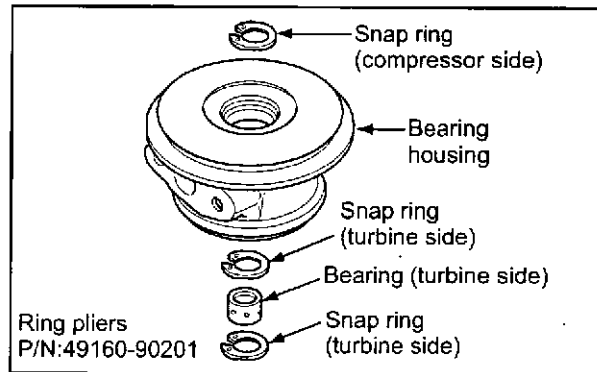
- Install the following parts.

Bearing housing
Snap ring (turbine side)
Bearing (turbine side)
Snap ring (compressor side)

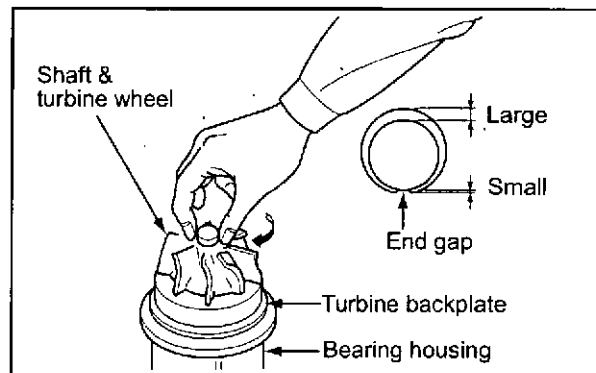
- Place the bearing housing on the compressor cover, and install the turbine backplate.
- Insert the piston ring into the groove on the shaft & turbine wheel.
- When installing the shaft & turbine wheel mounted with the piston ring in the bearing housing, position the ring on the shaft as shown in the drawing, and insert the shaft & turbine wheel while rotating.
- 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.

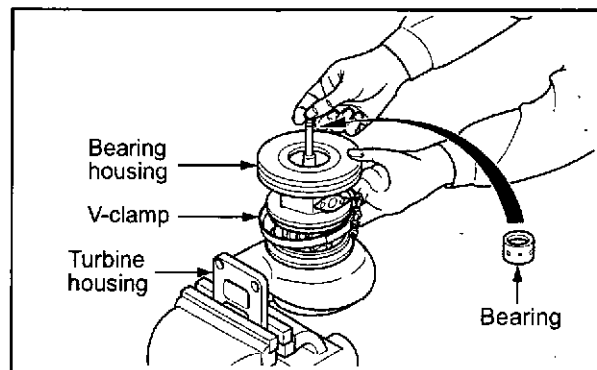
After the assembly was completed, mount the bearing housing on the turbine housing and tighten the bolts and clamp plates temporarily.



Installing shaft & turbine wheel and bearing (1)



Installing shaft & turbine wheel and bearing (2)

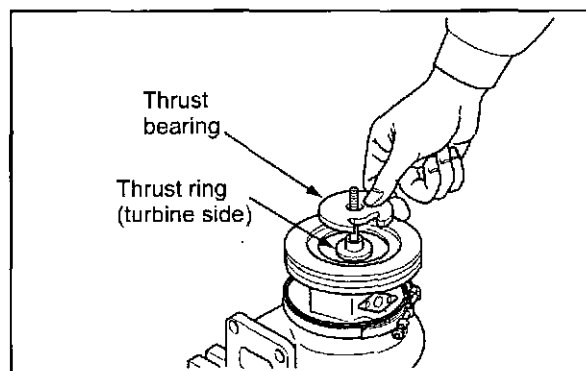


Installing shaft & turbine wheel and bearing (3)

8.4.2 Installing thrust bearing

Apply engine oil to both sides of the thrust ring and thrust bearing.

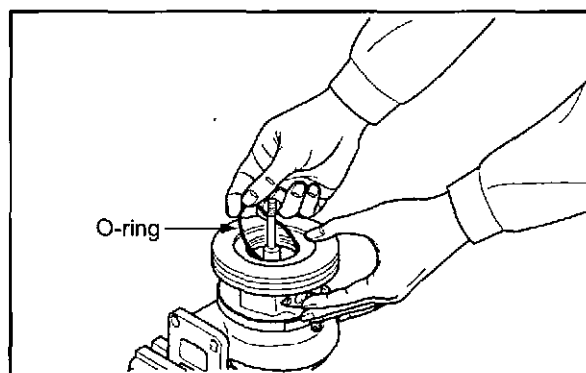
To install the thrust bearing, align the notch to the groove pin.



Installing thrust ring

8.4.3 Installing O-ring

Apply grease to O-ring, and install.

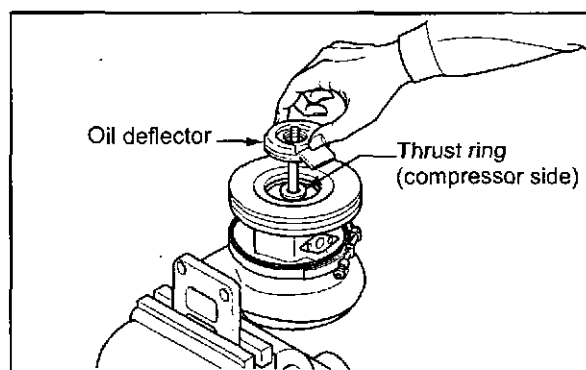


Installing O-ring

8.4.4 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

8.4.5 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 finger sleeve, then install on the insert carefully so as to avoid piston ring damage.

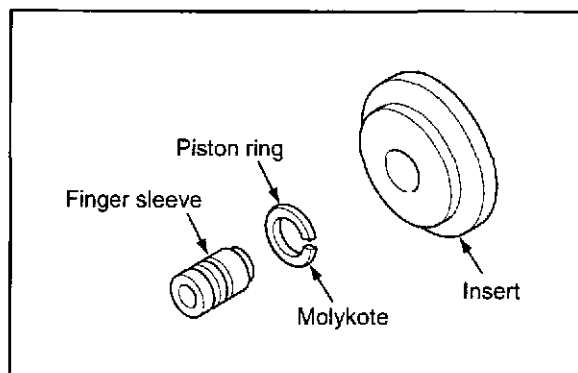
- (1) Install the following parts to the insert.

Finger sleeve

Piston ring

Insert

- (2) After installing the above parts, install the sub-assembly in the bearing housing.



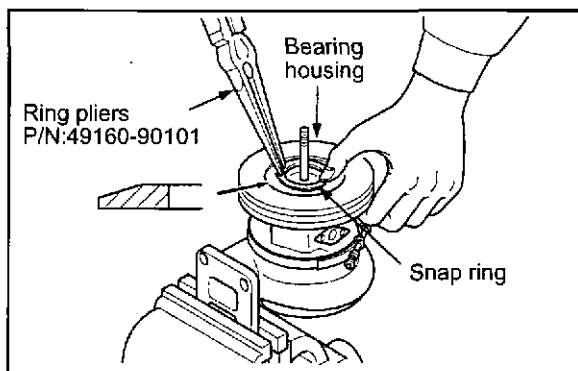
Reassembling insert sub-assembly

8.4.6 Installing snap ring

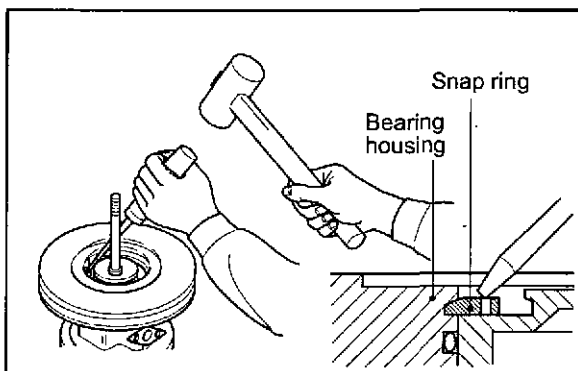
CAUTION

- (a) Be sure to install the special tool 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 ring pliers.



Installing snap ring (1)



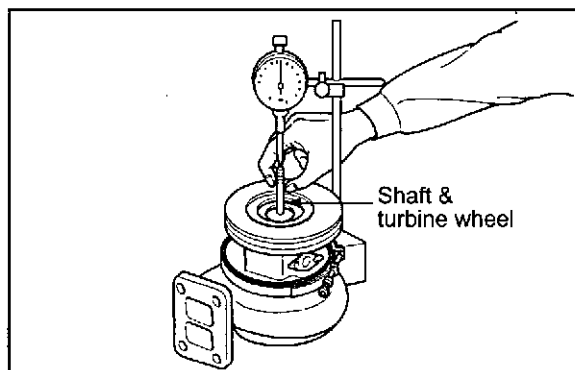
Installing snap ring (2)

8.4.7 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.]



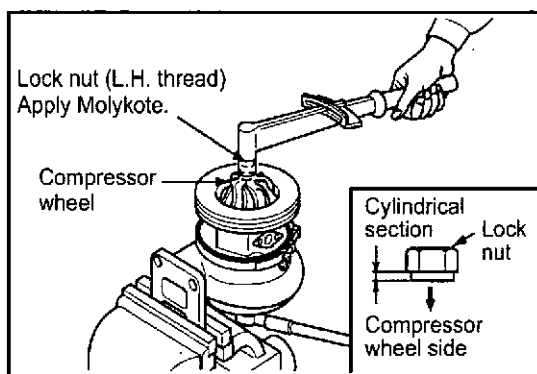
Measuring clearance between the shaft & turbine wheel and turbine housing

8.4.8 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 $80 \pm 3^\circ$.



Installing compressor wheel

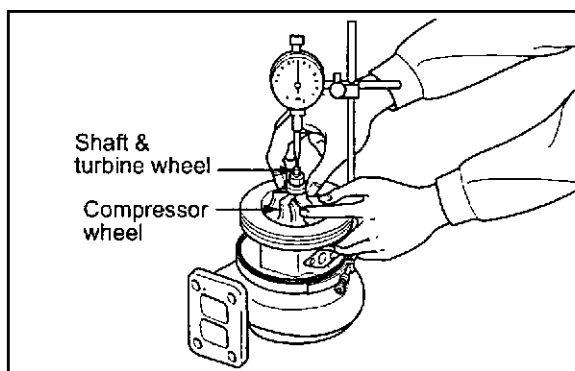
8.4.9 Measuring play of shaft & turbine wheel in axial direction

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 the shaft & turbine wheel in the axial direction

8.4.10 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.

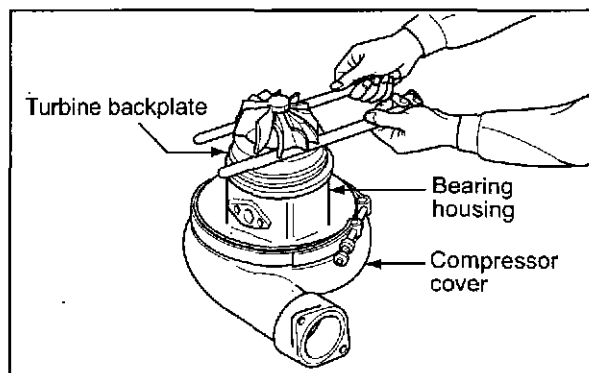
Remove the turbine housing from the bearing housing.

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.

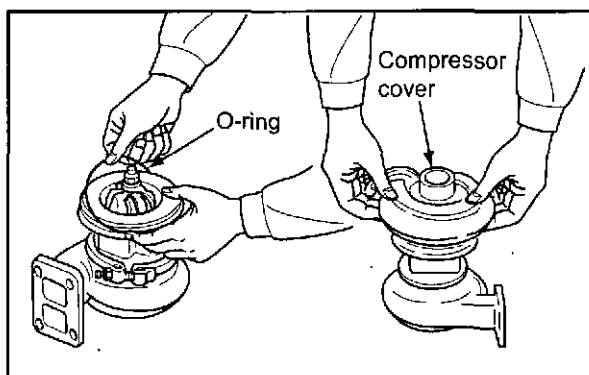
Item	Standard
Clearance between turbine backplate and back side of turbine wheel	0.65 to 1.25 mm [0.0256 to 0.0492 in.]



Measuring clearance between the turbine backplate and the backside of the turbine wheel

8.4.11 Installing compressor cover

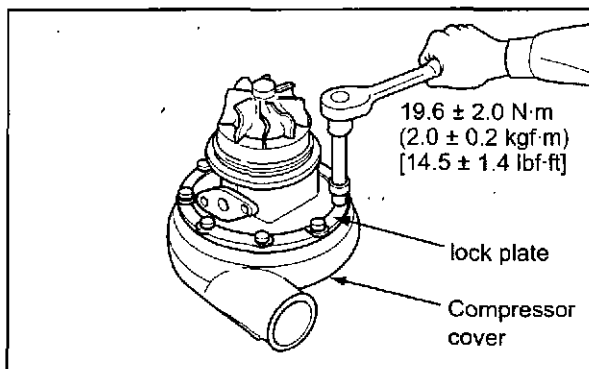
Check the mounting direction of the compressor cover, then install.



Installing turbine housing

8.4.12 Installing lock plate

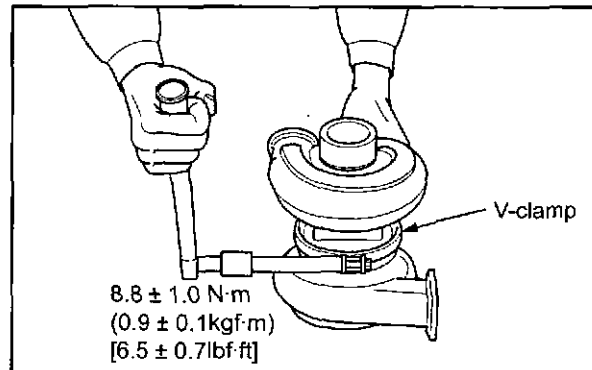
Install the lock plate and tighten the bolts to the specified torque.



Installing O-ring

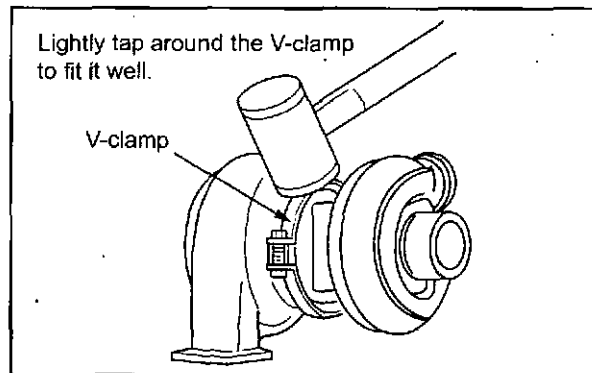
8.4.13 Installing turbine housing

- (1) Install the turbine housing to the bearing housing by lining up the match marks put during disassembly.
- (2) Apply molykote to the threads of the V-clamp and tighten its nut to the specified torque.



Installing compressor cover

- (3) Lightly tap around the V-clamp with a soft-faced hammer to fit the V-clamp well with the parts clamped.
- (4) Then, retighten the V-clamp nut to the specified torque.



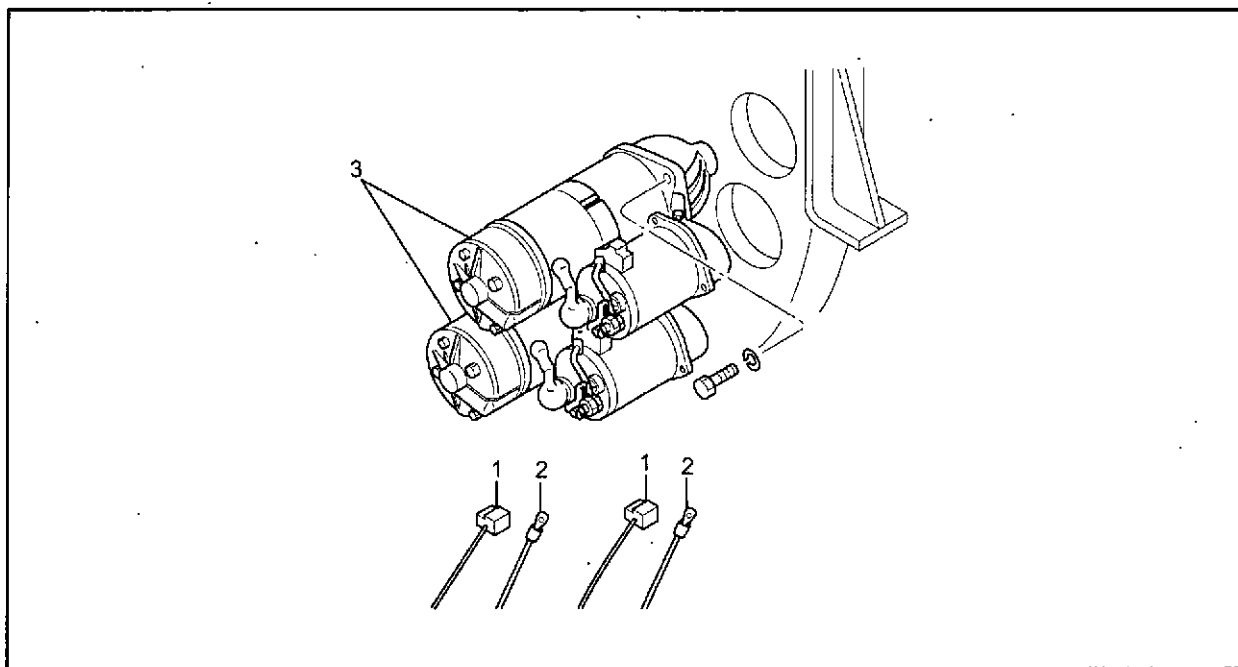
Installing lock plate

ELECTRICAL SYSTEM

1. Removing electrical system 12-2 1.1 Removing starter..... 12-2 1.2 Inspecting before removing alternator ... 12-3 1.2.1 Inspecting alternator operation..... 12-3 1.2.2 Handling precaution 12-3 1.3 Removing alternator..... 12-4 2. Disassembling, Inspecting and reassembling electrical system 12-5 2.1 Disassembling and inspecting starter 12-5 2.1.1 Removing magnet switch..... 12-6 2.1.2 Removing rear bracket..... 12-6 2.1.3 Removing armature and yoke assembly .. 12-6 2.1.4 Removing center bracket 12-7 2.1.5 Removing pinion set..... 12-7 2.2 Inspecting and correcting starter..... 12-8 2.2.1 Inspecting continuity of magnet switch (between M terminal and case)..... 12-8 2.2.2 Inspecting magnet switch function 12-8 2.2.3 Inspecting magnet switch contact point ... 12-8 2.2.4 Measuring armature shaft runout..... 12-9 2.2.5 Inspecting commutator radial runout..... 12-9 2.2.6 Measuring undercut depth 12-9 2.2.7 Measuring commutator outside diameter. 12-9 2.2.8 Inspecting armature coil 12-10 2.2.9 Inspecting continuity of yoke assembly .. 12-10 2.2.10 Inspecting overrunning clutch 12-10 2.2.11 Inspecting brushes for wear 12-11 2.2.12 Measuring brush spring load..... 12-11 2.2.13 Inspecting safety switch 12-11 2.3 Reassembling starter..... 12-12 2.3.1 Installing pinion shaft..... 12-12 2.3.2 Installing lever and pinion shaft..... 12-12 2.3.3 Installing armature, yoke, brush and brush holder 12-13 2.3.4 Installing rear bracket..... 12-13 2.3.5 Measuring armature end play 12-14 2.3.6 Measuring pinion shaft end play 12-14 2.3.7 Measuring pinion gear retraction length. 12-14 2.3.8 Installing magnetic switch 12-14 2.4 Disassembling and inspecting alternator 12-15 2.4.1 Separating front bracket from stator..... 12-16 2.4.2 Removing pulley..... 12-16 2.4.3 Removing rear bearing..... 12-16 2.4.4 Removing front bearing..... 12-16 2.4.5 Removing stator 12-17 2.4.6 Removing regulator assembly..... 12-17 2.4.7 Removing rectifier assembly 12-17 2.5 Inspecting and repairing alternator 12-18	2.5.1 Inspecting rectifier 12-18 2.5.2 Inspecting armature..... 12-18 2.5.3 Inspecting stator 12-19 2.5.4 Inspecting brushes for wear 12-19 2.5.5 Replacing brushes..... 12-20 2.6 Reassembling alternator 12-21 2.6.1 Installing rectifier assembly and regulator assembly 12-22 2.6.2 Installing stator 12-22 2.6.3 Installing front bearing 12-22 2.6.4 Installing rear bearing 12-23 2.6.5 Installing pulley 12-23 2.6.6 Assembling stator and front bracket 12-23 3. Reinstalling electrical system..... 12-24 3.1 Installing starter..... 12-24 3.2 Installing alternator..... 12-24
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1. Removing electrical system

1.1 Removing starter



Removing starter

Removing sequence

1 Harness

2 Harness

3 Starter.

1.2 Inspecting before removing alternator

1.2.1 Inspecting alternator operation

Locate the cause of faulty charging from malfunctions described below. Do not remove the alternator for inspection and repair unless inspection cannot be performed with the alternator installed on the engine.

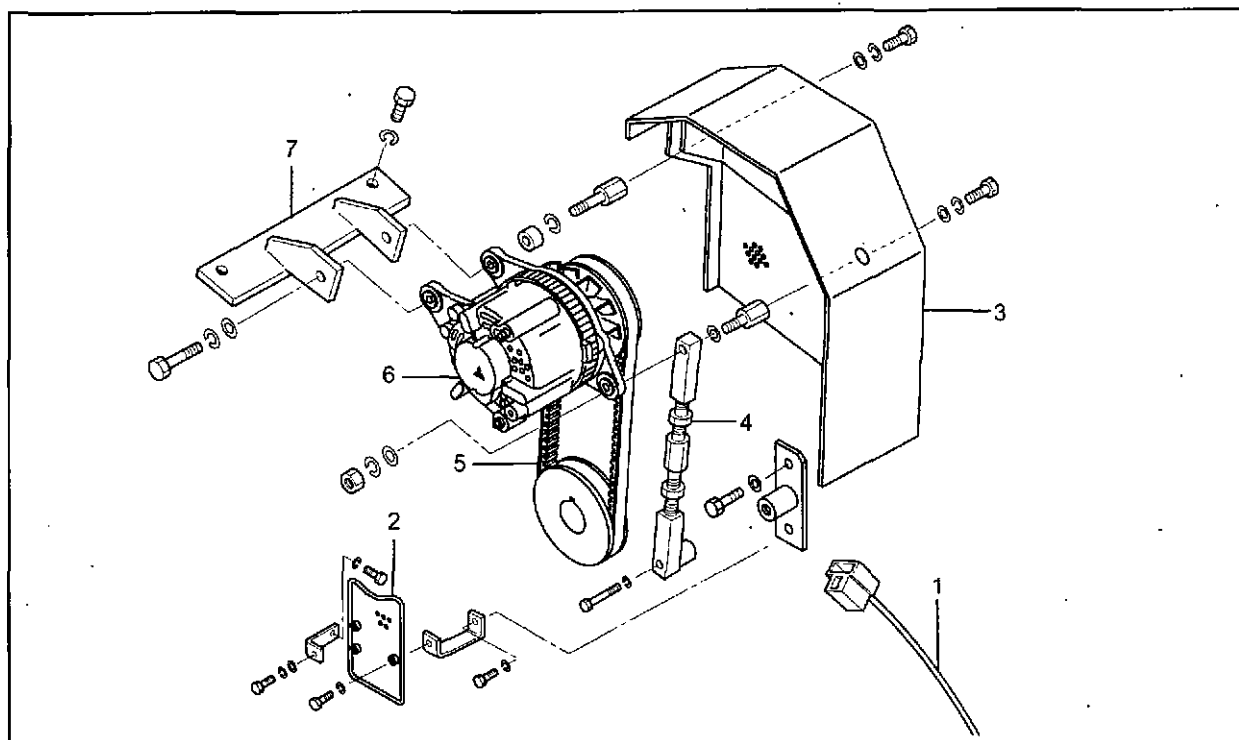
Overcharge	Adjusted value of voltage regulator is high.
	Faulty battery.
Over discharge	Low adjusted value of voltage relay.
	Faulty alternator output.
	Electric power consumption is extremely high.
	Special load is used.
	Faulty wiring.

1.2.2 Handling precaution

Improper handling could cause damage or failure to the alternator.

- (1) Connect battery cables correctly. The (-) cable is for grounding.
- (2) Do not use any high voltage tester such as megger.
- (3) Disconnect battery cables before recharging.
- (4) Do not disconnect lead wire from B terminal of the alternator while the engine is running.
- (5) Battery voltage is constantly applied to B terminal of the alternator. Do not ground at this terminal.
- (6) Do not short circuit or ground at L terminal. (For a built-in IC regulator type)
- (7) When a steam cleaner is used, do not allow the steam directly contact the alternator.

1.3 Removing alternator



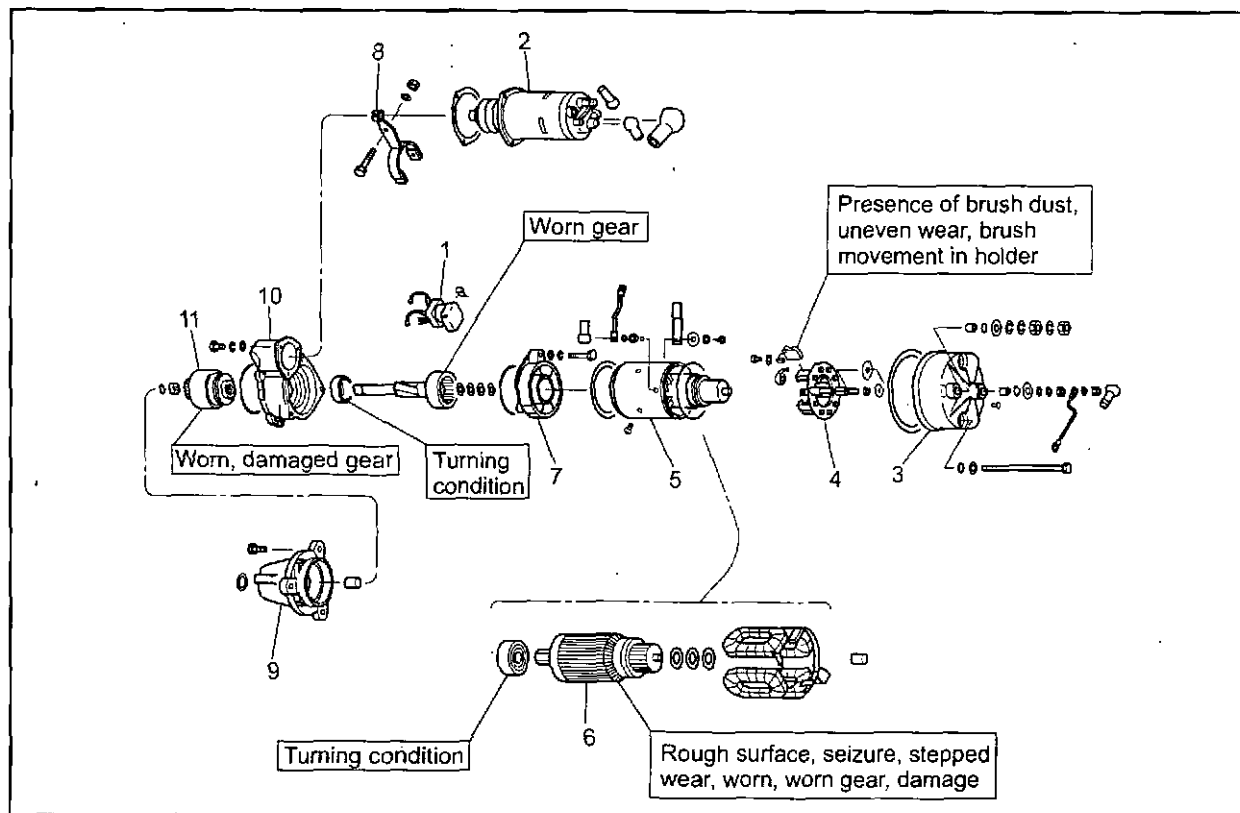
Removing alternator

Removing sequence

- | | | |
|--------------|-----------------------------|----------------------|
| 1 Harness | 4 Belt adjusting turnbuckle | 7 Alternator bracket |
| 2 Belt cover | 5 V belt | |
| 3 Belt cover | 6 Alternator | |

2. Disassembling, Inspecting and reassembling electrical system

2.1 Disassembling and inspecting starter



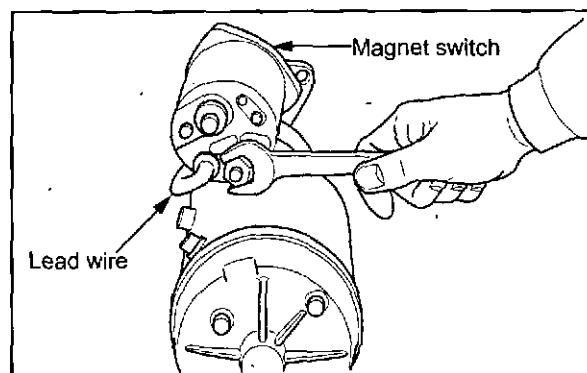
Disassembling and inspecting starter

Disassembling sequence

- | | | |
|----------------------------|---------------------|---------------------------|
| 1 Safety switch | 5 Yoke assembly | 9 Front bracket |
| 2 Magnetic switch assembly | 6 Armature assembly | 10 Pinion case |
| 3 Rear bracket | 7 Center bracket | 11 Pinion clutch assembly |
| 4 Brush holder assembly | 8 Lever assembly | |

2.1.1 Removing magnet switch

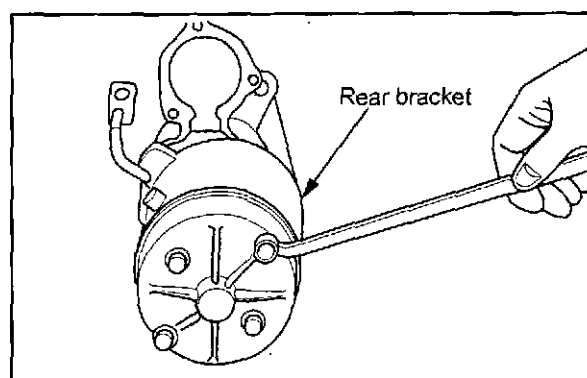
After removing the safety switch, disconnect the lead wire, then dismount the magnet switch assembly.



Removing magnetic switch

2.1.2 Removing rear bracket

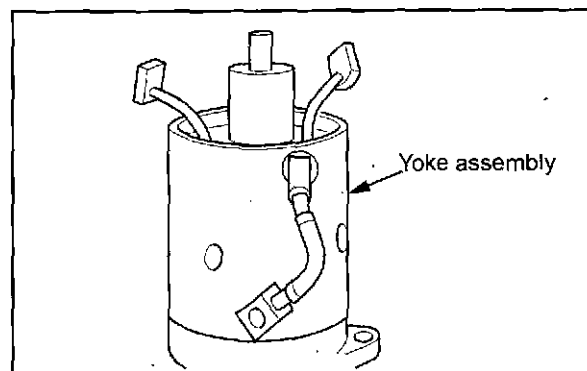
Remove the through bolts and screws of the brush holder, and then remove the rear bracket.



Removing rear bracket

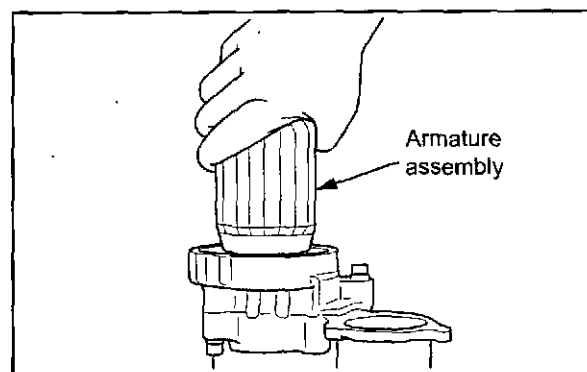
2.1.3 Removing armature and yoke assembly

(1) Remove the brushes from the brush holder assembly, then remove the yoke.



Removing yoke assembly

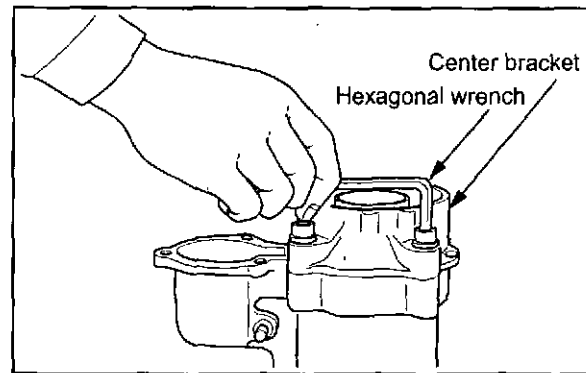
(2) Pull out the armature assembly.



Removing armature assembly

2.1.4 Removing center bracket

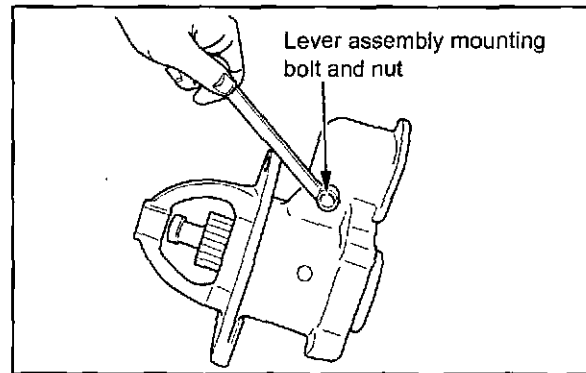
Remove the center bracket using a hexagonal wrench.



Removing center bracket

2.1.5 Removing pinion set

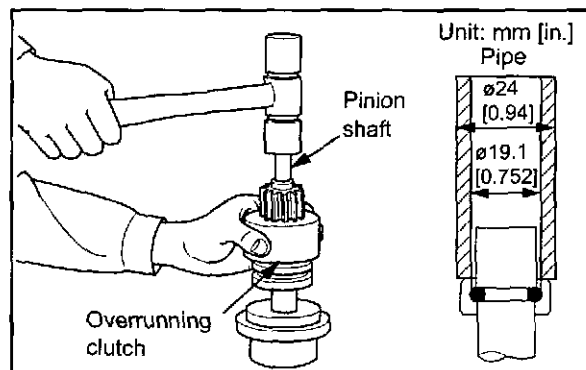
(1) Remove the lever pin, inner housing and shift lever from the pinion case.



Removing lever assembly

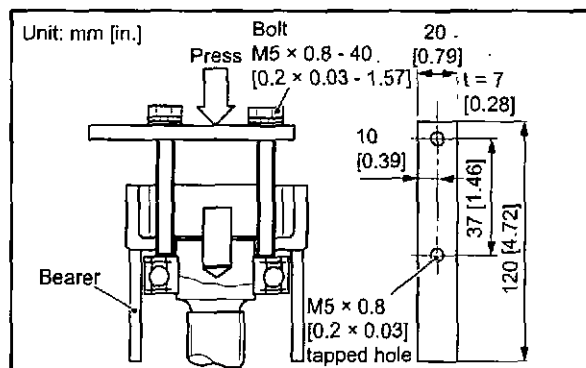
(2) Using a jig, remove the pinion stopper, then remove the overrunning clutch from the pinion shaft. Measure the outside diameter of the pinion shaft where the bearing is fitted. If the measured value is out of the standard range, replace the pinion shaft with a new one.

Item		Nominal	Standard	Remarks
Pinion shaft	Rear shaft outside diameter	ø 30 mm [1.18 in.]	30.002 to 30.011 mm [1.1812 to 1.1815 in.]	Replace pinion shaft.
	Front shaft outside diameter	ø 19 mm [0.75 in.]	18.90 to 18.94 mm [0.7441 to 0.7457 in.]	Replace pinion shaft.



Removing overrunning clutch

Note: To remove the pinion shaft bearing, use a bearing puller shown in the illustration.

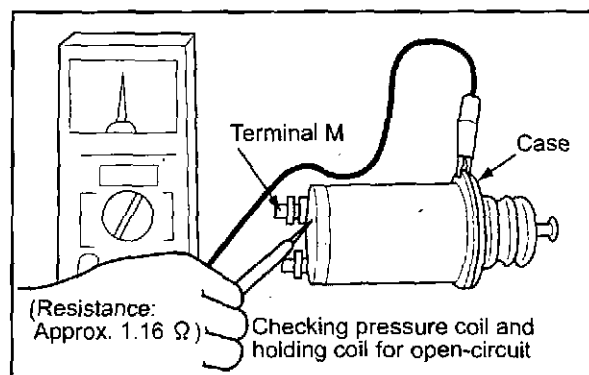


Pinion shaft bearing puller

2.2 Inspecting and correcting starter

2.2.1 Inspecting continuity of magnet switch (between M terminal and case)

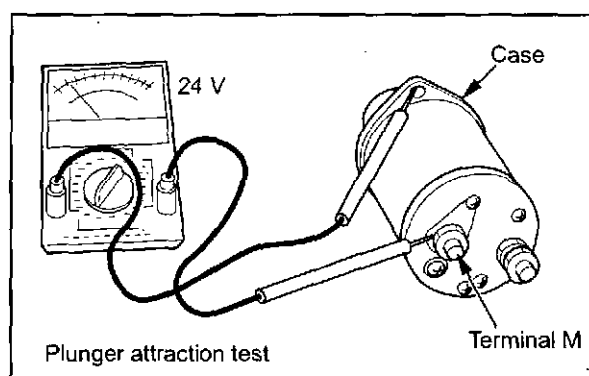
Check that there is continuity between M terminal and case. If no continuity is observed, replace the magnet switch with a new one.



Testing magnetic switch coil

2.2.2 Inspecting magnet switch function

Apply a voltage between M terminal and the case of magnet switch. Using the other hand, push the plunger in, then release the plunger. The magnet switch is normal if the plunger is not be attracted when the plunger is released.



Testing magnetic switch plunger

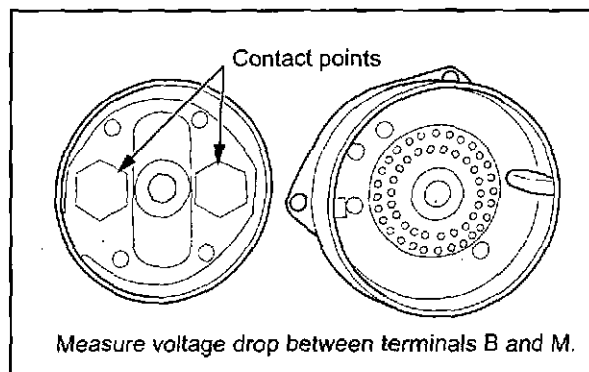
2.2.3 Inspecting magnet switch contact point

CAUTION

Never conduct an operation test with a dismantled magnet 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.



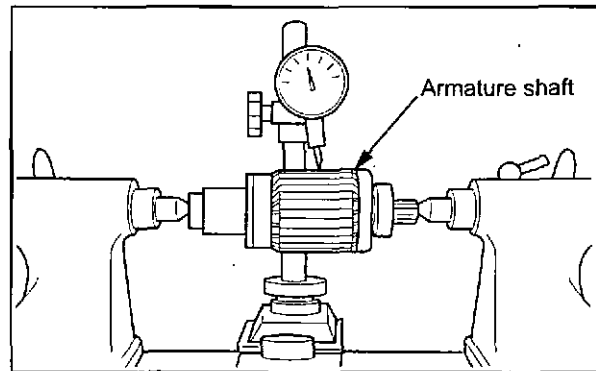
Inspecting magnetic switch contact point

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 shaft runout	0.12 mm [0.0047 in.]

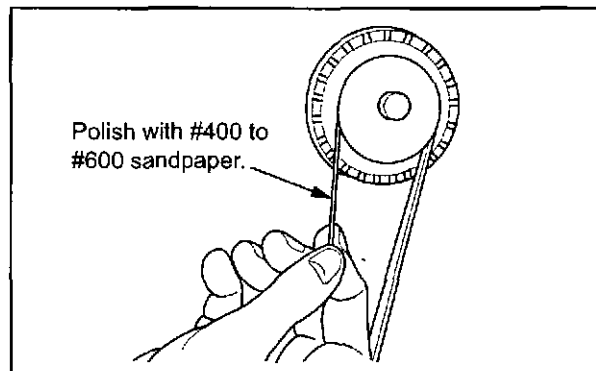


Measuring armature shaft runout

2.2.5 Inspecting 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 radial runout using a dial gauge. If the measured value exceeds the limit, replace the commutator with a new one.

Item	Standard	Limit
Commutator radial runout	0.06 mm [0.0024 in.] or less	0.10 mm [0.0039 in.]



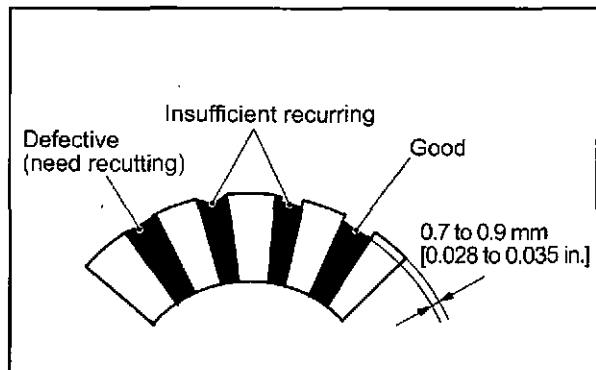
Polishing commutator surface

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.]



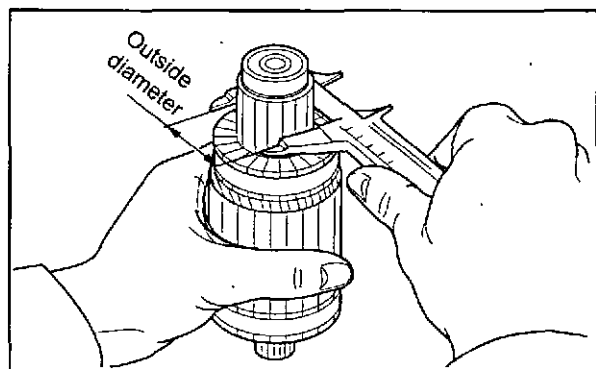
Measuring undercut depth

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.

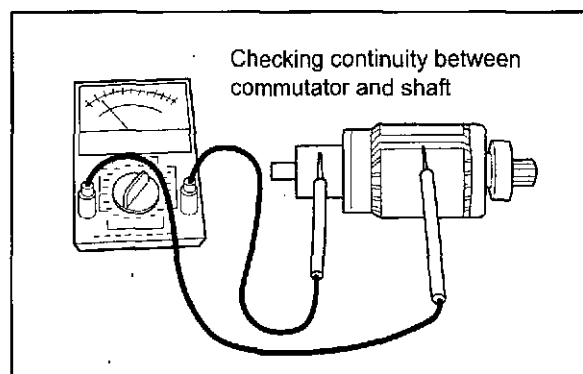
Item	Nominal	Limit
Commutator outside diameter	ø 43 mm [1.69 in.]	ø 42 mm [1.65 in.]



Measuring commutator outside diameter

2.2.8 Inspecting armature coil

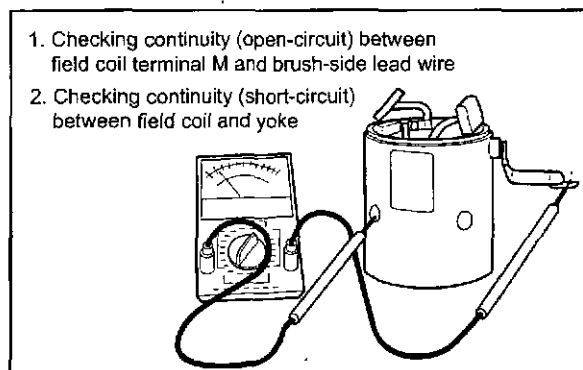
- (1) Inspect the armature coil using a growler.
Hold a piece of iron plate against the armature core. If the iron plate vibrates, replace the armature with a new one.
- (2) Check that there is continuity between segments in various combinations.
If poor or no continuity is observed, replace the armature 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.



Inspecting armature coil

2.2.9 Inspecting continuity of yoke assembly

- (1) 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.
- (2) Check for continuity between the field coil and yoke. Replace the yoke assembly if continuity (short-circuit) is indicated.



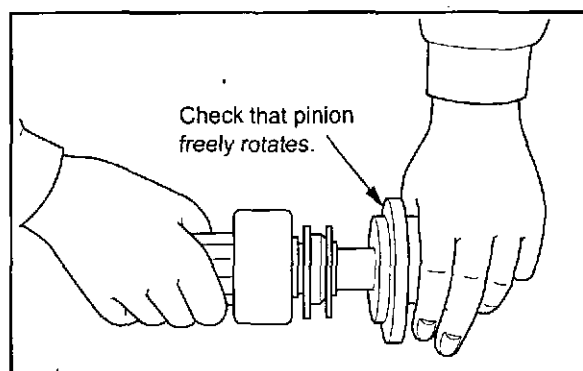
Inspecting field coil for open circuit

2.2.10 Inspecting overrunning clutch

CAUTION

Do not wash the overrunning clutch in wash oil.

Check to ensure that, when attempting to turn the overrunning clutch, it locks in one direction and rotates smoothly in the opposite direction.

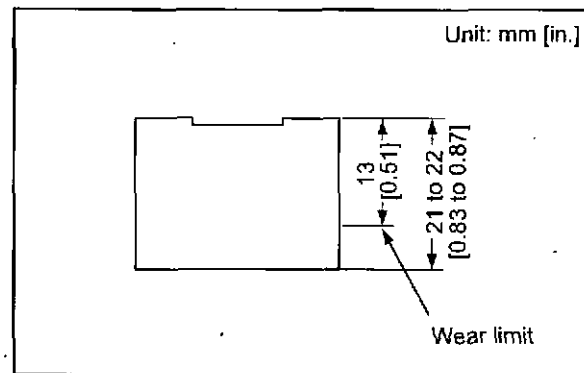


Inspecting overrunning clutch

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	21 to 22 mm [0.83 to 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]

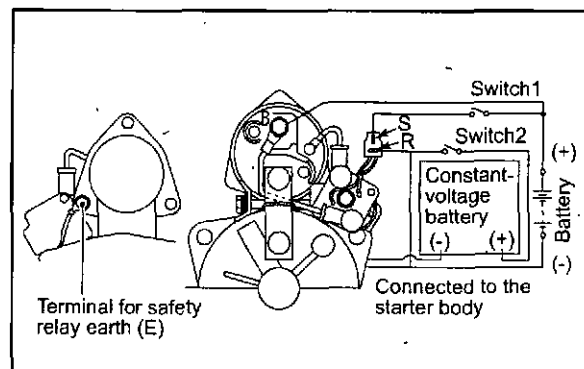
2.2.13 Inspecting safety switch**CAUTION**

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.

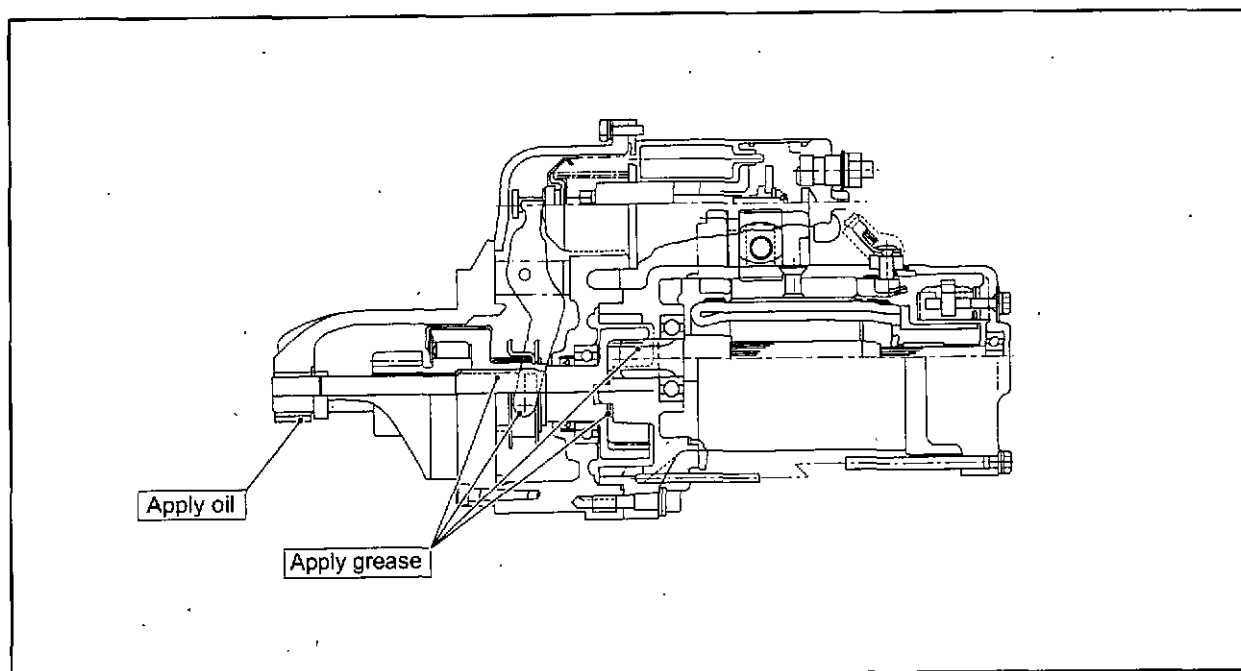
- (1) Connect the terminal R to the battery negative terminal.
- (2) Turn on the switch and check if the starter operates (rotates).
- (3) While operating the starter, disconnect the terminal R from the battery negative terminal and connect the terminal R to the battery positive terminal. Check if the starter stops.

Note: On some specifications, starter stops operation when the connection to the battery negative terminal is disconnected.



Inspecting safety switch

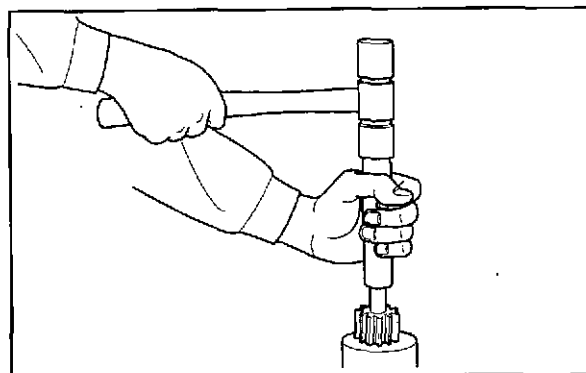
2.3 Reassembling starter



Reassembling starter

2.3.1 Installing pinion shaft

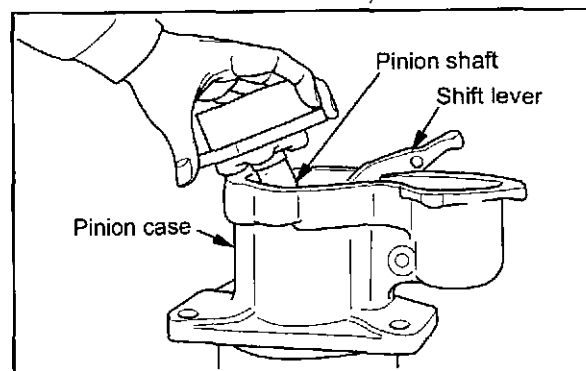
Install the center bracket, overrunning clutch and pinion stopper to the pinion shaft, and insert the shaft into position by tapping it with a soft-head mallet.



Installing pinion shaft

2.3.2 Installing lever and pinion shaft

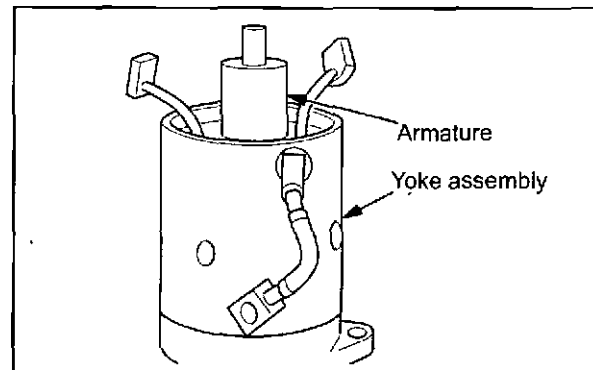
- (1) Install the shift lever and pinion shaft to the front bracket while aligning the mark on the shift lever with the mark on the bracket.
- (2) Coat the internal gear of the pinion shaft with a liberal amount of Nikko Grease R.



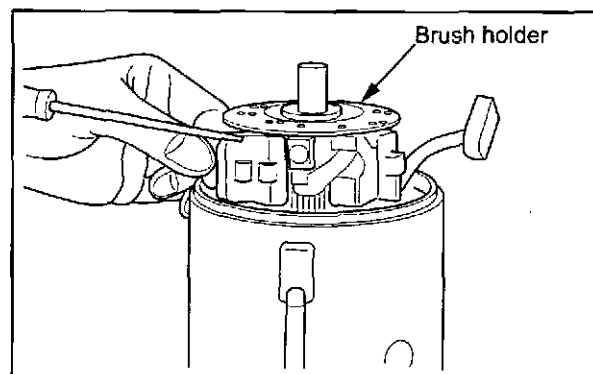
Installing lever and pinion shaft

2.3.3 Installing armature, yoke, brush and brush holder

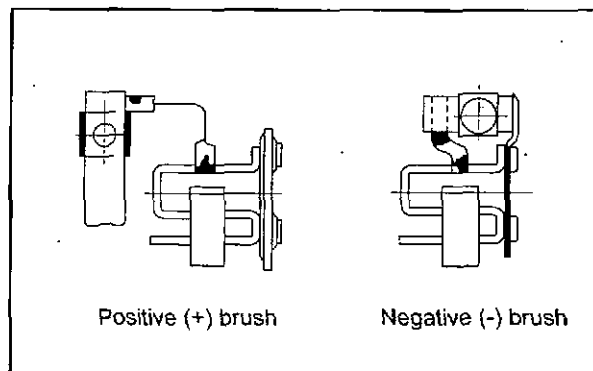
- (1) Align the knock pin with the center bracket and reassemble the armature to the yoke.
- (2) Reassemble the brush holder and brushes.



Installing armature and yoke



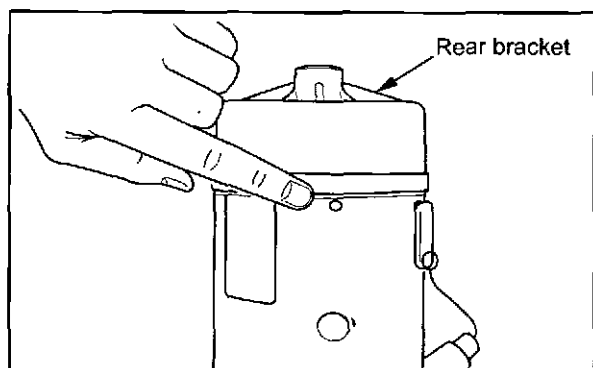
Installing brush holder and brush



Installing positive (+) and negative (-) brushes

2.3.4 Installing rear bracket

Install the rear bracket to the yoke, and tighten the through bolt and the brush holder screws.

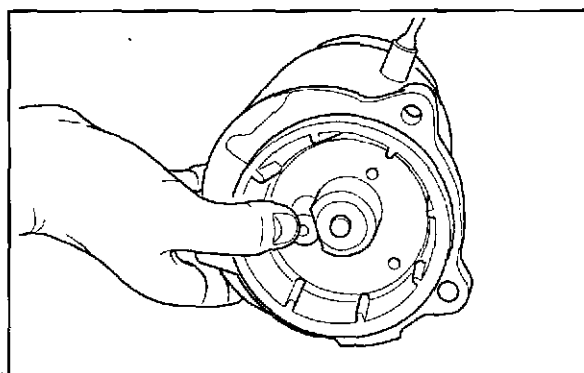


Installing rear bracket

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	0.15 to 0.75 mm [0.006 to 0.030 in.]

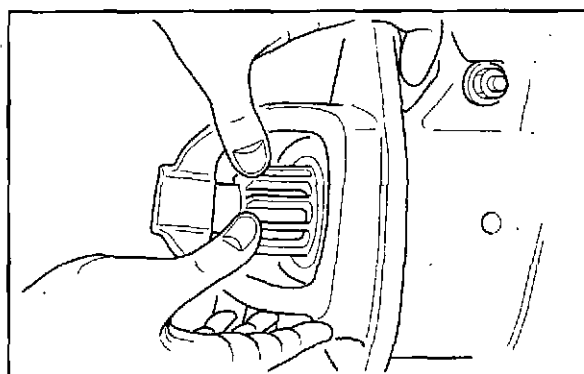


Measuring armature end play

2.3.6 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.

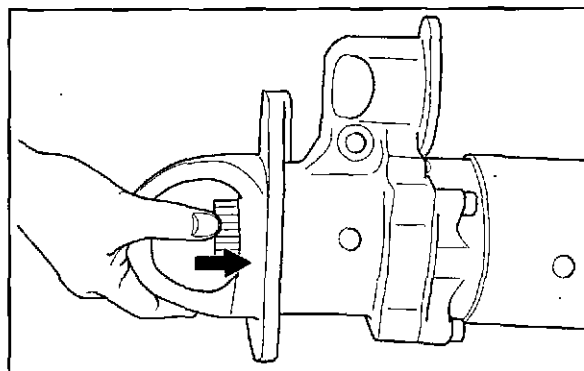
Item	Standard
Pinion shaft end play	0.2 to 0.8 mm [0.008 to 0.031 in.]



Measuring pinion shaft end play

2.3.7 Measuring pinion gear retraction length

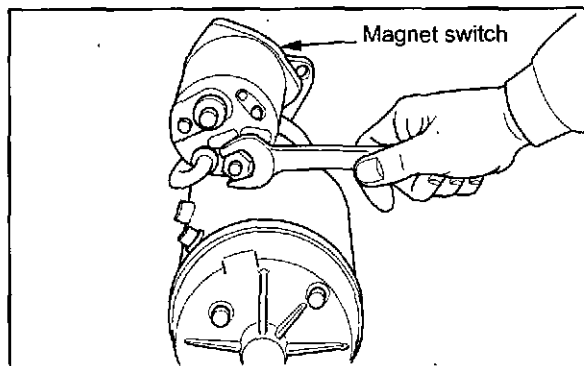
Apply a voltage of 24 V between terminals C and E. Connect the lead wire and supply a current between terminals M and E (for less than 1 second). After the pinion is moved, push the pinion gear and measure the pinion gear retraction length. If the measured value is not within the standard range, adjust the length using the adjust screw of the magnet switch.



Measuring pinion gear retraction length

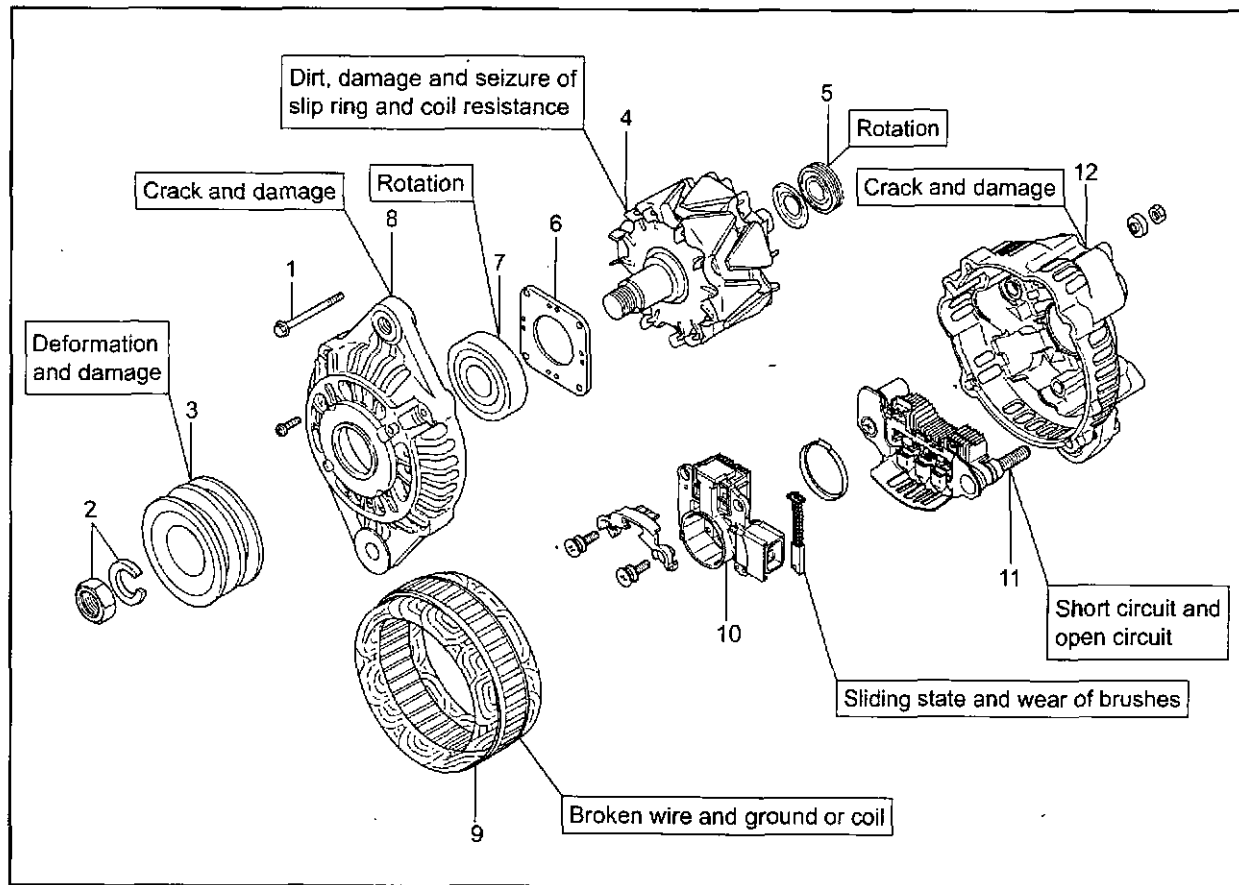
2.3.8 Installing magnetic switch

- (1) Install the magnetic switch and tighten screws to secure it.
- (2) Connect the terminal M and tighten the lock nuts.
- (3) Install the safety switch.



Installing magnetic switch

2.4 Disassembling and inspecting alternator



Disassembling and inspecting alternator

Disassembling sequence

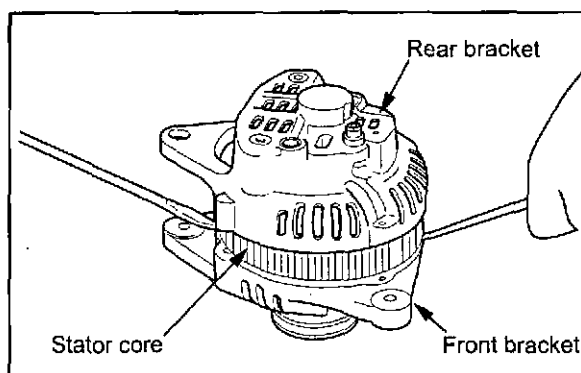
- | | | |
|----------------|--------------------|-----------------------|
| 1 Through bolt | 5 Rear bearing | 9 Stator |
| 2 Nut | 6 Bearing retainer | 10 Regulator assembly |
| 3 Pulley | 7 Front bearing | 11 Rectifier assembly |
| 4 Rotor | 8 Front bracket | 12 Rear bracket |

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.

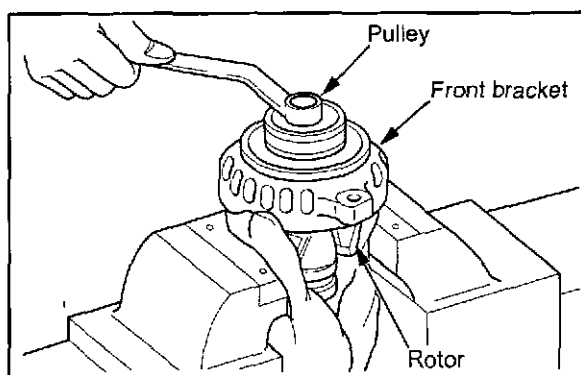


Separating front bracket from stator

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.

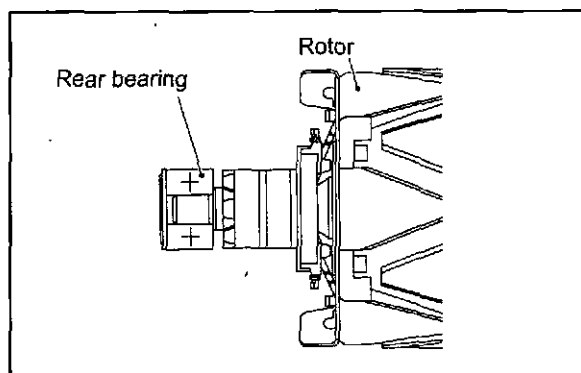
- (1) Apply a cloth to the rotor and set it in a vise.
- (2) Remove the pulley nut and then pull out the pulley.



Removing pulley

2.4.3 Removing rear bearing

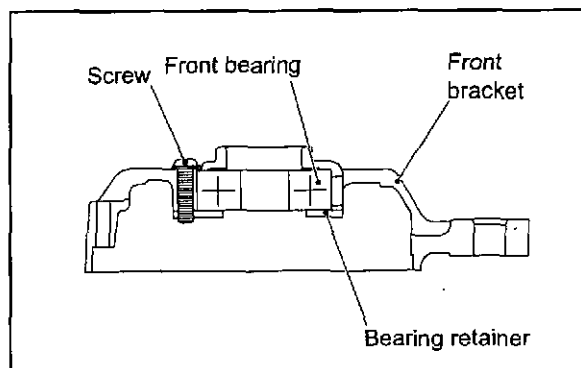
Remove the rear bearing from the rotor using a bearing puller.



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.



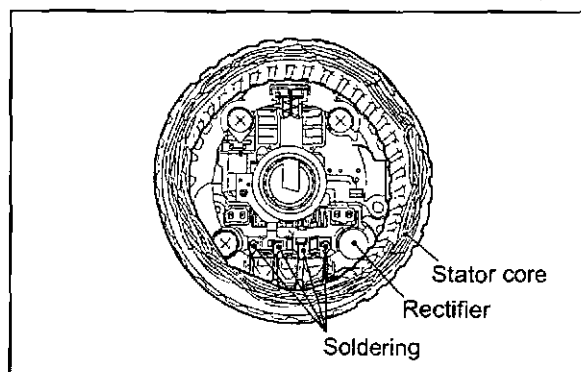
Removing front bearing

2.4.5 Removing stator

CAUTION

Unsoldering must be finished as quickly as possible.
Extended heating will damage the diodes.

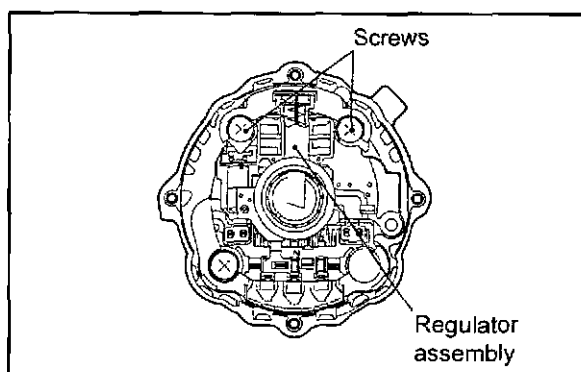
Cut off the joint of the stator and remove the stator from the rectifier.



Removing stator

2.4.6 Removing regulator assembly

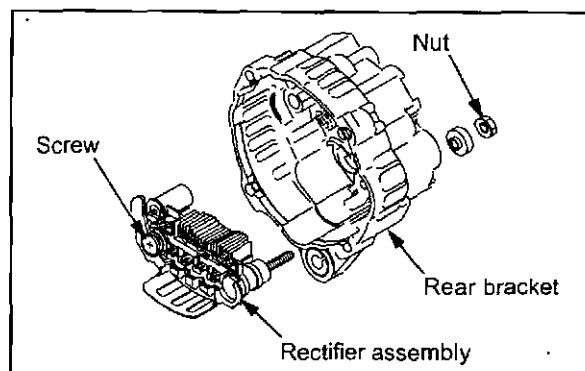
Remove the screws of the regulator assembly and then remove the regulator assembly.



Removing regulator assembly

2.4.7 Removing rectifier assembly

- (1) Remove the screw and nut from the rectifier.
- (2) Remove the rectifier assembly.



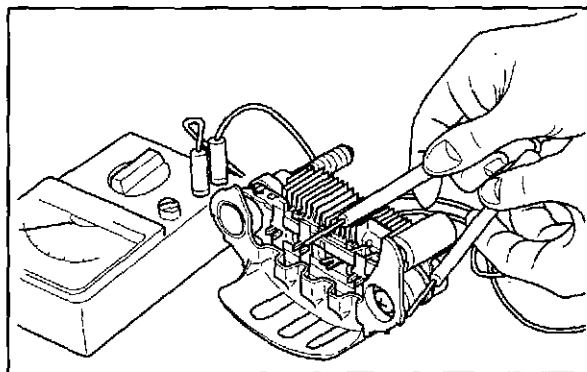
Removing rectifier assembly

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 $0\ \Omega$, the diode is short-circuited. In either case, replace the rectifier with a new one.

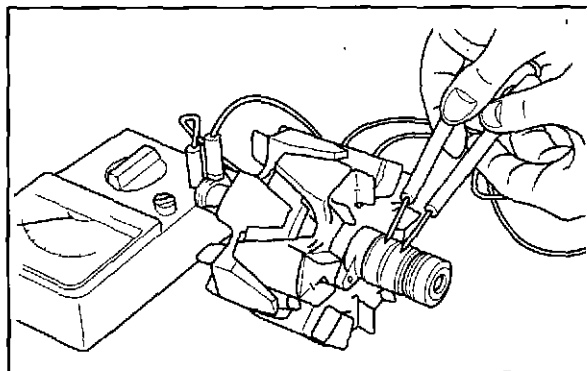
Note: Use a wide measuring range as much as possible. The current flow during test is significantly lower than the current that normally flows in the rectifier, by which the accurate resistance may not be measured using a tester, and this tendency is noticeable if the measuring range is small.



Inspecting rectifier

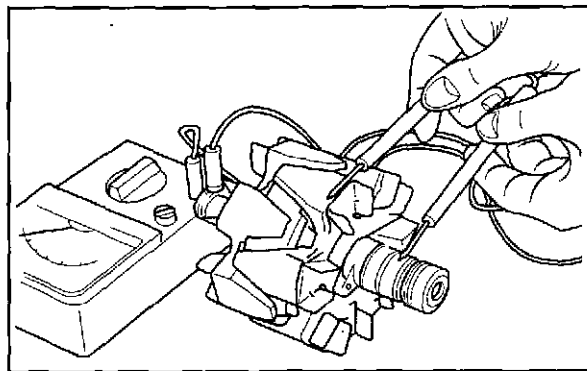
2.5.2 Inspecting armature

(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

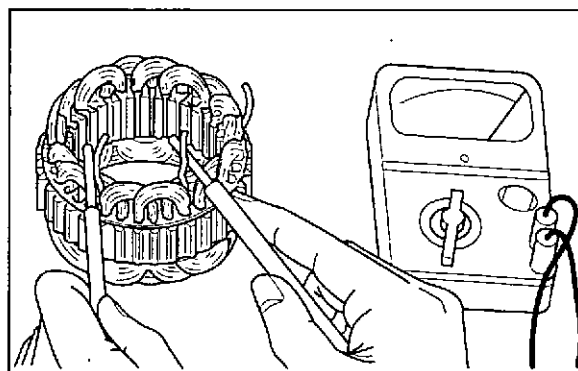
2.5.3 Inspecting stator

(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.

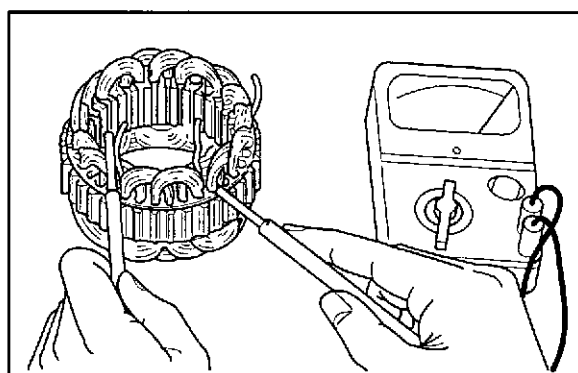


Inspecting for continuity between lead

(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.

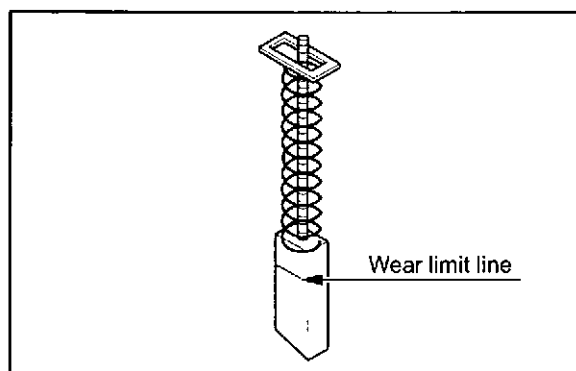


Inspecting for grounding between the lead and the core

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.

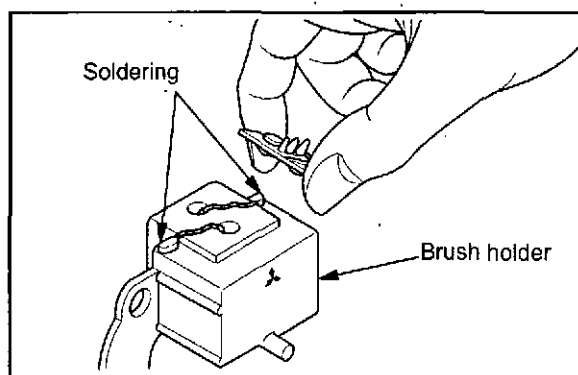
Item	Nominal	Limit
Brush height	21.5 mm [0.85 in.]	8 mm [0.31 in.]



Inspecting brushes

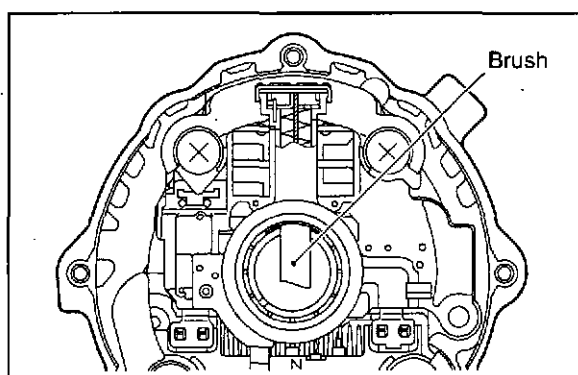
2.5.5 Replacing brushes

- (1) To remove the brush and the spring, unsolder the brush lead.



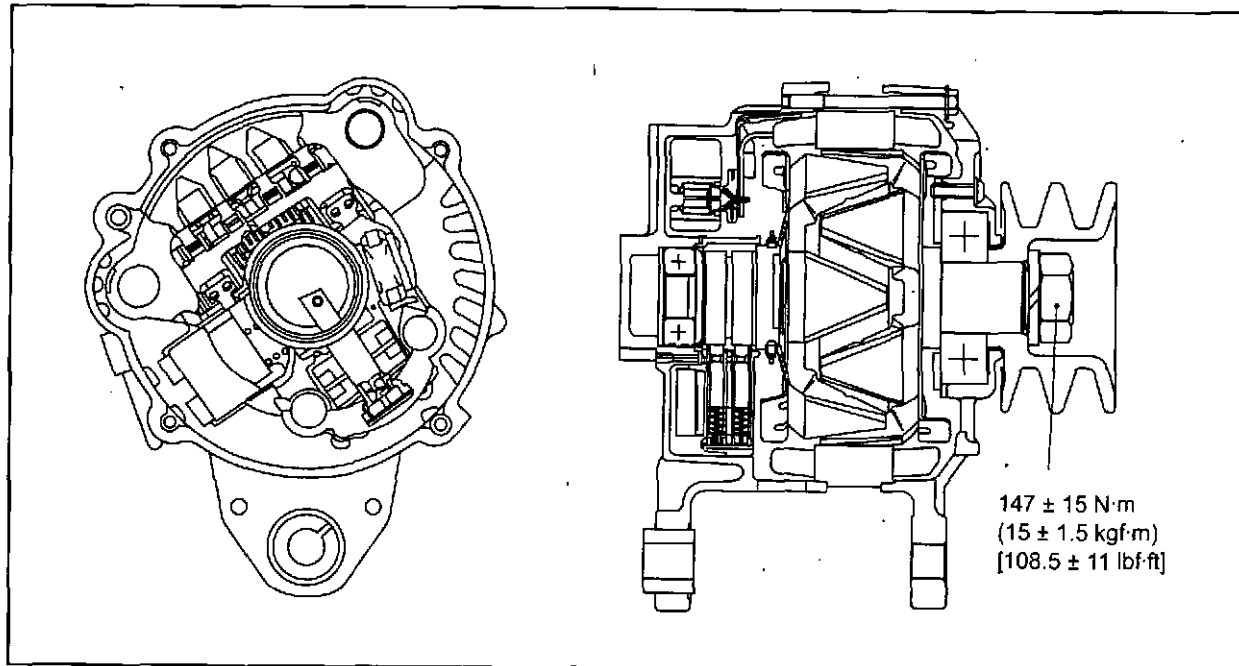
Replacing brushes

- (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

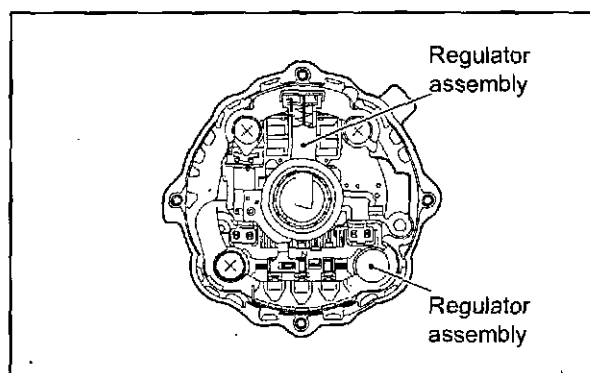
2.6 Reassembling alternator



Reassembling alternator

2.6.1 Installing rectifier assembly and regulator assembly

Install the rectifier assembly and regulator assembly on the rear bracket.



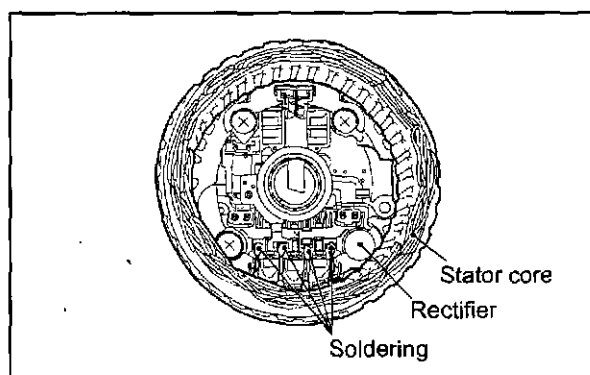
Installing rectifier assembly and regulator assembly

2.6.2 Installing stator

CAUTION

Soldering must be finished as quickly as possible.
Extended heating will damage the diodes.

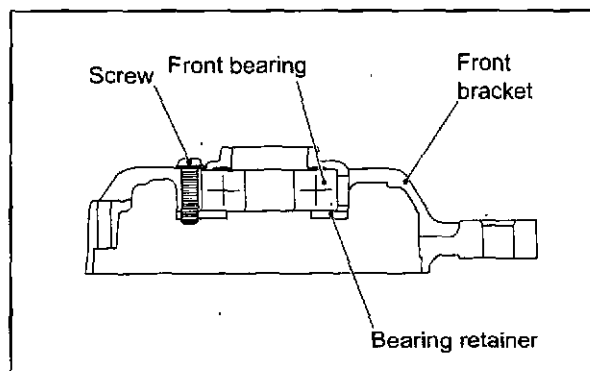
Install the stator and solder the leads of the stator to the rectifier.



Installing stator

2.6.3 Installing front bearing

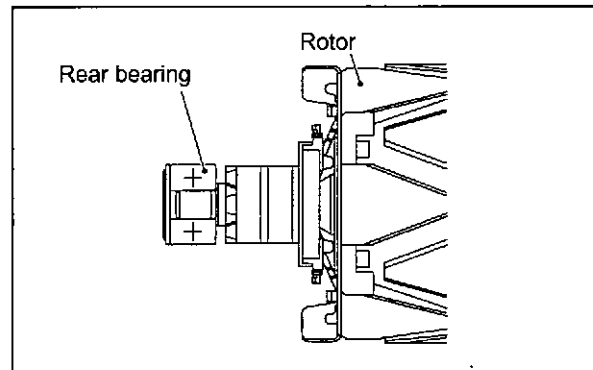
Drive the front bearing into the front bracket and secure the bearing retainer with a screw.



Installing front bearing

2.6.4 Installing rear bearing

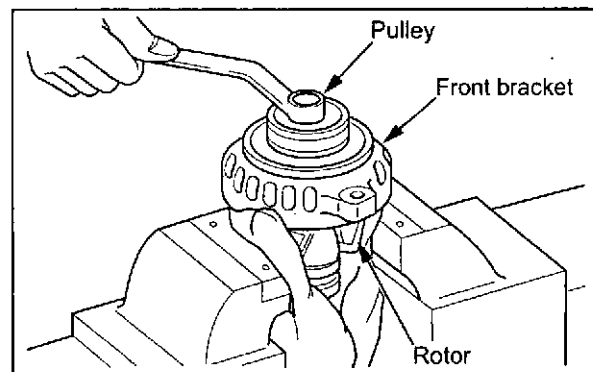
Press-fit the rear bearing to the rotor.



Installing rear bearing

2.6.5 Installing pulley

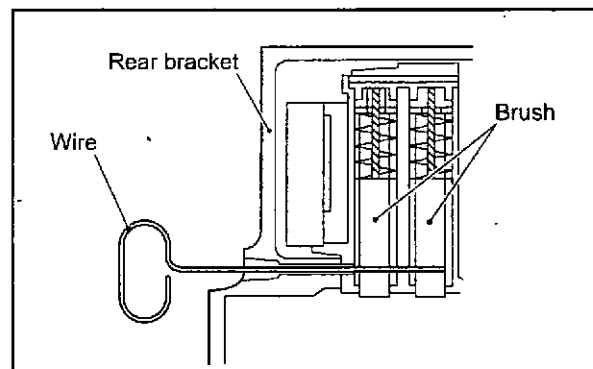
- (1) Insert the rotor into the front bracket.
Apply a cloth to the rotor and set it in a vise.
- (2) Install the spacer and pulley, and secure the pulley with a nut.



Installing pulley

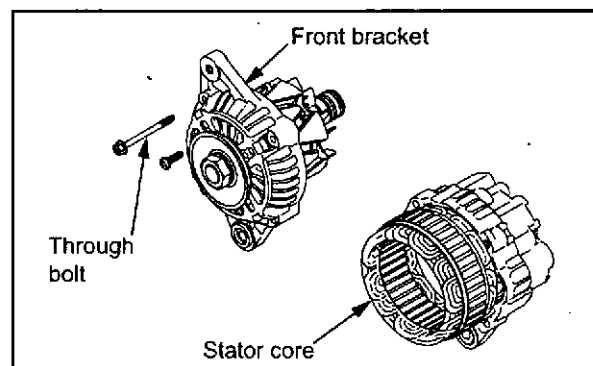
2.6.6 Assembling stator and front bracket

- (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

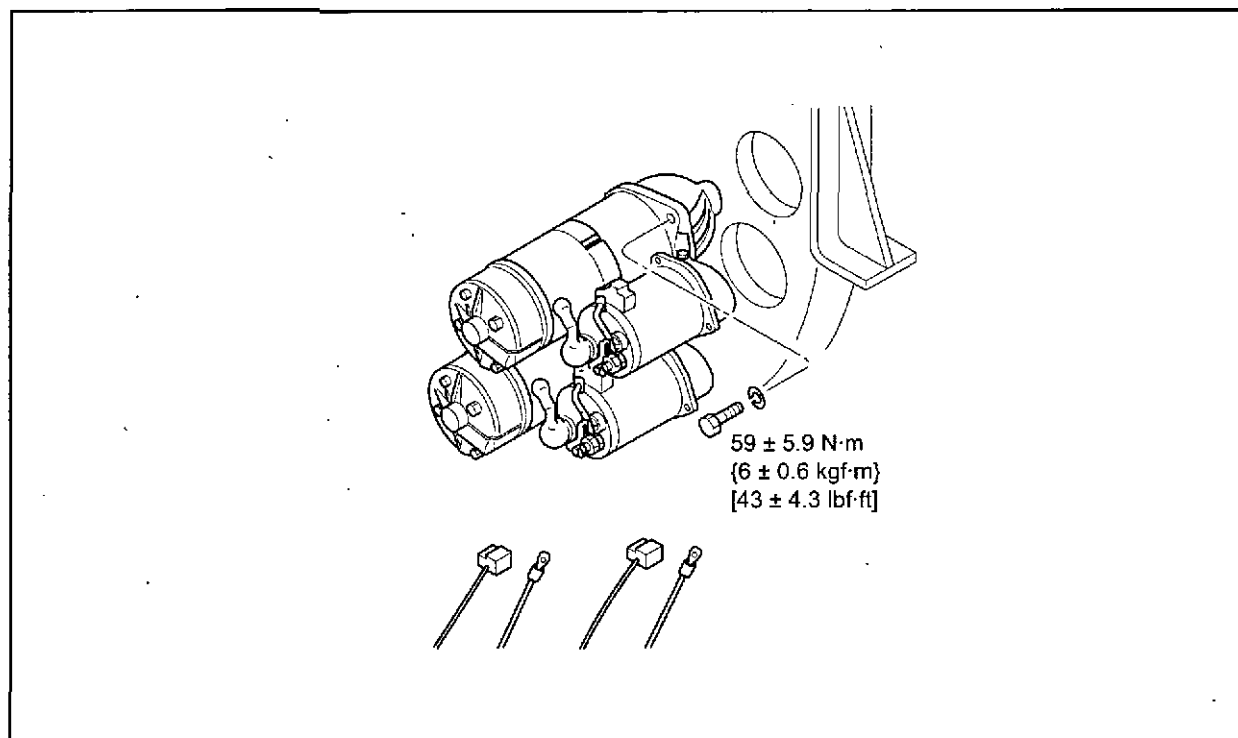
- (2) Assemble the front bracket, stator and rear bracket and secure them with through bolts.



Joining stator and front bracket

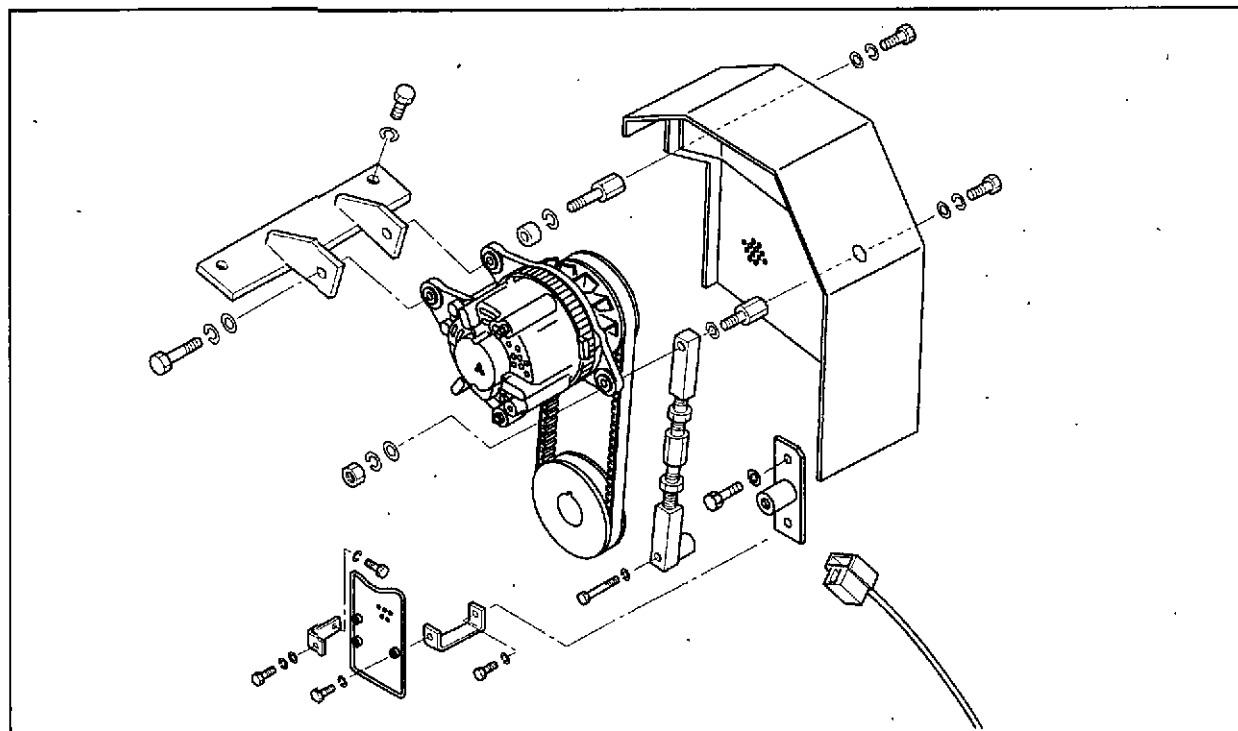
3. Reinstalling electrical system

3.1 Installing starter



Installing starter

3.2 Installing alternator



ADJUSTMENT AND OPERATION

1. Adjusting engine.....	13-2
1.1 Inspecting and adjusting valve clearance.....	13-2
1.1.1 Inspecting clearance between bridge and valve rotator.....	13-2
1.1.2 Using turning gear.....	13-2
1.1.3 Inspecting valve clearance.....	13-3
1.1.4 Adjusting front and rear valve heights by valve bridge.....	13-4
1.1.5 Adjusting valve clearance.....	13-4
1.2 Bleeding air from fuel system.....	13-5
1.2.1 Bleeding from water separator.....	13-5
1.2.2 Bleeding from fuel injection pump.....	13-5
1.2.3 Tightening priming pump cap.....	13-6
1.3 Inspecting and adjusting fuel injection timing.....	13-7
1.3.1 Fuel injection timing and its indication location.....	13-7
1.3.2 Inspecting No. 1 cylinder top dead center on compression stroke.....	13-7
1.3.3 Inspecting fuel injection timing.....	13-8
1.3.4 Adjusting fuel injection timing.....	13-8
1.4 Inspecting and adjusting low idle speed and high idle speed.....	13-9
1.5 Inspecting V-belt and adjusting belt tension.....	13-10
1.5.1 Inspecting and adjusting V-belt.....	13-10
1.5.2 Adjusting V-belt tension (Alternator side).....	13-10
1.5.3 Adjusting V-belt tension (Air cooler water pump side).....	13-10
2. Break-in operation.....	13-11
2.1 Starting up.....	13-11
2.2 Inspecting engine condition after starting up.....	13-11
2.3 Break-in operation time.....	13-11
2.4 Inspection and adjustment after break-in operation.....	13-11
3. Performance test (JIS standard).....	13-12
3.1 Engine equipment condition.....	13-12
3.2 Test items and purposes.....	13-12
3.2.1 Operation load test.....	13-12
3.2.2 Continuous load test.....	13-12
3.2.3 Low idle test.....	13-12
3.3 Other inspections.....	13-12
3.4 Engine output adjustment.....	13-12
3.4.1 Standard atmospheric conditions:.....	13-12
3.4.2 Calculation of corrected power.....	13-13

1. Adjusting engine

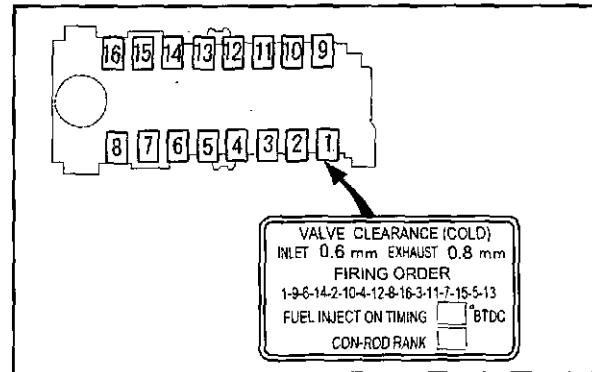
1.1 Inspecting and adjusting valve clearance

Inspect and adjust the valve clearance.

The valve clearance should be inspected and adjusted when the engine is cold.

Note: (a) The inlet valves are on the left side and the exhaust valves are on the right side as 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.

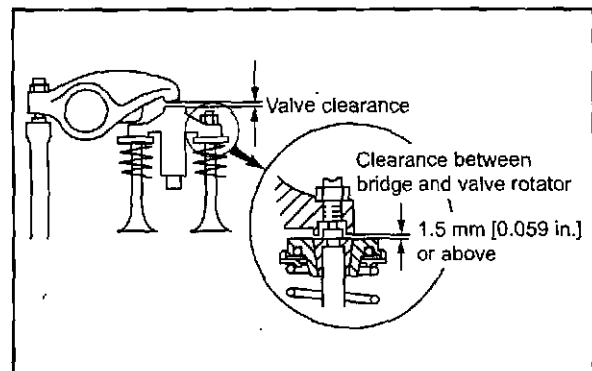


Valve clearance indication position

Item		Standard
Valve clearance	Inlet valves	0.6 mm [0.024 in.]
	Exhaust valves	0.8 mm [0.031 in.]

1.1.1 Inspecting clearance between bridge and valve rotator

The clearance between the bridge and the valve rotator should conform to the standard after the front and rear valve standard heights are achieved by adjusting the valve bridge. If the clearance is not within the tolerance, attain the standard value by grinding the bridge bottom on the screw side.

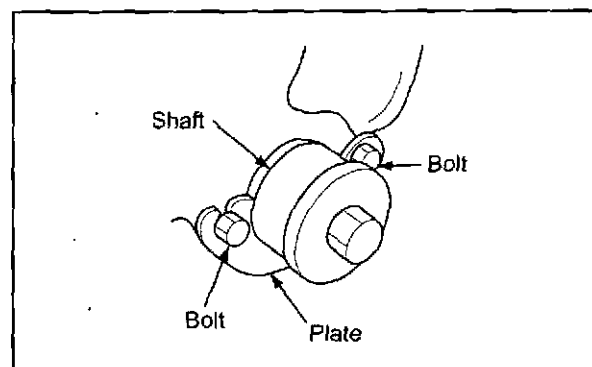


Inspecting clearance between bridge and valve rotator

1.1.2 Using turning gear

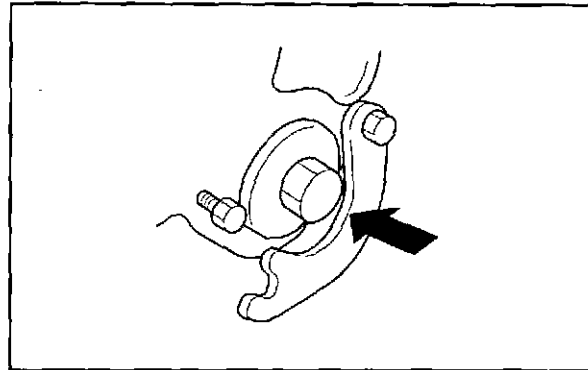
WARNING Make sure that the turning gear is at the original position when the engine is started. If the engine is started while the turning gear is depressed, it will cause not only damage the gear but could result in personal injuries.

(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.

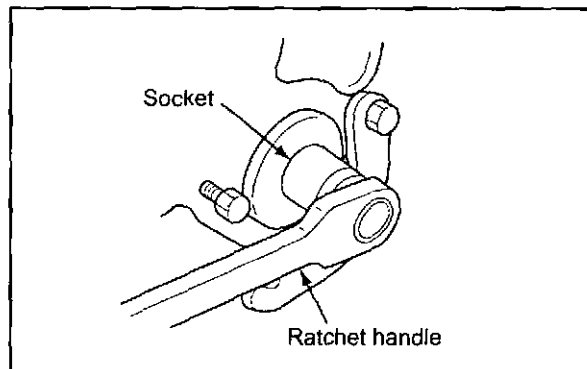


Using turning gear (when pushed)

- (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

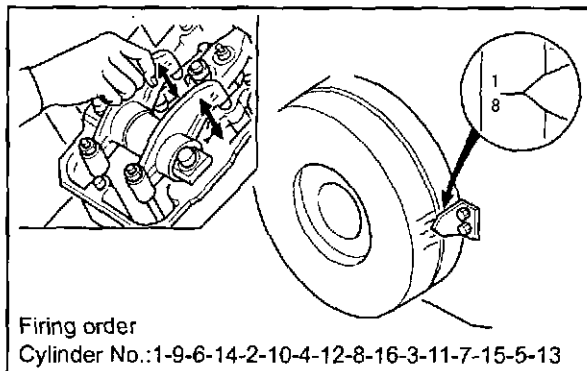
Check to make sure the plate is inserted securely into the slot of the shaft.



Using turning gear (when turning)

1.1.3 Inspecting valve clearance

- (1) Inspect the valve clearances in the firing order by turning the crankshaft in the normal direction to bring each piston to top dead center in compression stroke.
- (2) A piston is at the top dead center in compression stroke when its No. stamped on the vibration damper aligns with the pointer and the pushrods 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.



Firing order
Cylinder No.: 1-9-6-14-2-10-4-12-8-16-3-11-7-15-5-13

Inspecting valve clearance

1.1.4 Adjusting front and rear valve heights by valve bridge

CAUTION

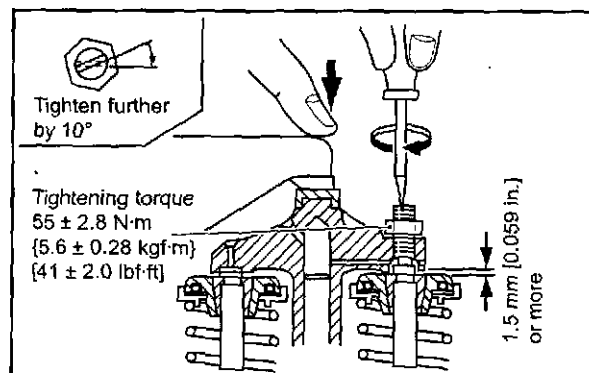
If there is no clearance between the bridge and valve rotator, the interference between them could cause the valve cotters to fall out. Be sure to provide the specified clearance.

When adjusting the front and rear valve heights with the valve bridge, bring the piston at the top dead center on the compression stroke.

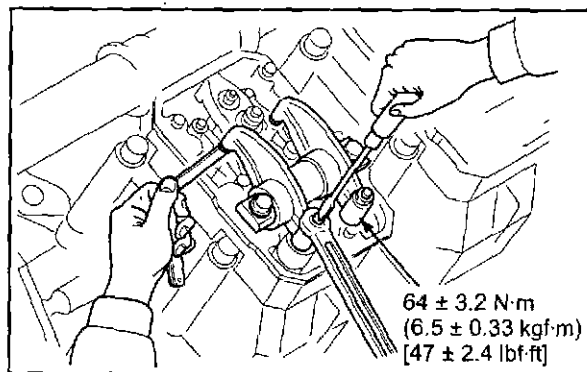
- (1) Prior to the valve clearance adjustment, it is necessary to adjust the front and rear valve heights with the valve bridge (bringing the bridge into contact with the front and rear valves). If the front and rear valve heights are not the same, which can occur due to such conditions as valve seat 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.
- (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.

1.1.5 Adjusting valve clearance

- (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 front and rear valve heights by valve bridge



Adjusting valve clearance

1.2 Bleeding air from fuel system

WARNING

- Wipe off any fuel spilled from the air vent plug thoroughly with a cloth. If the fuel remains, it could cause fire.
- After bleeding air, be sure to lock priming pump cap. If the lock is not insufficient, it could cause breakage of the pump and result in fire due to the leakage of fuel. 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 the fuel system, start at the place nearest to the fuel tank as follows: water separator → fuel filter → injection pump.

1.2.1 Bleeding from water separator

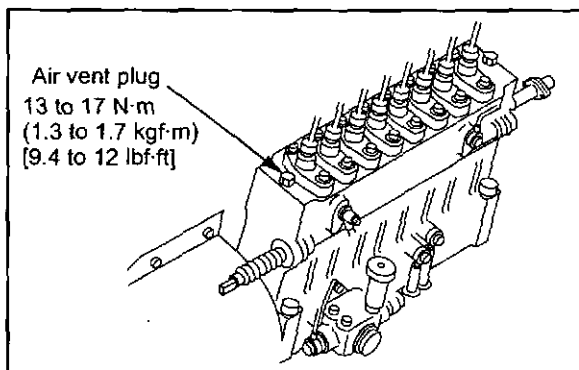
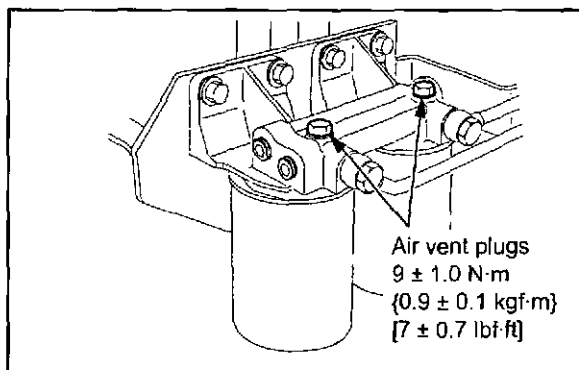
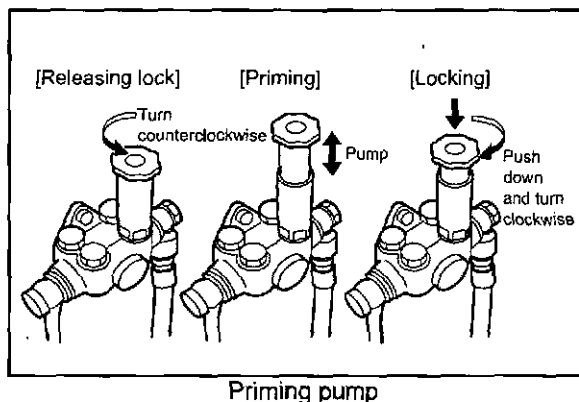
- Loosen air vent plug of the water separator (by rotating about 1.5 full turns).
- Turn priming pump cap counterclockwise to loosen, then move the priming pump cap up and down.
- When fuel flowing out of the air vent no longer contains air bubbles, close the air vent plug.
- Follow the same procedure for both right and left fuel filters.

1.2.2 Bleeding from fuel injection pump

- Loosen the air vent plugs for the injection pumps. (approx. 1.5 turns)
- Move the cap up and down repeatedly.
- When fuel flowing from the vent holes no longer contains air bubbles, tighten the air vent plugs.
- Follow the same procedure for the fuel injection pumps on both right and left sides.

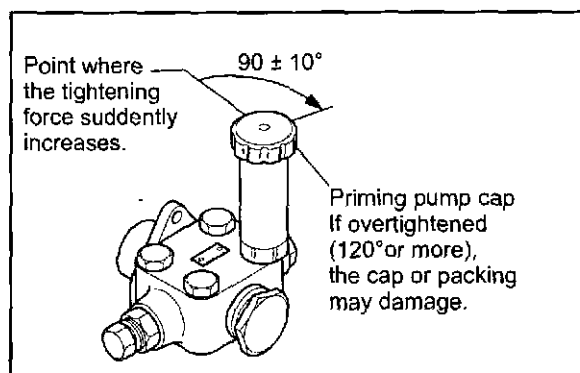
Note: (a) If all the vent plugs are tightened before the priming pump cap is locked, fuel pressure acts on the feed pump, making it impossible to return the cap to the original position.

- Wipe off fuel spilled from the vent holes thoroughly with a cloth.



1.2.3 Tightening priming pump cap

- (1) Tighten the priming pump cap by hand until the tightening force suddenly increases.
- (2) Mark the priming pump cap in this position to facilitate the subsequent procedure.
- (3) After step (1), further turn the priming pump cap by $90 \pm 10^\circ$ by wrench.



Tightening priming pump cap

- (4) After tightening, make sure the priming pump head packing is not dislodged from the installation position.

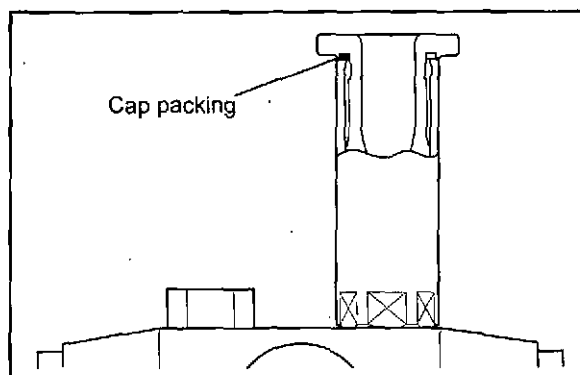
Note: If the packing at the head is protruding, loosen the priming pump cap to verify there is no damage to the packing, and then tighten the cap again.

If the packing is damaged, the priming pump must be replaced. Contact your local Mitsubishi dealer.

CAUTION

If the priming pump cap is not tightened firmly, vibrations of engine operation could cause rapid wear of the internal threads. This could eventually cause the priming pump cap to eject and fuel to flow out.

If the priming pump cap is tightened with excessive force (turned more than 120°), the head packing can dislodge from the installation position. Therefore, be sure to tighten the priming pump cap by the specified angle ($90 \pm 10^\circ$).

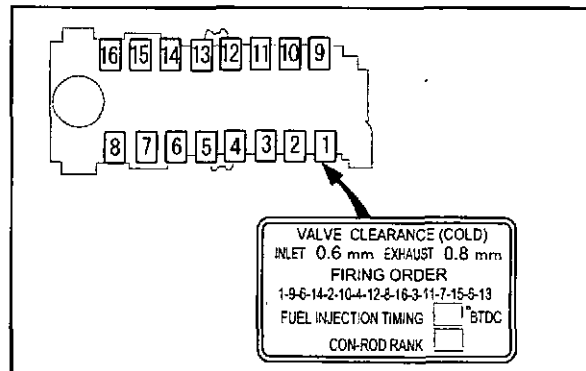


Priming pump cap packing

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, engine speed and other specifications, be sure to check the caution plate on the No.1 rocker cover.



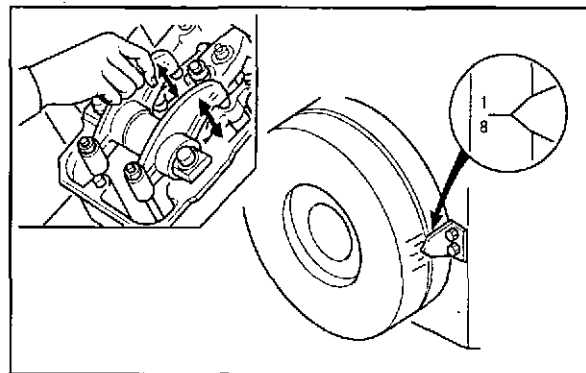
Injection timing and its indication location

1.3.2 Inspecting No. 1 cylinder top dead center on 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.

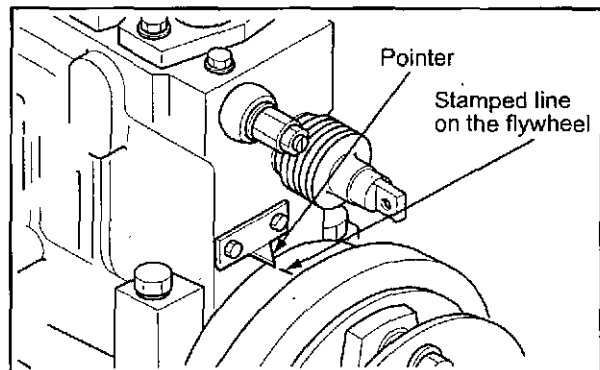
- (1) Using a ratchet handle, rotate the turning gear in the normal direction (clockwise when viewed from the front of the engine).
- (2) Stop turning when the cylinder number "1" stamped on the damper is aligned with the pointer.
- (3) Move the rocker arms of the inlet and exhaust valves for the No. 1 cylinder up and down, and make sure that the pushrods are not pushing the inlet and exhaust valves off their seats.



Inspecting No. 1 cylinder top dead center in compression stroke

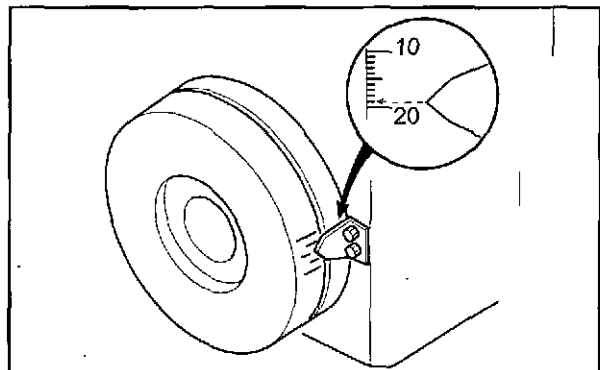
1.3.3 Inspecting fuel injection timing

- (1) Rotate the crankshaft about 60° in the reverse direction, then rotate it in the normal direction a little at a time to align the stamped line on the flywheel with the pointer on the pump case end face.



Inspecting fuel injection timing (1)

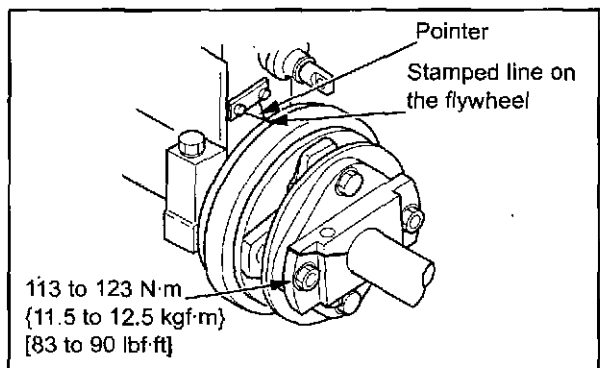
- (2) Read the injection mark (degree) on the circumference of the damper indicated by the pointer on the engine. The indicated angle is the injection timing of the engine. The negative (-) mark on the angle scale and BTDC indicate "Before Top Dead Center."



Inspecting fuel injection timing (2)

1.3.4 Adjusting fuel injection timing

- (1) Make sure the injection timing angle of No. 1 cylinder on the damper is aligned with the pointer on the engine.
- (2) Loosen the two nuts for the injection pump drive coupling (laminated plate).
- (3) Move the pump shaft until the stamped line on the flywheel aligns with the pointer on the pump case end face, then tighten one nut to the specified torque.
- (4) Rotate the crankshaft, and tighten the other nut.
- (5) Double-check the fuel injection timing by cranking the engine again.



Adjusting fuel injection timing

(Fuel injection pump on left side)

The position where the stamped mark Nos. 9 and 16 are aligned with the pointer is the top dead center in compression stroke. The valve clearance of both the inlet and exhaust valve is the prerequisite at this time. From there the fuel injection timing is adjusted in the same procedure as the right side.

1.4 Inspecting and adjusting low idle speed and high idle speed

CAUTION

The minimum no-load speed (low idle speed) and the maximum no-load speed (high idle speed) of each engine have been checked on test bench and then their setting bolts have been sealed at the factory. Only the service shops designated by Mitsubishi are authorized to perform checking and adjusting of these settings.

Be sure to seal all the external stoppers in the same manner as they were sealed at the factory if adjustments have been made on the governor.

Whether the seals are intact or not has important effect on the validity of claims under warranty. Be sure to seal all of the specified locations.

When inspecting and adjusting the governor, be prepared to operate the engine stop lever manually in anticipation of engine overrunning.

Note: Prior to inspecting and adjusting the governor, be sure to warm up the engine long enough to raise the coolant and oil temperatures to 70°C [158°F] or higher.

1.5 Inspecting V-belt and adjusting belt tension

CAUTION

- If defects such as cuts or surface separations are found on V-belt during inspection, replace V-belt. Keep the belt free from oil and grease, since they can cause the belt to slip and shorten the service life.
- Excessive V-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.

1.5.1 Inspecting and adjusting V-belt

(1) Inspect V-belt for defects such as wear, cuts or surface separations. If a defect is found, replace V-belt with a new one.

(2) Inspect belt tension as described below:

Push the belt downward with about $49 \pm 5 \text{ N}$ $\{5 \pm 0.5 \text{ kgf}\}$ $[36 \pm 4 \text{ lbf}]$ pressure midway between pulleys. If the deflection is $7 \pm 1 \text{ mm}$ $[0.28 \pm 0.04 \text{ in.}]$ for new belt and $9 \pm 1 \text{ mm}$ $[0.35 \pm 0.04 \text{ in.}]$ for retightening, the tension is correct.

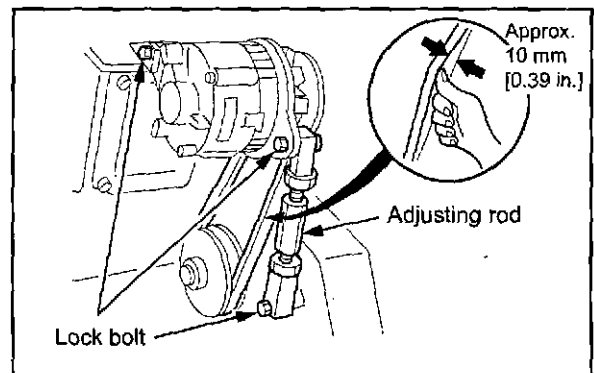
If the tension is out of the specified value, adjust belt tension.

1.5.2 Adjusting V-belt tension (Alternator side)

- Remove alternator front cover and V-belt cover.
- Loosen all the retaining bolts on the alternator and adjusting rod.
- Loosen the upper and lower lock nuts on the adjusting rod.

Note: The lower nut on the adjusting rod has left-hand threads.

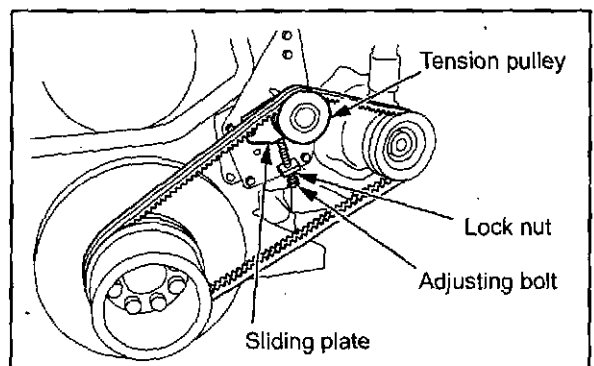
- Turn the adjusting rod to adjust V-belt tension.
- After having adjusted belt tension, tighten the upper and lower lock nuts.
- Tighten all the retaining bolts on the alternator and adjusting rod.
- Reinstall belt cover and alternator front cover.



Adjusting v-belt tension (alternator side)

1.5.3 Adjusting V-belt tension (Air cooler water pump side)

- Loosen all the retaining bolts on the tension pulley sliding plate.
- Loosen the lock nuts on the adjusting bolt and tighten to have belt tension.
- Retighten all the retaining bolts on the tension pulley sliding plate.



Adjusting V-belt tension (air cooler water pump side)

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

3.4 Engine output adjustment

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

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.

Calculation output = Correction factor (α_c) $\times$ Measured brake power

• Atmospheric conditions during test

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

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

$$\alpha_c = (f_a)^{f_m} \quad f_a: \text{Atmospheric factor} \quad f_m: \text{Engine factor}$$

• Range of correction equation use

The range of correction factor (α_c) is as follows:

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

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)

$$37.2 \leq q_c \leq 65 \text{ mg/(l-cycle)}$$

$$\cdot q_c \leq 37.2 \text{ mg/(l-cycle)} : f_m = 0.2 (\text{constant})$$

$$\cdot 65 \text{ mg/(l-cycle)} \leq q_c : f_m = 1.2 (\text{constant})$$

