SERVICE MANUAL

MITSUBISHI DIESEL ENGINE

S12H

June 2003

MITSUBISHI HEAVY INDUSTRIES, LTD.

INTRODUCTION

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

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

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

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

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

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How to Use This Manual

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

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

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

1. Methods of Indication

(1) Parts shown in illustrations and described in text are numbered to correspond with the sequence of disassembly.

(2) Inspections to be conducted during disassembly are indicated in a box [ ] in disassembled views.

(3) Maintenance standards for inspection and repair are described in text where they are relevant, are also listed in Group 1 in the General Contents.

(4) The sequence in which parts are to be assembled is summarized below each assembled view.
Such as: ⑤→④→③→②→①.

(5) The following marks are used in this manual to emphasize important safety cautions.

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

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

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

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

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

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

2. Terms Used in This Manual

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

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

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

3. Abbreviations, Standards, Etc.

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

4. Units of Measurement

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

- Pressure: 1 MPa = 10.197 kgf/cm^2
- Torque: 1 N·m = 0.10197 kgf·m
- Force: 1 N = 0.10197 kgf
- Horsepower: 1 kW = 1.341 HP = 1.3596 PS
- Meter of mercury: 1 kPa = 0.7 cmHg
- Meter of water: 1 kPa = 10.197 cmH_2O (cmAq)
- Rotational speed: 1 min^{-1} = 1 rpm

GENERAL CONTENTS

SAFETY CAUTIONS

⚠ WARNING Danger of Fire and Explosion

● Keep flames away

Do not use flames or smoke at a site where fuel or engine oil is handled or cleaning solvent is used for washing parts.
Flames can ignite such materials and result in a dangerous situation.
Spilled fuel and oil should be wiped immediately and thoroughly. Spilled fuel and oil can ignite and cause fire.
When storing fuel or engine oil, make sure that the storage area is well ventilated and the caps of containers are tightly closed.

● Keep surrounding area neat and clean

Do not leave combustible or explosive materials, such as fuel and engine oil, near the engine. They can cause fire or explosion.
Remove dust, dirt and other foreign materials accumulated on or near the engine. They can cause fire or engine overheating. Be sure to remove dust from the top side of the battery after maintenance. Dust can cause a short-circuit.
The engine must be positioned at least 1 m [3.28 ft] away from buildings and other equipment to prevent possible fire caused by engine heat.

● Do not open crankcase until engine cools

After the engine stops operation, let the engine cool for at least 10 minutes before opening the side cover of the crankcase.
Inflow of fresh air into the crankcase of a hot engine can cause oil mist to ignite and explode.

● Check for fuel and oil leaks

When fuel or oil leaks are found, repair the leakage immediately.
Fuel or engine oil spilled on a hot surface of the engine can cause fire and result in personal injury or equipment damage.

● Use shatterproof light

Use a shatterproof light when inspecting the fuel system, lubrication system, cooling system or battery fluid level.
A non-shatterproof light may catch fire and explode.

● Do not short-circuit electrical wires

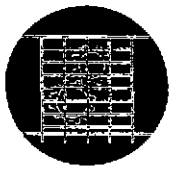
Do not inspect or repair the electrical system with the battery cables connected to the battery, since it can cause accidental short-circuiting and lead to fire. Be sure to disconnect the negative (-) battery cable from the battery before conducting work.
Loose terminals and damaged cables/wires can result in a short-circuit and cause fire. Inspect the terminals, cables and wires before servicing, and repair or replace when damage is found.

● Keep fire extinguishers and first aid kit nearby

Always keep fire extinguishers nearby, and be familiarized with their usage.
Keep a first aid kit at a designated place, and make sure it is easily accessible whenever needed.
Also, establish emergency response procedures to follow in the event of a fire or accident, and post emergency contact locations and contact methods.

⚠ WARNING Danger of Entanglement

● Install protective covers on rotating parts



Make sure the protective covers of the engine are installed correctly at rotating parts.
If protective covers are loose or damaged, repair.
Never remove the covers guarding rotating parts, such as the camshaft cover and rocker covers, when the engine is operating.
When the engine is coupled to other equipment or connected to a radiator, be sure to install covers on the exposed connecting belt and coupling.
Never remove protective covers.

● Check surrounding area for safety before starting engine

Before starting the engine, check to make sure no one is near the generator and tools are not left on or near the engine. Always verbally notify people within the immediate area when starting the engine.
When the starter switch is posted with a sign that prohibits startup operation, do not operate the engine.

● Stay clear of rotating parts while engine is in operation

Do not approach rotating parts while the engine is in operation.
Keep items that can be easily entangled away from rotating parts.
Rotating parts can entangle a persons' body or tools to cause serious.

● Lock out and tag out

Be sure to lock out and tag out before starting inspection and maintenance.
Lockout and tagout are effective methods of cutting off machines and equipment from energy sources.
To lock out and tag out, pull out the key from the starter switch, turn off the battery switch, and post a "Do Not Operate" tag or a similar sign on the starter switch.
The starter switch key should be kept by the person performing the inspection and maintenance.
If the engine is installed with an air starter system, close the main valve of the air tank, and post a "Do Not Open" tag on the main valve.

● Always stop engine before inspection and maintenance

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

● Always return turning tools to original position after use

Be sure to remove all turning tools used in inspection and maintenance. Return the turning gear in the original position before starting the engine.
Starting the engine with the turning tools inserted or turning gears engaged may not only cause engine damage but personal injury as well.

⚠ WARNING Danger of Burns

- Do not touch engine in operation or immediately after operation

Do not touch any part of the engine while the engine is operating or immediately after it stops operation. Touching the engine in operation or immediately after operation can cause burns.
When conducting inspection and maintenance, check the water temperature gage to make sure the engine has cooled sufficiently.

- Open radiator filler cap carefully

Never open the radiator filler cap while the engine is operating or immediately after it stops operation. Open the cap only after the engine stops and the coolant temperature drops sufficiently.
When opening the cap, slowly turn the cap to release internal pressure. To prevent burns caused by spurting steam, wear thick rubber gloves or cover the cap with a cloth.
When closing the cap, make sure to tighten it securely.
If the radiator filler cap is opened when the coolant is at operating temperature, steam and hot coolant may blow out, causing skin burns as a result.

- Add coolant after coolant temperature drops sufficiently

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

- Do not remove heat shields

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

⚠ WARNING Beware of Exhaust Gas Poisoning

- Operate engine in well-ventilated area

If the engine is installed in an enclosed area and an exhaust duct is used to discharge the exhaust gas to the outside, inspect the duct joints to make sure there is no exhaust gas leak from duct joints.
When the engine is used as a movable generator, do not use the engine in an enclosed area (inside a warehouse, tunnel, etc.) or at a site where all sides are blocked for poor ventilation. If the engine must be operated in an enclosed area, discharge the exhaust gas to the outside and provide adequate ventilation. Make sure the exhaust gas does not blow in the direction of plants or animals.
Exhaust gas from the engine contains carbon monoxide and other harmful substances. Operating the engine in an ill-ventilated area can cause gas poisoning.

⚠ WARNING Danger of Hearing Problems

- Wear ear plugs

Always wear ear plugs when entering the machine room (engine room).
Combustion sound and mechanical noise generated by the engine can cause hearing problems.

⚠ WARNING Beware of Falling Equipment

● Lift engine carefully

When lifting the engine, use wire ropes capable of supporting the entire weight of the engine.
Attach appropriate slings to the hangers provided on the engine to lift the engine.
Keep the engine balanced during lifting by considering center of gravity of the engine.
Keep the angle formed by wire ropes within 60°. If the angle exceeds this limit, excessive load is applied on the hangers and may damage the hangers.
If wire ropes contact the engine directly, place a cloth or other soft padding to prevent damage to the engine and wire ropes.

● Do not climb onto engine

Do not climb onto the engine, or set a foot on any part located on the side of the engine.
To work on parts located on the upper section, use a ladder, stand, etc., and be careful not to fall.
Climbing on the engine can damage engine parts, and a person may fall and get injured.

● Watch footing when conducting maintenance

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

⚠ CAUTION Cautions Regarding Engine Oil and LLC

● Use only specified fuel, engine oil and coolant

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

● Handle LLC (long life coolant) carefully

LLC contains strong alkali. Do not swallow or allow it to contact eyes.
Since drained coolant (containing LLC) is harmful, do not dispose of it into conventional sewage. Abide by the applicable law and regulations when discarding drained coolant.

● Properly disposed of drained oil and coolant

Do not disposed of drained engine oil or coolant into conventional sewage.
Laws and regulations prohibit disposal of oil and coolant into ordinary sewage systems.
When disposing oil waste, coolant and other environmentally hazardous waste, abide by the law and regulations.

⚠ CAUTION Cautions Regarding Battery

● Handle battery carefully

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

⚠ CAUTION Response to Abnormalities

● If engine overheats, conduct heating operation before stopping engine

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

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

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

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

● If oil pressure drops, stop engine immediately

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

● If fan belt breaks, stop engine immediately

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

⚠ CAUTION Other Cautions

● Never modify engine

Unauthorized modification of the engine will void the manufacturer's warranty.
Modification of the engine may not only cause engine damage but also result in personal injury.

● Never break seals

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

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

● Always perform specified pre-operation inspections and periodic inspections

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

● Break in new engine

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

● Conduct warm-up operation

After the engine starts, let it idle at low speed for 5 to 10 minutes before using the engine for work.
Warm-up operation circulates lubricants in the engine, thus prolonging the service life and contributing to high-performance and economical operation.
Do not conduct warm-up operation for an extended period of time. Prolonged warm-up operation causes carbon build-up in the cylinders that leads to incomplete combustion.

● Never operate engine under overload condition

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

● Conduct cooling operation before stopping engine

Before stopping the engine, conduct cooling operation (operating at low speed) for 5 to 6 minutes.
Abruptly stopping the engine immediately after high-load operation can cause partial overheating and shorten the service life of the engine.
During cooling operation, check the engine for abnormalities.

● Do not splash water on engine

Do not allow rain water to enter the engine through the air inlet or exhaust openings.
Do not wash the engine while it is operating. Cleaning fluid (water) can be sucked into the engine.
If water enters the combustion chambers of the engine, starting the engine can cause water hammer action, and may result in internal engine damage and serious accidents.

● Conduct proper maintenance of air cleaner

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

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

● Observe safety rules at workplace

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

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

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

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

● Wear proper work clothes and protective gear

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

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

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

● Use appropriate tools for maintenance work

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

If tools are damaged, replace with new tools.

● Do not operate starter for prolonged time

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

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

● Do not turn off battery switch while engine is operating

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

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

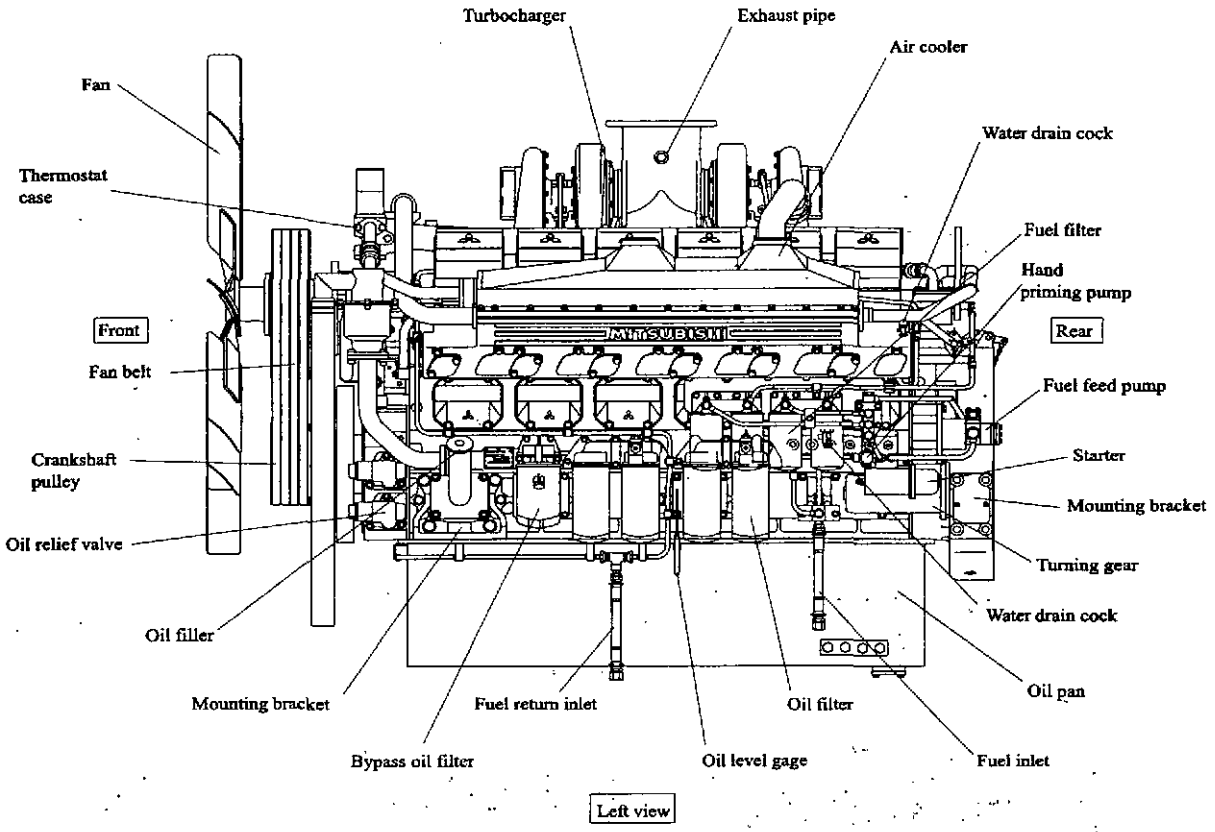
● Cautions in transporting engine

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

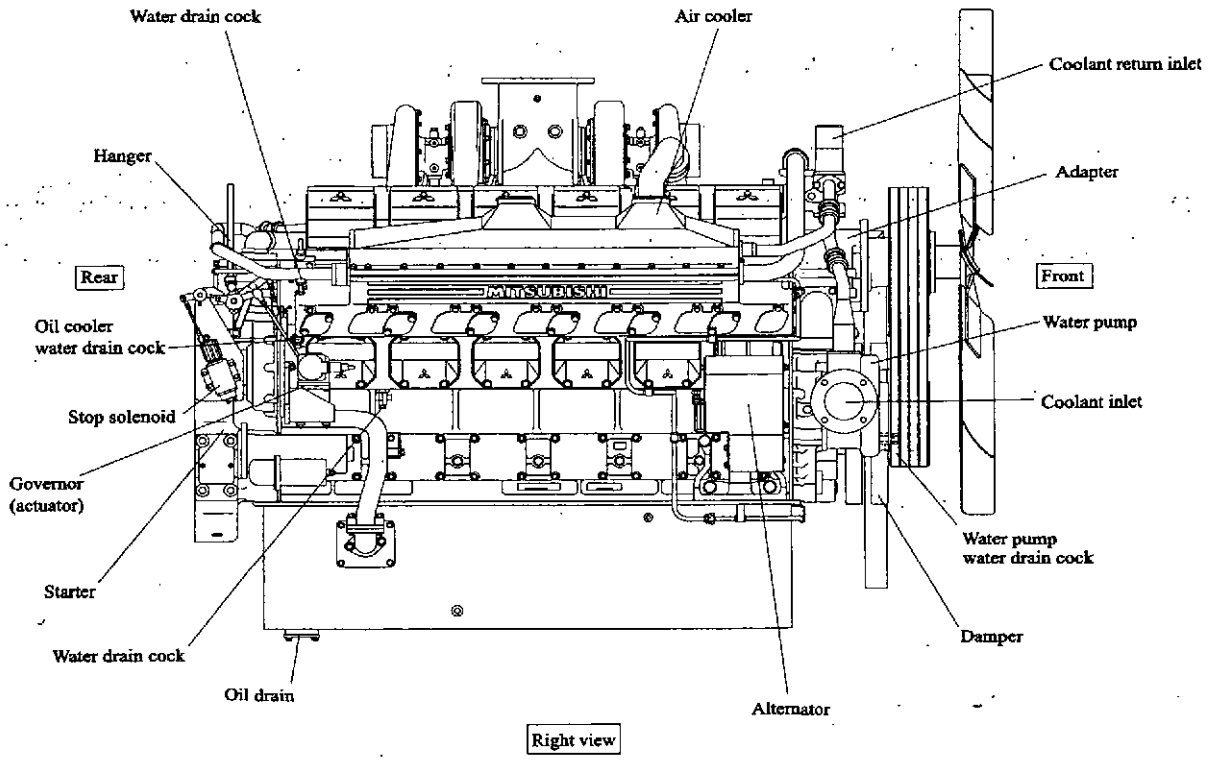
GENERAL

1. Outline

1.1 External View

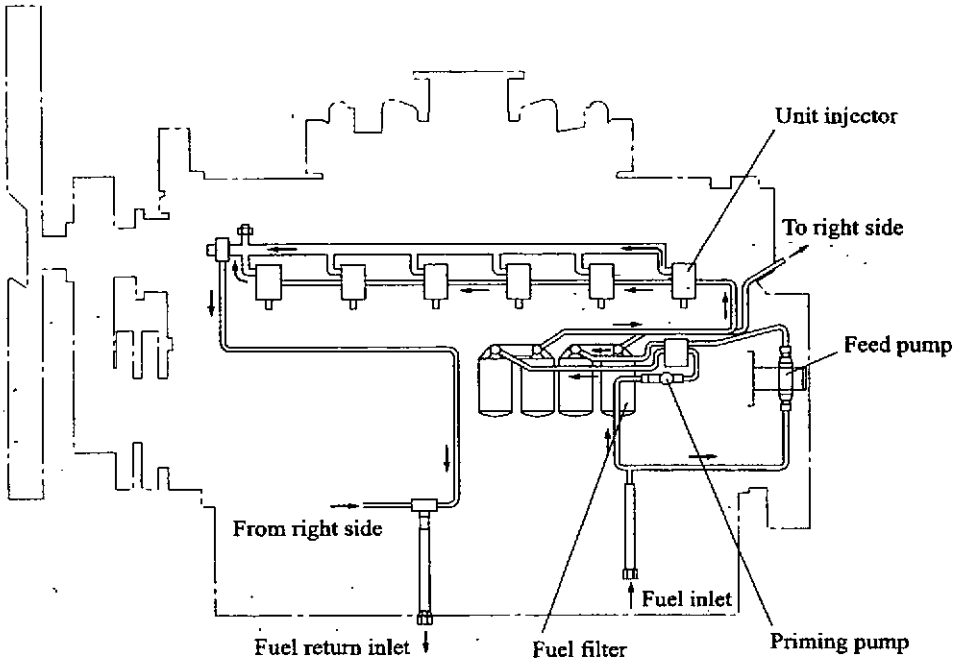


Engine left view



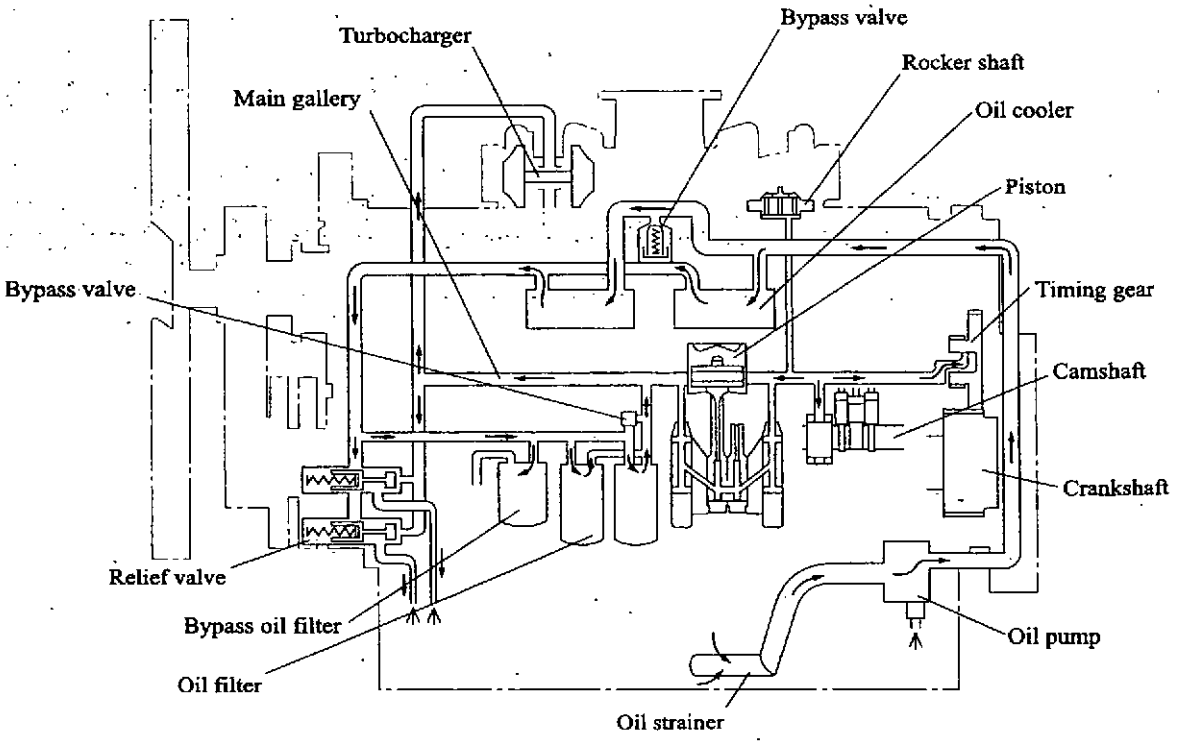
Engine right view

1.2 Outline of Fuel System



Outline of fuel system

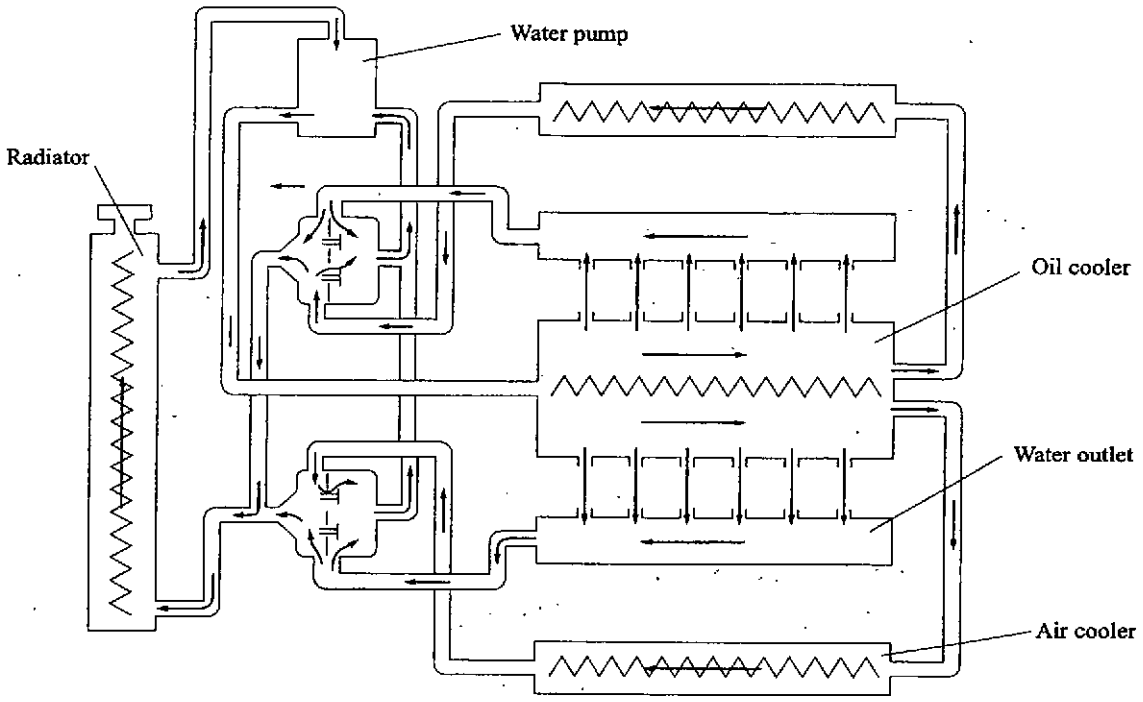
1.3 Outline of Lubrication System



Outline of lubrication system

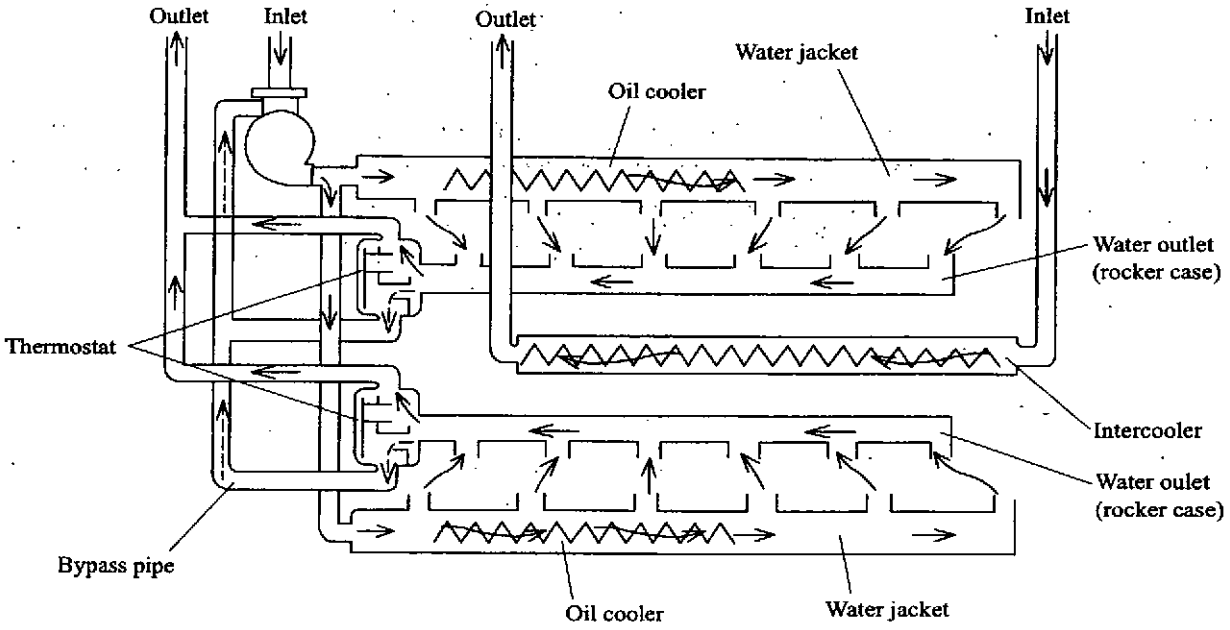
1.4 Outline of Cooling System

(1) Outline of cooling system of engine with radiator



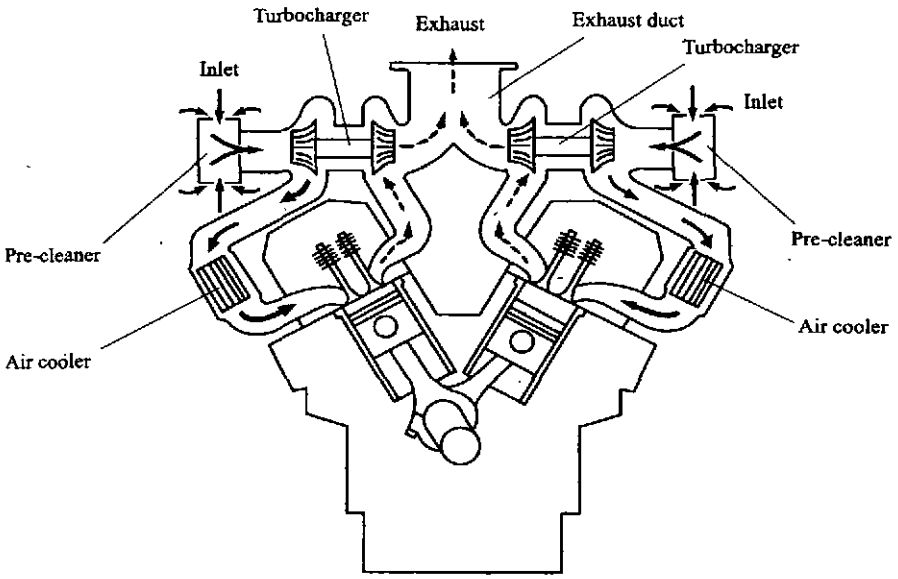
Outline of cooling system of engine with radiator

(2) Outline of cooling system of engine with external cooling water system
Dual-cooling system (parallel piping) PTK



Outline of cooling system of engine with external cooling water system

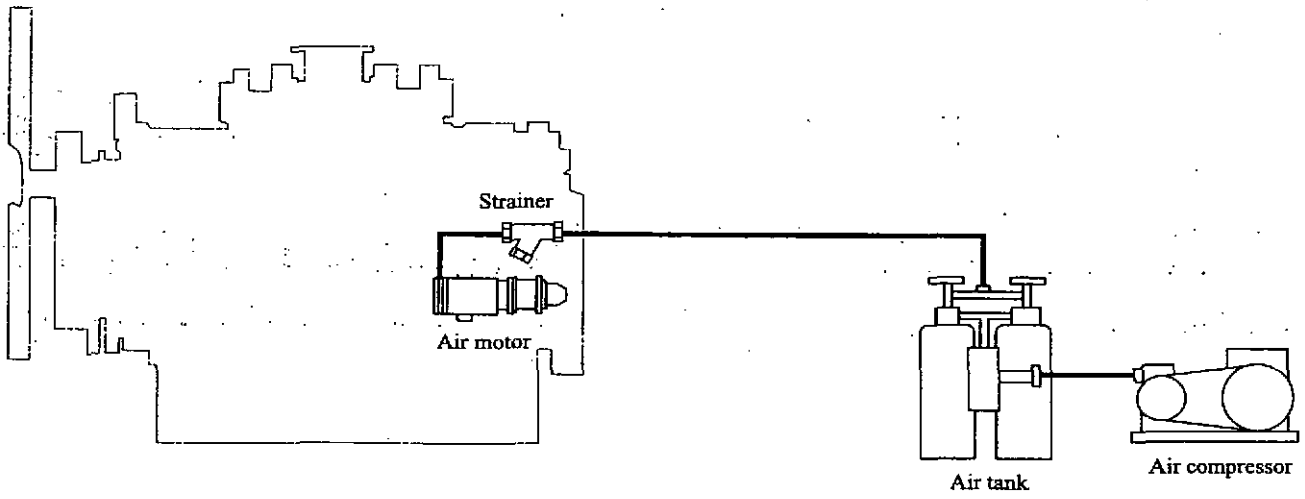
1.5 Outline of Inlet and Exhaust Systems



Outline of inlet and exhaust systems

1.6 Outline of Air Starter System

(1) Outline of air motor system



Outline of air motor system

1.7 Engine Serial Number

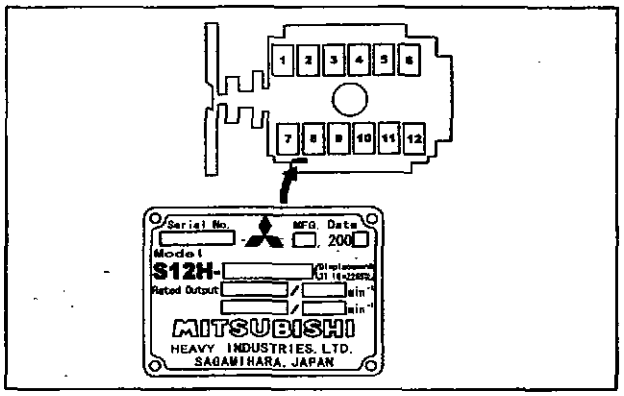
The engine serial number is stamped on the nameplate attached on the right rear side of the engine.

〈*Example*〉

Model	Engine serial number
S12H	30012

The nameplate is stamped with the engine serial number, rated output, and rated speed.

Numbers in the illustration indicate cylinder numbers.



Nameplate location

1.8 Engine Model and Application Code

S 12 H – □ □

- TA ····· Equipped with after-cooler and turbocharger
- TK ····· Equipped with intercooler and turbocharger

Application code

- Blank ··· For construction equipment
- P ····· For generator
- L ····· For railroad train
- MP ····· For marine generator and general power source for ship
- M ····· For ship engine

Series code

Number of cylinders

Manufactured at Sagamihara Machinery Works

2. Specifications

Engine type				S12H	
				TA	TK
Main specification	Type			Water-cooled, 4-cycle diesel engine with turbocharger	
				With after-cooler	With intercooler
	No. of cylinders - cylinder arrangement			12 - V	
	Combustion type			Direct injection	
	Valve mechanism			Overhead	
	Cylinder bore × stroke		mm [in.]	150 × 175 [5.91×6.9]	
	Displacement		ℓ [U. S. gal]	37.11 [9.80]	
	Compression ratio			14.0:1	
	Fuel			Diesel fuel (JIS K2204 Special No. 1 to No. 3) or Class-A heavy oil	
	Firing order			1-12-5-8-3-10-6-7-2-11-4-9	
	Rotating direction			Counterclockwise as viewed from flywheel side	
	Dimensions	Overall length	mm [in.]	1954 [76.9]	
		Overall width	mm [in.]	1472 [58]	
		Overall height	mm [in.]	1694 [66.7]	
	Dry weight		kg [lb.]	4190 [9237]	
Engine main parts	Cylinder liner	Type		Wet type	
	Piston ring	Quantity		Compression ring: 2 Oil ring (with expander): 1	
	Valve timing	Inlet valve	Open	BTDC 55°	
			Close	ABDC 65°	
		Exhaust valve	Open	BBDC 65°	
			Close	ATDC 55°	
	Valve clearance (when cold)		Inlet	0.6 [0.024]	
	mm [in.]		Exhaust	0.8 [0.031]	
	Engine support method			4-point support system	
	Starting system			Electric starter or air motor system	
Fuel system	Injector	Model		Mitsubishi Unit Injector	
		Manufacturer		Mitsubishi Heavy Industry	
		Plunger diameter	mm [in.]	14 [0.55]	
	Feed pump	Model		Trochoid type pump TOP-2HAMTVB	
		Manufacturer		Japan Oil Pump	
		Theoretical delivery capacity		12.0 cm^3 [0.73 cu. in]/rev.	
	Governor	Speed control system		< Hydraulic > · PSG	< Electric > · SG4030 · DYNA8200
	Injection nozzle	Type		Hole type	
		Manufacturer		Bosch Automotive Systems Corporation	
		No. of spray holes		10	
		Spray hole diameter - spray angle	mm [in.]	ϕ0.28 [0.0110], ϕ0.29 [0.0114], ϕ0.31 [0.0122]-160°	
		Injection pressure	MPa (kgf/cm^2) [psi]	29.4 (300) [4267.5]	
	Fuel filter	Type		Spin-on type with paper element	

Engine type				S12H	
				TA	TK
Lubrication system	Lubricating type			Forced circulation type (oil pump pressure feed type)	
	Engine oil	Standard		Class CD or CF (API service classification)	
		Capacity (oil filter including engine) ℓ [U. S. gal]		Approx. 200 [54.82] (Oil pan: 180 [47.55])	
	Oil pump	Type		Gear pump	
		Reduction ratio		1.125 (Z=64)	
		Theoretical delivery capacity ℓ [U. S. gal]/min		370 [98] (at engine speed of 1500 min^{-1})	
				450 [119] (at engine speed of 1800 min^{-1})	
		Safety valve	Type	Piston valve type	
			Valve opening pressure MPa (kgf/cm^2) [psi]	1.4±0.1 (14±1) [199±14]	
	Relief valve	Type		Main gallery pressure detection type	
		Valve opening pressure MPa (kgf/cm^2) [psi]		0.58±0.05 (5.9±0.5) [84±7]	
	Oil cooler	Type		Water-cooled, multi-plate type	
		Element		15 stages (100×558 mm [3.94×21.97 in.])	
	Oil filter	Type		Spin-on type with paper element	
	Bypass oil filter	Type		Spin-on type with paper element	
	Oil filter alarm	Type		Piston valve type, built-in electric contact points	
		Lamp lighting and valve opening pressure MPa (kgf/cm^2) [psi]		$0.15^{+0.03}_{0}$ ($1.5^{+0.3}_{0}$) [$21.34^{+4.27}_{0}$]	
	Oil cooler bypass valve	Lamp lighting and valve opening pressure MPa (kgf/cm^2) [psi]		0.44±0.05 (4.5±0.5) [64±7.2]	
	Piston cooling nozzle	Type		Check valve type	
		Valve opening pressure MPa (kgf/cm^2) [psi]		0.29±0.03 (3±0.3) [43±4.3]	
Cooling system	Cooling type			Water-cooled, forced circulation	
	Coolant capacity (engine) ℓ [U. S. gal]			Approx. 100 [26.4]	
	Water pump	Type		Centrifugal type	
		Reduction ratio		1.829 (75/41)	
		Delivery capacity ℓ [U. S. gal]/min		1600 [422.7] (at engine speed of 1800 min^{-1}), 1330 [351.3] (at engine speed of 1500 min^{-1})	
	Thermostat	Type		Wax type (2 stage opening/closing)	
		Valve opening temperature °C [°F]		Primary valve: 71±2 [159.8±35.6], secondary valve: 74±2 [165±35.6], fully opened: 85 [185]	
	Radiator	Type		Plate-and-fin type or corrugated fin type	
	Cooling fan	Type		Aluminum plate, arc blades (No. of blades: 8, diameter: ϕ1524 [60])	
	Fan belt	Type		Low-edge C type Cog belt	
		Pulley ratio		0.55 ··· 1800 min^{-1} (248/448)	0.66 ··· 1500 min^{-1} (248/373)
		Outer circumference mm [in.]		2085 [82.09]	1955 [77]

Engine type			S12H	
			TA	TK
Inlet and exhaust systems	Air cleaner	Type	Paper element type or pre-cleaner type	
	Turbocharger	Type	TD13	
		No. of units	2	
	Air cooler	Type	Multilayer fin-and-plate type	
Electrical system	Voltage – polarity		24 V - Negative (-) ground	
	Starter	Type	0-23000-6901	
		Manufacturer	Nikko Electric Industry	
		Piston mesh type	Pinion shift	
		Output V-kW	24-7.5×2	
		Pinion/ring gear ratio	16.545 (182/11)	
	Alternator	Type	3-phase alternating-current generator, built-in IC regulator	
		Manufacturer	Mitsubishi Electric	
		Output V-A	24-30	
		Rated output generating speed min^{-1}	5000 (at 27 V, 30 A)	
		Regulated voltage V	28.5±0.5	
	Safety relay (for starter chattering prevention)	Manufacturer	Nikko Electric Industry	
		Nominal voltage V	24	
		Rating sec.	30	
		Operating voltage V	8 to 24	
		Operation interval (at 24 V) sec.	1 ON-OFF cycle between SS and SW 2.5 to 3.0	
		Allowable temperature °C [°F]	-30 to +80[-86 to 176]	
		Grounding system	2-wire system	
Air starter system	Air motor	Type	Turbine type	
		Manufacturer	T. D. I. (U. S.)	
		Pinion mesh type	Pinion shift	
		Nominal output kW [PS]	14.71 [20] (at 0.93 MPa (9.5 kgf/cm^2) [135 psi])	
		Pinion/ring gear ratio	13 (182/14)	

3. Tips on Disassembly and Reassembly

This service manual describes service procedures recommended by Mitsubishi Heavy Industry, and also contains information of special tools and basic safety precautions. It should be noted that the manual cannot cover all potential dangers in maintaining, inspecting and servicing an engine.
When working on the engine, follow the directions in this manual and pay close attention to the following cautions.

3.1 Disassembly

(1) Use correct tools and instruments.
(2) Arrange a work bench and boxes for placing removed parts, if necessary, and follow the specified disassembly sequence.
(3) Lay down disassembled parts neatly and in order to prevent losing them.
(4) During disassembly, pay attention to alignment marks to ensure proper reassembly and if necessary, place alignment marks on parts before disassembly.
(5) Carefully check each part for abnormalities before disassembly and also during removal and cleaning in order to discover any signs of abnormalities or defects that may not be found after cleaning.
(6) Exercise utmost caution to ensure safety, particularly for balancing removed parts and transporting heavy parts. (Use jacks and chain blocks when necessary.)

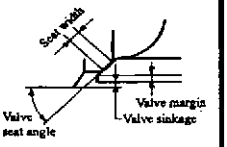
3.2 Reassembly

(1) Wash all engine parts, except for oil seals, O-rings, rubber seals, etc., in cleaning solvent and dry them with compressed air.
(2) Use correct tools and instruments.
(3) Use only high-quality lubricating oils and greases. Be sure to apply a coat of oil, grease or sealant to parts as specified.
(4) Use a torque wrench to tighten parts to specified tightening torque when tightening torque is indicated.
(5) Replace all gaskets, packings and O-rings with new one.

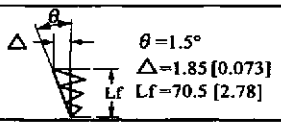
MAINTENANCE STANDARDS

1. Maintenance Standards Table

Unit mm [in.]

Group	Inspection point		Nominal value	Standard	Limit	Remark
General	Maximum speed (rated speed as reference value)			105 to 110%	115%	Rated speed is stamped on the nameplate
	Minimum speed			600 to 650min^{-1}		
	Compression pressure (at 120 min^{-1})			2.4 MPa (24.4 kgf/cm^2) [347.1 psi] or more	Faulty if 1.9 MPa (19.3 kgf/cm^2) [274.5 psi] or less	Oil and water temperature at 20 to 30°C [68 to 86°F]
	Lubricating oil pressure	Rated pressure		0.39 to 0.67 MPa (4 to 7 kgf/cm^2) [56.89 to 99.56 psi] or more	Faulty if 0.39 MPa (4 kgf/cm^2) [56.89 psi] or less	Oil temperature at 60 to 70°C [140 to 158°F]
		Idling		0.20 to 0.29 MPa (2 to 3 kgf/cm^2) [28.45 to 42.68 psi] or more	Faulty if 0.10 MPa (1.0 kgf/cm^2) [14.2 psi] or less	
	Valve timing (with 2 mm [0.08 in.] clearance on valve side, cold)	Inlet valve open		BTDC 14°		Values are only for checking valve timing and are different from actual opening/closing time.
		Inlet valve closed		ABDC 23°		
		Exhaust valve open		BBDC 21°		
		Exhaust valve closed		BTDC 15°		
	Valve clearance	Inlet valve		0.6 [0.024]		Cold
		Exhaust valve		0.8 [0.031]		
	Fuel injection start timing (BTDC)			±1° (crank angle)		Varies depending on specifications, refer to caution plate on No. 1 rocker cover.
Engine main parts	Rocker	Rocker bushing inside diameter	ϕ44 [1.734]	44.000 to 44.075 [1.734 to 1.735]	44.125 [1.737]	
		Rocker shaft diameter	ϕ44 [1.734]	43.975 to 43.991 [1.731 to 1.733]	43.030 [1.694]	
	Valve	Valve stem diameter	ϕ10 [0.39]	9.940 to 9.960 [0.39134 to 0.39213]	9.910 [0.39016]	Same for inlet and exhaust valves.
		Valve guide inside diameter	ϕ10 [0.39]	10.000 to 10.015 [0.39370 to 0.39429]	10.060 [0.39606]	
	Valve seat and valve	Valve seat angle		30°		
		Valve sinkage		-0.1 to 0.1 [-0.004 to 0.004]	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 [0.118]	2.8 to 3.2 [0.110 to 0.126]	Refacing permissible up to 2.5 [0.098]	
		Clearance between cylinder head bore diameter and valve seat diameter	ϕ55 [2.165]	-0.070 to -0.130 [-0.00276 to -0.00512]		Minus (-) value indicates interference in diameter.

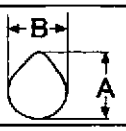
Unit mm [in.]

Group	Inspection point			Nominal value	Standard	Limit	Remark
Engine main parts	Valve spring	Free length			70.5 [2.78]	69 [2.72]	
		Perpendicularity				△= 2.2 [0.087] over entire length	
		Set length/load mm [in.]/N (kgf) [lbf]			61.8 [2.43] /254 to 281 (25.94 to 28.67 kgf) [57.2 to 63.2 lbf]		
	Pushrod	Deflection			Less than 0.5 [0.020]	0.5 [0.020]	TIR
	Cylinder head	Distortion of bottom surface			0.03 [0.0012] or less	0.50 [0.0197]	Reface slightly.
	Cylinder liner	Bore diameter		ϕ150 [5.906]	150.000 to 150.040 [5.906 to 5.907]	150.140 [5.911]	
		Circularity			0.02 [0.0008] or less		
		Cylindricity			0.02 [0.0008] or less		
		Perpendicularity of bottom flange surface to cylinder liner			0.03 [0.0012] or less		
		Cylinder liner collar protrusion			0.10 to 0.19 [0.004 to 0.0075]		
		Thickness of cylinder liner collar			$15^{+0.19}_{0.15}$ [$0.59^{+0.0075}_{0.0059}$]		
		Height of protrusion of cylinder liner			0.2±0.04 [0.008±0.002]		
	Piston	Outside diameter (at piston skirt)		ϕ150 [5.906]	149.78 to 149.92 [5.897 to 5.898]	149.68 [5.893]	Measure diameter in direction perpendicular to piston pin
		Weight difference in one engine			±30g [±0.07 lb.]		
		Pin bore diameter		ϕ58 [2.283]	58.002 to 58.012 [2.2852 to 2.2856]	58.020 [2.29]	
		Protrusion			0.38 to 0.89 [0.015 to 0.035]		
		End gap	Top	3.00 [0.118]	0.08 to 0.11 [0.003 to 0.004]	0.20 [0.008]	Measure using new rings.
			Second	2.55 [0.1]	0.07 to 0.10 [0.0275 to 0.0039]	0.15 [0.006]	
			Oil	5.00 [0.197]	0.05 to 0.09 [0.0197 to 0.0035]	0.15 [0.006]	
	Cylinder head gasket	Thickness when tightened		1.8 [0.071]	1.77 to 1.83 [0.0697 to 0.0720]		
	Piston and cylinder head	Clearance between piston and cylinder head			0.88 to 1.45 [0.035 to 0.057]		
	Piston ring	End gap	Top		0.6 to 0.8 [0.02 to 0.03]	2.0 [0.08]	If gage is not available, approximate value can be obtained at cylinder bore.
			Second		0.5 to 0.7 [0.0197 to 0.0275]	2.0 [0.08]	
			Oil		0.5 to 0.7 [0.0197 to 0.0275]	2.0 [0.08]	

Unit mm [in.]

Group	Inspection point			Nominal value	Standard	Limit	Remark
Engine main parts	Piston pin		Diameter	ϕ58 [2.283]	57.987 to 58.000 [2.2847 to 2.2852]	57.970 [2.28]	
	Connecting rod	Bushing inside diameter		ϕ58 [2.283]	58.02 to 58.04 [2.2843 to 2.2868]	58.070 [2.29]	
		Bend and twist			0.05/100 [0.0020/3.94] or less		
		End play (clearance) (rod and crankpin widths)		54 [2.13] ×2	0.4 to 0.6 [0.016 to 0.024]	0.8 [0.03]	
		Big-end bore diameter (To be measured in combination with caps.)		ϕ110 [4.3307]	110.000 to 110.022 [4.3307 to 4.3316]	110.047 [4.3326]	Roundness (Max. - Min.) less than 0.1 mm [0.004 in.]
	Connecting rod bearing	Thickness at center	STD	3.000 [0.118]	2.987 to 3.000 [0.1176 to 0.1181]	2.950 [0.116]	Replace bearings before limit is reached, regrind crankpins and use undersize bearings if limit is exceeded.
			-0.25 [-0.01]	3.125 [0.123]	3.112 to 3.125 [0.1225 to 0.1230]	3.075 [0.121]	
			-0.50 [-0.02]	3.250 [0.128]	3.237 to 3.250 [0.127 to 0.128]	3.200 [0.126]	
			-0.75 [-0.03]	3.375 [0.133]	3.362 to 3.375 [0.132 to 0.133]	3.325 [0.131]	
			-1.00 [-0.04]	3.500 [0.138]	3.487 to 3.500 [0.137 to 0.138]	3.450 [0.136]	
	Flywheel	Perpendicularity runout			0.28 [0.011] or less		
		Periphery runout			0.13 [0.005] or less		
	Damper	Periphery runout			0.5 [0.0197] or less	1.5 [0.0591]	Replace after 8000 service hours.
		Perpendicularity runout			0.5 [0.0197] or less	1.5 [0.0591]	
	Fuel feed pump accessory drive	Drive case bearing bore diameter		ϕ68 [2.679]	67.988 to 68.018 [2.6787 to 2.6799]		
		Bearing	Bore diameter	ϕ40 [1.576]	39.988 to 40.000 [1.5743 to 1.5748]		
			Outside diameter	ϕ68 [2.679]	67.985 to 68.000 [2.6766 to 2.6771]		
		Drive shaft journal diameter		ϕ40 [1.576]	39.995 to 40.011 [1.5758 to 1.5764]		
	Timing gear backlash	Right side camshaft gear to idler gear			0.11 to 0.25 [0.0043 to 0.009]	0.50 [0.0197]	
		Idler gear to idler gear			0.12 to 0.22 [0.0047 to 0.0086]	0.50 [0.0197]	
		Crankshaft gear to idler gear			0.11 to 0.26 [0.0043 to 0.0102]	0.50 [0.0197]	
		Left side camshaft gear to idler gear			0.10 to 0.24 [0.0039 to 0.0095]	0.50 [0.0197]	
		Left side camshaft gear to fuel feed pump drive gear			0.12 to 0.18 [0.0047 to 0.007]	0.50 [0.0197]	

Unit mm [in.]

Group	Inspection point		Nominal value	Standard	Limit	Remark
Engine main parts	Timing gear	Idler bushing inside diameter	ϕ50 [1.97]	50.000 to 50.025 [1.96850 to 1.96948]	50.060 [1.97086]	
		Idler shaft diameter	ϕ50 [1.97]	49.950 to 49.975 [1.96653 to 1.96752]	49.900 [1.96456]	
		Idler gear end play		0.3 to 0.5 [0.012 to 0.020]	0.7 [0.028]	
	Front gear backlash	Crankshaft gear to idler gear		0.12 to 0.18 [0.005 to 0.007]	0.50 [0.0197]	
		Water pump gear to idler gear		0.12 to 0.18 [0.005 to 0.007]	0.50 [0.0197]	
	Front gear	Idler bushing inside diameter	ϕ50 [1.97]	50.000 to 50.025 [1.96850 to 1.96948]	50.060 [1.97086]	
		Idler shaft diameter	ϕ50 [1.97]	49.950 to 49.975 [1.96653 to 1.96752]	49.900 [1.96456]	
		Idler gear end play		0.3 to 0.5 [0.012 to 0.020]	0.7 [0.028]	
	Camshaft	Cam lift (A - B) Inlet		14.525 to 14.625 [0.572 to 0.576]	13.78 [0.543]	
		Cam lift (A - B) Exhaust		9.425 to 9.525 [0.371 to 0.375]	8.68 [0.342]	
		Deflection (1/2 value of runout measured at center journal when camshaft is supported at both end journals)		0.05 [0.0020] or less	0.08 [0.0031]	Repair or replace.
		Journal diameter	ϕ100 [3.94]	99.92 to 99.94 [3.937 to 3.938]	99.86 [3.934]	
		Camshaft bushing inside diameter (as installed in crankcase)	ϕ100 [3.94]	100.000 to 100.115 [3.94 to 3.945]	100.160 [3.946]	
		End play (clearance)		0.2 to 0.4 [0.008 to 0.016]	0.55 [0.022]	Replace thrust plate.
	Cam follower	Follower bushing inside diameter	ϕ30 [1.182]	30.000 to 30.075 [1.182 to 1.184]	30.125 [1.187]	
		Cam follower shaft diameter	ϕ30 [1.182]	29.959 to 29.980 [1.180 to 1.181]	29.930 [1.179]	
		Tappet roller diameter	ϕ41 [1.6142]	40.995 to 41.050 [1.614 to 1.617]	40.985 [1.6148]	

Unit mm [in.]

Group		Inspection point	Nominal value	Standard	Limit	Remark
Engine main parts	Crankshaft	Crankpin diameter	ϕ104 [4.098]	103.900 to 103.920 [4.0905 to 4.0913]	103.960 [4.0929]	Replace with undersize bearing if worn beyond limit.
		Crankpin journal diameter	ϕ140 [5.516]	139.930 to 139.950 [5.5091 to 5.5098]	139.970 [5.5106]	
		Center to center distance between journal and crankpin	87.5 [3.45]	87.4 to 87.6 [3.4409 to 3.4488]		
		Parallelism between journals and crankpins		0.01 [0.0004] or less	0.03 [0.0012]	Repair.
		Roundness of journals and crankpins (diameter difference)		0.01 [0.0004] or less	0.03 [0.0012]	Repair.
		Cylindricity of journals and crankpins (diameter difference)		0.02 [0.0008] or less	0.03 [0.0012]	
		Fillet radius of crankpins	7 [0.276]	6.8 to 7.0 [0.268 to 0.276]		
		Fillet radius of journals	7 [0.276]	6.8 to 7.0 [0.268 to 0.276]		
		Hardness of journals and crankpins		Hv>620		
		Angular deviation between pins		±0.3°		
		Deflection (1/2 value of runout measured at center journal when crankshaft is supported at both end journals)		0.04 [0.0016] or less	0.10 [0.0039]	Repair or replace.
		End play (Clearance between thrust bearing journal width of crankshaft)	58 [2.29]	0.20 to 0.40 [0.0079 to 0.0157]	0.50 [0.0197] +1.18 [+0.0465] for crankshaft width	Replace thrust bearings if worn *down to limit. Use* oversize thrust bearings if worn beyond limit. +0.25[+0.01], +0.50 [+0.02], +0.75 [+0.03]
	Main bearing	Thickness at center — STD	3.500 [0.138]	3.467 to 3.480 [0.1366 to 0.1371]	3.425 [0.135]	Replace bearings if worn down to limit. Regrind crank journals and use undersize bearings if worn beyond limit.
		Thickness at center — -0.25 [-0.01]	3.625 [0.143]	3.592 to 3.605 [0.1415 to 0.1420]	3.550 [0.140]	
		Thickness at center — -0.50 [-0.02]	3.750 [0.148]	3.717 to 3.730 [0.146 to 0.147]	3.675 [0.145]	
		Thickness at center — -0.75 [-0.03]	3.875 [0.153]	3.842 to 3.855 [0.151 to 0.152]	3.800 [0.150]	
		Thickness at center — -1.00 [-0.04]	4.000 [0.158]	3.967 to 3.980 [0.156 to 0.157]	3.925 [0.155]	
	Crankcase	Gasket surface distortion		0.05 [0.002] or less	0.20 [0.008]	Slightly reface.
		Main bearing bore diameter	ϕ147 [5.792]	147.000 to 147.025 [5.792 to 5.793]	147.045 [5.79]	

Unit mm [in.]

Group		Inspection point		Nominal value	Standard	Limit	Remark
Fuel system	Unit injector	Stopper spring wire diameter		φ0.4 [0.016]	0.3992 to 0.4008 [0.0157 to 0.1556]	0.25 [0.0099]	
		Stopper protrusion diameter		φ4 [0.1576]	3.85 to 3.95 [0.1517 to 0.1556]	3.5 [0.1378]	
		Wear on needle valve cotnact area of distance piece			0 [0]	-0.2 [-0.0079]	
		Needle valve spring	Free length		27.6 [1.0874]	27.2 [1.0709]	
			Perpendicularity		Less than 0.5 [0.0197]	0.5 [0.0197] or more	
		Spring cage inside diameter		φ14 [0.552]	14.01 to 14.02 [0.5520 to 0.5524]	14.6 [0.5752]	
		Plunger tappet diameter		φ18 [0.710]	17.966 to 17.984 [0.7079 to 0.7086]	17.959 [0.7076]	
		Plunger spring	Free length	84[3.310]	84±2[3.310±0.08]	81.5 [3.21]	
			Perpendicularity		Less than 1.5 [0.060]	1.5 [0.060] or more	
		Plunger pushrod deflection				0.15 [0.006]	
		Control rack	Sliding resistance N (gf) [lbf]			0.49 (50) [0.11]	
			Deflection			0.03 [0.0012]	
	Injection nozzle	Valve opening pressure MPa (kgf/cm²)[psi]		29.42 (300) [4268]	28.93 to 30.89 (295 to 315) [4196 to 4481]		Shim thickness should be less than 0.8 mm [0.032 in.]. If it exceeds the limit, replace the spring.
		Spray cone angle		160°			Use hand-operated tester.
	Governor drive	Drive shaft bearing housing diameter of case		φ52 [2.05]	51.988 to 52.018 [2.04677 to 2.04795]		
		Drive shaft bearing	Outside diameter	φ52 [2.05]	51.987 to 52.000 [2.04673 to 2.04724]		
			Inside diameter	φ25 [0.98]	24.990 to 25.000 [0.98386 to 0.98425]		
		Bearing journal diameter of drive shaft		φ25 [0.98]	25.002 to 25.011 [0.98433 to 0.98469]		
		Idler shaft bearing housing diameter of case		φ52 [2.05]	51.988 to 52.018 [2.04677 to 2.04795]		
		Idler shaft bearing	Outside diameter	φ52 [2.05]	51.987 to 52.000 [2.04673 to 2.04724]		
			Inside diameter	φ25 [0.98]	24.990 to 25.000 [0.98386 to 0.98425]		
		Bearing journal diameter of idler shaft		φ25 [0.98]	25.002 to 25.011 [0.98433 to 0.98469]		
		Drive gear end play			0.24 to 0.96 [0.0095 to 0.038]		

Unit mm [in.]

Group	Inspection point		Nominal value	Standard	Limit	Remark
Lubrication system	Oil pump	Drive and driven gear base tangent length		27.983 to 28.055 [1.1025 to 1.1054]	27.93 [1.1004]	
		Clearance between drive or driven gears and case		0.095 to 0.140 [0.004 to 0.006]	Tip clearance 0.190 [0.007]	
		Gear end side clearance in case		0.095 to 0.155 [0.004 to 0.006]	0.29 [0.0114]	
		Drive and driven gears shaft diameter	ϕ40 [1.576]	39.986 to 40.000 [1.575 to 1.576]	39.930 [1.573]	
		Bushing inside diameter	ϕ40 [1.576]	40.040 to 40.059 [1.577 to 1.578]	40.140 [1.582]	
		Safety valve — Valve opening pressure		1.4±0.1 MPa (14±1 kgf/cm²) [199.15±14.23 psi]		Change in oil pressure is 0.04 MPa (0.4 kgf/cm²) [5.8 psi] with a low 2 mm [0.08 in.] shim.
		Safety valve — Spring set length/load		73.4 [2.89]/ 971±69 N (99.0±7 kgf) [218±5.16 lbf]	834 N (85.0 kgf) [187 lbf]	
	Relief valve	Valve opening pressure		0.58±0.05 MPa (5.9±0.5 kgf/cm²) [83.93±7.12 psi]		Change in oil pressure is 0.04 MPa (0.4 kgf/cm²) [5.8 psi] with a low 2 mm [0.08 in.] shim.
	Oil cooler bypass valve	Valve opening pressure		0.44±0.05 MPa (4.5±0.5 kgf/cm²) [63.82±7.12 psi]		
	Oil filter alarm (bypass)	Lamp lighting and valve opening pressure (differential pressure)		$0.15^{+0.03}_{0}$ ($1.5^{+0.3}_{0}$) [$21.3^{+4.27}_{0}$]		Change in oil pressure is 0.007 MPa (0.07 kgf/cm²) [1.00 psi] with a low 1 mm [0.039 in.] shim.

Unit mm [in.]

Group		Inspection point			Nominal value	Standard	Limit	Remark
Cooling system	Water pump	Bearing bore diameter of pump case			ϕ120 [4.72]	119.987 to 120.022 [4.72389 to 4.72527]		
		Bearing bore diameter of cover			ϕ110 [4.33]	110.005 to 110.040 [4.33090 to 4.33227]		The same applies to the bearing cover.
		Bearing	Large	Outside diameter	ϕ120 [4.72]	119.985 to 120.000 [4.72382 to 4.72441]		
				Bore diameter	ϕ55 [2.17]	54.985 to 55.000 [2.16476 to 2.16535]		
			Small	Outside diameter	ϕ110 [4.33]	109.985 to 110.000 [4.33012 to 4.33071]		
				Bore diameter	ϕ50 [1.97]	49.988 to 50.000 [1.96803 to 1.96850]		
		Shaft bearing journal diameter			ϕ55 [2.17]	55.011 to 55.024 [2.16758 to 2.16629]		
					ϕ50 [1.97]	50.011 to 50.024 [2.16758 to 2.16629]		
		Vane front face clearance			1.04. [0.041]	0.58 to 1.50 [0.023 to 0.059]		
	Thermostat	Valve opening temperature				71±2 °C [159.8±3.6 °F]		Check at atmospheric pressure.
		Temperature at which valve lift is 10 mm [0.394 in.] or more				85 °C [185 °F]		
	Fan drive	Bearing bore diameter of case			ϕ120 [4.72]	119.987 to 120.022 [4.72389 to 4.72527]		
					ϕ110 [4.33]	109.987 to 110.022 [4.3335 to 4.3349]		
		Bearing	Large	Outside diameter	ϕ120 [4.72]	119.985 to 120.000 [4.72382 to 4.72441]		
				Bore diameter	ϕ45 [1.77]	44.988 to 45.000 [1.7725 to 1.773]		
			Small	Outside diameter	ϕ110 [4.33]	109.985 to 110.000 [4.33012 to 4.33071]		
				Bore diameter	ϕ50 [1.97]	49.988 to 50.000 [1.9694 to 1.970]		
		Shaft bearing journal diameter		Outside diameter	ϕ45 [1.77]	45.002 to 45.013 [1.7731 to 1.7735]		
				Bore diameter	ϕ50 [1.97]	50.002 to 50.013 [1.9701 to 1.9705]		

Unit mm [in.]

Group	Inspection point			Nominal value	Standard	Limit	Remark
Electrical system	Starter	Commutator	Outside diameter	ϕ43 [1.69]		ϕ42 [1.65]	
			Deflection		0.06 [0.00236] or less	0.10 [0.00394]	
			Mica depth in commutator		0.7 to 0.9 [0.028 to 0.035]	0.2 [0.008]	
		Height of brush			21 to 22 [0.827 to 0.866]	13 [0.512]	
		Tension of brush spring N (kgf) [lbf]		44.13 (4.5) [64.10]	39.23 to 49.03 (4.0 to 5.0) [8.82 to 11.02]	39.23 (4.0) [8.82]	When brush is installed
		Armature	Shaft deflection (1/2 valve of measurement at center journal shaft when shaft is supported at both ends)		0.05 [0.00197]		
			Diameter of shaft rear side	ϕ14 [0.55]	13.941 to 13.968 [0.54886 to 0.54992]		
			Diameter of shaft front side	ϕ25 [0.98]	25.002 to 25.011 [0.98433 to 0.98469]		
		Pinion shaft	Diameter of pinion shaft rear side	ϕ30 [1.18]	30.002 to 30.011 [1.18118 to 1.18153]		
			Diameter of pinion shaft front side	ϕ19 [0.748]	18.900 to 18.940 [0.74409 to 0.74567]		
		Bearing	Front bearing	ϕ19 [0.748]	19.000 to 19.033 [0.74803 to 0.74933]	0.25 [0.0098]	Clearance between shaft and bearing
			Pinion	ϕ19 [0.748]	19.000 to 19.033 [0.74803 to 0.74933]	0.25 [0.0098]	
		End play	Armature		0.3 to 0.7 [0.012 to 0.028]		
			Pinion shaft		0.2 to 0.8 [0.008 to 0.0315]		
	Alternator	Slip ring outside diameter		33 [1.30]	32.8 to 33.2 [1.291 to 1.307]	32.4 [1.276]	
		Height of brush		21.5 [0.846]		8.0 [0.31]	Up to wear limit
		Tension of brush spring N (gf) [lbf]		3.7 (380) [0.84]	3.1 to 4.3 (320 to 440) [0.70 to 0.97]	2.0 (200) [0.45]	
	V-belt tension (deflection when pressed with thumb as shown in the right diagram. 98 to 147 N (10 to 15 kgf) [22 to 33 lbf])				Approx. 10 to 15 [0.394 to 0.591]		

2. Tightening Torque Table

2.1 Important Bolts and Nuts

(1) Engine main parts

Description	Threads Diameter × Pitch mm	Torque			Remark
		N·m	kgf·m	lbf·ft	
Cylinder head	M22×2.5	539±27	55±2.75	398±20	[Wet] 2-step tightening method (Note a)
Rocker case	M12×1.25	108±5.4	11±0.55	80±4.0	
	M10×1.25	60±3.0	6±0.3	44±2.2	
Rocker shaft	M16×2.0	167±8.4	17±0.85	123±6.2	
Rocker arm lock nuts	M12×1.25	64±3.2	6.5±0.33	47±2.36	
Bridge lock nuts	M10×1.25	55±2.8	5.6±0.28	42±2.07	
Camshaft gear	M14×1.5	176±8.8	18±0.9	130±6.5	
Camshaft thrust plate	M12×1.25	108±5.4	11±0.55	80±4.0	
Cam follower shaft	M12×1.25	88±4.4	9±0.45	65±3.2	
Adapter	M12×1.25	78±3.9	8±0.4	58±2.9	
Main bearing cap	M22×2.5	490±24.5	50±2.5	362±18.1	[Wet] (Note b)
Main bearing cap side bolt	M16×1.5	147±7.4	15±0.75	108±5.4	[Wet] (Note b)
Rear hanger	M16×1.5	245±24.5	26±2.6	181±1.9	
Piston cooling nozzle	M12×1.75	34±1.7	3.5±0.18	25±1.3	(Note c)
Timing gear case	M12×1.25	98±4.9	10±0.5	72±3.6	Tighten the crankcase.
	M12×1.25	69±3.5	7±0.35	51±2.6	Tighten the rear plate and the nut.
	M16×1.5	245±12.3	26±1.3	181±9.1	
Rear plate	M12×1.25	108±5.4	11±0.55	80±4.0	
Front mounting bracket	M20×1.5	392±39.2	40±4.0	289±28.9	
Rear mounting bracket	M18×2.5	294±29.4	30±3.0	217±21.7	
Connecting rod bearing cap	M18×1.5	343±17	35±1.8	253±12.5	[Wet] 2-step tightening method (Note d)
Balance weight	M16×1.5	196±9.8	20±1.0	145±7.2	[Wet]
Flywheel	M22×1.5	588±29.4	60±3.0	434±21.7	[Wet]
Damper	M22×1.5	490±24.5	50±2.5	362±18.1	
Rear idler shaft	M12×1.25	108±5.4	11±0.55	80±4.0	
Rear idler shaft thrust plate	M10×1.25	29±1.45	3±0.15	22±1.1	
Front gear case	M12×1.25	98±9.8	10±1.0	72±7.2	Tighten the crankcase.
	M12×1.25	69±6.9	7±0.7	51±5.1	Tighten the front plate and the nut.
	M16×1.5	255±2.55	26±2.6	188±1.9	
Front plate	M12×1.25	108±10.8	11±1.1	80±8.0	
Front idler shaft	M12×1.25	108±5.4	11±0.55	80±4.0	
Front idler shaft thrust plate	M16×1.5	216±10.8	22±1.1	159±8.0	
Cancel rod	M10×1.25	33±1.67	3.4±0.17	24±1.2	
Cancel rod control lever reamer bolt	M8×1.25	30±1.52	3.1±0.16	22±1.1	
Cam follower shaft	M12×1.25	88±4.41	9±0.45	65±3.3	

Note: (a) To tighten cylinder head bolts according to the angle method, follow the sequence described below.
① Tighten to snug torque of 294±14.7 N·m (30±1.5 kgf·m) [217±10.8 lbf·ft].
② Tighten by turning 30±1.5°.
③ Tighten by further turning 30±1.5°. (total of 60±3° turn)
④ Loosen all bolts, and tighten again according to the angle method. (2-step tightening method)
(b) To tighten main bearing cap bolts and main bearing cap side bolts, observe the specified sequence.
Tightening sequence
① Tighten the main bearing cap bolts to the specified torque.
② Tighten the side bolts on the right side of the engine to the specified torque.
③ Tighten the side bolts on the left side of the engine to the specified torque.
(c) To tighten piston cooling nozzles (check valves) to the specified torque, be sure to use a torque wrench. *Tightening without the use of a torque wrench can result in excessive tightening force, and this can cause* check valve malfunctions and lead to seizing of pistons due to insufficient supply of lubricating oil during engine operation.
(d) To tighten connecting rod caps according to the angle method, follow the sequence described below.
① Tighten to snug torque of 147±7.4 N·m (15±0.75 kgf·m) [108±14.5 lbf·ft].
② Tighten by turning 45±3°.
③ Loosen all bolts, and tighten again according to the angle method. (2-step tightening method)
(e) When [Wet] is indicated, apply engine oil to the threads and bearing surfaces of the bolts and nuts.

(2) Fuel system

Description	Threads Diameter × Pitch mm	Torque			Remark
		N·m	kgf·m	lbf·ft	
Unit injector gland nut	M16×1.5	(Note f)	(Note f)	(Note f)	[Wet] 2-step tightening method
Unit injector gland stud (screw-in side)	M16×2.0	127±6.35	13± 0.65	94±4.68	Apply Locktite
Unit injector gage stand	M8×1.25	7.8 to 9.8	0.8 to 1.0	5.8 to 7.2	
Unit injector retaining nut	M45×1.5	314±10	32±1	232±7.4	
Unit injector nozzle retaining nut	M30×1.5	216±5	22±0.5	159±3.7	
Fuel pipe eyebolt	M10×1.25	15±1.5	1.5±0.15	11±1.1	
Priming pump and fuel filter eyebolt	M14×1.5	20 to 25	2.0 to 2.5	15 to 18	
Priming pump and its neighboring parts	M16×1.5	34±3.4	3.5±0.35	25±2.5	
Fuel feed pump eyebolt	M20×1.5	59±5.9	6.0±0.6	43±4.4	
Fuel feed pump bolt	M8×1.25	20 to 22	2.0 to 2.2	15 to 16	
Fuel rack control lever	M8×1.25	25±2.5	2.5±0.25	18.1±1.8	2-step tightening method
Fuel filter air vent plug	M8×1.25	8 to 10	0.8 to 1.0	5.8 to 7.2	It is not used in normal priming procedure.
Governor drive case	M12×1.25	108±10.8	11±1.1	80±8	

Note: (f) To tighten cylinder head bolts according to the angle method, follow the sequence described below.
① Tighten to snug torque of 176±9 N·m (18±0.9 kgf·m) [130±6.6 lbf·ft].
② Loosen all bolts, and retighten to 127±6.4 N·m (13±0.7 kgf·m) [94±4.7 lbf·ft].

(3) Lubrication system

Description		Threads Diameter × Pitch mm	Torque			Remark
			N·m	kgf·m	lbf·ft	
Oil pump		M10×1.25	59±5.9	6.0±0.6	43±4.4	
Oil pump cover		M10×1.25	34 to 74	3.5 to 7.5	25 to 54	
Safety valve plug		M40×2.0	196±20	20±2	144±15	
Oil cooler element nut		M10×1.25	24.5±5	2.5±0.5	18±3.7	
Oil cooler pipe		M10×1.5	39.2±5	4.0±0.5	29±3.7	
Turbocharger lubrication	Eye bolt	M10×1.5	29±1.45	3±0.15	22±1.1	
	Flange	M10×1.5	59±3.0	5.9±0.30	42.7±2.2	

(4) Cooling system

Description	Threads Diameter × Pitch mm	Torque			Remark
		N·m	kgf·m	[lbf·ft	
Water pump	M12×1.25	108±10.8	11±1.1	80±8.0	
Water pump shaft pulley nut	M30×1.5	392±20	40±2.0	289±14.0	For alternator coupling
Fan pulley cap nut	M30×1.5	392±39	40±4.0	289±29	
Fan	M10×1.5	33±1.8	3.4±0.2	24±1.3	

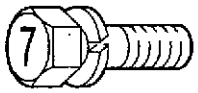
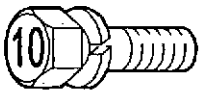
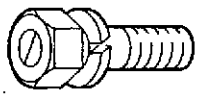
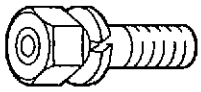
(5) Inlet and exhaust systems

Description	Threads Diameter × Pitch mm	Torque			Remark
		N·m	kgf·m	lbf·ft	
Exhaust manifold coupling nut	M6×1.0	7.8 to 8.8	0.8 to 0.9	5.8 to 6.5	
Exhaust manifold mounting bolt	M10×1.5	49 to 59	5 to 6	36 to 43	

(6) Electrical system

Description	Threads Diameter × Pitch mm	Torque			Remark
		N·m	kgf·m	lbf·ft	
Starter mounting bolt	M12×1.25	59±5.88	6±0.6	44±4.4	

2.2 Standard Bolts and Nuts

	Threads Diameter × Pitch (mm)	Width across flats (mm) [in.]	Strength classification					
			7 T			10.9		
Metric automobile screw threads								
			N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft
	8×1.25	12 [0.47]	17	1.7	13	30	3.1	22
	10×1.25	14 [0.55]	33	3.4	24	60	6.1	44
	12×1.25	17 [0.67]	60	6.1	44	108	11.0	80
	14×1.5	22 [0.87]	97	9.9	72	176	17.9	130
	16×1.5	24 [0.94]	145	14.8	107	262	26.7	193
	18×1.5	27 [1.06]	210	21.4	155	378	38.5	279
	20×1.5	30 [1.18]	291	29.7	215	524	53.4	386
	22×1.5	32 [1.26]	385	39.3	284	694	70.8	512
	24×1.5	36 [1.42]	487	49.7	359	878	89.5	648
	27×1.5	–	738	75.3	544	1328	135.5	979
Metric course screw threads								
			N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft
	10×1.5	14 [0.55]	32	3.3	24	58	5.9	43
	12×1.75	17 [0.67]	57	5.8	42	102	10.4	75
	14×2	22 [0.87]	93	9.5	69	167	17.0	123
	16×2	24 [0.94]	139	14.2	103	251	25.6	185
	18×2.5	27 [1.06]	194	19.8	143	350	35.7	258
	20×2.5	30 [1.18]	272	27.7	201	489	49.9	361
	22×2.5	32 [1.26]	363	37.0	268	653	66.6	482
	24×3	36 [1.42]	468	47.7	345	843	86.0	622
	27×3	–	686	70.0	506	1236	126.0	912

Note: (a) This table lists the tightening torque for standard bolts and nuts.
(b) The numerical values in the table are for fasteners with spring washers.
(c) The table shows the standard values with a maximum tolerance value of ±10%.
(d) Use the tightening torque in this table unless otherwise specified.
(e) Do not apply oil to threaded sections. (Dry)

2.3 Standard Eyebolts

Threads Diameter × Pitch (mm)	Width across flats (mm) [in.]	Strength classification 4 T		
		N·m	kgf·m	lbf·ft
8×1.25	12 [0.47]	8±1	0.8±0.1	5.9±0.74
10×1.25	14 [0.55]	15±2	1.5±0.2	11.1±1.48
12×1.25	17 [0.67]	25±3	2.5±0.3	18.4±2.21
14×1.5	19 [0.75]	34±4	3.5±0.4	25.1±2.95
16×1.5	22 [0.87]	44±5	4.5±0.5	32.5±3.69
18×1.5	–	74±5	7.5±0.5	54.2±3.69
20×1.5	27 [1.06]	98±10	10.0±1.0	72.3±7.38
22×1.5	32 [1.26]	147±15	15.0±1.5	108.4±11.1
24×1.5	–	226±20	23.0±2.0	166.7±14.8

(Dry)

2.4 Standard Union Nuts

Nominal diameter	Cap nut size M (mm)	Width across flats (mm) [in.]	N·m	kgf·m	lbf·ft
63	14×1.5	17 [0.67]	39	4	29
80	16×1.5	19 [0.75]	49	5	36
100	20×1.5	22 [0.87]	78	8	58
120	22×1.5	24 [0.94]	98	10	72
150	27×1.5	30 [1.18]	157	16	116
180	30×1.5	32 [1.26]	196	20	145
200	30×1.5	32 [1.26]	196	20	145
220	33×1.5	36 [1.42]	245	25	181
254	36×1.5	41 [1.61]	294	30	217

(Maximum tolerance value: ±10%, dry)

2.5 High-Pressure Fuel Injection Pipes

Cap nut size M (mm)	N·m	kgf·m	lbf·ft
12×1.5	39±5	4±0.5	29±3.7
14×1.5	49±5	5±0.5	36±3.7
18×1.5	59±1	6±0.1	44±0.7

(Dry)

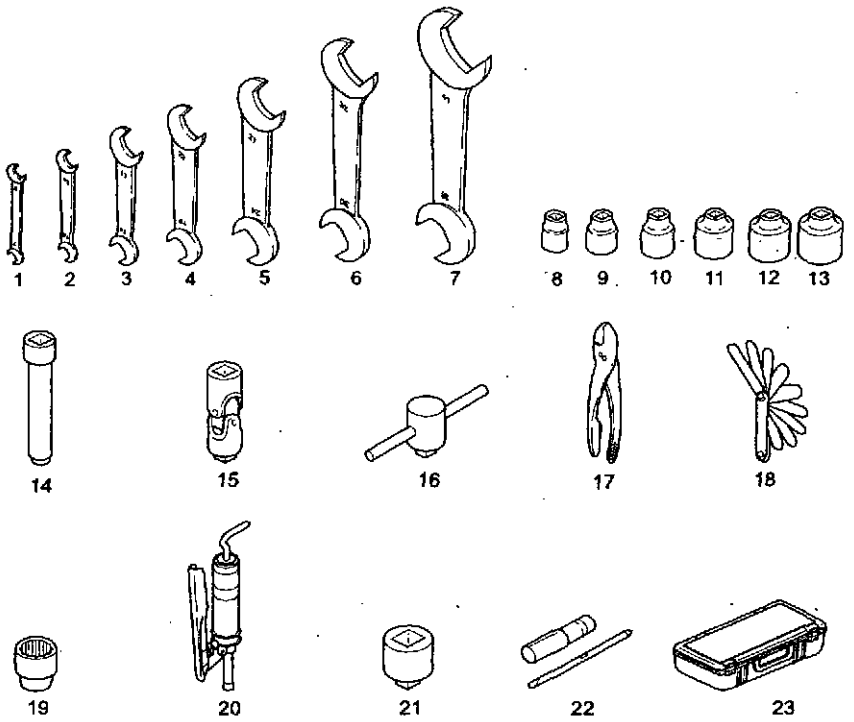
3. Sealants and Lubricants Table

Group	Application point		Sealant or lubricant	How to use
Engine main parts	Cylinder head sealing cap		Hermeseal S-2	Coat holes in crankcase Note (1)
	Cylinder head copper tube		ThreeBond 1207C	Apply to the end joint.
	Cylinder liners		Engine oil	Grease O-ring joint
	Front plate, gear case, crankcase and oil pan		Herdite	Coat three-face-mating portions
	Rear plate, gear case, crankcase and oil pan		Herdite	Coat three-face-mating portions
	Crankcase taper plugs		Seal-lock or Loctite 271	Apply to tapered threads
	Crankcase sealing cap		ThreeBond 1121	Coat holes in crankcase
	Oil pan and crankcase		Herdite	Coat joint portions only on both sides of packing
	Front and rear oil seal		Engine oil	Coat lip face
			Mounting Paste	Coat outer casing or holes in crankcase. Note (2)
	Rear plate, timing gear case and crankcase		ThreeBond 1211	Coat both sides of packing
	Front plate, front gear case and crankcase		ThreeBond 1211	Coat both sides of packing
	Cylinder head gasket		ThreeBond 1211	Apply to areas around tappet chambers and oil passage areas. Note (3)
Fuel system	Unit injector		Grease	Nozzle gasket
			Engine oil	O-ring installation location
Cooling system	Water pump	Oil seal	Engine oil	Coat lip face
		Unit seal	LLC solution (antifreeze)	Coat floating seat
			ThreeBond 1102	Coat outer ring
	Fan drive	Oil seal	Engine oil	Coat lip face
Inlet system	Air cooler	Between the element and the both side of plate	Shin-Etsu Chemical Co., Ltd. KE45-W or equivalent sealant or lubricant	Fill the gap between the element and the plate.
Others	Tapered threads of tapered plugs and cocks not coated with Seal-lock		Valcanized seal tape	Wrap threads with two rounds of tape Note (4) (no film on high-temperature exhaust sections)
	Prevention of seizing of metal joints and sliding sections		Moly Disulfide (G paste)	Apply to surfaces
	Prevention of rust on machine finished metal surfaces of flywheel and timing gear case		NOX-RUST 366-20 rust-preventive oil or equivalent (manufactured by Parker Industries, Inc.)	Apply with brush

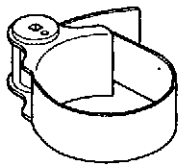
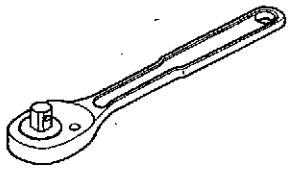
Note: (1) When the use of Hermeseal S-2 is specified, be sure to use the designated liquid sealant manufactured by Japan Hermetic Co., Ltd.
(2) Lubricant for smoothly pressing the seals using an installer and Mounting Paste manufactured by Tip Top Japan Inc.
(3) For the method of applying a sealer to cylinder gasket, refer to REASSEMBLY OF ENGINE MAIN PARTS pages.
(4) Seal-lock is a coating sealer with sealing and locking functions. (manufacturer: ThreeBond)
(5) ThreeBond 1121 may be used to hold O-rings in place (fall prevention).
(6) The grease is industrial grease. Sunlight Grease 1 manufactured by Showa Shell Sekiyu K.K. or equivalent.

BASIC AND SPECIAL TOOLS

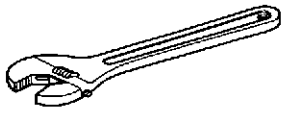
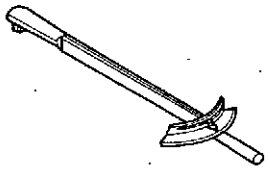
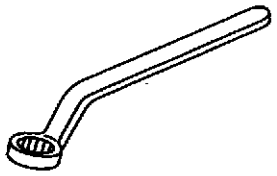
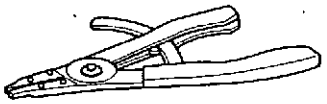
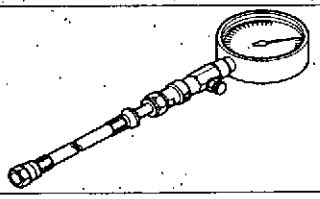
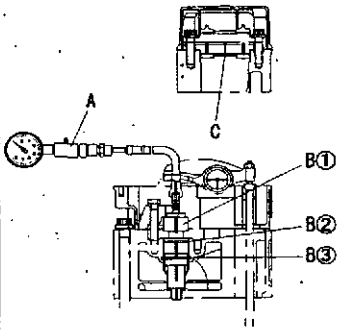
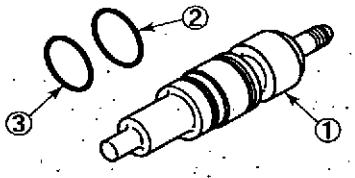
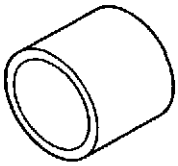
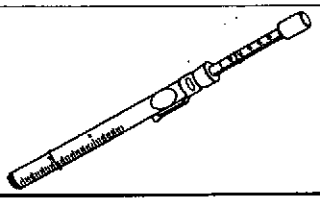
1. Basic Tools

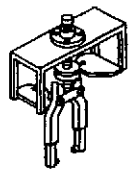
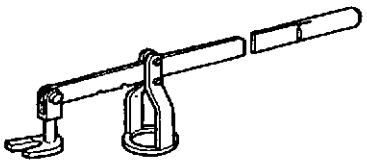
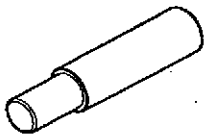
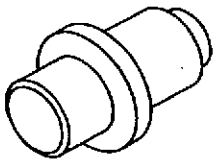
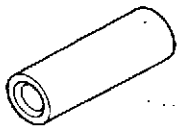
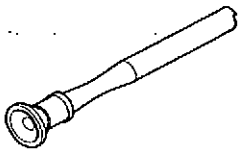
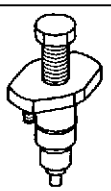


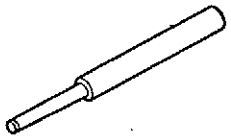
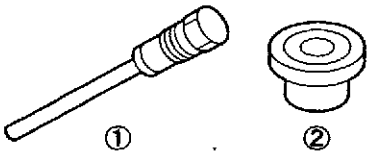
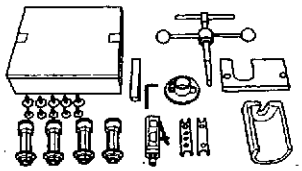
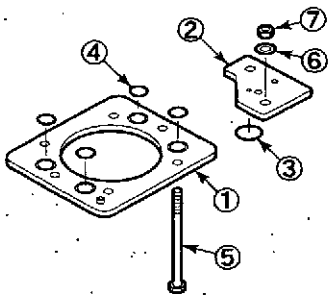
No.	Tool name	Part No.	Remark
—	Tool set	32591-00012	Includes parts No.1 through 23
1	Open-end wrench	F9600-07008	Width across flats: 7×8 mm [0.28×0.31 in.]
2	Open-end wrench	F9600-10012	Width across flats: 10×12 mm [0.39×0.47 in.]
3	Open-end wrench	F9600-14017	Width across flats: 14×17 mm [0.55×0.67 in.]
4	Open-end wrench	F9600-19022	Width across flats: 19×22 mm [0.75×0.87 in.]
5	Open-end wrench	F9600-24027	Width across flats: 24×27 mm [0.9×1.06 in.]
6	Open-end wrench	F9600-30032	Width across flats: 30×32 mm [1.18×1.26 in.]
7	Open-end wrench	F9600-36041	Width across flats: 36×41 mm [1.42×1.61 in.]
8	Socket	F9614-17000	Width across flats: 17 mm [0.67 in.]
9	Socket	F9614-22000	Width across flats: 22 mm [0.87 in.]
10	Socket	F9614-24000	Width across flats: 24 mm [0.95 in.]
11	Socket	F9614-27000	Width across flats: 27 mm [1.06 in.]
12	Socket	F9614-30000	Width across flats: 30 mm [1.18 in.]
13	Socket	F9614-32000	Width across flats: 32 mm [1.26 in.]
14	Extension bar	F9615-25000	12.7 mm [0.50 in.]-square drive, L=250 mm [9.84 in.]
15	Universal joint	F9617-10000	12.7mm [0.50 in.]-square drive, L=75 mm [2.95 in.]
16	Slide handle	F9618-30000	12.7 mm [0.50 in.]-square drive, L=300 mm [11.81 in.]
17	Pliers	F9630-15000	L=150 mm [5.91 in.]
18	Feeler gages	30091-06501	Set of 9 gages, MIN 0.04 [0.002 in.] to MAX 0.30 mm [1.18 in.]
19	Socket	33491-13500	Width across flats: 36 mm [1.42 in.]
20	Grease pump	64309-15300	Capacity: 0.08 ℓ [0.0211 U.S.gal]
21	Adapter	33491-03600	19.15×12.7 mm [0.75×0.500 in.]-square drive
22	Screwdriver	91267-00201	(+) (-) Slotted and Phillips ends
23	Tool box	MC420083	L352×W146×H82, [13.9×5.57×3.23 in.] weight capacity: 7 kg [15.4 lb.] or less

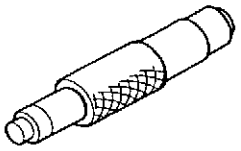
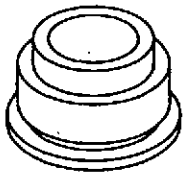
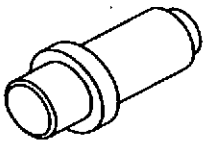
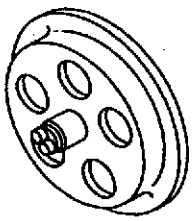
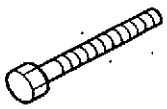
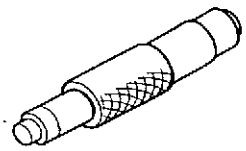
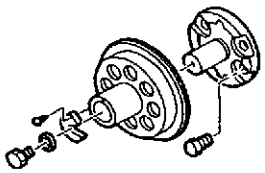
Tool name	Part No.	Shape	Use
Filter wrench	32591-22100		Removal of various oil filters and fuel filters
Rachet handle	37191-03300		For socket

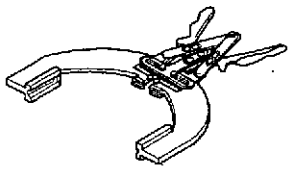
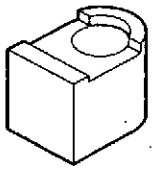
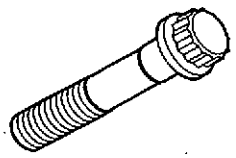
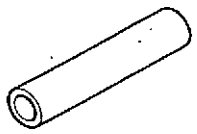
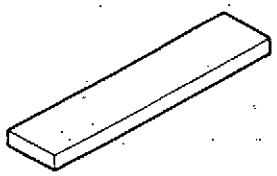
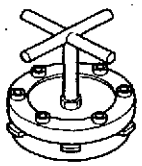
2. Special Tools

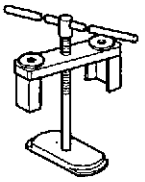
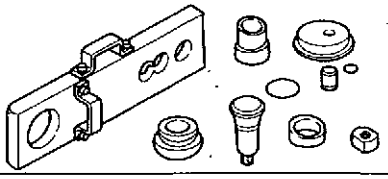
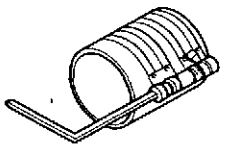
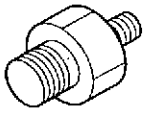
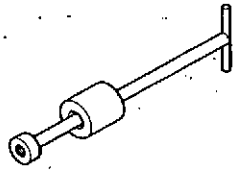
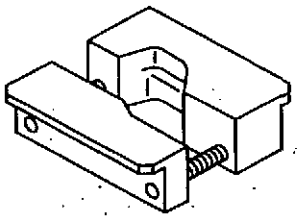
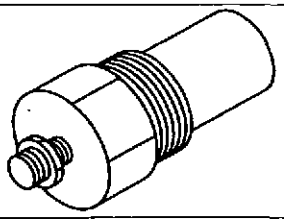
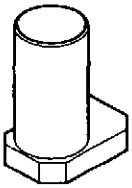
Application	Tool name/part no.	Shape	Use
General	Adjustable wrench F9611-15000		Maximum opening width: 20 mm [0.79 in.]
	Torque wrench 32191-03100		Measuring range: 0 to 539 N·m (0 to 55 kgf·m) [0 to 398 lbf·ft]
	Offset wrench 35C91-00500		Valve clearance adjustment
	Ring pliers 45191-08400		Snap ring removal/installation
Inspection for overhaul need and testing	Adapter assembly 35C91-12020	Includes A through C	Compression pressure measurement
	A Compression gage 35A91-03100		
	B Gage adapter ① 35C91-12200 ② 05507-10460 ③ 05507-10420		
	C Spacer 35C91-02100		
Inspection	V-belt gage 32591-09100		V-belt tension inspection

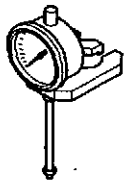
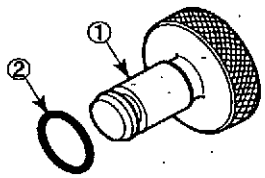
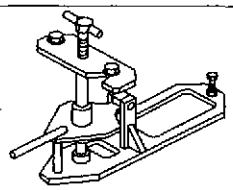
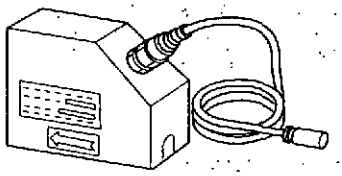
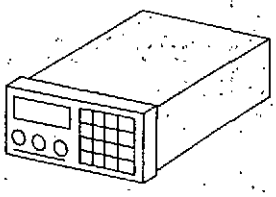
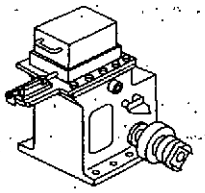
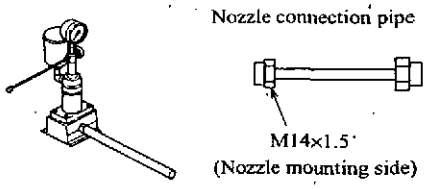
Application		Tool name/part no.	Shape	Use
Engine main parts	Cylinder head and valve mechanism	Unit injector puller 35C91-11400		Unit injector removal
		Eye nut 37591-02400		Cylinder head assembly removal/installation
		Valve spring pusher 33591-04500		Inlet/exhaust valve spring removal/installation Handle plate Length: 600 mm [23.6 in.]
		Copper tube pusher 35B91-06600		Unit injector copper tube removal
		Rocker bushing installer 35C91-01800		Rocker bushing replacement
		Seal installer 32591-10300		Valve guide and stem seal installation
		Valve lapper 30091-08800		Inlet/exhaust valve lapping
		Tube tool 35C91-21010		Unit injector copper tube installation

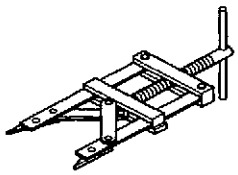
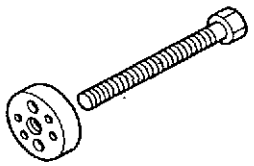
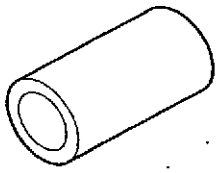
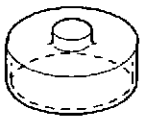
Application		Tool name/part no.	Shape	Use
Engine main parts	Cylinder head and valve mechanism	Cam gear stop bolt 35B91-06500		Camshaft gear retaining
		Valve guide remover 33591-04300		Valve guide removal
		Valve seat cutter ① 37591-06400 ② 37591-06430		Valve seat correction
		Valve seat puller 32591-04200		Valve seat removal
		Leak tester assembly 35C91-03010 ① 35C91-03100 ② 35C91-03200 ③ F3153-04000 ④ F3153-02600 ⑤ 35C91-03300 ⑥ F2500-14000 ⑦ F2300-14000		Cylinder head water pressure testing

Application		Tool name/part no.	Shape	Use
Engine main parts	Flywheel, timing gear and camshaft	Idler bushing puller 32591-02500		Idler bushing removal/installation
		Cam bushing installer 35C91-11600		Camshaft bushing installation
		Follower bushing installer 35C91-01700		Follower bushing replacement
		Rear seal installer 35B91-06010		Rear oil seal installation
		Jack-bolt 64362-68500	M12×1.25-95 mm [3.74 in.] 	Flywheel removal
	Damper and front gear	Idler bushing puller 32591-02500		Idler bushing replacement
		Front seal installer assembly 37591-05010		Front oil seal installation

Application		Tool name/part no.	Shape	Use
Engine main parts	Cylinder liner, piston and connecting rod	Eye bolt MM321420		Piston removal: M10×1.5 mm
		Ring expander 37191-03200		Piston ring removal/installation Range: ϕ101.6 to 177.8 mm [4 to 7 in.]
		Liner pusher 37591-06200		Cylinder liner collar protrusion measurement
		Bolt 37591-06300		Cylinder liner collar protrusion measurement: M22×2.5 mm
		Cylinder head bolt spacer 37598-09100		Cylinder liner collar protrusion measurement
		Projection plate 37598-09201		Crankcase counterbore depth measurement
		Crankcase grinder 32591-04050		Crankcase counterbore depth correction

Application		Tool name/part no.	Shape	Use
Engine main parts	*Cylinder liner, piston and connecting rod*	Cylinder liner remover 32591-04100		Cylinder liner removal
		Connecting rod bushing installer 32591-18010		Connecting rod bushing removal/installation
		Piston installer 37191-07100		Piston installation
	Crankcase, crankshaft and main bearing	Cap remove adapter 32591-04300		Main bearing cap removal
		Nozzle remover 36291-00900		Main bearing cap removal
Fuel system	Unit injector	Clamp 48749-01000		Unit injector disassembly and reassembly
		Connector 48749-00100		Unit injector adjustment
		Gage stand 48749-03080		Unit injector pre-stroke adjustment

Application		Tool name/part no.	Shape	Use
Fuel system	Unit injector	Gage 48749-02010		Unit injector pre-stroke adjustment
		① Plug 48749-00201 ② O-ring F3150-01010		
		Pre-stroke test stand 48749-05000		
		Flow sensor 48749-05600		
		Control indicator 48749-05700		
		Injection gage 48749-04000		
		Nozzle tester 04239-00050		Nozzle opening pressure measurement and spray pattern inspection

Application		Tool name/part no.	Shape	Use
Cooling system	Water pump	Water pump pliers 37591-03100		Water pump cover snap ring removal
		Impeller remover 37591-03200		Water pump impeller removal: M18×1.5 mm
		Ring remover 37791-03400		Water pump unit seal removal
		Ring installer 37791-03300		Water pump unit seal installation
		Unit seal installer 37191-06300		Water pump unit seal ring installation
Engine adjustment, break-in operation and performance tests		Height gage 35C91-01100		Injection timing adjustment

OVERHAUL INSTRUCTIONS

1. Determination of Overhaul Timing

In most cases, the engine should be overhauled when the compression pressure of the engine is low and decreased compression pressure results in a noticeable increase in engine oil consumption and blow-by gas and these symptoms can be used to evaluate the engine condition.

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

Reduced compression pressure manifests 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.

(a) Decreased output power
(b) Increased fuel consumption
(c) Increased engine oil consumption
(d) Increased blow-by gas through the breather due to worn cylinder liners and piston rings
(e) Increase gas leakage due to poor seating of inlet and exhaust valves
(f) Difficulty in starting
(g) Increased noise from engine parts
(h) 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 (b) and (f) can result from improper fuel injection volume and timing of the fuel injection pump, 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 (d), and once this is determined, it is reasonable to take other problems into consideration for making the final judgment.

2. Testing the Compression Pressure

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

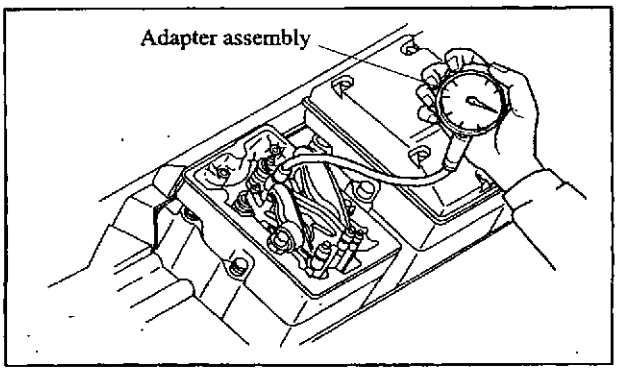
(2) Install the adapter assembly in place of the injection nozzle, then connect the compression gage to the adapter.

Name of special tool	Part No.
Adapter assembly	35C91-12020

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

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

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



Testing the compression pressure

⚠ CAUTION

(a) Measure the compression pressure in all cylinders, since it is not a good practice to measure the compression pressure in only a few cylinders and assume the compression pressure to be the same in other cylinders.

(b) As compression pressure varies with the engine speed, check the engine speed when measuring compression pressure.

	Standard	Limit
Compression pressure	2.4 MPa (24.4 kgf/cm^2) [347.1 psi] or more	1.9 MPa (19.3 kgf/cm^2) [274.5 psi] or less

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

⚠ CAUTION

Measure the compression pressure at regular intervals and keep the record of changes of compression pressure.

- Compression pressure will be slightly higher in a new or overhauled engine.
- After piston rings, valve seats, etc. break-in, compression pressure decreases to the standard.
- When parts wear, compression pressure decreases.

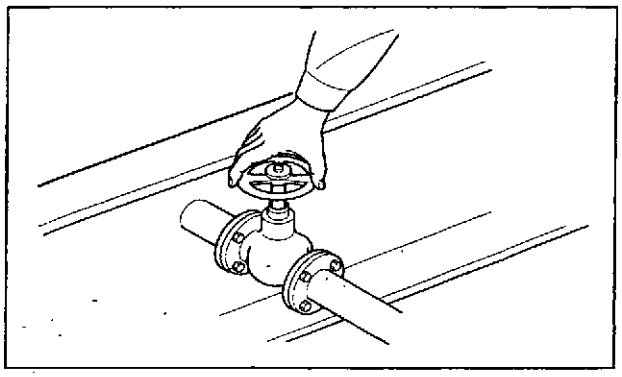
PREPARATION FOR DISASSEMBLY

1. Preparation

1.1 Cutting off Fuel Supply

⚠ CAUTION

Before disassembling the engine, close the main fuel supply valve, and drain fuel from the pipe completely.
If fuel is remaining in the pipe, serious accidents such as an explosion and fire may result.

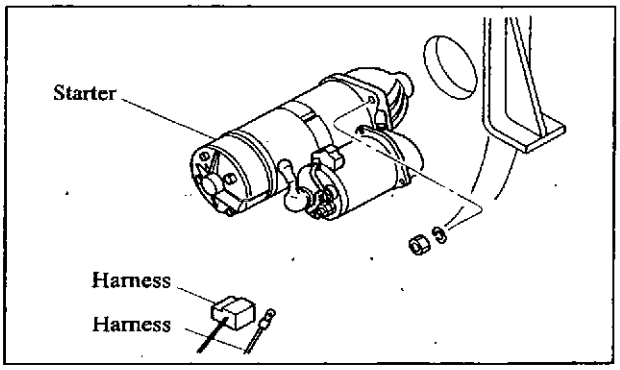


Cutting off fuel supply

1.2 Removing Electrical Wiring

Disconnect harnesses and wires from the following devices.
Before disconnecting, attach tags or other indications on the terminals to facilitate reconnection.

- Starter
- Switches
- Pickup, etc.

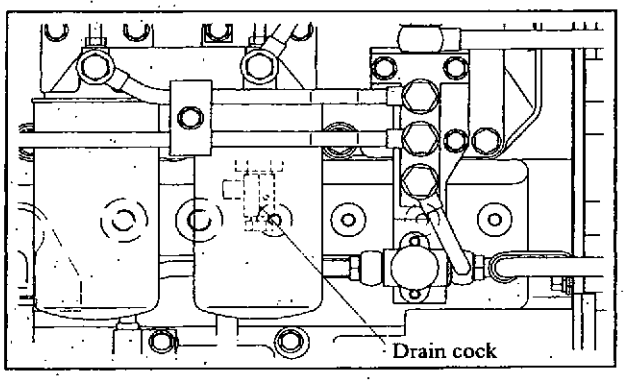


Removal of electrical wiring

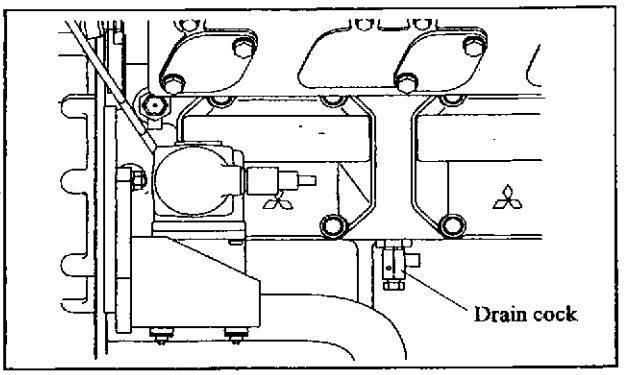
1.3 Draining Coolant

Loosen the drain cocks at the following locations to drain coolant.

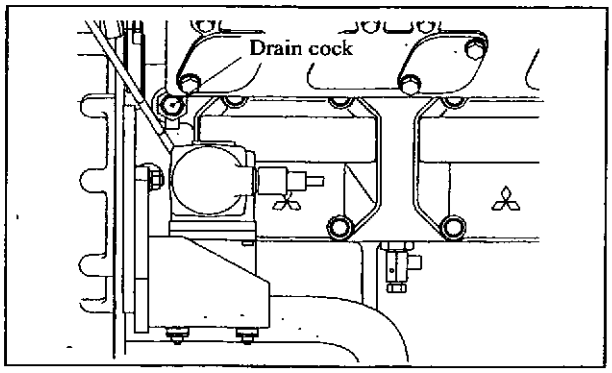
- Both sides of crankcase at the rear side
- Right side of oil cooler at the rear side
- Water pump
- Both sides of air cooler pipe at the rear side



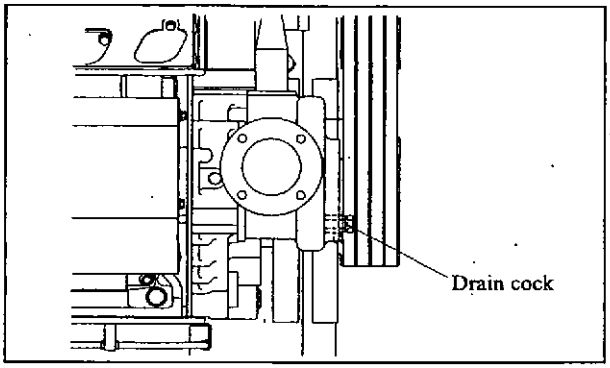
Coolant drain cocks of crankcase (left side)



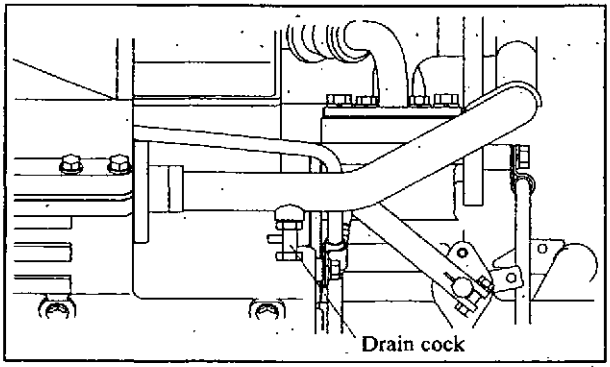
Coolant drain cocks of crankcase (right side)



Oil cooler coolant drain cock



Water pump coolant drain cock



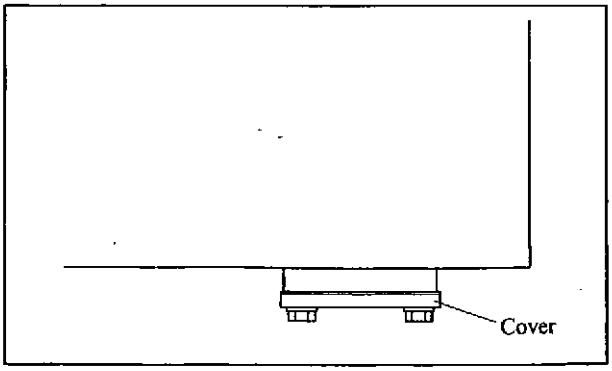
Air cooler coolant drain cock

1.4 Draining Engine Oil

Remove the cover from the bottom of oil pan to drain engine oil.
(Oil pan capacity: 180 ℓ [47.55 U. S. gal])

⚠ CAUTION

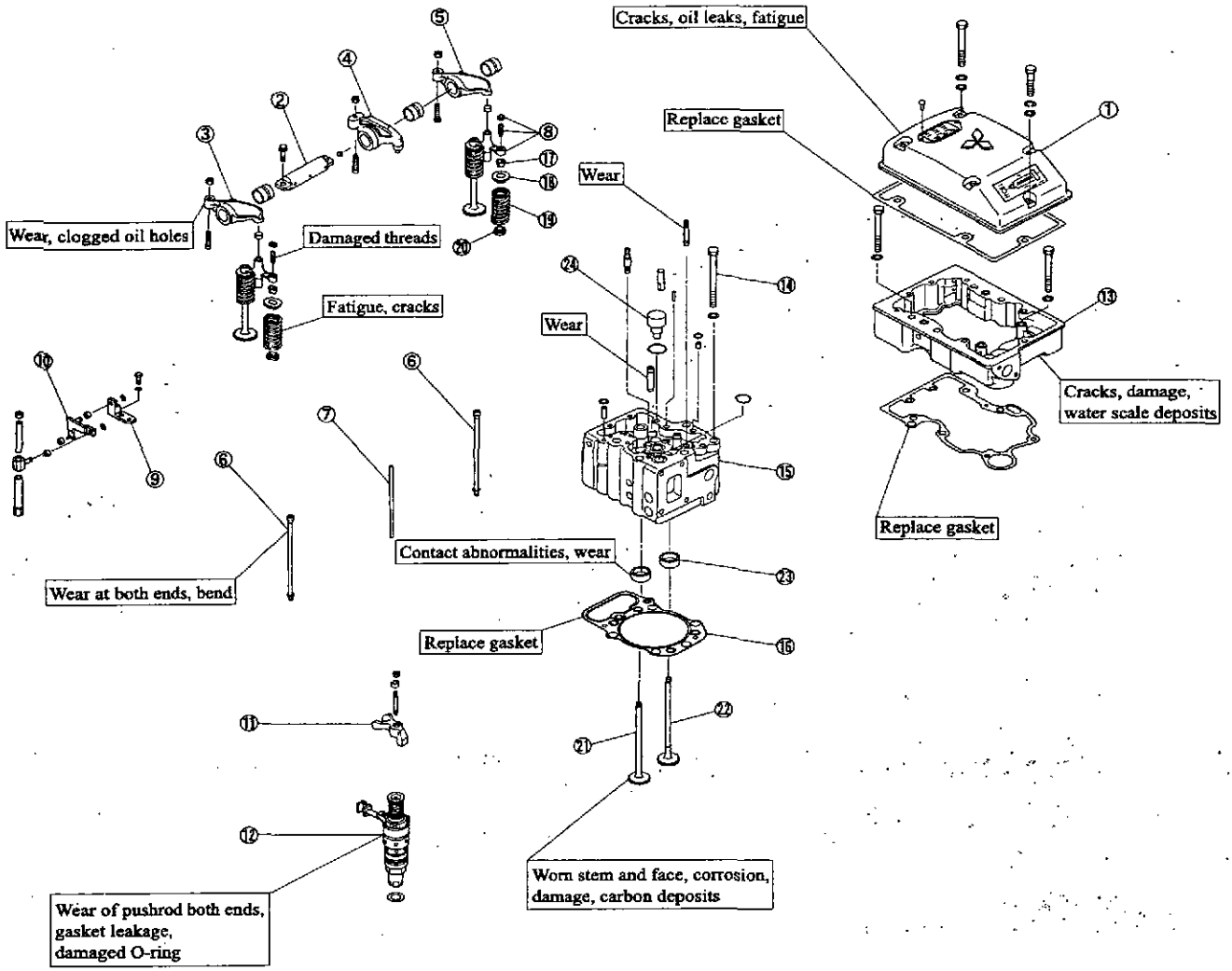
Be careful not to touch hot drained engine oil since it can cause burns.



Oil pan drain plug

DISASSEMBLY OF ENGINE MAIN PARTS

1. Cylinder Heads and Valve Mechanisms



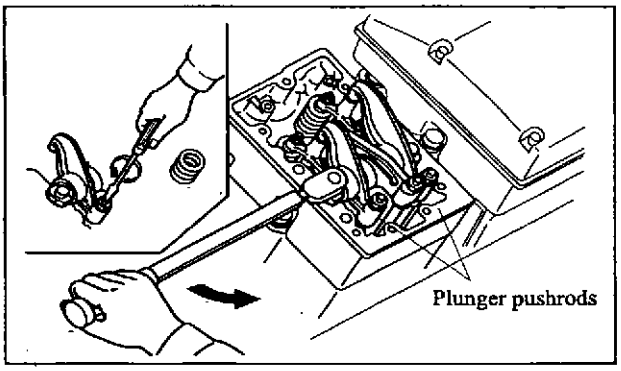
Disassembly and inspection of cylinder heads and valve mechanisms

< Disassembly sequence >

① Rocker cover
② Rocker shaft
③ EXH rocker
④ UI rocker
⑤ IN rocker
⑥ IN&EXH pushrod
⑦ UI pushrod
⑧ Bridge, screw and nut
⑨ Bracket
⑩ Rack lever
⑪ Gland
⑫ *Unit injector assembly*
⑬ Rocker case
⑭ Cylinder head bolt
⑮ Cylinder head (weight: approx. 33 kg [72.75 lb.])
⑯ Gasket
⑰ Cotter
⑱ Rotor
⑲ Valve spring
⑳ Valve stem seal
㉑ EXH valve
㉒ IN valve
㉓ Valve seat
㉔ Copper tube

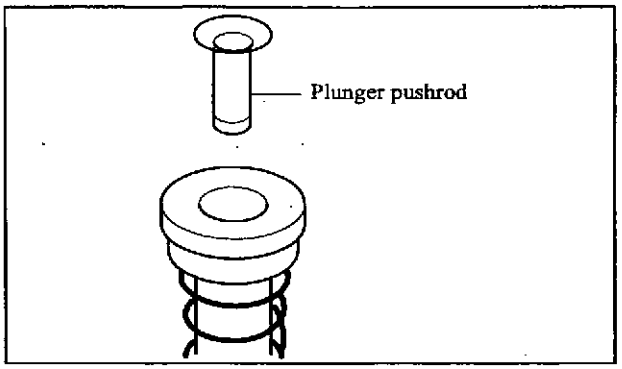
1.1 Removal of Rocker Shaft Assemblies

(1) Loosen the adjusting screw on each rocker.
(2) Remove the rocker shaft assembly with mounting bolts together as a set and store.



Removal of rocker shaft assembly

(3) The rocker shaft assembly may have plunger pushrod. In this case, carefully remove the plunger pushrod.



Removal of plunger pushrod

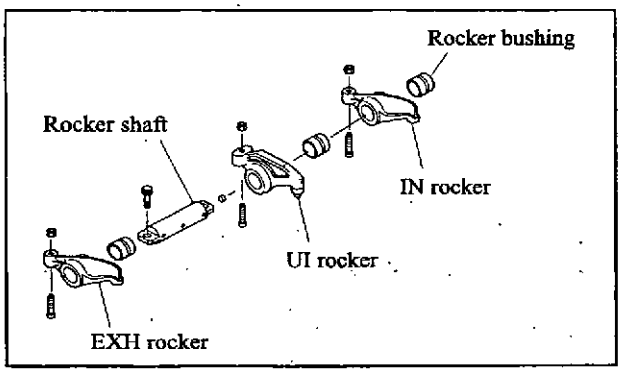
1.2 Disassembly of Rocker Shaft Assemblies

Arrange the disassembled rockers in the order of removal, and reassemble them in the same order during reassembly. This will ensure the same rocker shaft clearances as before.

1.3 Removal of Valve Bridges

Remove the valve bridge and bridge cap.

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



Disassembly of rocker shaft assembly

1.4 Removal of Unit Injector

(1) Remove the bracket and rack lever.
(2) Remove the gland.
(3) Install the unit injector puller on the rocker cover using bolts.
(Use rocker cover bolts or similar bolts.)

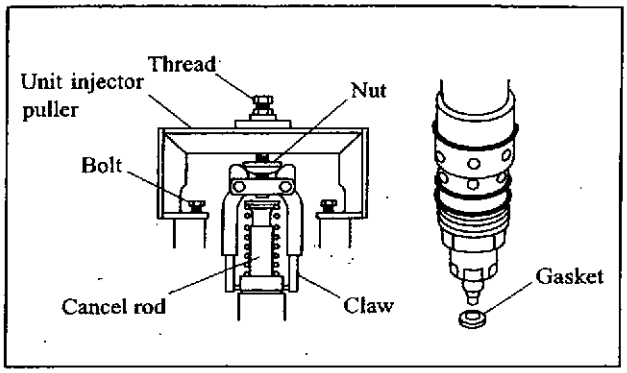
Name of special tool	Part No.
Unit injector puller	35C91-11400

(4) Put claws of the unit injector puller into holes on the unit injector. Turn the nut by hand until the claws are securely inserted in the holes. Turn the bolt to remove the injector.

(5) Remove the gasket from inside of the cylinder head using the wire or other tools.

⚠ CAUTION

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



Removal of cylinder head assembly

1.5 Removal of Cylinder Head Assemblies

(1) Each cylinder head is positioned properly by dowel pins, so the cylinder head must be lifted at an angle by using the eye nut.

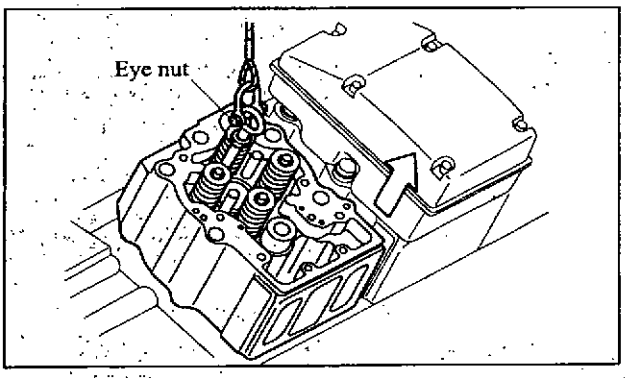
Name of special tool	Part No.
Eye nut	37591-02400

(Cylinder head weight: approx. 33 kg [72.75 lb.])

(2) Remove the cylinder head gasket.

⚠ CAUTION

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



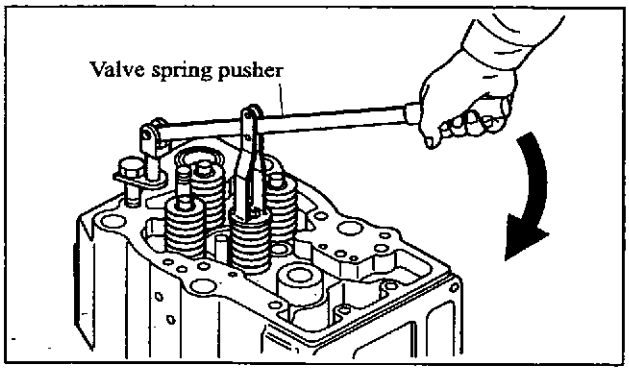
Removal of cylinder head assembly

1.6 Removal of Valves and Valve Springs

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

Name of special tool	Part No.
Valve spring pusher	33591-04500

Note: If the valves are to be reused, mark them to indicate their original installation positions, and install them with the original combination of valve seat and valve guide during reassembly.

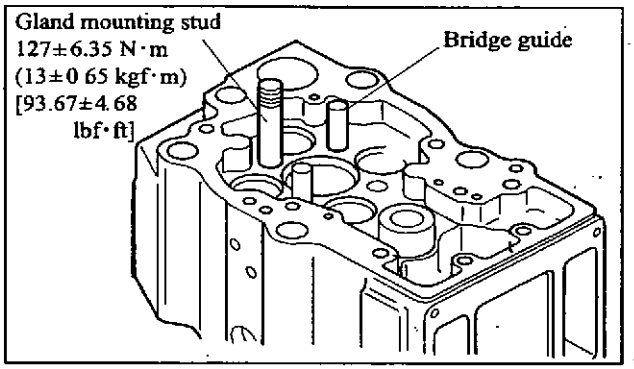


Removal of valve and valve spring

1.7 Removal of Studs and Guides

(1) Do not remove the nozzle gland mounting stud or bridge guide from the cylinder head unless absolutely necessary.

(2) If any of these parts are removed, apply thread lock agent to the threads in the bolt holes and install new parts.



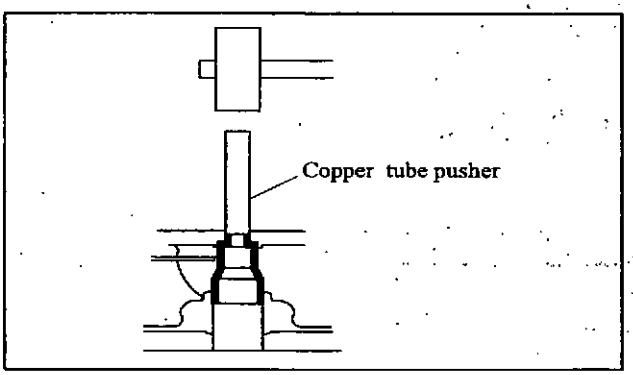
Removal of stud and guide.

1.8 Removal of Copper Tubes

Place the copper tube pusher on the lower end surface of the copper tube from underneath the cylinder head and use a hammer to remove the copper tube.

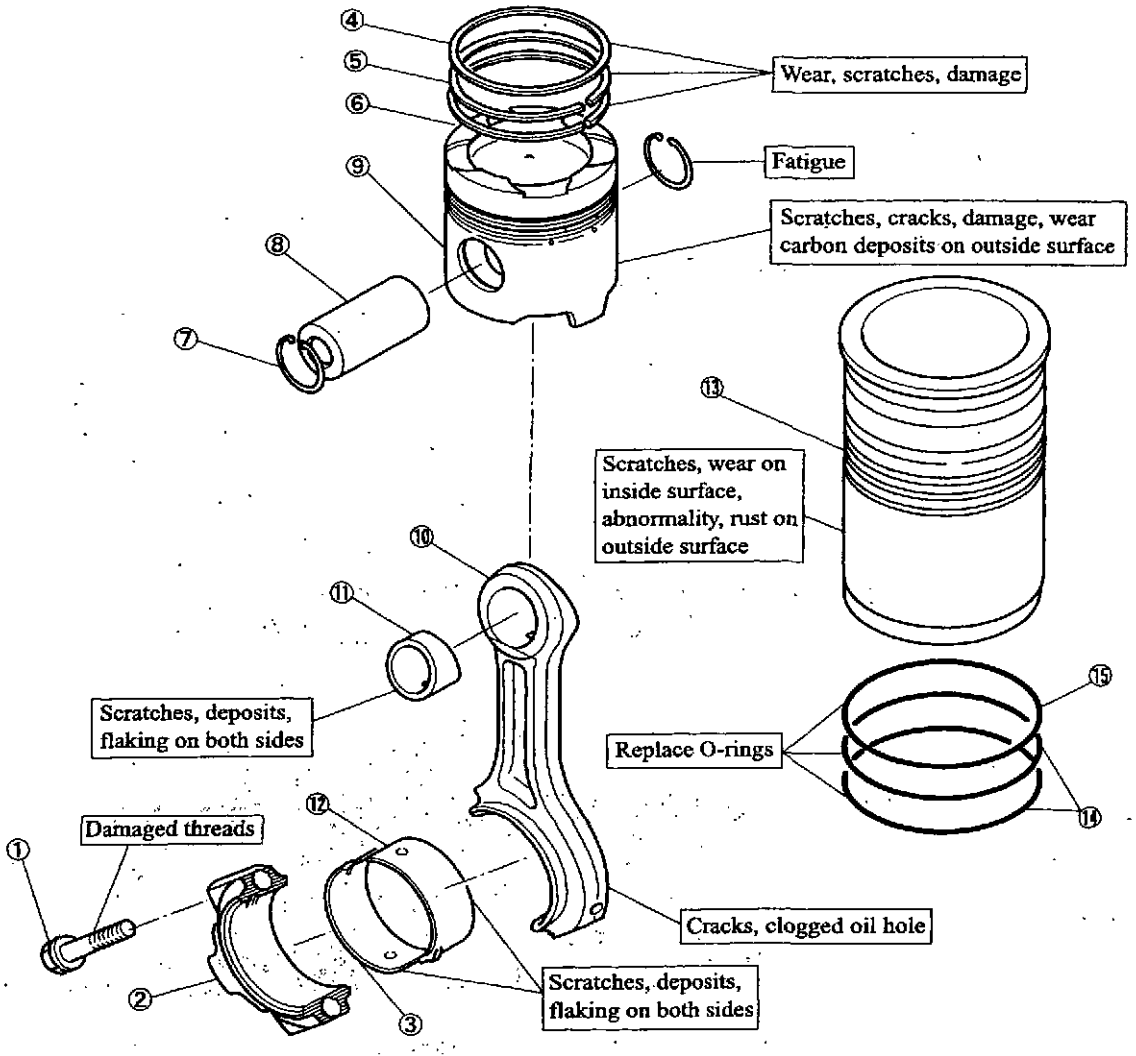
Name of special tool	Part No.
Copper tube pusher	35B91-06600

Note: Remove the copper tube gradually. Do not attempt to remove it by a single strike of a hammer.



Removal of copper tube

2. Cylinder Liners, Pistons and Connecting Rods



Disassembly and inspection of cylinder liners, pistons and connecting rods.

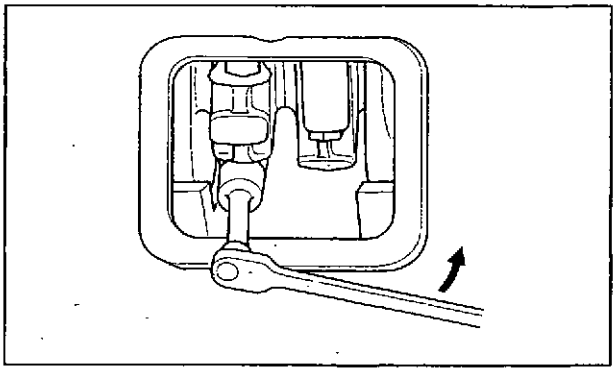
< Disassembly sequence >

① Bolt
② Connecting rod cap
③ Connecting rod bearing, lower
④ Top compression ring
⑤ Second compression ring
⑥ Oil ring
⑦ Snap ring
⑧ Piston pin
⑨ Piston
⑩ Connecting rod
⑪ Connecting rod bushing
⑫ Connecting rod bearing, upper
⑬ Cylinder liner
⑭ O-ring
⑮ O-ring

2.1 Removal of Connecting Rod Caps

Unscrew the connecting rod bolt from the inspection window on the side of the crankcase, and remove the cap.

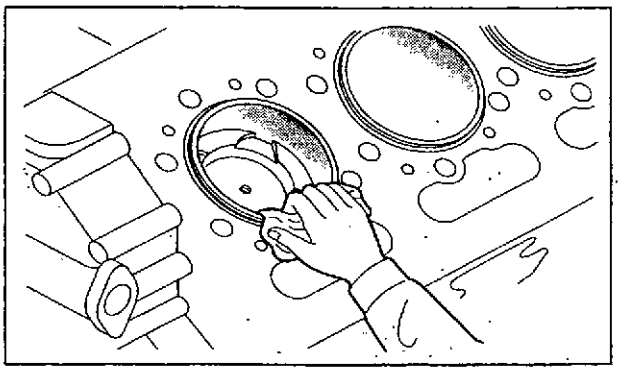
Note: (a) Do not damage the bearings by dropping them in the oil pan.
(b) Mark the removed connecting rod bearings for identification of cylinder numbers and for upper or lower position.



Removal of connecting rod cap

2.2 Preparation for Removal of Pistons

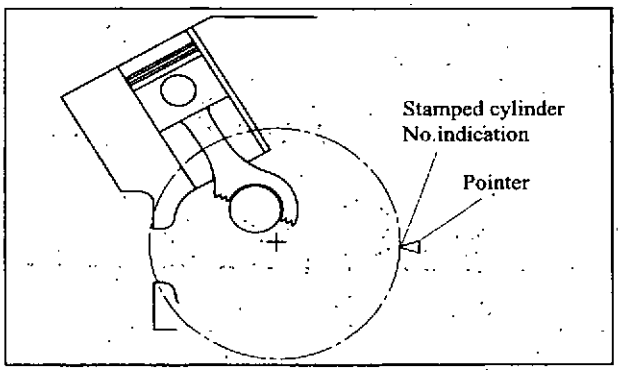
If carbon deposits are present at the upper section of the cylinder liner, the piston may be difficult to lift up for removal. In that case, remove the carbon deposits with a cloth or oil paper.



Preparation for removal of piston

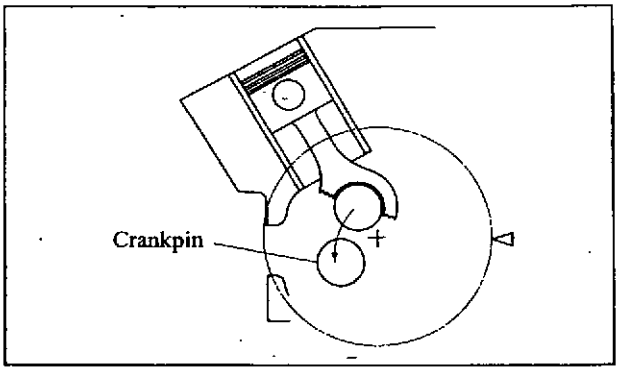
2.3 Removal of Pistons from Right Bank Cylinders

(1) Turn the crankshaft to bring the piston assembly from which the connection rod cap has been removed to the top dead center.



Removal of piston from right bank cylinder (1)

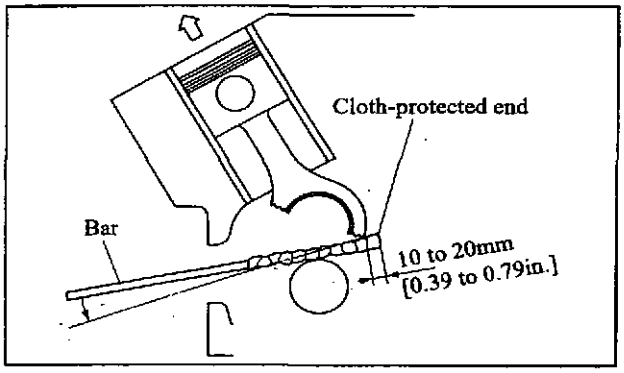
(2) Turn the crankshaft in reverse direction until the crankpin is disengaged from the connecting rod and the bolt hole of the connecting rod becomes visible through the inspection window on the side of the crankcase.



Removal of piston from right bank cylinder (2)

(3) Cover a bar with a cloth for protection, and position the tip of the bar under the bottom of the big-end of the connecting rod, then pry up using the crankpin as a fulcrum. This raises the piston slightly.

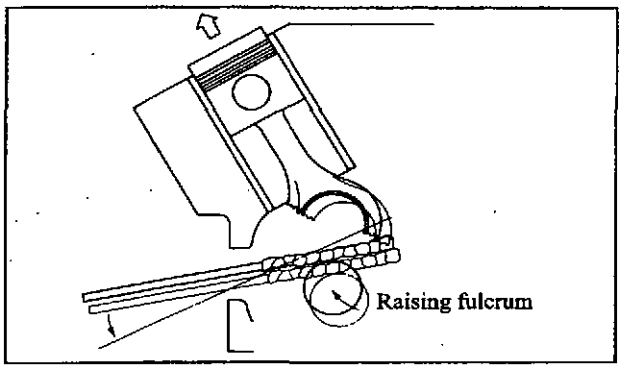
Note: If the bar is inserted too far, it contacts the cylinder liner and disallows the removal of the piston, then insert the bar so that it extends about 10 to 20 mm [0.39 to 0.79 in.] from the bottom end of the connecting rod big-end.



Removal of piston from right bank cylinder (3)

(4) Turn the crankshaft in the normal direction a little at a time to raise the crankpin (fulcrum) while pushing down on the outer end of the bar to raise the piston.

Note: Raise the piston carefully so that the connecting rod will not contact the piston cooling nozzle.

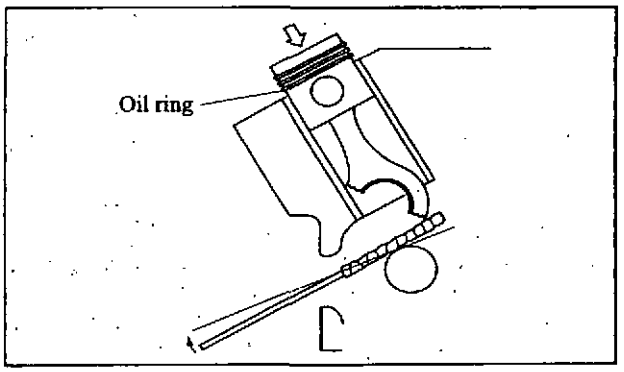


Removal of piston from right bank cylinder (4)

(5) When the oil ring of the piston comes out of the cylinder liner, raise the outer end of the bar slightly and gently rest the oil ring on the edge of the cylinder liner.

⚠ CAUTION

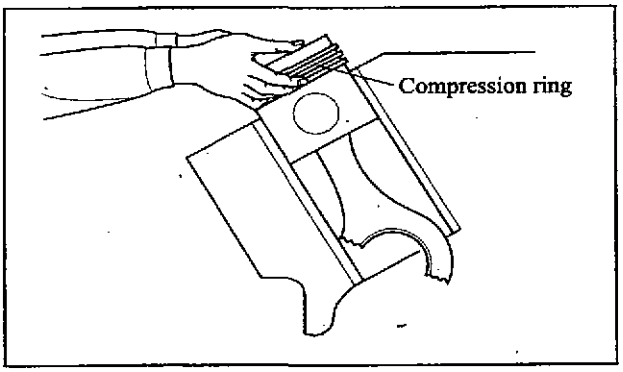
Sudden lifting of the bar can damage the oil ring. Also, do not rotate the piston.



Removal of piston from right bank cylinder (5)

(6) Hold the compression ring with both hands, gently lift the piston from the cylinder liner, and rest the piston skirt section on the top surface of the crankcase.

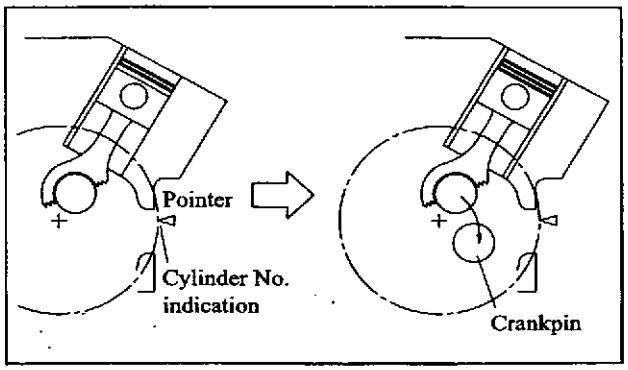
(7) Hold the piston pin with both hands, and pull the piston out of the cylinder liner.



Removal of piston from right bank cylinder (6)

2.4 Removal of Pistons from Left Bank Cylinders

The removal procedure is the same as that for removing pistons from right bank cylinders, but the crankpin position and the crankshaft rotating direction are reversed.



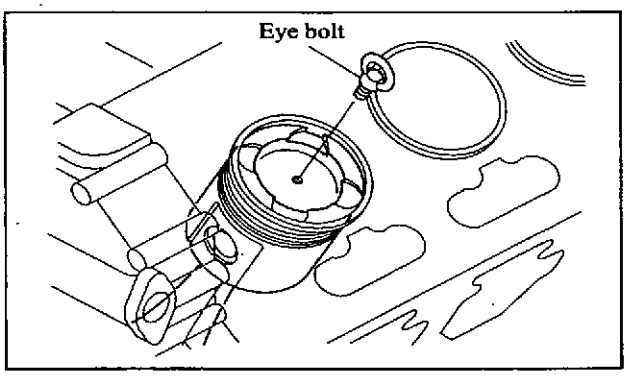
Removal of piston from left bank cylinder

2.5 Removal of Pistons Using Piston Remover

(1) Turn the crankshaft to bring the piston to be removed to approximately 50° after top dead center, if the piston is in the right bank.

(2) Attach the piston remover to the top of the piston, and slowly lift the piston and connecting rod out of the cylinder liner at an angle.

Name of special tool	Part No.
Eye bolt	MM321420



Removal of piston using piston remover

⚠ CAUTION

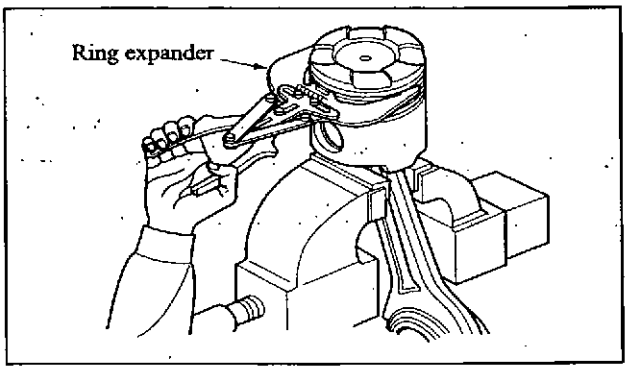
(a) Because the piston swings suddenly as it comes out of the cylinder liner, support the piston to prevent the piston skirt from hitting the connecting rod.

(b) Support the connecting rod to prevent it from scratching the inside wall of the cylinder liner.

2.6 Removal of Piston Rings

Using the ring expander, remove the piston rings.

Name of special tool	Part No.
Ring expander	37191-03200

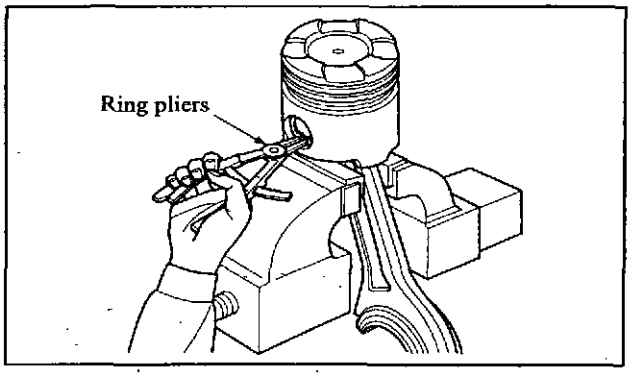


Removal of piston ring

2.7 Removal of Piston Pins

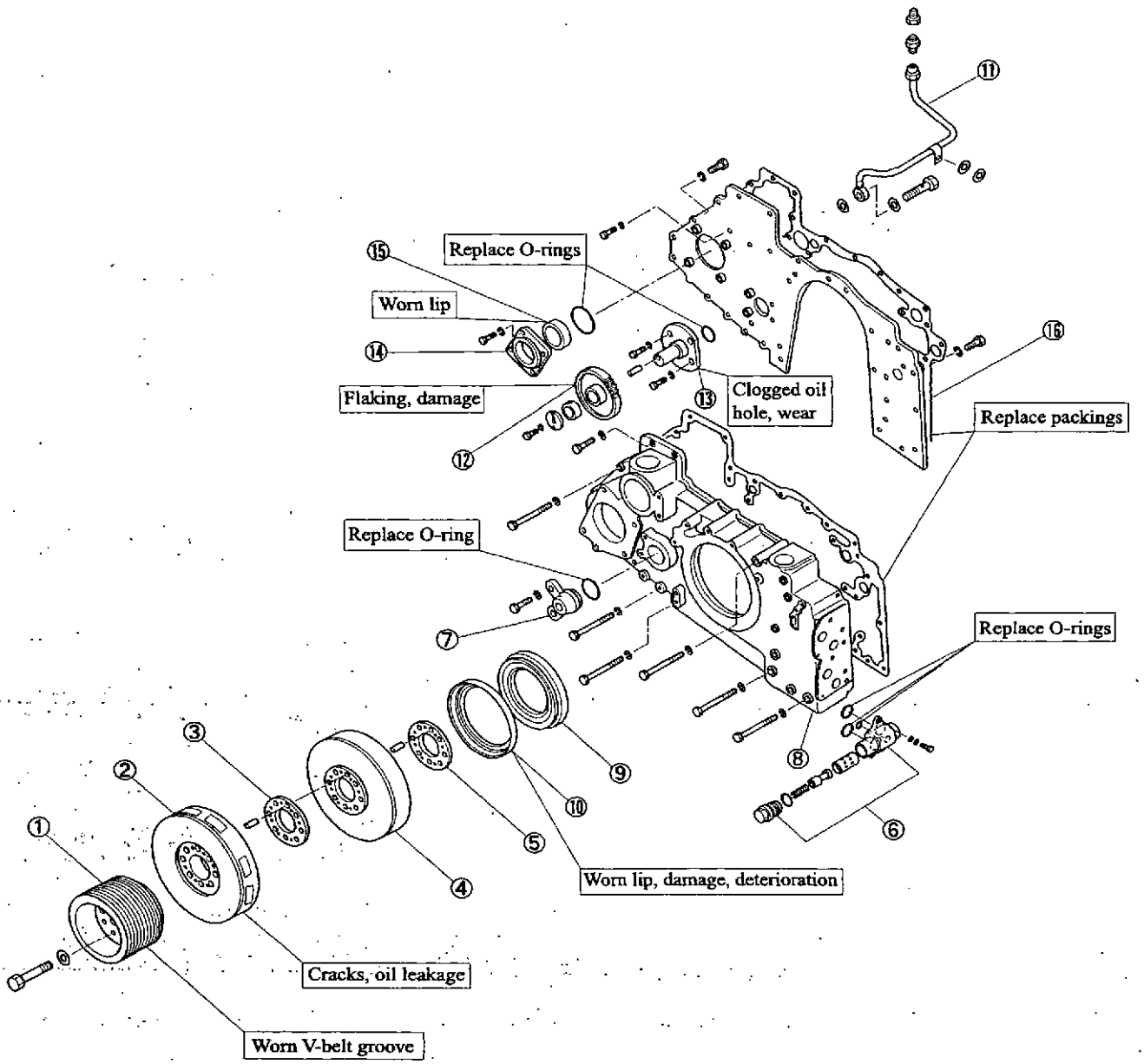
(1) Using the ring pliers, remove the snap ring.
(2) Remove the piston pin, and separate the piston from the connecting rod.
(3) If it is difficult to pull out the piston pin, heat the piston with a piston heater or in hot water.

Name of special tool	Part No.
Ring pliers	45191-08400



Removal of piston pin

3. Damper and Front Gears



Disassembly and inspection of damper and front gears

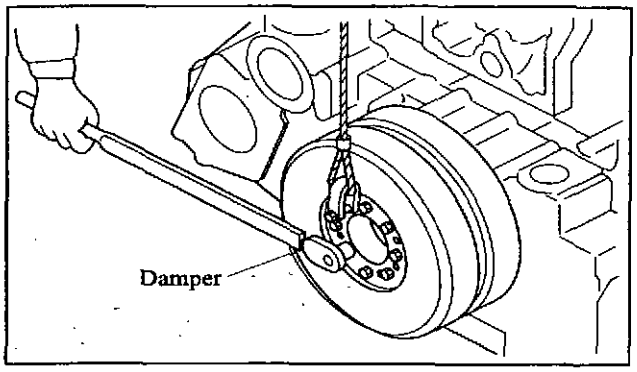
< Disassembly sequence >

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

3.1 Removal of Damper

(1) Attach a sling to the damper, and unscrew the damper mounting bolts.

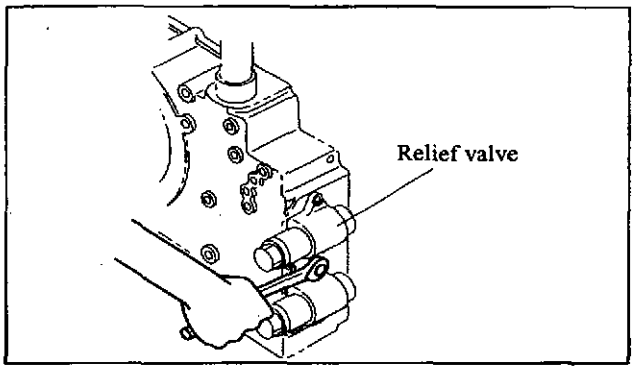
(2) Screw two jack-bolts (M12×1.25-50 mm [1.97 in.]) evenly into bolt holes, and remove the damper by lifting.
(Weight: approx. 53 kg [117 lb.] for front piece, approx. 56 kg [123 lb.] for rear piece)



Removal of damper

3.2 Removal of Relief Valve

Disconnect the relief valve mounting bolt, then remove the relief valve.

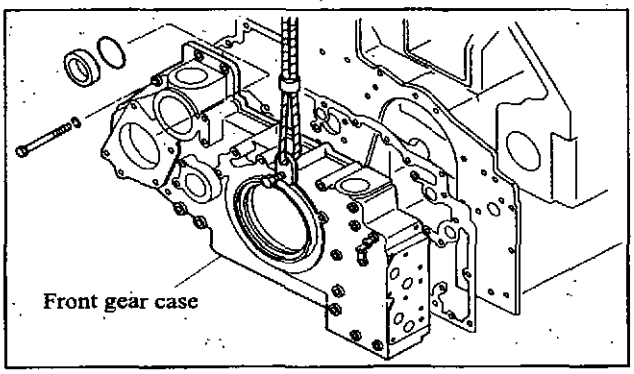


Removal of fan drive idler gear and idler shaft (1)

3.3 Removal of Front Gear Case

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

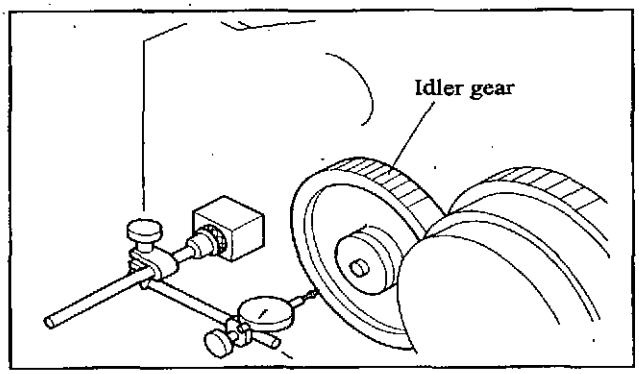
(2) Unscrew the front gear case mounting bolts, and remove the suspended gear case by sliding it out until the gear case is disengaged from the dowel pins. When removing the gear case, be careful not to damage the oil seal or bend the pointer by hitting.
(Weight: approx. 54 kg [119 lb.])



Removal of front gear case

3.4 Measurement of Idler Gear Backlash and End Play

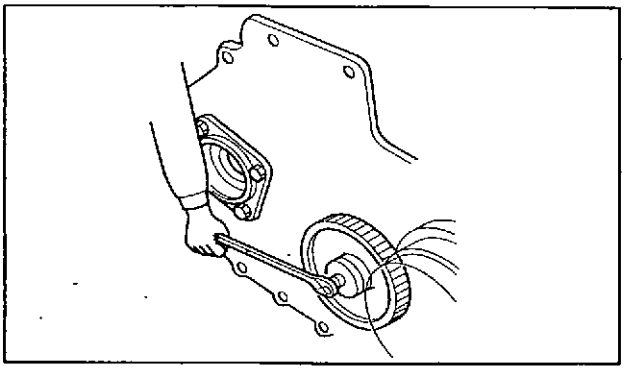
Measure the backlash and end play of the idler gear to obtain the data for parts replacement.



Measurement of idler gear backlash and end play

3.5 Removal of Idler Gears

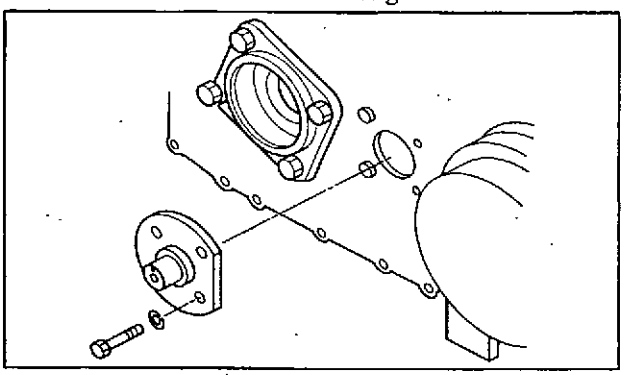
Unscrew the thrust plate mounting bolts, and remove the idler gear.



Removal of idler gear

3.6 Removal of Idler Shafts

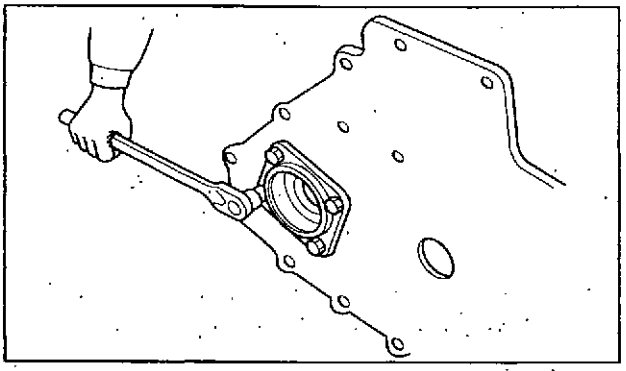
Do not remove the idler shaft unless absolutely necessary. To remove the shaft for repair or replacement, unscrew the mounting bolts, and screw in two jack-bolts (M10×1.25 mm) evenly and remove shaft.



Removal of idler shaft

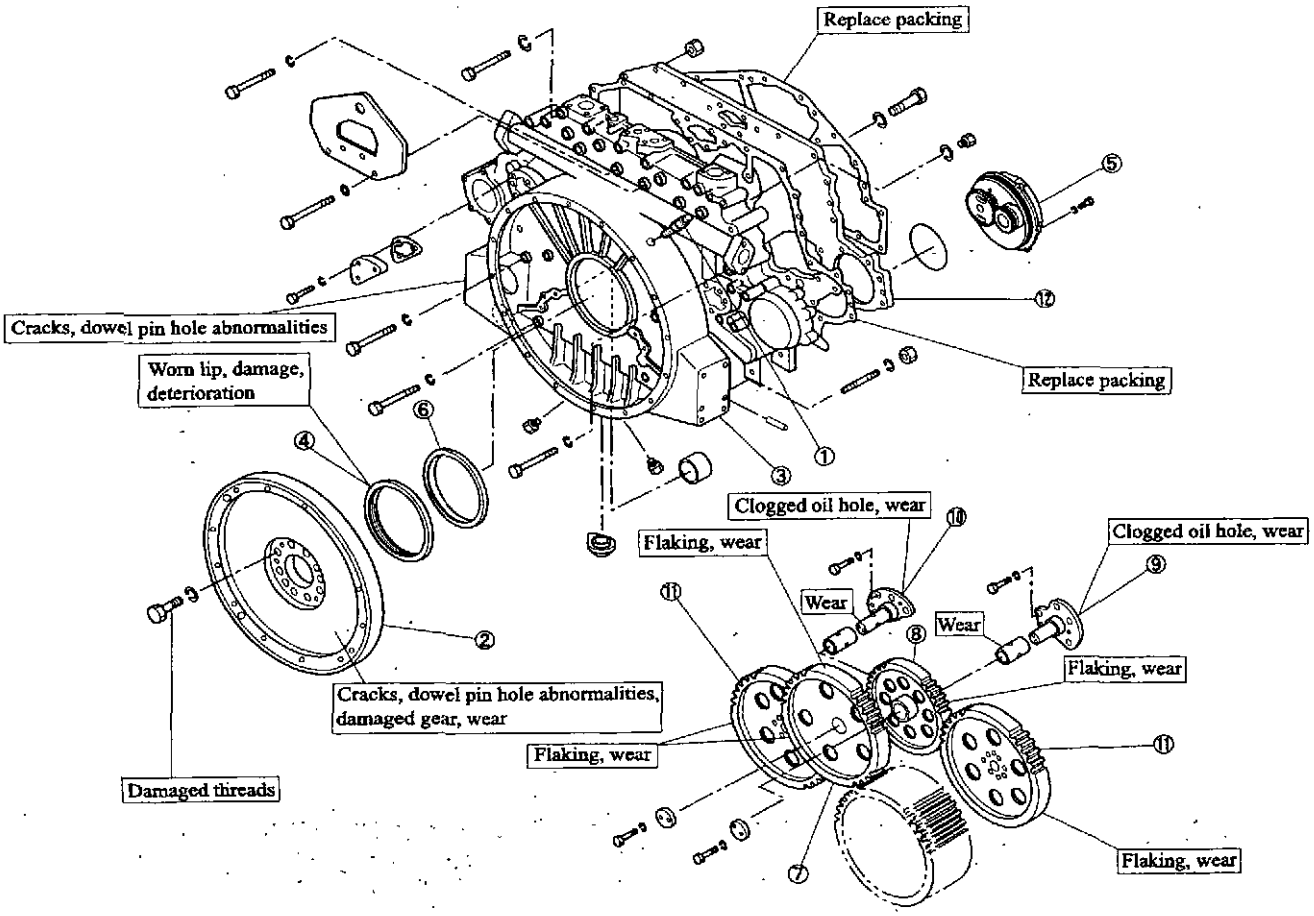
3.7 Removal of Water Pump Bearing Cover

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



Removal of water pump bearing cover

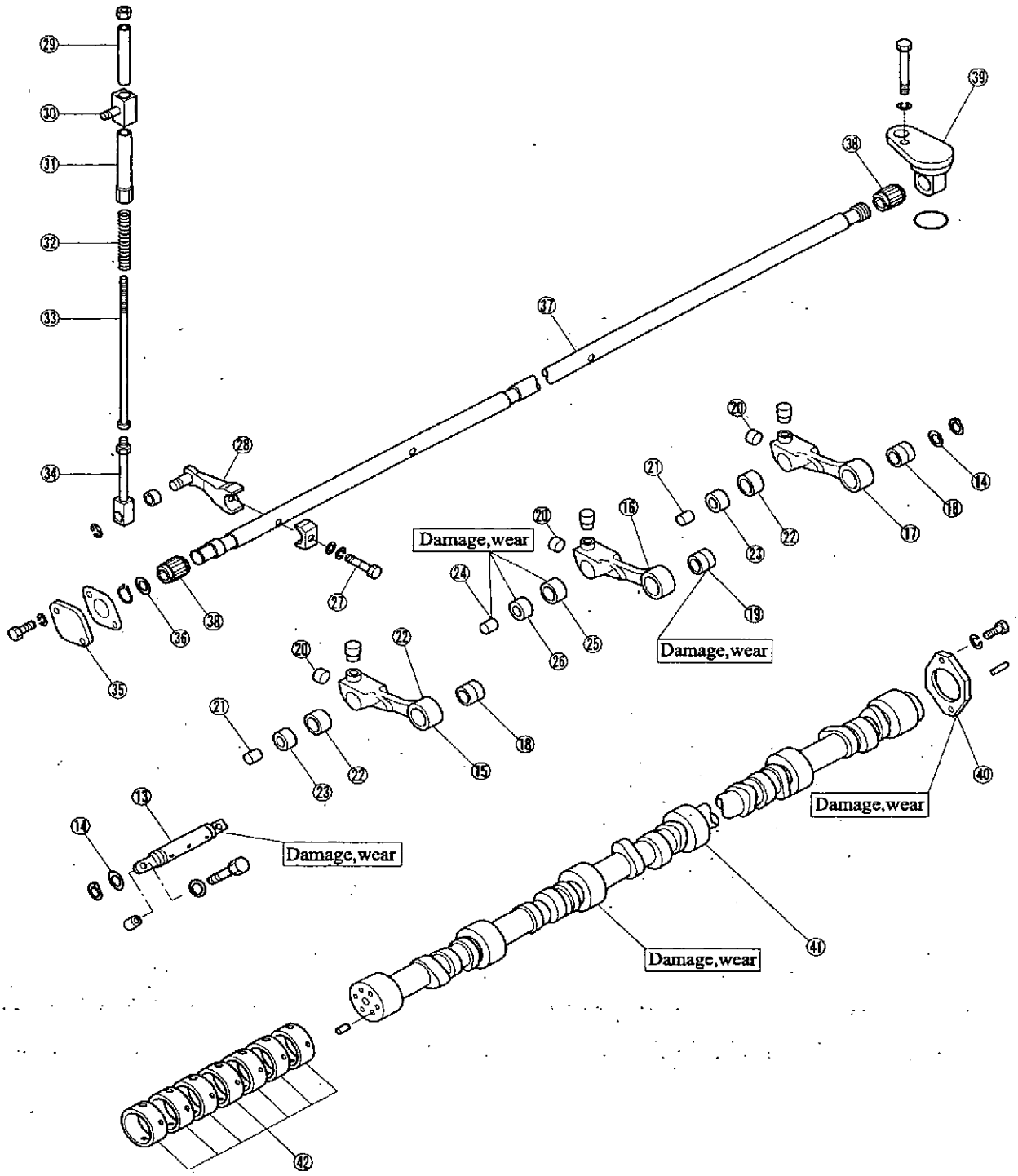
4. Flywheel, Timing Gears, Camshafts and UI Control



Disassembly and inspection of flywheel and timing gears

< Disassembly sequence >

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



Disassembly and inspection of camshaft and UI control

< Disassembly sequence >

⑬ Cam follower shaft
⑭ Cam follower spacer
⑮ IN follower
⑯ UI follower
⑰ EXH follower
⑱ Follower bushing
⑲ UI follower bushing
⑳ Set screw
㉑ Roller pin
㉒ Tappet roller
㉓ Roller bushing
㉔ UI roller pin
㉕ UI tappet roller
㉖ UI roller bushing
㉗ Reamer bolt
㉘ Control lever
㉙ Spacer
㉚ Pin
㉛ Spring case
㉜ Cancel spring
㉝ Cancel link
㉞ Cancel rod
㉟ Flange
㊱ Washer
㊲ Control shaft
㊳ Needle gage
㊴ Control bracket
㊵ Thrust plate
㊶ Camshaft (weight: approx. 58 kg [128 lb.])
㊷ Camshaft bushing

4.1 Removal of Flywheel

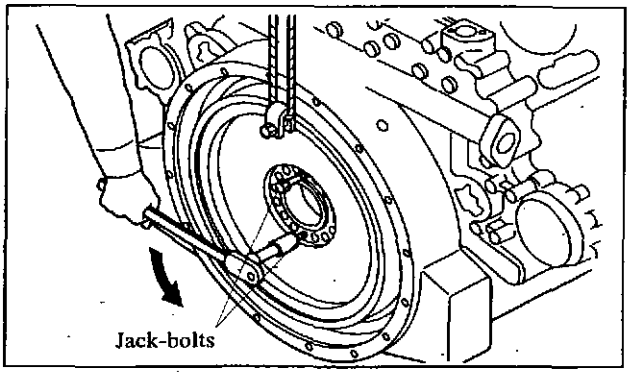
(1) Attach a sling to the flywheel.
(2) Unscrew the flywheel mounting bolts.
(3) Screw two jack-bolts evenly into the flywheel removing holes, and dismount the flywheel.

Name of special tool	Part No.
Jack-bolt	64362-68500

(Flywheel weight: approx. 100 kg [220 lb.])

⚠ CAUTION

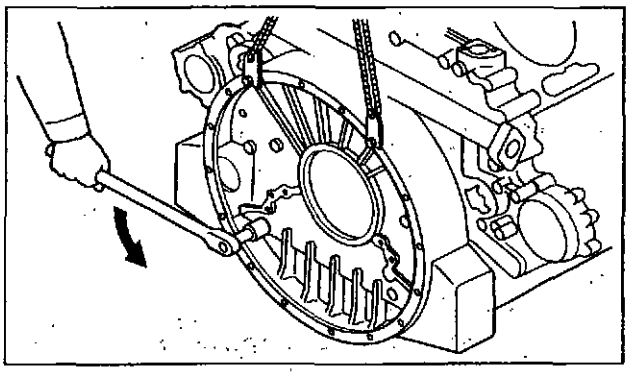
(a) Carefully remove the flywheel to avoid dropping or scratching the part.
(b) The ring gear is bolted to the flywheel. Do not remove the ring gear unless it has to be replaced.



Removal of flywheel

4.2 Removal of Timing Gear Case

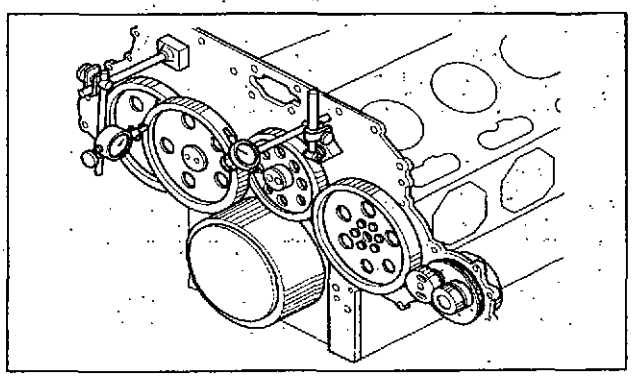
(1) Attach slings to the timing gear case.
(2) Unscrew the timing gear case mounting bolts.
(3) Remove the timing gear case by sliding it out until the gear case is disengaged from the dowel pins. Conduct this removal procedure while suspending the timing gear case, and be careful not to damage the oil seal.
(Timing gear case weight: approx. 170 kg [375 lb.])



Removal of timing gear case

4.3 Measurement of Backlash and End Play

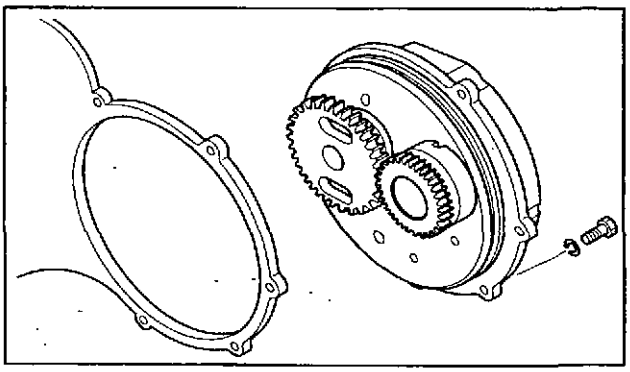
Measure the backlash and end play of each gear to obtain the data for parts replacement.



Measurement of timing gear backlash and end play

4.4 Removal of Governor Drive (PSG)

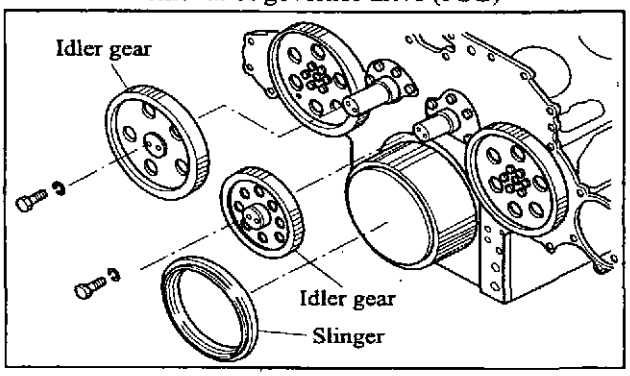
Unscrew the mounting bolts of the injection pump drive case, and dismount the governor drive. Be careful not to damage the gear teeth.
(See the "Fuel System" section for disassembly, inspection and reassembly.)



Removal of governor drive (PSG)

4.5 Removal of Idler Gears

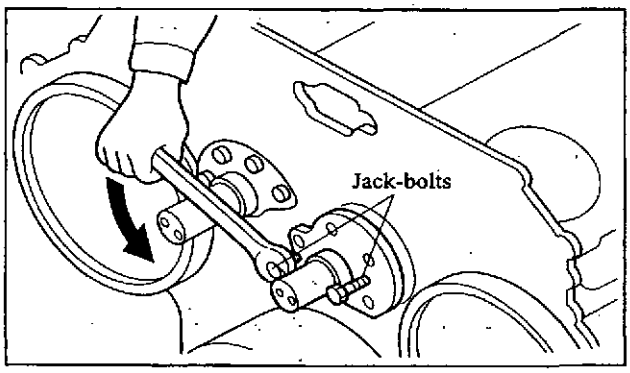
(1) Remove the slinger from the crankshaft.
(2) Remove the idler gears (right and left).



Removal of idler gear

4.6 Removal of Idler Shafts

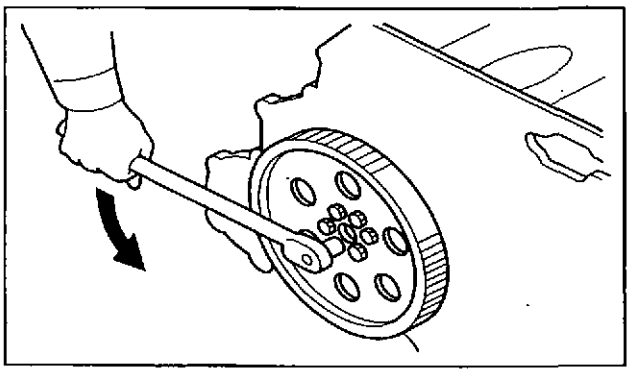
Do not remove the idler shafts unless they have to be repaired or replaced.
To remove the shaft for repair or replacement, screw two jack-bolts (M10×1.25 mm) in the idler shaft mounting bolts in evenly and remove shaft.



Removal of idler shaft

4.7 Removal of Camshaft Gears

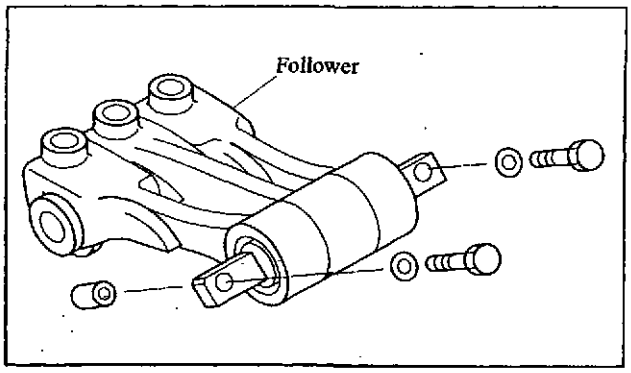
Unscrew the camshaft gear mounting bolts, and remove the camshaft gear.



Removal of camshaft gear

4.8 Removal of Followers

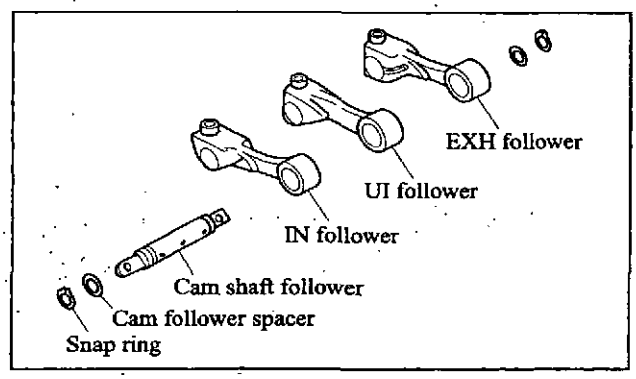
Remove the cam follower shaft mounting bolts and dismount the follower.



Removal of cam follower

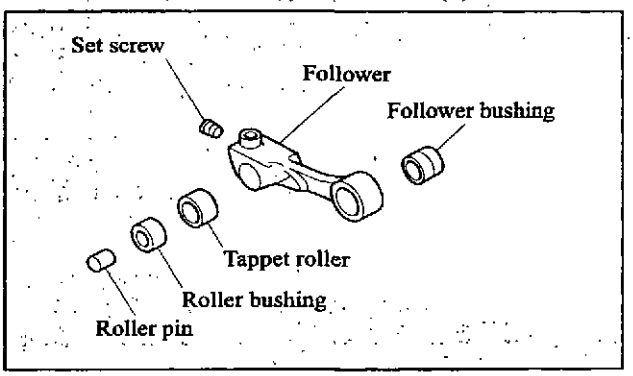
4.9 Disassembly of Followers

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



Disassembly of follower (1)

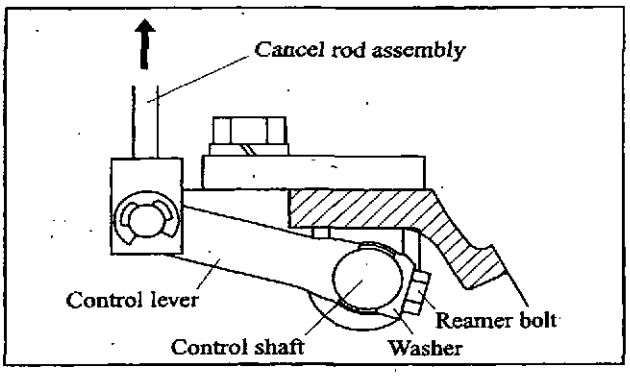
(2) Pull out the follower bushing from each follower.
(3) Remove the set screw, pull out the roller pin, and remove the tappet roller and roller bushing.



Disassembly of follower (2)

4.10 Removal of Cancel Rod Assemblies

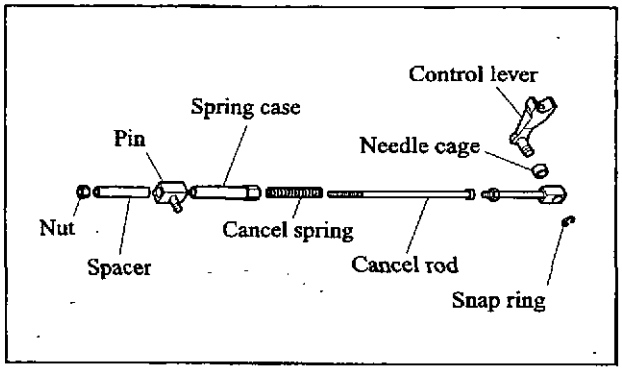
(1) Unscrew the reamer bolt, and remove the control lever from the control shaft. In this process, be careful not to drop the washer into the crankcase.
(2) Pull out the cancel rod assembly from the crankcase.



Removal of cancel rod assembly

4.11 Disassembly of Cancel Rod Assemblies

(1) Remove the snap ring, and dismount the control lever and needle cage.
(2) Remove the nut, and dismount the spacer and pin.
(3) Separate the spring case and cancel rod, and remove the cancel spring and cancel link.

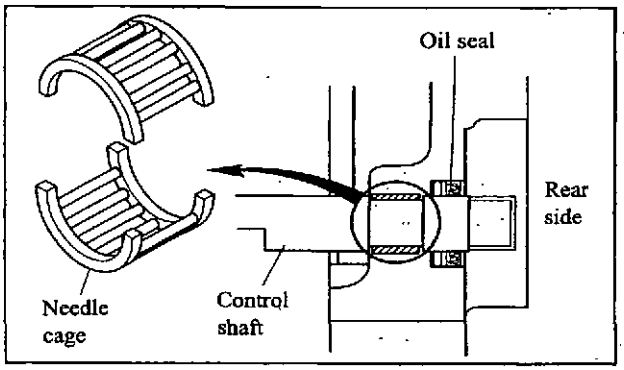


Disassembly of cancel rod assembly

4.12 Removal of Control Shafts

(1) Remove the flange from the front side of the crankcase.
(2) Pull out the control shaft from the front side of the crankcase, and remove the needle cage at the same time.

Note: (a) Be sure to pull out the control shaft from the front side of the crankcase since an oil seal is installed on the rear side of the crankcase.
(b) When removing the control shaft, do not drop the needle cage in the crankcase. The needle cage is shaped like a compound of two half-round objects.



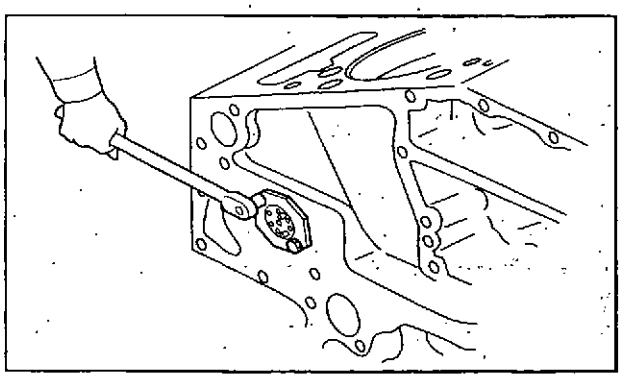
Removal of control shaft

4.13 Removal of Camshafts

Unscrew the thrust plate mounting bolts, and remove the camshaft from the crankcase.
(Camshaft weight: approx. 58 kg [128 lb.])

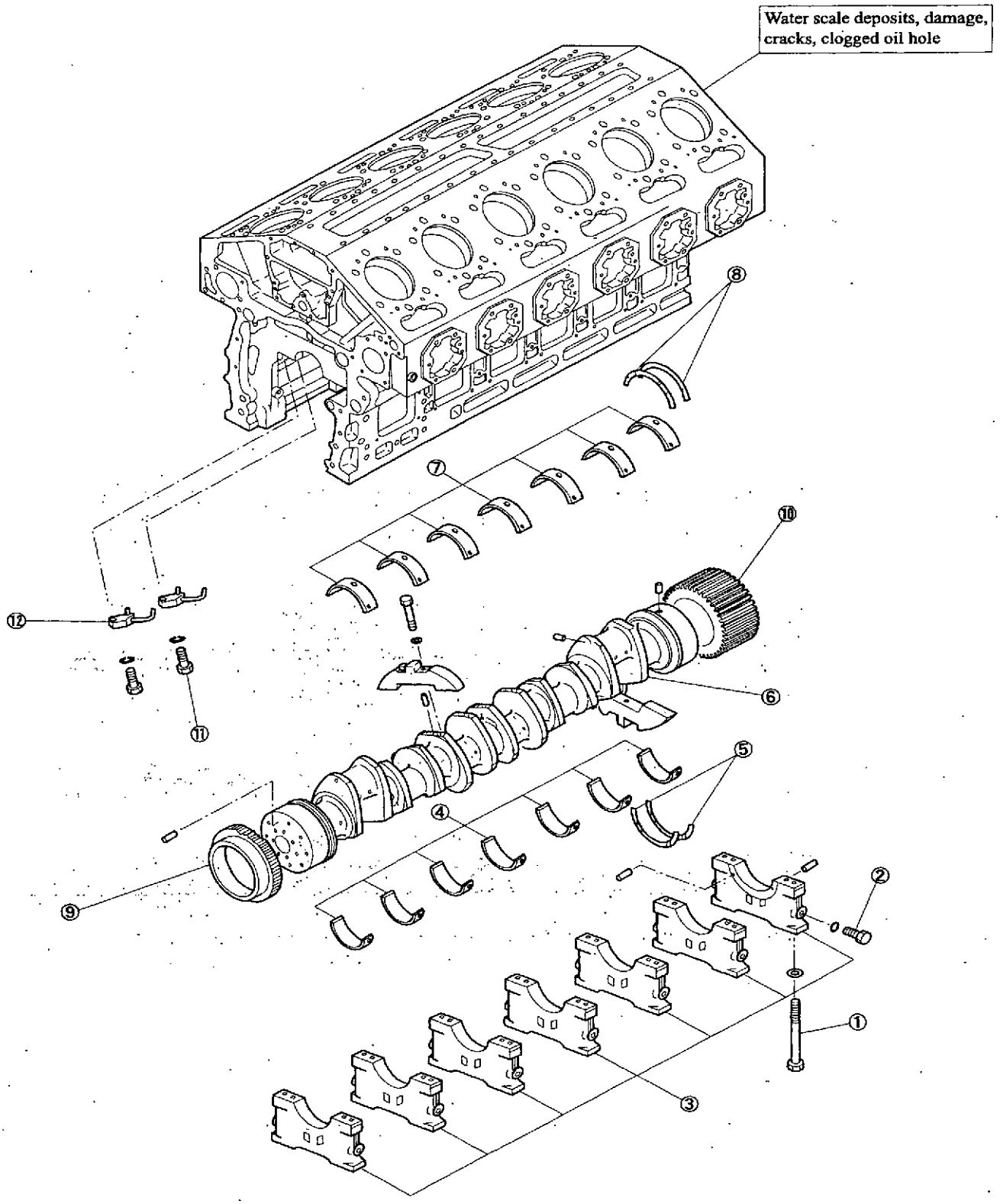
⚠ CAUTION

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.



Removal of camshaft

5. Crankcase, Crankshaft and Main Bearings



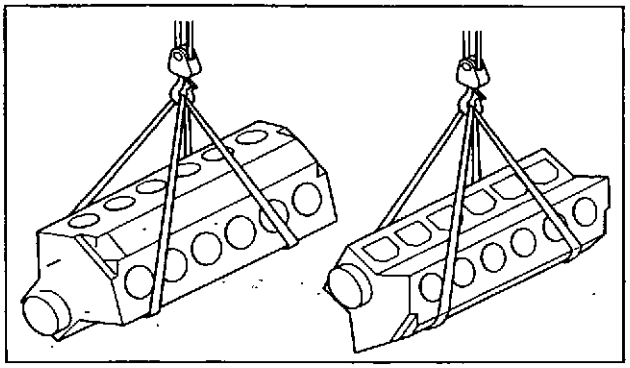
Disassembly and inspection of crankcase, crankshaft and main bearings

< Disassembly sequence >

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

5.1 Reversal of Crankcase

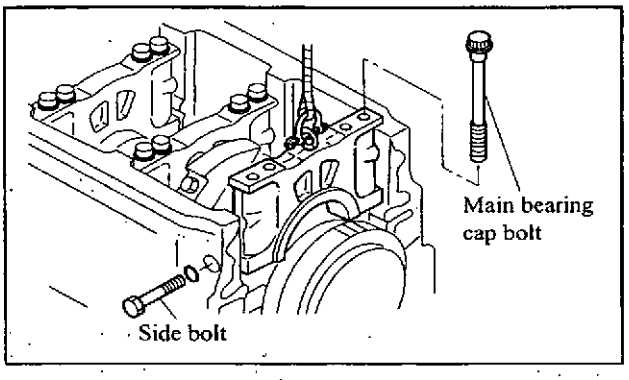
Using a chain block and shackles, lay the crankcase on its side, hook a wire rope to the crankcase, then turn the crankcase upside down.
(Crankcase and crankshaft weight: approx. 1850 kg [4079 lb.])



Reversal of crankcase

5.2 Removal of Main Bearing Caps

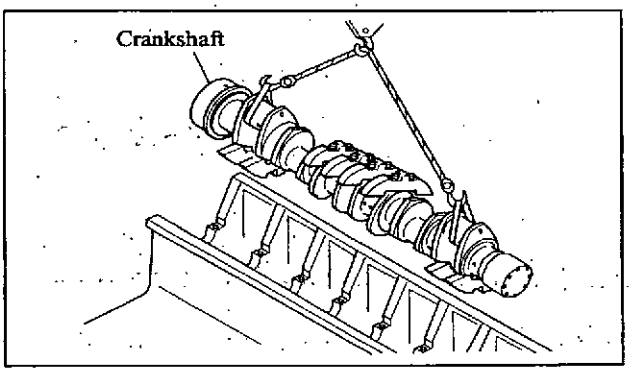
(1) Unscrew the main bearing cap bolts and side bolts, and remove the main bearing cap by using the cap remover or crane (eye bolt: M12×1.25 mm).
(2) Conduct the removal procedure carefully to prevent damage to the thrust plate attached to the No. 7 bearing cap.



Removal of main bearing cap

5.3 Removal of Crankshaft

(1) Remove the front upper halves of the thrust plates by rotating them slowly.
(2) Carefully lift the crankshaft from the crankcase, keeping it horizontal.
(3) Remove the rear upper halves of the thrust bearings from the crankcase.
(Crankshaft assembly weight: 375 kg [827 lb.])

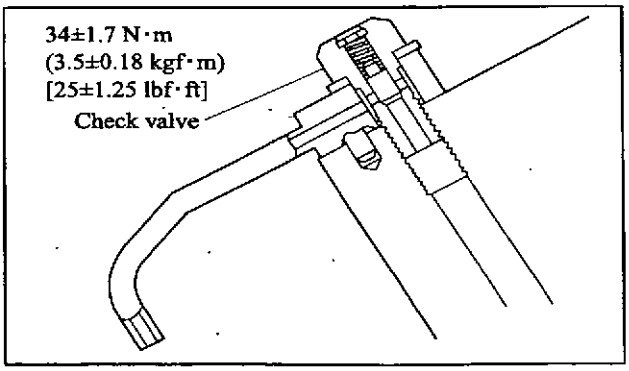


Removal of crankshaft

5.4 Removal of Piston Cooling Nozzles

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

Note: (a) Be sure to use new nozzles when the piston cooling nozzles are removed.
(b) When the piston cooling nozzles are replaced, use a torque wrench to tighten the check valve 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.



Removal of piston cooling nozzle

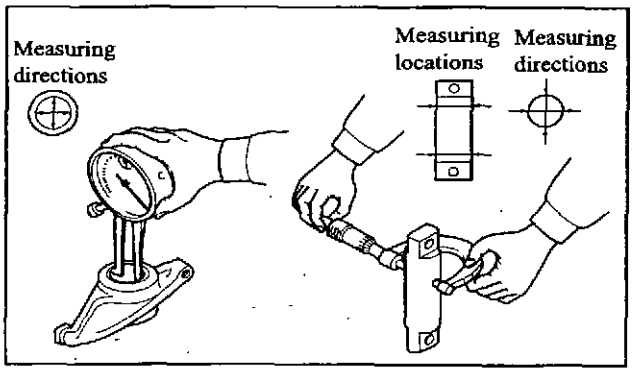
INSPECTION AND REPAIR OF ENGINE MAIN PARTS

1. Cylinder Heads and Valve Mechanisms

1.1 Measurement of Rocker Bushing Inside Diameter and Rocker Shaft Diameter

Unit mm [in.]

	Nominal value	Standard	Limit
Rocker bushing inside diameter	ϕ44 [1.734]	44.000 to 44.075 [1.734 to 1.735]	44.125 [1.737]
Rocker shaft diameter	ϕ44 [1.734]	43.975 to 43.991 [1.731 to 1.733]	43.030 [1.694]



Measurement of rocker bushing inside diameter and rocker shaft diameter

1.2 Replacement of Rocker Bushings

To replace the rocker bushings, use the rocker bushing tool.

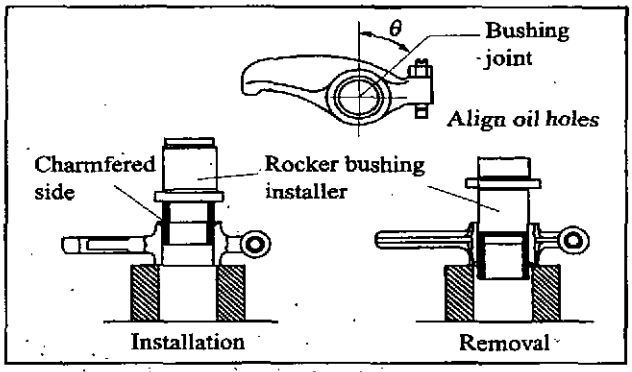
Name of special tool	Part No.
Rocker bushing tool	35C91-01800

Note: (a) Insert the bushing from the chamfered side of the rocker bushing hole.

(b) Align the oil holes in the bushing and rocker.

Rocker	θ (°)
IN, EXH	55°
UI	45°

(c) After installing the bushing, measure the inside diameter to make sure it is $\phi 44^{+0.075}_{0}$ mm [$1.734^{+0.003}_{0}$ in.]. If the measured diameter is not within this tolerance, refinish by reaming to $\phi 44^{+0.045}_{+0.011}$ mm [$1.734^{+0.0017}_{+0.0004}$ in.] 0.8 Ra.



Replacement of rocker bushing

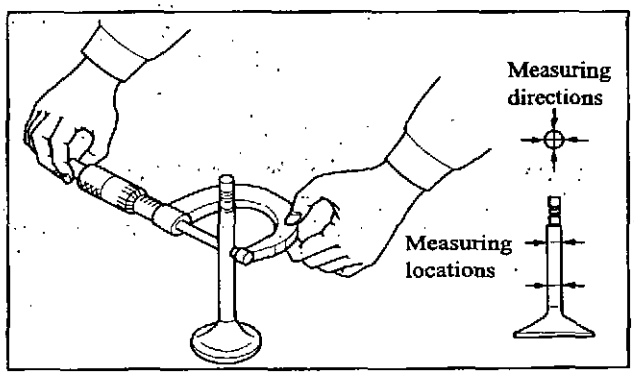
1.3 Measurement of Valve Stem Diameter and Valve Guide Inside Diameter

Because the valve guide wears more rapidly at the upper and lower ends, measure the diameter at both ends in two crossing directions.

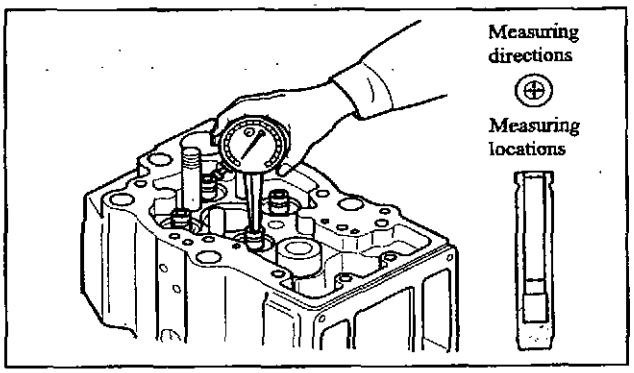
If the limit is exceeded, replace worn parts.

Unit mm [in.]

	Nominal value	Standard	Limit
Valve stem diameter	ϕ10 [0.39]	9.940 to 9.960 [0.39134 to 0.39213]	9.910 [0.39016]
Valve guide inside diameter	ϕ10 [0.39]	10.000 to 10.015 [0.39370 to 0.39429]	10.060 [0.39606]



Measurement of valve stem diameter

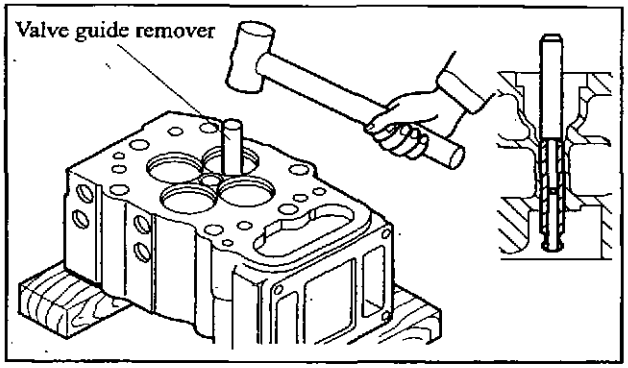


Measurement of valve guide inside diameter

1.4 Replacement of Valve Guides and Stem Seals

(1) To remove the valve guides, use the valve guide remover.

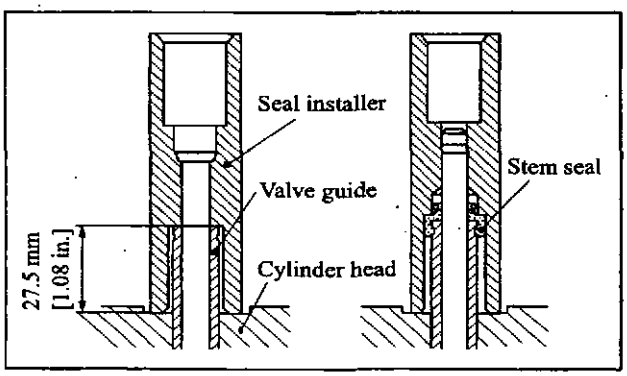
Name of special tool	Part No.
Valve guide remover	33591-04300



Removal of valve guide

(2) To press-fit the valve guides, use the seal installer and operate the press gently.

Name of special tool	Part No.
Seal installer	32591-10300



Installation of valve guide and stem seal

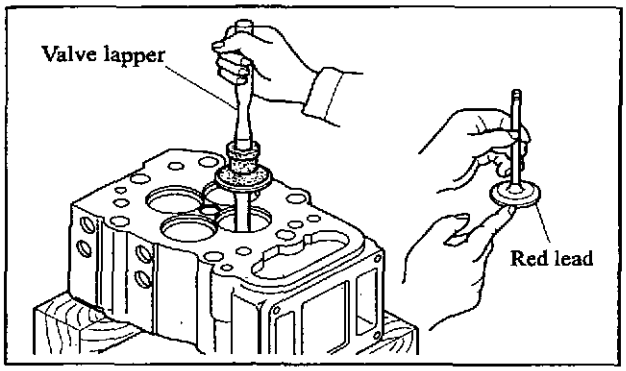
⚠ CAUTION

(a) Because the valve guide must be inserted to the specified depth, be sure to use the seal installer.
(b) Do not apply oil or liquid sealant to the contact surfaces of the stem seal and valve guide. To ensure initial lubrication of the stem seal lip, apply engine oil to the valve stem before installing the stem seal.
(c) Use new stem seals during reassembly.

1.5 Inspection of Valve Faces

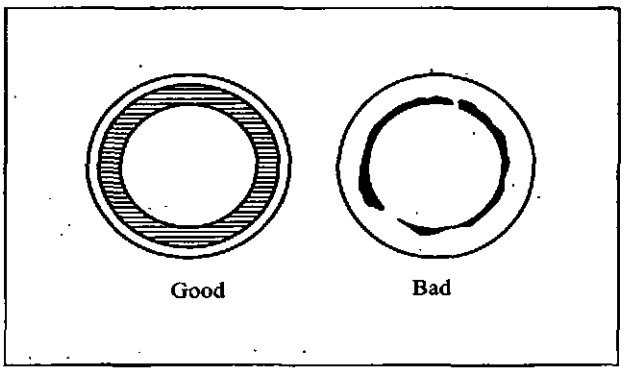
Coat the valve face lightly with red lead, and use the valve lapper to inspect the valve contact with its seat. If the contact is not uniform and the valve is defective, or if the limit is exceeded, replace the valve and valve seat.

Name of special tool	Part No.
Valve lapper	30091-08800



Inspection of valve face

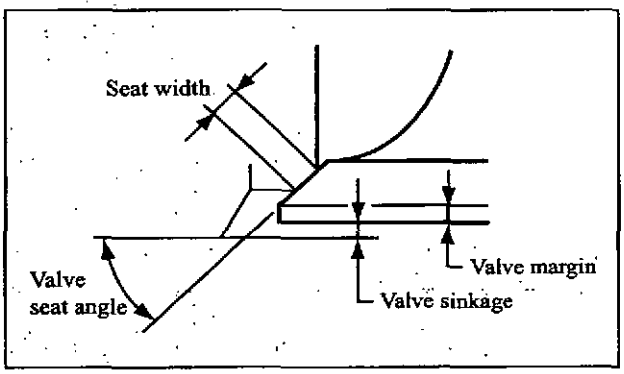
Note: (a) Inspect the valve face after the valve guide is inspected or replaced.
(b) When pressing the valve coated with red lead against the valve seat, do not rotate the valve.



Valve contact with seat

Unit mm [in.]

		Standard	Limit
Valve seat	Valve seat angle	30°	
	Valve sinkage	-0.1 to 0.1 [-0.004 to 0.004]	1.0 [0.039]
	Seat width	2.15 to 2.45 [0.0846 to 0.0965]	2.8 [0.110]
Valve margin		2.8 to 3.2 [0.110 to 0.126]	Refacing permissible up to 2.5 [0.098]

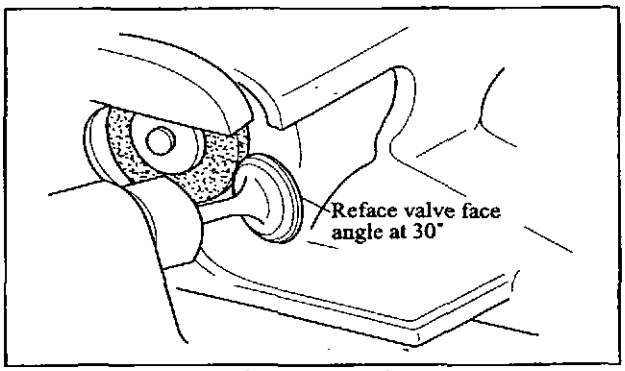


Reassembly of valve seat and valve

1.6 Refacing Valve Faces

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

Note: (a) Reface the valve face to an angle of 30°.
(b) Be sure to ensure the valve margin limit. If the grinding results in nonconformity of the dimension, replace the valve.



Refacing valve face

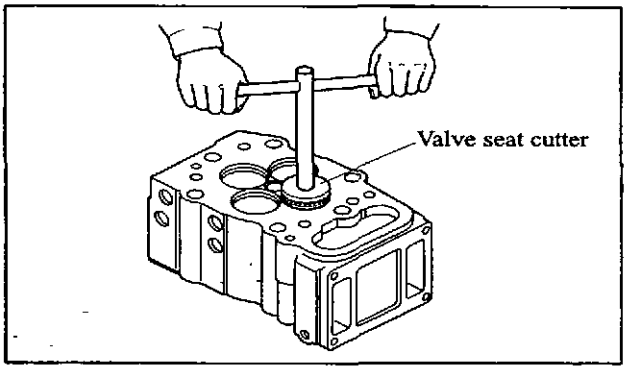
1.7 Repair of Valve Seats

(1) Use the valve seat cutter or valve seat grinder to reface the valve seat.
After refacing, grind the seat lightly using #400-grade sandpaper inserted between the cuter and valve seat.

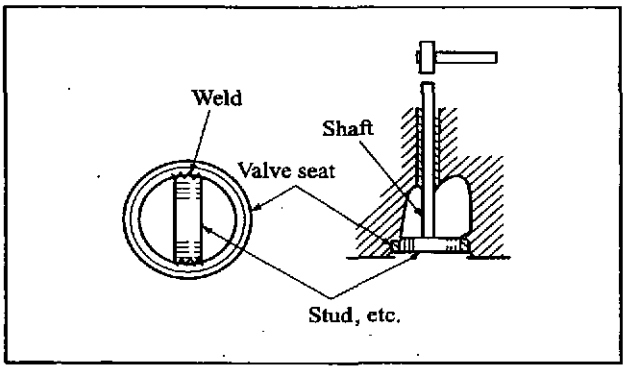
Name of special tool	Part No.
Valve seat cutter	37591-06400 37591-06430

(2) Lap the valve in the valve seat.

Note: (a) Grind the valve seat as little as possible.
(b) If the seat width exceeds the limit as a result of grinding, replace the valve seat.
(c) If the valve sinkage exceeds the limit as a result of grinding, replace the valve seat.



Repair of valve seat



Removal of valve seat

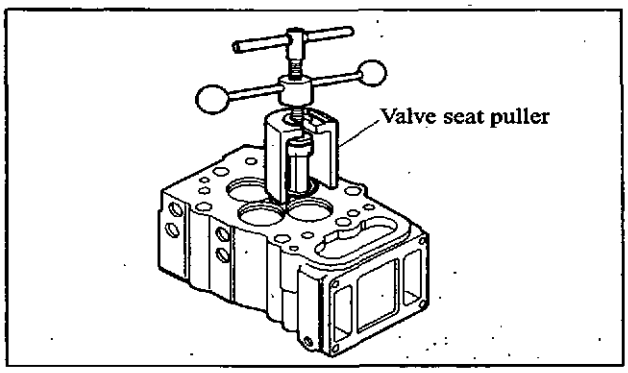
1.8 Replacement of Valve Seats

(1) (a) Weld a stud to the valve seat, and insert a shaft into the valve guide hole from the top of the cylinder head, and drive the seat off the cylinder head.

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

(b) Use the valve seat puller.

Name of special tool	Part No.
Valve seat puller	32591-04200



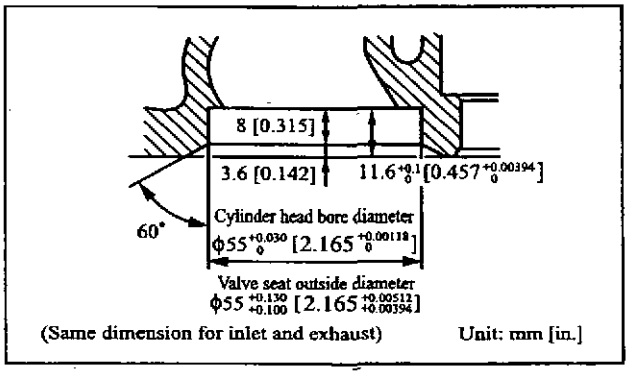
Removal of valve seat (using valve seat puller)

(2) Before inserting a new valve seat, measure the cylinder head bore diameter and valve seat outside diameter to make sure the clearance is within the clearance standard.

Unit mm [in.]

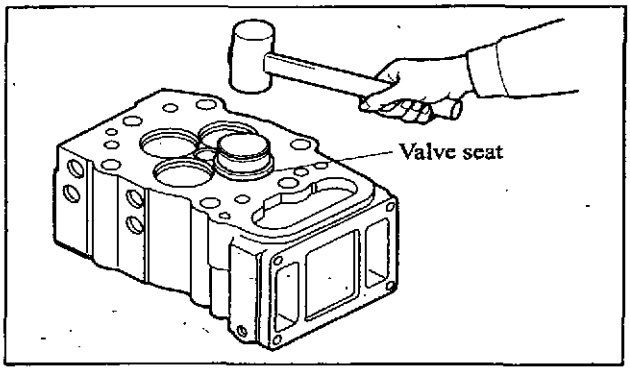
	Nominal value	Standard
Clearance between cylinder head bore diameter and valve seat outside diameter	ϕ55 [2.165]	-0.070 to -0.130 [-0.00276 to -0.00512]

Note: Minus (-) value indicates interference.



Valve seat dimensions

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



Installing valve seat

1.9 Lapping of Valves against Valve Seats

Be sure to lap the valves in the valve seats after the seats have been refaced or replaced.

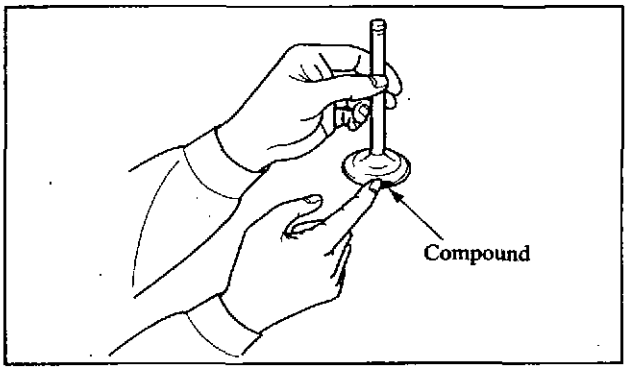
(1) Coat the seat contact surface of the valve face lightly and evenly with a lapping compound.

Note: (a) Do not allow the compound to adhere on the valve stem.
(b) Use a compound of medium coarseness (120 to 150 mesh) for initial lapping, and use a finer compound (200 mesh or finer) for finishing.
(c) Mix a small amount of engine oil with the compound for smooth and even application.

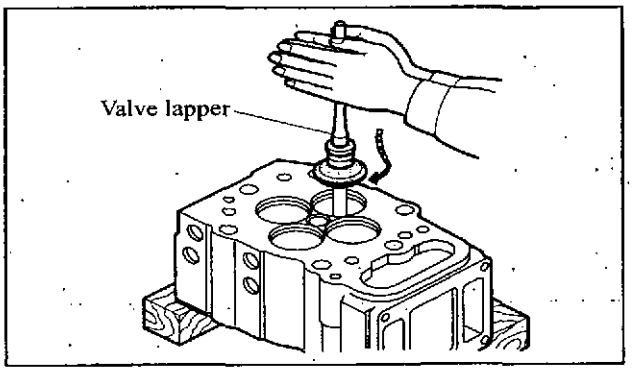
(2) Use the valve lapper to lap the valve in the seat. To lap, strike the valve against the valve seat while rotating the valve a little at a time.

Name of special tool	Part No.
Valve lapper	30091-08800

(3) Wash off the compound with diesel fuel.
(4) Coat the seat contact surface of the valve face with engine oil, then lap the valve again.
(5) Inspect the valve face for contact.



Coating valve with lapping compound

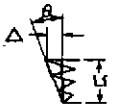


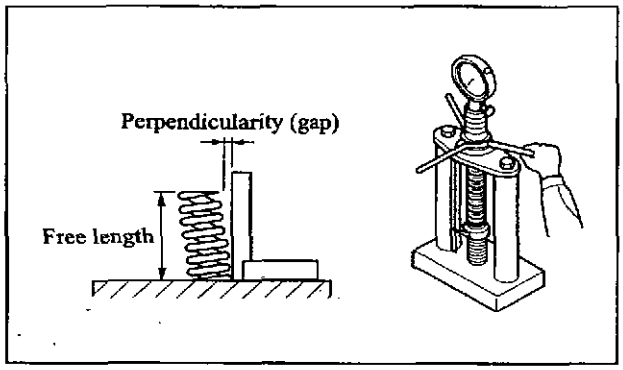
Lapping valve in valve seat

1.10 Measurement of Valve Spring Perpendicularity and Free Length

Measure the free perpendicularity and free length of each valve spring and if the limit is exceeded, replace the spring.

Unit mm [in.]

	Standard	Limit
Free length	70.5 [2.78]	69 [2.72]
Perpendicularity	 θ=1.5° or less Δ (gap) = 1.85 [0.073] Lf=70.5 [2.78]	Δ = 2.2 [0.087] over entire length
Set length/load (mm [in.]/N (kgf) [lbf])	61.8 [2.43]/254 to 281 (25.94 to 28.67) [57.2 to 63.2]	

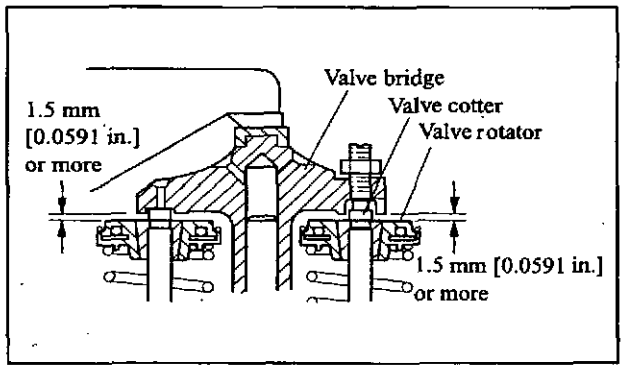


Measurement of valve spring perpendicularity and free length

1.11 Inspection of Clearance between Valve Bridge with Valve Cotter and Valve Rotator

(1) If the clearance is 1.5 mm [0.0591 in.] or less, check the valve stem top for cupping. When the stem top is badly cupped, replace the valve to obtain a clearance of 1.5 mm [0.0591 in.] or more.

(2) Check the bridge cap. If it is excessively worn, replace the bridge cap.



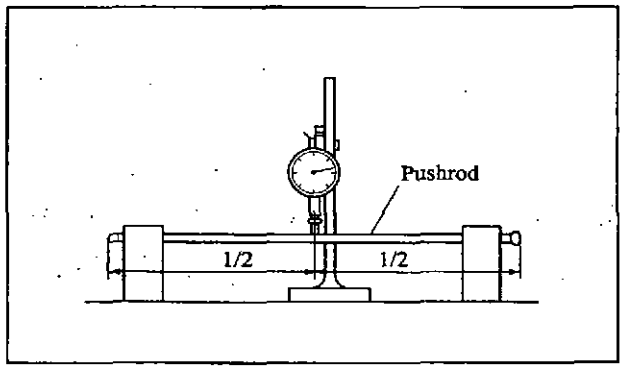
Inspection of clearance between valve bridge with valve cotter and valve rotator

1.12 Measurement of Pushrod Deflection

If the deflection exceeds the standard, replace the pushrods.

Unit mm [in.]

	Standard	Limit	Remarks
Pushrod deflection	Less than 0.5 [0.020]	0.5 [0.020]	TIR



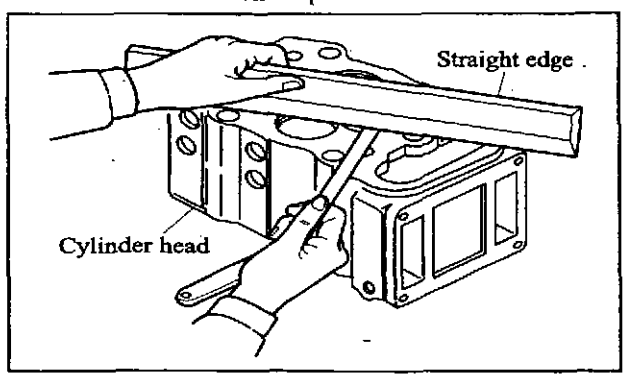
Measurement of pushrod deflection

1.13 Measurement of Distortion of Cylinder Head Bottom Surfaces

Using a straight edge and feeler gages, measure the amount of surface distortion. If the warping exceeds the limit, reface the bottom surface with a surface grinder.

Unit mm [in.]

	Standard	Limit
Distortion of bottom surface	0.03 [0.0012] or less	0.50 [0.0197]



Measurement of distortion of cylinder head bottom surface

2. Cylinder Liners, Pistons and Connecting Rods

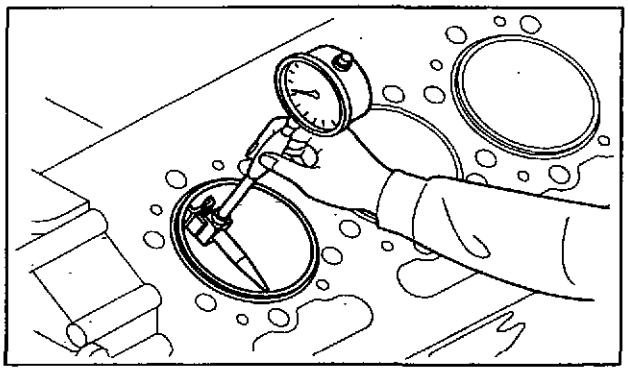
2.1 Measurement of Cylinder Liner Bore Diameter

Measure the bore diameter of each cylinder liner in two directions, parallel and traverse to the piston pin, at two positions, the upper section (most worn section) and middle section.

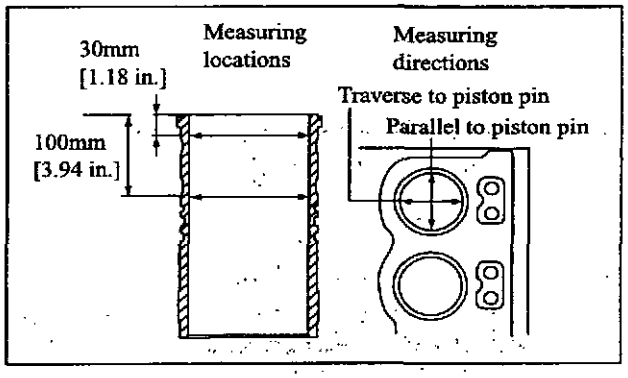
If the measurements exceed the limit, replace the cylinder liner.

Unit mm [in.]

		Nominal value	Standard	Limit
Cylinder liner	Bore diameter	ϕ150 [5.906]	150.000 to 150.040 [5.906 to 5.907]	150.140 [5.911]
	Circularity		0.02 [0.0008] or less	
	Cylindricity		0.02 [0.0008] or less	
	Perpendicularity of bottom flange surface to cylinder liner		0.03 [0.0012] or less	



Measurement of cylinder liner bore diameter



Measurement of cylinder liner dimensions

2.2 Measurement of Cylinder Liner Collar Protrusion

Measure the protrusion of each cylinder liner in the following method.

Note: The method of measuring the protrusion of a new cylinder liner is different from the method of measuring the protrusion of a liner which is not pulled out for replacement.

Unit mm [in.]

	Standard
Cylinder liner collar protrusion	0.10 to 0.19 [0.004 to 0.0075]

⚠ CAUTION

If the amount of protrusion is insufficient, the gasket will fail to seal the bore, causing gas leakage.

· When cylinder head has just been removed

(1) Make sure the gasket surface of the crankcase and the top of the cylinder liner are clean.

(2) Using the liner pushers and bolts, tighten the top of the cylinder liner uniformly at four places to apply even force.

Name of special tool	Part No.
Liner pusher	37591-06200
Bolt	37591-06300

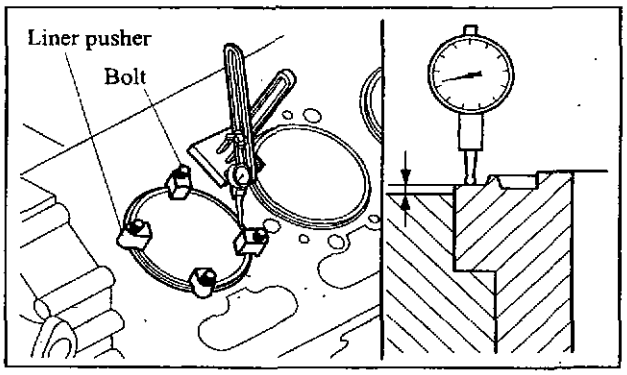
Note: When using cylinder head bolts to tighten the liner pushers, be sure to use the head bolt spacers.

Name of special tool	Part No.
Head bolt spacer	37598-09100

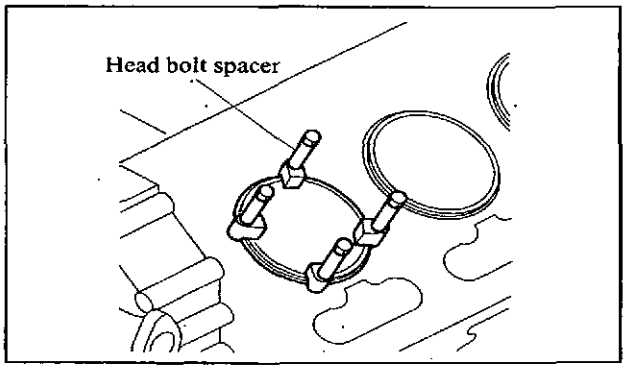
(3) Set up the dial gage at the top face of the crankcase and set the gage point to 0 (zero).

(4) Measure the protrusion at four top surface sections of the cylinder liner, and obtain the average value.

(5) If the average value is less than the assembly standard, insert a shim under the collar of the cylinder liner.



Measurement of cylinder liner collar protrusion (1)



Measurement of cylinder liner collar protrusion (2)

· When cylinder liner is to be replaced (See section (2.3))

(1) Remove the cylinder liner, and observe the cylinder liner contacting surface of the crankcase.

(2) If the cylinder liner contacts the crankcase only on one side, use the crankcase grinder to grinder the surface to keep the differences of depth in four directions A, B, C, and D within 0.05 mm [0.0020 in.].

Name of special tool	Part No.
Crankcase grinder	32591-04050

(3) Measure the crankcase counterbore depth. Since the top surface of the crankcase may be slightly distorted, use the projection plate.

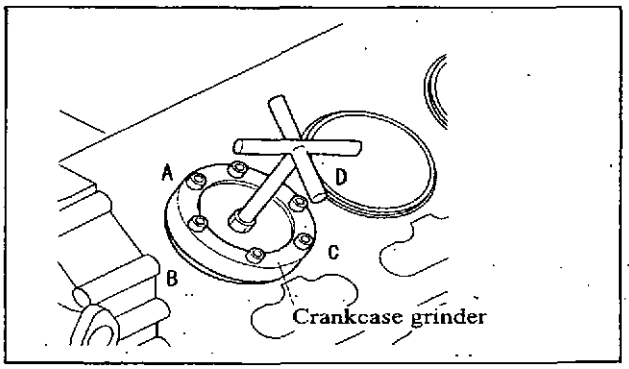
Name of special tool	Part No.
Projection plate	37598-09201

(4) Measure at locations A, B, C, and D, then obtain the average value.

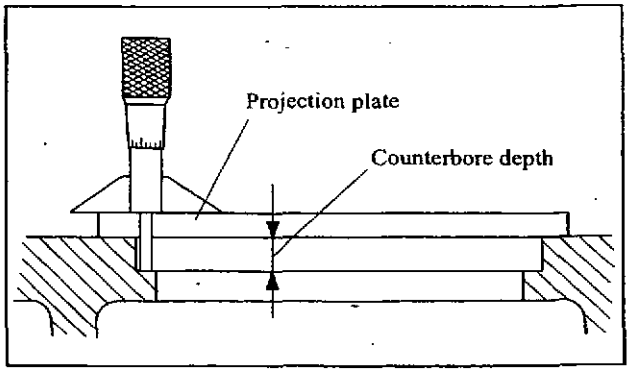
(5) Measure the thickness (standard: 15 mm [0.59 in.]) of the projection plate with a micrometer, and subtract the projection plate thickness from the measured crankcase counterbore depth to obtain the actual counterbore depth from the top surface of the crankcase.

Unit mm [in.]

	Standard
Crankcase counterbore depth	$15^{+0.05}_{0}$ [$0.59^{+0.0020}_{0}$]



Correction of crankcase counterbore depth



Measurement of crankcase counterbore depth

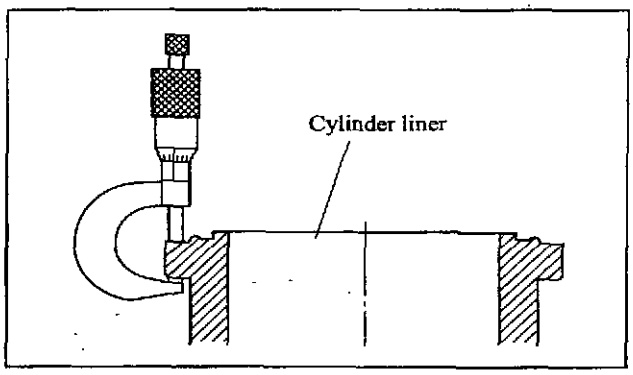
(6) Measure the thickness of the cylinder liner collar with a micrometer.

Unit mm [in.]

	Standard
Thickness of cylinder liner collar	$15^{+0.19}_{0.15}$ [$0.59^{+0.0075}_{+0.0059}$]

(7) Subtract the crankcase counterbore depth from the cylinder liner collar thickness.
This value is the cylinder liner collar protrusion.

(8) If the value is less than the standard, insert a shim under the collar of the cylinder liner collar.



Thickness of cylinder liner collar

• *Measurement of height of protrusion of cylinder liner collar*

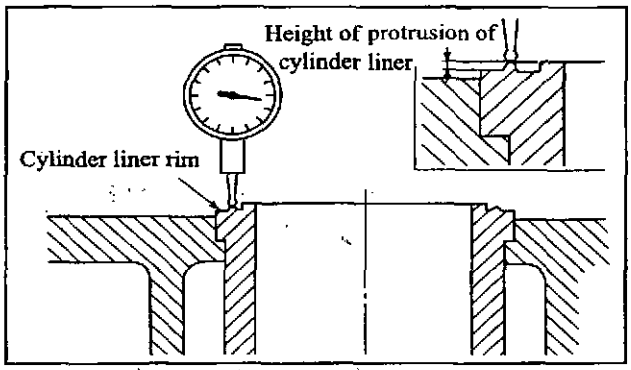
(1) Place a dial gage on the rim of the cylinder liner collar, and set the indicator to 0 (zero).

(2) Measure the cylinder liner step at four locations, and obtain the average value.

Unit mm [in.]

	Standard
Height of protrusion of cylinder liner	0.2±0.04 [0.008±0.002]

(3) If the average value is less than the standard or if the step has sectional chipping, replace the cylinder liner. (See section (2:3))



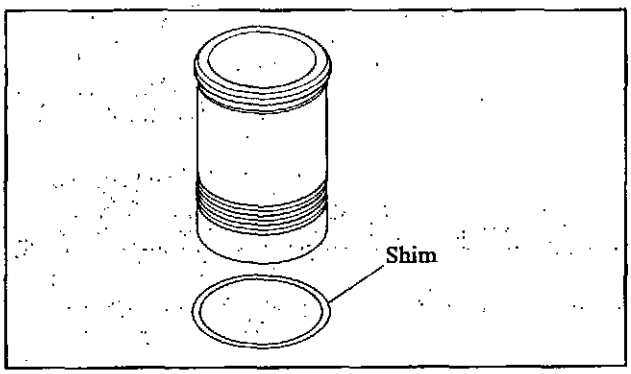
Measurement of height of protrusion of cylinder liner collar

• Insertion of cylinder liner shim

(1) Remove the cylinder liner, and insert a shim between the cylinder liner and crankcase.

Note: From the table below, select the appropriate shim thickness that achieves the largest protrusion within the standard range for cylinder liner collar protrusion.

Thickness of shim	Part No.
0.05 mm [0.0019 in.]	35C07-09600
0.10 mm [0.0039 in.]	35C07-09200
0.15 mm [0.0059 in.]	35C07-09700
0.20 mm [0.0079 in.]	35C07-09300
0.25 mm [0.0099 in.]	35C07-09800
0.30 mm [0.0118 in.]	35C07-09400
0.35 mm [0.0138 in.]	35C07-09900
0.40 mm [0.0157 in.]	35C07-09500

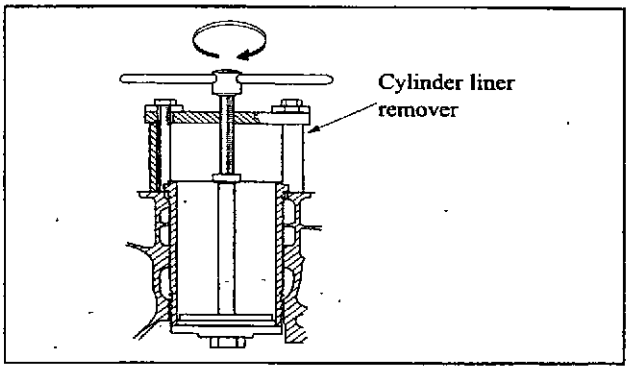


Insertion of cylinder liner shim

2.3 Replacement of Cylinder Liners

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

Name of special tool	Part No.
Cylinder liner remover	32591-04100

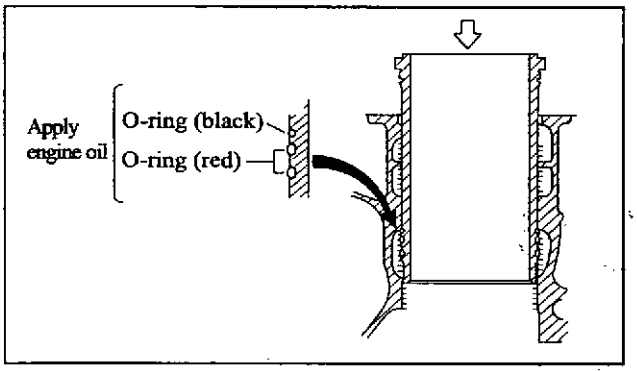


Removal of cylinder liner

(2) Attach O-rings to the new cylinder liner, and then slowly insert the cylinder liner into the bore of the crankcase.

⚠ CAUTION

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

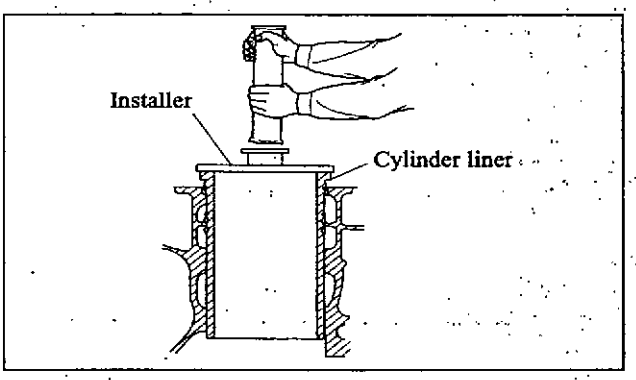


Installation of O-rings to cylinder liner

(3) Using the installer, lightly tap the new cylinder liner until the collar rests firmly on the crankcase. Then, tap several times to ensure proper seating.

Note: (a) After installing the cylinder liner, conduct a water-pressure leak test to check the cylinder liner sealing.

(b) Check the protrusion of the cylinder liner from the crankcase.



Installation of cylinder liner

2.4 Inspection of Piston Exterior

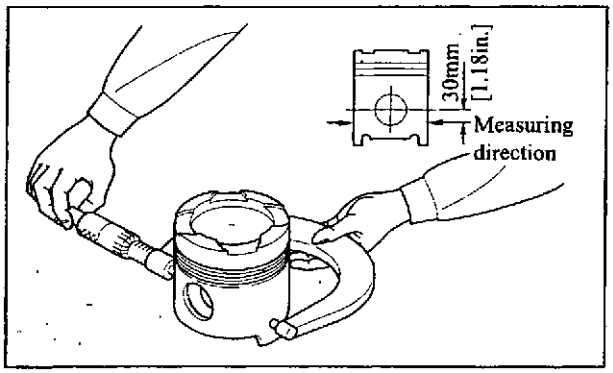
Check the combustion surfaces and pin bore surfaces, replace the piston if any defects are found.

2.5 Measurement of Piston Outside Diameter

(1) Using a micrometer, measure the diameter of each piston in a direction perpendicular to the piston pin.
If the limit is exceeded, replace the piston. When any of the pistons have to be replaced, select new pistons so that the weight difference in the engine is within the standard.

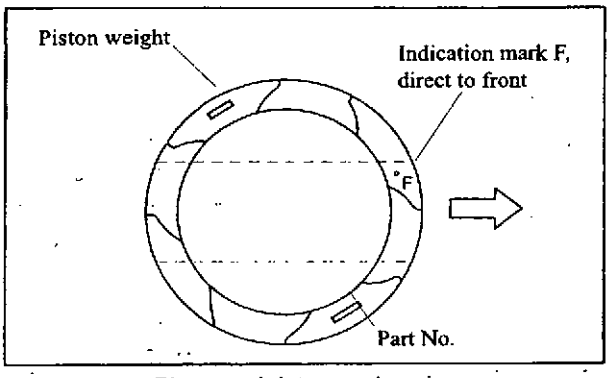
Unit mm [in.]

	Nominal value	Standard	Limit
Piston outside diameter	ϕ150 [5.906]	149.78 to 149.82 [5.897 to 5.898]	149.68 [5.893]
Weight difference	—	±30 g [±0.07 lb.] in one engine	



Measurement of piston outside diameter

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



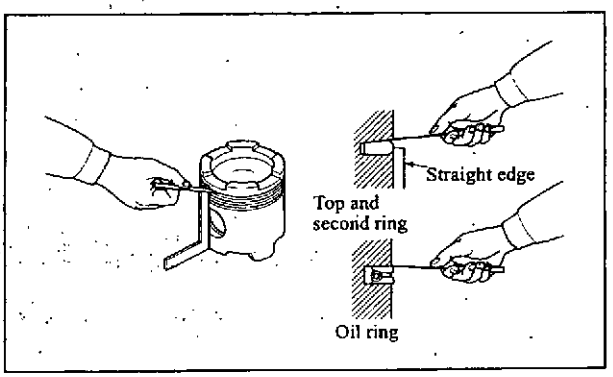
Piston weight stamp location

2.6 Inspection of Piston Ring Side Clearance

Put new piston rings into the ring grooves in the piston, and measure with the feeler gages.
To measure the clearance on the top and second rings, press in the ring with a straightedge until its face is flush with the piston.
If the limit is exceeded, replace with new parts.

⚠ CAUTION

Remove carbon, and inspect the side clearance all the way around the piston.



Measurement of piston ring side clearance

Unit mm [in.]

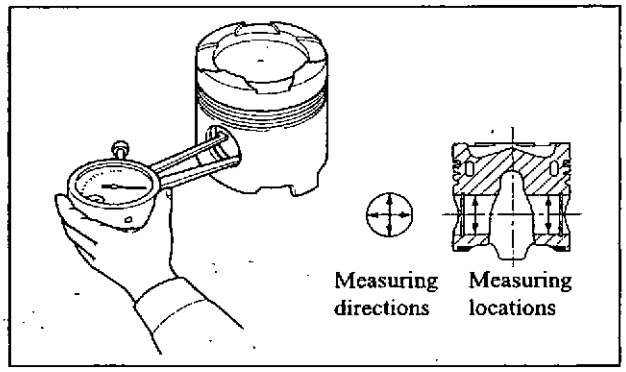
		Nominal value	Standard	Limit
Piston ring side clearance (with new rings)	Top	3.00 [0.118]	0.08 to 0.11 [0.003 to 0.004]	0.20 [0.008]
	Second	2.55 [0.1]	0.07 to 0.10 [0.0275 to 0.0039]	0.15 [0.006]
	Oil	5.00 [0.197]	0.05 to 0.09 [0.0197 to 0.0035]	0.15 [0.006]

2.7 Measurement of Piston Pin Bore Diameter

Using calipers or a cylinder gage, measure the piston pin bore diameter. If the limit is exceeded, replace the piston.

Unit mm [in.]

	Nominal value	Standard	Limit
Piston pin bore diameter	ϕ58 [2.283]	58.002 to 58.012 [2.2852 to 2.2856]	58.020 [2.29]



Measurement of piston ring end gap

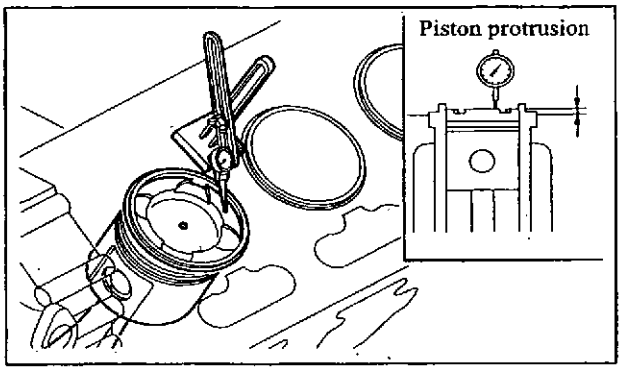
2.8 Measurement of Piston Protrusion

Measure the protrusion of each piston in the following method. If the measured value is not within the standard, inspect the clearance of the parts.

(1) Using a dial gage, bring the piston to the top dead center.

(2) Set the dial gage at the top of the crankcase, and set the gage indicator to 0 (zero).

(3) Measure the protrusion at four locations on the piston head, and obtain the average value. Subtract the piston protrusion from the thickness of the cylinder head gasket as installed to determine the clearance between the piston top and cylinder head.



Measurement of piston protrusion

Unit mm [in.]

	Standard
Piston protrusion	0.38 to 0.89 [0.015 to 0.035]
Thickness when tightened (cylinder head gasket)	1.77 to 1.83 [0.0697 to 0.0720]
Clearance between piston and cylinder head	0.88 to 1.45 [0.035 to 0.057]

⚠ CAUTION

Keep the piston protrusion within the standard range to maintain high engine performance and to prevent the valves from contacting the piston.

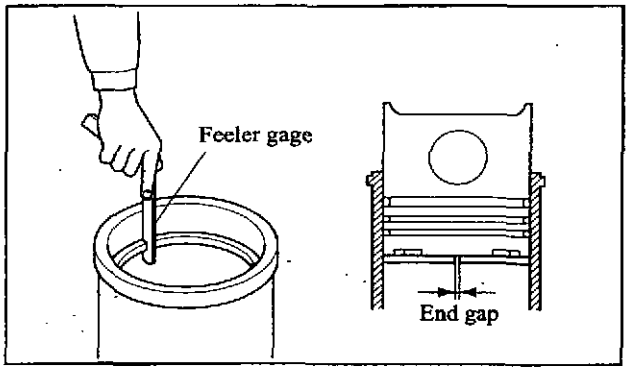
2.9 Measurement of Piston Ring End Gaps

Place the piston rings in a gage or new cylinder liner, and measure the gap of each ring with feeler gages. If the limit is exceeded, replace all the rings as a set.
Inside diameter of gage: 150±0 mm [5.906±0 in.]

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

Unit mm [in.]

		Standard	Limit
Piston ring end gap	Top	0.6 to 0.8 [0.024 to 0.03]	2.0 [0.078]
	Second	0.5 to 0.7 [0.0197 to 0.0275]	
	Oil	0.5 to 0.7 [0.0197 to 0.0275]	



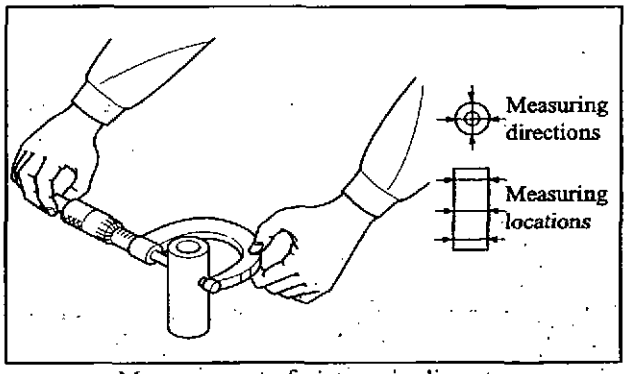
Measurement of piston ring end gap

2.10 Measurement of Piston Pin Diameter

Using a micrometer, measure the diameter of each piston. If the limit is exceeded, replace the pin.

Unit mm [in.]

	Nominal value	Standard	Limit
Piston pin diameter	ϕ58 [2.283]	57.987 to 58.000 [2.2847 to 2.2852]	57.970 [2.28]



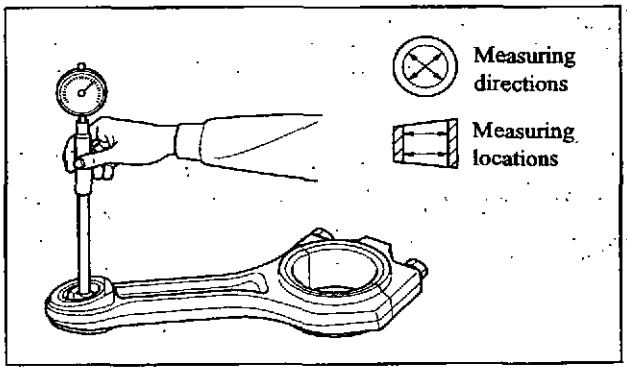
Measurement of piston pin diameter

2.11 Measurement of Connecting Rod Bushing Inside Diameter

Measure the inside diameter of each connecting rod bushing with feeler gages. If the limit is exceeded, replace the connecting rod bushing.

Unit mm [in.]

	Nominal value	Standard	Limit
Connecting rod bushing inside diameter	ϕ58 [2.283]	58.02 to 58.04 [2.2843 to 2.2868]	58.070 [2.29]



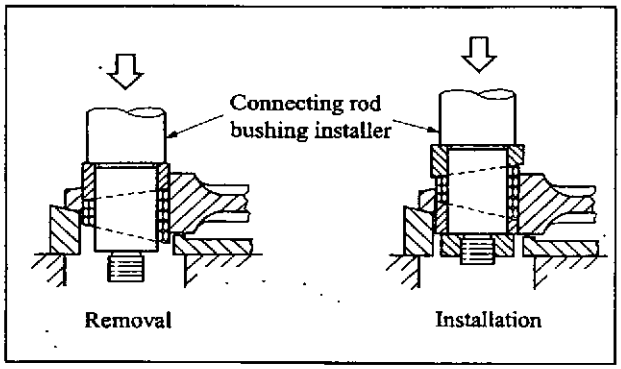
Measurement of connecting rod bushing inside diameter

2.12 Replacement of Connecting Rod Bushings

(1) Use the connecting rod bushing installer as shown in the diagram to replace the connecting rod bushing.

Name of special tool	Part No.
Connecting rod bushing installer	32591-18010

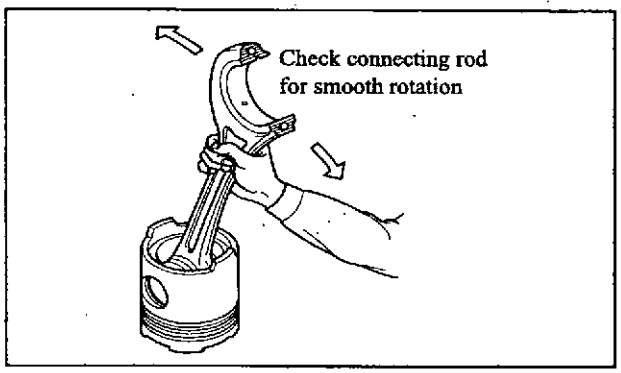
(2) Align the oil holes of the bushing and connecting rod.



Replacement of connecting rod bushing

(3) After installing the bushing, ream its inside diameter to $\phi 58^{+0.040}_{+0.020}$ mm [$2.283^{+0.0016}_{+0.0008}$ in.] 0.4 Ra and its parallelism to the big-end bearing to 0.05 mm [0.002 in.].

(4) Insert the piston pin, and make sure the pin rotates freely without rattling.

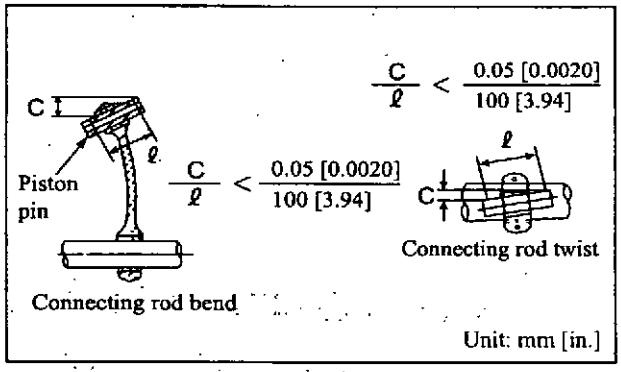


Checking connecting rod bushing

2.13 Inspection of Connecting Rod Bend and Twist

(1) Measure C and ℓ as shown in the diagram, if measurement C is more than 0.05 mm [0.0020 in.] per 100 mm [3.94 in.] of ℓ, straighten the connecting rod with a press.

Note: Before inspecting bend, install the cap to the connecting rod, then tighten the cap bolts to the specified torque.

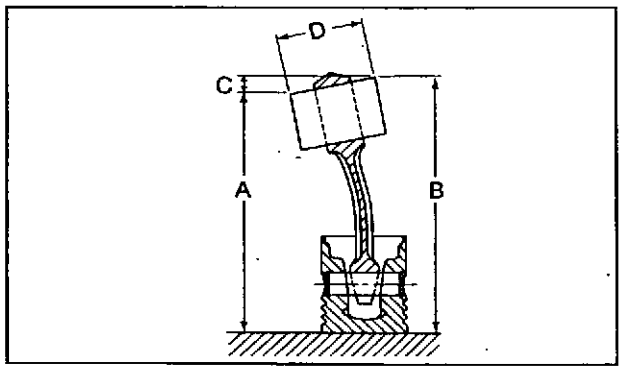


Inspection of connecting rod bend and twist

(2) To inspect the connecting rod assembled with the piston, place the piston on a surface plate, insert a round bar having the same diameter as the crankpin into the big-end bore, then measure the height of the bar with a dial gage.

Unit mm [in.]

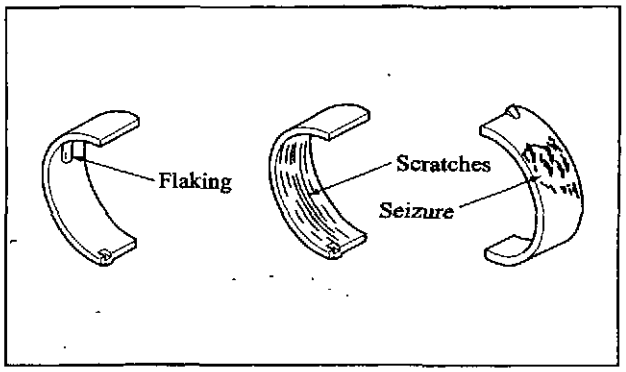
	Standard
Connecting rod bend and twist (C/D)	0.05/100 [0.020/3.94] or less



Measurement of connecting rod bend (using dial gage)

2.14 Inspection of Connecting Rod Bearings

Inspect each connecting rod bearing, if defects such as dents and scratches are found, replace the bearing.



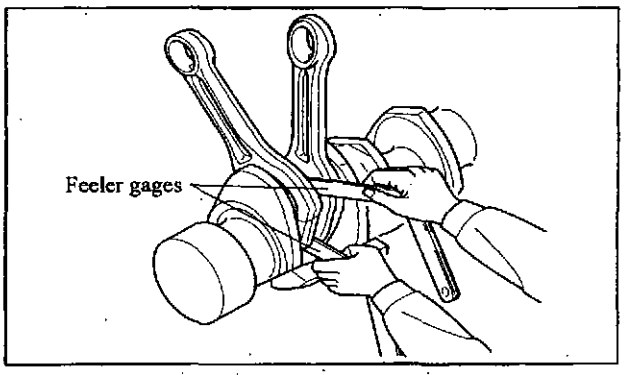
Inspection of connecting rod bearing

2.15 Measurement of Connecting Rod End Play

Install the connecting rod to its mating crankpin, and tighten the cap bolts to the specified torque, using feeler gages, measure the end play. If the limit is exceeded, replace the connecting rod.

Unit mm [in.]

	Nominal value	Standard	Limit
Connecting rod end play (rod and crankpin widths)	54 [2.13] ×2	0.4 to 0.6 [0.016 to 0.024]	0.8 [0.03]



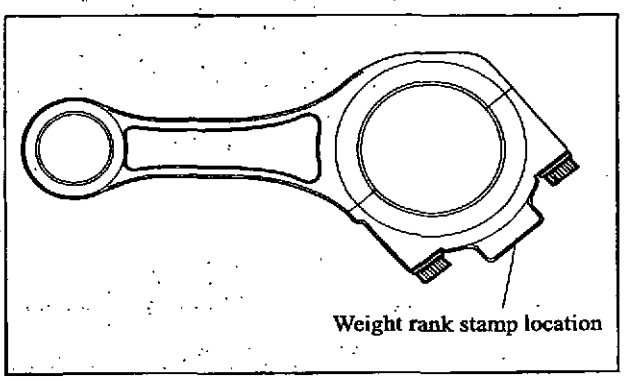
Measurement of connecting rod end play

2.16 Weight Difference of Connecting Rods in One Engine

When replacing connecting rods, install new connecting rods of the same weight rank.

Weight rank table

Weight rank	Weight (g [oz.])
A	7100 [250]
B	7200 [254]
C	7300 [257.5]
D	7400 [261]
E	7500 [265]
F	7600 [268]
G	7700 [271]
H	7800 [275]



Weight rank stamp location on connecting rod

2.17 Measurement of Connecting Rod Big-End Bore Diameter and Circularity

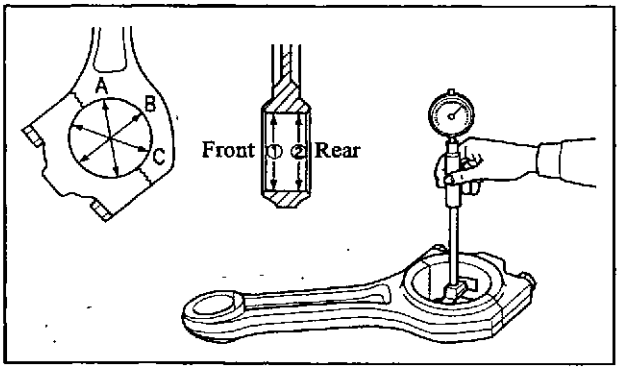
Measure the connecting rod big-end bore diameter in directions A, B, and C and at front and rear positions ① and ②, as shown in the diagram.

To obtain the circularity value, subtract the smallest measured value among A, B and C from the largest measured value.

If the limit is exceeded, replace the connecting rod.

Unit mm [in.]

	Nominal value	Standard	Limit	Roundness limit
Connecting rod big-end bore diameter	ϕ110 [4.3307]	110.000 to 110.022 [4.3307 to 5.15845]	110.047 [4.3326]	0.1 [0.004]



Measurement of connecting rod big-end bore diameter

2.18 Inspection of Connecting Rod Big-End Bore Serration

Inspect the serration on each connecting rod big-end by conducting a Magnaflux (magnetic particle) test, if cracking or damage is found, replace the connecting rod.

2.19 Measurement of Connecting Rod Bearing Thickness

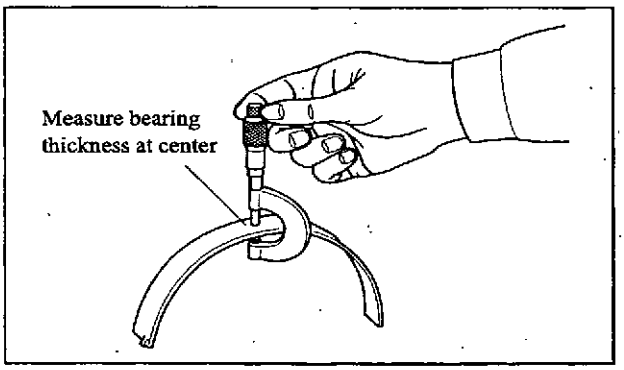
Using a micrometer (ball-point type), measure the thickness at the center of each bearing.

If the limit is exceeded, replace both upper and lower bearings as a set.

Unit mm [in.]

		Nominal value	Standard	Limit
Connecting rod bearing thickness	STD	3.000 [0.118]	2.987 to 3.000 [0.1176 to 0.118]	2.950 [0.116]
	-0.25 [-0.01]	3.125 [0.123]	3.112 to 3.125 [0.1225 to 0.123]	3.075 [0.121]
	-0.50 [-0.02]	3.250 [0.128]	3.237 to 3.250 [0.127 to 0.128]	3.200 [0.126]
	-0.75 [-0.03]	3.375 [0.133]	3.362 to 3.375 [0.132 to 0.133]	3.325 [0.131]
	-1.00 [-0.04]	3.500 [0.138]	3.487 to 3.500 [0.137 to 0.138]	3.450 [0.136]

Note: Four undersizes are available: -0.25 [-0.01 in.], -0.50 [-0.02 in.], -075 [-0.03 in.] and -1.00 mm [-0.04 in.].



Measurement of connecting rod bearing thickness

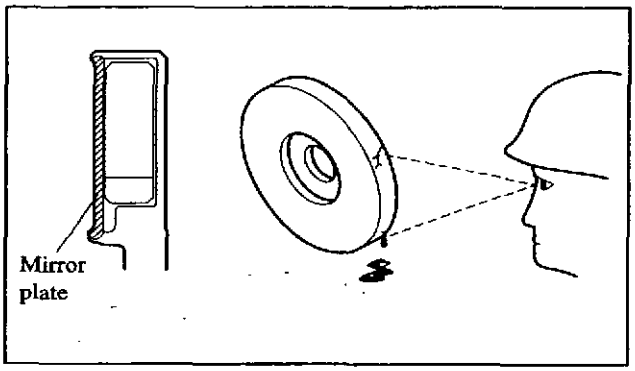
3. Damper and Front Gears

3.1 Inspection of Damper

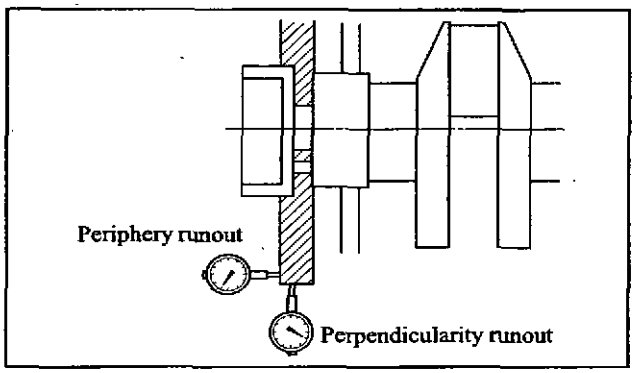
Check the damper for cracks, swelling and cracking in the mirror plate, silicone oil leakage, discoloration due to excessive heating, and flaking.
Replace them with new parts after 8000 service hours, even when no defect is observed.
Measure the perpendicularity runout and periphery runout with a dial gage, if the measured values exceed the limits, replace the damper.

Unit mm [in.]

	Standard	Limit	Remarks
Perpendicularity runout	0.5 [0.0197] or less	1.5 [0.0591]	Replace after 8000 service hours.
Periphery runout	0.5 [0.0197] or less	1.5 [0.0591]	



Inspection of damper



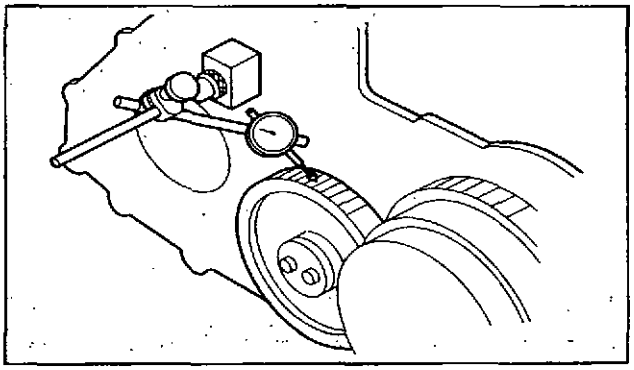
Measurement of damper periphery runout

3.2 Measurement of Gear Backlash

Set a dial gage 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 gage is not available, measure the backlash by inserting feeler gages between the teeth of the gear. If the limit is exceeded, replace the gear.

Unit mm [in.]

	Standard	Limit
Backlash	0.12 to 0.18 [0.0047 to 0.0071]	0.50 [0.0197]



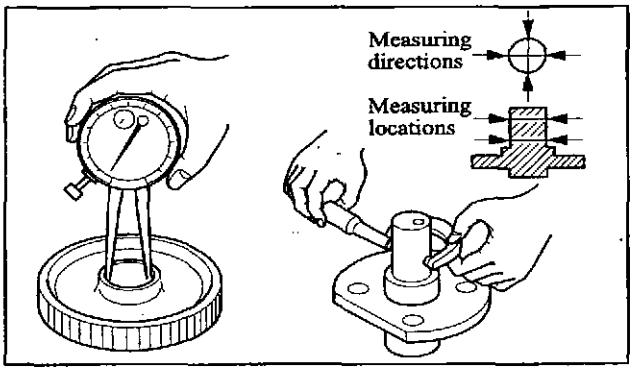
Measurement of gear backlash

3.3 Measurement of Idler Bushing Inside Diameter and Idler Shaft Diameter

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

Unit mm [in.]

	Nominal value	Standard	Limit
Idler bushing inside diameter	ϕ50 [1.97]	50.000 to 50.025 [1.96850 to 1.96948]	50.060 [1.97086]
Idler shaft diameter	ϕ50 [1.97]	49.950 to 49.975 [1.96653 to 1.96752]	49.900 [1.96456]



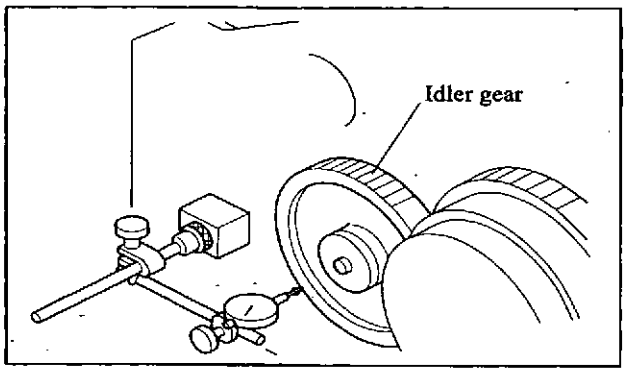
Measurement of idler bushing inside diameter and idler shaft diameter

3.4 Measurement of Idler Gear End Play

Using feeler gages or a dial gage, measure the idler gear end play, if the limit is exceeded, replace the thrust plate for the idler gear, or the idler shaft for the fan drive idler gear.

Unit mm [in.]

	Standard	Limit
Idler gear end play	0.3 to 0.5 [0.012 to 0.020]	0.7 [0.028]



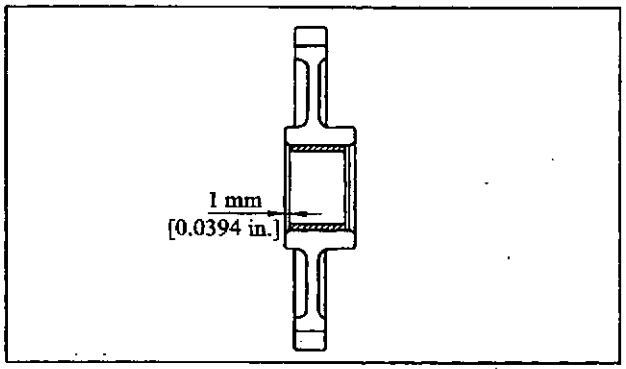
Measurement of idler gear end play

3.5 Replacement of Idler Bushings

(1) To replace the bushing, use the idler bushing puller.

Name of special tool	Part No.
Idler bushing puller	32591-02500

(2) Press-fit the bushing into the gear until the end face of the bushing is 1 mm [0.0394 in.] recessed from the end face of the gear boss. After installing the bushing, make sure the bushing inside diameter is within the standard. If it is less than the standard, ream the bushing to achieve the inside diameter of $\phi 50^{+0.025}_{0}$ mm [$1.97^{+0.00098}_{0}$ in.] 0.4 Ra.



Replacement of idler bushing

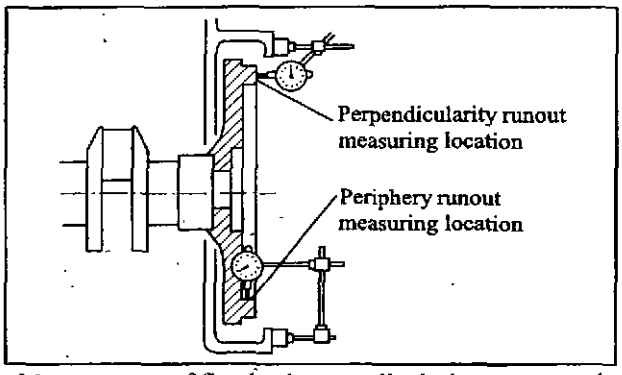
4. Flywheel, Timing Gears and Camshafts

4.1 Measurement of Flywheel Perpendicularity Runout and Periphery Runout

Measure the runouts of the flywheel in the installed condition. If the runouts exceed the standard, check for loose bolts and adhesion of foreign particles on the flywheel mounting face.

Unit mm [in.]

	Standard
Perpendicularity runout	0.28 [0.011] or less
Periphery runout	0.13 [0.005] or less



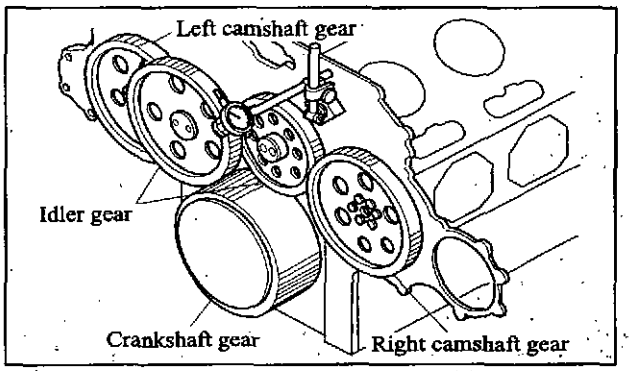
Measurement of flywheel perpendicularity runout and periphery runout

4.2 Measurement of Timing Gear Backlash

Set a dial gage 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 gage is not available, measure the backlash by inserting feeler gages between the teeth of the gear. If the limit is exceeded, replace the gear.

Unit mm [in.]

Backlash inspection point	Standard	Limit
Right side camshaft gear to idler gear	0.11 to 0.25 [0.0043 to 0.009]	0.50 [0.0197]
Idler gear to idler gear	0.12 to 0.22 [0.0047 to 0.0086]	0.50 [0.0197]
Crankshaft gear to idler gear	0.11 to 0.26 [0.0043 to 0.0102]	0.50 [0.0197]
Left side camshaft gear to idler gear	0.10 to 0.24 [0.0039 to 0.0095]	0.50 [0.0197]



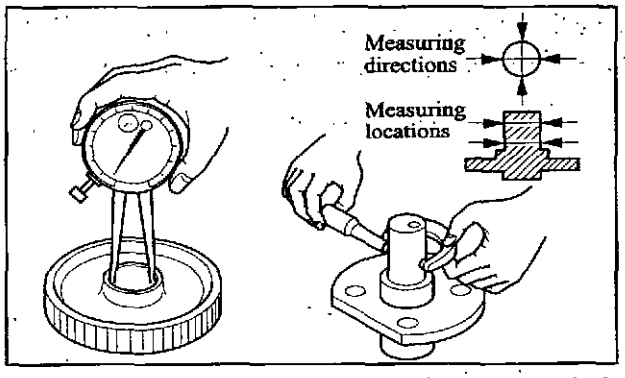
Measurement of timing gear backlash

4.3 Measurement of Idler Bushing Inside Diameter and Shaft Diameter

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

Unit mm [in.]

	Nominal value	Standard	Limit
Idler bushing inside diameter	ϕ50 [1.97]	50.000 to 50.025 [1.96850 to 1.96948]	50.060 [1.97086]
Idler shaft diameter	ϕ50 [1.97]	49.950 to 49.975 [1.96653 to 1.96752]	49.900 [1.96456]



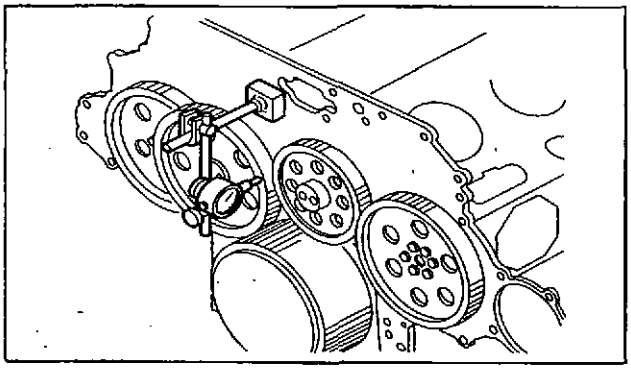
Measurement of idler bushing inside diameter and shaft diameter

4.4 Measurement of Idler Gear End Play

Using feeler gages or a dial gage, measure the idler gear end play. If the limit is exceeded, replace the thrust collar.

Unit mm [in.]

	Standard	Limit
Idler gear end play	0.3 to 0.5 [0.012 to 0.020]	0.7 [0.028]



Measurement of idler gear end play

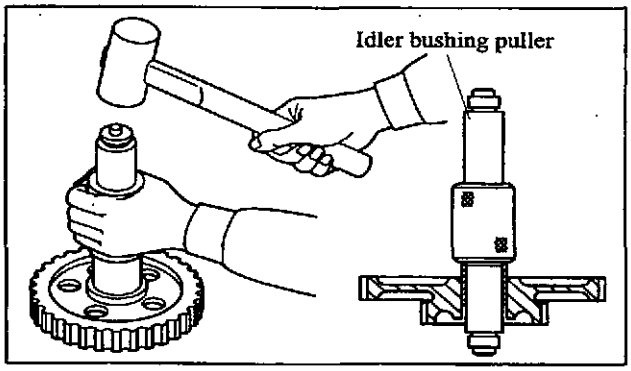
4.5 Replacement of Idler Bushings

(1) To replace the bushing, use the idler bushing puller.

Name of special tool	Part No.
Idler bushing puller	32591-02500

(2) Press-fit the bushing into the gear until the end face of the bushing is 1 mm [0.0394 in.] recessed from the end face of the gear boss.

(3) After installing the bushing, make sure the bushing inside diameter is within the standard. If it is less than the standard, ream the bushing to achieve the inside diameter of $\phi\ 50^{+0.025}_{0}$ mm [$1.97^{+0.00098}_{0}$ in.] 0.4 Ra.



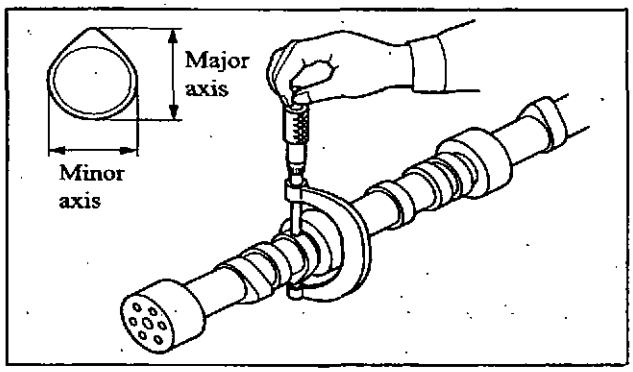
Replacement of idler bushing

4.6 Measurement of Cam Lift

Using a micrometer, measure the major axis and minor axis of each cam, if the limit is exceeded, replace the camshaft.

Unit mm [in.]

		Standard	Limit
Cam lift (major axis - minor axis)	Inlet	14.525 to 14.625 [0.572 to 0.576]	13.78 [0.543]
	Exhaust	9.425 to 9.525 [0.371 to 0.375]	8.68 [0.342]



Measurement of cam lift

4.7 Measurement of Camshaft Deflection

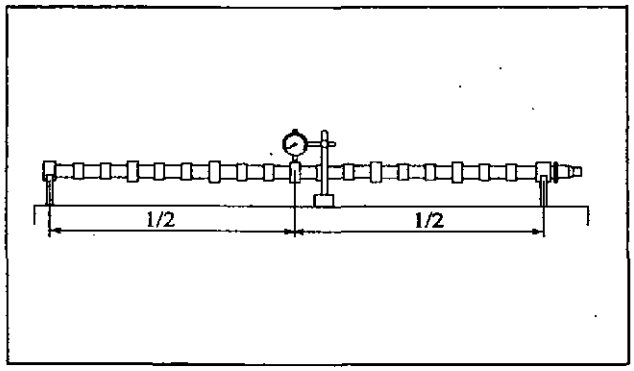
Measure the camshaft deflection, if the limit is exceeded, correct with a press, or replace the camshaft.

⚠ CAUTION

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

Unit mm [in.]

	Standard	Limit
Camshaft deflection (1/2 value of runout measured at center journal when camshaft is supported at both end journals)	0.05 [0.0020] or less	0.08 [0.0031]



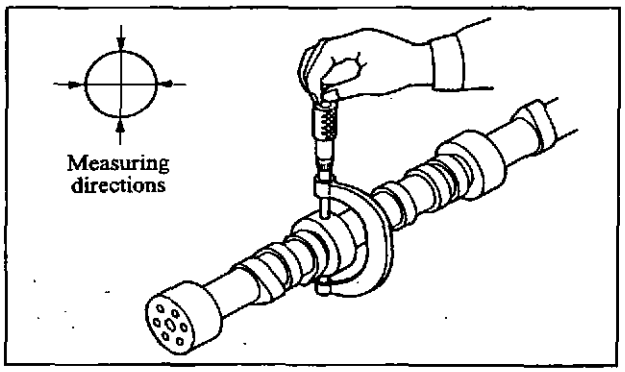
Measurement of camshaft deflection

4.8 Measurement of Camshaft Journal Diameter

Using a micrometer, measure the diameter of each journal in two directions at right angle to each other, if the limit is exceeded, replace the camshaft.

Unit mm [in.]

	Nominal value	Standard	Limit
Camshaft journal diameter	ϕ100 [3.94]	99.92 to 99.94 [3.937 to 3.938]	99.86 [3.934]



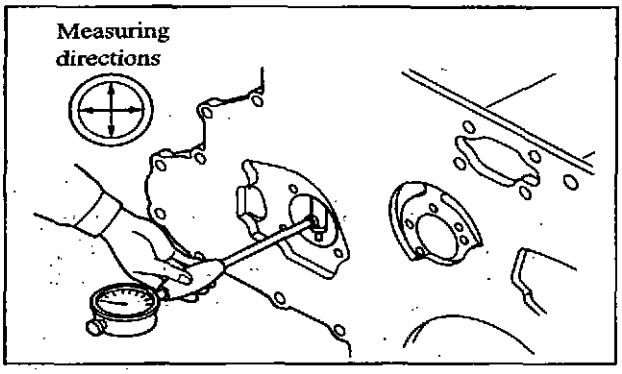
Measurement of camshaft journal diameter

4.9 Measurement of Camshaft Bushing Inside Diameter

With the camshaft bushings installed in the crankcase, measure the inside diameters with a cylinder gage, if the limit is exceeded, replace the bushing.

Unit mm [in.]

	Nominal value	Standard	Limit
Camshaft bushing inside diameter	ϕ100 [3.94]	100.000 to 100.115 [3.94 to 3.945]	100.160 [3.946]



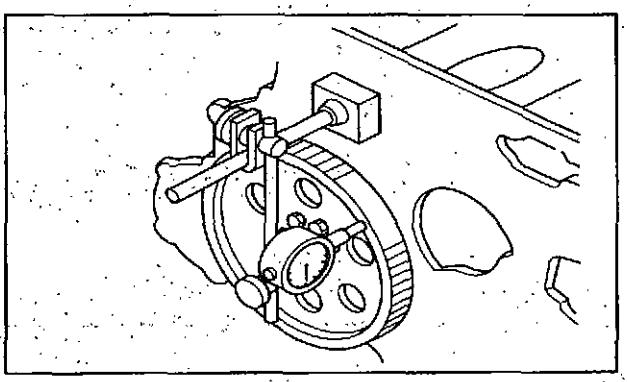
Measurement of camshaft bushing inside diameter

4.10 Measurement of Camshaft End Play

With the gear installed to the camshaft, measure the end play with a dial gage, if the limit is exceeded, replace the thrust plate.

Unit mm [in.]

	Standard	Limit
Camshaft end play	0.2 to 0.4 [0.008 to 0.016]	0.55 [0.022]



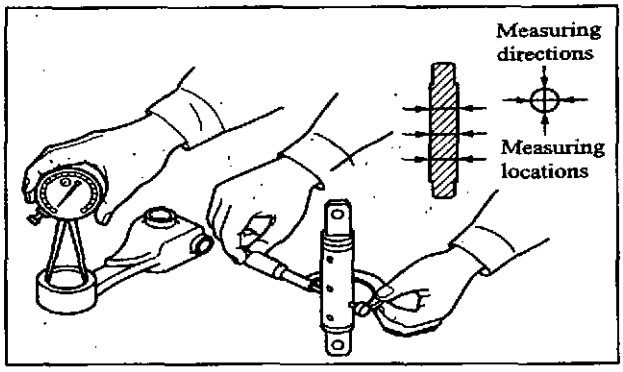
Measurement of camshaft end play

4.11 Measurement of Follower Bushing Inside Diameter and Shaft Diameter

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

Unit mm [in.]

	Nominal value	Standard	Limit
Follower bushing inside diameter	ϕ30 [1.182]	30.000 to 30.075 [1.182 to 1.184]	30.125 [1.187]
Cam follower shaft diameter	ϕ30 [1.182]	29.959 to 29.980 [1.180 to 1.181]	29.930 [1.179]

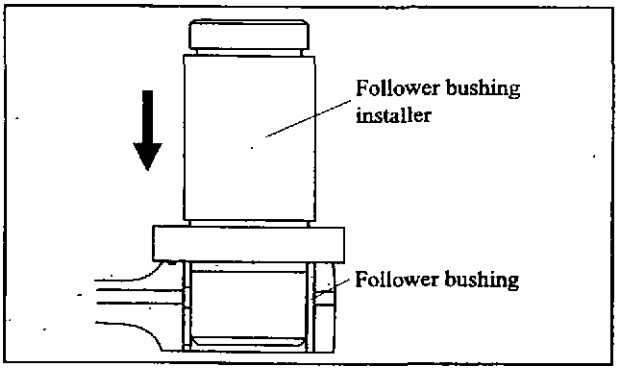


Measurement of follower bushing inside diameter and shaft diameter

4.12 Replacement of Follower Bushings

(1) Using the follower bushing installer, replace the bushing.

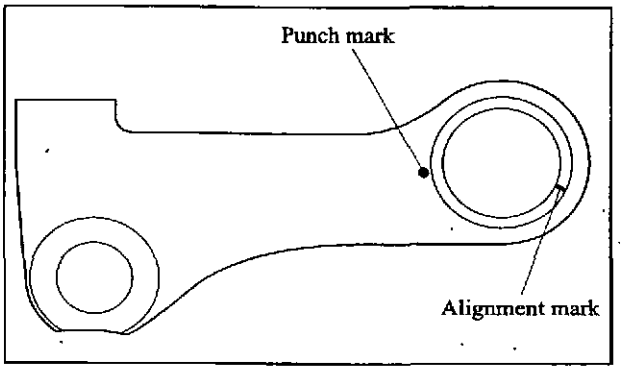
Name of special tool	Part No.
Follower bushing installer	35C91-01700



Replacement of follower bushing

(2) Install the bushing so that the punch mark (oil hole alignment mark for bushing) on the follower may align with the bushing notch at the opposite side.

(3) After installing the bushing, make sure that its inside diameter is within the standard. If it is less than the assembly standard, ream the bushing to its inside diameter of $\phi 30^{+0.075}_{0}$ mm [$1.19^{+0.003}_{0}$ in.] 1.6 Ra.



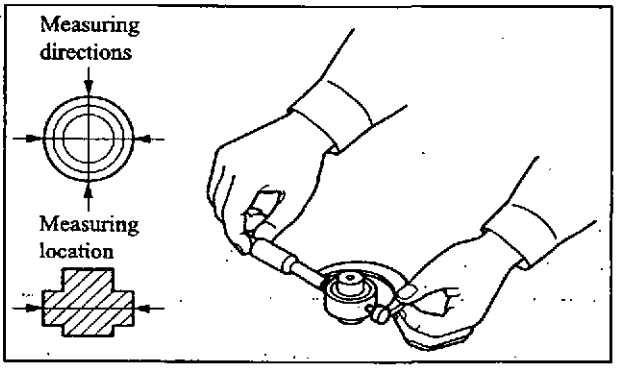
Installation location of follower bushing

4.13 Measurement of Tappet Roller Diameter

Measure the outside diameter of the tappet roller and if the diameter exceeds the limit, replace it with a new one.

Unit mm [in.]

	Nominal value	Standard	Limit
Tappet roller diameter	ϕ41 [1.6142]	40.995 to 41.050 [1.614 to 1.617]	40.985 [1.6148]

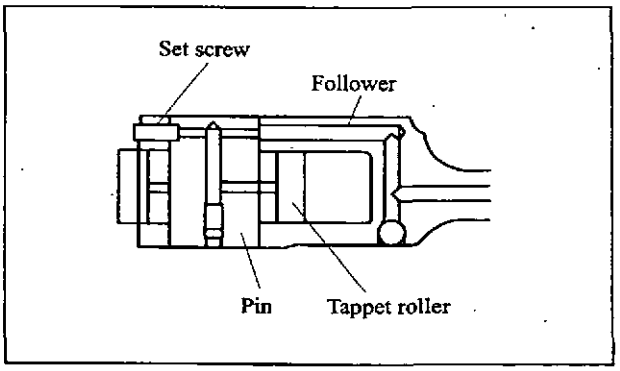


Measurement of tappet roller diameter

4.14 Replacement of Tappet Roller

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

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



Replacement of tappet roller

5. Crankcase, Crankshaft and Main Bearings

5.1 Measurement of Crankshaft, Crankpin and Journal Diameters

(1) Using a micrometer, measure the crankpin and journal diameters. If the limit is exceeded, grind them according to the next undersize bearing (-0.25, -0.50, -0,75 or -1.00 mm) [-0.01, -0.02, -0.03, -0.04 in.].

(2) Based on the outside diameter measurements, determine the circularity and cylindricity.

(3) If the -1.00 mm [-0.04 in.] undersize journals and crankpins exceed the limit, replace the crankshaft.

Unit mm [in.]

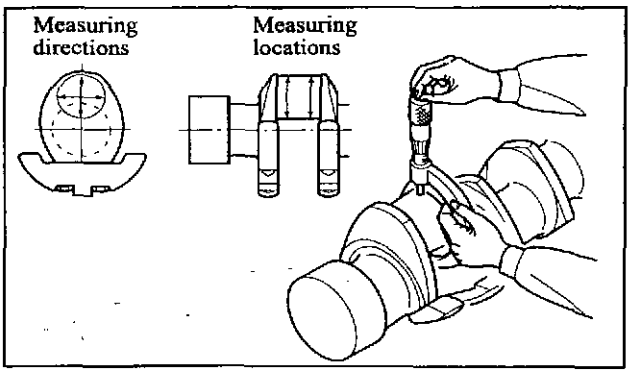
			Nominal value	Standard	Limit
Crankpin diameter			ϕ104 [4.098]	103.900 to 103.920 [4.0905 to 4.0913]	103.960 [4.0929]
Crank journal diameter			ϕ140 [5.516]	139.930 to 139.950 [5.5091 to 5.5098]	139.970 [5.5106]
Pin and journal	Parallelism			0.01 [0.0004] or less	0.03 [0.00118]
	Roundness			Diameter difference of 0.01 [0.0004] or less	0.03 [0.00118]
	Cylindricity			Diameter difference of 0.02 [0.0008] or less	0.03 [0.00118]
	Fillet radius	Pin	7 [0.276]	6.8 to 7.0 [0.268 to 0.276]	
		Journal	7 [0.276]	6.8 to 7.0 [0.268 to 0.276]	
	Hardness			Hv>620	

5.2 Grinding of Crankshaft

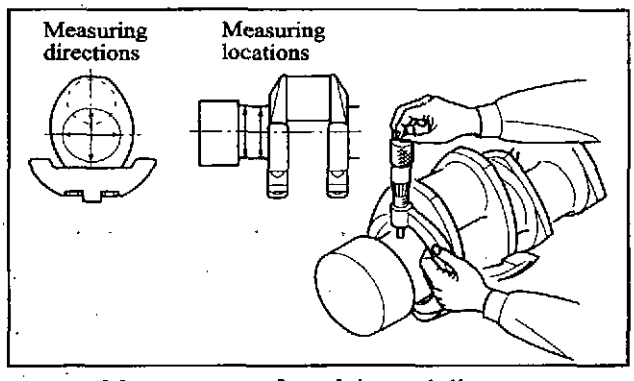
Refinish the crankshaft according to the dimensions of the undersize main bearing and connecting rod bearing.

When grinding the crankshaft, do not change the fillet radius or width and if the surface hardness is suspected to be significantly, re-harden the crankshaft, and conduct a Magnaflux (magnetic particle) test.

The crankpins and journals should have a hardness of 620 or more (Vickers hardness number). After grinding, make sure the finishing accuracy of the crankpins and journals is 0.2 Ra.



Measurement of crankpin diameter



Measurement of crank journal diameter

Grinding dimensions for undersize crankshaft Unit mm [in.]

	Under-size	Finishing dimension	Circu-larity	Cylin-dricity
Crankpin diameter	0.25 [0.01]	103.65 to 103.67 [4.083 to 4.084]	Diame-ter differ-ence of 0.01 [0.0004] or less	Diame-ter differ-ence of 0.02 [0.0008] or less
	0.50 [0.02]	103.40 to 103.42 [4.073 to 4.074]		
	0.75 [0.03]	103.15 to 103.17 [4.0641 to 4.0648]		
	1.00 [0.04]	102.90 to 102.92 [4.054 to 4.055]		
Journal diameter	0.25 [0.01]	139.68 to 139.70 [5.503 to 5.504]		
	0.50 [0.02]	139.43 to 139.45 [5.493 to 5.494]		
	0.75 [0.03]	139.18 to 139.20 [5.483 to 5.484]		
	1.00 [0.04]	138.93 to 138.95 [5.473 to 5.450]		

5.3 Crankshaft End Play

(1) If the crankshaft end play (clearance between thrust bearing journal width of crankshaft and width of thrust caps installed to bearing caps) exceeds the standard, replace the thrust plates with new parts.

(2) If the end play still exceeds the standard after new thrust plates are installed, use oversize thrust plates. There are three oversizes: +0.25, +0.50 and +0.75 mm [+0.01, +0.02 and +0.03 in.].
Generally, the rear journal wears quicker than the front journals, therefore, replacement of the rear thrust plates will be sufficient in most cases.

Unit mm [in.]

	Standard	Limit
Crankshaft end play	0.20 to 0.40 [0.0079 to 0.0157]	0.50 [0.0197]

Crankshaft journal grinding dimensions for oversize thrust plates

Unit mm [in.]

	Oversizes for journals or thrust plates	Oversizes for both journals and thrust plates	Tolerance
+0.25 [0.01] O. S.	58.25 [2.295]	58.50 [2.305]	
+0.50 [0.02] O. S.	58.50 [2.305]	59.00 [2.325]	$^{+0.03}_{0}$ [$^{+0.0012}_{0}$]
+0.75 [0.03] O. S.	58.75 [2.315]	59.50 [2.344]	

5.4 Measurement of Crankshaft Deflection

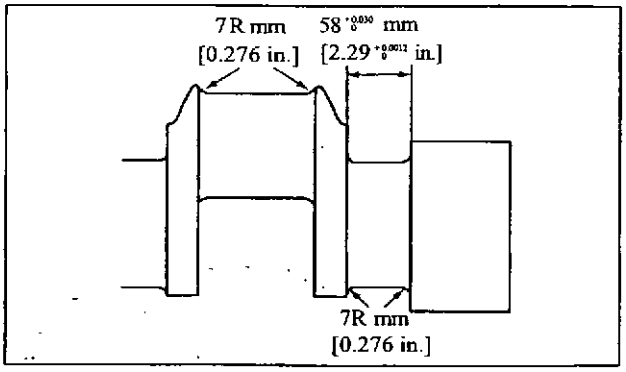
Support the crankshaft on its journals in V-blocks, then measure the face runout at the center journal with a dial gage. Compare the amount of runout with the standard and if the runout is small, correct by grinding. If the runout is large straighten with a press. If it exceeds the limit, replace the crankshaft.

Unit mm [in.]

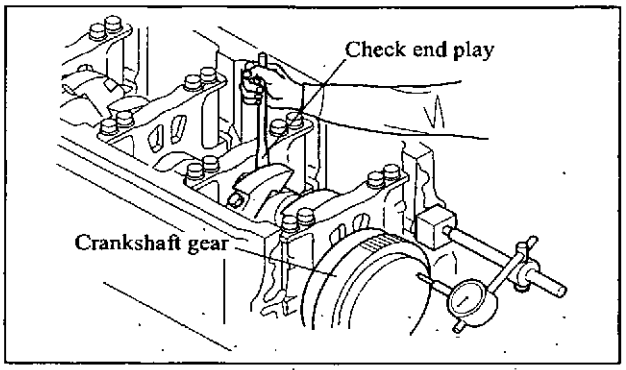
	Standard	Limit
Crankshaft deflection (1/2 value of runout measured at center journal when crankshaft is supported at both end journals)	0.04 [0.0016] or less	0.10 [0.0039]

5.5 Replacement of Oil Seal Slingers

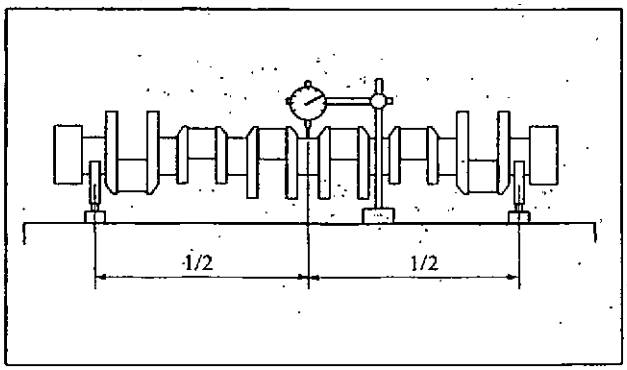
If the slingers are dented, scratched or distorted enough to cause oil leaks, replace according to the following directions.



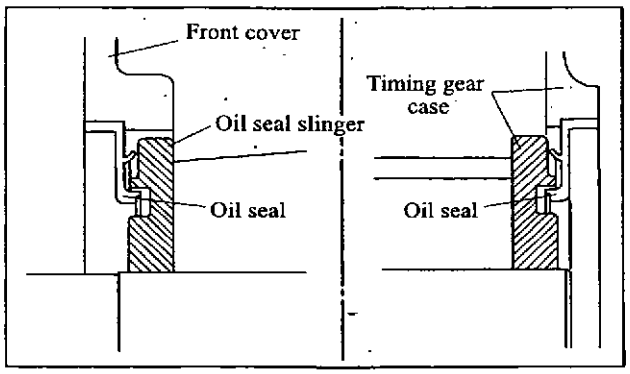
Measurement of thrust bearing journal length



Measurement of crankshaft end play

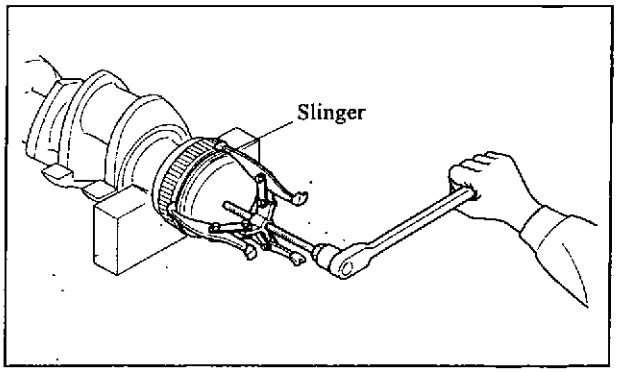


Measurement of crankshaft deflection



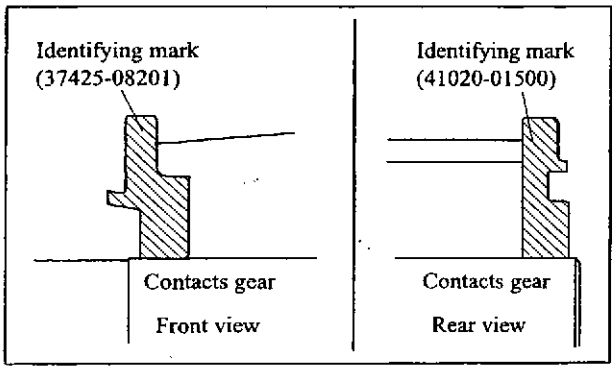
Replacement of oil seal slinger

(1) Removal of slinger
Using a gear puller, remove the slinger from the crankshaft.



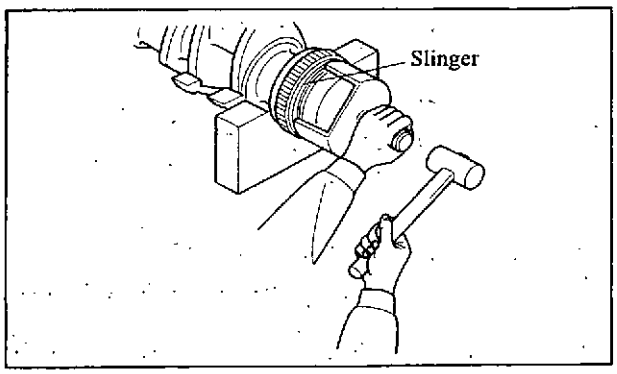
Removal of slinger

(2) Installation of slinger
Identify the front slinger and the rear slinger, and pay attention to the installation directions.



Installation of slinger (1)

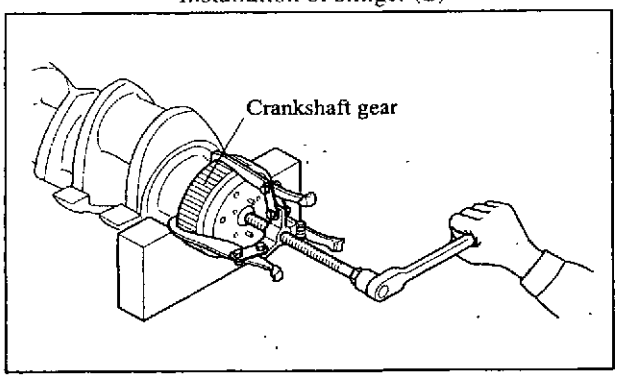
Heat the slinger to a temperature of 110 °C [230 °F] or higher, and install the slinger with the slinger installer until it firmly contacts the gear.
If the slinger stops before it contacts the gear, tap the center or shoulder of the installer with a copper hammer.



Installation of slinger (2)

5.6 Replacement of Crankshaft Gear

(1) Removal of gear
Using the gear puller, remove the gear from the crankshaft.
Do not remove the gear by hitting it with a hammer.



Removal of crankshaft gear

(2) Installation of crankshaft gear

Before installing the crankshaft gear, measure the crankshaft diameter and the inside diameter of the crankshaft gear, and make sure the interference confirms with the standard (front side: 0.106 to 0.171 mm [0.00417 to 0.00673 in.], rear side: 0.140 to 0.209 mm [0.00551 to 0.00823 in.])

Heat the gear to a temperature of 180 to 200 °C [356 to 392 °F].

(Do not heat the gear to a temperature above 200 °C [392 °F].)

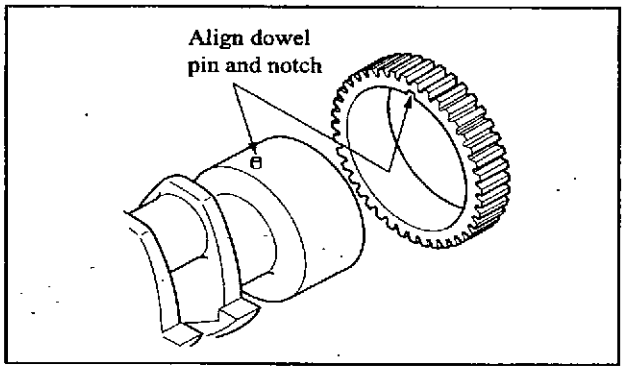
When installing the rear crankshaft gear, make sure the crankshaft dowel pin is aligned with the notch in the gear, then tap the gear face with a copper hammer to install.

There is no positioning notch in the front crankshaft gear, and it can be installed in any rotational position.

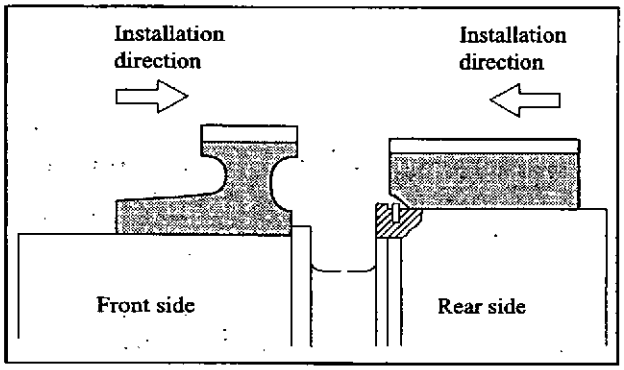
⚠ CAUTION

(a) Install the gear to the crankshaft until it contacts the collar.

(b) Make sure not to mistake the direction of gear during installation.



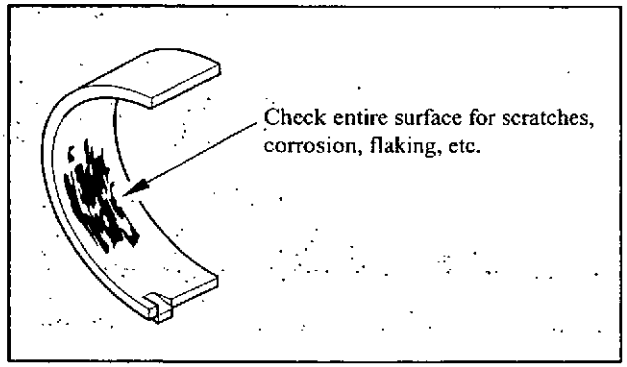
Installation of crankshaft gear



Crankshaft gear installation directions

5.7 Inspection of Main Bearing Surfaces

Inspect each bearing surface for abnormal contact marks, scratches by foreign particles and other abnormalities. Also check for sighs of poor seating in the bore of the crankcase, main bearing cap or bearing back metal.



Inspection of main bearing surface

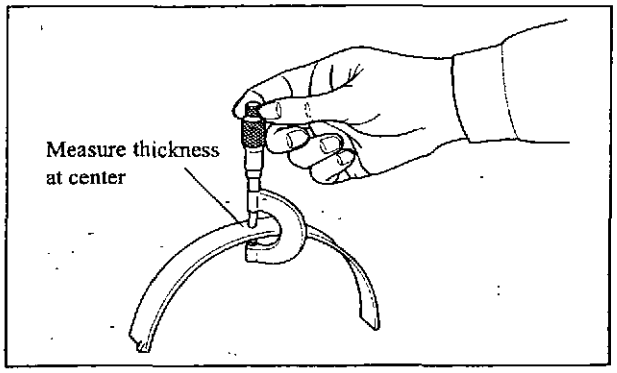
5.8 Measurement of Main Bearing Thickness

Use a ball point micrometer to measure the center of each bearing shell.
If the limit is exceeded, replace the upper and lower bearings as a set.

Unit mm [in.]

		Nominal value	Standard	Limit
Main bearing thickness at center	STD	3.500 [0.138]	3.467 to 3.480 [0.1366 to 0.1371]	3.425 [0.135]
	-0.25 [-0.01]	3.625 [0.143]	3.592 to 3.605 [0.1415 to 0.1420]	3.550 [0.140]
	-0.50 [-0.02]	3.750 [0.148]	3.717 to 3.730 [0.146 to 0.147]	3.675 [0.145]
	-0.75 [-0.03]	3.875 [0.153]	3.842 to 3.855 [0.151 to 0.152]	3.800 [0.150]
	-1.00 [-0.04]	4.000 [0.158]	3.967 to 3.980 [0.156 to 0.157]	3.925 [0.155]

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



Measurement of main bearing thickness

5.9 Replacement of Main Bearings

If the main bearing thickness is less than the limit, replace the main bearing, or refinish the crankshaft and use undersize bearings. When the crankshaft is refinished to the specified bore dimension, the main bearing does not need to be ground after installation.

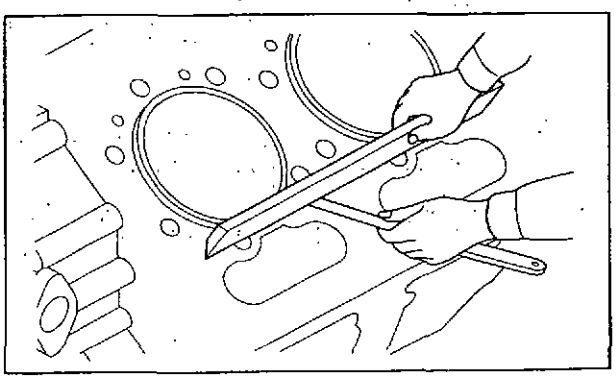
5.10 Measurement of Crankcase Gasket Surface Distortion

Measure the amount of distortion by placing a straight edge and using feeler gages. If the standard is exceeded, reface the gasket surface with a surface grinder.

Unit mm [in.]

	Standard	Limit
Crankcase gasket surface distortion	0.05 [0.002] or less	0.20 [0.008]

Note: *Limit the amount of crankcase grinding to prevent* the piston protrusions from exceeding the standard.


Measurement of crankcase gasket surface distortion

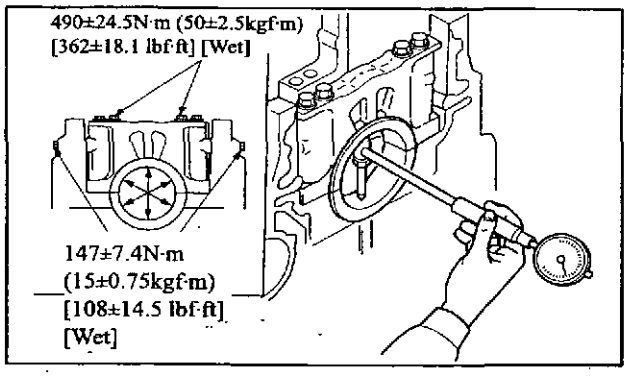
5.11 Measurement of Main Bearing Bore Diameter

(1) Tighten the main bearing cap to the specified torque. Be sure to observe the following tightening sequence when installing the main bearing cap bolts and side bolts.
   (a) Tighten the cap bolts to the specified torque.
   (b) Tighten the side bolt on the right side of the engine.
   (c) Tighten the side bolt on the left side of the engine.

(2) Measure the main bearing bore diameter in three direction: vertically and diagonally.

Unit mm [in.]

	Nominal value	Standard	Limit
Main bearing bore diameter	ϕ147 [5.792]	147.000 to 147.025 [5.792 to 5.793]	147.045 [5.79]



Measurement of main bearing bore diameter

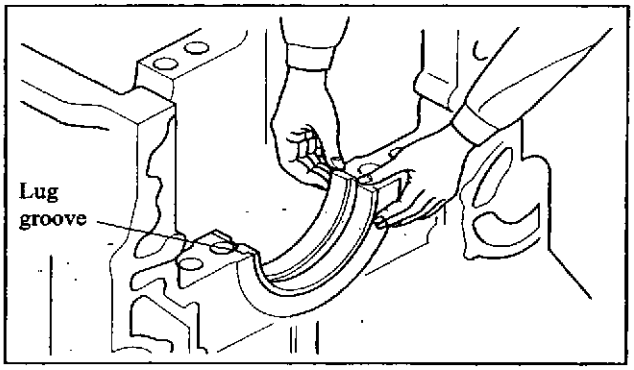
REASSEMBLY OF ENGINE MAIN PARTS

1. Crankcase, Crankshaft and Main Bearings

To reassemble, follow the disassembly sequence in reverse.

1.1 Installation of Main Bearings

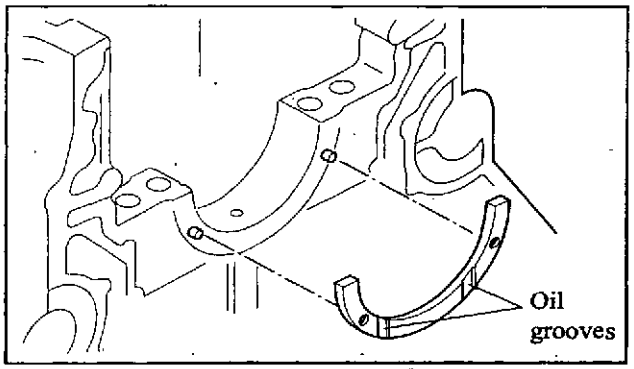
(1) Fit the main bearings (upper halves) into the lug grooves in the crankcase.
(2) The oil holes in the bearings and crankcase are aligned when the bearings are installed as described above.
(3) Apply a small amount of engine oil to each bearing.



Installation of main bearing

1.2 Installation of Thrust Plates

(1) Install the thrust plate to the crankcase outside face of the No. 7 bearing, making sure that the oil groove side of the thrust plate is facing toward the outside.
(2) After installing the crankshaft, install the thrust plate to the crankcase inside face, making sure that the oil groove side of the thrust plate is facing toward the inside.



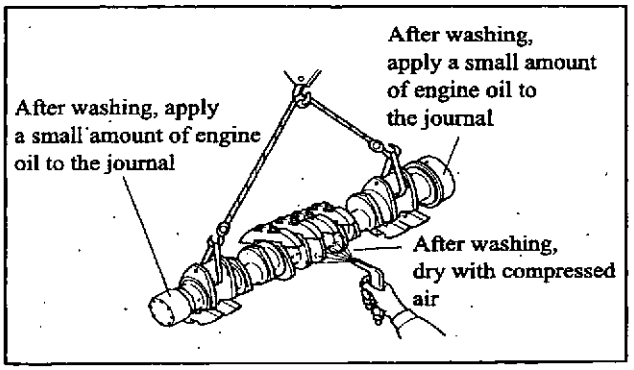
Installation of thrust plate

1.3 Installation of Crankshaft

(1) Wash the crankshaft thoroughly with cleaner, and dry it with compressed air.

Note: When washing the crankshaft, be sure to clean the oil holes and make sure they are not clogged by dust or foreign particles.

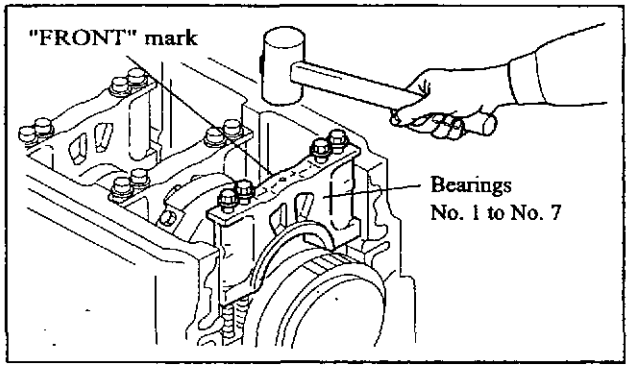
(2) Hold the crankshaft horizontally with a hoist, then carefully place it into the crankcase.
(3) Apply a small amount of engine oil to the crankshaft journals.



Installation of crankshaft

1.4 Installation of Main Bearing Caps

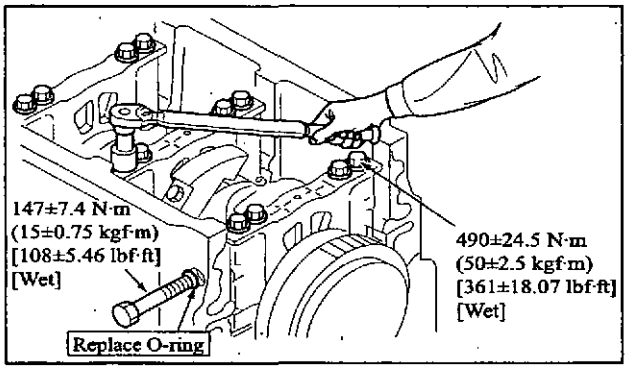
(1) Fit the main bearings (lower halves) to each main bearing cap.
(2) Install the thrust plate to the No. 7 bearing cap, making sure that the oil groove side is facing toward the outside of the cap.
(3) From the front of the engine toward the back, bearing numbers 1 to 7 are stamped on the bearing caps. Install the caps according to the numbers, and the "FRONT" mark on 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.



Installation of main bearing caps

1.5 Installation of Main Bearing Cap Bolts

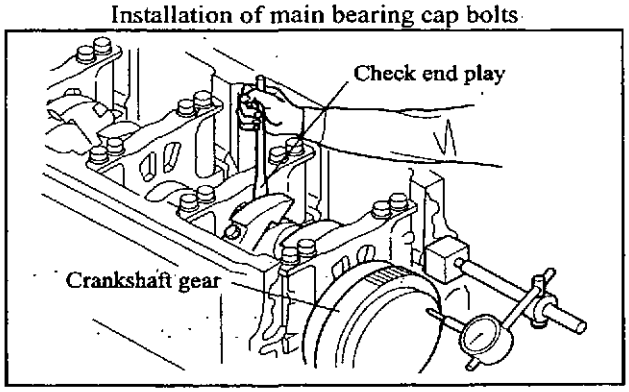
(1) Be sure to observe the following tightening sequence when installing the main bearing cap bolts and side bolts.
  (a) Tighten the cap bolts to the specified torque.
  (b) Tighten the side bolt on the right side of the engine.
  (c) Tighten the left bolt on the right side of the engine.
(2) Make sure the crankshaft rotates smoothly.



Installation of main bearing cap bolts

1.6 Measurement of Crankshaft End Play

(1) Tighten No. 1 through No. 6 bearing cap bolts and side bolts to the specified torque and with the No. 7 bearing cap bolts temporarily tightened, measure the end play.
(2) After tightening the No. 7 bearing cap bolts, measure the end play again to check.
(3) Make sure all cap bolts and side bolts are tightened.

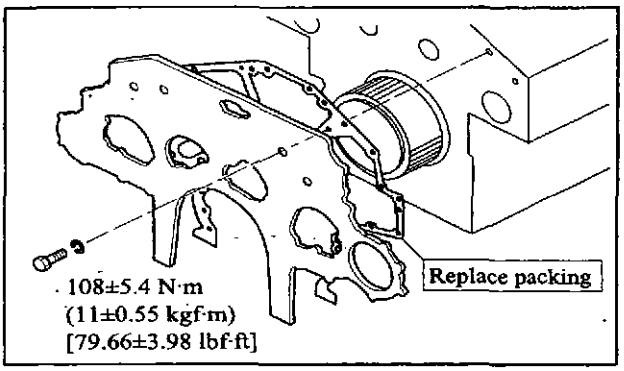


Measurement of crankshaft end play

2. Flywheel, Timing Gears and Camshafts

2.1 Installation of Rear Plates

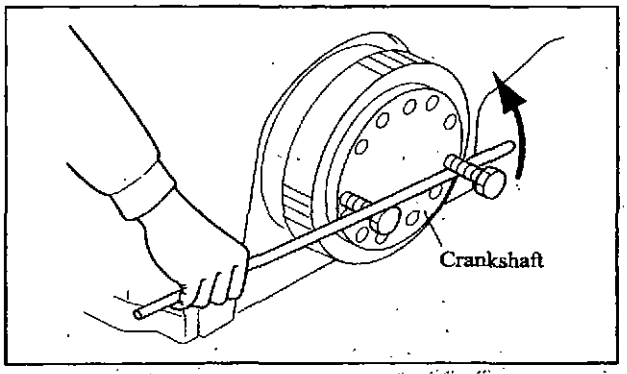
(1) Apply sealant (Herdite) to the rear plate mounting surface of the crank case, then place the packing in position. Apply the same sealant to the packing, then install the rear plate.
(2) Replace the dowel pins if they are worn or if the cover is replaced.
(3) Check to make sure the lower end of the plate is flush with the bottom surface of the crankcase. Cut off any excess packing neatly.



Installation of rear plate

2.2 Turning the Engine

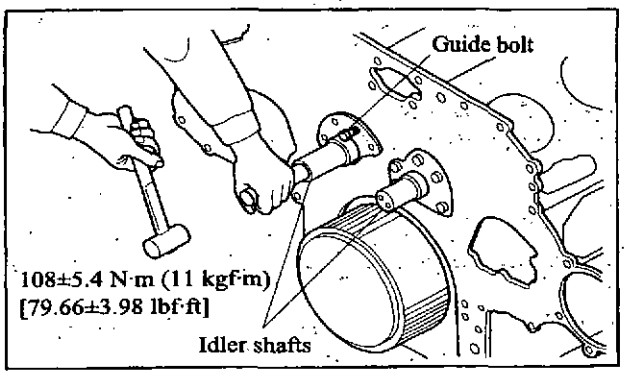
(1) Install bolts (M22×1.5 mm) to the flywheel mounting holes.
(2) Using these bolts and a bar, turn the crankshaft to bring the No. 1 cylinder piston to the top dead center.



Turning the engine

2.3 Installation of Idler Shafts

(1) Using the guide bolt, drive in the idler gear shaft.
(2) Tighten the idler gear shaft mounting bolts to the specified torque.

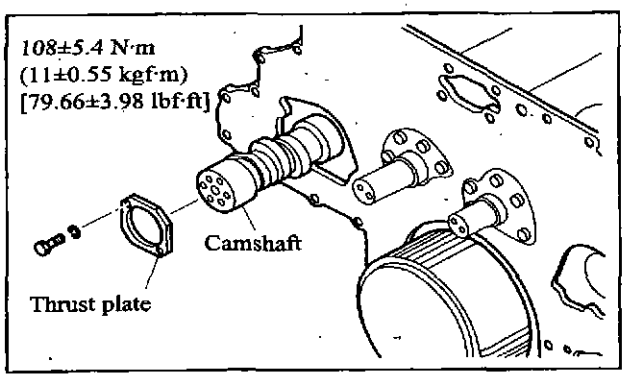


Installation of idler shaft

2.4 Installation of Camshafts (Right and Left)

(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 the camshaft rotates smoothly.

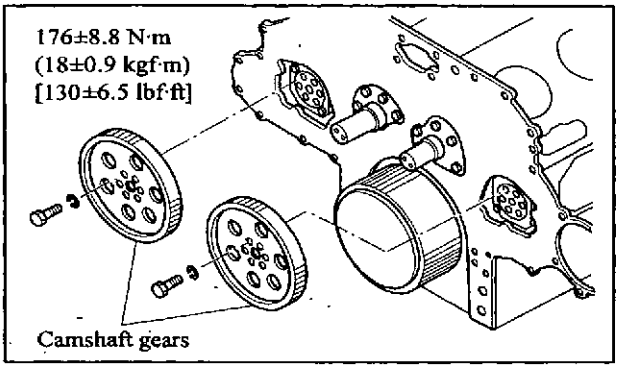
Note: Be sure install the right and left camshafts in their corresponding positions.



Installation of camshaft

2.5 Installation of Camshaft Gears

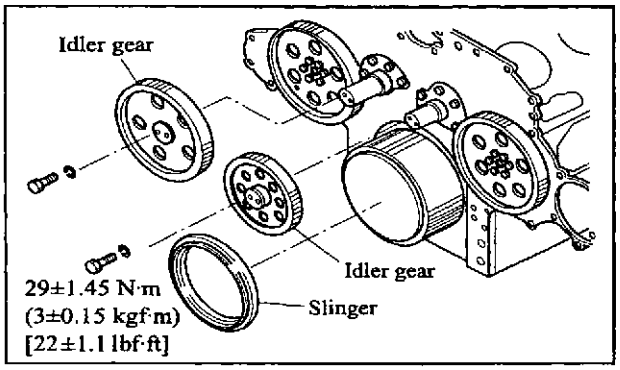
(1) Install each camshaft gear by aligning the hole with the dowel pin on the camshaft.
(2) Tighten the camshaft gear mounting bolts to the specified torque.
(3) After installing the camshaft gear, make sure the camshaft rotates smoothly.



Installation of camshaft gear

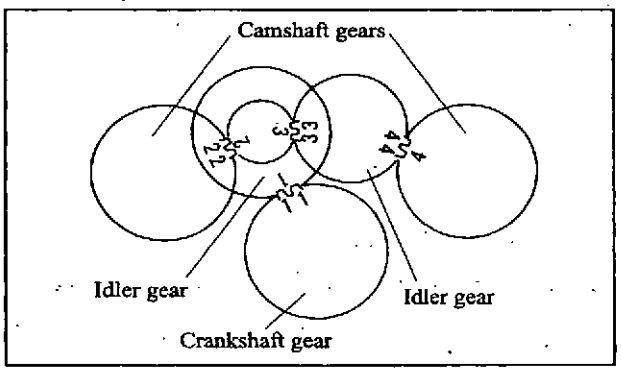
2.6 Installation of Idler Gears

(1) Install each idler gear by aligning its alignment mark with the marks on the crankshaft gear and camshaft gear, tighten the idler gear mounting bolts to the specified torque.
(2) Insert the slinger to the crankshaft.



Installation of idler gear

(3) Confirm that the alignment marks of the timing gears are as shown in the right diagram.
(4) Install the governor drive (PSG).



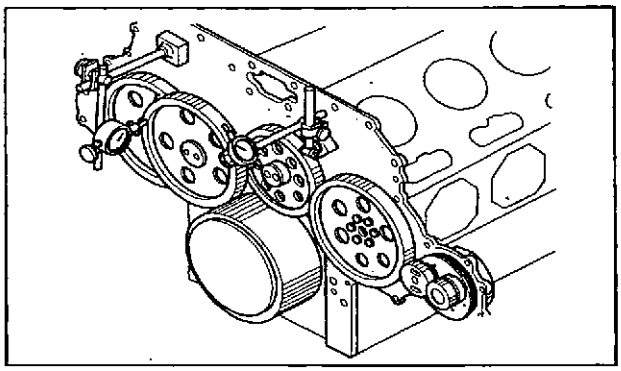
Timing gear train

2.7 Inspection and Adjustment of Timing Gear After Installation

Make sure to perform inspection and adjustment after disassembling and reassembling the timing gear.

(Inspection of backlash and end play)

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

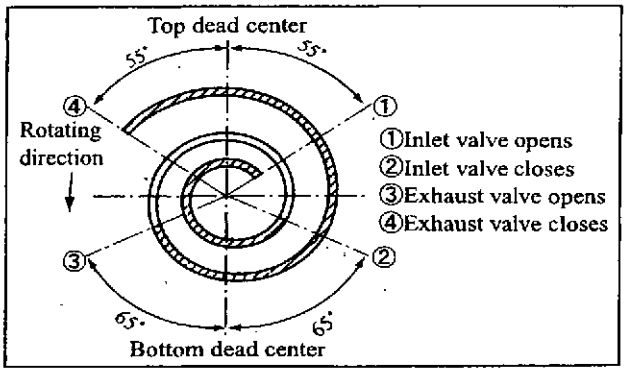


Measurement of timing gear backlash and end play

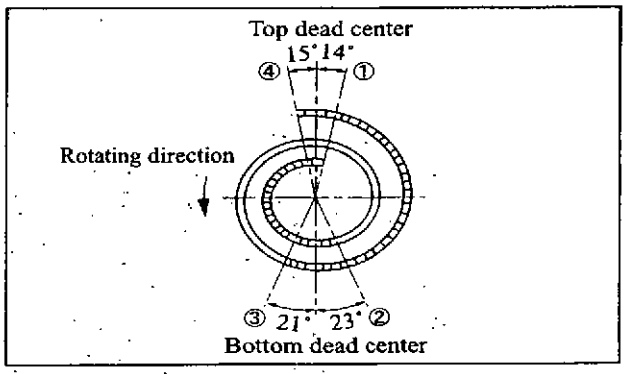
(1) Inspection of valve timing

It is not necessary to inspect the valve timing, provided that all alignment marks on the gears are aligned properly. However, it is recommended to check the valve timing.

To check the valve timing, use a 2 mm [0.08 in.] thick feeler gage, add 2 mm [0.08 in.] clearance to the inlet and exhaust valves of the No. 1 cylinder. Then, insert a 0.05 mm [0.002 in.] feeler gage between the bridge cap and rocker, and slowly turn the crankshaft to find the position where the feeler gage is firmly clamped (the valve starts opening) and the position where the feeler gage is released (the valve starts closing). Check to make sure that these positions coincide with the angular positions shown in the valve timing diagram with 2 mm [0.08 in.] clearance added to the valves.



Valve timing diagram (crank angle) (warm engine)

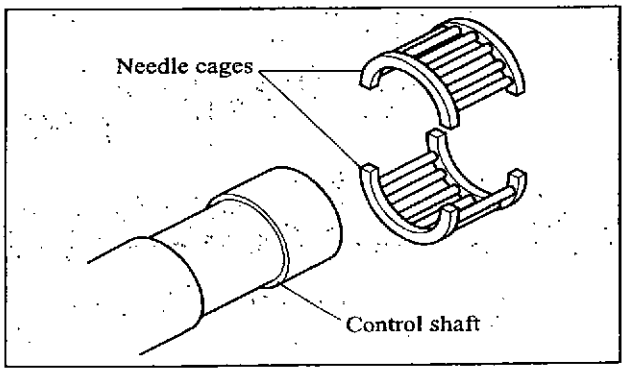


Valve timing diagram with 2 mm [0.08 in.] clearance added to valves (crank angle) (cold engine)

2.8 Installation of Control Shaft

(1) Install the control bracket into the crankcase.

(2) Insert the needle gage with control shaft into the rear side of crankcase so that the needle cage may not fall off.



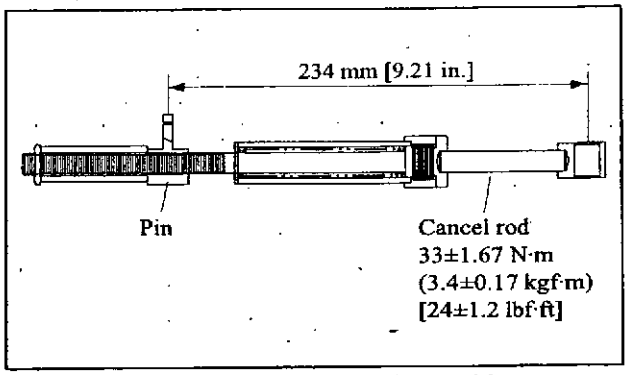
Installation of control shaft

2.9 Reassembly of Cancel Rod Assemblies

(1) Insert the cancel spring and cancel link into the spring case, apply Loctite to the threads of the cancel rod, and then tighten the cancel rod to the specified torque.

(2) Install the pin to the cancel link, ensuring that the installation dimension is as specified in the diagram on the right, and then secure it in place with the spacer and nut.

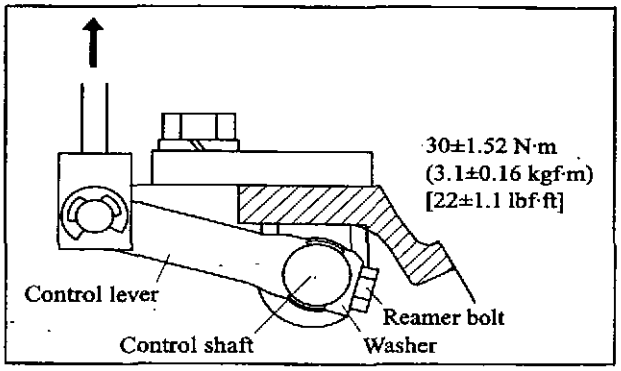
(3) Install the needle cage to the control lever and secure the cancel rod in place.



Reassembly of cancel rod assembly

2.10 Installation of Cancel Rod Assemblies

Mount the control lever and washer on the control shaft, and tighten the reamer bolt to the specified torque.

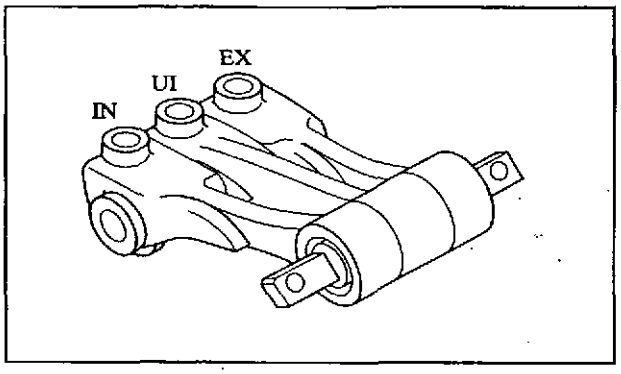


Installation of cancel rod assembly

2.11 Reassembly of Followers

(1) For the method of reassembly of the followers, refer to inspection and repair section.

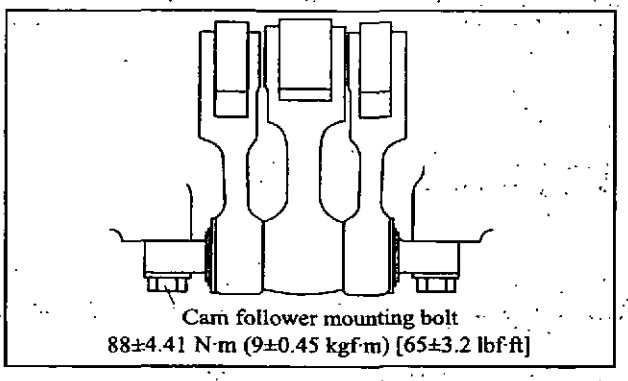
(2) When installing the followers on the cam follower shaft, be sure to arrange the IN, UI and EX followers from the left side in that order, as shown in the diagram.



Reassembly of follower

2.12 Installation of Followers

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



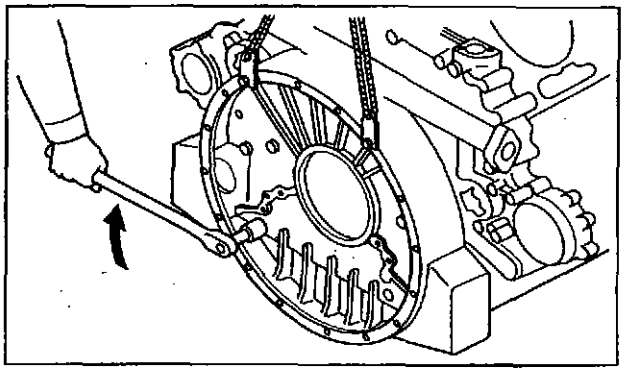
Installation of follower

2.13 Installation of Timing Gear Case

(1) Apply sealant (ThreeBond 1211) to the timing gear case mounting surface of the rear plate, then place the packing in position. Install the packing, apply the same sealant to the packing, then install the gear case. Carefully cut off any excess packing extending from the crankcase bottom surface.

(2) 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.



Installation of timing gear case

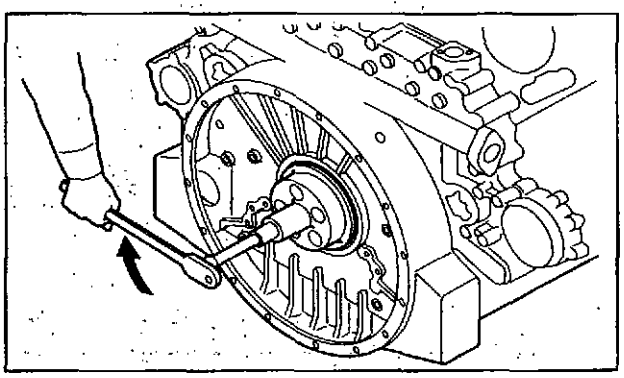
Tightening torque of timing gear case mounting bolt

Thread (mm)	Description	Tightening torque (N·m (kgf·m) [lbf·ft])
M12×1.25	Tighten the crankcase	98±4.9 (10±0.5) [72±3.6]
	Tighten the rear plate and nut	69±3.5 (7±0.35) [51± 2.6]
M16×1.5	Whole	245±12.3 (26±1.3) [181±9.1]

(4) Apply engine oil to the lip of the oil seal, and install the oil seal to the timing gear case.

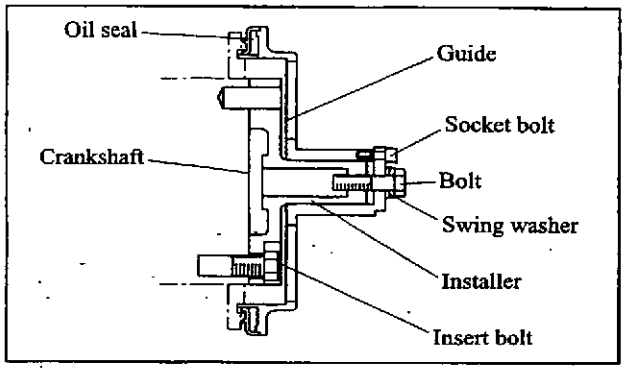
(5) Using the rear seal installer, insert the oil seal to the slinger, making sure that their dimensional relation is as shown in the diagram.

Name of special tool	Part No.
Rear seal installer	35B91-06010

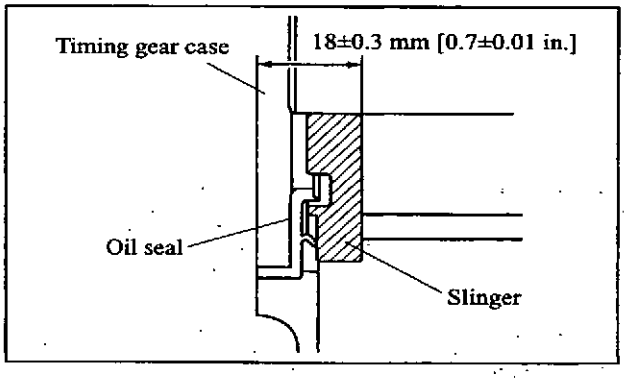


Installation of oil seal

- Install the guide at the rear end of the crankshaft with the insert bolt.
- Set the oil seal on the installer and insert it into the shaft of the guide
- After insertion, tighten the bolt on the installer. Install the oil seal on the gear case.
- Loosen the socket bolt and remove the swing washer from the bolt. Pull out the installer.
- Loosen the insert bolt and remove the guide from the crankshaft.



Rear seal installer

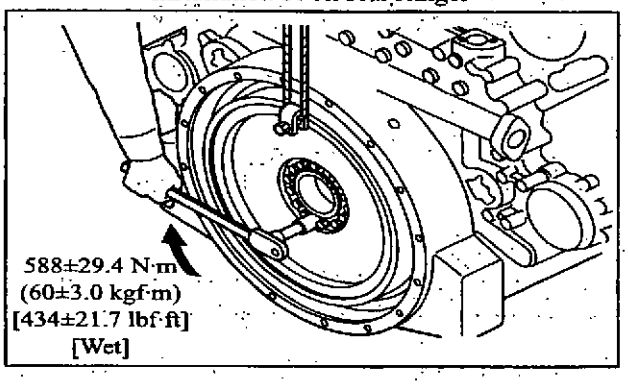


Installation of oil seal slinger

2.14 Installation of Flywheel

(1) Install the flywheel by aligning the holes with the dowel pins.

(2) Coat the threads and bolt seat surfaces of the flywheel mounting bolts with engine oil, then tighten the bolts to the specified torque.
Check the perpendicularity and periphery runouts of the flywheel.



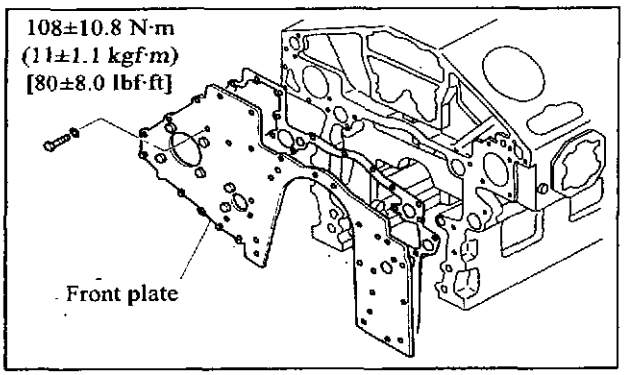
Installation of flywheel

3. Damper and Front Gears

To reassemble, follow the disassembly sequence in reverse.

3.1 Installation of Front Plates

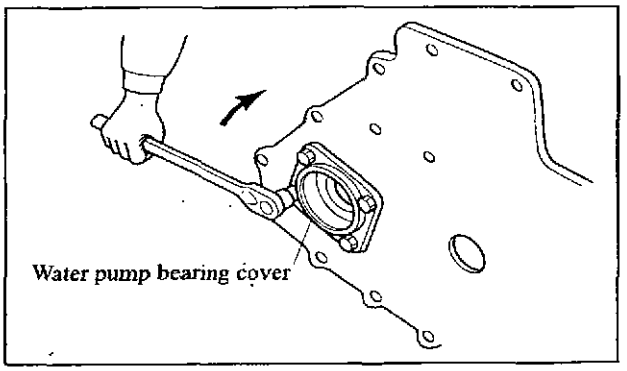
(1) Apply sealant (Herdite) to the front plate mounting surface of the crankcase, then place the packing in position. Apply the same sealant to the packing, then install the front plate.
(2) Replace the dowel pins if they are worn or if the plate is replaced.
(3) Check to make sure the lower end of the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



Installation of front plate

3.2 Installation of Water Pump Bearing Cover

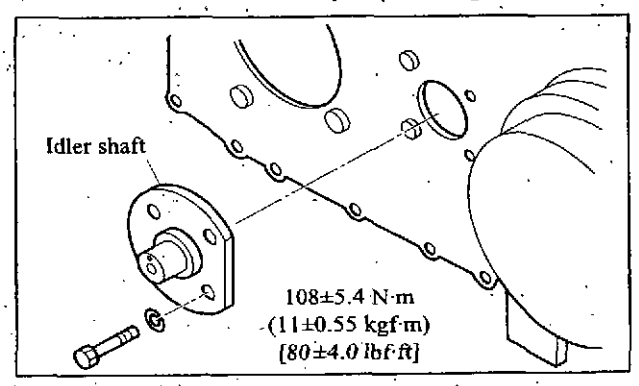
Insert the water pump bearing cover into the front plate, then tighten the cover mounting bolts to the specified torque.



Installation of water pump bearing cover

3.3 Installation of Idler Shafts

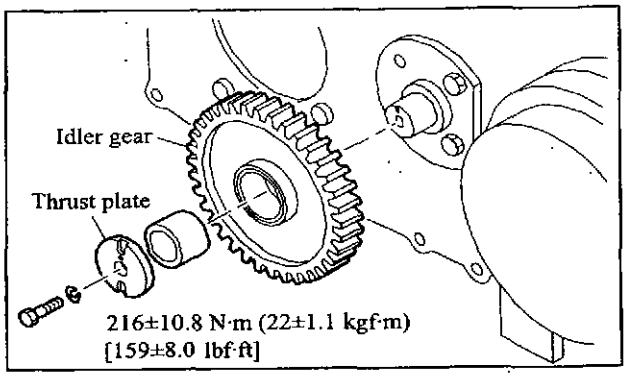
(1) Insert the idler shaft with guide bolts.
(2) Tighten the shaft mounting bolts to the specified torque.



Installation of idler shaft

3.4 Installation of Idler Gears

(1) Install the idler gear to the shaft, and mount the thrust plate.
(2) Tighten the thrust plate mounting bolts to the specified torque.



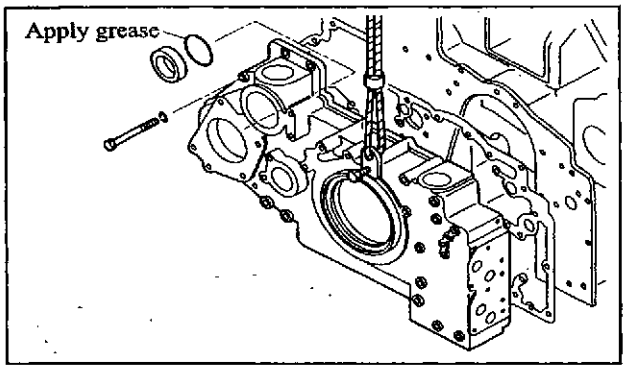
Installation of idler gear

3.5 Installation of Front Gear Case and Pointer

(1) Apply sealant (Herdite) to the front gear case packing mounting surface of the crankcase, then place the packing in position. Apply the same sealant to the packing, then install the front gear case.
(2) Replace the dowel pins if they are worn or if the plate is replaced.
(3) Tighten the case mounting bolts evenly to the specified torque.

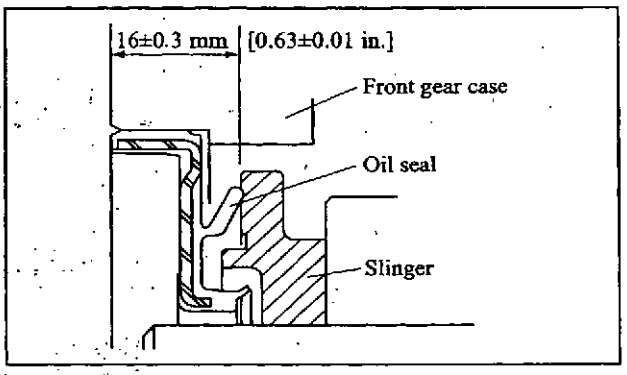
Tightening torque of timing gear case mounting bolt

Thread (mm)	Description	Tightening torque (N·m (kgf·m) [lbf·ft])
M12×1.25	Tighten the crankcase	98±9.8 (10±1.0) [72±7.2]
	Tighten the rear plate and nut	69±6.9 (7±0.7) [51±5.1]
M16×1.5	Whole	255±2.55 (26±0.26) [188±1.9]



Installation of front gear case

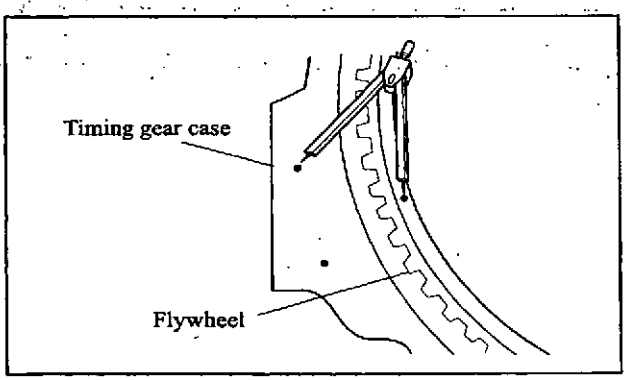
(4) Check to make sure the lower end of the front gear case is flush with the bottom surface of the crankcase. Cut off any excess packing neatly.
(5) Install the oil seal to the front gear case.
(6) Apply engine oil to the lip of the oil seal.
(7) Using the front seal installer assembly, insert the oil seal to the slinger, making sure that their dimensional relation is as shown in the diagram.



Installation of oil seal and slinger

(When pointer is removed or out of place)

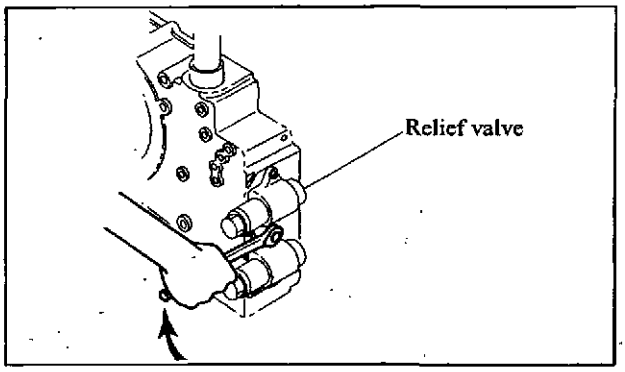
To determine the top dead center of No. 1 piston in compression stroke, bring the mark on the flywheel to the position where it is at the equal distance from the two marks punched on the timing gear case. When these three marks are positioned at the equal distance from one another, No. 1 and No. 6 pistons are at the top dead center.



Confirmation of top dead center using punched marks

3.6 Installation of Relief Valve

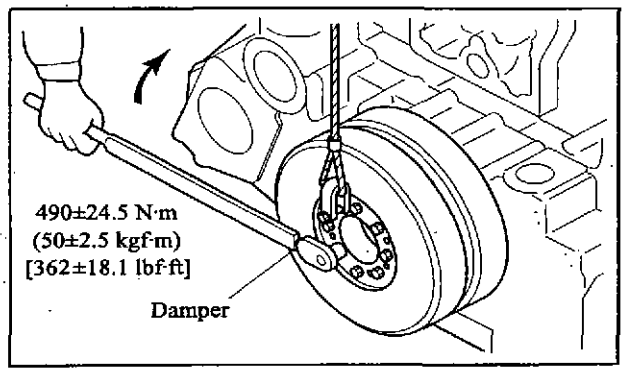
Install the relief valve using the mounting bolt.



Installation of relief valve

3.7 Installation of Damper

Tighten the damper mounting bolts to the specified torque.



Installation of damper

4. Cylinder Liners, Pistons and Connecting Rods

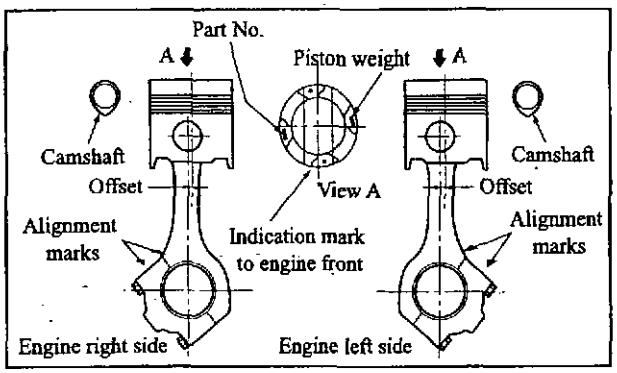
To reassemble, follow the disassembly sequence in reverse.

4.1 Reassembly of Pistons and Connecting Rods

(1) The piston pin is clearance-fitted to the piston. To facilitate pin insertion, heat the piston with a piston heater or in hot water.

(2) Coat the piston pin with engine oil, then insert it into the piston and through the connecting rod.

(3) Install the connecting rod so that the alignment marks on the big-end face the camshaft side.

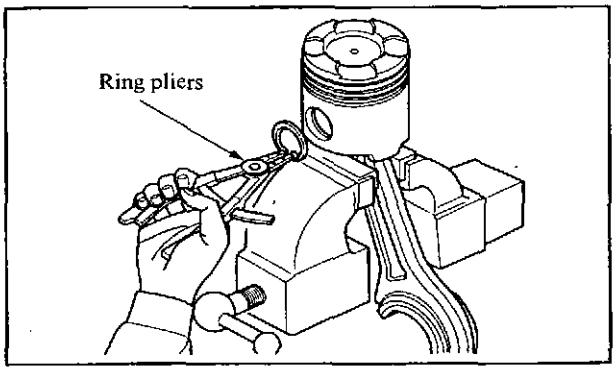


Alignment marks on connecting rod

(4) Using the ring pliers, install the snap rings into the grooves of the piston. Check the snap rings for tension and proper fitting in the grooves.

Name of special tool	Part No.
Ring pliers	45191-08400

Note: Position the end gap of each snap ring toward the bottom of the piston.



Reassembly of piston and connecting rod

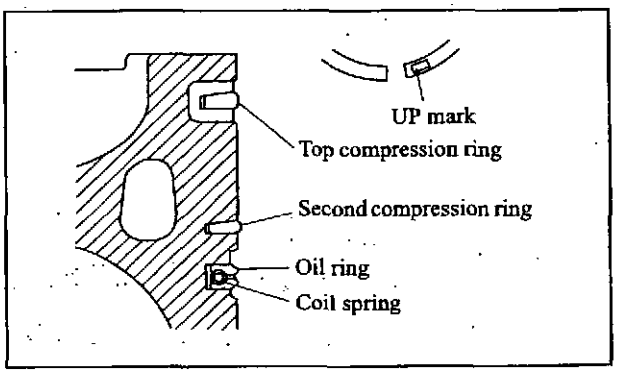
4.2 Installation of Piston Rings

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

Name of special tool	Part No.
Ring expander	37191-03200

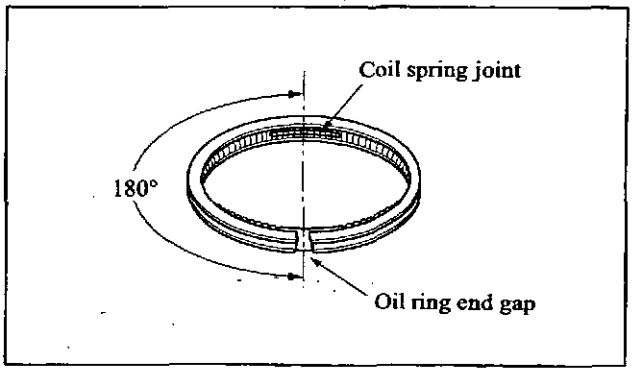
⚠ CAUTION

The top piston ring is marked "R" and second ring is marked "R2" near the end gap, and the oil ring is marked "R". Install the rings with these marks facing up. If the rings are faced in the wrong direction, excessive oil consumption and engine seizing will result.



Piston and piston ring arrangement

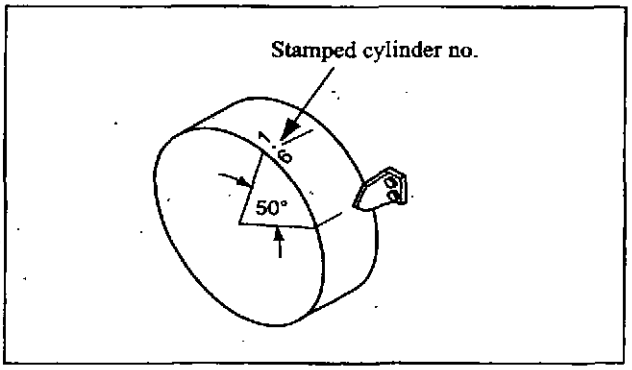
(2) Install the oil ring with its end gap positioned at 180° to the coil spring joint, as shown in the diagram.



Installation of oil ring and coil spring

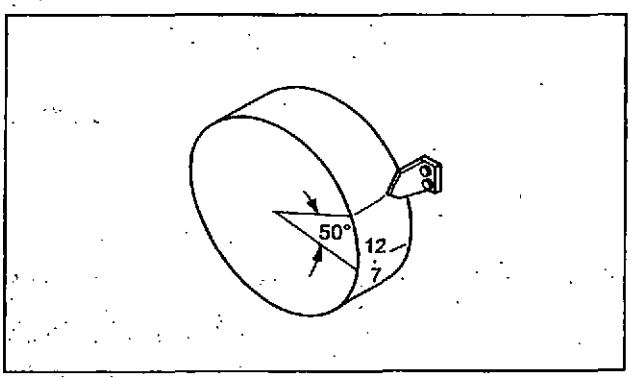
4.3 Preparation for Installation of Pistons

(1) Pistons for right bank cylinders
Turn the crankshaft in the normal direction until the stamped number mark of the cylinder to which the piston is to be installed is at the position approximately 50° before top dead center.



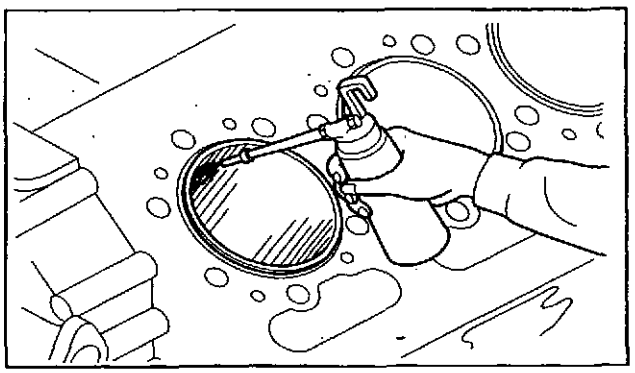
Preparation before installing piston in right bank cylinder

(2) Pistons for left bank cylinders
Turn the crankshaft in the normal direction until the stamped number mark of the cylinder to which the piston is to be installed is at the position approximately 50° after top dead center.



Preparation before installing piston in left bank cylinder

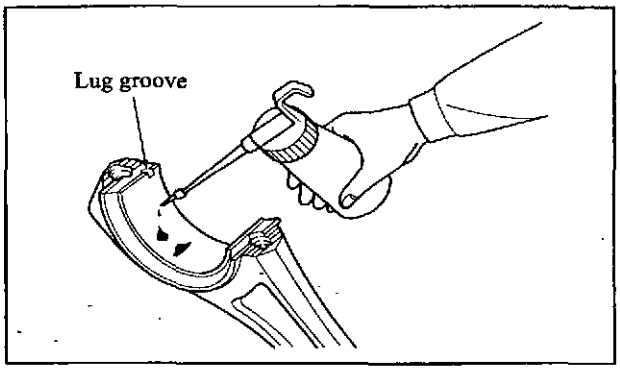
(3) Clean the cylinder liner bore surface and crankpin with a cloth, then apply engine oil.



Preparation before installing piston

4.4 Installation of Connecting Rod Bearing Upper Halves

Install the rod bearing upper half in the lug groove of the connecting rod big-end, and apply engine oil to the inside surface of the bearing. Make sure the oil holes in the rod and bearing are aligned.



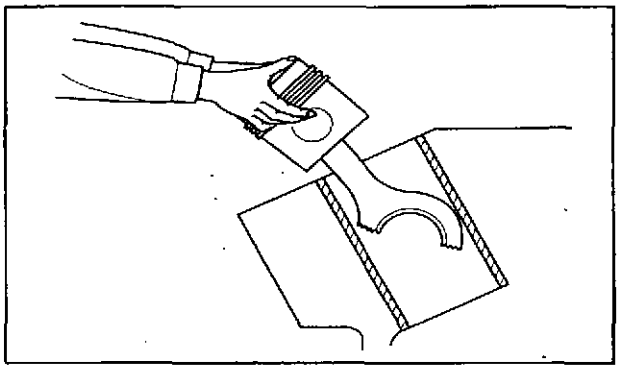
Installation of connecting rod bearing upper half

4.5 Installation of Pistons

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

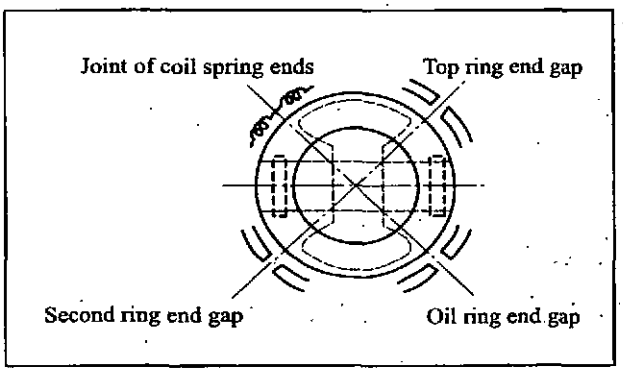
⚠ CAUTION

Make sure the F mark on the piston top points toward the front side of the engine.
Since the connecting rod can contact and damage the piston cooling nozzle during the installation of the piston, observe the connecting rod from the inspection window on the side of the crankcase.
Do not rotate the piston during installation.



Installation of piston (1)

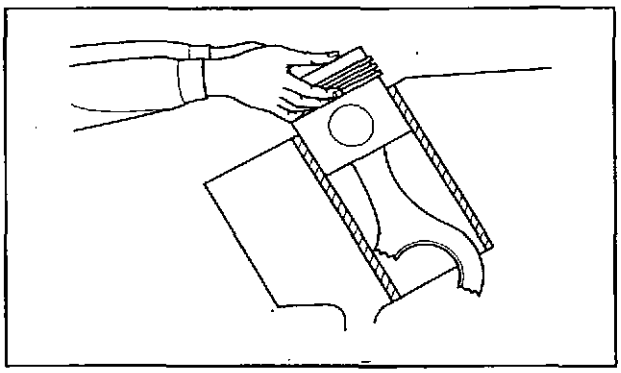
(2) Apply engine oil to the piston rings, then move the piston rings so that the end gaps do not align with the pin direction, thrust direction or counter-thrust direction.



Installation of piston (2)

(3) Hold the compression ring with both hands, and carefully insert the piston into the cylinder liner.

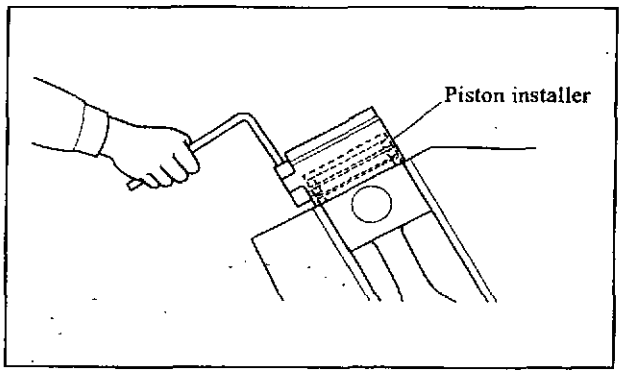
Note: (a) Do not pinch finger between the oil ring and cylinder liner.
(b) Slowly insert the piston to avoid damaging the oil ring.



Installation of piston (3)

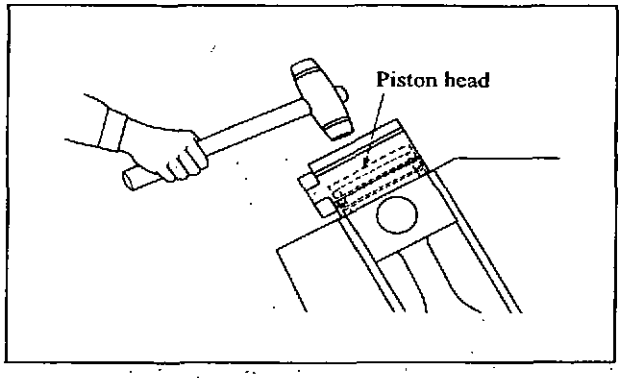
(4) After making sure that the piston ring gaps are positioned properly, coat the rings with engine oil, then clamp the piston rings firmly with the piston installer.
Be sure to apply engine oil to the inside surface of the piston installer.

Name of special tool	Part No.
Piston installer	37191-07100



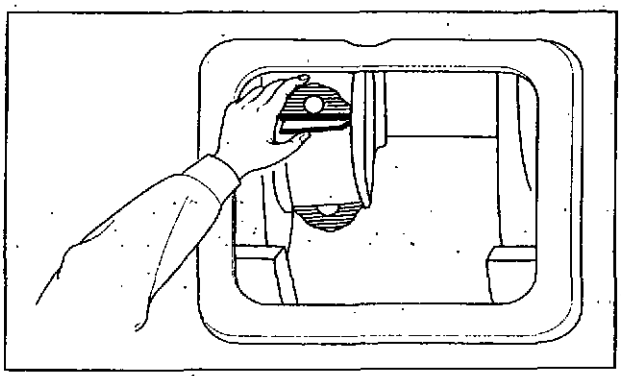
Installation of piston (4)

(5) Lightly tap the piston head with a soft-head mallet to insert the piston into the cylinder liner.
If the piston does not go into the cylinder liner, move the big-end of the connecting rod back and forth through the crankcase inspection window.



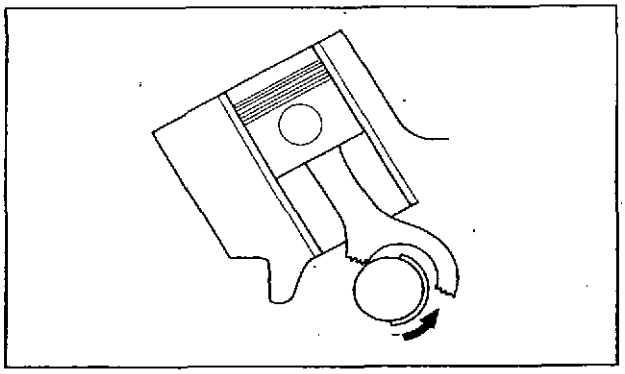
Installation of piston (5)

(6) Insert hand through the crankcase inspection window, and check to make sure that the connecting rod bearing upper half is properly positioned in the big-end of the connecting rod. If it is displaced slightly, push up the bearing by hand and adjust.



Installation of piston (6)

• If the upper half of the bearing is off the connecting rod big-end, turn the crankshaft, then allow clearance between the connecting rod big-end and the crankshaft pin. Contact the rod metal closely with the crankpin and insert it by sliding.



Installation of piston (7)

4.6 Installation of Connecting Rod Caps

⚠ CAUTION

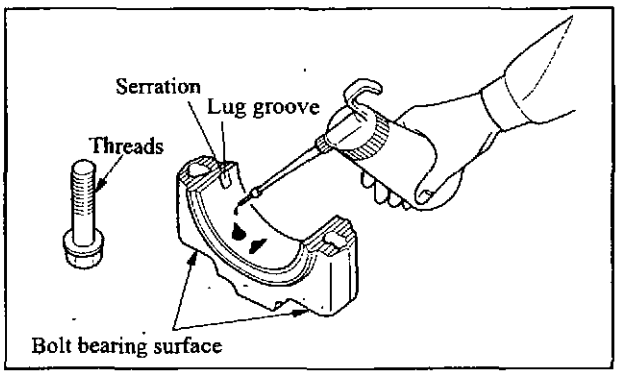
When installing connecting rod caps, make sure that dust or bearing chips does not enter the cap serration, the seat surface and the bolt threads.

(1) Insert the connecting rod bearing lower half into the lug groove of the connecting rod cap.

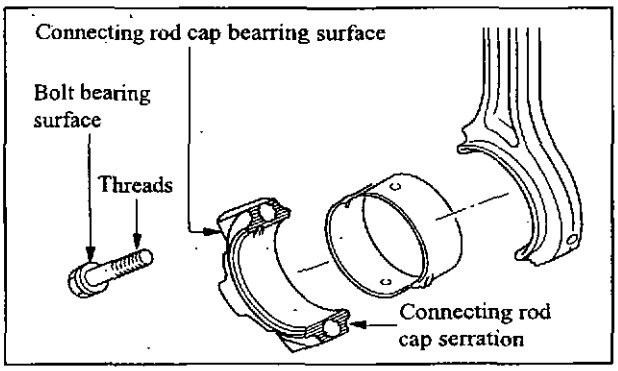
(2) Apply engine oil to the following positions

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

Note: Apply engine oil evenly with a clean cloth or a clean finger.



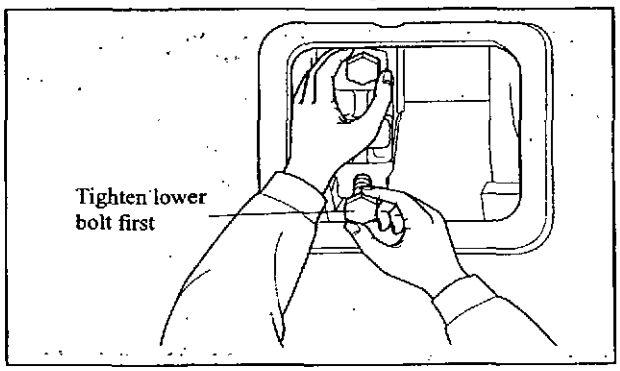
Installation of connecting rod cap (1)



Installation of connecting rod cap (2)

(3) Install the connecting rod cap. By holding the upper section of the cap with hand and tightening the bolt at the lower end first, the cap can be installed without accidentally dropping into the oil pan. Apply engine oil to the threads and seat surfaces of the bolts, then tighten the bolts temporarily.

(4) Touch the joint between the connecting rod and cap. and make sure there is no ridge. When the surfaces are flush with each other, tighten the bolts to the specified torque.

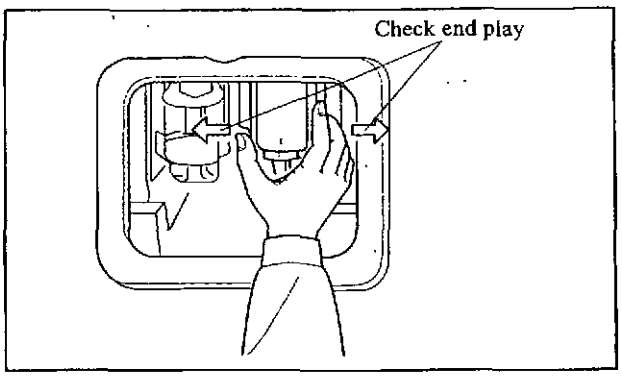


Installation of connecting rod cap (3)

⚠ CAUTION

Make sure the alignment marks on the cap and connecting rods are on the same side.

(5) Temporarily tighten the cap bolts of the connecting rod installed later, then press the connecting rod installed first toward the other connecting rod by tapping evenly. Move the big-end of this connecting rod in the thrust direction, and check the end play (make sure there is a clearance of 0.4 to 0.6 mm [0.016 to 0.024 in.]).



Installation of connecting rod cap (4)

(6) After tightening the connecting rod cap mounting bolts to the specified torque, loosen the bolts and retighten them.

Note: (a) Be sure to tighten the two connecting rod bolts evenly.

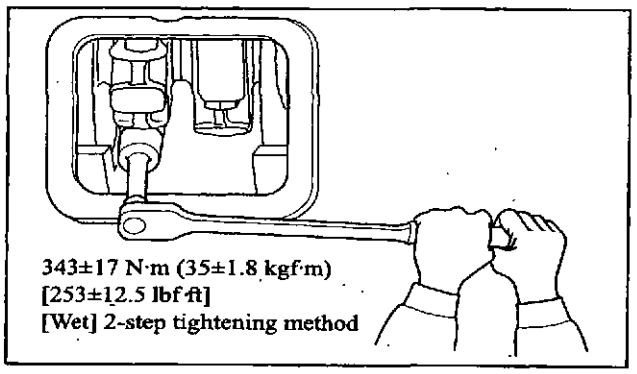
(b) Tighten in two or three steps before tightening to the specified torque (example: to achieve tightening torque of 343 N·m (35 kgf·m) [253 lbf·ft], tighten the bolt in three separate steps to 98, 196 and 343 N·m (10, 20 and 35 kgf·m) [72, 144 and 253 lbf·ft]). Then loosen the bolt, and re-tighten to 343 N·m (35 kgf·m) [253 lbf·ft] in the same three-step method. (2-step tightening method)

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

① Tighten to snug torque of 147±7.4 N·m (15±0.75 kgf·m) [108±5.4 lbf·ft].

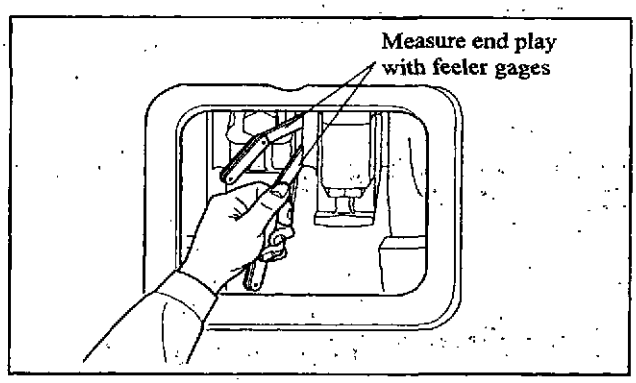
② Tighten by turning 45±3°.

③ After tightening all bolts, retighten according to angle method. (2-step tightening method)



Installation of connecting rod cap (5)

(7) Using feeler gages, measure the end play of the connecting rod, and make sure the clearance is equal on the top and bottom sides of the crankpin.



Installation of connecting rod cap (6)

⚠ CAUTION

Before installing the cylinder head, measure the protrusion of the piston, and make sure the measurement is correct.

5. Cylinder Heads and Valve Mechanisms

To reassemble, follow the reassembly sequence in reverse.

5.1 Installation of Copper Tubes

(1) Install O-ring inside the cylinder. Apply liquid gasket (ThreeBond 1207C) to the inside wall ϕ22.6 mm [0.89 in.] of the cylinder head. Make sure that liquid gasket does not extend to the side indicated by ※ in the diagram.

(2) *Insert copper tube into the cylinder head.*
Wipe off any excess liquid gasket on the bottom surface of the cylinder head.

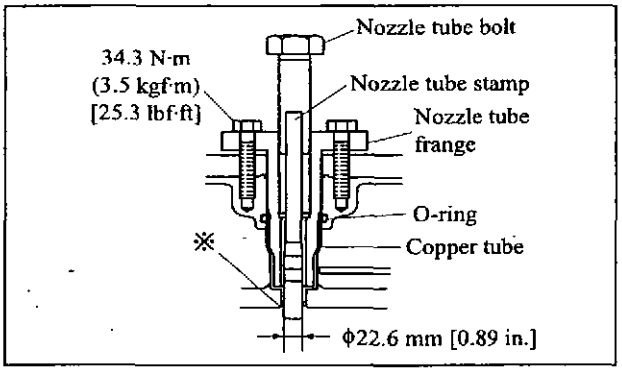
(3) Install the nozzle tube tool flange of the tube tool on the top surface of the cylinder head using tightening torque.

Name of special tool	Part No.
Tube tool	35C91-21010

(4) Apply engine oil to the nozzle tube stamp of the tube tool. Insert the copper tube. During this step, make sure that the stamp tip protrudes from the bottom side of the cylinder head.

(5) Press the nozzle tube bolt of the tube tool until the stamp can be pulled out from the bottom side of the cylinder head.

(6) Remove the tube tool, and inspect the copper tube for abnormalities.

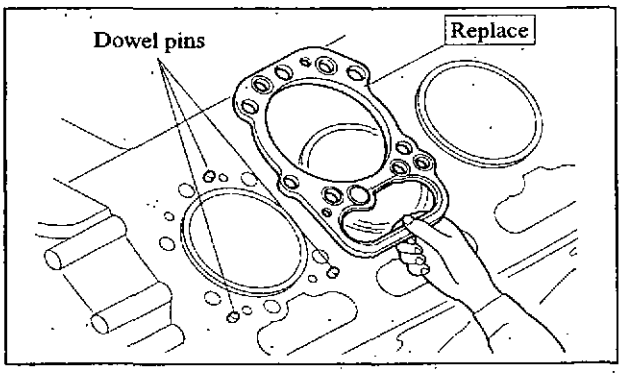


Installation of copper tube

5.2 Installation of Cylinder Head Gaskets

(1) Clean the gasket surfaces of the cylinder head and crankcase with a cloth to remove oil and grease thoroughly from the surfaces.

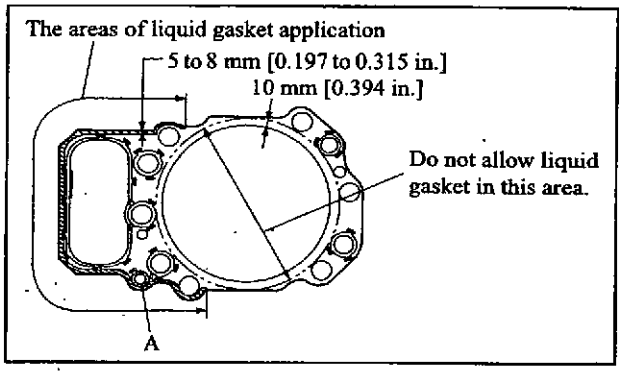
(2) Apply liquid gasket around holes and oil passage holes on the head gasket to prevent oozing (oil bubbles) of oil through the gasket.



Installation of cylinder head gasket

- Application of liquid gasket

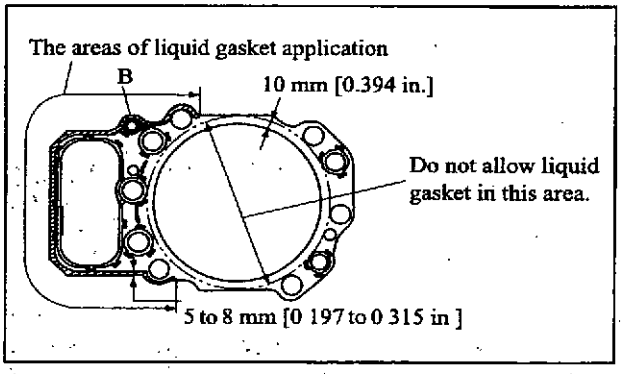
Apply a thin coat of liquid gasket (37594-01300) around the tappet holes and oil passage holes on both sides of the head gasket, and install the gasket before the liquid gasket dries.
Do not apply an excessive amount of liquid gasket, since it can impair the head gasket O-ring and cause deformation. Do not allow liquid gasket to adhere around the bore; otherwise, gas leakage can occur.
Before installation, be sure to wipe off oil and grease from the bottom surface of the cylinder head, the top face of the crankcase and the head gasket, and make sure they are clean.



Application of liquid gasket (head-facing side)

The drawing on the right shows the areas and amounts of liquid gasket application.

Note: (a) Apply liquid gasket (37594-01300) to areas 5 to 8 mm [0.197 to 0.315 in.] from the periphery of the head gasket.
(b) Liquid gasket should be applied to the areas indicated in the diagram on the right.
(c) Apply liquid gasket to both sides of the head gasket, and spread it with a finger to a thickness of 0.2 to 0.5 mm [0.008 to 0.020 in.].
(d) Since sections (A) and (B) are very close to O-rings, do not apply a large amount of liquid gasket to these sections.



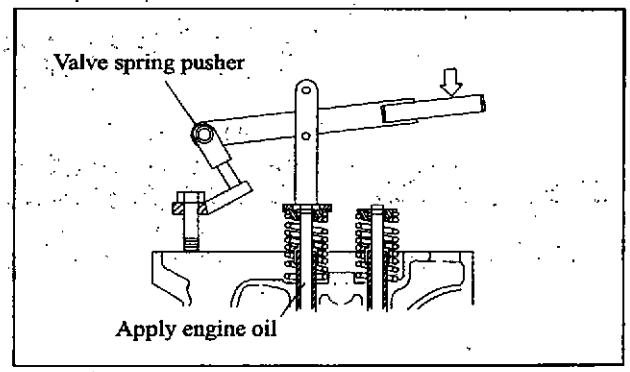
Application of liquid gasket (crankcase side)

(3) Install the cylinder head gasket by aligning holes with the dowel pins.

5.3 Reassembly of Cylinder Head Assemblies

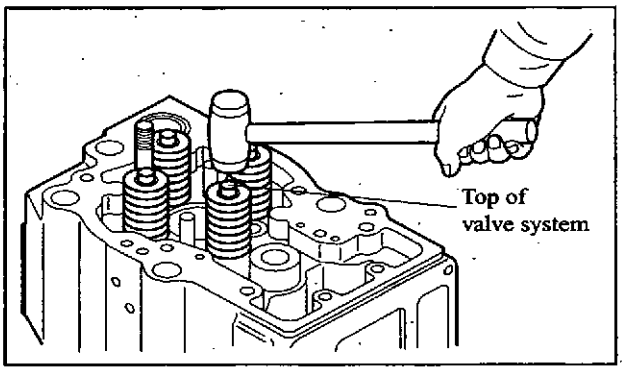
(1) Coat the valve stems with engine oil, then insert them into the valve guides.
(2) Install the valve springs and rotators to the valve guides, and install the valve cotters by using the valve spring pusher.

Name of special tool	Part No.
Valve spring pusher	33591-04500



Reassembly of cylinder head assembly (1)

(3) Lightly tap the top of each valve stem with a soft-head mallet several times to make sure the valve spring and cotter are properly installed.



Reassembly of cylinder head assembly (2)

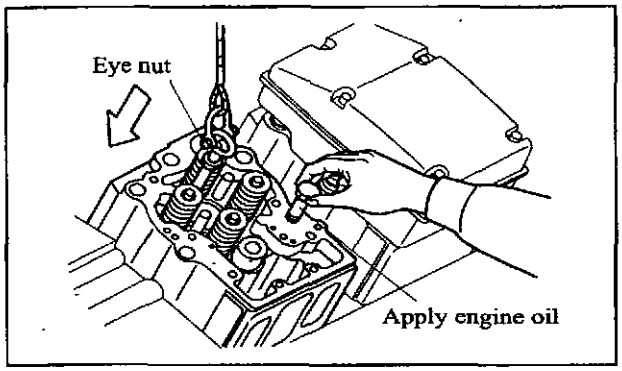
5.4 Installation of Cylinder Head Assemblies

⚠ CAUTION

Before installing the cylinder head assemblies, measure the protrusion of each piston to make sure the protrusion is correct.

(1) Install the eye nut to the stud bolt, connect a shackle and wire rope, then lift the cylinder head assembly. Position the head properly by aligning the holes with the dowel pins, and keep the head slightly lifted. Apply engine oil to the threads and seat surfaces of the head bolts, then tighten the head bolts.

Name of special tool	Part No.
Eye nut	37591-02400



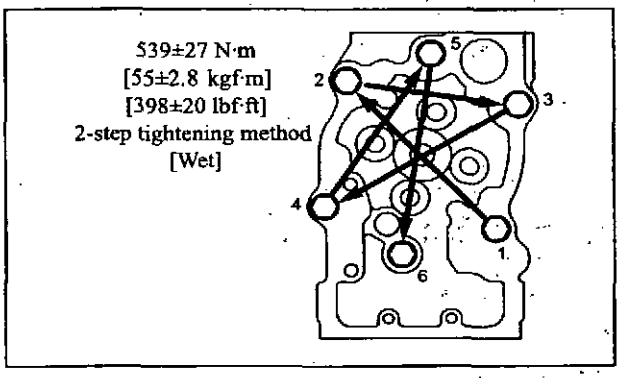
Installation of cylinder head assembly

⚠ CAUTION

After applying engine oil to the cylinder head bolts, remove excess oil before installing.

(2) Tighten the cylinder head bolts with the specified torque in the sequence shown in the drawing.

- Tightening cylinder head bolts according to the angle method
  - (a) Tighten the cylinder head bolts to snug torque (initial torque) of 294±14.7 N·m (30±1.5 kgf·m) [22±1.1 lbf·ft]in the indicated sequence.
  - (b) Tighten each bolt in the indicated sequence by turning 30±1.5°. Then, tighten again in the indicated sequence by turning 30±1.5° (total of 60±3° turn).
  - (c) After tightening all bolts, tighten by further turning 30±1.5°. (2-step tightening method)



Cylinder head bolt tightening sequence

5.5 Installation of Unit Injector

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

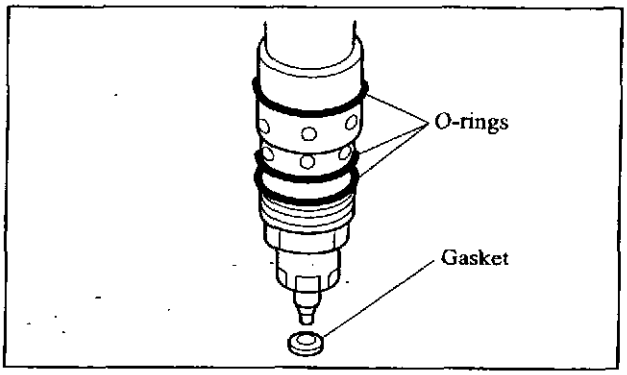
(2) Clean the area where copper tube is installed in the cylinder head so that no foreign matter such as dust may not remain. Dust in the hole may result in gas leakage or fuel leakage.

(3) Make sure to check that the old gasket is completely removed from the bottom inner surface of the copper tube by using a wire or other tool.

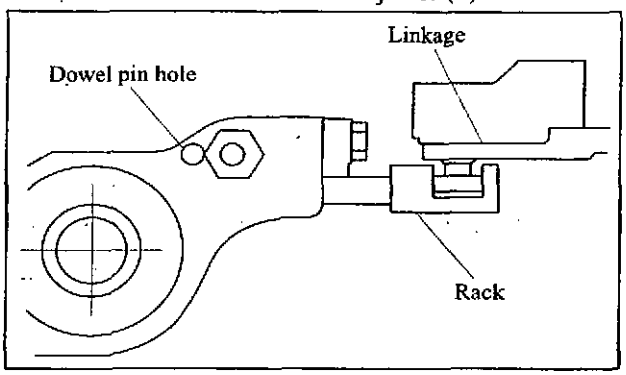
(4) Apply grease, silicon oil or lubricant to the O-ring outside the injection nozzle.

⚠ CAUTION

Handle the injection nozzle carefully to prevent dust, or do not damage the O-ring.
Make sure that the old gasket is completely removed from the bottom section of the copper tube. If a new gasket is installed on top of the previous gasket, damage can occur in the injector.



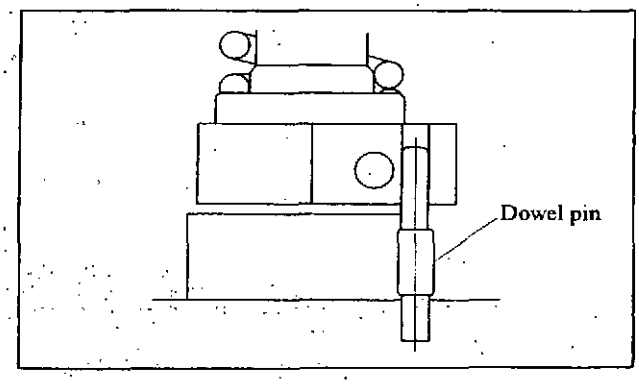
Installation of unit injector (1)



Installation of unit injector (2)

(5) Insert the unit injector into the cylinder head. Insert it completely so that the dowel pin hole, the rack and the linkage are aligned.

(6) Install the gland and tighten the fixing nut manually. Make sure that the unit injector is fully inserted, that the dowel pin is inserted, that the gland is not on the unit injector, and that the control racks engaged with the link bearing.



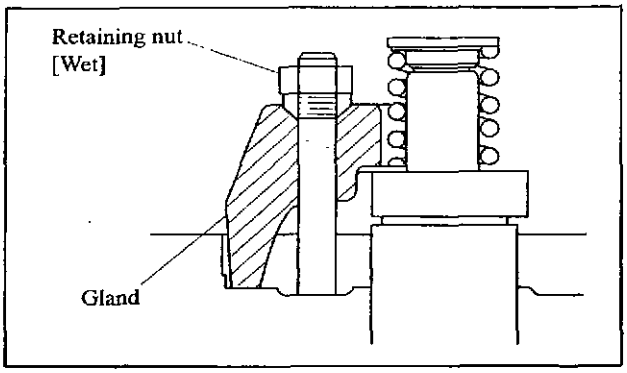
Installation of unit injector (3)

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

· Tightening sequence of retaining nuts

(a) Tighten the retaining nut to 176±9 N·m (18±0.9 kgf·m) [130±6.6 lbf·ft].

(b) Loosen the nut and retighten it to 127±6.4 N·m (13±0.7 kgf·m) [94±4.7 lbf·ft].

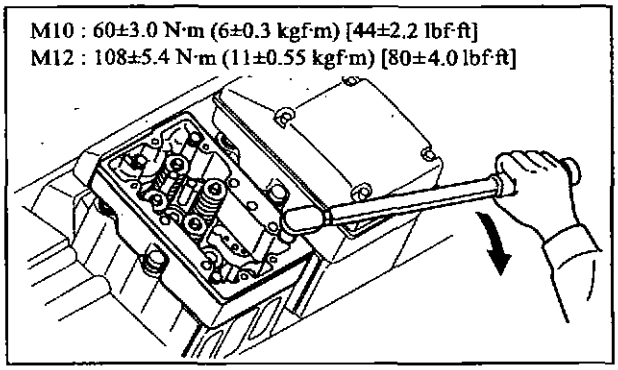


Installation of unit injector (4)

(8) Connect the bracket and rack lever to the cancel rod assembly.
(9) Adjust the linkage of the cancel rod assembly.
(Refer to INSTALLATION OF FUEL SYSYEM.)

5.6 Installation of Rocker Cases

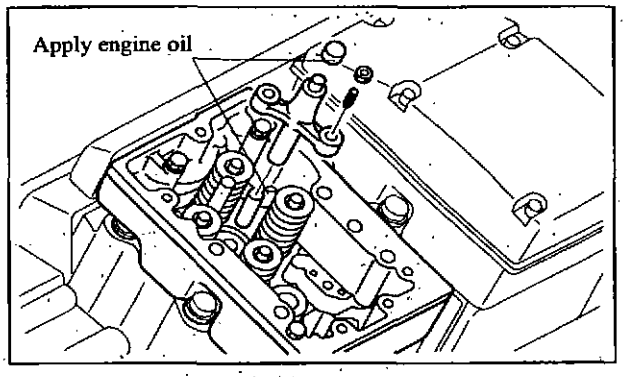
(1) Install the rocker case by aligning the holes with the dowel pins.
(2) Tighten the rocker case mounting bolts to the specified torque.



Installation of rocker case

5.7 Installation of Bridges and Bridge Caps

(1) Apply engine oil to the bridge guides, then install the bridges to the guides with the screws positioned on the exhaust manifold side.
(2) Apply engine oil to the bridge contact face of the bridge caps, and install the caps in position carefully to prevent them from falling into the crankcase through the pushrod holes.



Installation of bridge and bridge cap

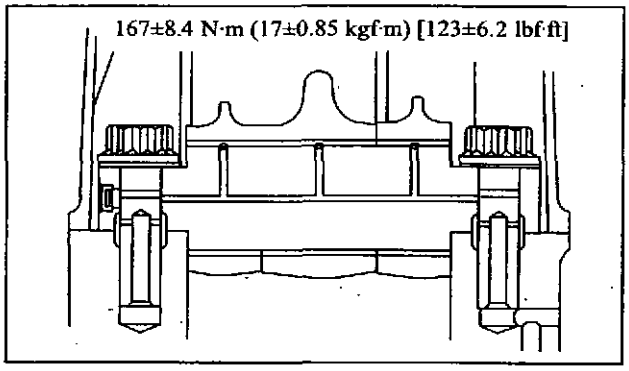
5.8 Installation of Rocker Shaft Assemblies

(1) Install the rocker shaft assembly to the rocker case with the locating pin entering its hole.

⚠ CAUTION

(a) Move the rocker arm up and down to make sure the arm moves freely.

(b) While tightening the rocker shaft mounting bolts temporarily, position the rocker shaft so that the rocker tip contacts the bridge top evenly.
Make sure that the adjusting screw of each rocker arm match to the pushrod.



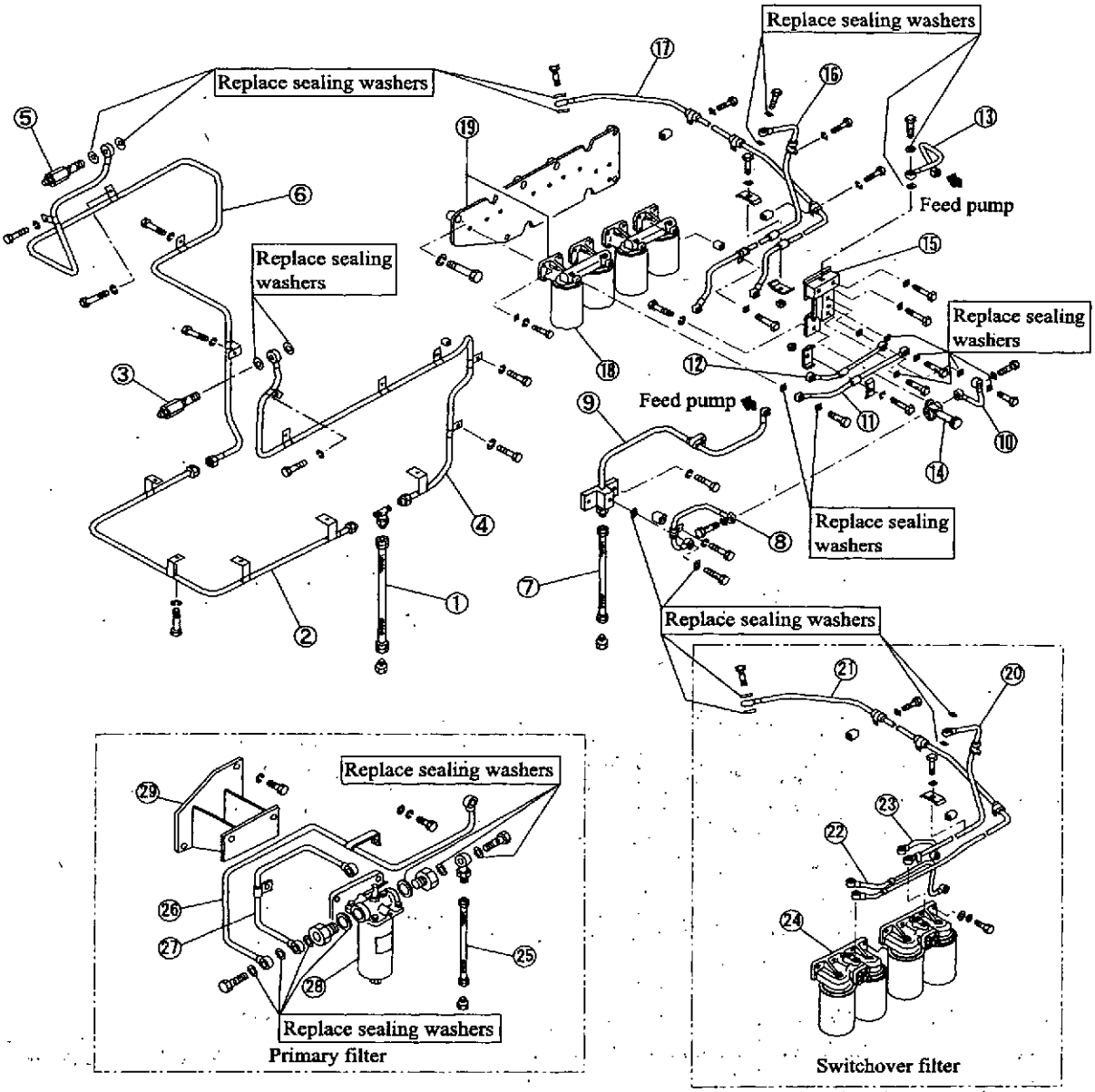
Installation of rocker shaft assembly

5.9 Adjustment of Valve Clearances

Refer to the "Engine Adjustment (1.1) Inspection and Adjustment of Valve Clearances."

REMOVAL OF FUEL SYSTEM

1. Fuel Filters and Fuel Pipes (Part 1)



Removal of fuel filters and fuel pipes (part 1).

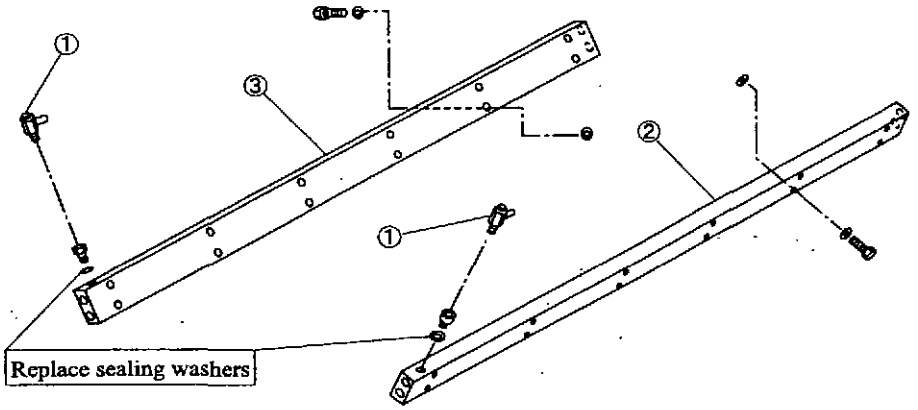
< Removal sequence >

① Drain pipe
② Fuel leak pipe
③ Left side check valve
④ Fuel pipe (left hand)
⑤ Right side check valve
⑥ Fuel pipe (right hand)
⑦ Inlet pipe
⑧ Fuel pipe
⑨ Fuel pipe
⑩ Fuel pipe
⑪ Fuel pipe
⑫ Fuel pipe
⑬ Fuel pipe
⑭ Priming pump
⑮ Bracket
⑯ Fuel pipe
⑰ Fuel pipe
⑱ Fuel filter
⑲ Bracket
⑳ Fuel pipe
㉑ Fuel pipe
㉒ Fuel pipe
㉓ Fuel pipe
㉔ Fuel filter assembly (switchover)
㉕ Inlet pipe
㉖ Fuel pipe
㉗ Fuel pipe
㉘ Fuel filter assembly (primary)
㉙ Bracket

⚠ CAUTION

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

2. Fuel Filters and Fuel Pipes (Part 2)

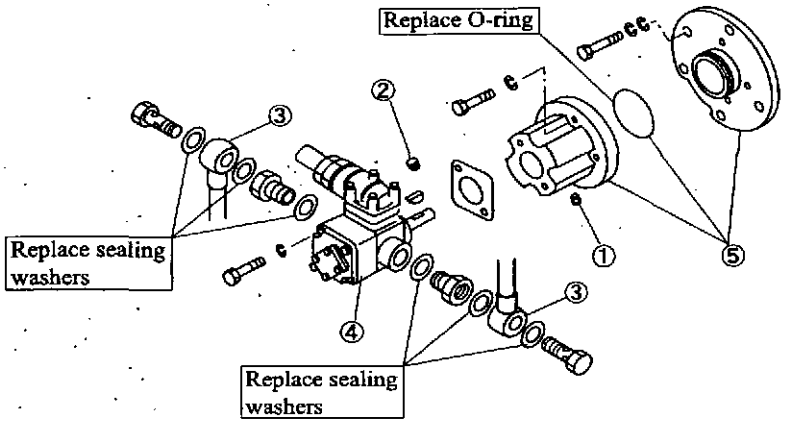


Removal of fuel filters and fuel pipes (part 2)

< Removal sequence >

① Air valve (right and left) ⑦ Fuel pipe ⑬ Fuel pipe

3. Fuel Feed Pump and Accessory Drive

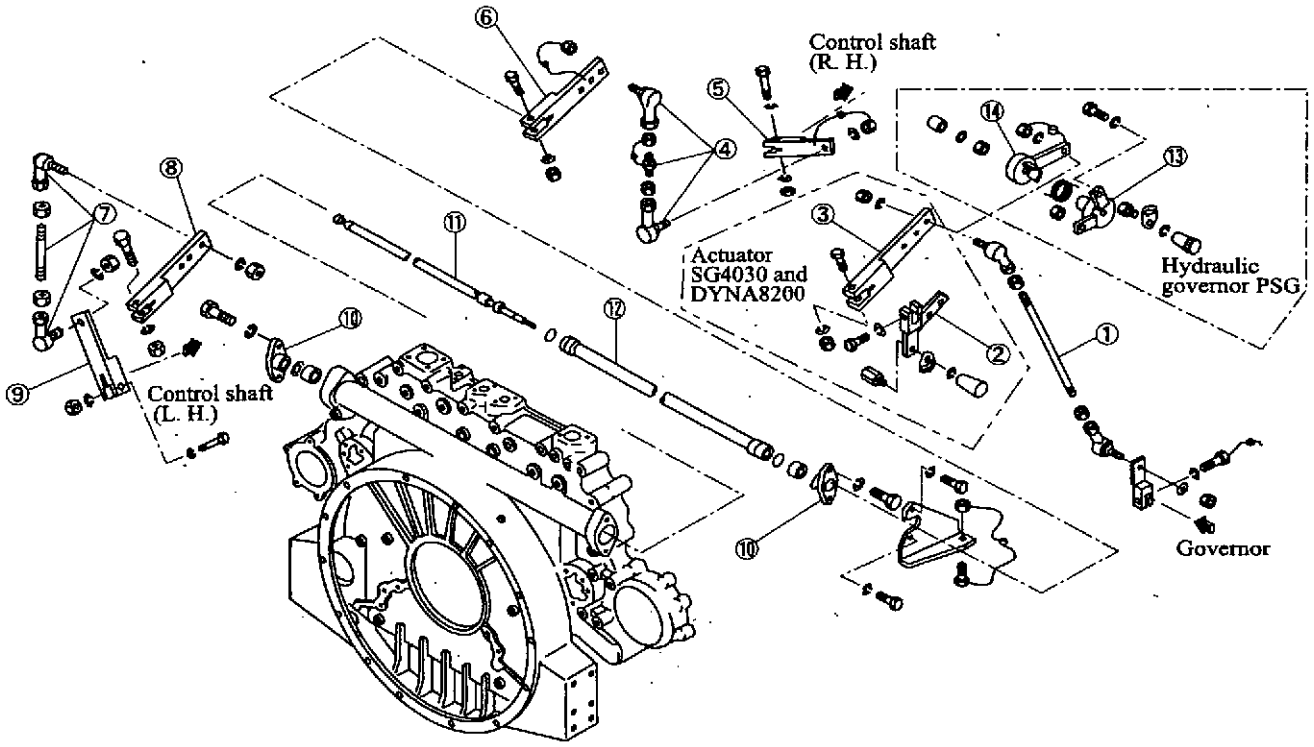


Removal of fuel feed pump and accessory drive

< Removal sequence >

① Plug ② Screw ③ Fuel pipe ④ Feed pump ⑤ Accessory drive

4. Fuel Control Links

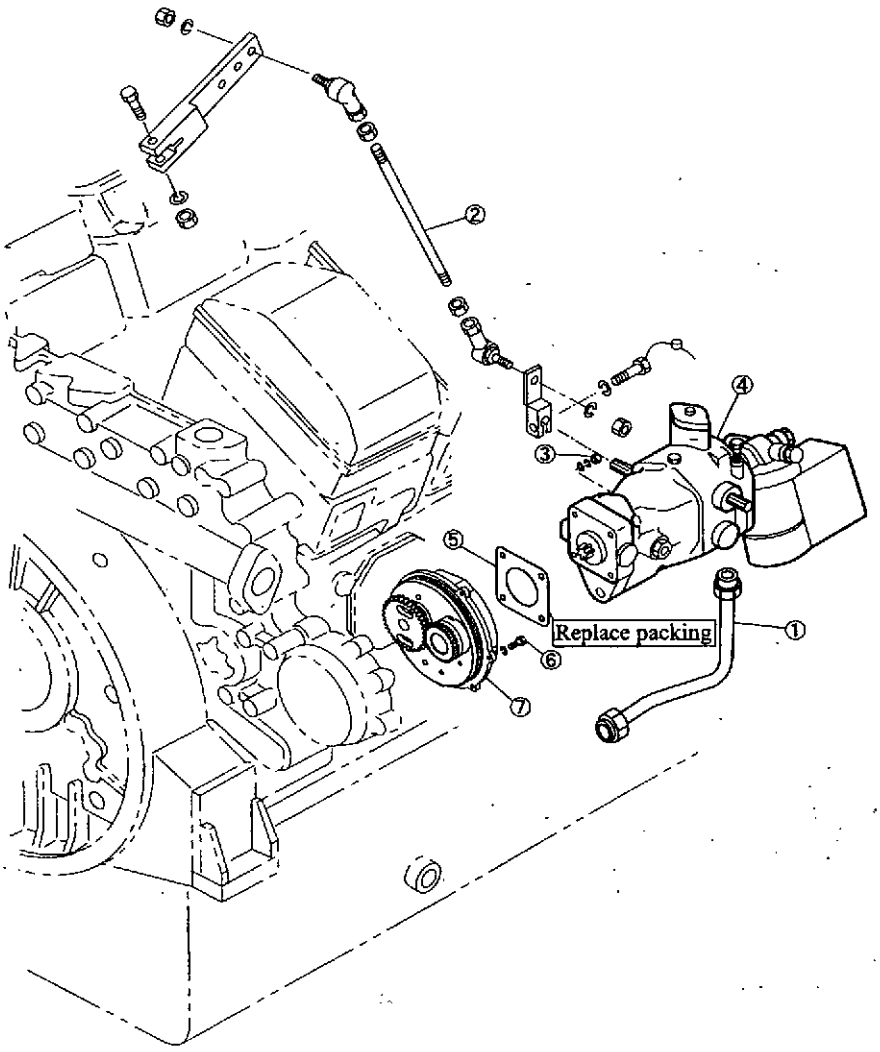


Removal of fuel control link

< Removal sequence >

① Control link
② Stop lever
③ Control lever
④ Control link
⑤ Control lever
⑥ Control lever
⑦ Control link
⑧ Control lever
⑨ Control lever
⑩ Bearing cover
⑪ Control shaft
⑫ Timing case pipe
⑬ Cancel lever A
⑭ Cancel lever B

5. Governor (PSG)

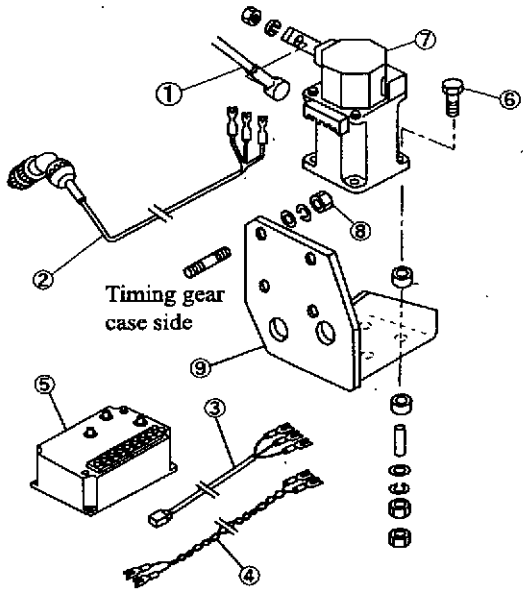


Removal of governor (PSG)

< Removal sequence >

① Drain pipe
② Rod assembly
③ Nut
④ Governor assembly
⑤ Packing
⑥ Bolt
⑦ Governor drive

6. Actuator (DYNA8200)

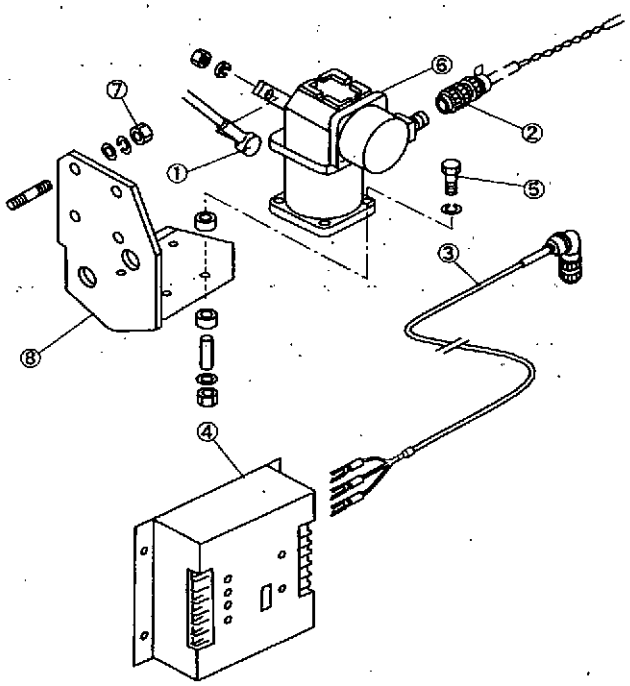


Removal of actuator (DYNA8200)

< Removal sequence >

① Rod
② Connector cable
③ Cable
④ Cable
⑤ Controller
⑥ Bolt
⑦ Actuator
⑧ Nut
⑨ Actuator bracket

7. Actuator (SG4030)



Removal of actuator (SG4030)

< Removal sequence >

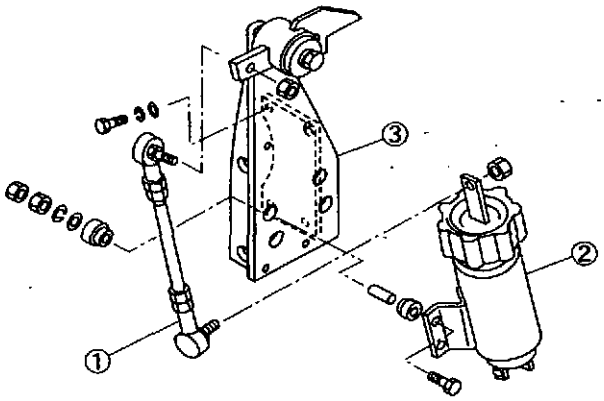
① Rod
② Connector
③ Connector cable
④ Speed controller
⑤ Bolt
⑥ Actuator
⑦ Nut
⑧ Actuator bracket

8. Unit Injector

For unit injector removal procedure, refer to the section on REMOVAL OF ENGINE MAIN PARTS.

9. Stop Solenoids

9.1 Removal of Stop Solenoids (RUN-ON)

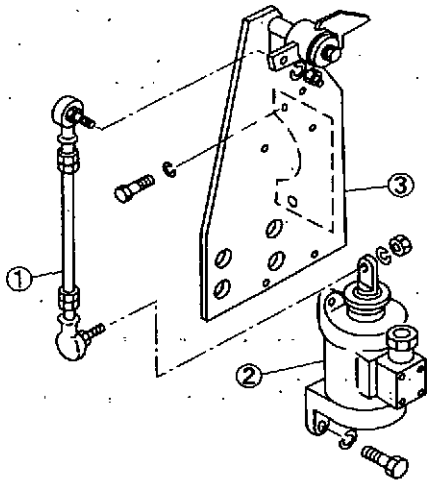


Removal of stop solenoids (RUN-ON)

< Removal sequence >

① Rod assembly ② Stop solenoid ③ Stop solenoid bracket

9.2 Removal of Stop Solenoids (RUN-OFF)



Removal of stop solenoids (RUN-OFF)

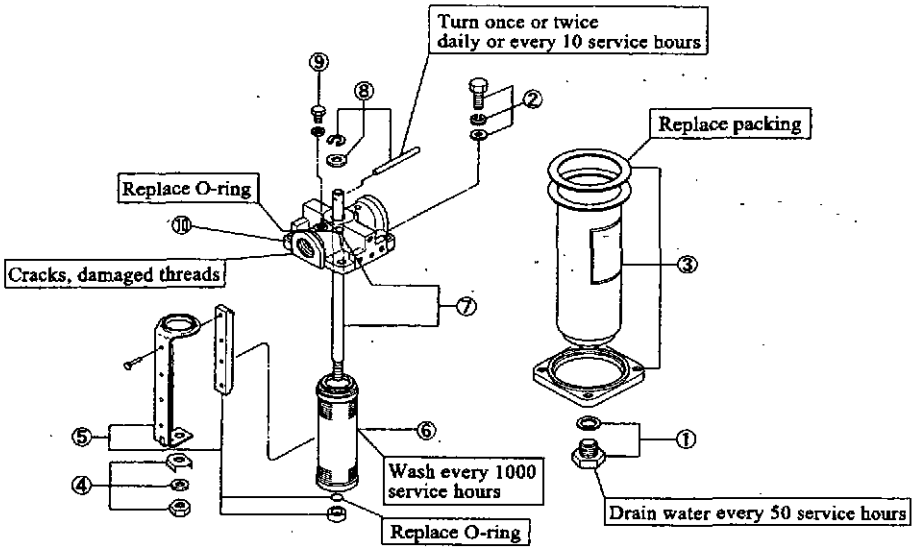
< Removal sequence >

① Rod assembly ② Stop solenoid ③ Stop solenoid bracket

DISASSEMBLY, INSPECTION AND REASSEMBLY OF FUEL SYSTEM

1. Fuel Filters (Wire Element Type for Class A Heavy Oil)

1.1 Disassembly and Inspection of Fuel Filters (Wire Element Type for Class A Heavy Oil)



Disassembly and inspection of fuel filters (wire element type for class A heavy oil)

< Removal sequence >

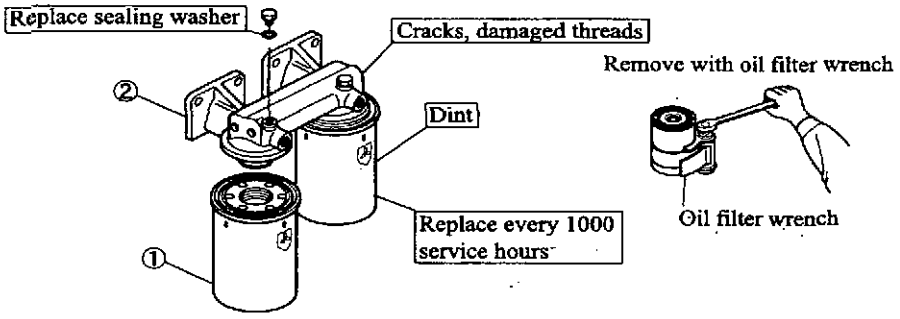
① Drain plug and packing
② Bolt, spring washer and washer
③ Lower case, flange and packing
④ Nut
⑤ Plate, scraper, collar and O-ring
⑥ Element
⑦ Rod and O-ring
⑧ Snap ring, washer and handle
⑨ Bolt
⑩ Cover

1.2 Reassembly of Fuel Filters (Wire Element Type for Class A Heavy Oil)

To reassemble, follow the disassembly sequence in reverse.

2. Fuel Filters

2.1 Disassembly and Inspection of Fuel Filters



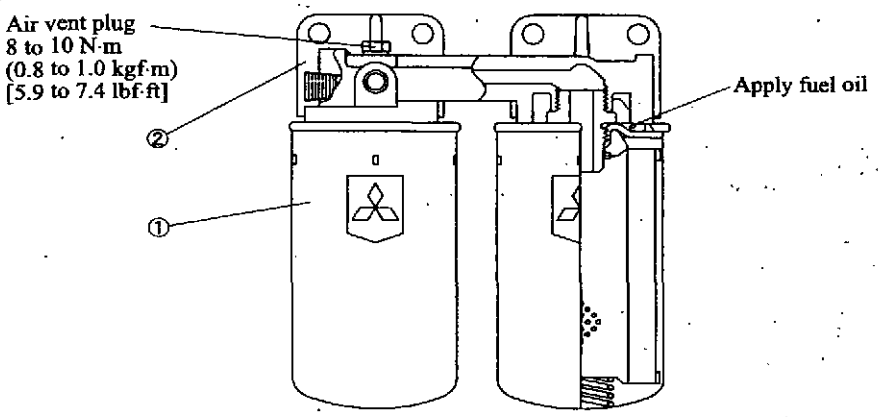
Disassembly and inspection of fuel filters

< Disassembly sequence >

① Element ② Fuel filter bracket

Name of basic tool	Part No.
Oil filter wrench	32591-22100

2.2 Reassembly of Fuel Filters



Reassembly of fuel filters

< Reassembly sequence >

②→①

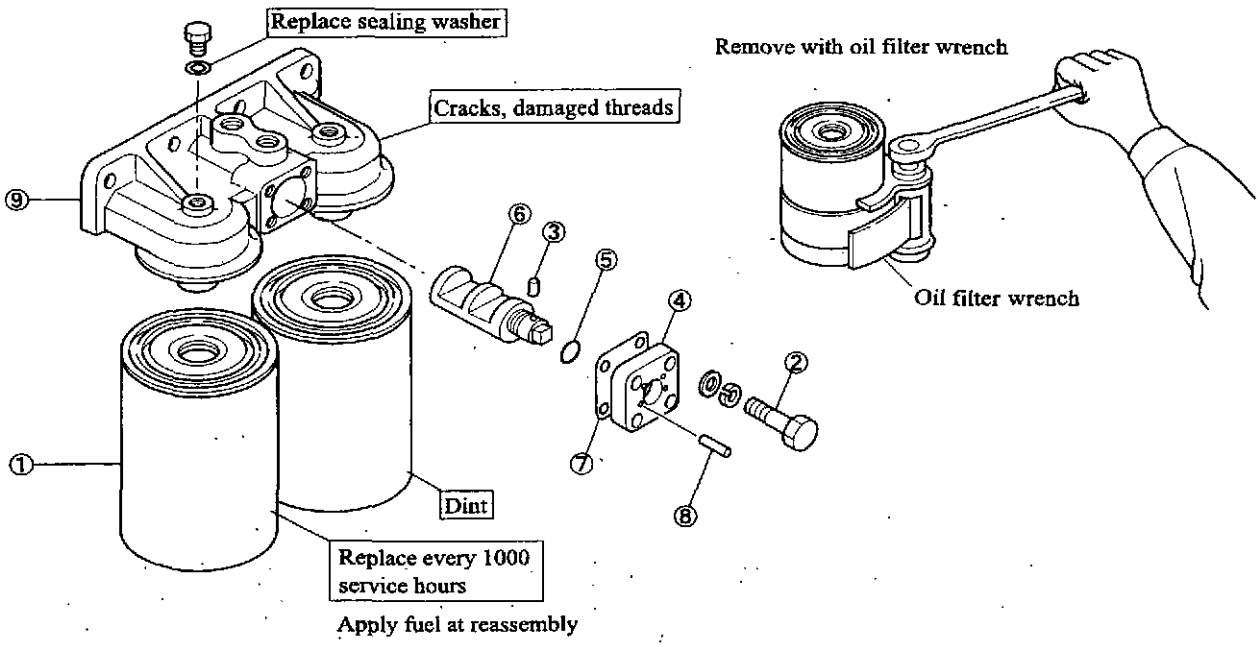
⚠ CAUTION

After reassembly, start the engine and check for fuel leaks.

Before installing the cartridge, clean the mounting surface of the cartridge, coat the gasket with clean fuel oil. Screw in the cartridge until the gasket contacts the seal surface of the bracket, then further rotate 3/4 to 1 turn by hand. (Do not use a filter wrench for installation. Do not use a filter that has dents or scratches, since damaged filter can break during engine operation.)

3. Switchover Fuel Filters

3.1 Disassembly and Inspection of Switchover Fuel Filters



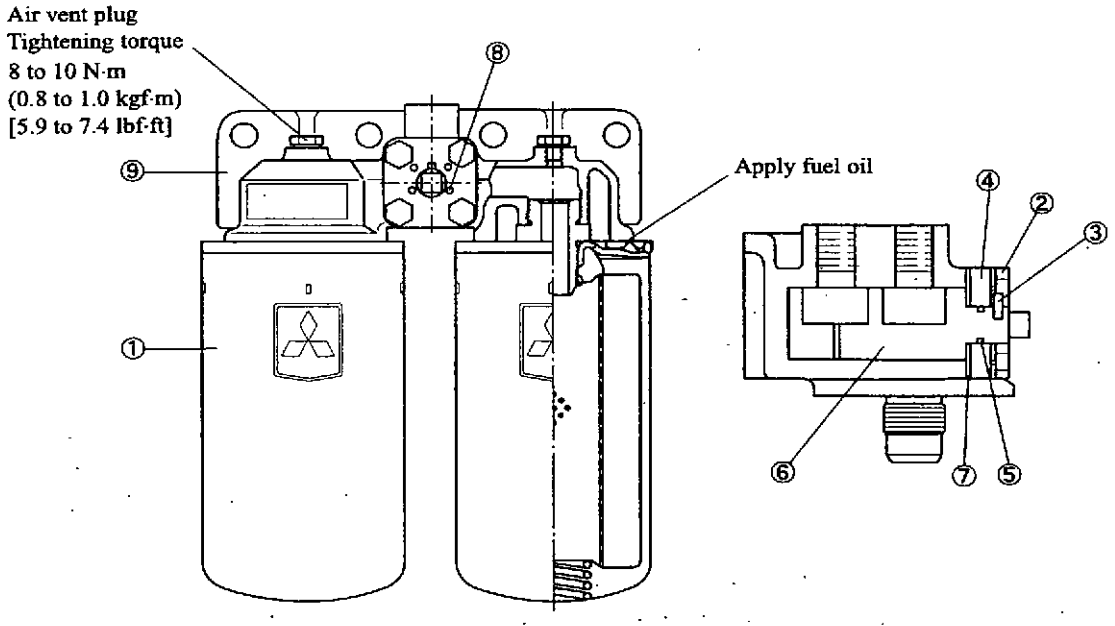
Disassembly and inspection of switchover fuel filters

Name of basic tool	Part No.
Oil filter wrench	32591-22100

< Disassembly sequence >

① Element
② Bolt
③ Pin
④ Cover
⑤ O-ring
⑥ Cock
⑦ Gasket
⑧ Pin
⑨ Fuel filter bracket

3.2 Reassembly of Switchover Fuel Filters



Reassembly of switchover fuel filters

< Reassembly sequence >

⑨→⑧→⑦→⑥→⑤→④→③→②→①

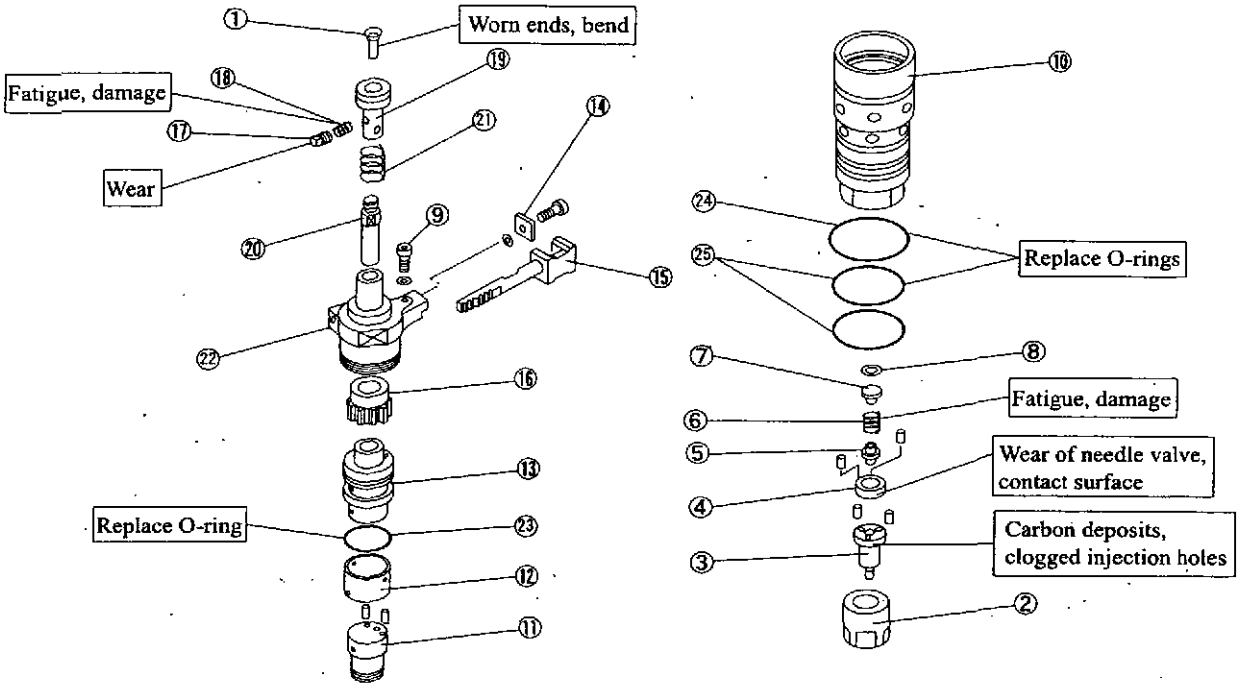
Before installing the cartridge, clean the mounting surface of the cartridge, coat the gasket with clean fuel oil. Screw in the cartridge until the gasket contacts the seal surface of the bracket, then further rotate 3/4 to 1 turn by hand. (Do not use a filter wrench for installation. Do not use a filter that has dents or scratches, since damaged filter can break during engine operation.)

⚠ CAUTION

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

4. Unit Injector

4.1 Disassembly and Inspection of Unit Injector



Disassembly and inspection of unit injector

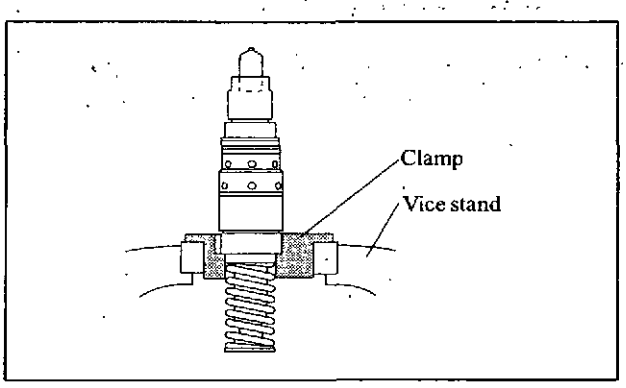
<Disassembly sequence>

① Plunger pushrod
② Nozzle retaining nut
③ Nozzle tip
④ Distance piece
⑤ Lower retainer
⑥ Needle valve spring
⑦ Spring seat
⑧ Needle valve shim
⑨ Stand gage
⑩ Body retaining nut
⑪ Spring gage
⑫ Spill deflector
⑬ Plunger barrel
⑭ Adjusting plate
⑮ Control rack
⑯ Pinion
⑰ Stopper
⑱ Stopper spring
⑲ Plunger tappet
⑳ Plunger
㉑ Plunger spring
㉒ Body
㉓ O-ring
㉔ O-ring
㉕ O-ring

⚠ CAUTION

(a) Use the clamp to fix the unit injector on the vice stand for disassembly.
(b) Arrange the disassembled unit injector for each cylinder. Make sure that the parts are not mixed with other cylinder parts.

Name of special tool	Part No.
Clamp	48749-01000



Fixing unit injector

(1) Removal of plunger pushrod

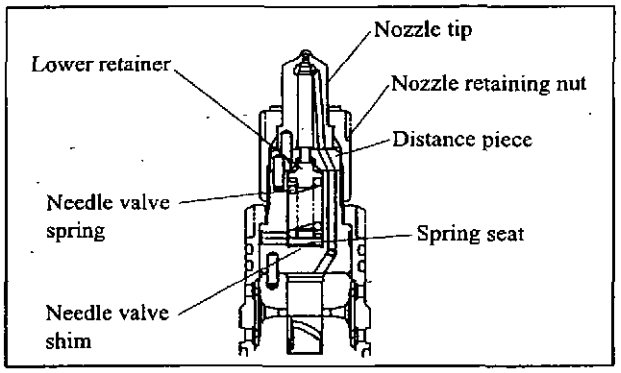
Remove the plunger pushrod from the plunger tappet.

(2) Removal of nozzle tip

Remove carbon deposits thoroughly from the nozzle using a wire brush. Remove the copper gasket.

If the copper gasket is not on the unit injector, it is still attached to the engine cylinder head. In that case, be sure to remove it from the cylinder head..

Loosen the nozzle retaining nut, and remove the nozzle tip, the distance piece, the lower retainer, the needle valve spring, the spring seat and the needle valve shim.



Removal of nozzle tip

⚠ CAUTION

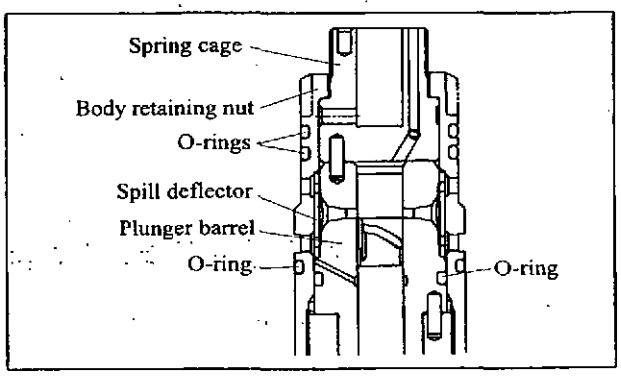
Remove carbon and dust from the nozzle tip contact area of the nozzle retaining nut.

If dust and carbon remains between the nozzle tip and the nozzle retaining nut, combustion gas can enter the unit injector insertion section. This can cause the injector to eject due to a pressure buildup of gas that entered during disassembly, thusleading to injuries and accident.

Note: Make sure that the needle valve shim is not left inside spring cage.

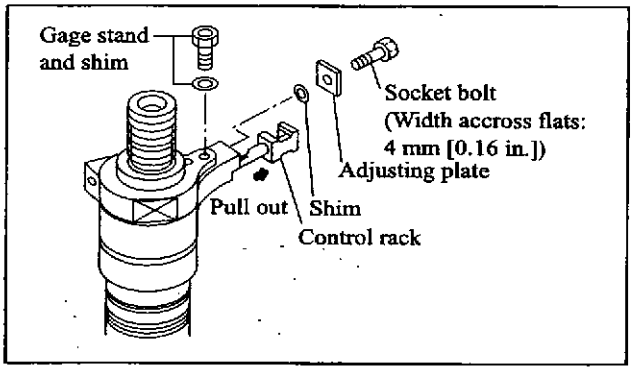
(3) Removal of the plunger barrel

Loosen the body retaining nut and remove the spring cage, the spill deflector and the plunger barrel. Remove O-rings, then install new O-rings.



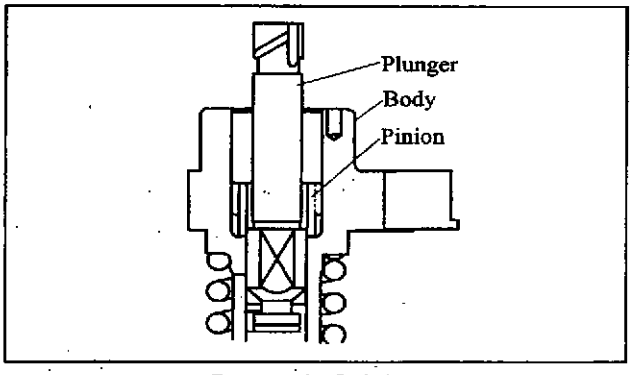
Removal of plunger barrel

(4) Removal of control rack
Remove the stand gage and the shim. Remove the screw, then remove the adjusting plate and the shim. Slowly pull out the control rack according to the pinion rotation.



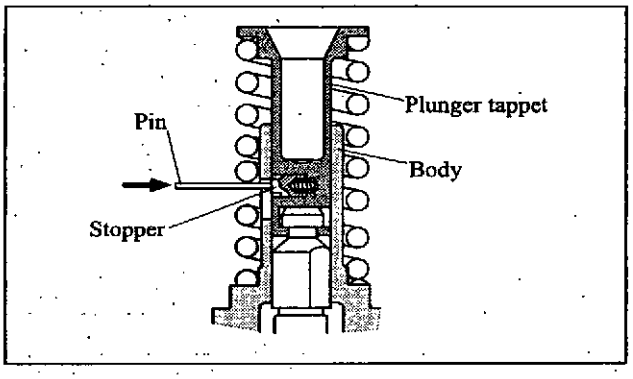
Removal of control rack

(5) Removal of pinion
Remove the pinion from the plunger.



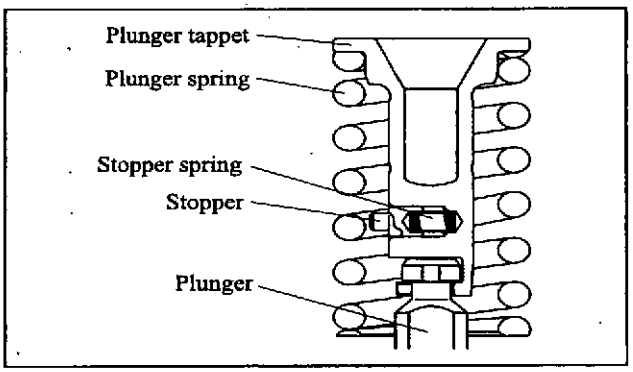
Removal of pinion

(6) Removal of stopper



Removal of stopper

(7) Disassembly of tappet sub assembly
Remove the plunger spring, then take out the stopper and the stopper spring. Separate the plunger tappet from the plunger.



Disassembly of tappet sub assembly

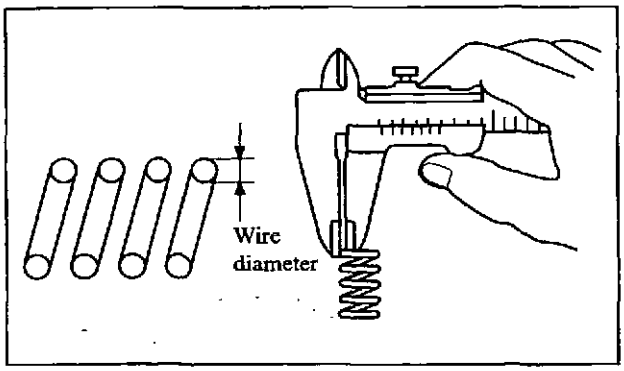
4.2 Inspection of Unit Injector

(1) Measurement of wire diameter of stopper spring

Measure the wire diameter of the stopper spring. If the measured diameter is smaller than the service limit, replace with a new part.

Unit mm [in.]

	Nominal value	Standard	Limit
Stopper spring wire diameter	ϕ0.4 [0.016]	0.3992 to 0.4008 [0.0157 to 0.1556]	0.25 [0.0099]



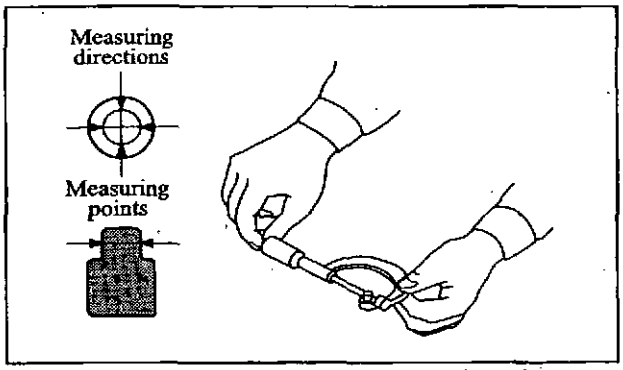
Measurement of wire diameter of stopper spring

(2) Measurement of diameter protruded section of stopper diameter

Measure the diameter of the protruded section of the stopper. If the measured diameter is smaller than the limit, replace with a new part.

Unit mm [in.]

	Nominal value	Standard	Limit
Stopper protrusion diameter	ϕ4 [0.1576]	3.85 to 3.95 [0.1517 to 0.1556]	3.5 [0.1378]



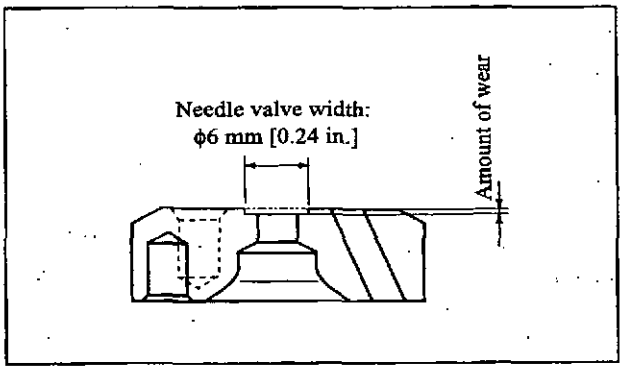
Measurement of diameter protruded section of stopper diameter

(3) Measurement of wear on needle valve contact area of distance piece

Measure the amount of wear on the needle valve contact area of the distance piece. If the measured value exceeds the service limit, replace with a new part.

Unit mm [in.]

	Standard	Limit
Wear on needle valve contact area of distance piece	0 [0]	-0.2 [-0.0079]



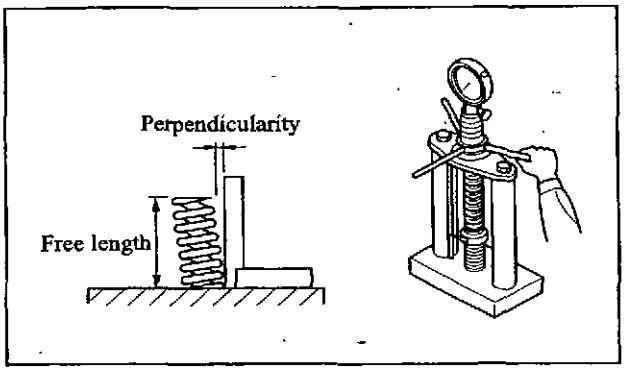
Measurement of wear on needle valve contact area of distance piece

(4) Measurement of needle valve spring perpendicularity and free length

Inspect the amount of needle valve spring perpendicularity and the decrease of free length. If the measured value exceeds the service limit, replace with a new part.

Unit mm [in.]

	Standard	Limit
Free length	27.6 [1.0874]	27.2 [1.0709]
Perpendicularity	Less than 0.5 [0.0197]	0.5 [0.0197] or more

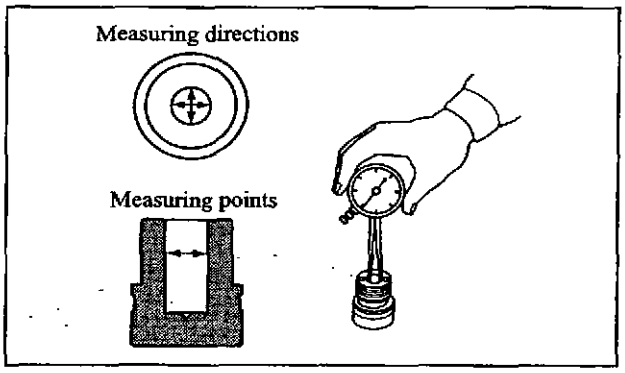


Measurement of needle valve spring perpendicularity and free length

(5) Measurement of spring cage inside diameter
Measure the inside diameter of the spring cage. If the measured diameter exceeds the service limit, replace with a new part.
Diameter measured at groove caused by wear must not exceed the service limit.

Unit mm [in.]

	Nominal value	Standard	Limit
Spring cage inside diameter	ϕ14 [0.552]	14.01 to 14.02 [0.5520 to 0.5524]	14.6 [0.5752]

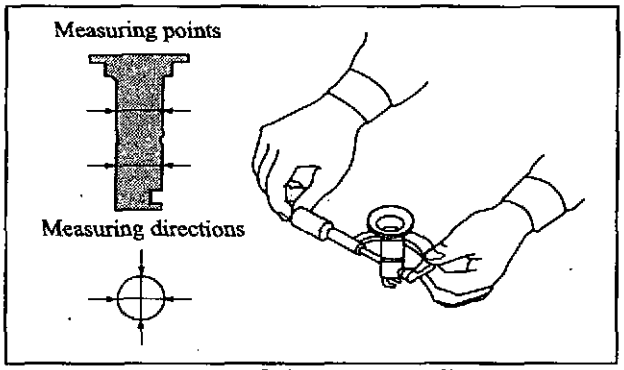


Measurement of spring cage inside diameter

(6) Measurement of plunger tappet diameter
Measure the diameter of the plunger tappet.
If the measured diameter is smaller than the limit, replace with a new part.

Unit mm [in.]

	Nominal value	Standard	Limit
Plunger tappet diameter	ϕ18 [0.710]	17.966 to 17.984 [0.7079 to 0.7086]	17.959 [0.7076]

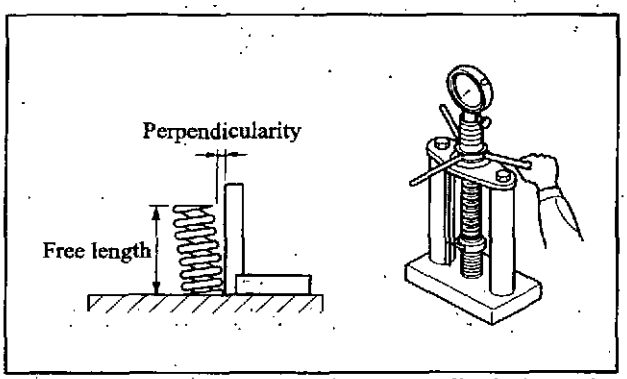


Measurement of plunger tappet diameter

(7) Measurement of plunger spring perpendicularity and free length
Inspect the amount of needle valve spring perpendicularity and the decrease of free length. If the measured value exceeds the limit, replace with new parts.

Unit mm [in.]

	Standard	Limit
Free length	84±2 [3.310±0.08]	81.5 [3.21]
Perpendicularity	Less than 1.5 [0.060]	1.5 [0.060] or more

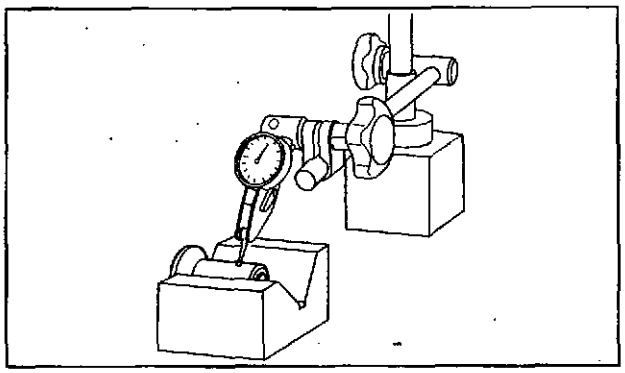


Measurement of plunger spring perpendicularity and free length

(8) Measurement of plunger pushrod deflection
Measure the deflection of plunger pushrod. If the limit is exceeded, replace with new parts.

Unit mm [in.]

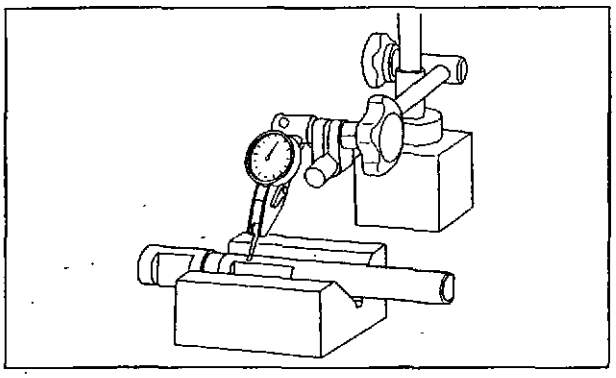
	Limit
Plunger pushrod deflection	0.15 [0.006]


Measurement of plunger pushrod deflection

(9) Measurement of control rack deflection
Measure the deflection of plunger pushrod. If the limit is exceeded, replace with new parts.
If the sliding resistance exceeds the limit, replace with the new parts.

Unit mm [in.]

		Limit
Control rack	Deflection	0.03 [0.0012]
	Sliding resistance	0.49 N (50 gf) [0.11 lbf]



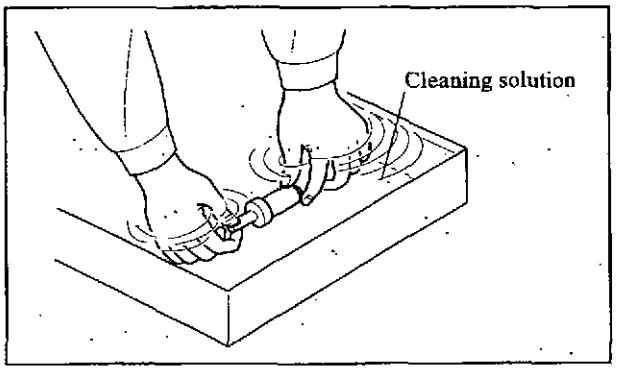
Measurement of control rack deflection

(10) Inspection of nozzle tip
(a) *Spray pattern of nozzle tip*
Refer to the "3.3 Adjustment" section.
(b) Check the needle valve movement, injection hole clogging and carbon deposits. If any abnormalities are found, clean or replace the nozzle tip.

(11) Cleaning nozzle tip
(a) Clean the needle valve and body in cleaning solution.

⚠ CAUTION

Be sure to use clean solution.



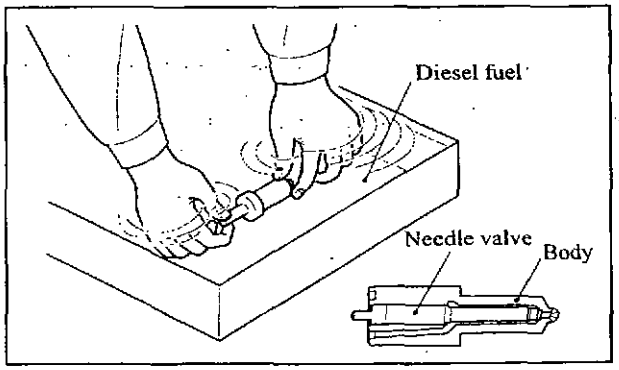
Cleaning nozzle tip (1)

(b) After washing, assemble the needle valve and body in clean diesel fuel.

Note: The needle valve and body are precision parts. Therefore, handle them with care, and never change the combination of the original needle valve and body set.

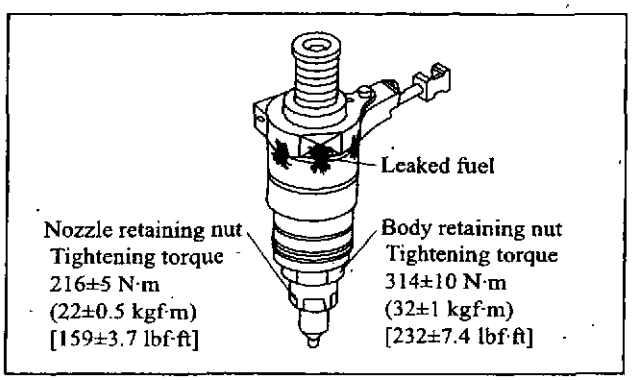
(c) If the spray pattern is still bad after the nozzle has been adjusted and cleaned, replace the nozzle tip.

Note: New nozzle tips are pre-coated with Vaseline and a rust-preventive agent. Be sure to wash off these coatings with cleaning solution, then clean again with diesel fuel before assembling.



Cleaning nozzle tip (2)

(12) Inspection of unit injector fuel leakage
Inspect the entire surface of the body for marks left by leaked fuel. If fuel leakage is suspected, inspect the O-ring on the plunger barrel, and tighten the nozzle retaining nut or body retaining nut to the specified torque.



Inspection of unit injector fuel leakage

4.3 Adjustment of Unit Injector

⚠ CAUTION

(a) Special equipment is required for the adjustment of unit injectors. Therefore, unit injectors must be adjusted by a service shop equipped with proper tools.

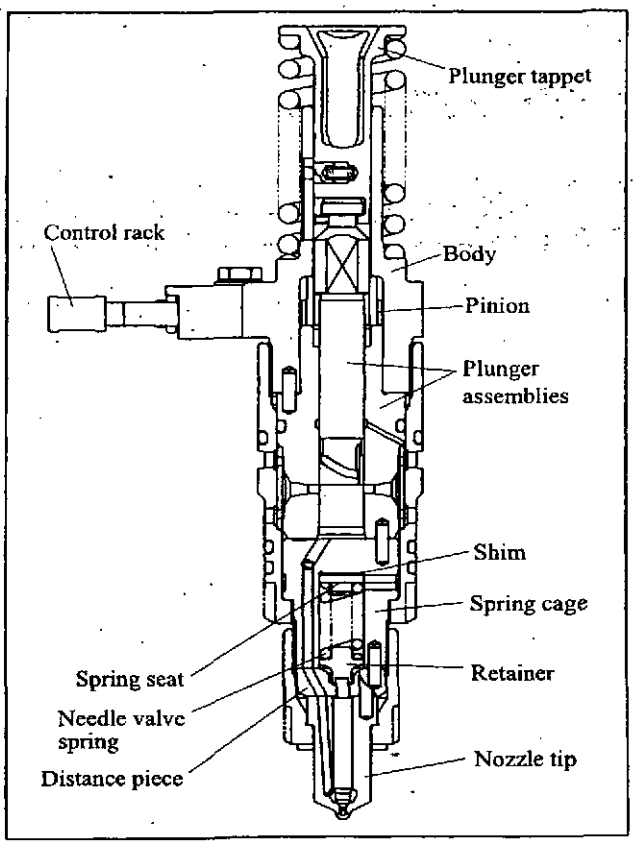
(b) Adjustment items differ depending on parts to be replaced. Make necessary adjustments according to the following table. If unit injectors are overhauled as specified, it is necessary to perform all designated adjustments.

Items to be adjusted when parts are replaced

Replaced part	Valve opening pressure adjustment	Injection volume adjustment	Prestroke adjustment
Nozzle tip	○		
Distance piece	※		
Lower retainer	※		
Spring cage	※		
Needle valve spring	○		
Spring seat	※		
Shim	※		
Plunger assembly		○	○
Pinion		○	
Control rack		○	
Body		○	○
Plunger tappet			○

○ : Adjustment is necessary even when another part is replaced.

※ : Adjustment is necessary only when another part is also replaced.
Adjustment is not necessary when no other part is replaced.

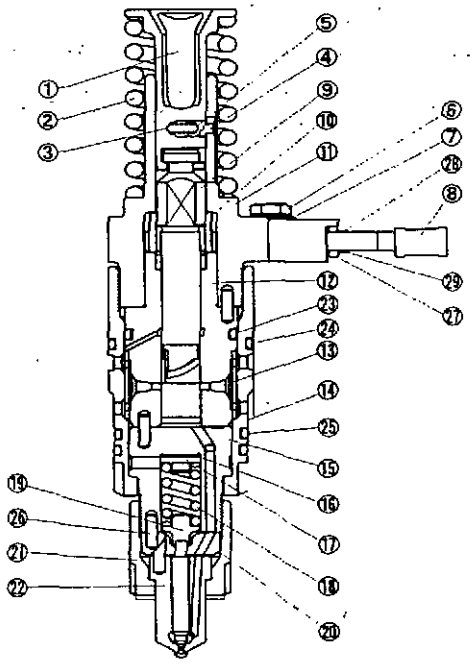


Adjustment of unit injector

Replacement and inspection timing

○ Replace △ Inspect

No.	Name of part	Part No.	Every 2000 service hours	Every 6000 service hours	Every 12000 service hours	Every 24000 service hours
①	Plunger pushrod	48745-10100			△	○
②	Plunger spring	48745-10500			○	○
③	Plunger tappet	48745-10200			△	○
④	Stopper	48745-00301			△	○
⑤	Stopper spring	48745-00401			○	○
⑥	Gage stang	48743-10400				△
⑦	Shim	48743-00300				△
⑧	Control rack	48742-00202			△	○
⑨	Plunger	48741-03020	Replace as a set	△	△	△
⑩	Pinion	48742-00102			△	○
⑪	Body	48743-20100			△	○
⑫	Plunger barrel	48741-03010	Replace as a set	△	△	△
⑬	Spill deflector	48744-00302		△	△	△
⑭	Body retaining nut	48744-00201				△
⑮	Spring gage	48746-10100		△	△	○
⑯	Needle valve shim	48742-00301	○	○	○	○
⑰	Spring seat	48746-00601		△	△	○
⑱	Needle valve spring	48746-00401		○	○	○
⑲	Retainer	48746-10501		△	○	○
⑳	Distance piece	48746-10201		△	○	○
㉑	Nozzle retaining nut	48744-00101				△
㉒	Nozzle tip	37561-07800	○	○	○	○
㉓	O-ring	05507-10340	○	○	○	○
㉔	O-ring	05507-10400	○	○	○	○
㉕	O-ring	05507-10420	○	○	○	○
㉖	Dowel pin	F8001-40014				△
㉗	Shim	48722-00300				△
㉘	Bolt	F1210-05010				△
㉙	Adjusting plate	48722-00400				△



(1) Adjustment of valve opening pressure

(a) Insert the dowel pin into the spring cage, then install the connector.

Name of special tool	Part No.
Connector	48749-00100

(b) Tighten the body retaining nut to the specified torque by 2-step tightening method.

Note: Before tightening the body retaining nut, apply engine oil

(c) Insert the dowel pin into the spring cage. Install the needle valve shim, the spring seat, the needle valve spring and the lower retainer, then place the distance piece in position.

Note: Be sure to install the needle valve shim and the spring seat in proper order.

(d) Insert the dowel pin into the distance piece. Install the nozzle tip, then tighten the nozzle retaining nut to the specified torque by 2-step tightening method.

Note: Before tightening the nozzle retaining nut, apply engine oil to the threads and the shoulder section of the nozzle tip.

(e) Connect the nozzle tester. Press the handle at a rate of once every 1 second and read the pressure level at which fuel injection begins. Also, visually check the spray pattern for abnormalities. If the measured value deviates from the assembly standard, replace the shim.

Name of special tool	Part No.
Nozzle tester	04239-00050

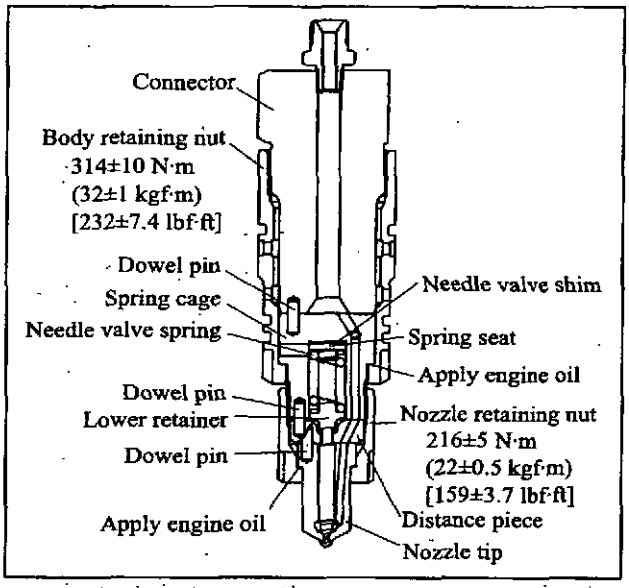
Unit MPa (kgf/cm^2) [psi]

	Nominal value	Standard	Remedy
Valve opening pressure	29.42 (300) [4268]	28.93 to 30.89 (295 to 315) [4196 to 4481]	Shim thickness should be less than 0.8 mm [0.032 in.]. If it exceeds the limit, replace the spring.

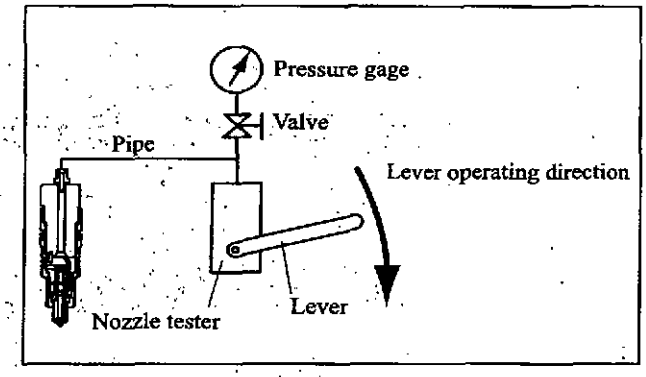
⚠ CAUTION

Do not touch the fuel spray. Fuel is sprayed from the nozzle under high pressure, and it can penetrate the skin, thus causing serious health problems.

Note: If the specified valve opening pressure cannot be achieved with a 0.80 mm [0.032 in.] shim, replace the needle valve spring.



Inspection of unit injector valve opening pressure (1)



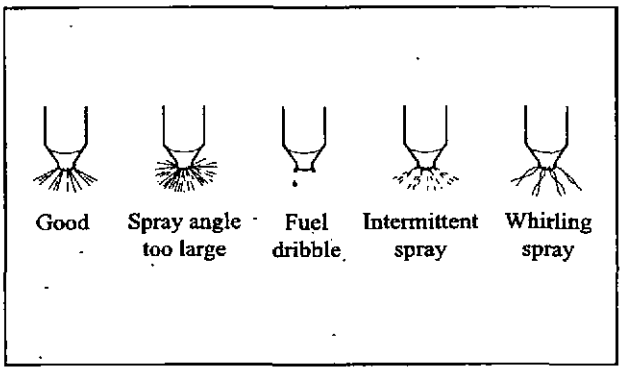
Inspection of unit injector valve opening pressure (2)

Shim types

$P=29.42^{+1.47}_{-0.49}$ MPa (300^{+15}_{-5} kgf/cm^2) [$4267^{+213}_{-71.1}$ psi]

Part No.	Shim thickness mm [in.]	Valve opening pressure (MPa (kgf/cm^2) [psi])
48742-00311	0.40 [0.016]	-3.20 (-32.6) [-463.7]
48742-00321	0.50 [0.020]	-1.60 (-16.3) [-231.9]
48742-00331	0.60 [0.024]	0.0 (0.0) [0.0] standard
48742-00341	0.70 [0.028]	1.60 (16.3) [231.9]
48742-00351	0.80 [0.032]	3.20 (32.6) [463.7]

(f) Spray pattern
When adjusting the injection pressure with the nozzle tester, also check the nozzle for clogs, spray pattern and fuel leaks, if the spray pattern is faulty, clean or replace the nozzle tip.
When the handle of the nozzle tester is pressed hard, the nozzle should spray fuel from its ten holes at the same time to form a clean cone-shaped spray pattern with a spray angle of 160°. The spray should consist of finely atomized fuel particles without any large droplets and spray should terminate with no dripping.



Nozzle spray pattern

(g) After adjusting the valve opening pressure, disassemble to prepare for final reassembly.

⚠ CAUTION

Subsequent adjustments require special equipment. Do not attempt to make adjustments at a maintenance or repair site. To make a fuel injection adjustment, it is necessary to measure the injection volume at the operation adjustment point.

(2) Adjustment of pre-stroke

(a) Set the gage and the gage stand as shown in the diagram.

Name of special tool	Part No.
Gage	48749-02010
Gage stand	48749-03080

(b) Remove the gage stand.

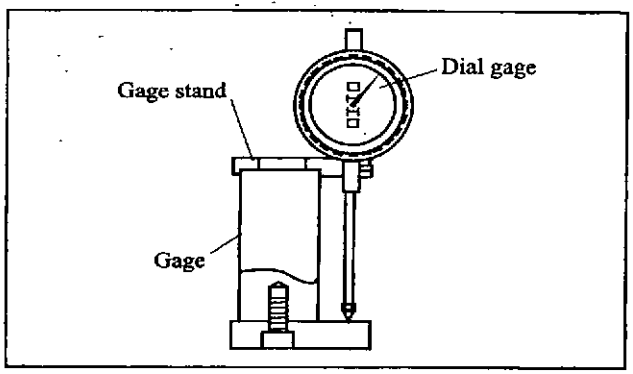
(c) Install the unit injector on the pre-stroke test stand.

Name of special tool	Part No.
Pre-stroke test stand	48749-05000

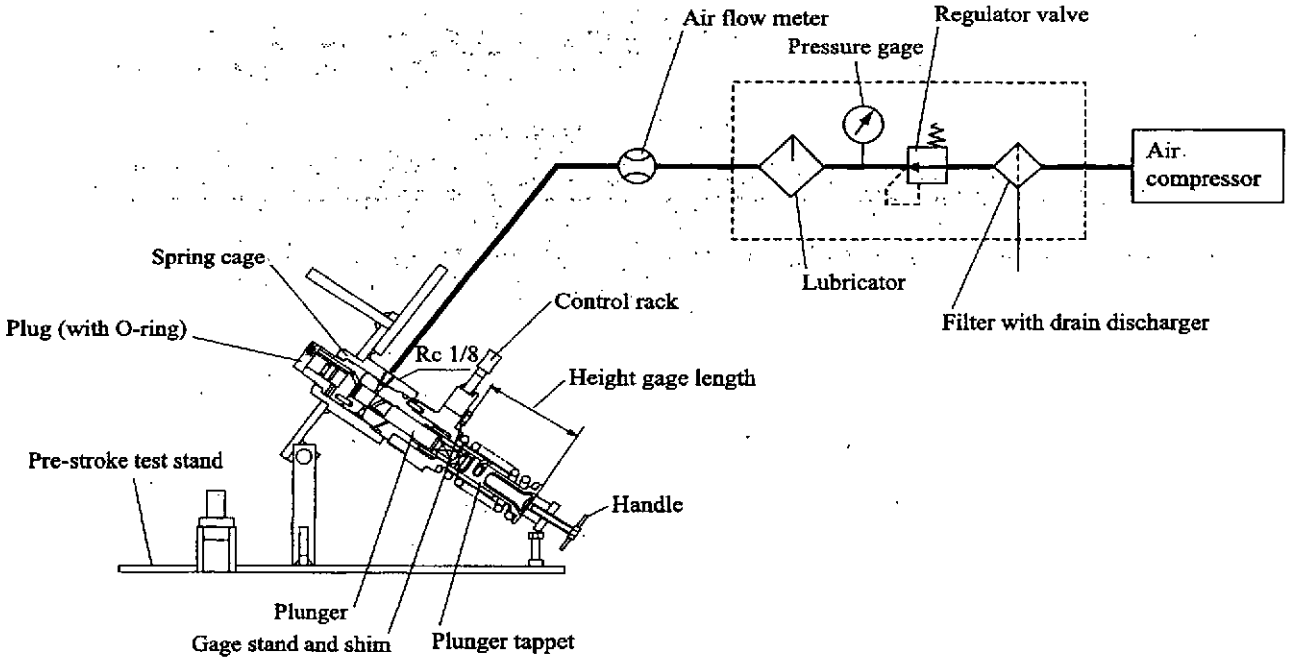
(d) Connect pipes to the air compressor, filter with drain discharger, regulator valve, pressure gage, lubricator, air flow meter, and test stand screw hole (Rc 1/8), as shown in the diagram.

(e) Install the plug attached with the O-ring on the spring cage to cover the leak-off hole.

Name of special tool	Part No.
Plug	48749-00201
O-ring	F3150-01010



Adjustment of pre-stroke (1)



Adjustment of pre-stroke (2)

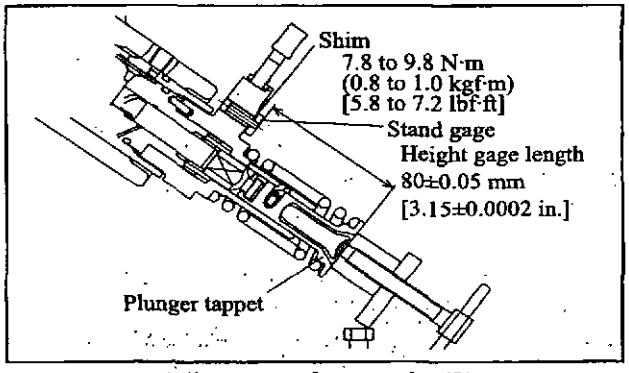
[Test conditions]
- Air temperature Ordinary temperature
- Air supply pressure 0.10 MPa (1 kgf/cm^2) [14.23 psi] or more
- Adjust the regulator valve so that air flows at a rate of approximately 850 cm^3 [51.87 cu. in]/min when the control rack is pressed in (rack 0). (Gage pressure: approx. 0. 01 MPa (0.1 kgf/cm^2) [1.42 psi])

(f) Pull the control rack fully (maximum injection volume).

(g) Rotate the handle of the test stand while ensuring that the plunger is pressed at all times to prevent backlash. Stop turning the handle when the air flow meter indicates 200±10 cm^3 [12.2±0.61cu.in]/min.

(h) Measure the distance between the plunger tappet and the stand gage using the gage stand. Using a shim, adjust the height gage to a length of 80±0.05 mm [3.15±0.0002 in.], then tighten to the specified torque. (Tightening torque: 7.8 to 9.8 N·m (0.8 to 1.0 kgf·m [5.8 to 7.2 lbf·ft])

(i) After adjusting the height gage length, mark the body with paint from the side of the stand gage. This paint mark also serves as an indication of adjustment completion.



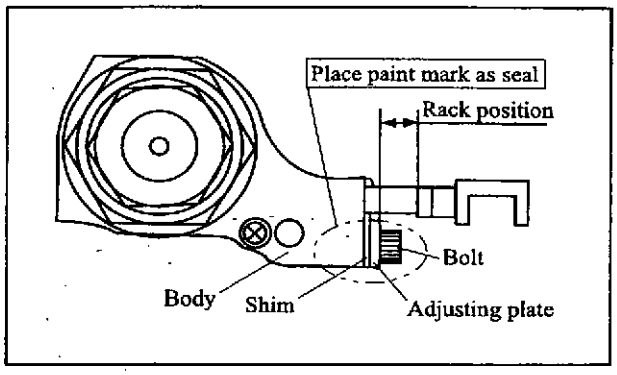
Adjustment of pre-stroke (3)

(3) Adjustment of injection volume

Injection volume adjustment and check points

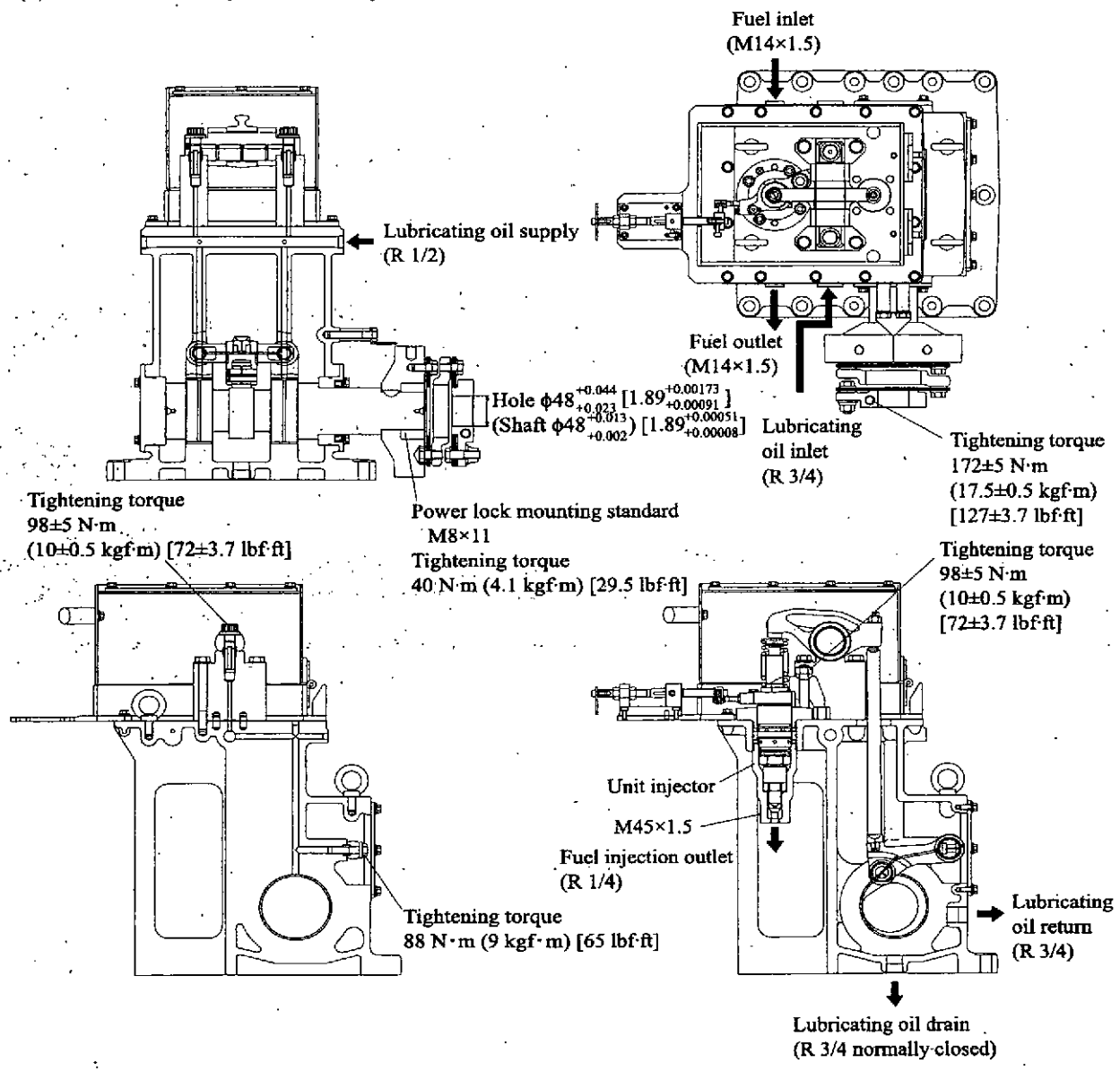
Part No. Identification code	Unit injector part No.	Nozzle type mm [in.]	Cam rotating speed min^{-1}	Engine rotation speed min^{-1}	Rack position mm [in.]	Injection volume g [oz.]/ 400 st	Remedy
AA	48740-13010	φ0.29 [0.0114]- 160° 10 holes	750	1500	8.5 [0.33]	18 to 22 [0.63 to 0.78]	Operation adjustment point
					19 [0.74]	147 to 163 [5.19 to 5.75]	Injection volume check
			300	600	11 [0.43]	14 to 32 [0.49 to 1.13]	Injection volume check
AB	48740-13020	φ0.31 [0.0122]- 160° 10 holes	900	1800	8 [0.31]	15 to 19 [0.53 to 0.67]	Operation adjustment point
					19 [0.75]	147 to 163 [5.19 to 5.75]	Injection volume check
			300	600	11 [0.43]	8 to 26 [0.28 to 0.92]	Injection volume check
CA	48740-12030	φ0.26 [0.0102]- 160° 10 holes	900	1800	8.5 [0.33]	18 to 22 [0.63 to 0.78]	Operation adjustment point
					19[0.74]	147 to 163 [5.19 to 5.75]	Injection volume check
			300	600	11 [0.43]	14 to 32 [0.49 to 1.13]	Injection volume check

(a) Use a shim to adjust the rack installation position at the operation adjustment point to the specified value.



Unit injector rack position

(b) Install the unit injector to the injection volume measurement tester.



Injection volume measurement tester

[Reassembly and operating conditions]

Nozzle gland tightening torque	98±5 N·m (10±0.5kgf·m) [72.33±3.62lbf·ft]
Rocker shaft tightening torque	98±5 N·m (10±0.5kgf·m) [72.33±3.62lbf·ft]
Height gage length	83±0.05 mm [3.270±0.002in.]
Height gage length adjustment timing	30° B T D C (to be set during cam base circle) Note: The height gage used for this adjustment is different from the height gage used for engine reassembly.
Fuel supply pressure	0.39±0.05 MPa (4±0.5kgf/cm^2) [56.9±7.11 psi]
Lubricating oil supply pressure	0.59±0.05 MPa (6±0.5kgf/cm^2) [85.6±7.11psi]
Fuel temperature	35±5°C [95±9°F]

Note: The indicated tightening torque for nozzle gland and rocker shaft is for mounting them on the injection volume measuring instrument, and it is different from the torque used for installation on the engine.

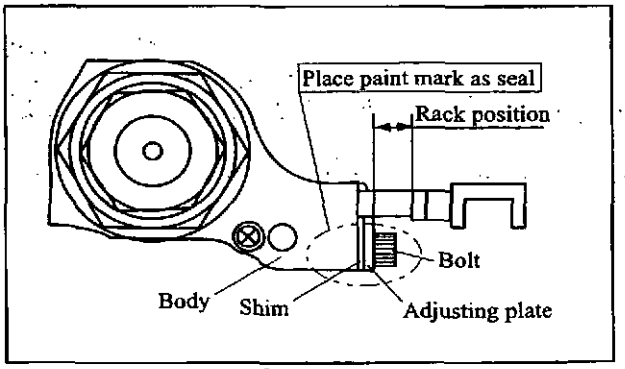
(c) Measure the volume of fuel injected at the operation adjustment point by 400 strokes. Check to see if the fuel volume is within the specified range. If the measured value is not within the specified range, adjust by varying the shim thickness.

Shim thickness	Part No.	Shim thickness	Part No.
0.40 mm [0.016 in.]	48722-00310	0.90 mm [0.035 in.]	48722-00360
0.50 mm [0.020 in.]	48722-00320	1.00 mm [0.039 in.]	48722-00370
0.60 mm [0.024 in.]	48722-00330	1.10 mm [0.043 in.]	48722-00380
0.70 mm [0.028 in.]	48722-00340	1.20 mm [0.047 in.]	48722-00390
0.80 mm [0.032 in.]	48722-00350	—	—

Note: In the SH series, when a thicker shim is installed, the injection volume increases.

(d) When the injection volume is within the specified range at the operation adjustment point, check to see if the injection volume is within the specified range at the injection volume check point.

(e) After adjusting the injection volume, secure the adjusting plate in place using the bolt, then mark the bolt, plate and body with paint to indicate the completion of adjustment.



Unit injector rack position

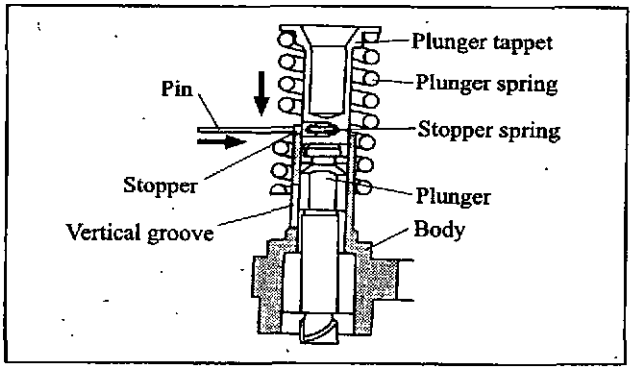
4.4 Reassembly of Unit Injector

(1) Installation of plunger tappet

(a) Install the plunger, the stoper spring, and the stopper in the plunger tappet, and place the plunger spring in position.

(b) Push in the stopper using the pin, and insert the plunger and plunger tappet into the body. Position the stopper into the vertical groove on the body.

(c) Check to make sure the stoppers firmly positioned in the vertical groove on the body.

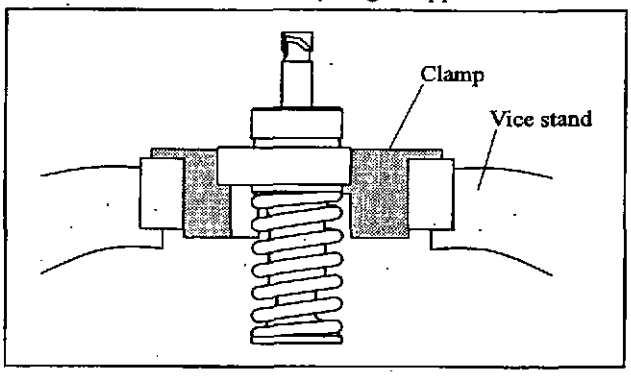


Installation of plunger tappet

(2) Mounting on vice stand

Use the clamp to secure the unit injector in the vice stand.

Name of special tool	Part No.
Clamp	48749-01000



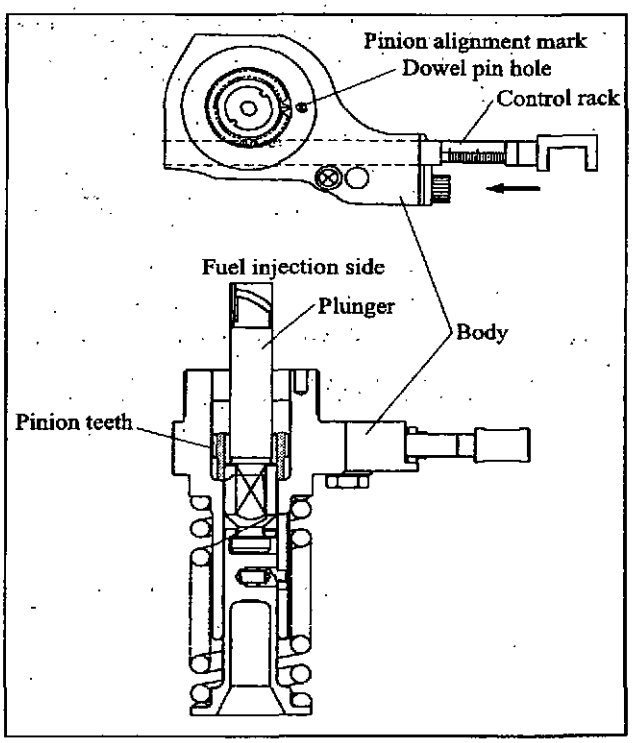
Mounting on vice stand

(3) Installation of control rack

(a) Install the pinion in the plunger, making sure that the teeth of the pinion faces up (fuel injection side).

(b) Align the mark on the pinion with the dowel pin hole.

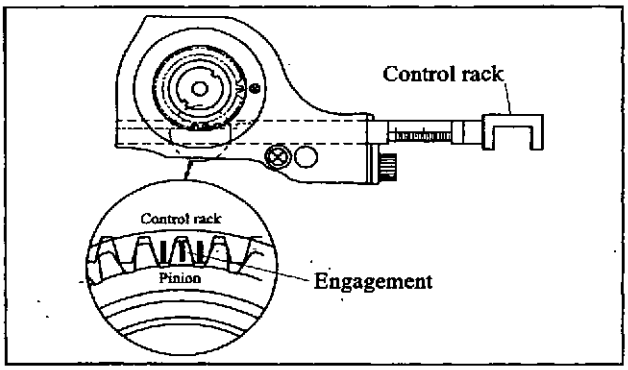
(c) With the parts in the above condition, insert the control rack in the body, making sure that the teeth of the control rack faces the pinion.



Installation of control rack

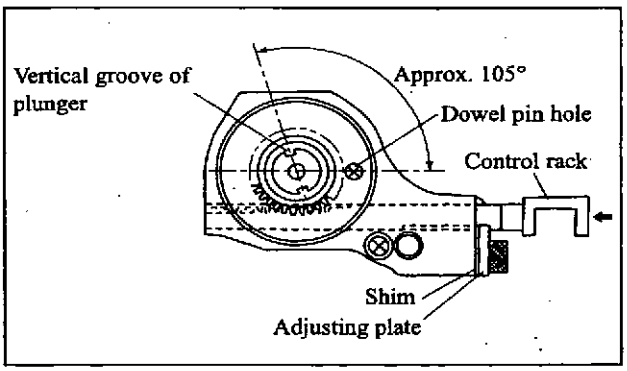
(4) Checking pinion and control rack teeth engagement
  (a) Press the control rack down to check that the alignment mark on the control rack aligns with the mark on the pinion.

Note: Repeat section (3) until the teeth are properly engaged.



Checking pinion and control rack teeth engagement (1)

  (b) Install the shim, and temporarily install the adjusting plate.
  (c) Press the control rack down to check that the angle formed by the vertical groove on the plunger and the dowel pin hole is approximately 105°. If the groove position deviated significantly, repeat from above step (a).



Checking pinion and control rack teeth engagement (2)

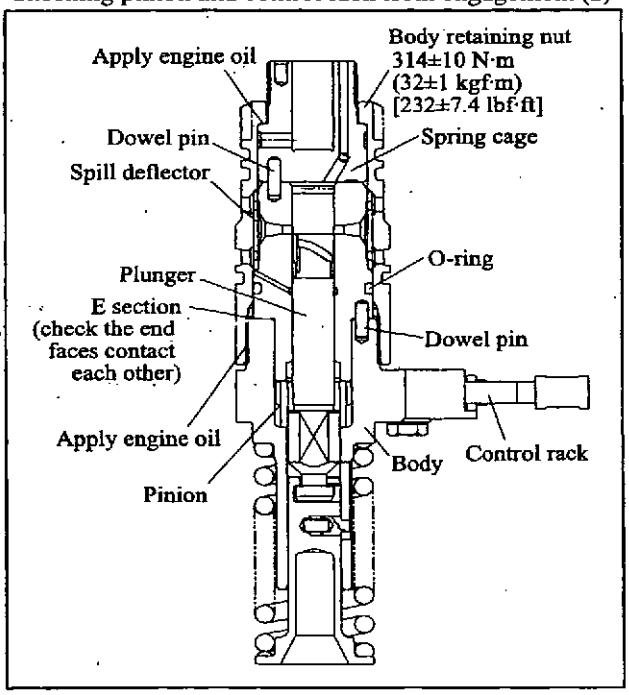
(5) Installation of plunger barrel
  (a) Insert the dowel pin into the bodt. Insert the plunger barrel into the plunger, making sure that there is no interference between the plunger barrel and the plunger.

Note: If the plunger is not properly engaged to the pinion, a gap (approx. 2 mm [0.08 in.]) is produced at the E section. To prevent this gap, check to make sure the end faces contact each other. If a gap is observed, repeat the procedures starting from section (3).

  (b) Install the new O-ring on the plunger barrel, and apply engine oil.
  (c) Install the spill deflector, then check to make sure it rotates smoothly.
  (d) Insert the dowel pin into the plunger barrel, the n install the spring cage.
  (e) Tighten the body retaining nut to the specified torque by 2-step tightening method. (Loosen the nut until it can be turned by hand before tightening second time to the specified torque.)

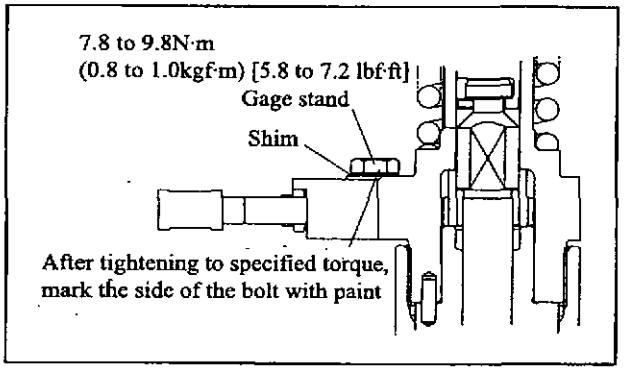
Note: Before tightening the body retaining nut, apply engine oil to the threads, the shoulder section of the spring cage, and the O-ring. Be sure to tighten to the specified torque. Excessive tightening force can result in plunger sticking, while insufficient tightening force can cause fuel leaks.

  (f) Ensure smooth rack operation. (Sliding resistance: 0.49 N (50 gf) [0.11 lbf] or less)



Installation of plunger barrel

(6) Adjustment of pre-stroke
  (a) Install the shim, and temporarily tighten the gage stand.
  (b) Adjust the pre-stroke.
  (c) After adjustment, tighten the gage stand to the specified torque.
  (d) After tightening, mark the side of the bolt with paint.

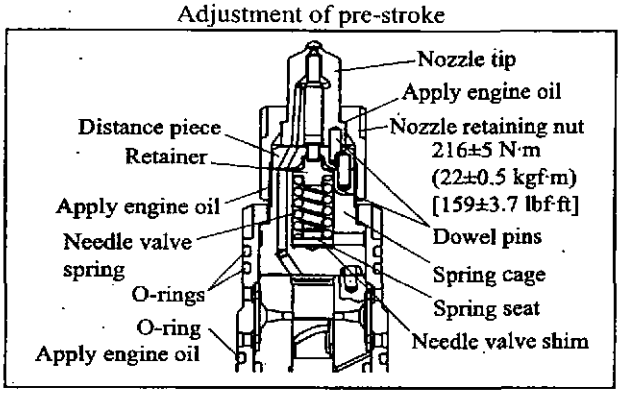


Adjustment of pre-stroke

(7) Installation of nozzle tip
  (a) Insert pre-adjusted needle valve shim in the spring cage. Install the spring seat, the needle valve spring and the lower retainer.
  (b) Install the dowel pin into the spring cage. Install distance piece.
  (c) Install the dowel pin into the distance piece. Install the nozzle tip.
  (d) Tighten the nozzle retaining to the specified torque using the 2-step tightening method. (Loosen the nut until it can be turned by hand before tightening second time to the specified torque.)

Note: Before tightening the nozzle retaining nut, apply engine oil to the threads and the shoulder section of the nozzle tip. Be sure to tighten to the specified torque. Excessive tightening force can result in nozzle needle valve sticking, while insufficient tightening force can cause fuel leaks.

  (e) Install new O-rings, and apply engine oil.

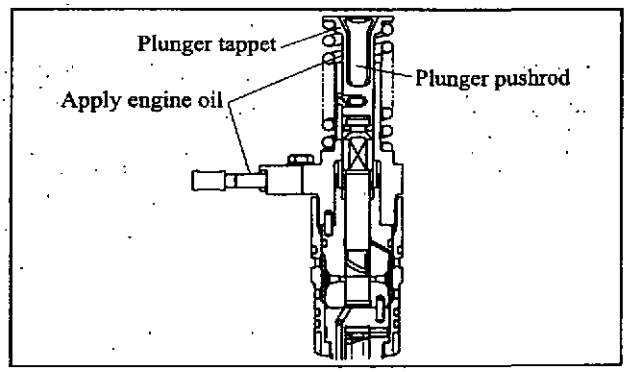


Installation of nozzle tip

(8) Installation of plunger pushrod

Install the plunger pushrod to the plunger tappet.

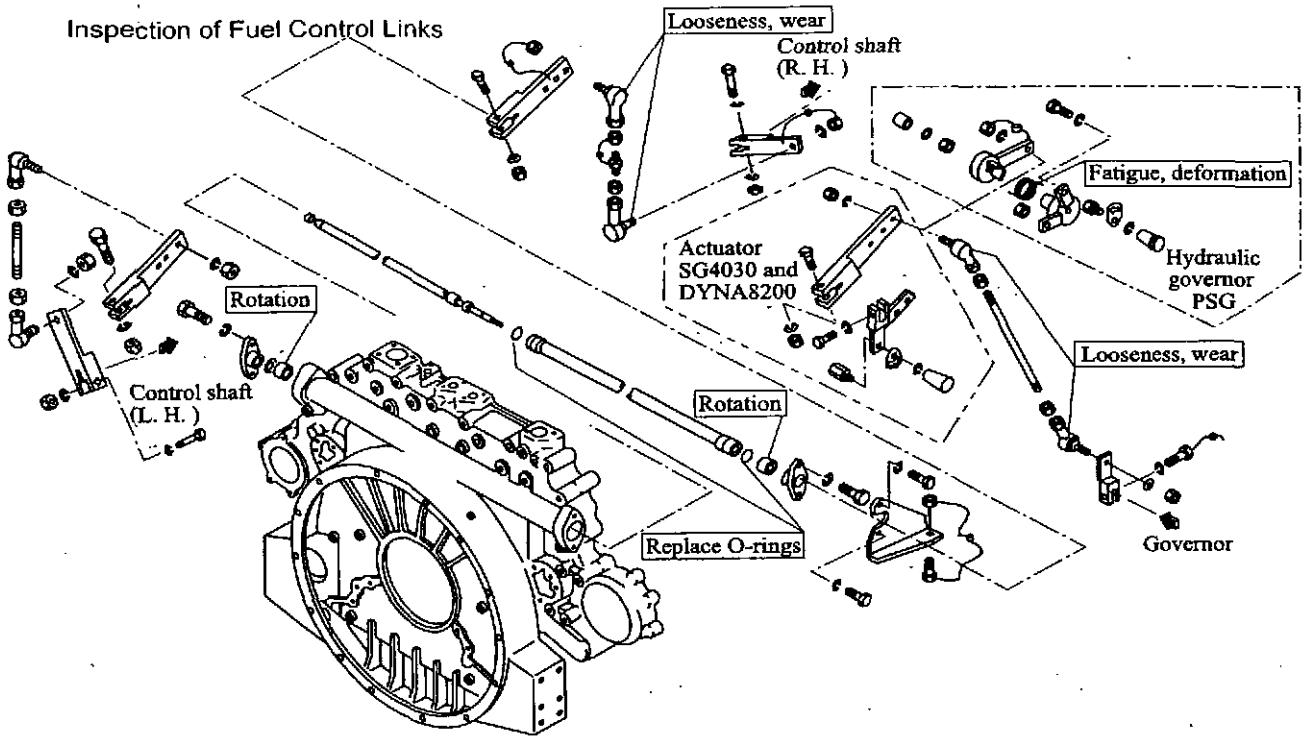
Note: (a) Apply engine oil to sliding surfaces of the plunger tappet and the control rack.
  (b) Unit injectors can be stored safely for up to six months when they are left in the packaged condition. After six months of storage, unit injectors must be operated in order to prevent rust generation and parts sticking due to degraded oil.



Installation of plunger pushrod

5. Fuel Control Links

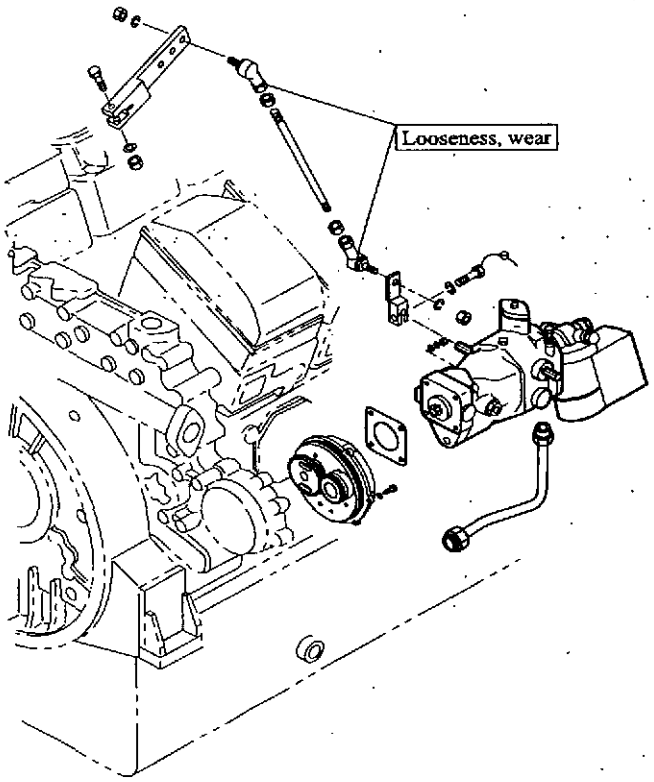
Inspection of Fuel Control Links



Inspection of fuel control link

6. Governor Control Links (PSG)

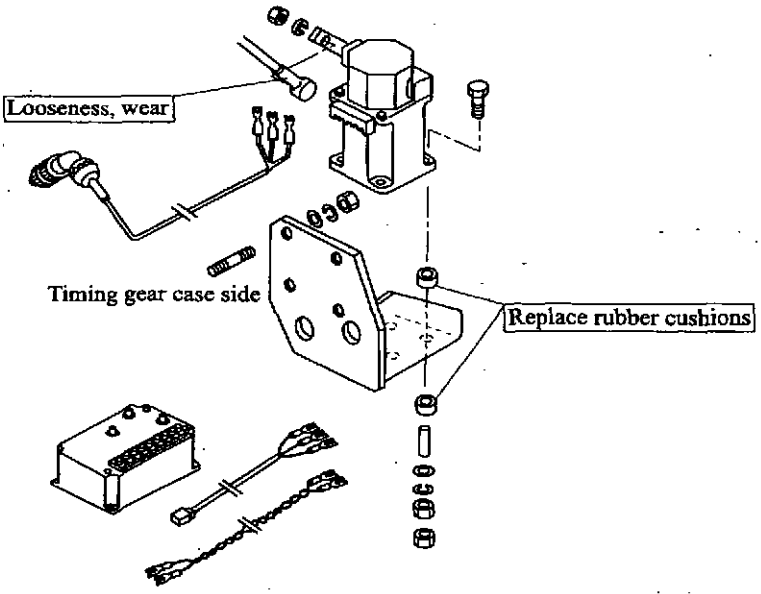
Inspection of Governor Control Links (PSG)



Inspection of governor control link (PSG)

7. Actuator Control Links (DYNA8200)

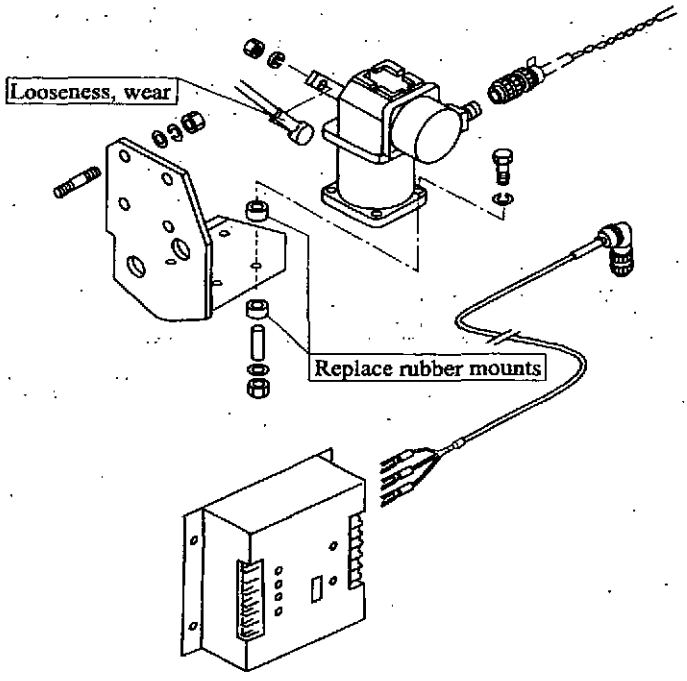
Inspection of Actuator Control Links (DYNA8200)



Inspection of actuator control link (DYNA8200)

8. Actuator Control Links (SG4030)

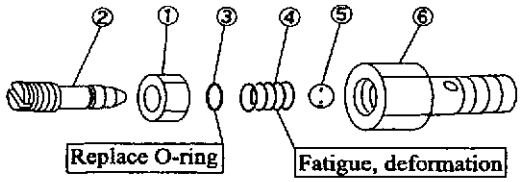
Inspection of Actuator Control Links (SG4030)



Inspection of actuator control link (SG4030)

9. Fuel Pipe Check Valve

9.1 Disassembly and Inspection of Fuel Pipe Check Valve

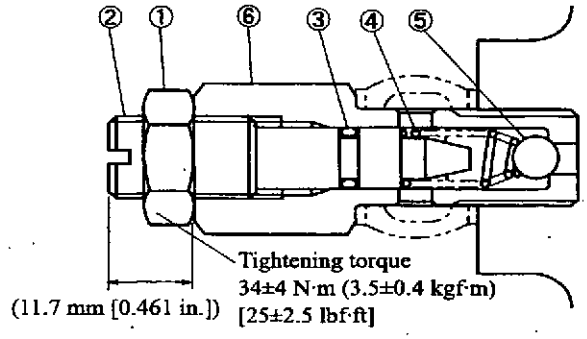


Disassembly and inspection of fuel pipe check valve

<Disassembly sequence>

① Jam nut
② Screw
③ O-ring
④ Valve spring
⑤ Ball
⑥ Valve body

9.2 Reassembly of Fuel Pipe Check Valve



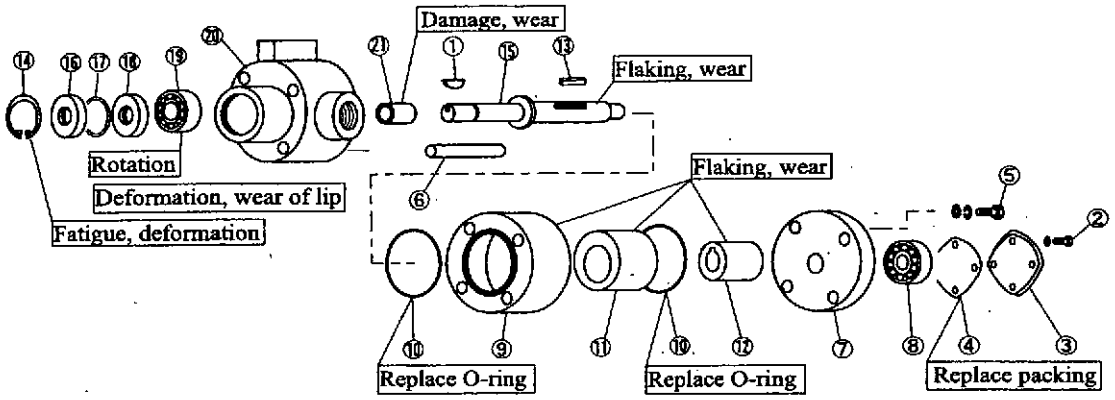
Reassembly of fuel pipe check valve

< Reassembly sequence >

⑥→⑤→④→③→②→①

10. Fuel Feed Pump

10.1 Disassembly and Inspection of Fuel Feed Pump

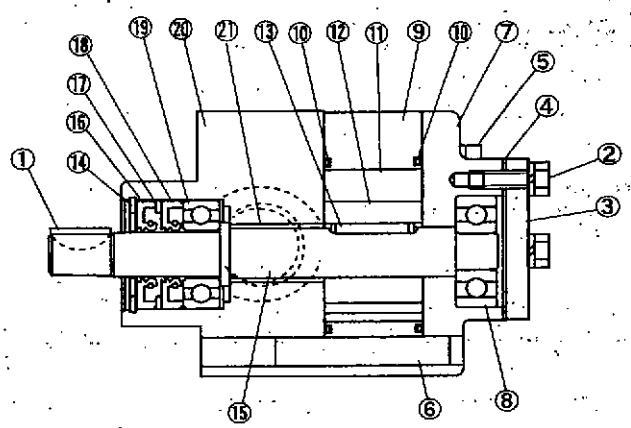


Diasassembly and inspection of fuel feed pump

<Disassembly sequence>

① Key
② Bolt
③ Top cover
④ Packing
⑤ Bolt
⑥ Pipe knock
⑦ Housing
⑧ Bearing
⑨ Body
⑩ O-ring
⑪ Outer rotor
⑫ Inner rotor
⑬ Inner key
⑭ Snap ring
⑮ Shaft
⑯ Oil seal
⑰ Backup ring
⑱ Oil seal
⑲ Bearing
⑳ Housing
㉑ Bushing

10.2 Reassembly of Fuel Feed Pump



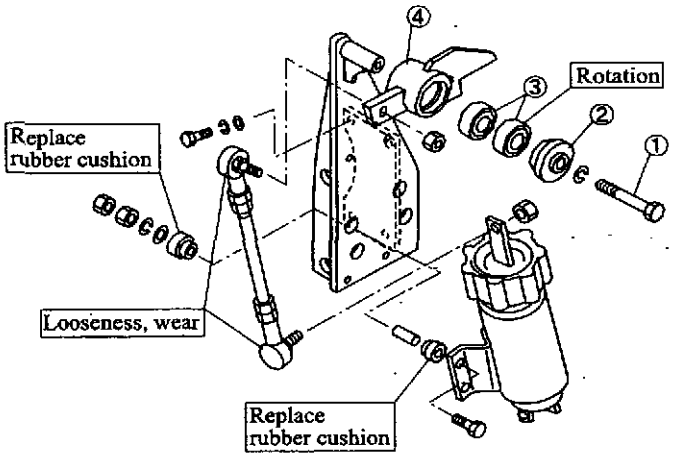
Reassembly of fuel feed pump

<Reassembly sequence>

㉑→⑳→⑲→⑱→⑰→⑯→⑮→⑭→⑬→⑫→⑪→⑩→⑨→⑧→⑦→⑥→⑤→④→③→②→①

11. Stop Solenoids

11.1 Disassembly and Inspection of Stop Solenoids (RUN-ON)



Disassembly and inspection of stop solenoid (RUN-ON)

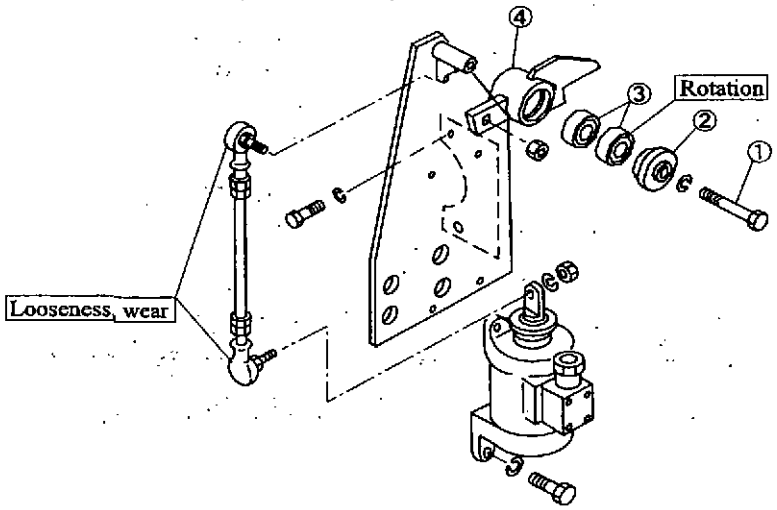
<Disassembly sequence>

① Bolt ② End play ③ Ball bearing ④ Stop lever

11.2 Reassembly of Stop Solenoids (RUN-ON)

To reassemble, follow the disassembly sequence in reverse.

11.3 Disassembly and Inspection of Stop Solenoids (RUN-OFF)



Disassembly and inspection of stop solenoid (RUN-OFF)

<Disassembly sequence>

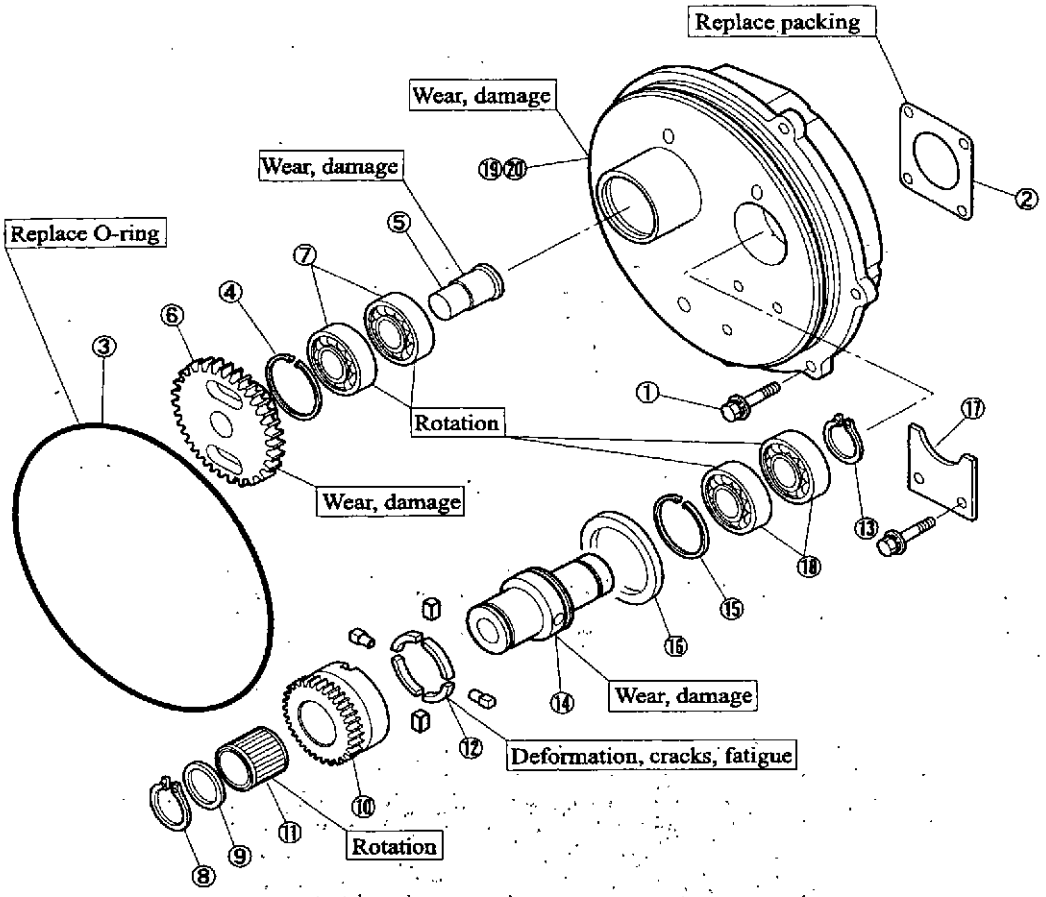
① Bolt ② End play ③ Ball bearing ④ Stop lever

11.4 Reassembly of Stop Solenoids (RUN-OFF)

To reassemble, follow the disassembly sequence in reverse.

12. Governor Drive (PSG)

12.1 Disassembly and Inspection of Governor Drive

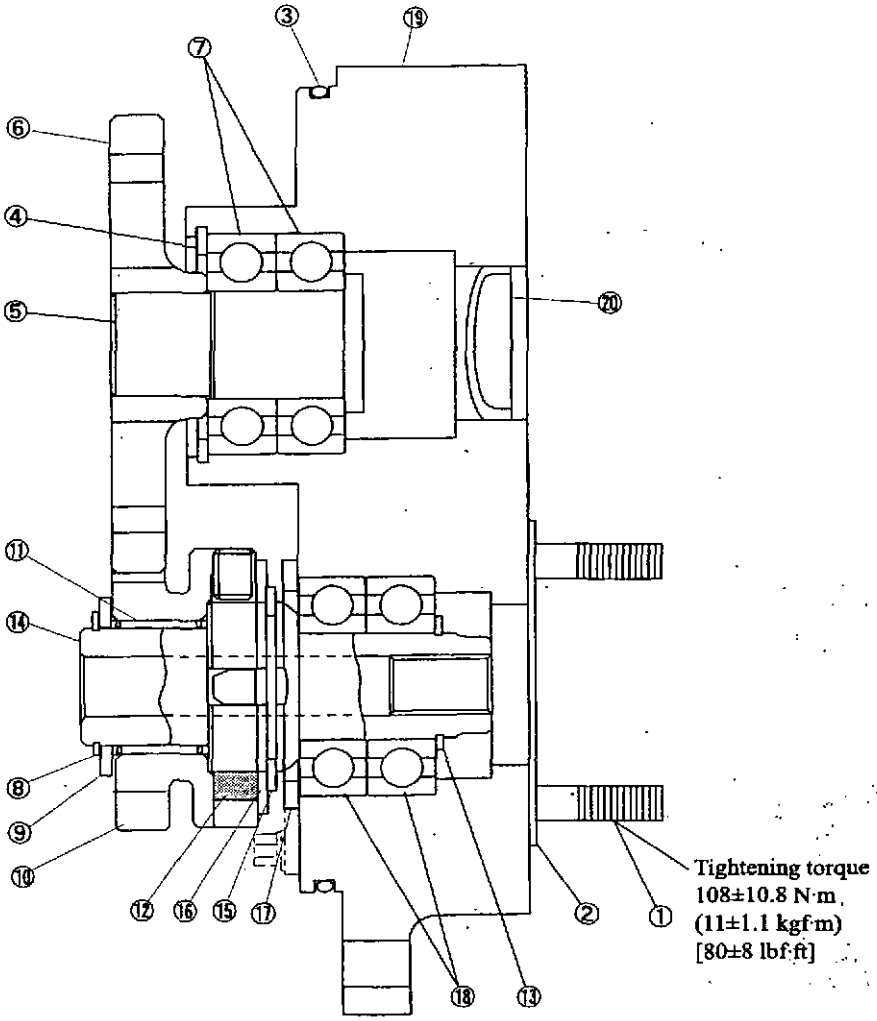


Disassembly and inspection of governor drive

< Disassembly sequence >

① Bolt
② Packing
③ O-ring
④ Snap ring
⑤ Idler shaft
⑥ Idler gear
⑦ Ball bearing
⑧ Snap ring
⑨ Washer
⑩ Drive gear
⑪ Needle bearing
⑫ Rubber
⑬ Snap ring
⑭ Drive shaft
⑮ Snap ring
⑯ Washer
⑰ Plate
⑱ Ball bearing
⑲ Drive case
⑳ Seal cap

12.2 Reassembly of Governor Drive



Reassembly of governor drive

< Reassembly sequence >

⑳→⑲→⑱→⑰→⑬→⑫→⑪→⑩→⑨→⑧→⑦→④→⑥→⑤→③→②→①

⑯→⑮→⑭

INSTALLATION OF FUEL SYSTEM

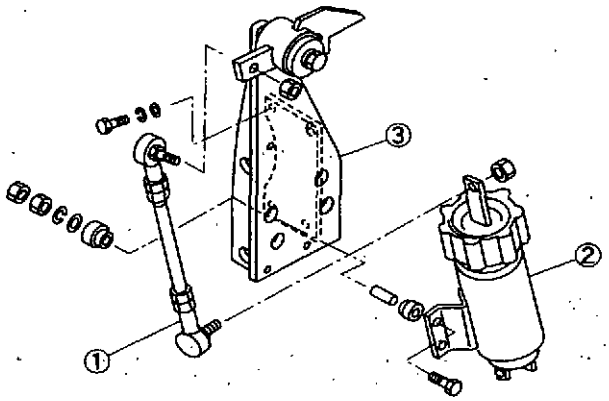
1. Procedures After Installation

To reinstall the fuel system, follow the removal sequence in reverse, and conduct the following procedures after installation.

(1) Add engine oil to the specified level.
(2) Add coolant.
(3) Check all connections for oil and water leaks.
(4) Bleed the fuel system.
(5) The fuel injection pump installation procedure is shown below. After installing the fuel injection pumps, be sure to check and adjust the fuel injection timing.

2. Stop Solenoids

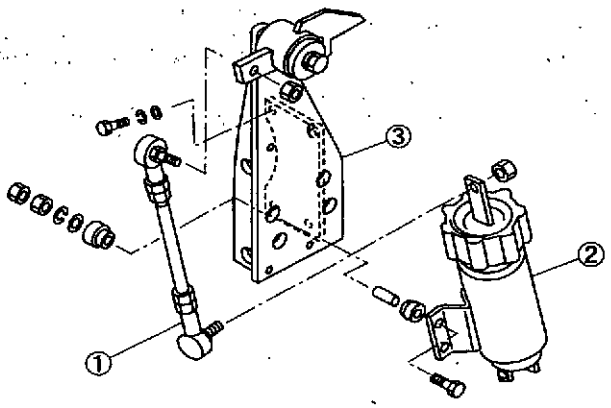
2.1 Installation of Stop Solenoids (RUN-ON)



Installation of stop solenoids (RUN-ON)

< Installation sequence >
③→②→①

2.2 Installation of Stop Solenoids (RUN-OFF)



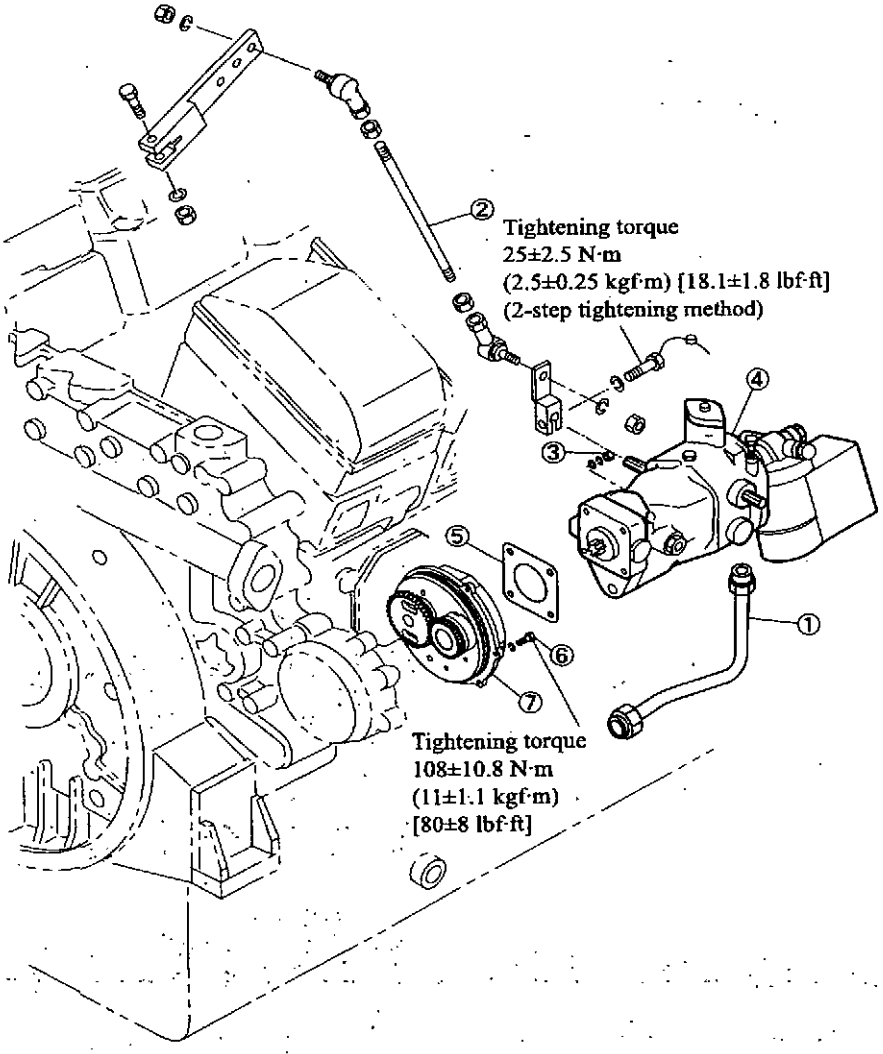
Installation of stop solenoids (RUN-ON)

< Installation sequence >
③→②→①

3. Unit Injector

For the method of installing the unit injector, refer to REASSEMBLY OF ENGINE MAIN PARTS pages.

4. Governor (PSG)

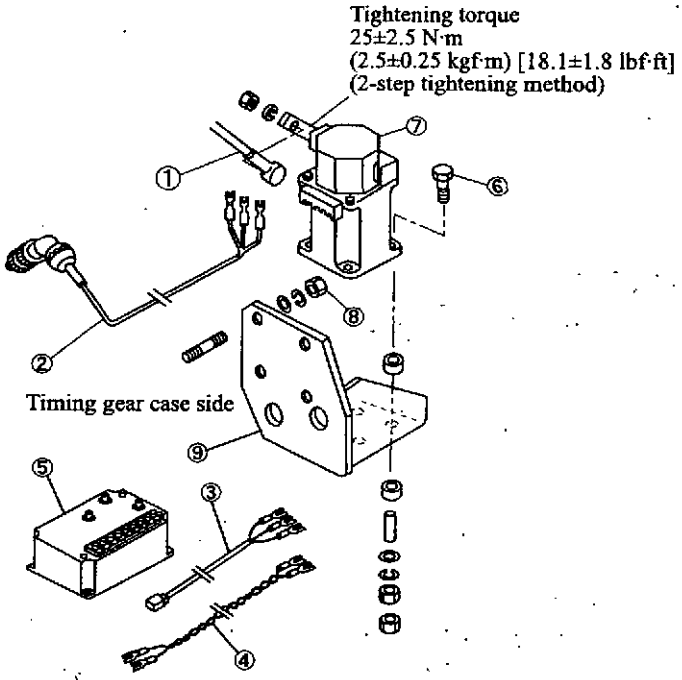


Installation of governor (PSG)

< Installation sequence >

⑦→⑥→⑤→④→③→②→①

5. Actuator (DYNA8200)

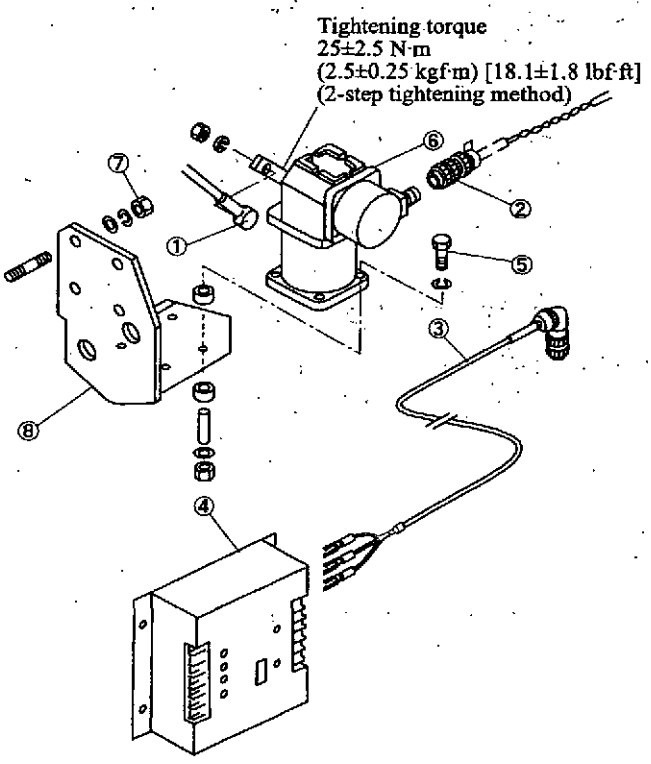


Installation of actuator (DYNA8200)

< Installation sequence >

⑨→⑧→⑦→⑥→⑤→④→③→②→①

6. Actuator (SG4030)

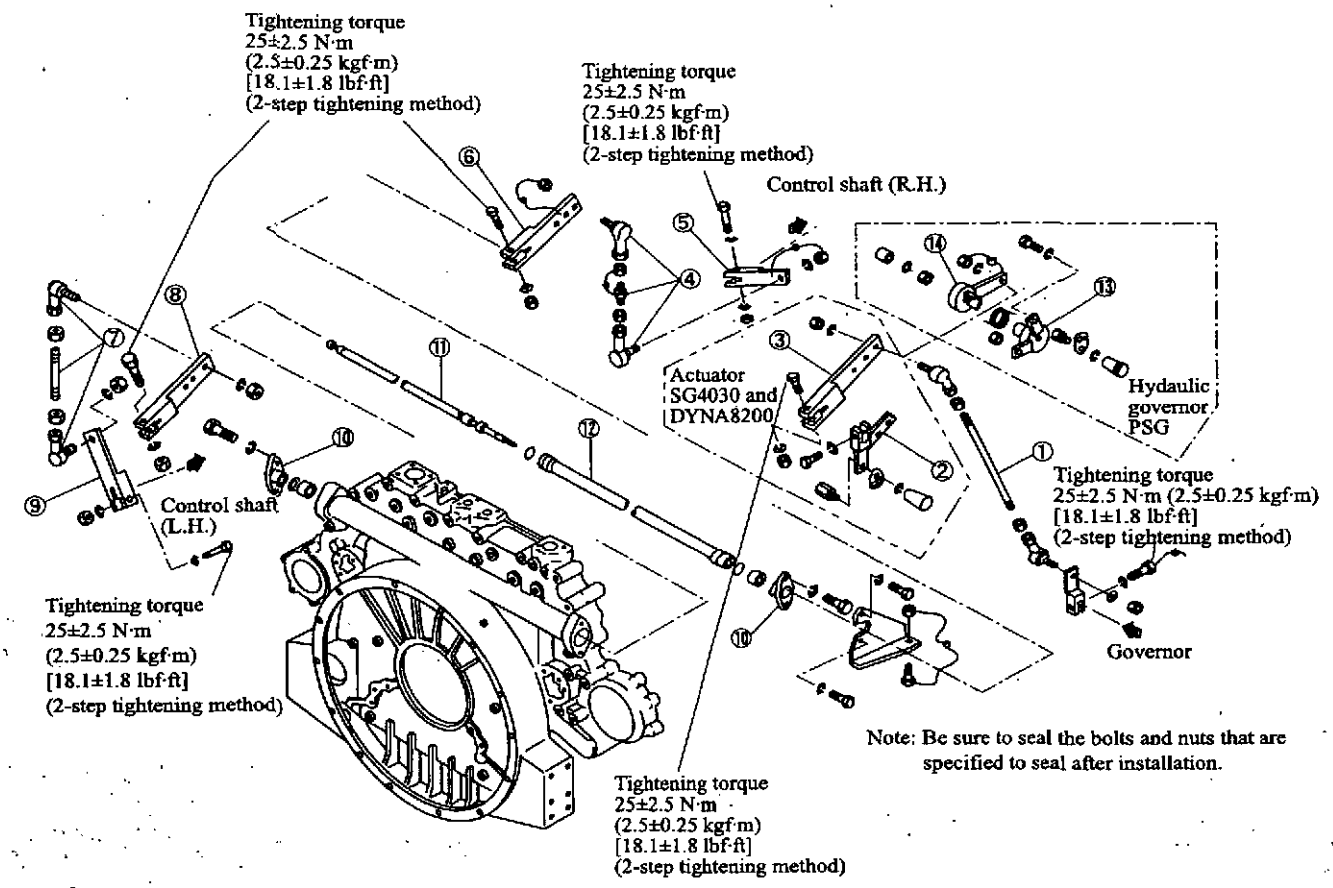


Installation of actuator (SG4030)

< Installation sequence >

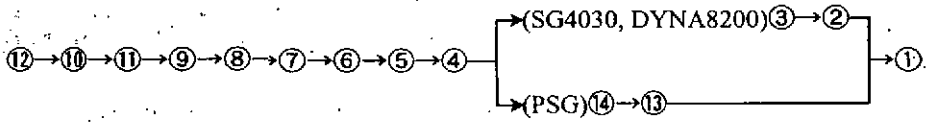
⑧→⑦→⑥→⑤→④→③→②→①

7. Fuel Control Links

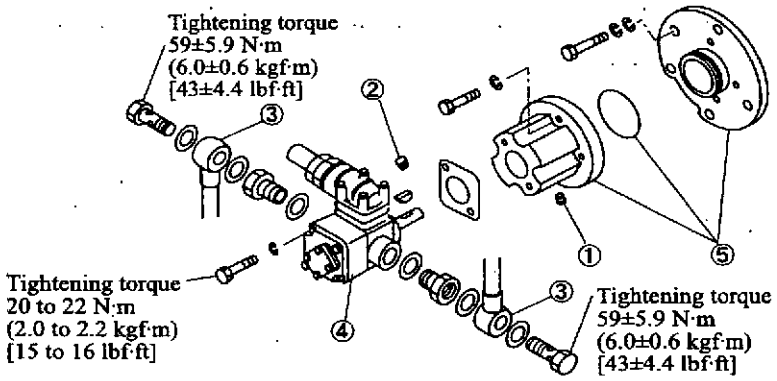


Installation of fuel control links

<*Installation sequence*>



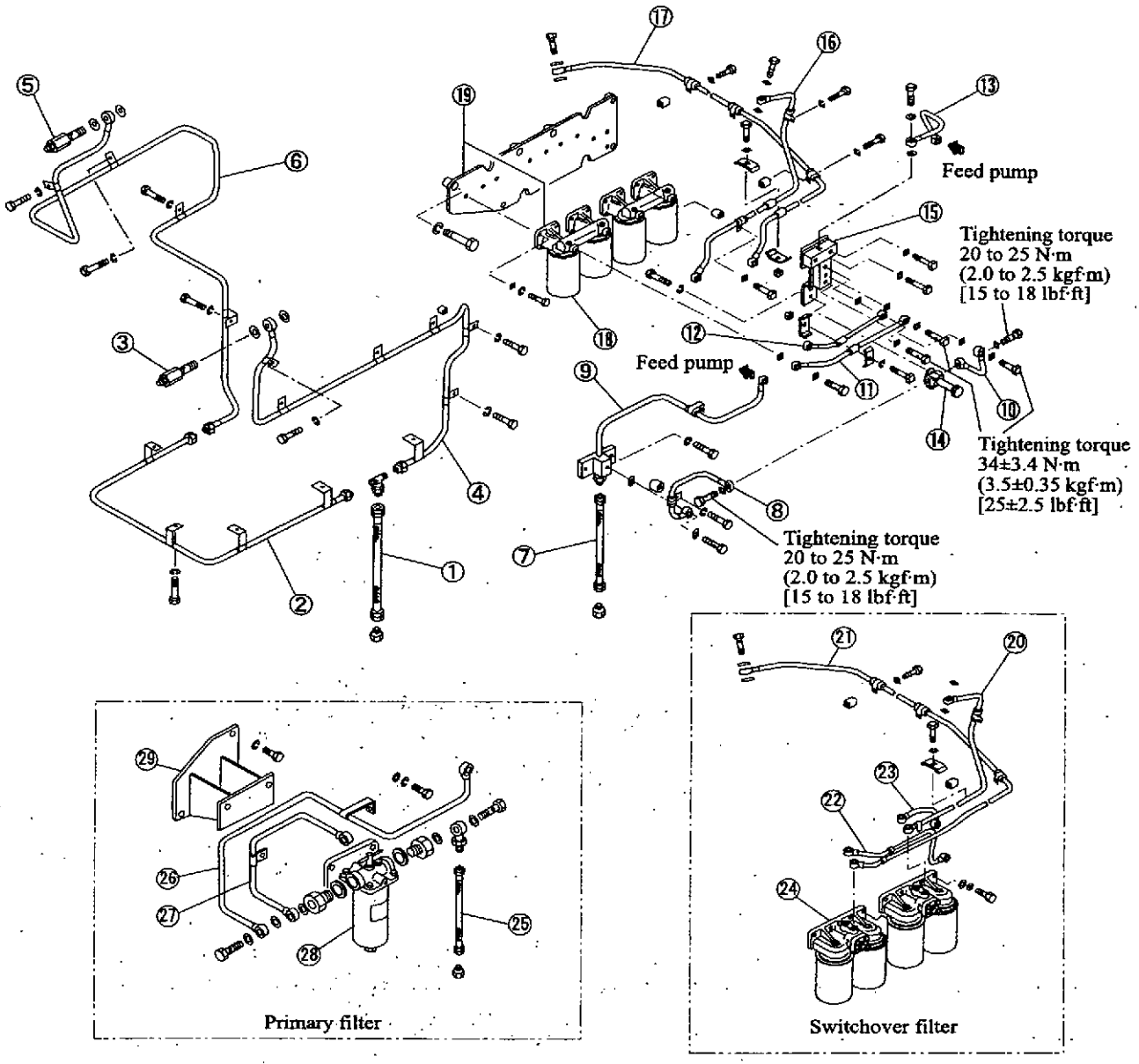
8. Fuel Feed Pump and Accessory Drive



Installation of fuel feed pump and accessory drive

<Installation sequence>
⑤→④→③→②→①

9. Fuel Filters and Fuel Pipes (Part 1)



Installation of fuel filters and fuel pipes (part 1)

<Installation sequence>

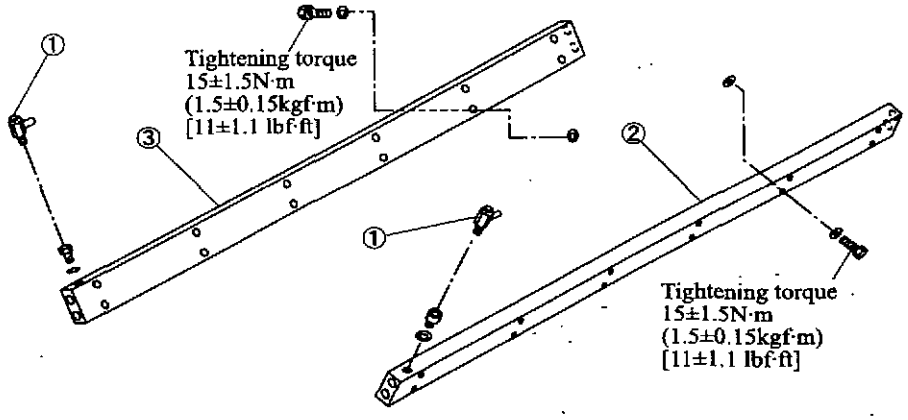
(Primary filter) ㉙→㉘→㉗→㉖→㉕

⑲ → (Switchover type) ㉔→㉓→㉒→㉑→⑳ → ⑮→⑭→⑬→⑫→⑪→⑩→⑨→⑧→⑦→⑥

⑲ → ⑱→⑰→⑯→⑫→⑪ → ⑮→⑭→⑬→⑫→⑪→⑩→⑨→⑧→⑦→⑥

⑥→⑤→④→③→②→①

10. Fuel Filters and Fuel Pipes (Part 2)



Installation of fuel filters and fuel pipes (part 2)

<Installation sequence>
③→②→①

11. Adjustment of Fuel Control Links

11.1 Adjustment in Normal Condition

(1) With the unit injector rack pressed fully against the adjusting plate (no-injection position), adjust the cancel rod of the cancel rod assembly by turning the pin until there is no play in each control link.

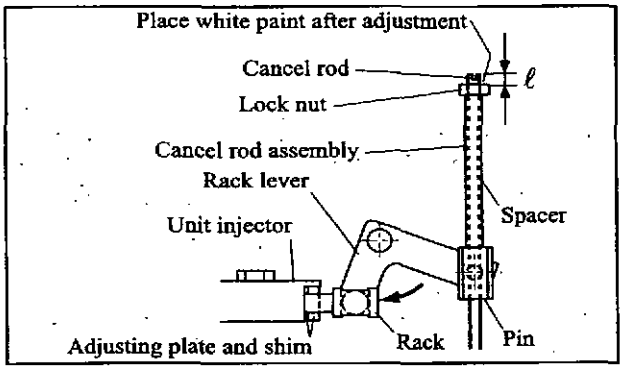
Note: (a) Set the protruded thread section (dimension ℓ) to the following range.

Unit mm [in.]

Adjustment range of dimension ℓ	7±1.5 [0.28±0.06]

(b) Dimension ℓ is set within the above range for proper adjustment before shipment, but if it deviates significantly from the above range, follow the directions in "11.2 Adjustment in Case of Nonconformance of Dimension ℓ " on the following page.

(2) Make sure that there is no looseness in the right and left links after adjustment, and lock the links securely.

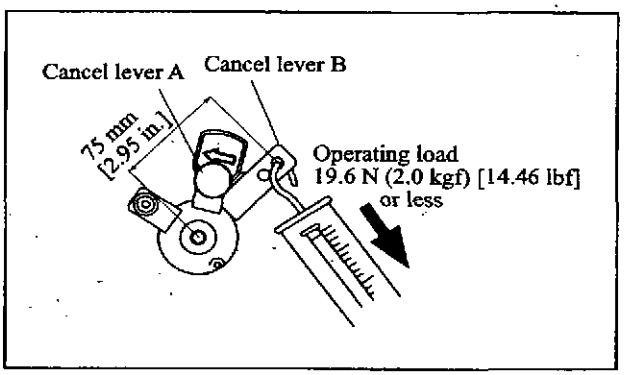


Adjustment of fuel control link (1)

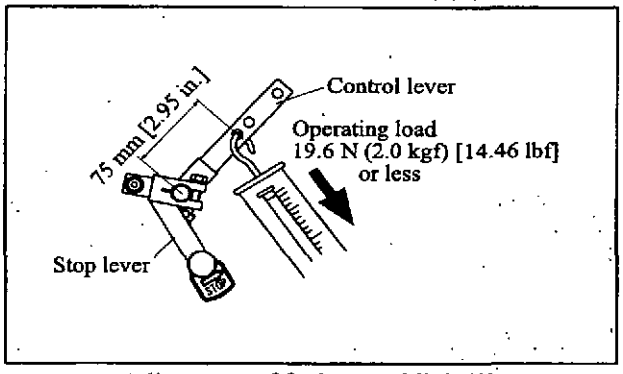
(3) Move the control link by hand to make sure it moves smoothly.
(Hook a spring scale in the hole linking the governor and actuator, and measure the operating load.)

Unit N (kgf) [lbf]

Operating load	19.6 (2.0) [14.46] or less



Adjustment of fuel control link (2) (PSG)



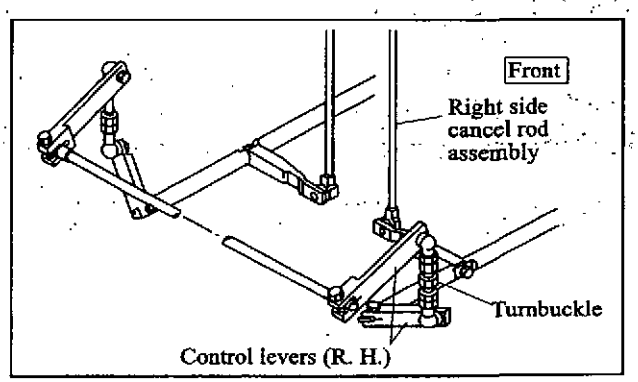
Adjustment of fuel control link (2) (DYNA8200, SG4030)

11.2 Adjustment in Case of Nonconformance of Dimension ℓ

Note: The following adjustment is required only when parts other than the lock nut of the cancel rod are removed. Otherwise it is not necessary to perform this adjustment.

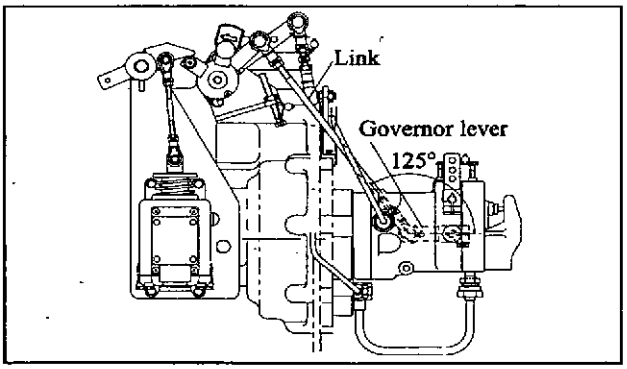
(1) Remove the control link adjustment turnbuckle on the right side only.
(2) Check again to make sure that the unit injector racks for all cylinders are pressed against the rack stoppers (no-injection position). If the rack is not pressed against the stopper for any of the cylinders, adjust the right and left links to eliminate any looseness and lock the links.

Note: The adjustment must be made with all unit injector racks pressed against the rack stoppers.
(The links move to the no-injection position due to their own weight.)



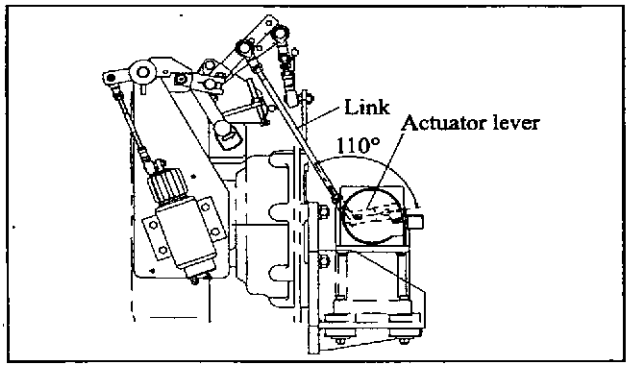
Adjustment of fuel control link (3)

(3) Make sure that the angle formed by the governor lever of the hydraulic governor and the link is 125° (in contact with the stopper).

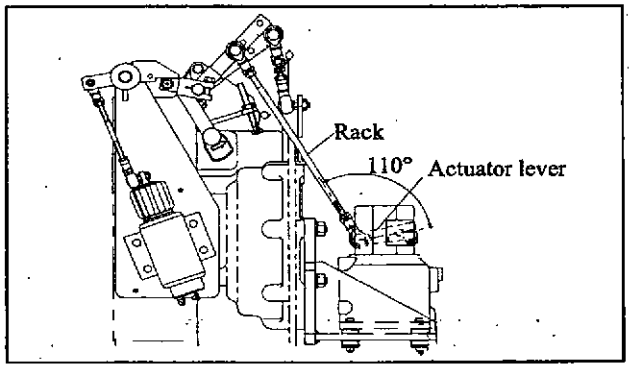


Adjustment of fuel control link (4) (PSG)

(4) Make sure that the angle formed by the actuator lever of the electronic governor and the link is 110° (in contact with the stopper).



Adjustment of fuel control link (4) (SG4030)

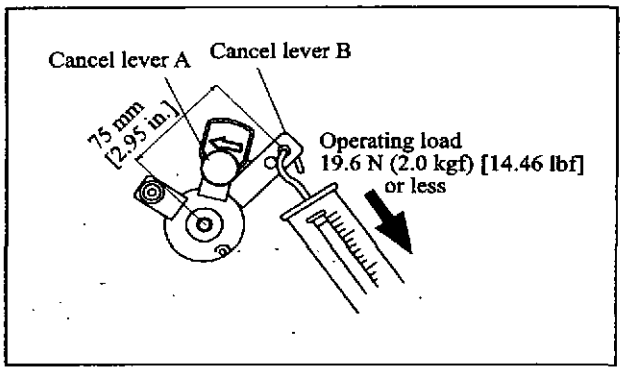


Adjustment of fuel control link (4) (DYNA8200)

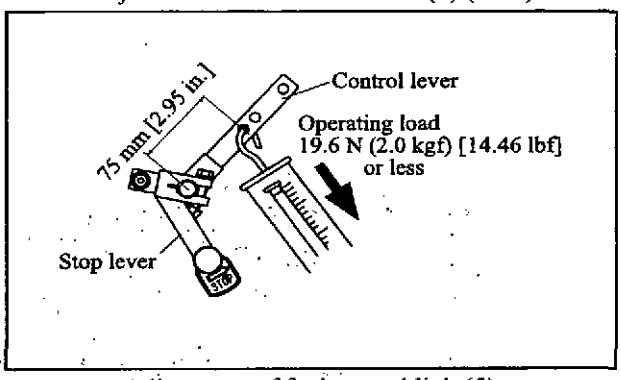
(5) Move the linkage by hand to make sure it moves smoothly.
(Hook a spring scale in the hole linked to the governor, and measure the operating load.)

Unit N (kgf) [lbf]

Operating load	19.6 (2.0) [14.46] or less



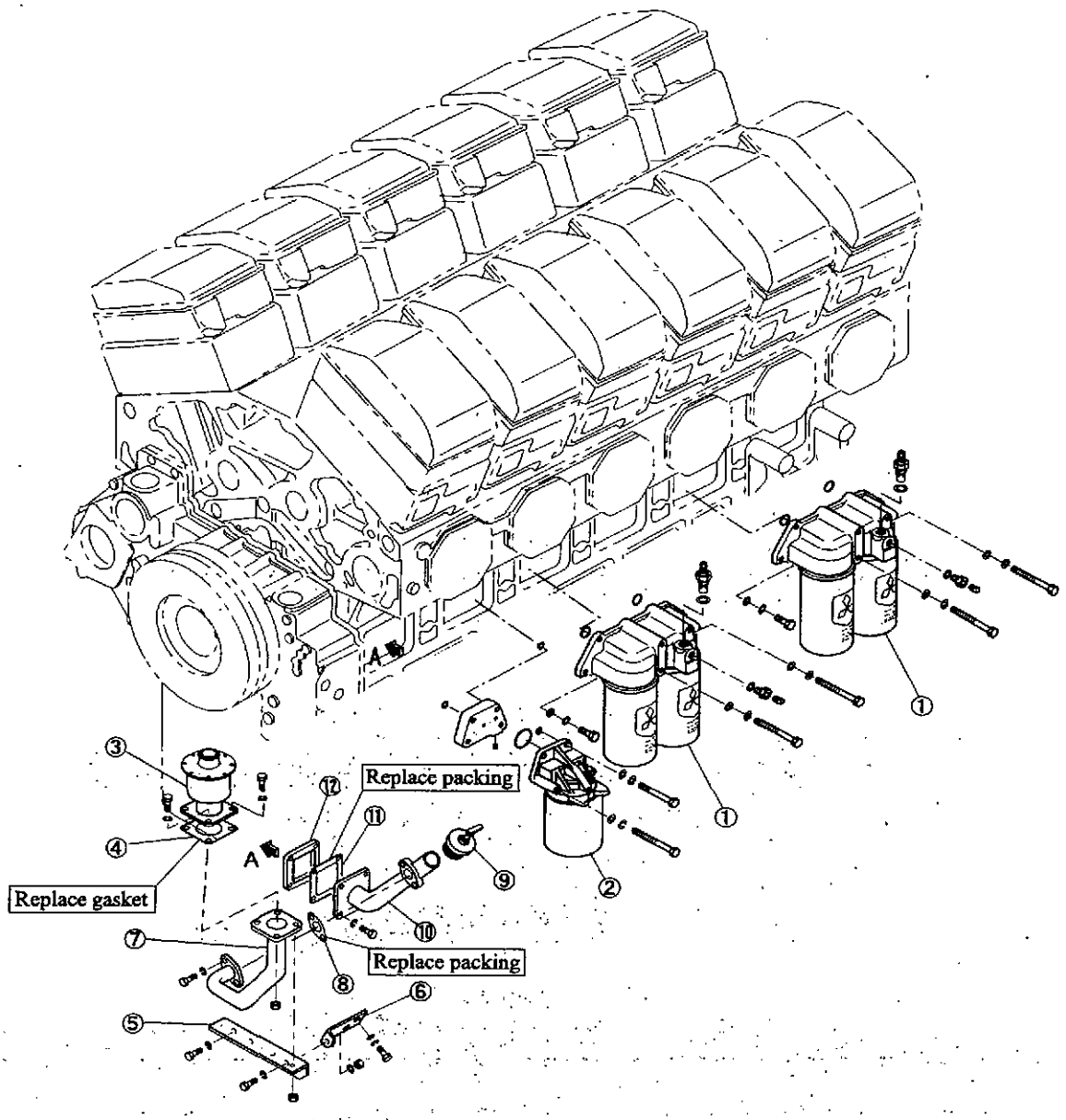
Adjustment of fuel control link (5) (PSG)



Adjustment of fuel control link (5)
(DYNA8200, SG4030)

REMOVAL OF LUBRICATION SYSTEM

1. Oil Filters, Oil Bypass Filters and Breather

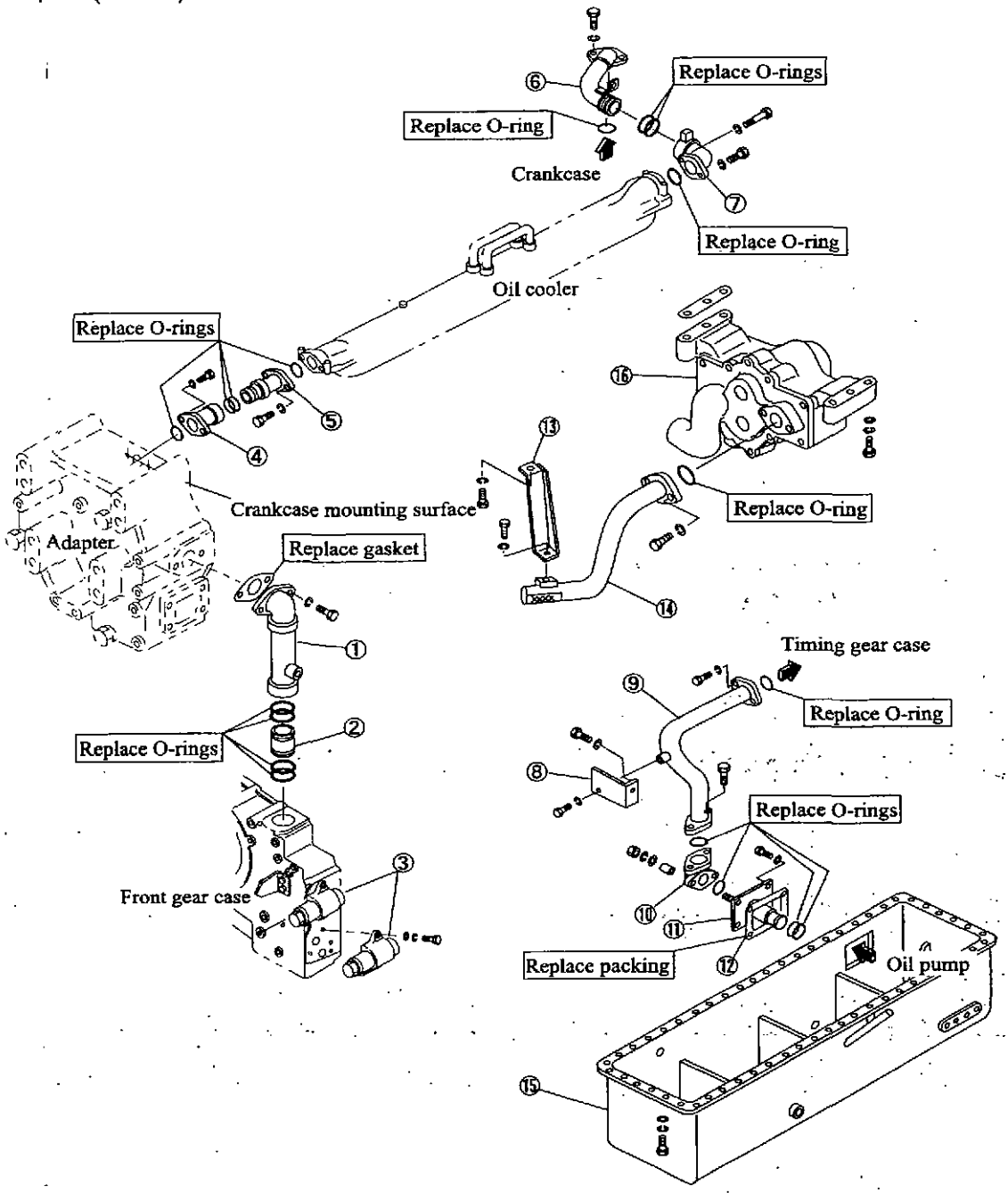


Removal of oil filter, oil bypass filter and breather

< Removal sequence >

① Oil filter
② Oil bypass filter
③ Breather assembly
④ Gasket
⑤ Stay
⑥ Stay
⑦ Breather pipe
⑧ Packing
⑨ Oil cap
⑩ Oil filler
⑪ Packing
⑫ Side cover

2. Oil Pipes (Part 1)

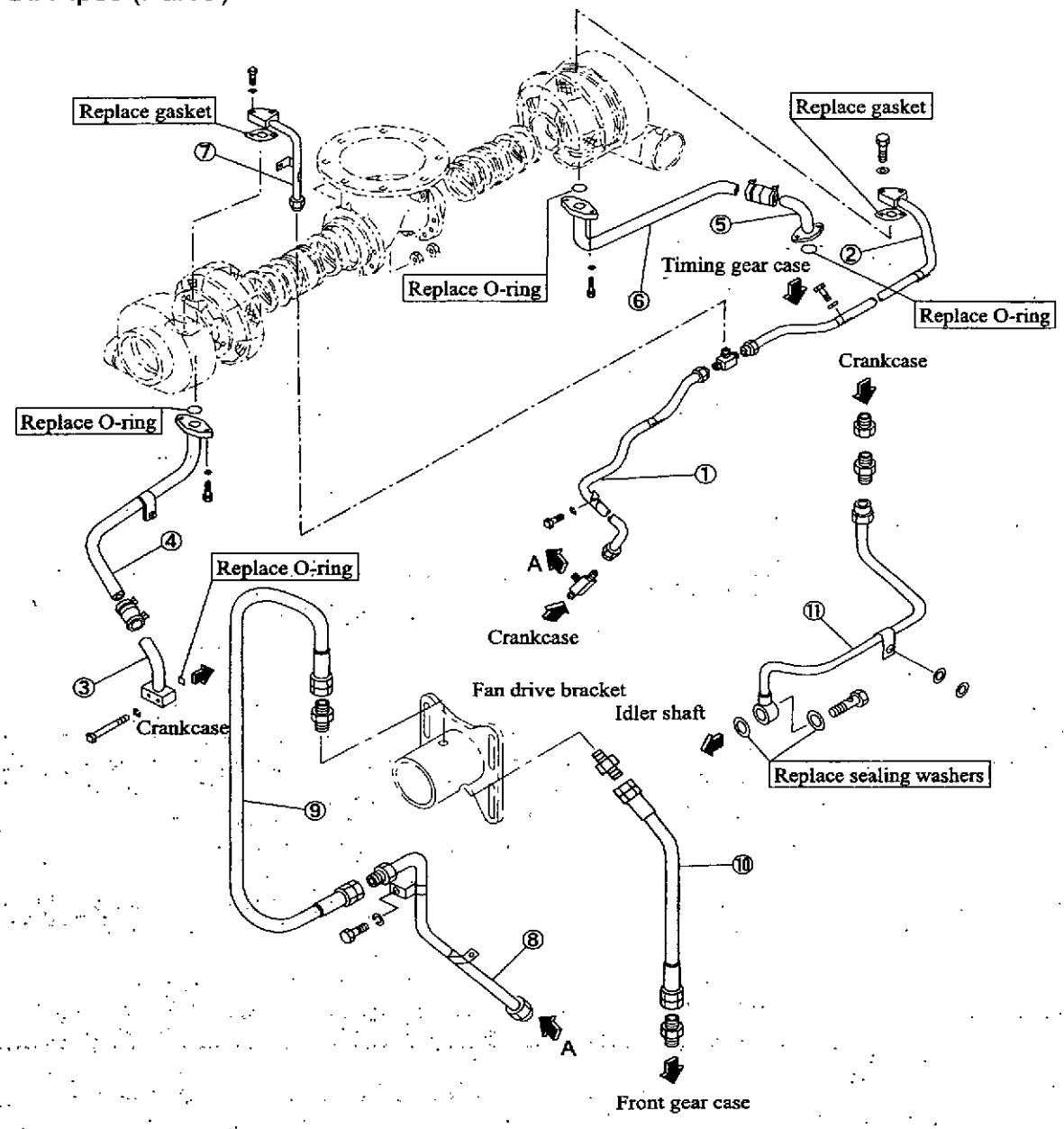


Removal of oil pipes (1)

<Removal sequence>

① Oil pipe	⑤ Connector	⑨ Oil pipe	⑬ Strainer stay
② Connector	⑥ Oil pipe	⑩ Connector	⑭ Oil strainer
③ Relief valve assembly	⑦ Connector	⑪ Connector	⑮ Oil pan (weight: approx. 70 kg [lb.])
④ Connector	⑧ Stay	⑫ Packing	⑯ Oil pump (weight: approx. 33 kg [lb.])

3. Oil Pipes (Part 2)

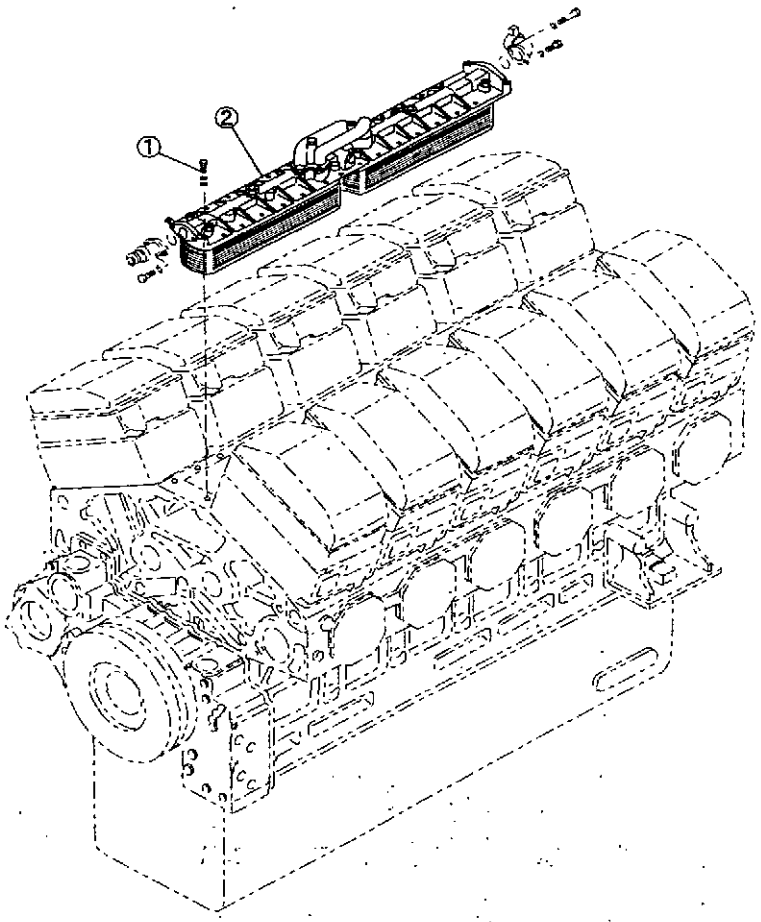


Removal of oil pipe (2)

<Removal sequence>

① Oil pipe
② Oil pipe
③ Drain pipe
④ Drain pipe
⑤ Drain pipe
⑥ Drain pipe
⑦ Oil pipe
⑧ Fan pipe
⑨ Flexible pipe
⑩ Flexible pipe
⑪ Oil pipe

4. Oil Cooler



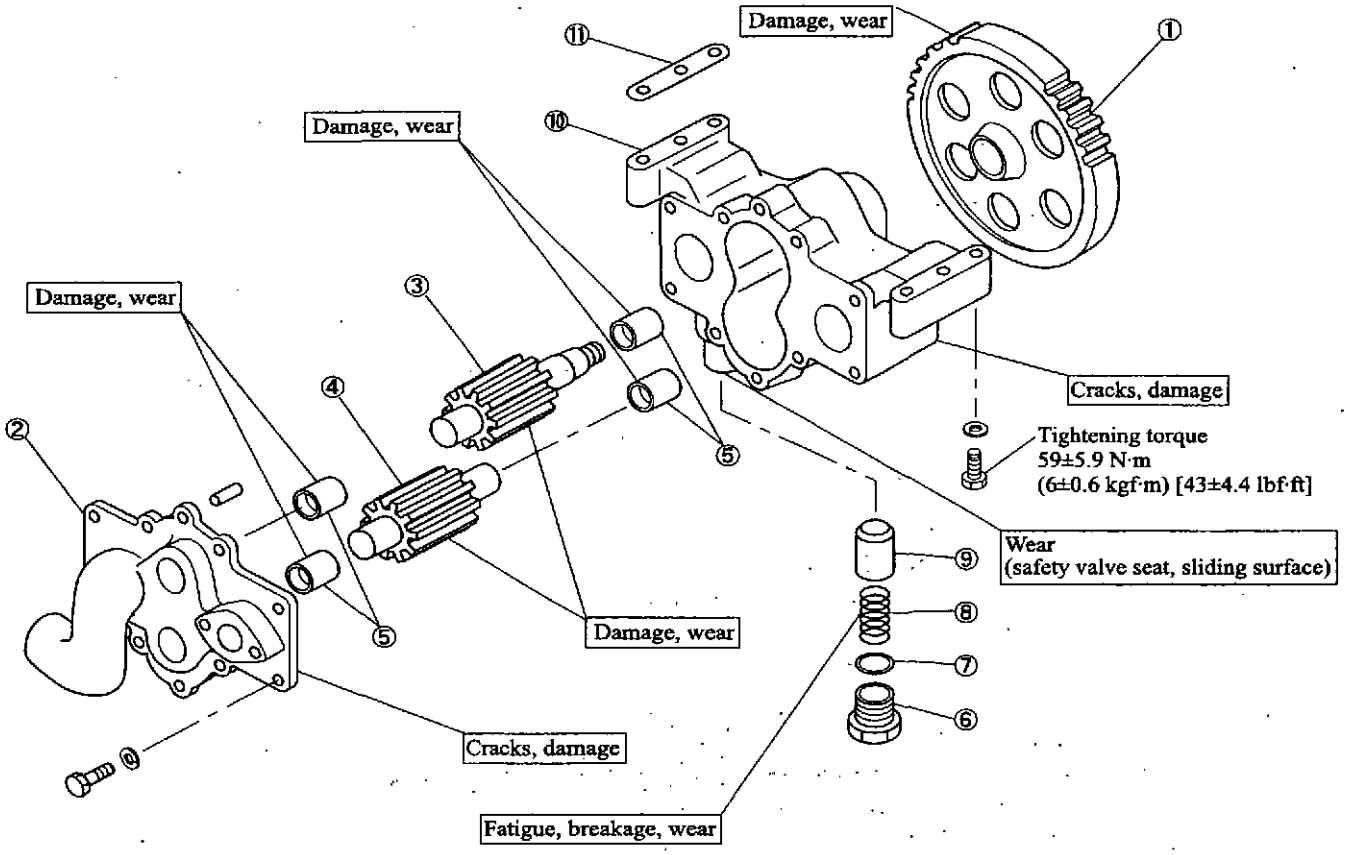
Removal of oil cooler

<Removal sequence>
① Bolt
② Oil cooler

DISASSEMBLY, INSPECTION AND REASSEMBLY OF LUBRICATION SYSTEM

1. Oil Pump and Safety Valve

1.1 Disassembly and Inspection of Oil Pump and Safety Valve



Disassembly and inspection of oil pump and safety valve

< Disassembly sequence >

① Driving gear
② Pump cover
③ Drive gear
④ Driven gear
⑤ Bushing
⑥ Safety plug
⑦ Shim
⑧ Spring
⑨ Safety valve
⑩ Oil pump case
⑪ Shim

1.2 Inspection of Oil Pump and Safety Valve

(1) Inspection of gear backlash
  (a) Inspect the drive gear and driven gear backlash.
  (b) If the limit is exceeded, replace the gears.

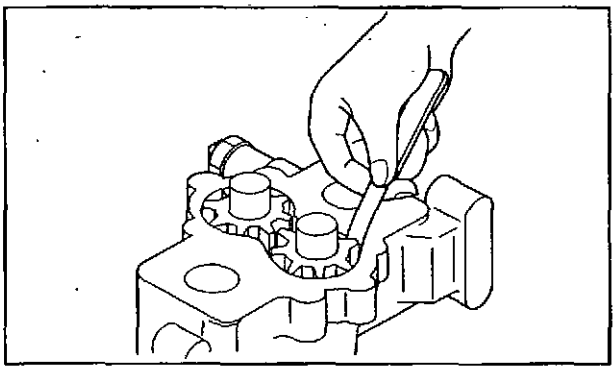
Unit mm [in.]

	Standard	Limit
Drive gear and driven gear backlash	27.983 to 28.055 [1.1025 to 1.1054]	27.93 [1.1004]

(2) Measurement of clearance between gears and case
  (a) Using feeler gages, measure the clearance between drive or driven gears and case
  (b) If the limit is exceeded, replace the gears or body.

Unit mm [in.]

	Standard	Limit
Clearance between drive or driven gears and case	0.095 to 0.140 [0.004 to 0.006]	Tip clearance 0.190 [0.007]

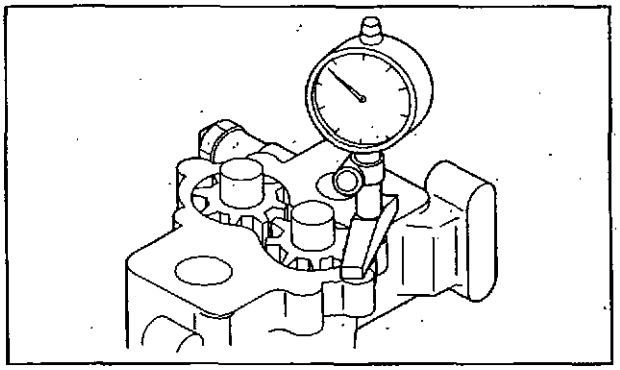


Measurement of clearance between drive or driven gears and case

(3) *Measurement of side clearance of gears in case*
  (a) Using dial gage; measure the clearance of gears in case.
  (b) If the limit is exceeded, replace the gears or case.

Unit mm [in.]

	Standard	Limit
Gear end side clearance in case	0.095 to 0.155 [0.004 to 0.006]	0.29 [0.0114]



Measurement of side clearance of drive and driven gears in case

(4) *Measurement of drive and driven gear shaft diameters and bushing inside diameter*
  (a) Inspect the gear teeth. If abnormalities are found, replace the defective gear.
  (b) Measure the gear shaft and bushing diameters.
  (c) If the limit is exceeded, replace with new parts.

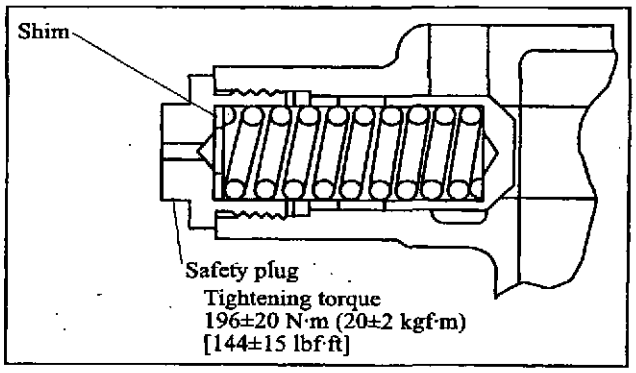
Unit mm [in.]

	Nominal value	Standard	Limit
Drive and driven gears shaft diameter	ϕ40 [1.576]	39.986 to 40.000 [1.575 to 1.576]	39.930 [1.573]
Bushing inside diameter		40.040 to 40.059 [1.577 to 1.578]	40.140 [1.582]

(5) Inspection of safety valve
(a) Check the following locations. If abnormalities are found, replace.
- Excessive wear of seat
- Excessive fatigue and breakage of valve spring

(b) If valve springs in the oil pump safety valve for fatigue. If excessive fatigue, wear or damage is observed, replace the springs.

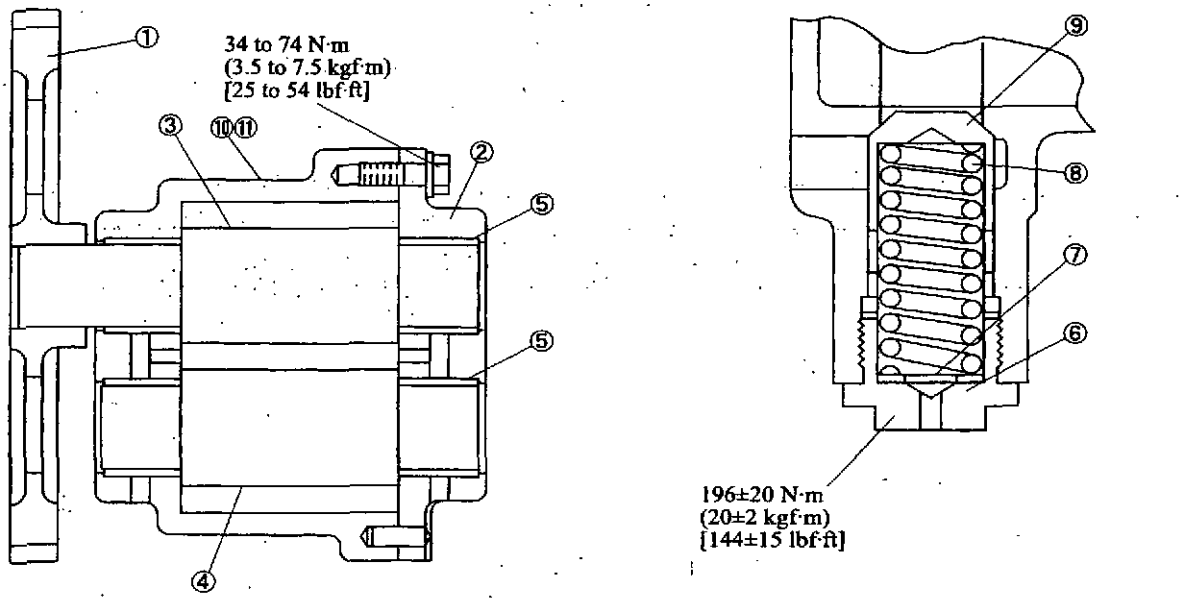
(c) Measure the safety valve opening pressure. If the measured value is not within the standard range, adjust the pressure by inserting shims between the spring and plug.
A shim with a thickness of 1 mm [0.04 in.] results in a pressure difference of approximately 0.10 MPa (1 kgf/cm^2) [14.2 psi].



Inspection of safety valve

	Standard	Limit	Remedy
Safety valve opening pressure	1.4±0.1 MPa (14±1 kgf/cm^2) [199.15±14.23 psi]	–	Change in oil pressure is 0.04 MPa (0.4 kgf/cm^2) [5.8 psi] with a low 2 mm [0.08 in.] shim.
Safety valve spring set length/load	73.4 [2.89]/ 971±69 N (99.0±7 kgf) [218±5.16 lbf]	834 N (85.0 kgf) [187 lbf]	

1.3 Reassembly of Oil Pump and Safety Valve



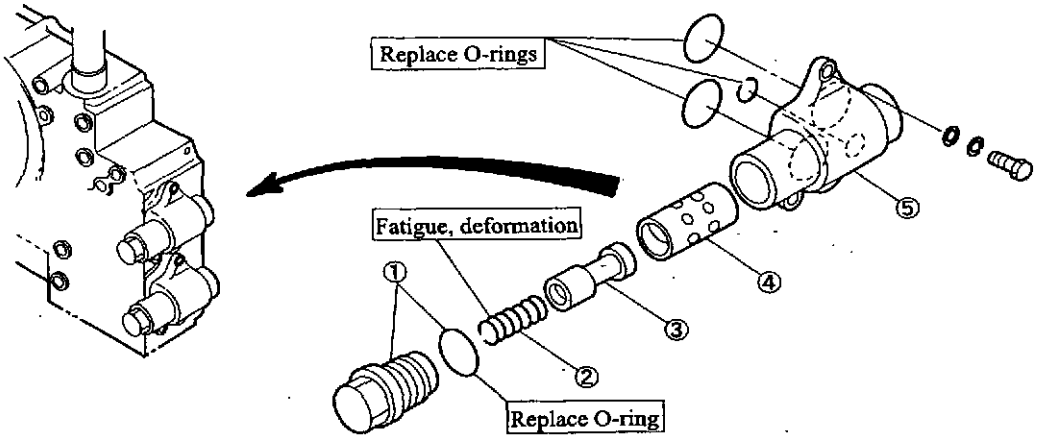
Reassembly of oil pump and safety valve

Note: During reassembly, apply engine oil to each part of components.

<Reassembly sequence>
⑩→⑨→⑧→⑦→⑥→④→⑤→③→②→①→⑪

2. Relief Valve

2.1 Disassembly and Inspection of Relief Valve



Disassembly and inspection of relief valve

<Disassembly sequence>
① Plug and O-ring
② Spring
③ Relief valve
④ Sleeve
⑤ Case

2.2 Inspection of Relief Valve

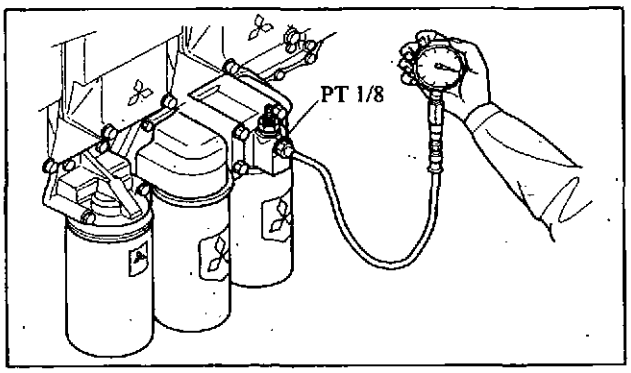
(1) Measurement of relief valve pressure
(a) Remove the taper plug, and set a pressure gage.
(b) Conduct a warm-up operation until the oil temperature reaches 70 to 90 °C [158 to 194 °F].
(c) Measure the oil pressure at idling and at maximum speed.

	Standard
Valve opening pressure	0.58±0.05 MPa (5.9±0.5 kgf/cm²) [83.93±7.12 psi]

(d) If the measured oil pressure is lower than the standard, adjust by inserting washers between the spring and valve.

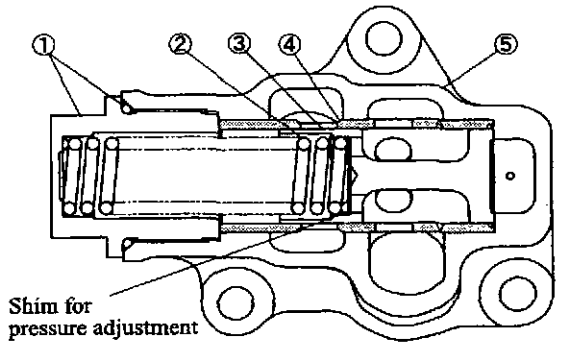
Unit MPa (kgf/cm²) [psi]

Pressure difference every 2 mm [0.08 in.] thickness of shim	0.04 (0.4) [5.8]



Measurement of relief valve pressure

2.3 Reassembly of Relief Valve

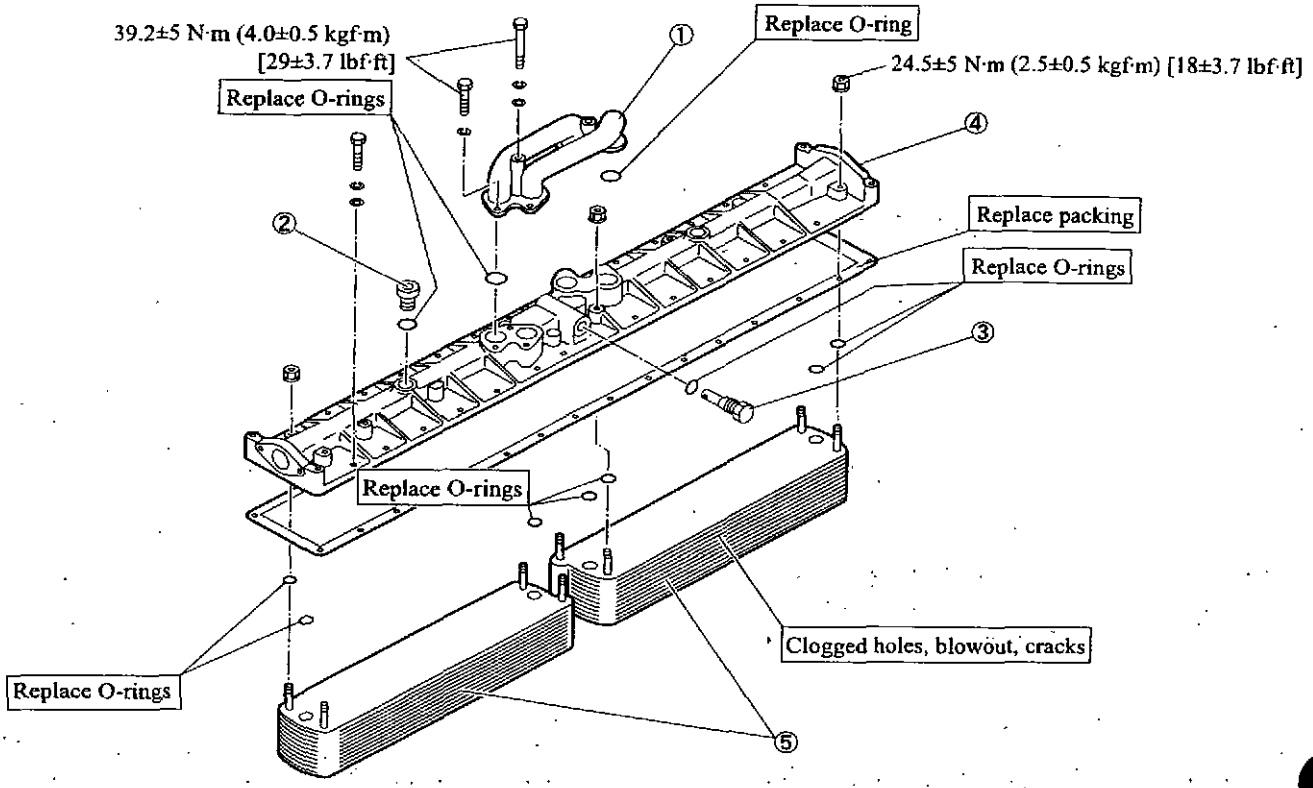


Reassembly of relief valve

<Reassembly sequence>
⑤→④→③→②→①

3. Oil Cooler

3.1 Disassembly and Inspection of Oil Cooler



Disassembly and inspection of oil cooler

<Disassembly sequence>

① Pipe
② Plug
③ Bypass valve
④ Cover
⑤ Element

3.2 Inspection of Oil Cooler

(1) Test the oil passages of the element with specified pressure to check for damage and cracks in the element.
If there is any leakage, replace the element.

Compressed air pressure	1.47 MPa (15 kgf/cm^2) [213 psi]

(2) Check the bypass valve opening pressure, if it exceeds the standard, replace.

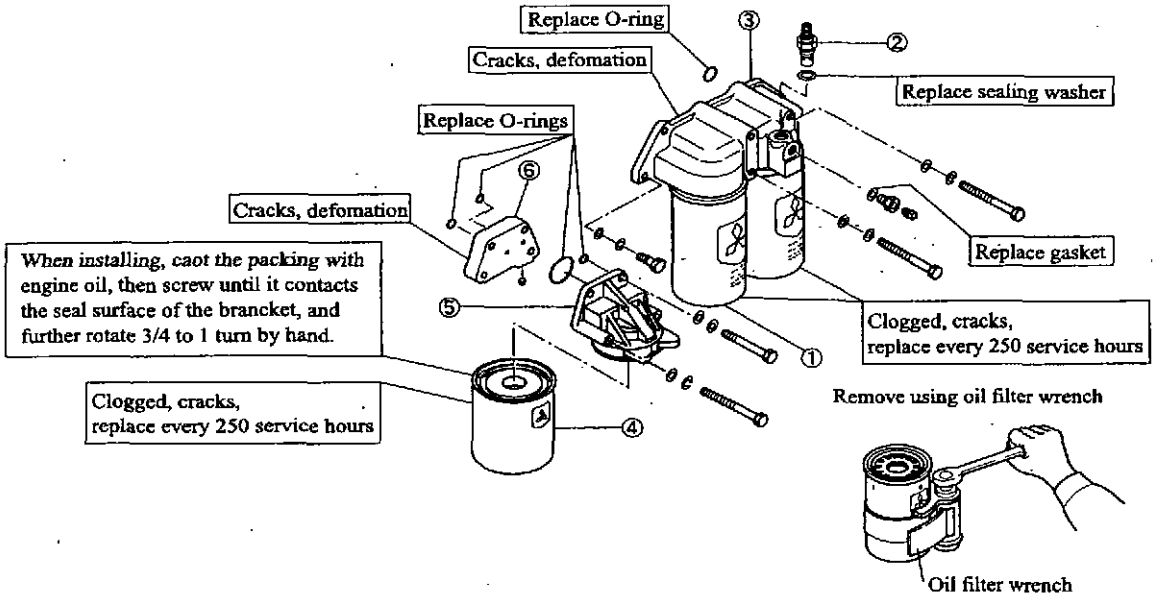
	Standard
Bypass valve opening pressure (differential pressure)	0.44±0.05 MPa (4.5±0.5 kgf/cm^2) [63.82±7.12 psi]

3.3 Reassembly of Oil Cooler

To reassemble, follow the disassembly sequence in reverse.

4. Oil Filters, Oil Bypass Filter and Oil Filter Alarm

4.1 Disassembly and Inspection of Oil Filters, Oil Bypass Filters and Oil Filter Alarm



Disassembly and inspection of oil filters, oil bypass filter and oil filter alarm

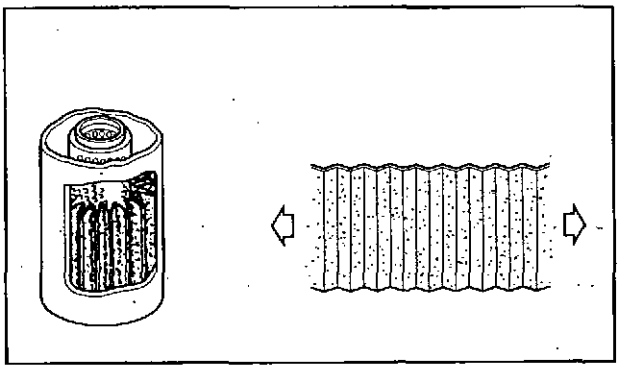
<Disassembly sequence>

① Oil filter element
② Oil filter alarm
③ Oil filter bracket
④ Bypass filter element
⑤ Bypass filter bracket
⑥ Spacer

Name of basic tool	Part No.
Oil filter wrench	32591-22100

4.2 Inspection of Oil Filters, Oil Bypass Filters and Oil Filter Alarm

(1) When replacing the oil filter, sample the oil (500 cm^3 [30.5 cu. in]) and check for metal and other particles. If metal or other particles are found, cut and unfold the element, and check the color and shape of metal particles trapped in the element to identify the cause.



Inspection of oil filter

(2) Inspection of oil filter alarm

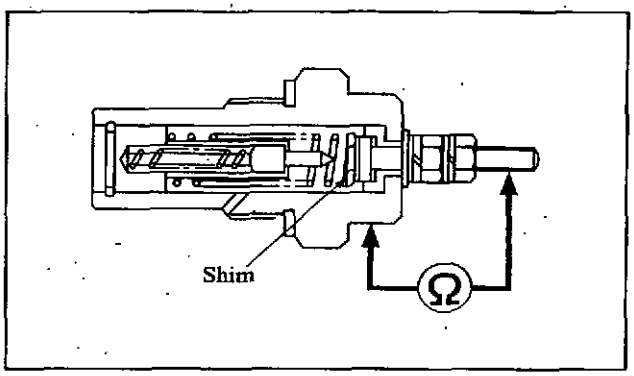
(a) Use a tester to check the alarm for insulation and continuity. If the alarm is found to be defective, disassemble and repair.
If the bakelite or rubber insulations are deteriorated or damaged, replace the alarm.

(b) Inspect the pressure when electricity is turned on.

	Standard
Oil filter alarm (bypass) lamp lighting pressure (differential pressure)	$0.15^{+0.03}_{0}$ MPa ($1.5^{+0.3}_{0}$ kgf/cm^2) [$21.3^{+3.27}_{0}$ psi]

(c) If the filter alarm lamp lighting pressure exceeds the standard, adjust by inserting shims.

Pressure difference every 1 mm [0.04 in.] thickness of shim	0.007 MPa (0.07 kgf/cm^2) [1.00 psi]



Inspection of oil filter alarm

4.3 Reassembly of Oil Filters, Oil Bypass Filter and Oil Filter Alarm

To reassemble, follow the disassembly sequence in reverse.

(1) Install new packings and O-rings in reassembly.

(2) Thoroughly wash the oil passages in the oil filter brackets and other parts with cleaner, and clean with compressed air before reassembly.

(3) Mount the bracket before installing the oil filter element.

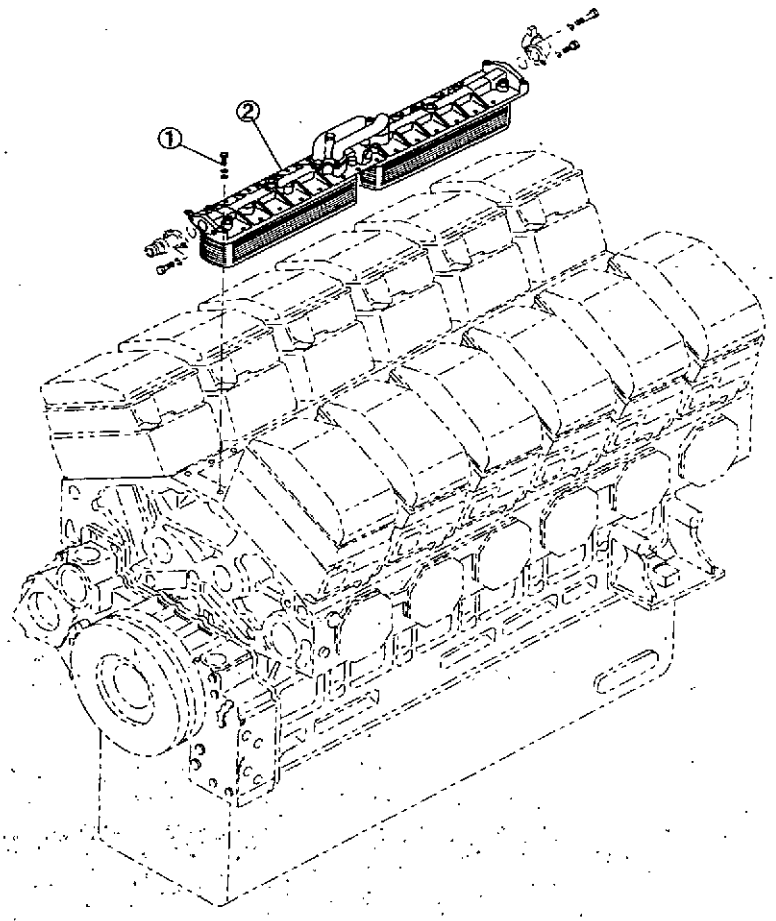
(4) Before installing the cartridge, clean the mounting surface of the cartridge, coat the gasket with clean fuel oil. Screw in the cartridge until the gasket contacts the seal surface, then further rotate 3/4 to 1 turn by hand. (Do not use a filter wrench for installation. Do not use a filter that has dents or scratches, since damaged filter can break during engine operation.)

⚠ CAUTION

After reassembly, start the engine and check for oil leaks.

INSTALLATION OF LUBRICATION SYSTEM

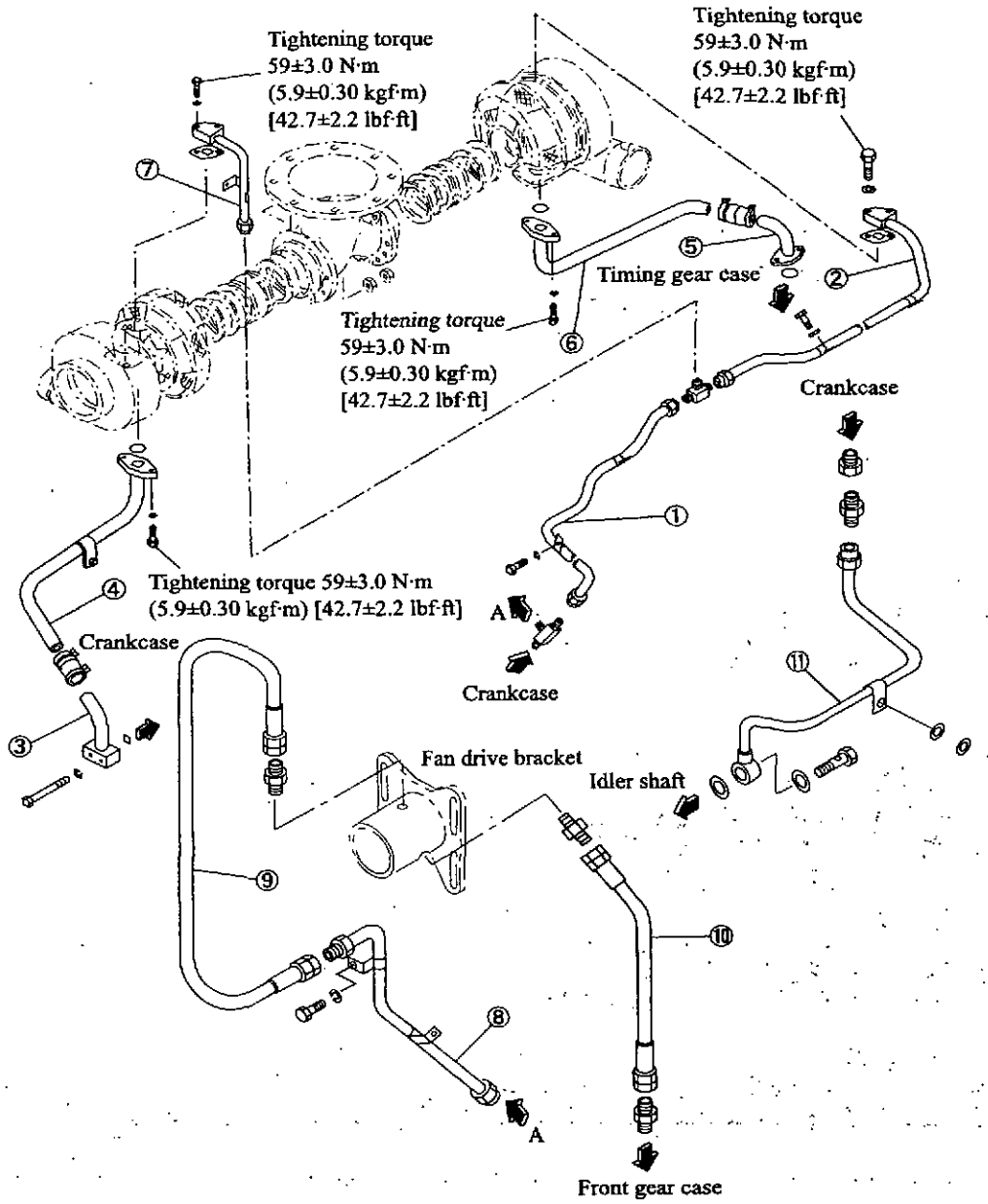
1. Oil Cooler



Installation of oil cooler

< Installation sequence >
②→①

2. Oil Pipes (Part 1)

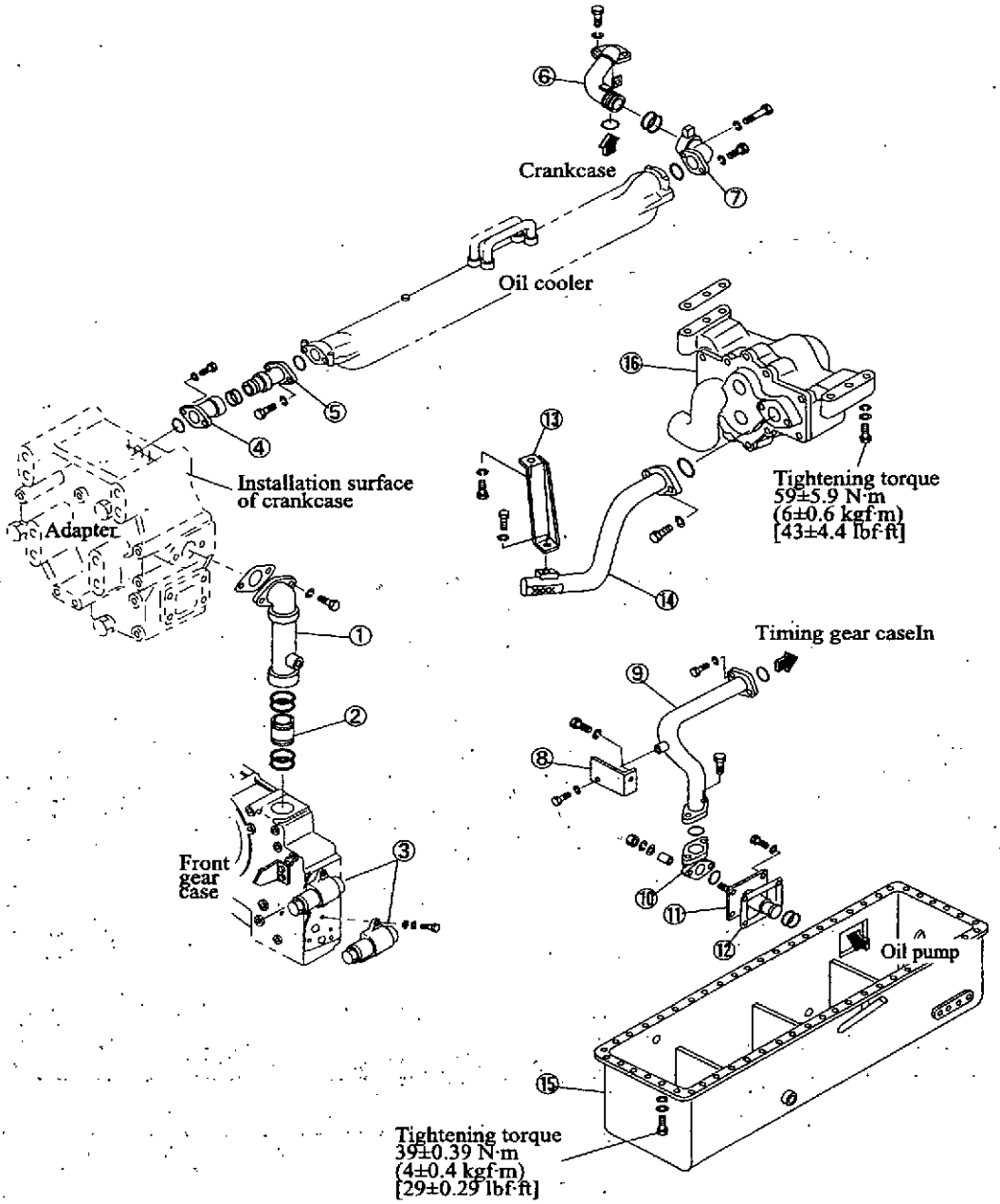


Installation of oil pipes (part 1)

< Installation sequence >

⑪→⑩→⑨→⑧→⑦→⑥→⑤→④→③→②→①

3. Oil Pipes (Part 2)

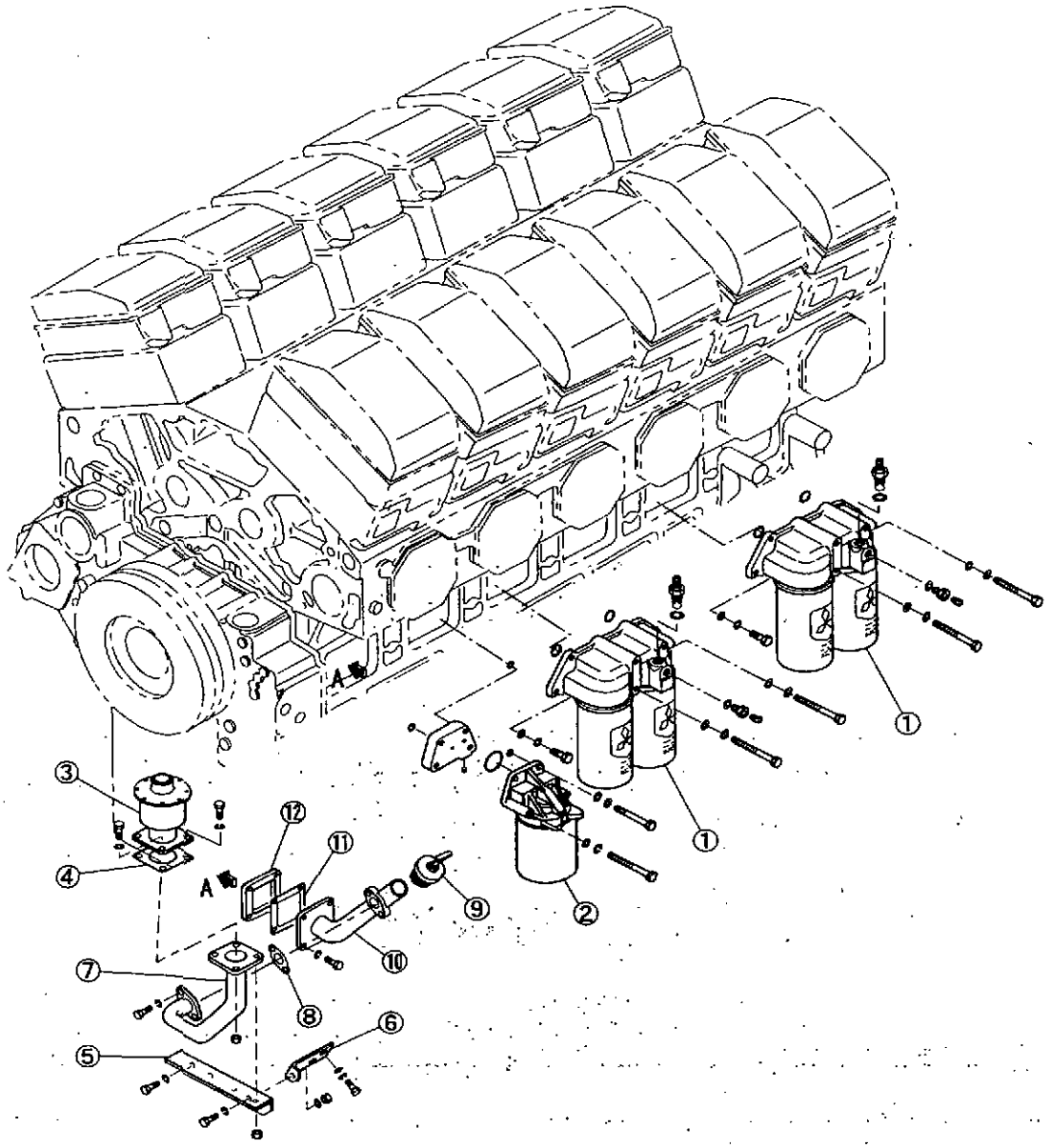


Installation of oil pipes (part 2)

< Installation sequence >

⑫→⑪→⑩→⑨→⑧→⑦→⑥→⑤→④→③→②→①

4. Oil Filters, Oil Bypass Filters and Breather



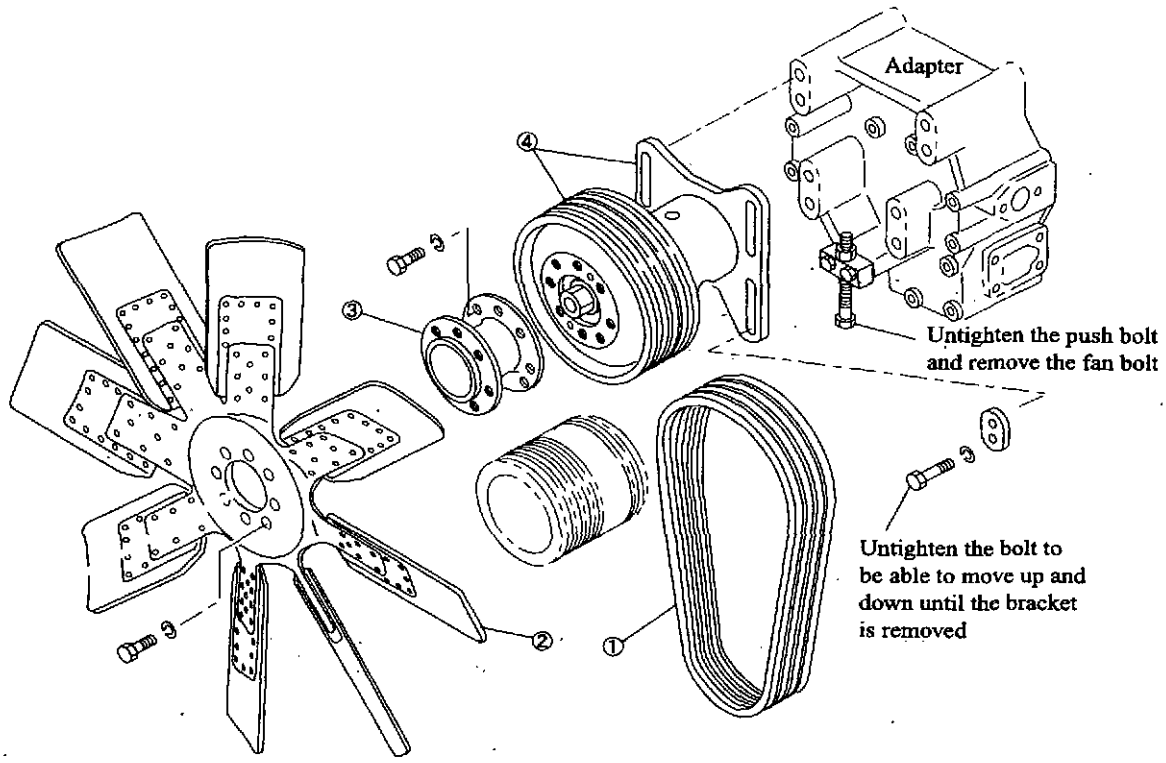
Installation of oil filters, oil bypass filter and breather

<Installation sequence>

⑫→⑪→⑩→⑨→⑧→⑦→⑥→⑤→④→③→②→①

REMOVAL OF COOLING SYSTEM

1. Fan and Fan Drive

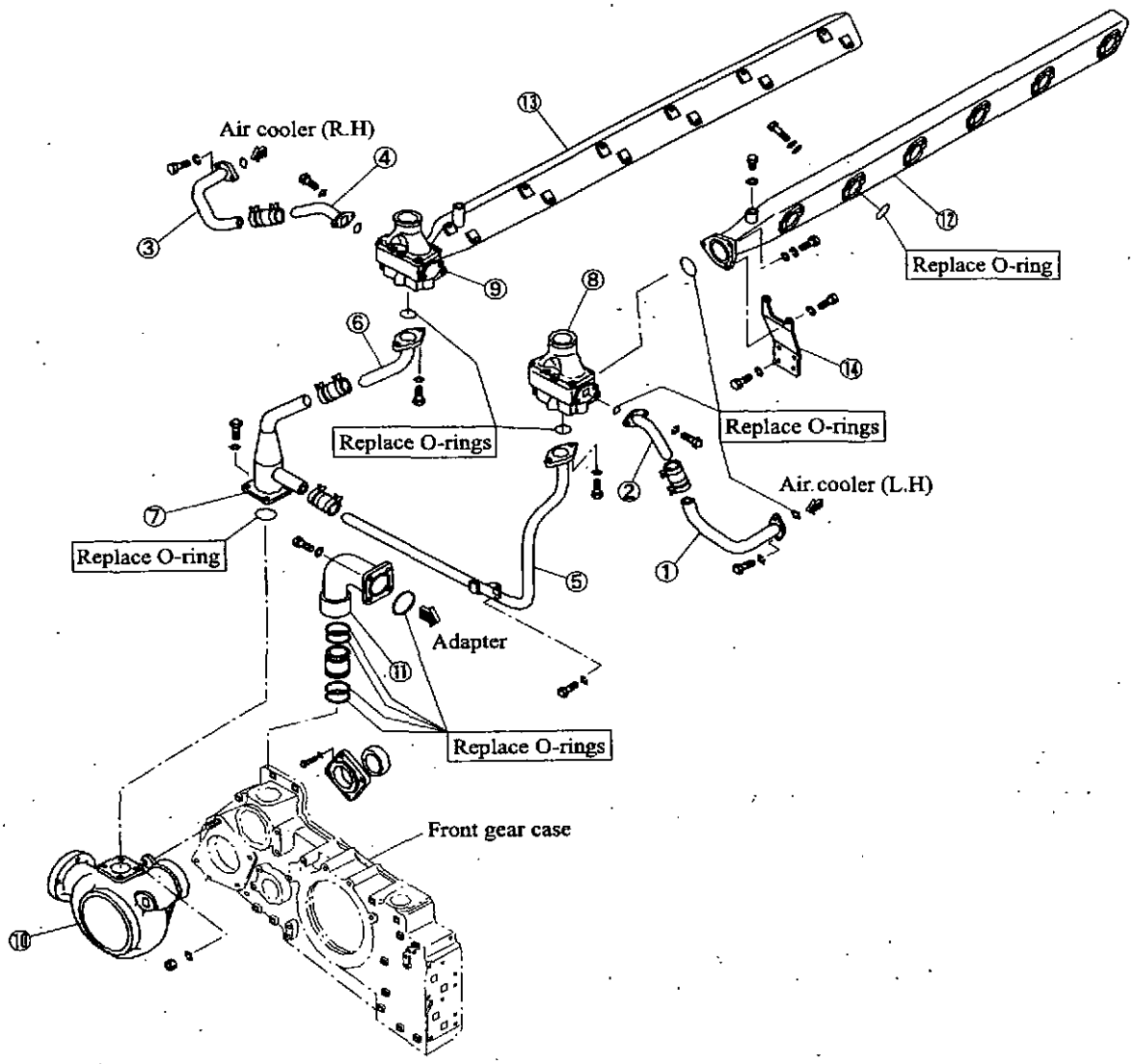


Removal of fan and fan drive

< Removal sequence >

① Fan drive V-belt
② Fan (weight: approx. 82 kg [181 lb.])
③ Spacer
④ Fan pulley assembly and bracket (weight : approx. 45 kg [99.21 lb.])

2. Water Pump and Thermostat

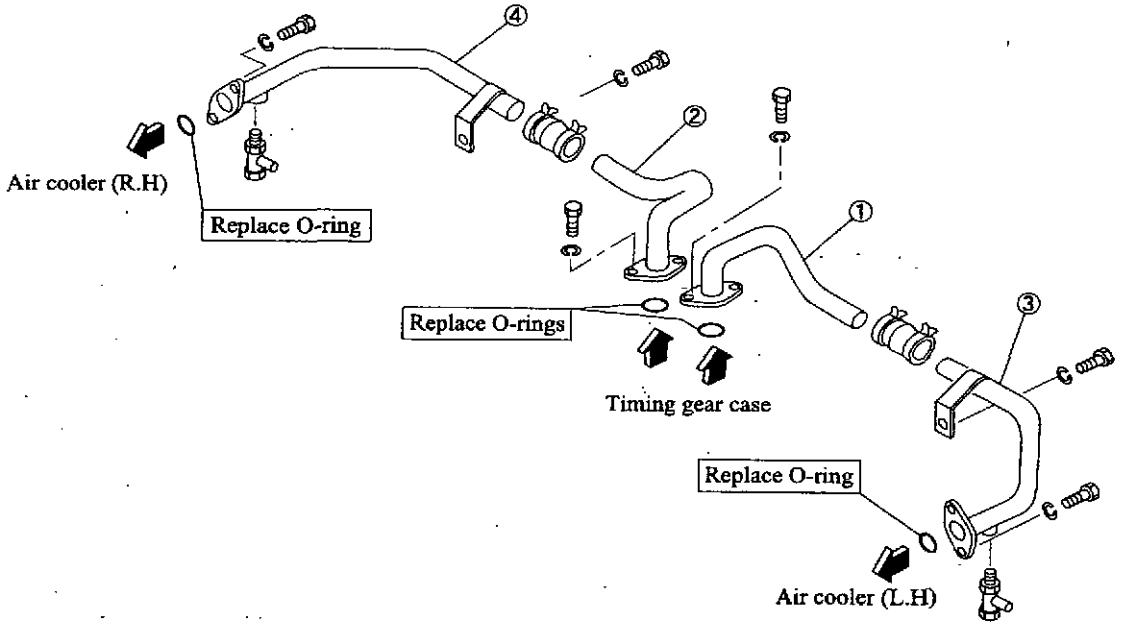


Removal of water pump and thermostat

<Removal sequence>

① Air cooler pipe (L. H.)
② Air cooler pipe
③ Air cooler pipe (R. H.)
④ Air cooler pipe
⑤ Bypass pipe (L. H.)
⑥ Bypass pipe (R. H.)
⑦ Bypass pipe (R. H.)
⑧ Thermostat assembly
⑨ Thermostat assembly
⑩ Water pump (weight: approx. 39 kg [85.98 lb.])
⑪ Water pipe
⑫ Outlet water pipe (L. H.)
⑬ Outlet water pipe (R. H.)
⑭ Stay

3. Air Cooler Pipes

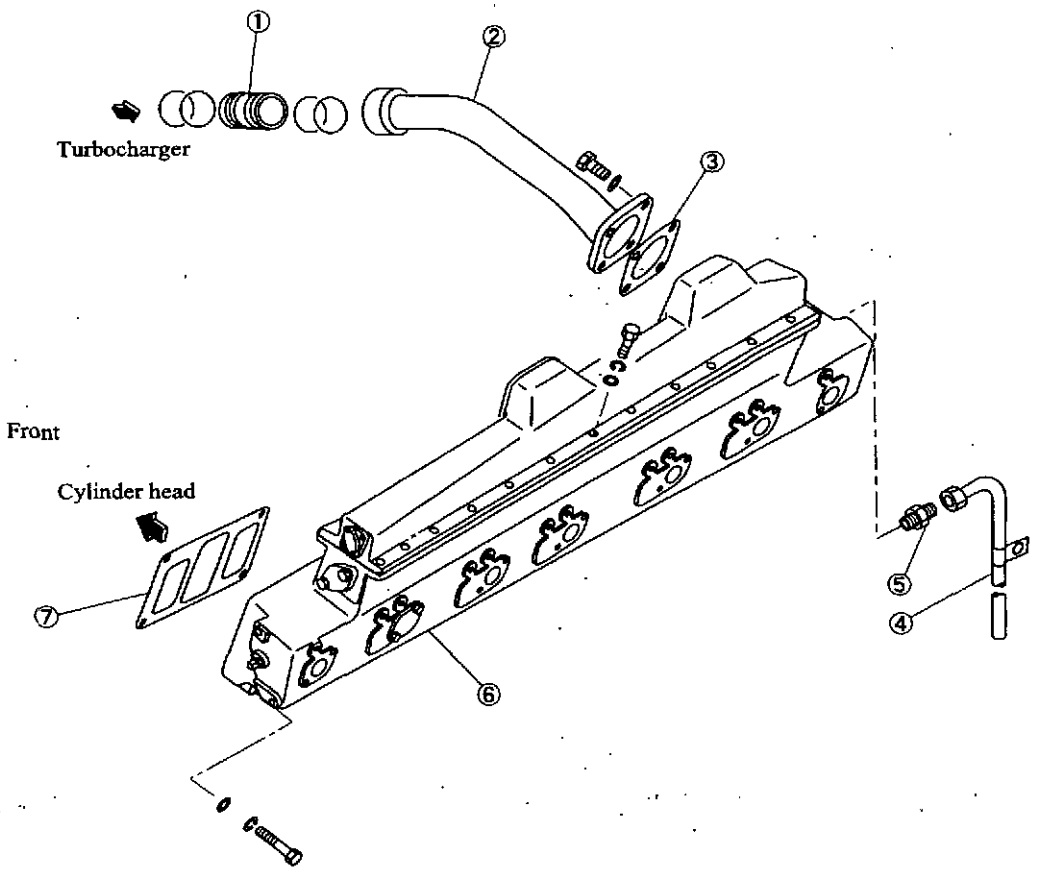


Removal of air cooler

<Removal sequence>
① Air cooler pipe (L. H.)
② Air cooler pipe (R. H.)
③ Air cooler pipe (L. H.)
④ Air cooler pipe (R. H.)

4. Right and Left Side Air Cooler (Left Side)

(Follow the same inspection procedure as that for the right side units.)



Removal of air cooler

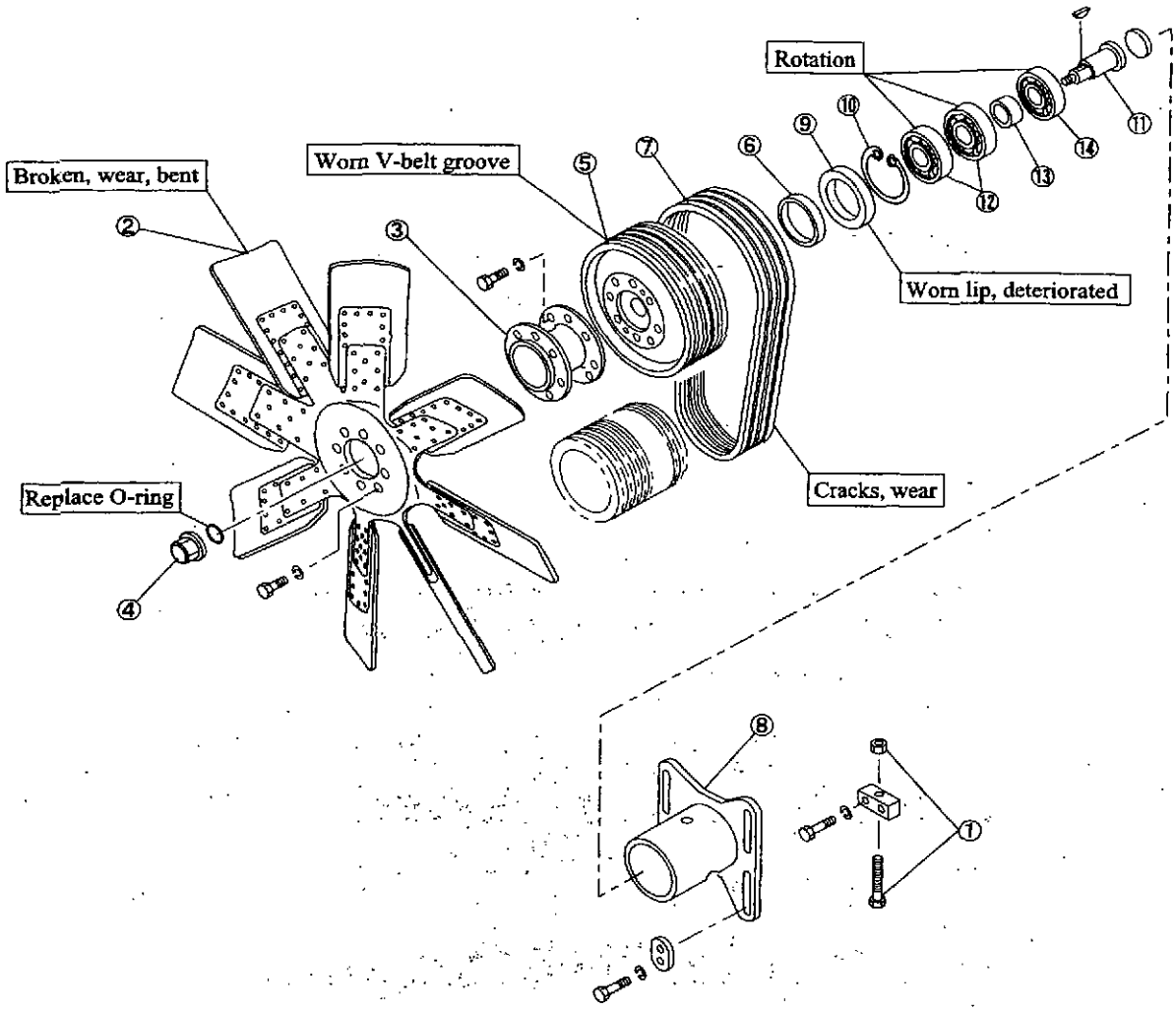
< Removal sequence >

① Joint
② Inlet duct
③ Gasket
④ Drain pipe
⑤ Connector
⑥ Air cooler (L. H.) (weight: approx. 71 kg [156.5 lb.])
⑦ Packing

DISASSEMBLY, INSPECTION AND REASSEMBLY OF COOLING SYSTEM

1. Fan Drive

1.1 Disassembly and Inspection of Fan Drive



Disassembly and inspection of fan drive

<Disassembly sequence>

① Adjust bolt and nut
② Fan
③ Fan spacer
④ Cap nut
⑤ Fan pulley
⑥ Sleeve
⑦ V-belt
⑧ Bracket
⑨ Oil seal
⑩ Snap ring
⑪ Shaft
⑫ Ball bearing
⑬ Spacer
⑭ Ball bearing

1.2 Inspection of Fan Drive

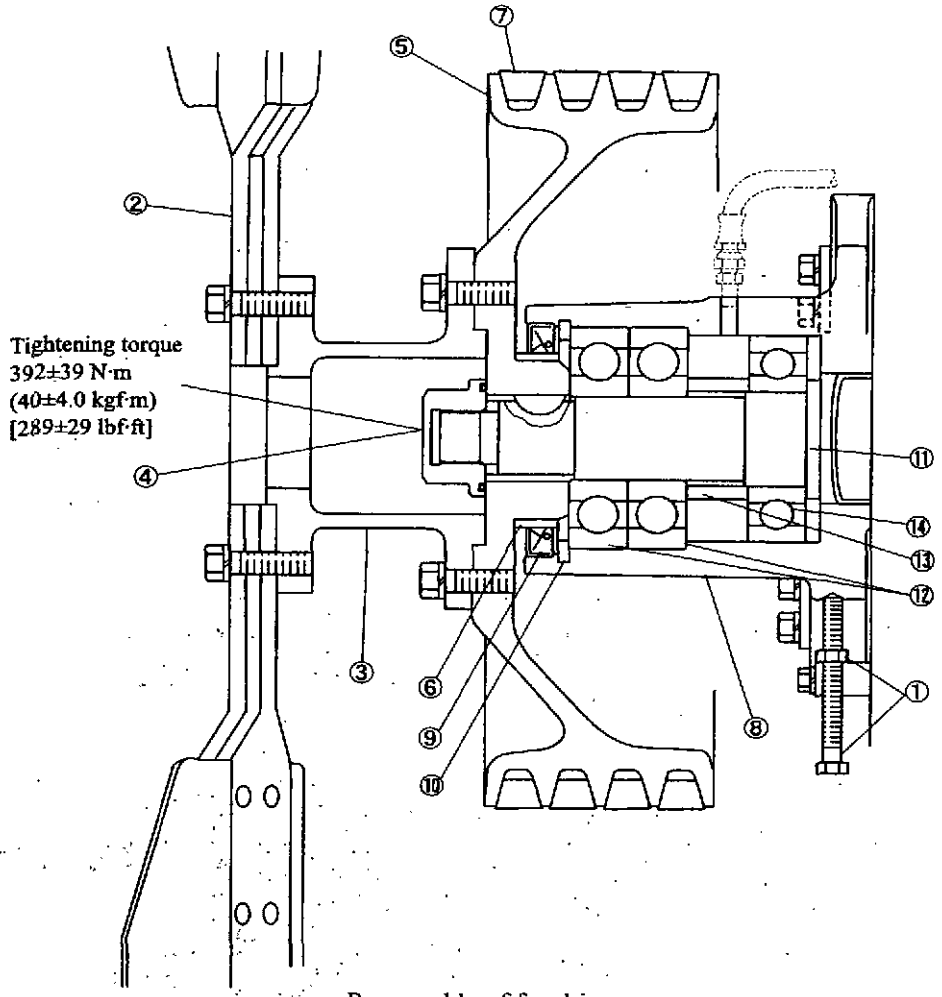
(1) Measure the diameter of bearing fitting sections of the shaft and case.

(2) If they are damaged or worn excessively, replace the bearing and shaft or case.

Unit mm [in.]

			Nominal value	Standard
Case bearing bore diameter			ϕ110 [4.33]	109.987 to 110.022 [4.3335 to 4.3349]
			ϕ120 [4.72]	119.987 to 120.022 [4.72389 to 4.72527]
Bearing	Large	Outside diameter	ϕ120 [4.72]	119.985 to 120.000 [4.72382 to 4.72441]
		Bore diameter	ϕ45 [1.77]	44.988 to 45.000 [1.7725 to 1.773]
	Small	Outside diameter	ϕ110 [4.33]	109.985 to 110.000 [4.33012 to 4.33071]
		Bore diameter	ϕ50 [1.97]	49.988 to 50.000 [1.9694 to 1.970]
Shaft bearing journal diameter			ϕ45 [1.77]	45.002 to 45.013 [1.7731 to 1.7735]
			ϕ50 [1.97]	50.002 to 50.013 [1.9701 to 1.9705]

1.3 Reassembly of Fan Drive



Reassembly of fan drive

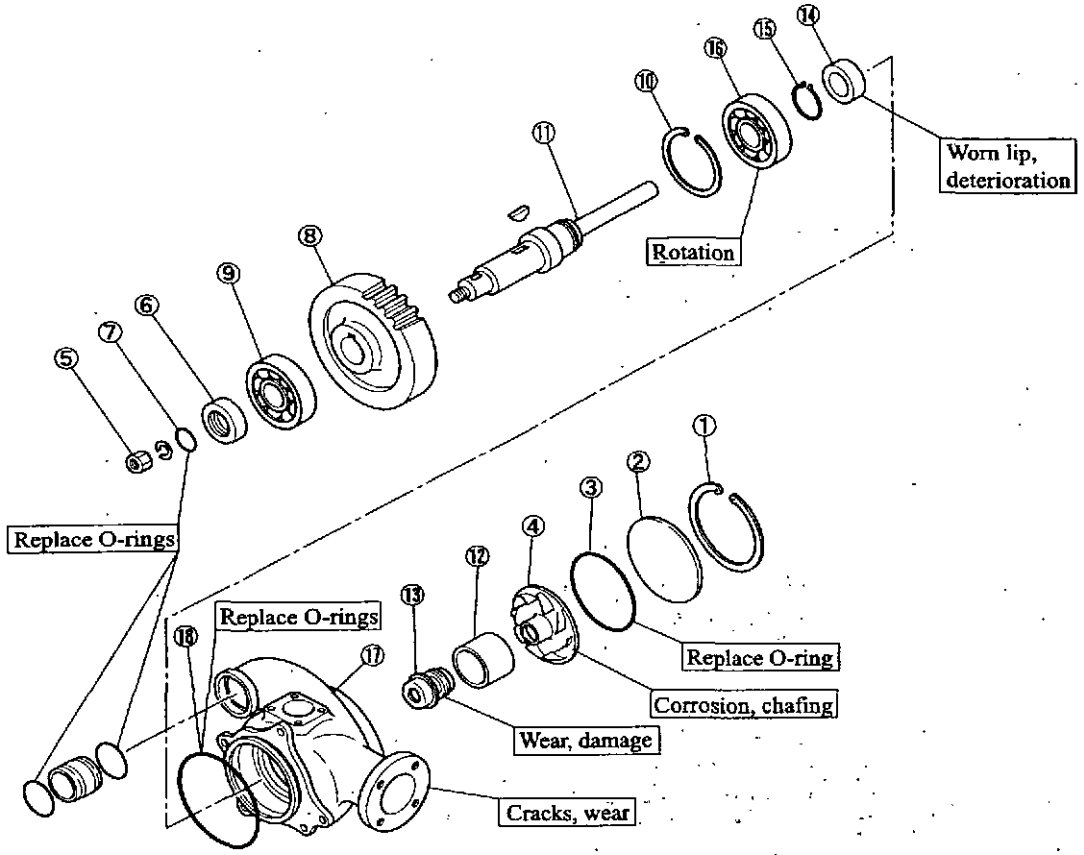
＜Reassembly sequence＞

⑪→⑭→⑬→⑫→⑧→⑩→⑨→④→⑦→③→②→①

⑥→⑤

2. Water Pump

2.1 Disassembly and Inspection of Water Pump

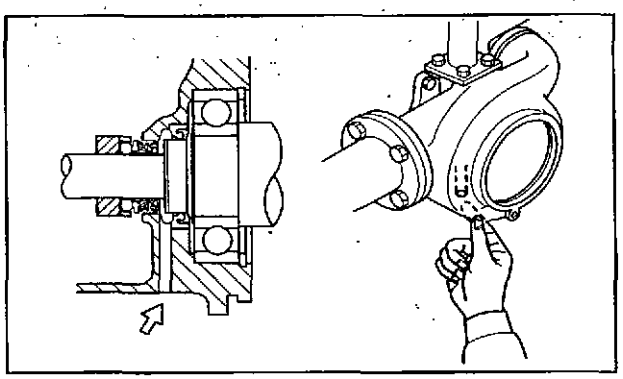


Disassembly and inspection of water pump

<Disassembly sequence>

① Snap ring
② Cover
③ O-ring
④ Water pump impeller
⑤ Nut
⑥ Oil seal sleeve
⑦ O-ring
⑧ Water pump gear
⑨ Bearing
⑩ Snap ring
⑪ Water pump shaft
⑫ Ring
⑬ Unit seal
⑭ Oil seal
⑮ Snap ring
⑯ Bearing
⑰ Pump case (weight: approx. 28 kg [61.7 lb.])
⑱ O-ring

(1) Inspection of pump mounted on engine
With fingers, touch the drain port located on the bottom surface of the pump case near the center.
If it is wet with water, the unit seal is defective.
If it is wet with oil, the oil seal is defective.

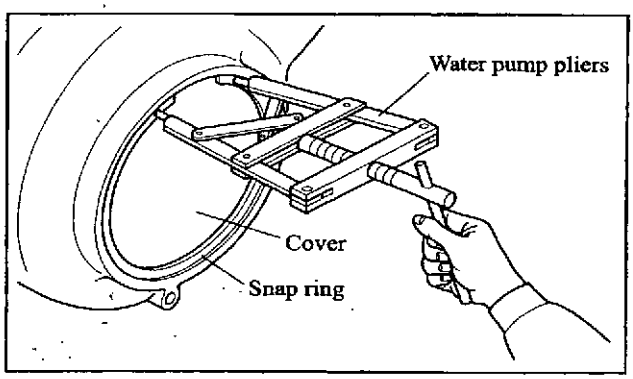


Inspection of pump mounted on engine

(2) Removal of impeller

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

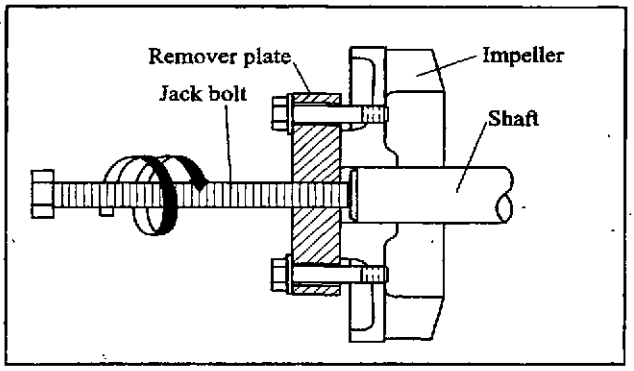
Name of special tool	Part No.
Water pump pliers	37591-03100



Removal of water pump cover

(b) Using the impeller remover, pull out the impeller.

Name of special tool	Part No.
Impeller remover	37591-03200



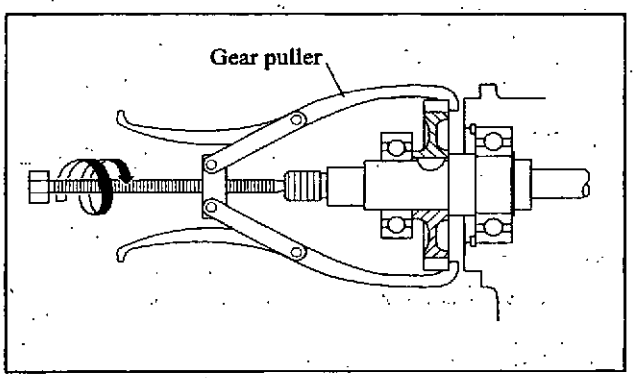
Removal of water pump impeller

(3) Removal of water pump gear

(a) Remove the oil seal sleeve.

(b) Using the gear puller, remove the gear and ball bearing together.

(c) Remove the snap ring from the impeller-side ball bearing.



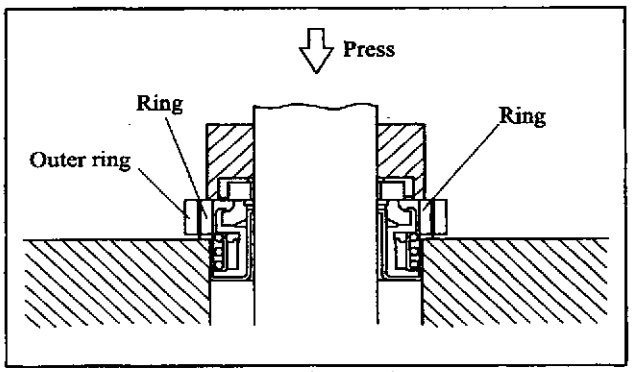
Removal of water pump gear

(d) Insert the two half ring pieces of the ring remover between the unit seal and pump case, as shown in the diagram.

Name of special tool	Part No.
Ring remover	37591-03400

(e) Fit the outer ring on the outside, making sure that the half ring pieces will not be dislodged.

(f) While holding the pump case, press the impeller end face with a hand-operated press in the direction of the arrow indicated in the diagram to remove the gear.



Removal of water pump shaft

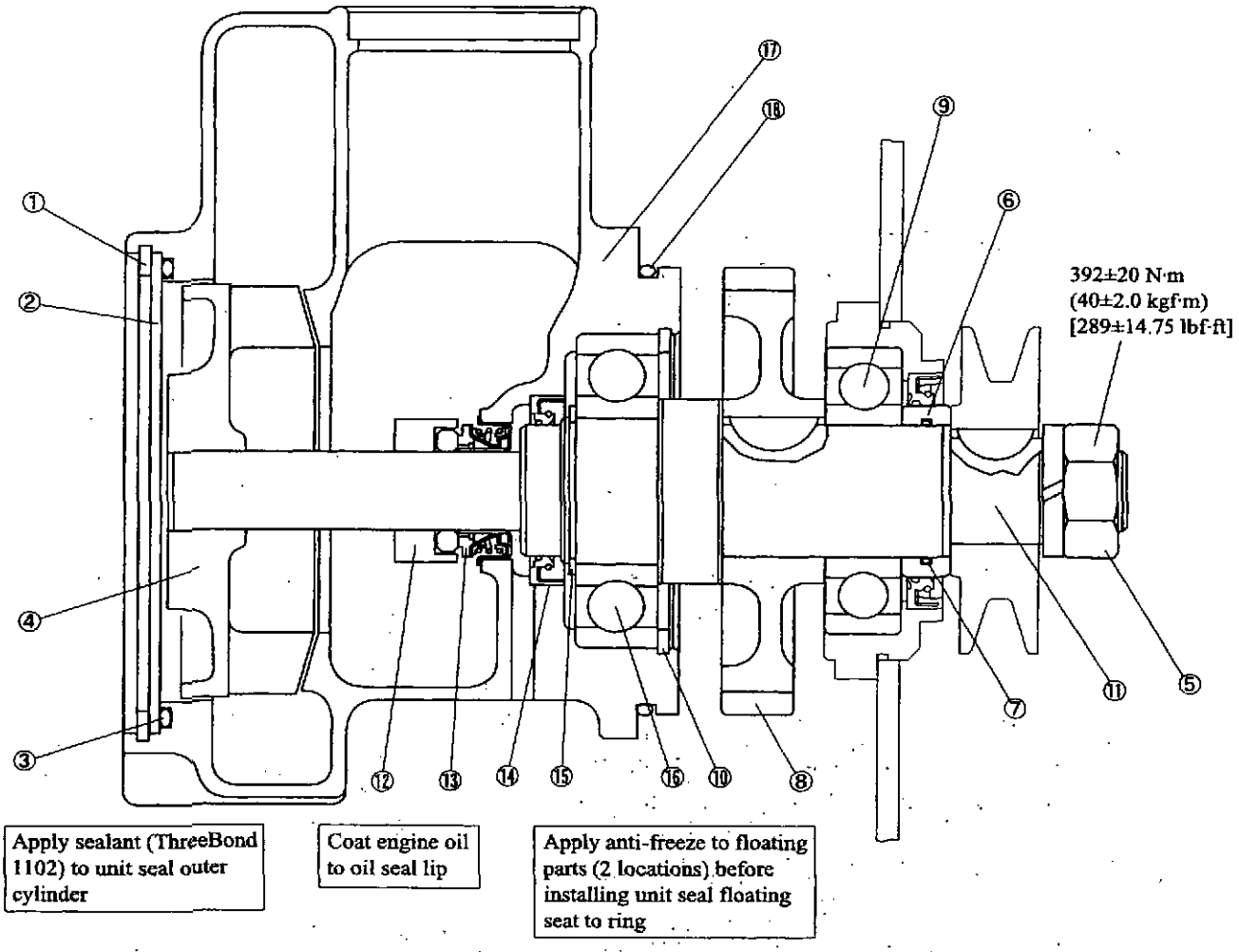
2.2 Inspection of Water Pump

Measure the bearing fitting sections of the water pump case, bearing cover and shaft. If they are damaged or worn excessively, replace the bearing and case or shaft.

Unit mm [in.]

			Nominal value	Standard
Bearing bore diameter of pump case			ϕ120 [4.72]	119.987 to 120.022 [4.72389 to 4.72527]
Bearing bore diameter of cover			ϕ110 [4.33]	110.005 to 110.040 [4.33090 to 4.33227]
Bearing	Large	Outside diameter	ϕ120 [4.72]	119.985 to 120.000 [4.72382 to 4.72441]
		Bore diameter	ϕ55 [2.17]	54.985 to 55.000 [2.16476 to 2.16535]
	Small	Outside diameter	ϕ110 [4.33]	109.985 to 110.000 [4.33012 to 4.33071]
		Bore diameter	ϕ50 [1.97]	49.988 to 50.000 [1.96803 to 1.96850]
Shaft bearing journal diameter			ϕ55 [2.17]	55.011 to 55.024 [2.16578 to 2.16629]
			ϕ50 [1.97]	55.011 to 50.024 [2.16578 to 2.16629]
Vane front face clearance			1.04 [0.041]	0.58 to 1.50 [0.023 to 0.059]

2.3 Reassembly of Water Pump



Reassembly of water pump

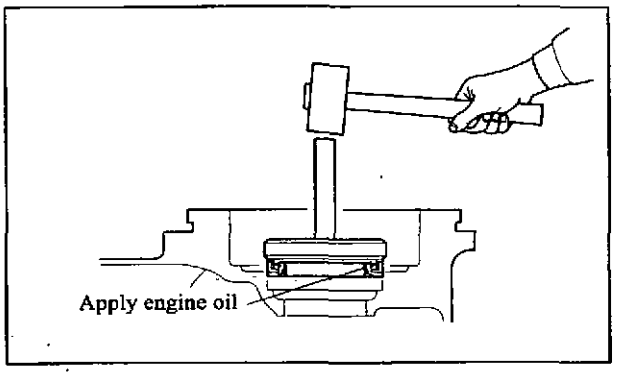
< Reassembly sequence >

⑦↓
⑰→⑭→⑬→⑩→⑧→⑨→⑥→⑤→⑫→④→③→②→①→⑱
⑪→⑯→⑮↑

⚠ CAUTION

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

(1) Using unit seal installer, press-fit the oil seal. Be sure to coat the oil seal lip with engine oil.

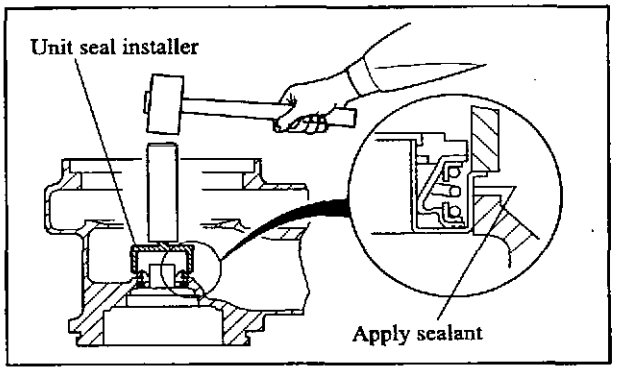


Installation of oil seal

(2) Using the unit seal installer, press-fit the unit seal into the pump case.

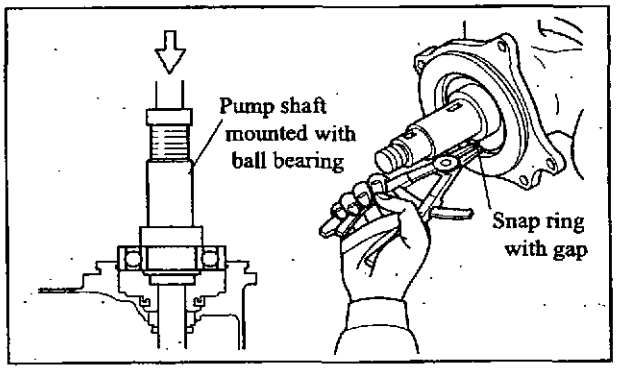
Note: When the unit seal has been removed from the pump case, be sure install a new unit seal. Coat the periphery of the unit seal with sealant (ThreeBond 1102) before installation.

Name of special tool	Part No.
Unit seal installer	37591-03400



Installation of unit seal

(3) Using a press, install the pump shaft mounted with the impeller-side ball bearing to the case.
Install the snap ring with the gap facing downward.

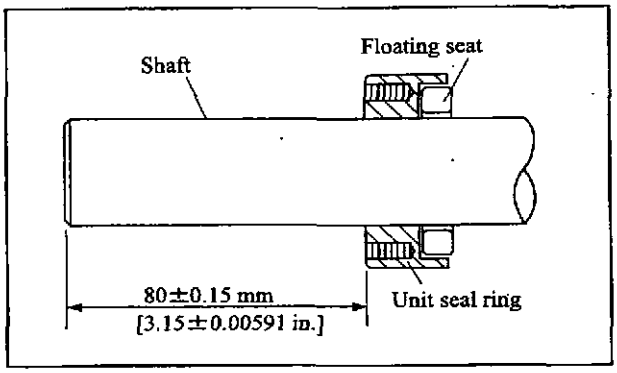


Installation of ball bearing

(4) Using a press and the ring installer, gently install the unit seal ring mounted with the unit seal floating seat to the specified dimension.

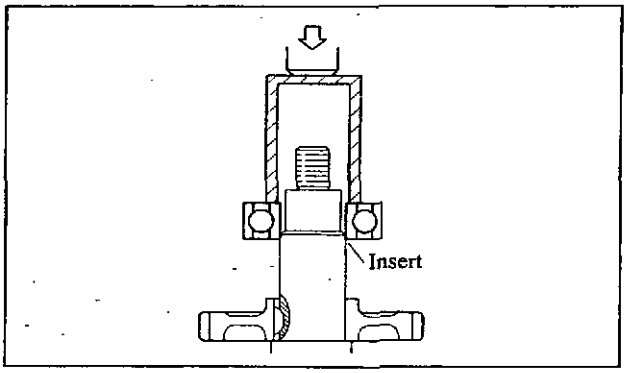
Note: Apply LLC solution (anti-freeze) to two locations on the float seat before installation.

Name of special tool	Part No.
Ring installer	37791-03300



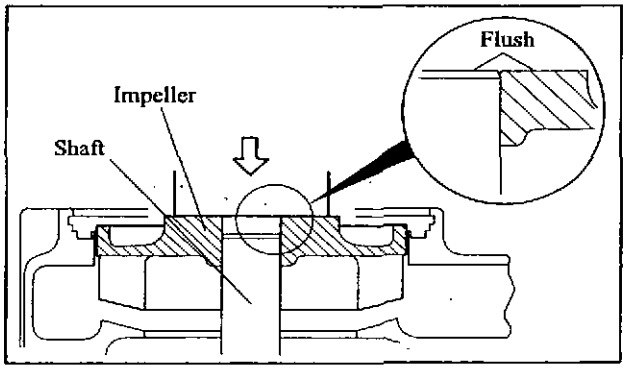
Assembly of unit seal ring

(5) Install the gear to the shaft by aligning the key, then use a press to insert the nut-side ball bearing.



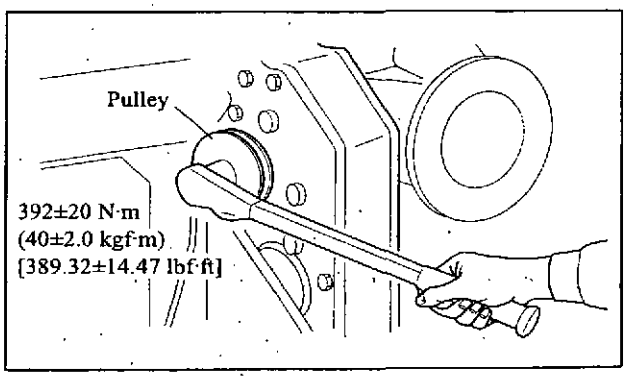
Installation of ball bearing

(6) Using a press, press-fit the impeller. Make sure the boss end surface of the impeller is flush with the pump shaft end face.



Installation of water pump impeller

(7) After the water pump assembly is installed, mount the alternator pulley on the rear end of the pump shaft, and tighten the nut to the specified torque.

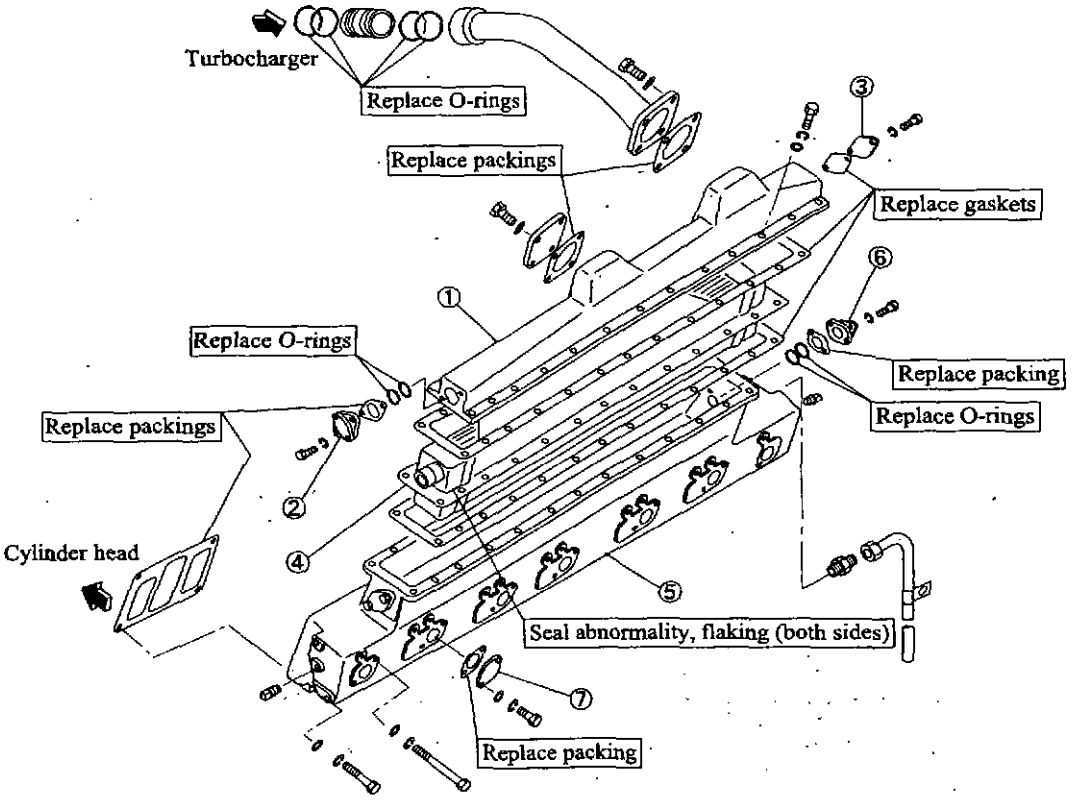


Installation of alternator pulley

3. Right and Left Side Air Cooler (Left Side)

(Follow the same inspection procedure as that for the right side units.)

3.1 Disassembly and Inspection of Air Cooler (Left Side)



Disassembly and inspection of air cooler (left side)

<Disassembly sequence>

① Air cooler cover
② Connector
③ Flange
④ Air cooler element
⑤ Inlet manifold
⑥ Connector
⑦ Cover

3.2 Reassembly of Air Cooler (Left Side)

To reassembly, follow the disassembly sequence in reverse.

3.3 Inspection of Air Cooler

(1) Cleaning air cooler

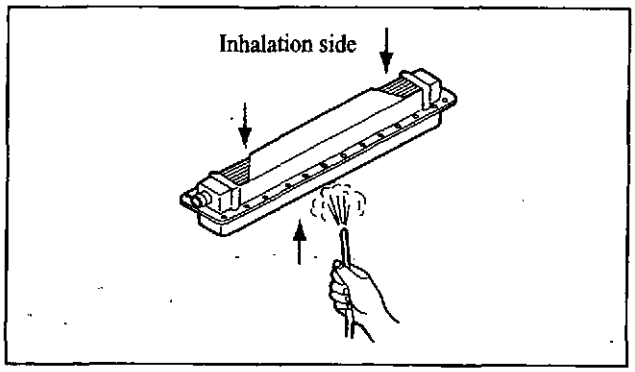
(a) Blow compressed air in the direction opposite to the normal air flow to remove dust and other materials, and inspect the air cooler for corrosion and cracks.

Compressed air pressure	0.29 to 0.49 MPa (3 to 5 kgf/cm^2) [42.06 to 71.07 psi] or less

(b) Wash the fresh water or salt water pipes caustic soda in water or soda lime, then remove scale deposits.

⚠ CAUTION

Protect your hands with rubber gloves when handling caustic soda or soda lime.



Cleaning air cooler

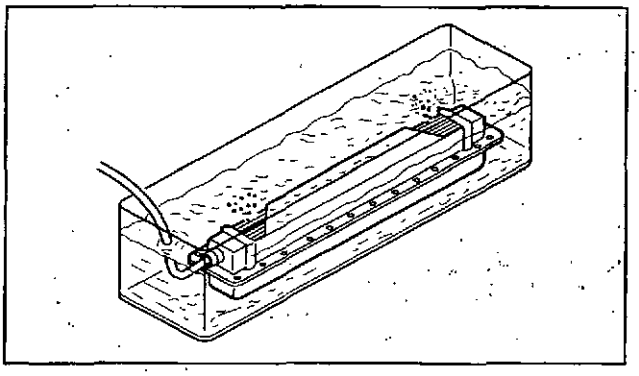
(2) Inspection of air cooler for leakage

Immerse the air cooler in a tank filled with water, and supply compressed air to the air cooler to check for air leaks.

Compressed air pressure	0.39 MPa (4 kgf/cm^2) [56.56 psi]

⚠ CAUTION

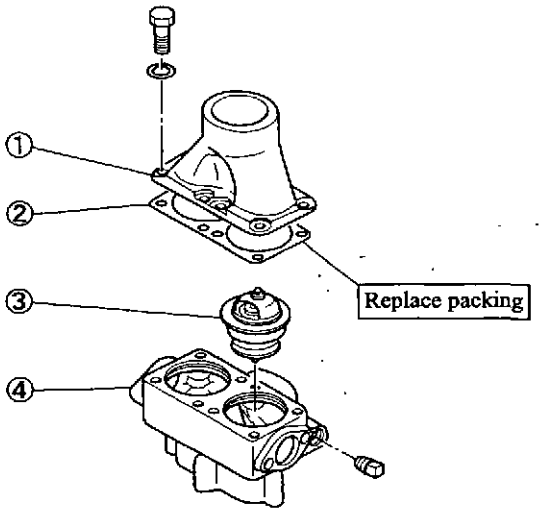
Note that the structure and material of the air cooler for fresh water are different from those for sea water.



Inspection of air cooler for leakage

4. Thermostat

4.1 Disassembly and Inspection of Thermostat



Disassembly and inspection of thermostat

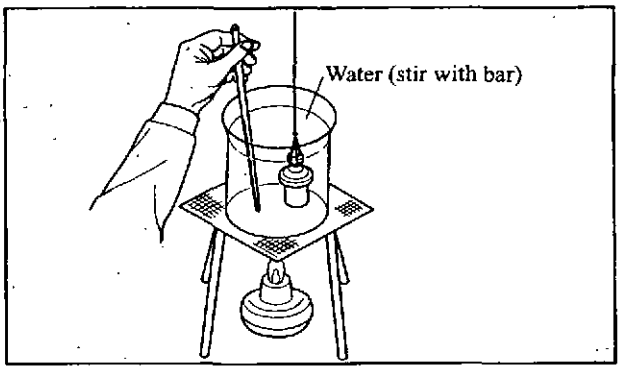
<Disassembly sequence>
① Case cover
② Packing
③ Thermostat
④ Thermostat case

4.2 Inspection of Thermostat

(1) Testing thermostat operation
  (a) Immerse the thermostat in a container filled with water.
  (b) Heat the water, while measuring the water temperature. Record the temperature at which the valve opens and the temperature at which the valve lift becomes 10 mm [0.394 in.] or more.
  (c) If the temperatures are not within the standard range, replace the thermostat.

Unit C° [F°]

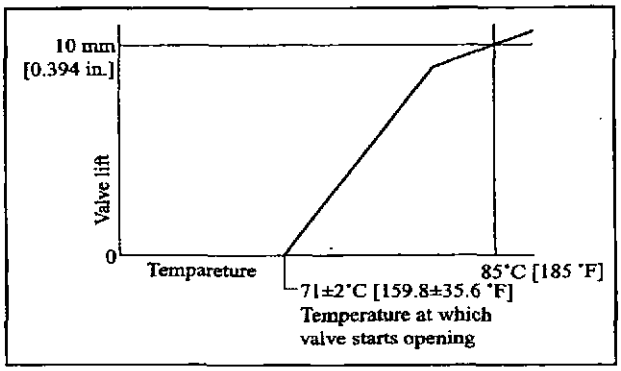
	Standard
Valve opening temperature	71±2 [159.8±35.6]
Temperature at which valve lift is 10 mm [0.394 in.] or more	85 [185]



Inspection of water thermostat

⚠ CAUTION

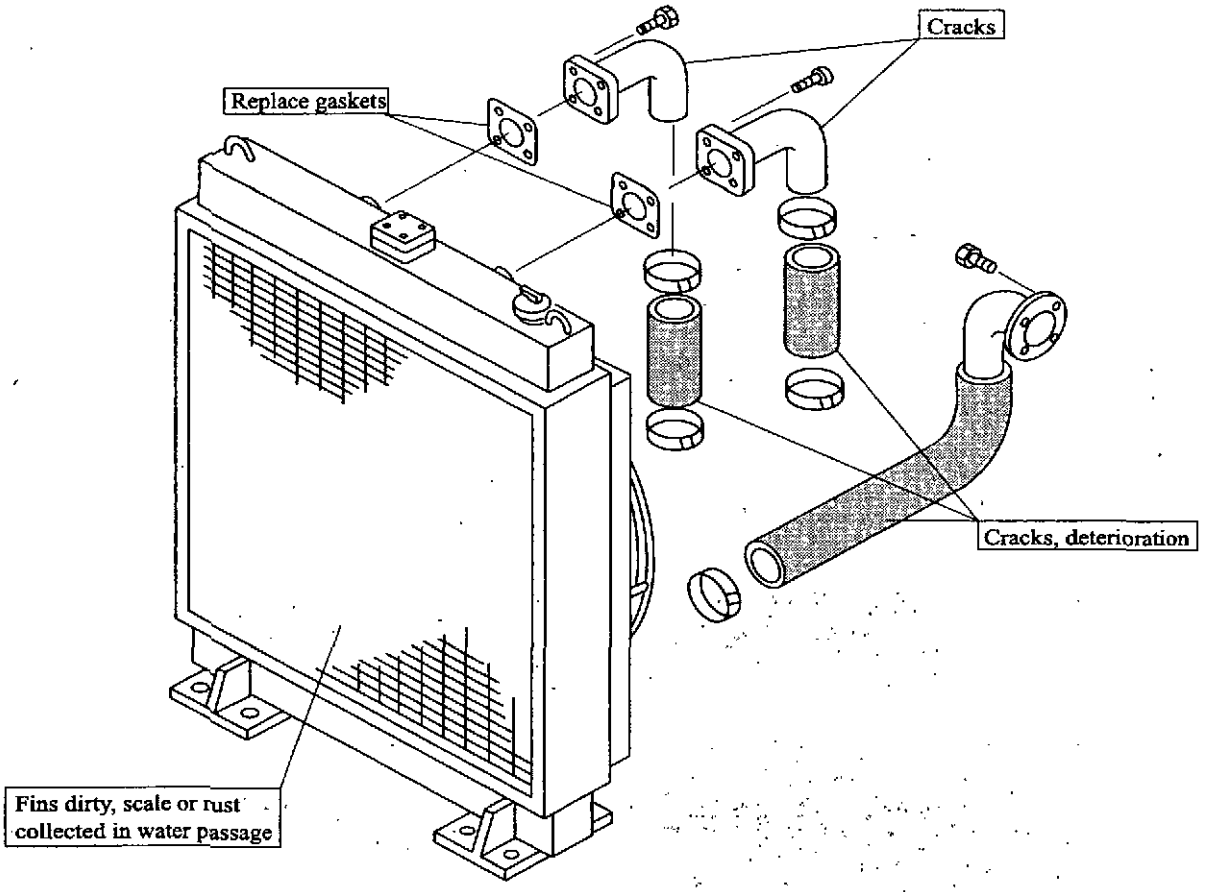
- Stir the water in the container with bar to ensure uniform temperature distribution.
- When installing the thermostat, be sure to check the valve opening temperature stamped on the thermostat valve end face.



Thermostat performance curve

5. Radiator

Inspection of Radiator

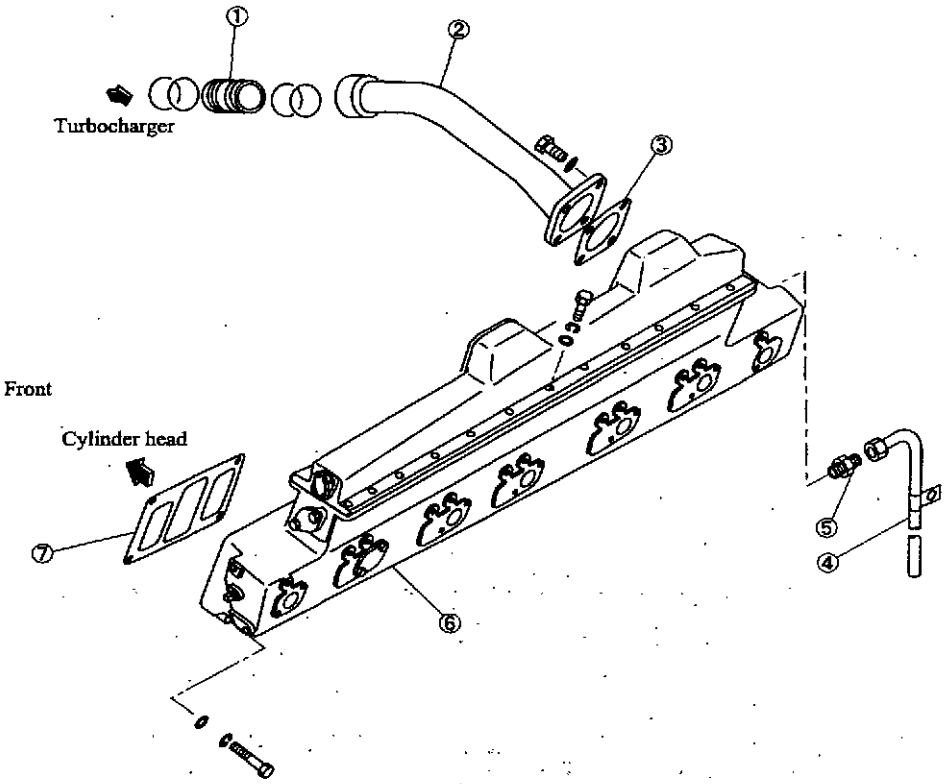


Inspection of radiator

INSTALLATION OF COOLING SYSTEM

1. Right and Left Side Air Cooler (Left Side)

(Follow the same inspection procedure as that for the right side units.)

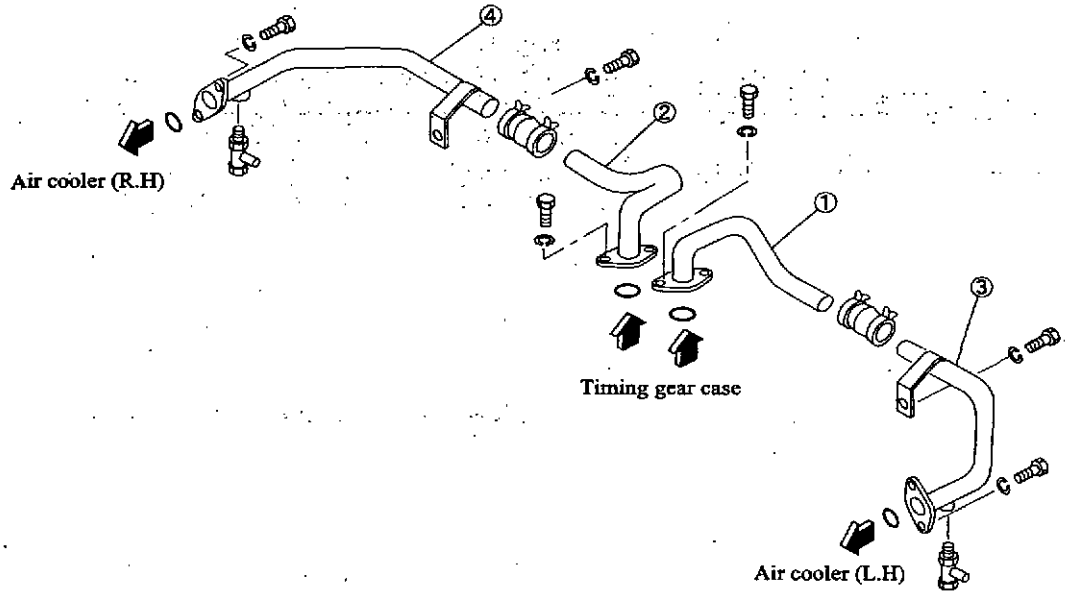


Installation of right and left air cooler (left side)

< Installation sequence >

⑦→⑥→⑤→④→③→②→①

2. Air Cooler Pipes

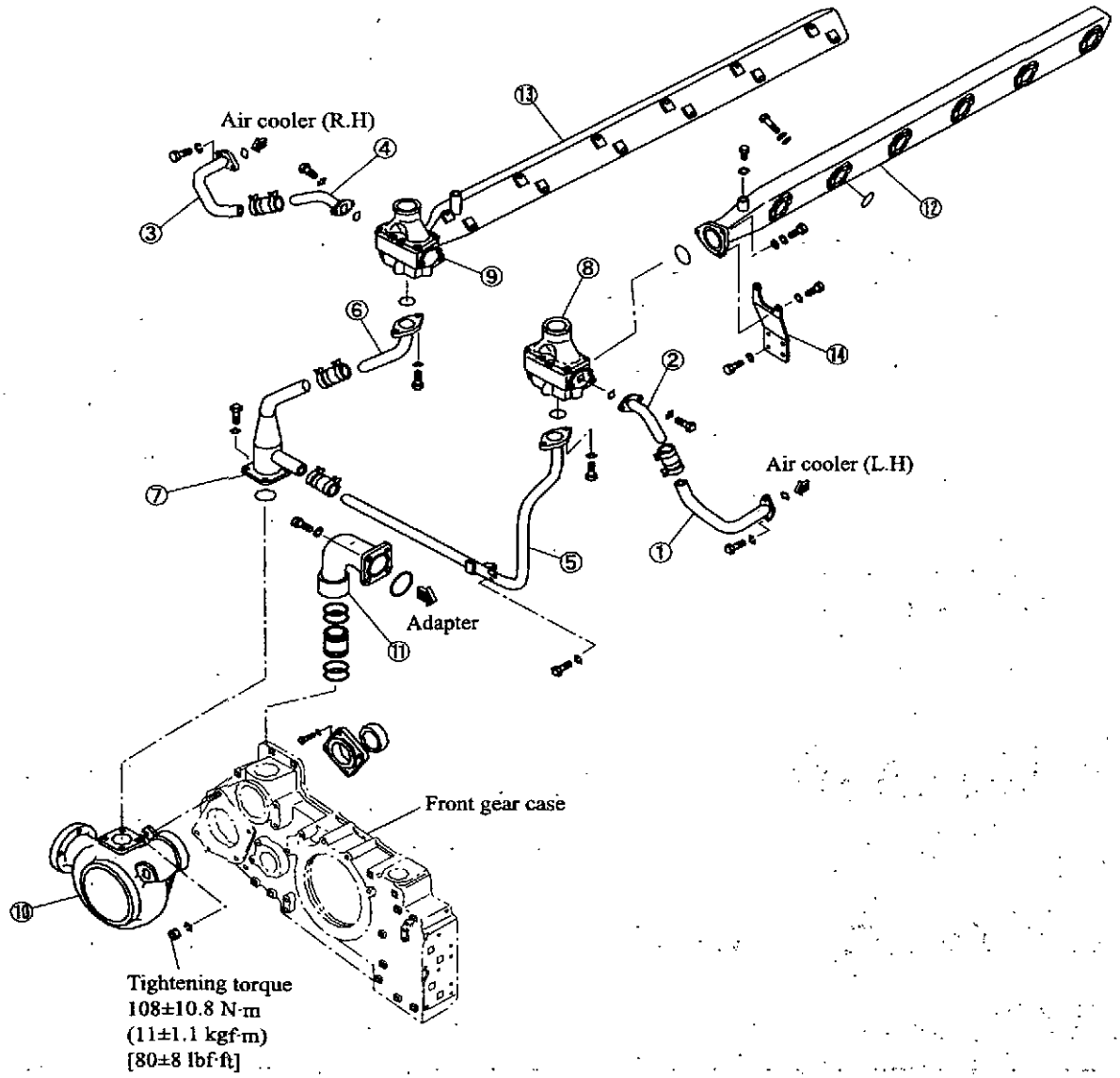


Installation of air cooler pipes

< Installation sequence >

④→③→②→①

3. Water Pump and Thermostat

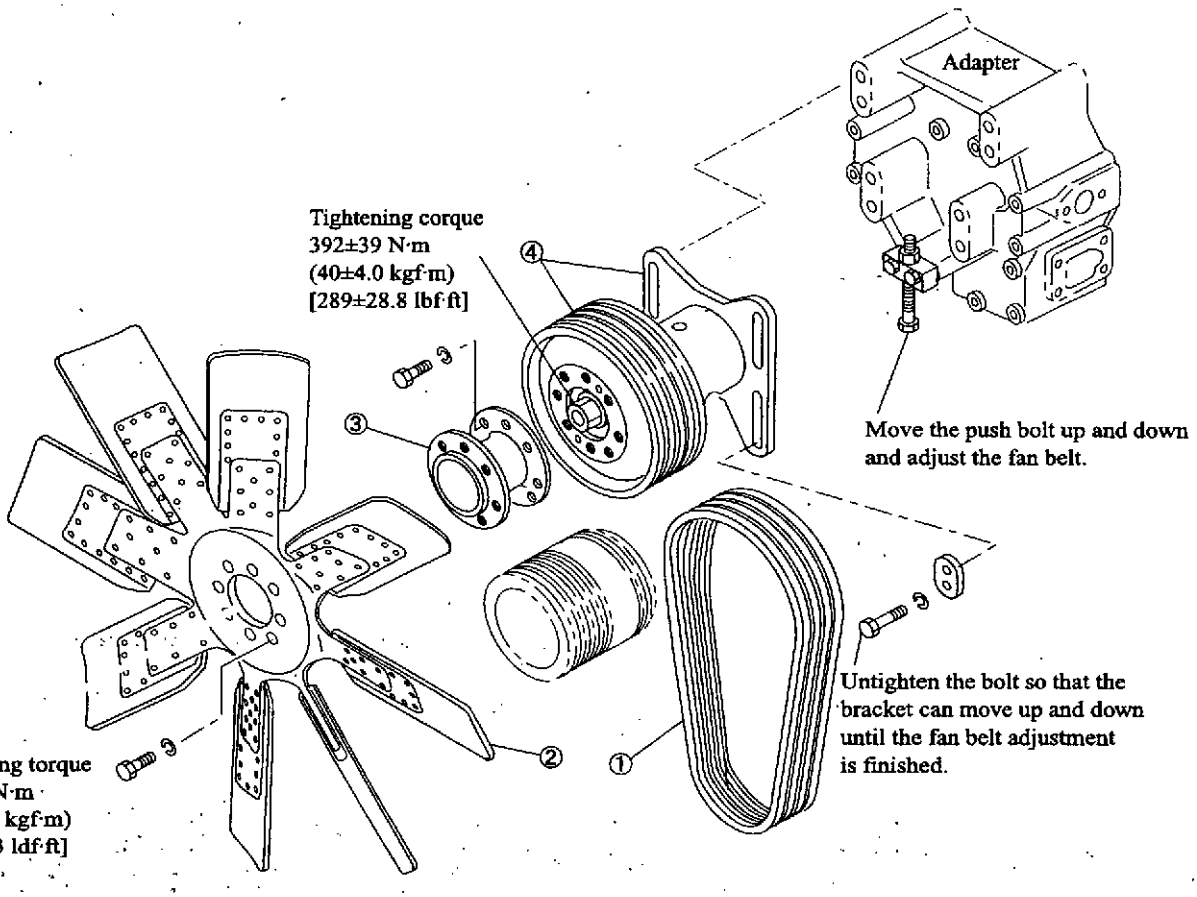


Installation of water pump and thermostat

< Installation sequence >

⑭→⑬→⑫→⑪→⑩→⑨→⑧→⑦→⑥→⑤→④→③→②→①

4. Fan and Fan Drive

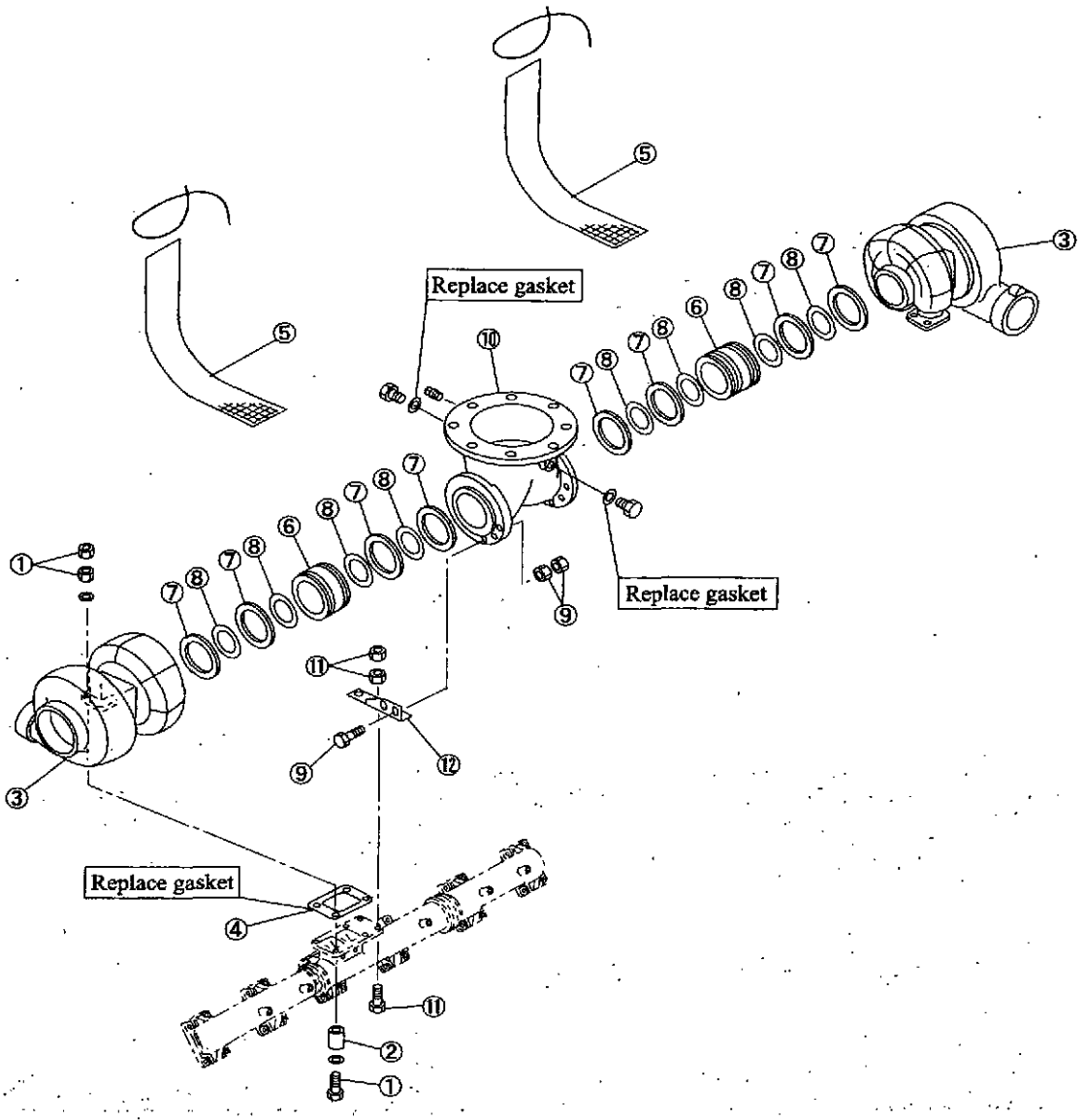


Installation of fan and fan drive

<Installation sequence>
④→③→①→②

REMOVAL OF INLET AND EXHAUST SYSTEMS

1. Turbocharger and Exhaust Pipes

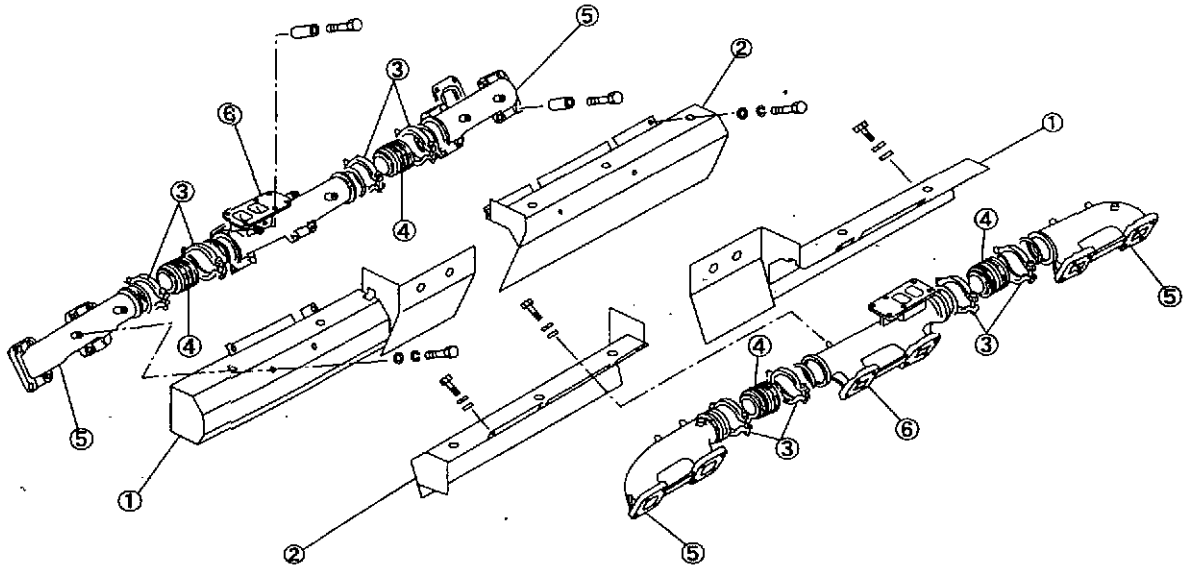


Removal of turbocharger and exhaust pipes

<Removal sequence>

① Bolt and nut
② Spacer
③ Turbocharger
④ Gasket
⑤ Heat insulator
⑥ Joint
⑦ Seal outer ring
⑧ Seal inner ring
⑨ Bolt and nut
⑩ Exhaust pipe
⑪ Bolt and nut
⑫ Bracket

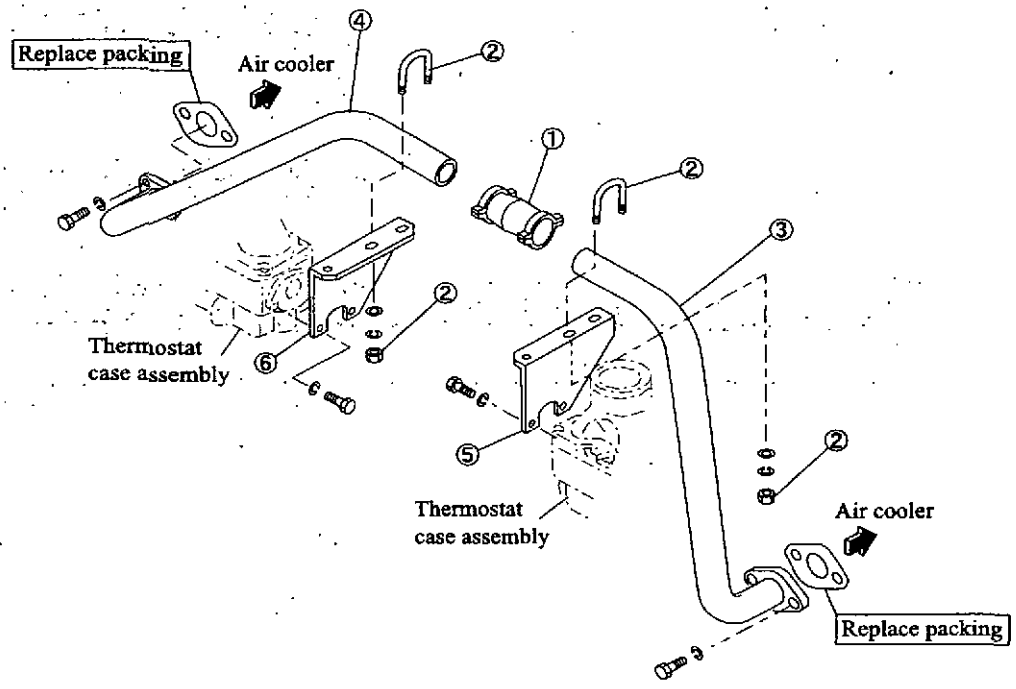
2. Exhaust Manifolds and Insulators



Removal of exhaust manifolds and insulators

<Removal sequence>
① Insulator (A)
② Insulator (B)
③ Coupling assembly
④ Flexible joint
⑤ Exhaust manifold
⑥ Exhaust manifold

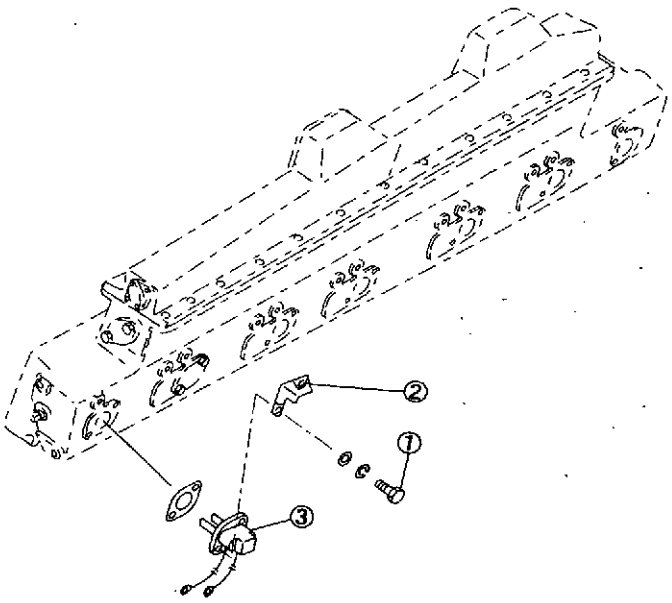
3. Air Pipes



Removal of air pipes

<Removal sequence>
① Coupling
② Bolt and nut
③ Air pipe (L. H.)
④ Air pipe (R. H.)
⑤ Pipe stay (L. H.)
⑥ Pipe stay (R. H.)

4. Air Heater



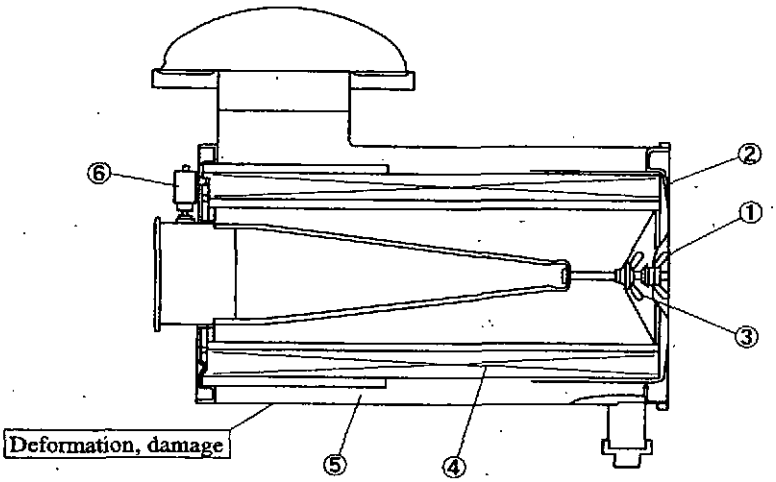
Removal of air heater

<Removal sequence>
① Bolt
② Insulator
③ Air heater

DISASSEMBLY, INSPECTION AND REASSEMBLY OF INLET AND EXHAUST SYSTEMS

1. Air Cleaner

1.1 Disassembly and Inspection of Air Cleaner



Disassembly and inspection of air cleaner

<Disassembly sequence>

① Wing nut	③ Wing nut	⑤ Air cleaner body
② Cover	④ Element	⑥ Dust indicator

⚠ CAUTION

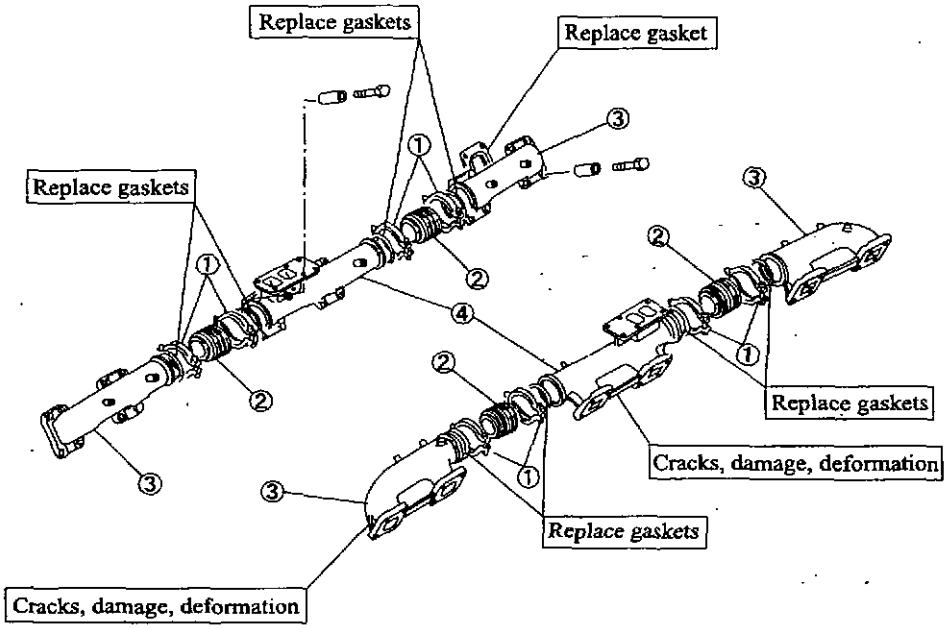
When removing the air cleaner, be sure to stop the engine and cover the air inlet port completely to prevent dust and other particles from entering the engine.

1.2 Reassembly of Air Cleaner

To reassemble, follow the reassembly sequence in reverse.

2. Exhaust Manifolds

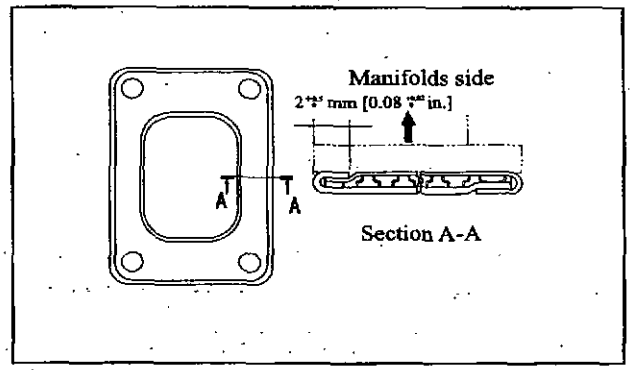
2.1 Disassembly and Inspection of Exhaust Manifolds



Disassembly and inspection of exhaust manifolds

<Disassembly sequence>
① Coupling assembly
② Flexible joint
③ Exhaust manifold
④ Exhaust gasket

Note: (a) Position the gasket so that the folded section faces the manifold, as shown in the diagram on the right.
(b) When installing the gasket, replace all other gaskets with new parts.



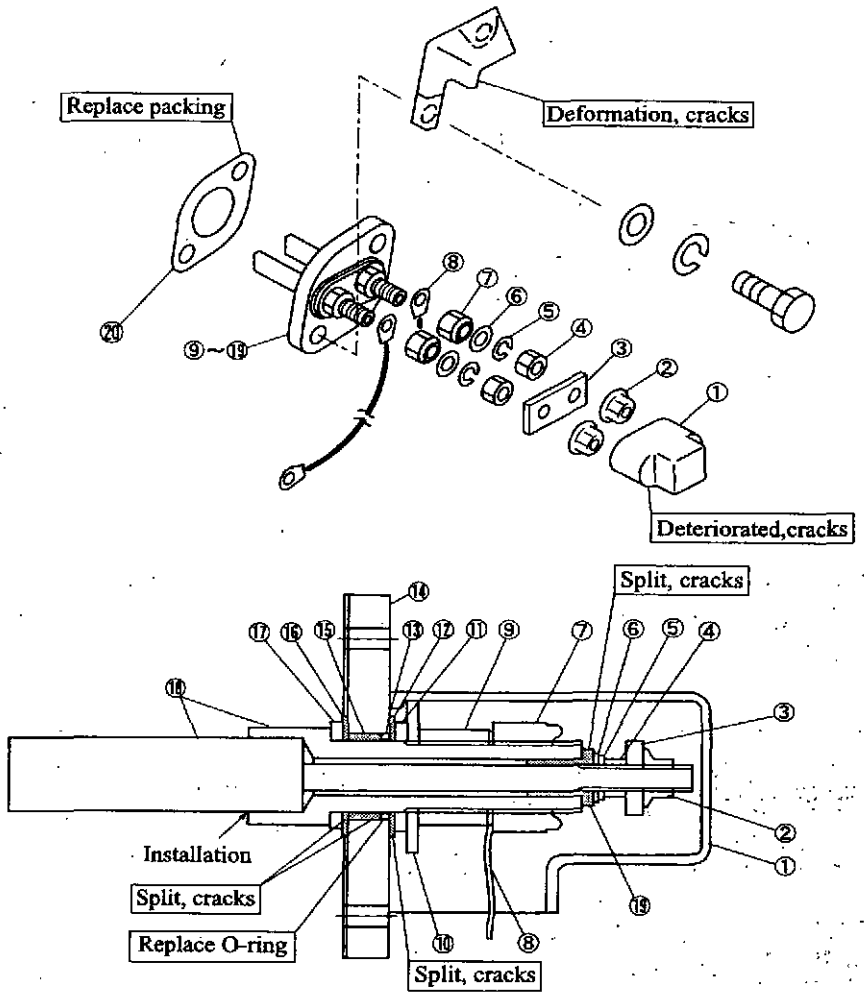
Installation of exhaust manifold gasket

2.2 Reassembly of Exhaust Manifolds

To reassemble, follow the disassembly sequence in reverse.

3. Air Heater

3.1 Disassembly and Inspection of Air Heater



Disassembly and inspection of air heater

<Disassembly sequence>

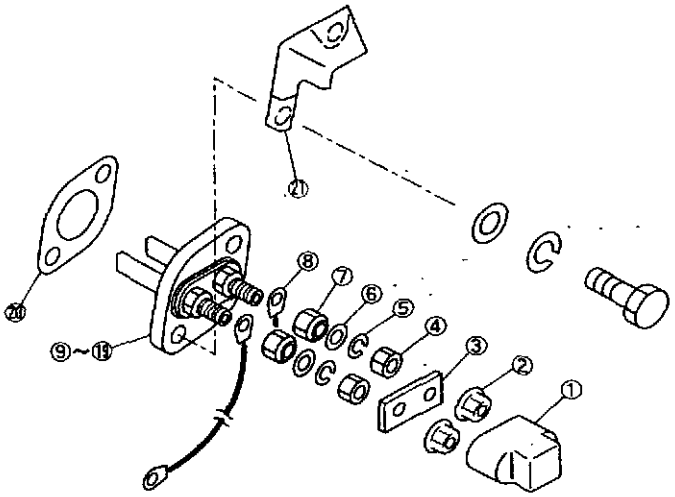
① Terminal cap	⑥ Washer	⑪ Washer	⑯ Insulator
② Flange nut	⑦ U-nut	⑫ Insulator	⑰ Washer
③ Short plate	⑧ Wire	⑬ O-ring	⑱ Heater
④ Nut	⑨ Nut	⑭ Plate	⑲ Insulator
⑤ Spring washer	⑩ Short plate	⑮ Bushing	⑳ Packing

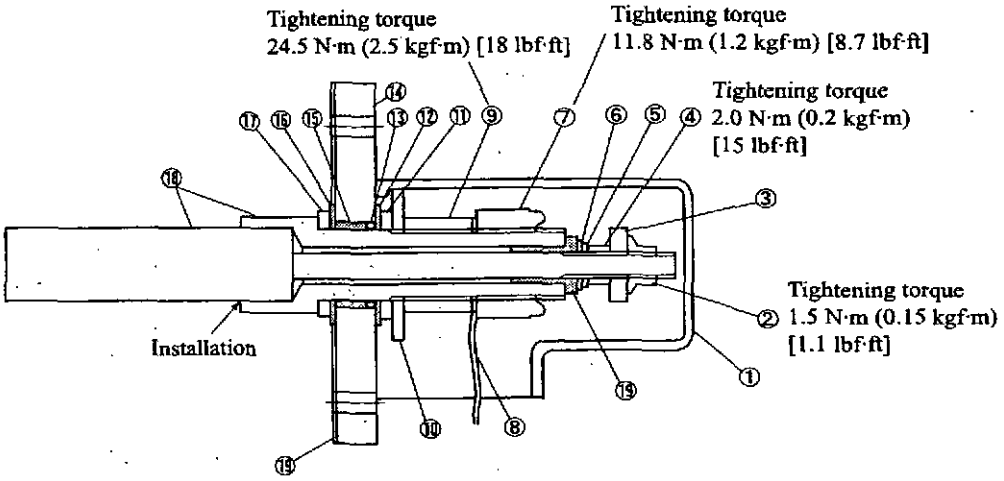
3.2 Inspection of Air Heater

(1) Using an ammeter or inspection lamp, check to see if an electric current flows through the indicator, relay switch and air heater when the starter switch is set to the "HEAT" position. Also, check that the current flow stops when the starter switch is moved to the "ON" or "OFF" position.

(2) Move the starter switch to "HEAT", and make sure that the indictor glows in 50 to 60 seconds. If the indicator does not glow, check the indicator and air heater for short-circuit and open-circuit with a tester.

3.3 Reassembly of Air Heater





Reassembly of air heater

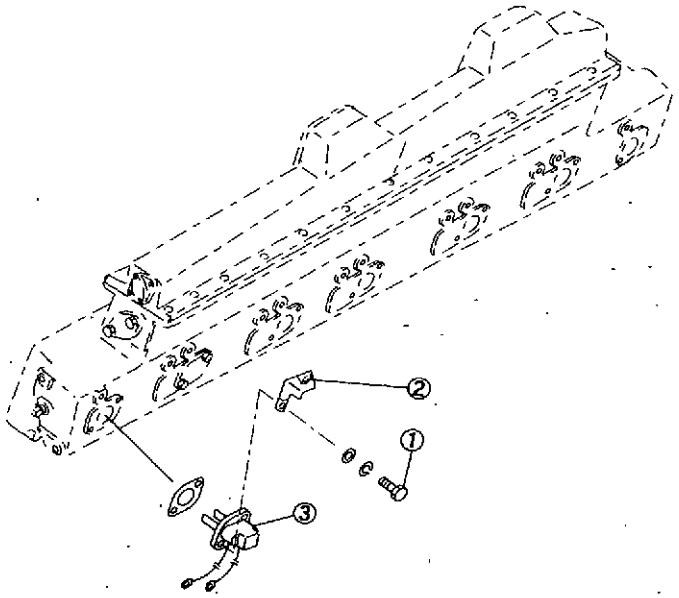
<Reassembly sequence>

⑲→⑱→⑰→⑯→⑫→⑪→⑩→⑨→⑧→⑦→⑥→⑤→④→③→②→①→⑳

⑮→⑭→⑬

INSTALLATION OF INLET AND EXHAUST SYSTEMS

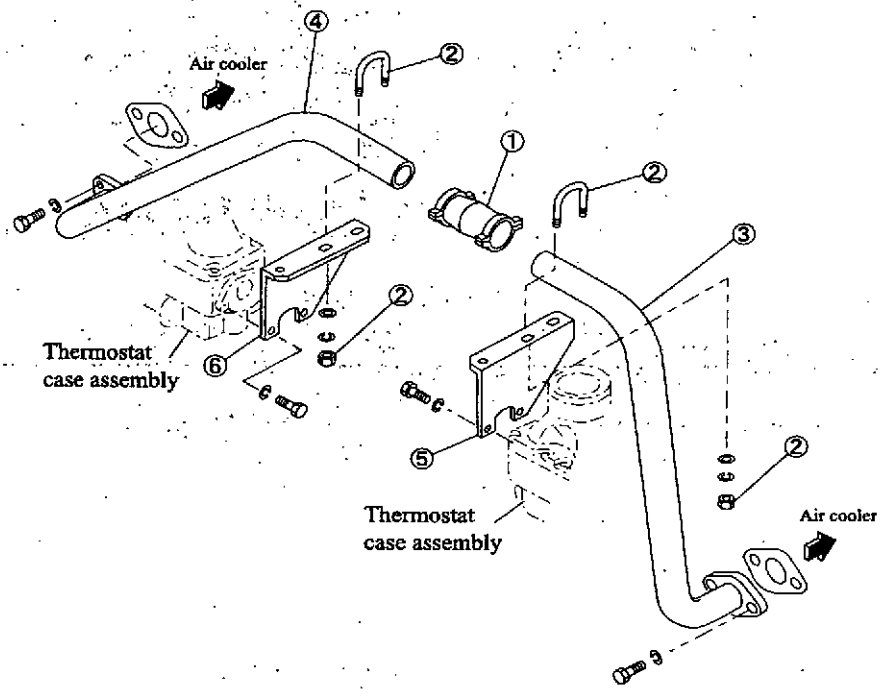
1. Air Heater



Installation of air heater

< Installation sequence >
③→②→①

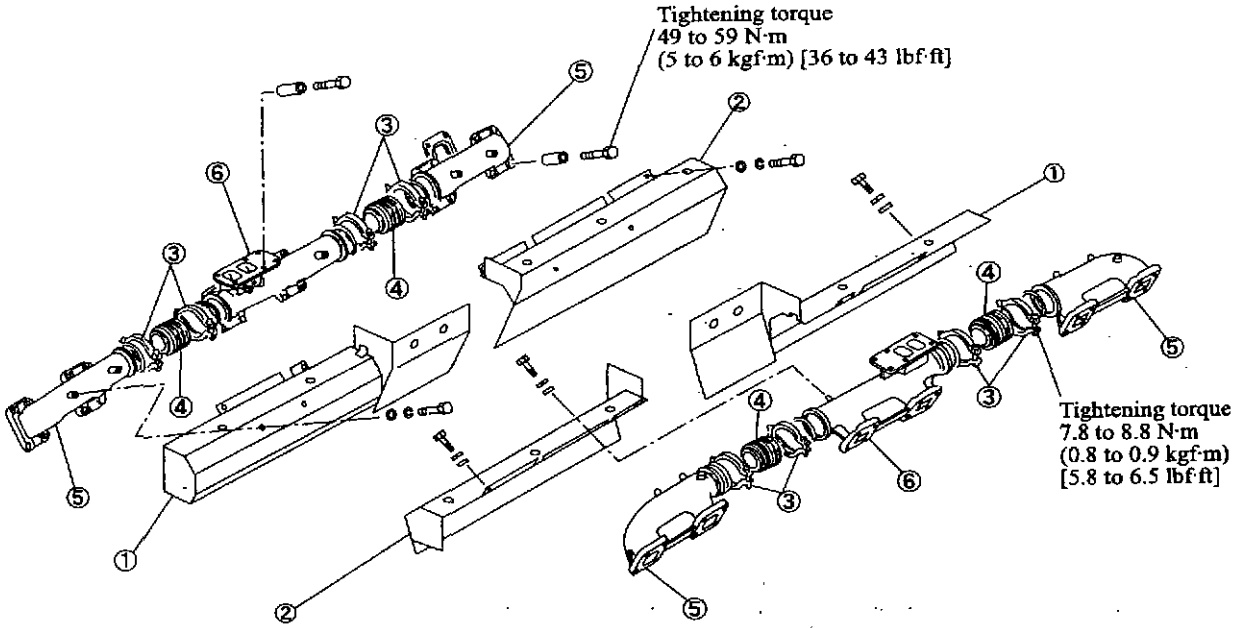
2. Air Pipes



Installation of air pipes

< Installation sequence >
⑥→⑤→④→③→②→①

3. Exhaust Manifolds and Insulators

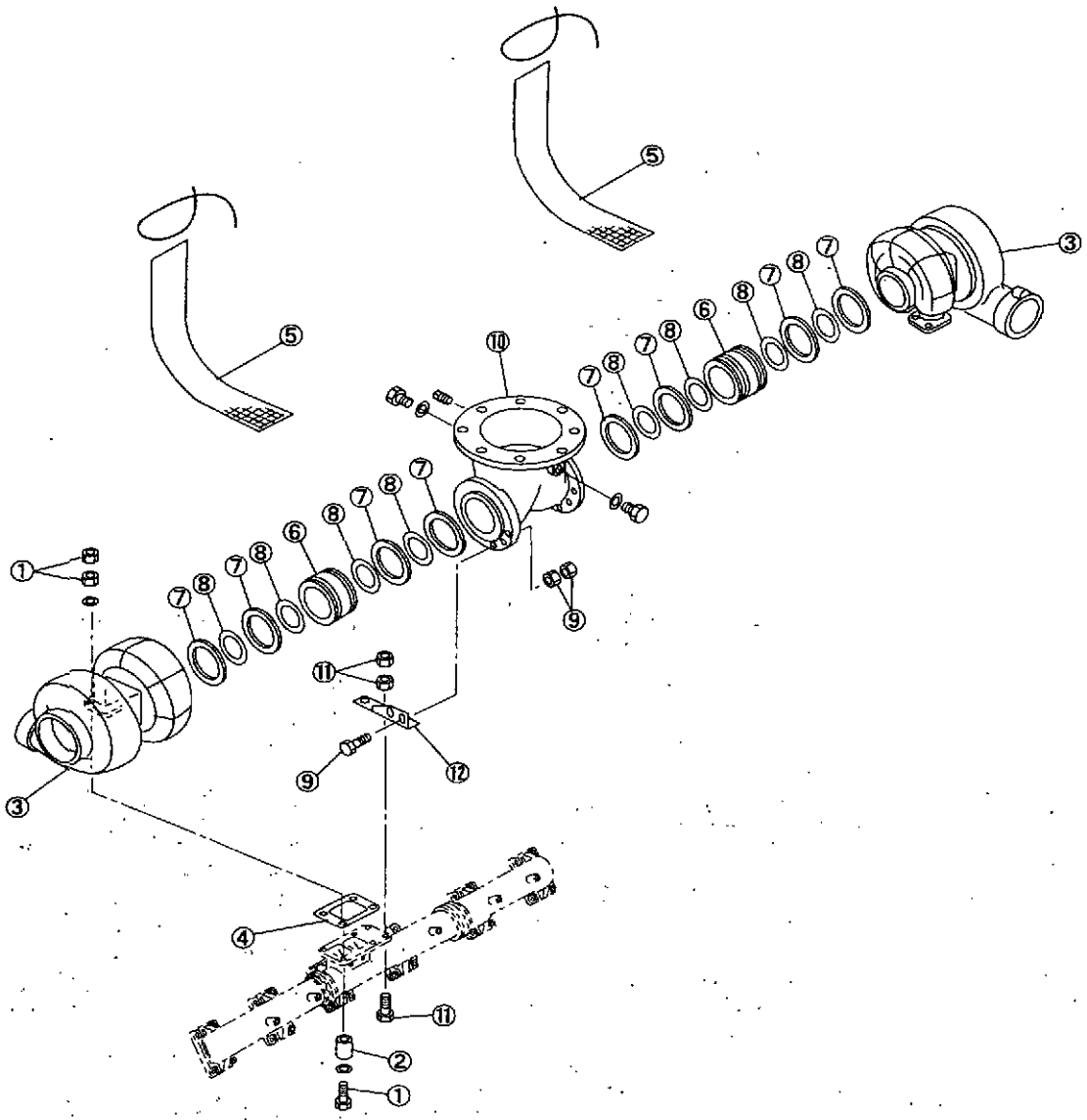


Installation of exhaust manifolds and insulators

< Installation sequence >

⑥→⑤→④→③→②→①

4. Turbocharger and Exhaust Pipes



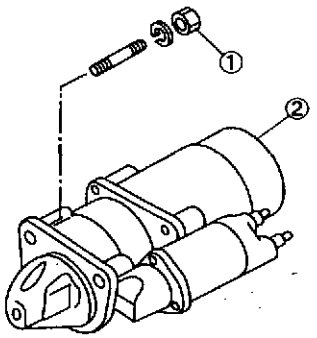
Installation of turbocharger and exhaust pipes

< Installation sequence >

⑫→⑪→⑩→⑨→⑧→⑦→⑥→⑤→④→③→②→①

REMOVAL OF ELECTRICAL SYSTEM

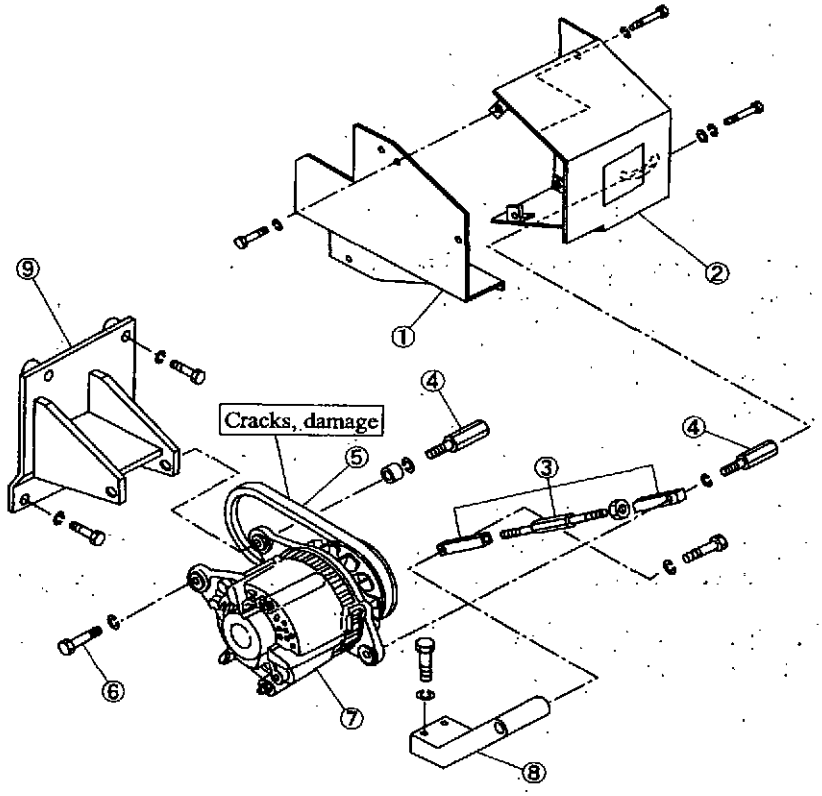
1. Starters



Removal of starter

<Removal sequence>
① Nut
② Starter

2. Alternator



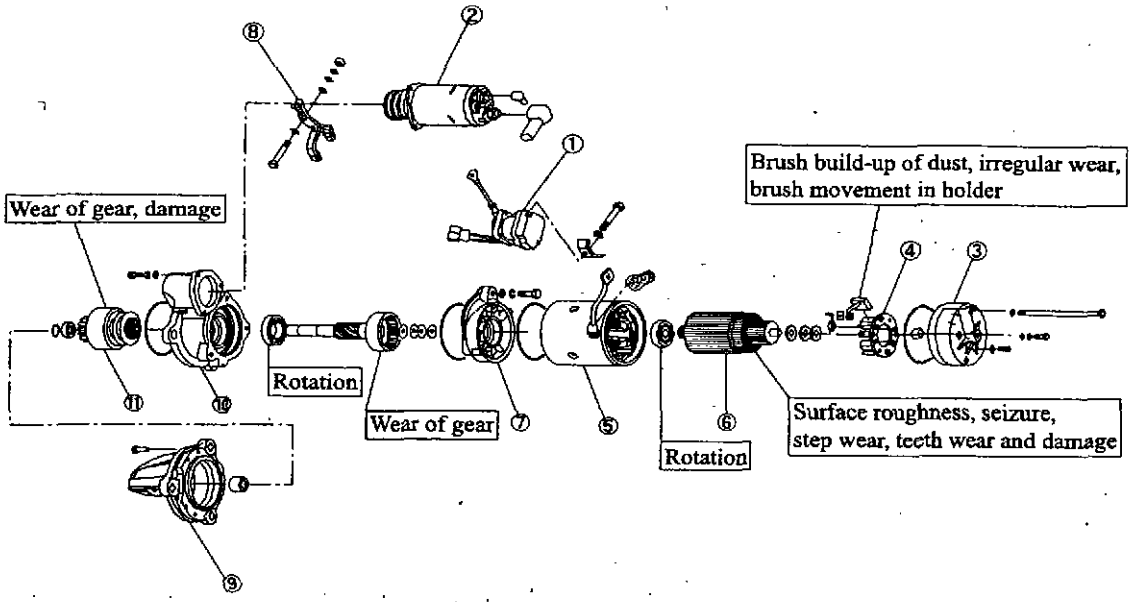
Removal of alternator

<Removal sequence>
① Belt cover
② Belt cover
③ Adjusting rod
④ Alternator mounting bolt
⑤ V-belt
⑥ Bolt
⑦ Alternator
⑧ Alternator bracket
⑨ Bracket

DISASSEMBLY, INSPECTION AND REASSEMBLY OF ELECTRICAL SYSTEM

1. Starters

1.1 Disassembly and Inspection of Starters

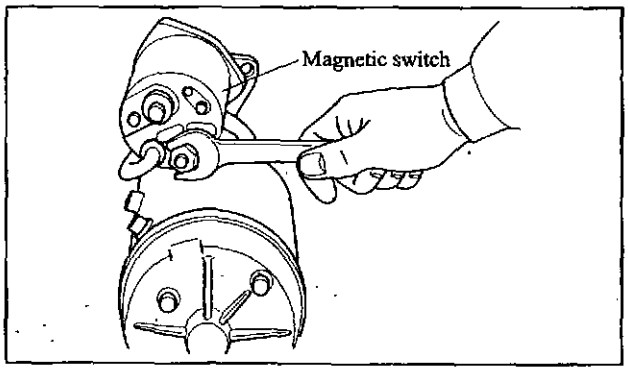


Disassembly and inspection of starter

< Disassembly sequence >

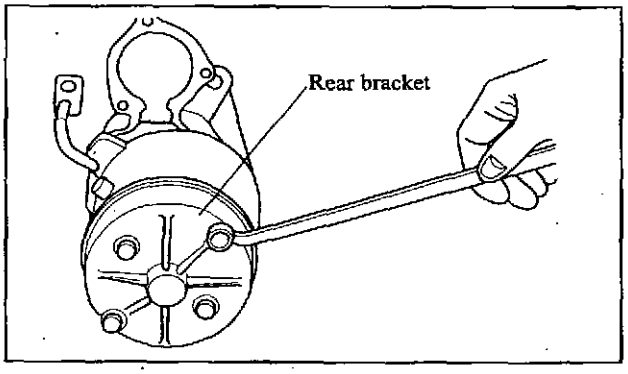
① Safety switch
② Magnetic switch assembly
③ Rear bracket
④ Brush holder assembly
⑤ Yoke assembly
⑥ Armature assembly
⑦ Center bracket
⑧ Lever assembly
⑨ Front bracket
⑩ Pinion case
⑪ Pinion clutch assembly

(1) After removing the safety switch, disconnect the lead wire, then dismount the magnetic switch.



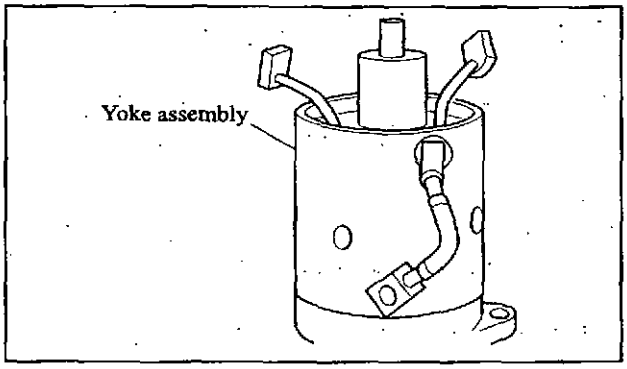
Removal of magnetic switch

(2) Unscrew the through bolts and brush holder mounting screws, then remove the rear bracket.



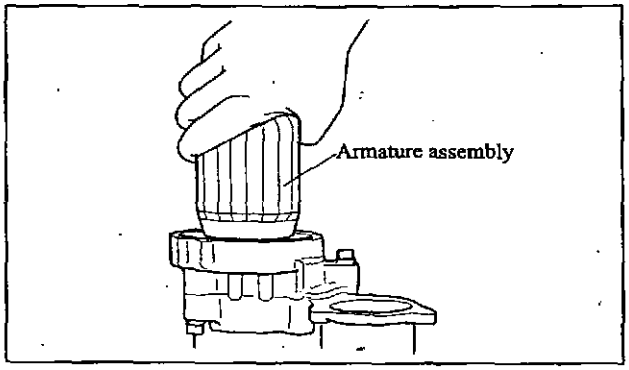
Removal of rear bracket

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



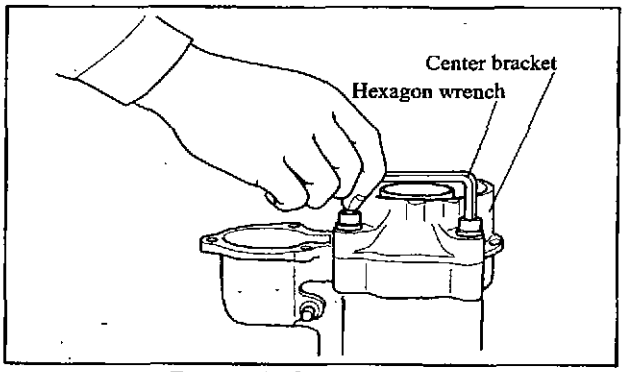
Removal of yoke assembly

(4) Pull out the armature assembly.



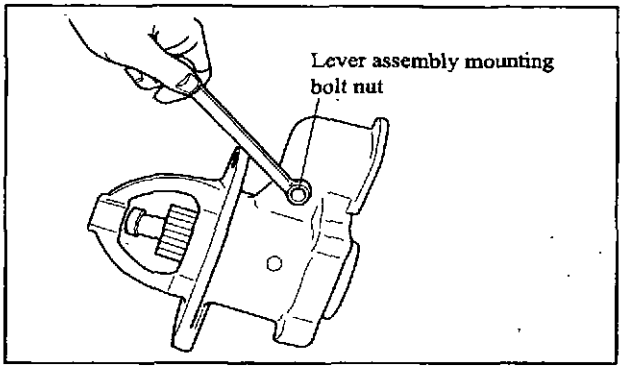
Removal of armature assembly

(5) Remove the center bracket.



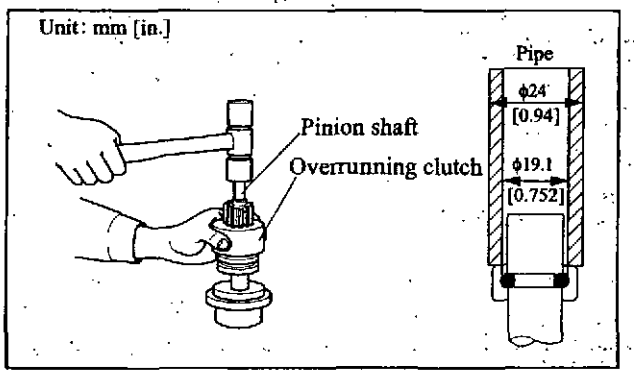
Removal of center bracket

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



Removal of lever assembly

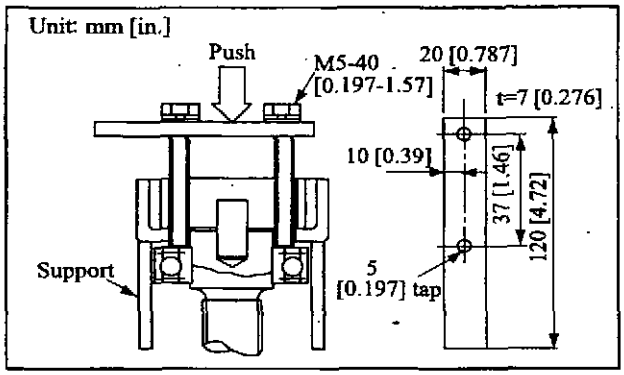
(7) Using a jig, remove the pinion stopper, then remove the overrunning clutch from the pinion shaft.
Measure the bearing fitting section of the pinion shaft. If the measured value is not within the standard range, replace the pinion shaft.



Removal of overrunning clutch

		Nominal value	Standard	Remarks
Pinion shaft	Diameter of rear side	ϕ30 [1.18]	30.002 to 30.011 [1.18118 to 1.18153]	Replace pinion shaft
	Diameter of front side	ϕ19 [0.748]	18.900 to 18.940 [0.74409 to 0.74567]	

Note: For easier removal of bearing from the pinion shaft, use a bearing puller as shown in the diagram.



Pinion shaft bearing puller

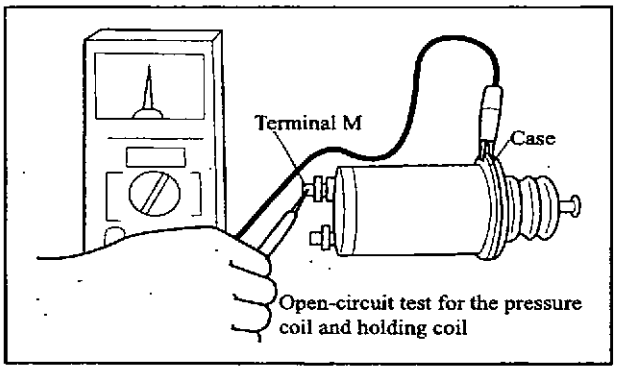
		Nominal value	Standard	Limit	Remarks
Bearing	Front bearing	ϕ30 [1.18]	30.002 to 30.011 [1.18118 to 1.18153]	0.25 [0.00984]	Clearance between bearing and shaft
	Pinion	ϕ19 [0.748]	18.900 to 18.940 [0.74409 to 0.74567]	0.25 [0.00984]	

1.2 Inspection and Repair of Starters

Magnetic switch

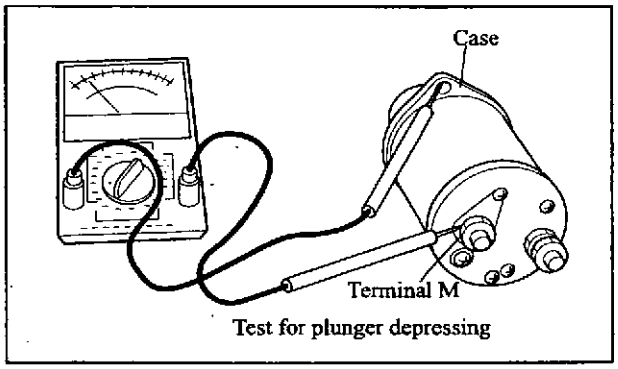
(1) Testing magnetic switch coil

(a) Using a tester, check the pressure coil and holding coil for open-circuit. The coils are open-circuited if there is no continuity between terminal M and the case of the magnetic switch.
(Resistance: approx. 1.16 Ω)



Testing magnetic switch coil

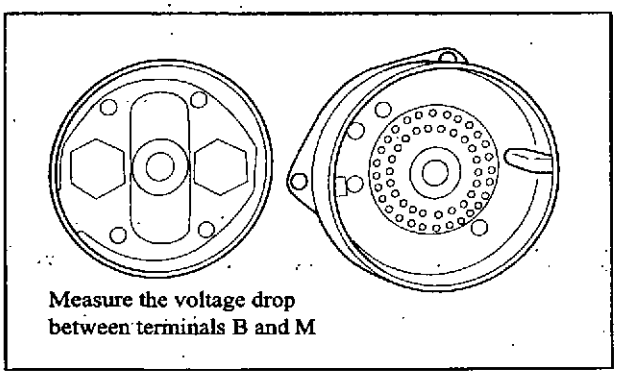
(b) Apply a voltage of 24 V between terminal M and the case of the magnetic switch. Under this condition, push in the plunger by hand. When you release your hand, the plunger should not be attracted.



Testing magnetic switch plunger operation

(2) Testing magnetic switch contact points
Measure the load current flowing through the starter. If the voltage drop between terminals B and M exceeds 0.3 V per 100 A, 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 this can damage the voltmeter. Always turn the starter switch to ON before measuring the voltage, then turn it to OFF after measuring.



Testing magnetic switch contact points

⚠ CAUTION

Never conduct an operation test with a dismounted magnetic switch unit.

Armature

(1) Measurement of armature shaft deflection and bearing journal diameters

(a) Using a dial gage, measure the shaft deflection. If the deflection exceeds the standard, repair or replace the armature.

Unit mm [in.]

	Standard	Remarks
Armature shaft deflection (1/2 value of measurement at center journal when shaft is supported at both ends)	0.05 [0.00197]	1/2 value of runout

(b) Measure the bearing journal diameters of the armature shaft. If the measured values are not within the standard ranges, replace the armature.

		Nominal value	Standard	Remarks
Armature	Diameter of shaft rear side	ϕ14 [0.55]	13.941 to 13.968 [0.54886 to 0.54992]	Replace armature
	Diameter of shaft front side	ϕ25 [0.98]	25.002 to 25.011 [0.98433 to 0.98468]	

(2) Inspection of commutator

(a) Check the condition of the commutator surface. If it is rough, polish it with #400 to #600 sandpaper. Also, check the commutator deflection with a dial gage. If the deflection exceeds the standard, replace the commutator.

Unit mm [in.]

	Standard	Limit
Commutator deflection (runout)	0.06 [0.00236] or less	0.10 [0.00394]

(b) Measurement of commutator mica depth

Measure the depth of each mica undercut with a depth gage. If the depth exceeds the limit, recondition the mica.

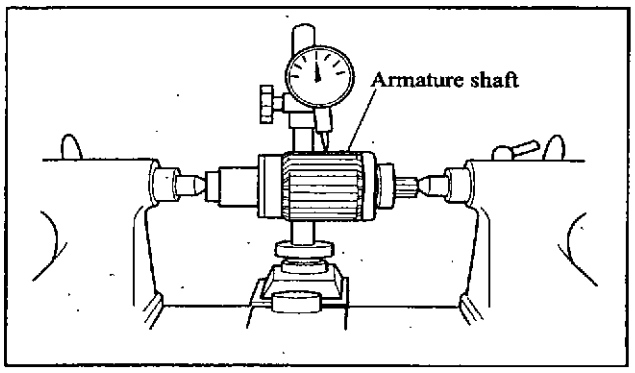
Unit mm [in.]

	Standard	Limit
Commutator mica depth	0.7 to 0.9 [0.028 to 0.035]	0.2 [0.008]

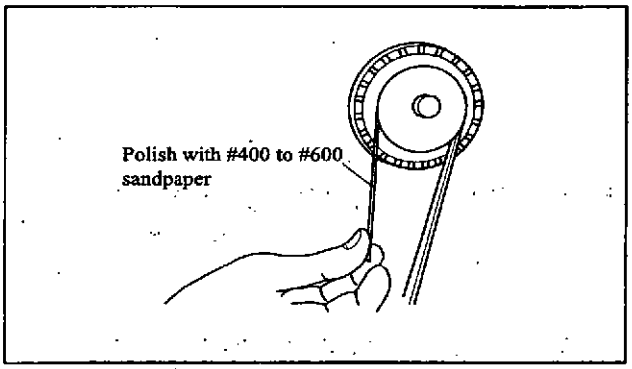
(c) Measure the commutator outside diameter. If the measured value is less than the limit, replace the armature.

Unit mm [in.]

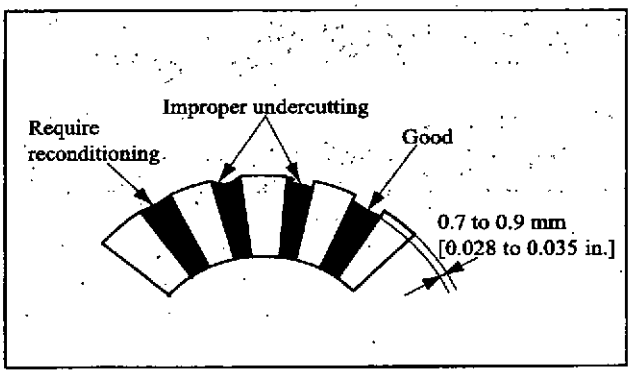
	Nominal value	Limit
Commutator mica diameter	ϕ43 [1.69]	ϕ42 [1.65]



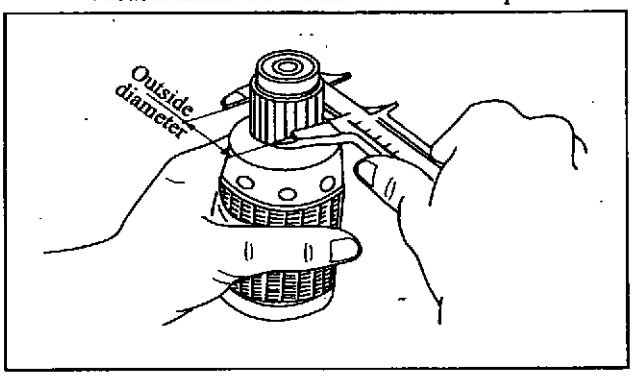
Measurement of armature shaft deflection



Polishing commutator surface



Measurement of commutator mica depth

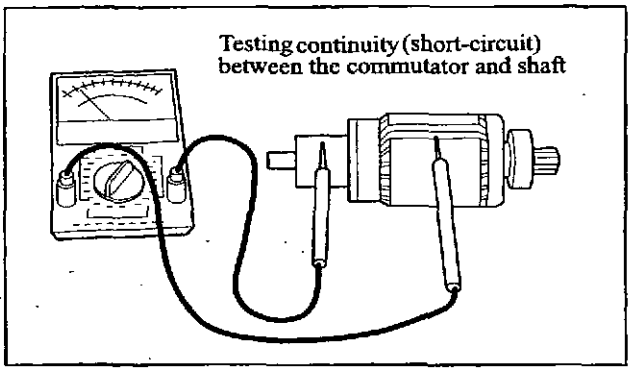


Measurement of commutator outside diameter

(3) Testing armature coil

(a) Use a glowler to test the armature. Position an iron piece on the armature core. If the iron piece vibrates, replace the armature.

(b) Use a tester to check continuity between the commutator and shaft. It there is continuity, replace the armature.

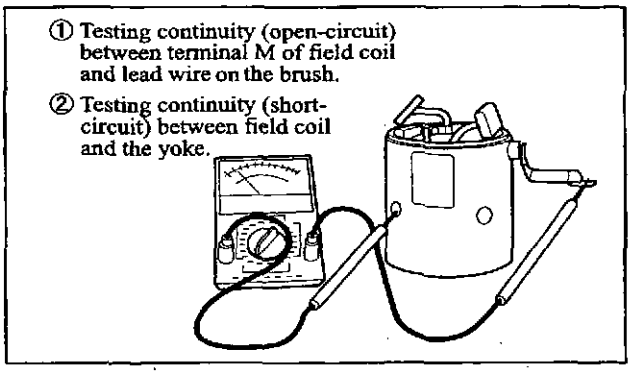


Testing armature coil for open-circuit

Field coil

(1) Testing field coil for open-circuit

If there is no continuity between terminal M of the field coil and the lead wire on the brush side, replace the field coil. If there is continuity between the field coil and yoke, replace the field coil.



Testing field coil for open-circuit

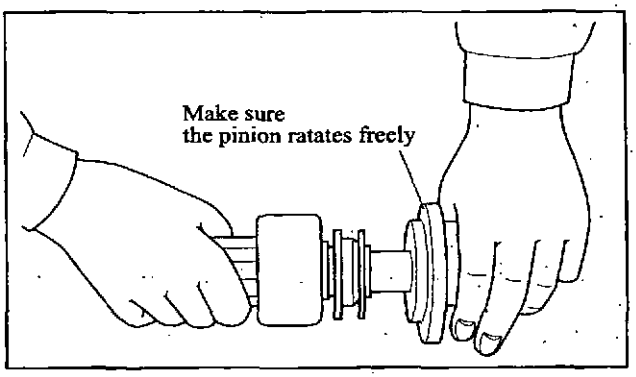
Overrunning clutch

The clutch is in good condition if it rotates freely only in one direction when turned by hand.

Check the pinion teeth. If they are worn or damaged, replace the pinion.

⚠ CAUTION

Do not immerse the overrunning clutch in a cleaning solvent for cleaning. Immersion in a cleaning solvent will cause the grease inside the clutch to flow out and result in seizing of clutch parts.



Inspection of overrunning clutch

Brushes

(1) Inspection of brushes for wear

Unit mm [in.]

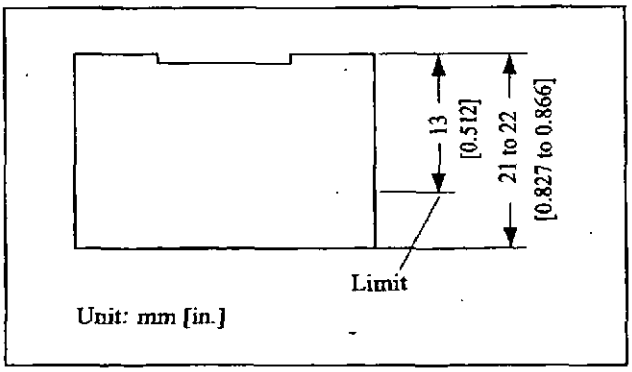
	Standard	Limit
Height of brush	21 to 22 [0.827 to 0.866]	13 [0.512]

If brushes are unevenly worn, repair.

(2) Testing brush spring tension

Unit N (kgf) [lbf]

	Standard	Limit
Tension of brush spring (when brush is installed)	39.23 to 49.03 (4.0 to 5.0) [8.82 to 11.02]	39.23 (4.0) [8.82]



Inspection of brush for wear

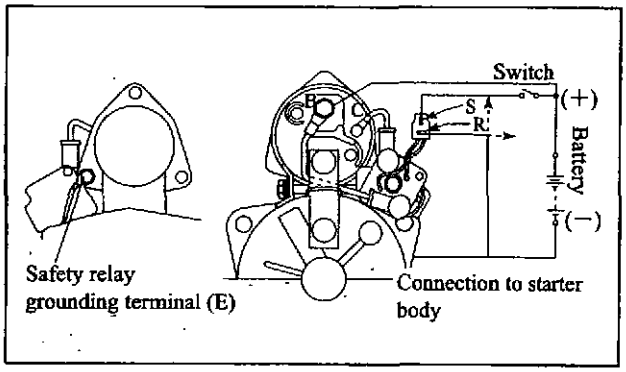
Safety switch

Connect the wires as shown in the diagram, and check the starter and safety switch operations.

(1) Connect terminal R to the battery negative (-) side.
(2) Turn on the switch, and check that the starter operates (rotates).
(3) After step (2), make sure the starter stops operating when the connection between terminal R and the battery negative (-) side is disconnected or when it is disconnected and then terminal R is connected to the battery positive (+) side.

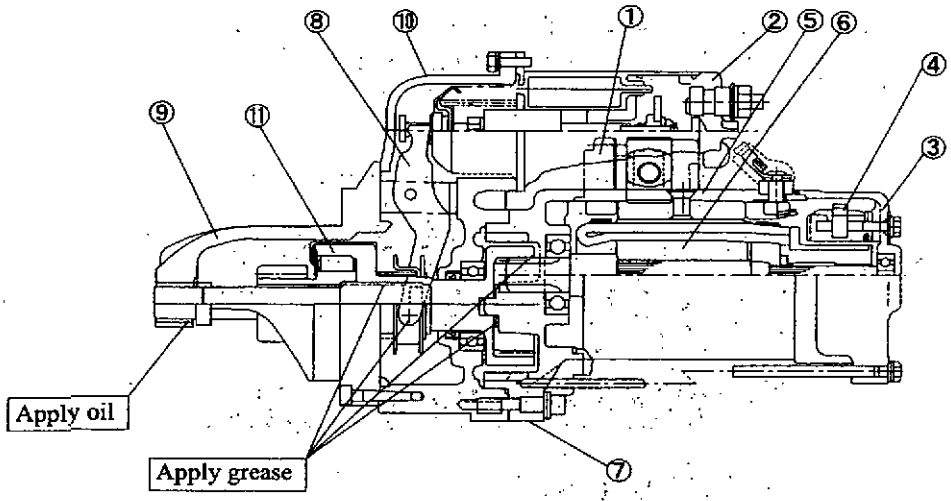
⚠ CAUTION

Check the battery's polarity (+) (-) carefully when connecting wires.



Checking safety switch operation

1.3 Reassembly of Starters

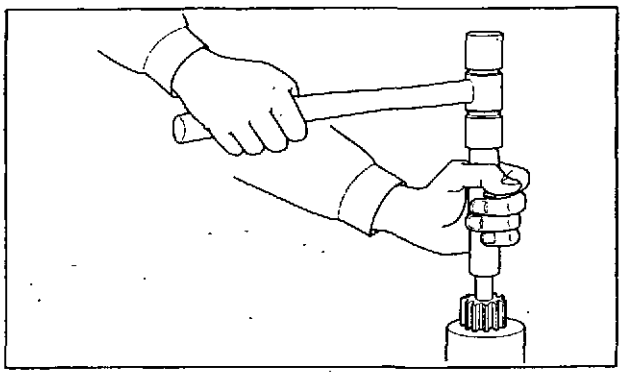


Reassembly of starter

< Reassembly sequence >

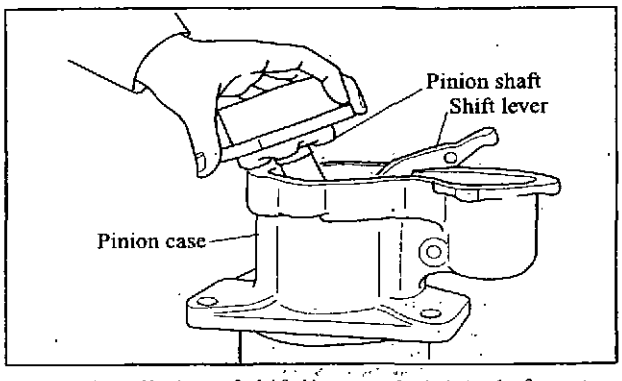
⑩→⑨→⑪→⑧→⑦→⑥→⑤→④→③→②→①

(1) 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.



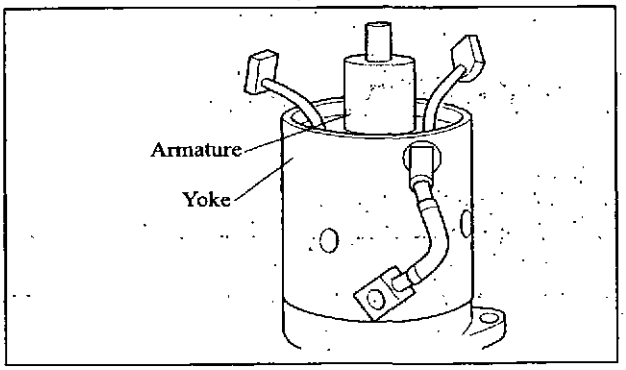
Installation of pinion shaft

(2) Install the shift lever and pinion shaft to the pinion case by aligning the alignment mark on the shift lever.



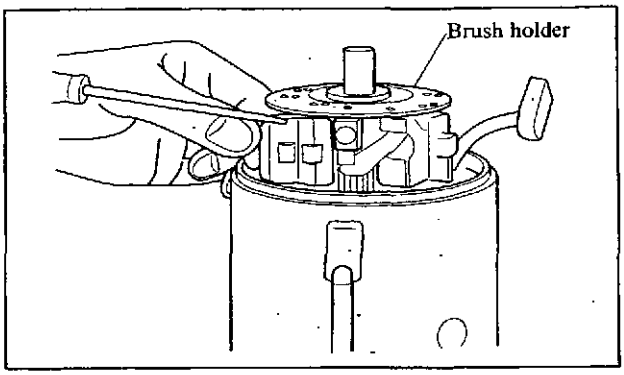
Installation of shift lever and pinion shaft

(3) Install the armature and yoke to the center bracket, making sure that the dowel pin enters the hole.



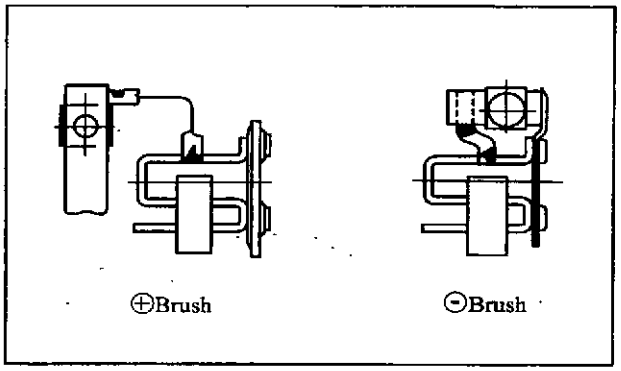
Installation of armature and yoke

(4) Install the brush holder and brushes.



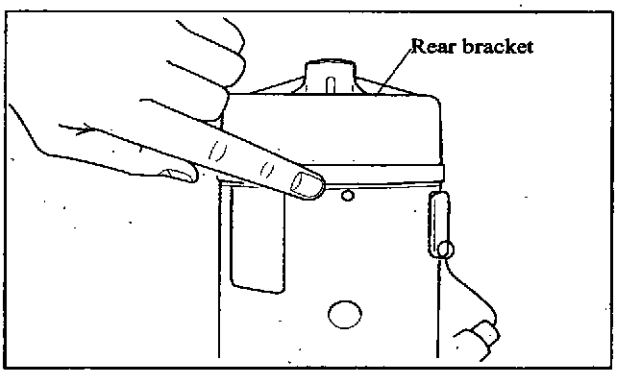
Installation of brush holder and brushes

Note: Install the positive (+) and negative (-) brushes as shown in the diagram on the right.



Installation of positive (+) and negative (-) brushes

(5) Install the rear bracket to the yoke by aligning the alignment marks, secure the brush holder with the bolts, then tighten the through bolts.

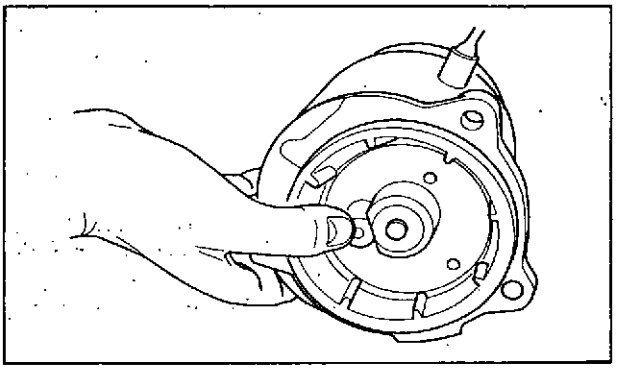


Installation of rear bracket

(6) Measure the end play of the armature. If the end play exceeds the standard, adjust it on the rear side.
Test the motor unit, and make sure the test results show 24 V.90 A or lower.

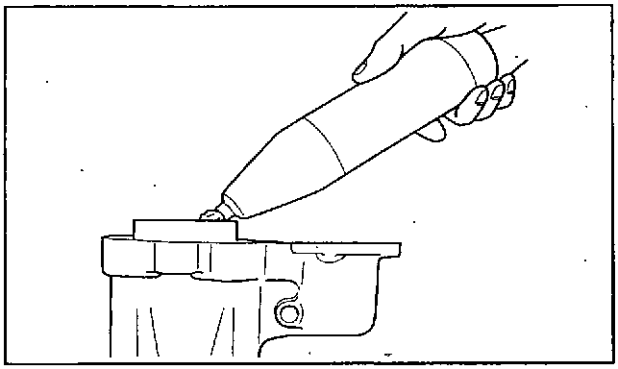
Unit mm [in.]

	Standard
Armature end play	0.3 to 0.7 [0.012 to 0.028]



Measurement of armature end play

(7) Coat the internal gear of the pinion shaft a liberal amount of Nikko Grease R, then install the pinion shaft.

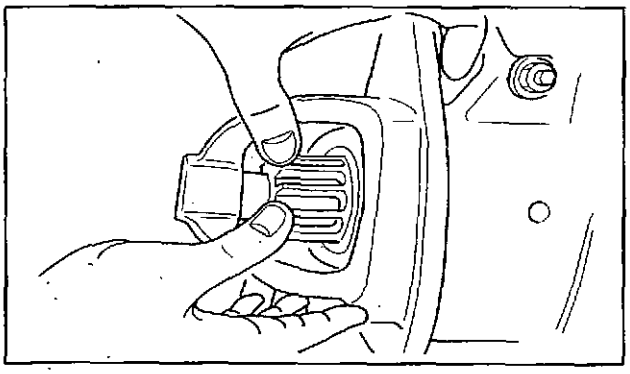


Application of grease to pinion shaft internal gear

(8) Measure the end play of the pinion shaft. If the end play exceeds the standard, adjust it on the internal gear side.

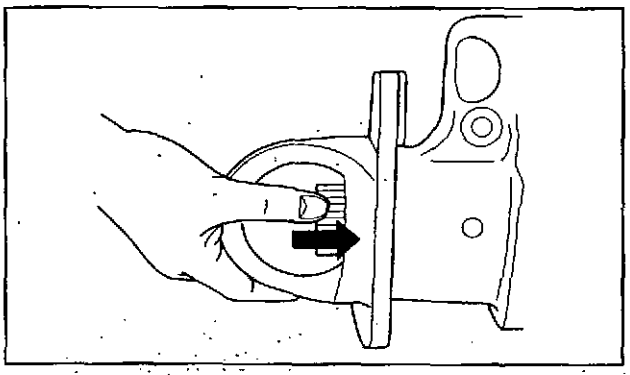
Unit mm [in.]

	Standard
Pinion shaft end play	0.2 to 0.8 [0.008 to 0.0315]



Measurement of pinion shaft end play

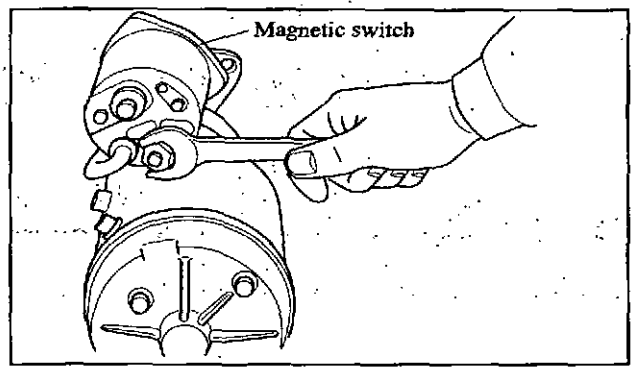
(9) Install the magnetic switch. Apply a voltage of 24 V between terminals C and E, and connect the lead wire and supply a current between terminals M and E (for less than 1 second). After the pinion moves, measure the pinion gear retraction length. If the measured value is not between 1.5 mm [0.0591 in.] and 5 mm [0.197 in.], use the magnetic switch adjusting screw for adjustment.



Measurement of pinion gear retraction length

(10) Install the magnetic switch, and connect the lead wire.

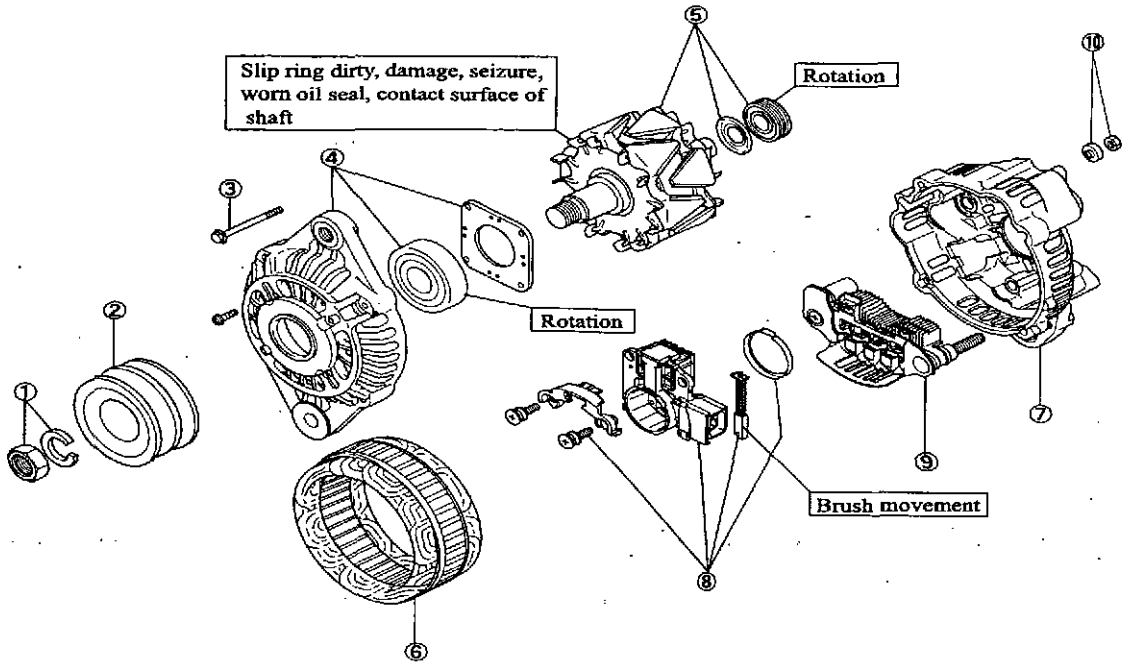
(11) Install the safety switch.



Installation of magnetic switch

2. Alternator

2.1 Disassembly and Inspection of Alternator



Disassembly and inspection of alternator

<Disassembly sequence>

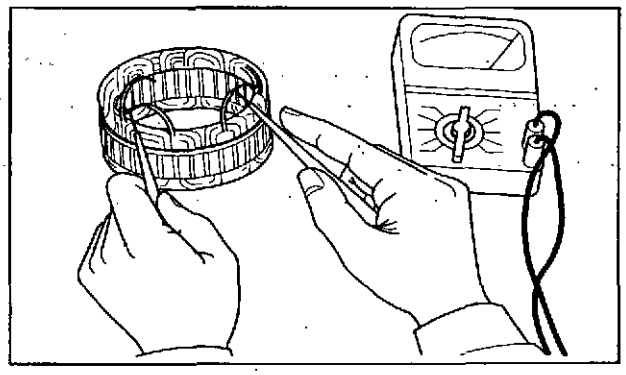
① Nut and washer
② Pulley
③ Screw
④ Front bracket assembly
⑤ Rotor assembly
⑥ Stator
⑦ Rear bracket
⑧ Regulator assembly
⑨ Rectifier assembly
⑩ Nut set

2.2 Inspection and Repair of Alternator

(1) Stator

(a) Testing coil for open-circuit
If there is no continuity among the four coil lead wires, replace the stator.

(b) Testing coil for grounding
If there is continuity between the coil and core, replace the stator.



Inspection of stator coil

(2) Rotor

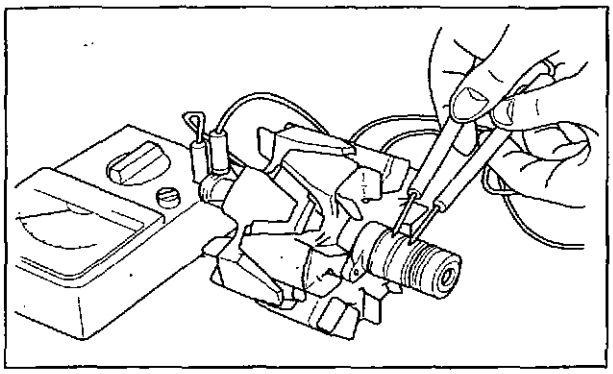
(a) Testing coil for open-circuit
If there is no continuity between the slip rings, replace the rotor.

(b) Testing coil for grounding.
If there is continuity between the slip ring and shaft (or core), replace the rotor.

(c) Measuring slip ring outside diameter
Using calipers, measure the outside diameter of each slip ring. If the limit is exceeded, replace the slip ring.

Unit mm [in.]

	Standard	Limit
Slip ring outside diameter	32.8 to 33.2 [1.291 to 1.307]	32.4 [1.276]



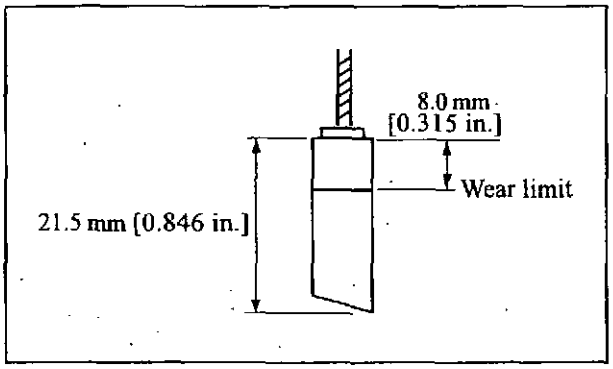
Testing field coil for open-circuit

(3) Brushes and springs

(a) Brush wear

Unit mm [in.]

	Nominal value	Limit
Height of brush	21.5 [0.846]	8.0 [0.315]



Checking brush for wear

(b) Spring tension

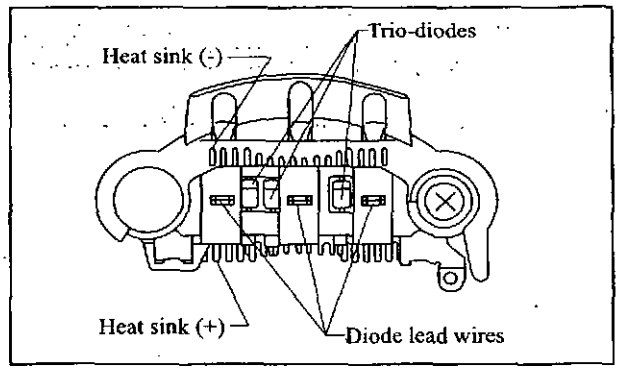
Unit N (gf) [lbf]

	Nominal value	Standard	Limit
Tension of brush spring	3.7 (380) [0.84]	3.1 to 4.3 (320 to 440) [0.70 to 0.97]	1.8 (180) [0.40]

(4) Inspection of rectifier

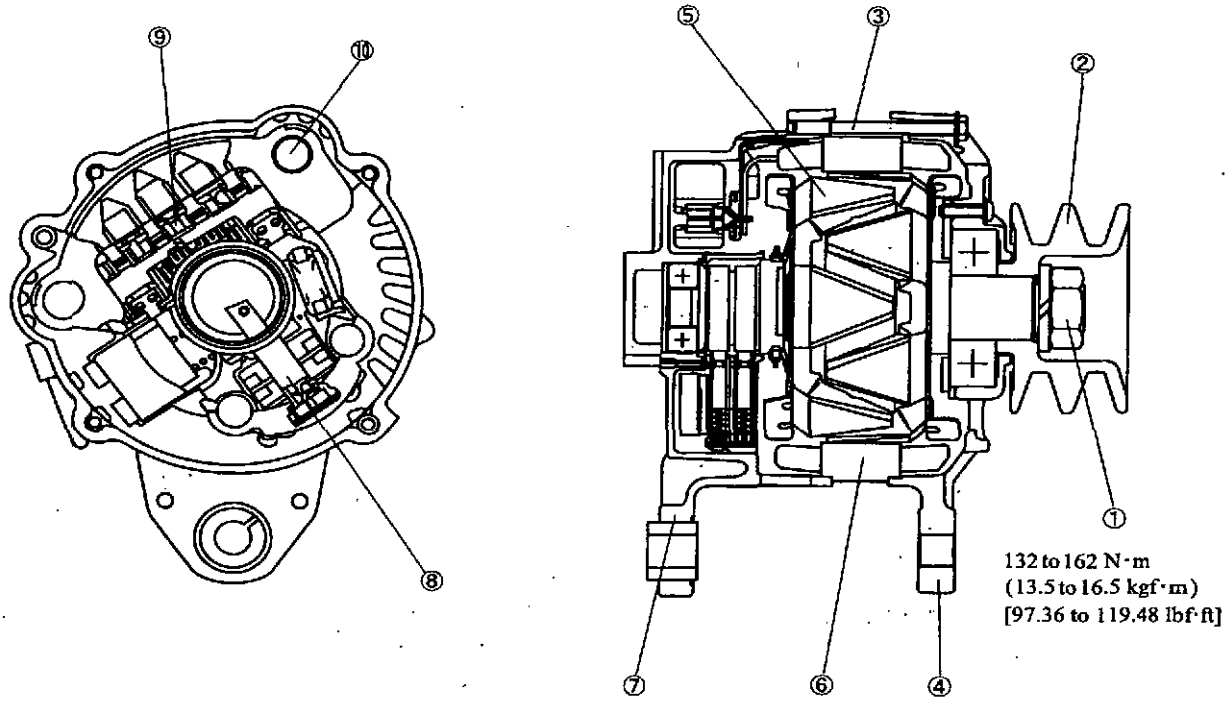
To check individual diodes, measure the resistance between the diode lead wire and heat sink. Connect the positive (+) test lead wire to the diode and measure resistance. Then, connect the negative (-) test lead wire to the diode and measure resistance again. If both measured values are infinity, the diode circuit is open-circuited. If both measured values are close to 0, the circuit is short-circuited.

If there is an open-circuit or short-circuit, the diode is defective, and the rectifier must be replaced.



Inspection of rectifier

2.3 Reassembly of Alternator



Reassembly of alternator

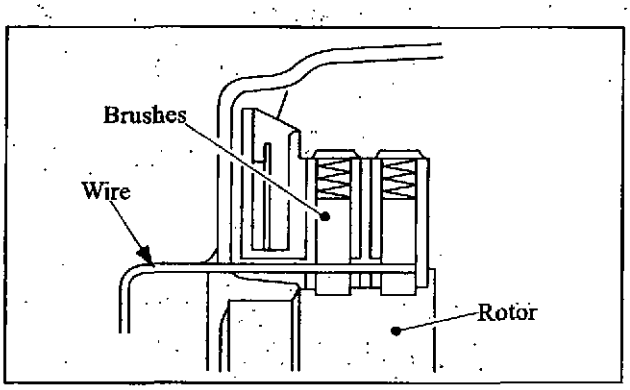
< Reassembly sequence >

⑦→⑩→⑨→⑧→⑥→⑤→④→③→②→①

(1) Installation of brushes

As shown in the diagram on the right, insert the brushes into the brush holder, and secure them in place using a wire. Then, install the rotor.

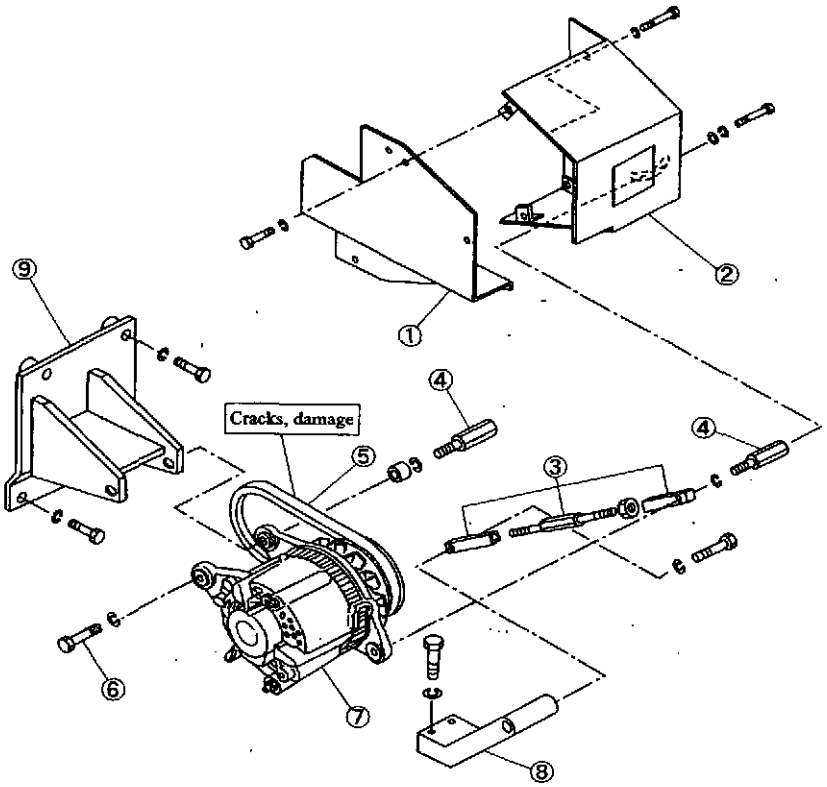
After the rotor is installed in place, be sure to remove the wire.



Installation of brushes

INSTALLATION OF ELECTRICAL SYSTEM

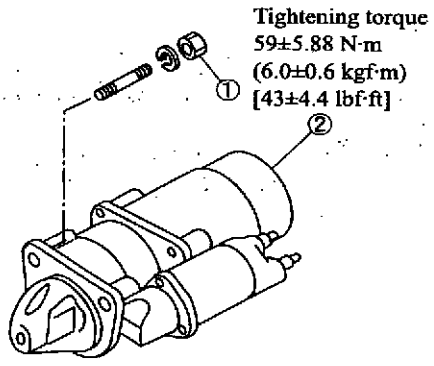
1. Alternator



Installation of alternator

< Installation sequence >
⑨→⑧→⑦→⑥→④→③→⑤→②→①

2. Starters

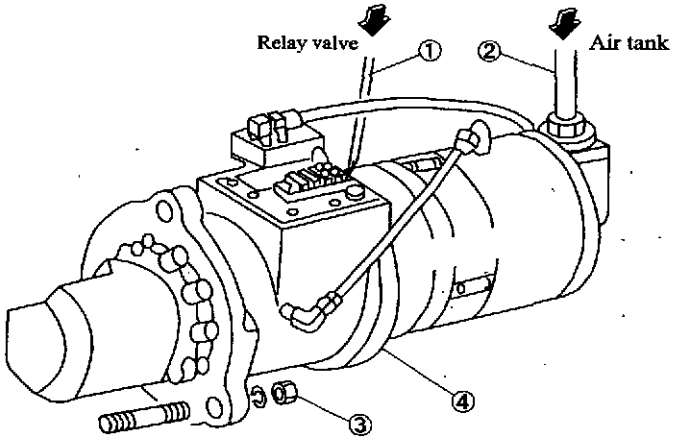


Installation of starter

< Installation sequence >
②→①

REMOVAL OF AIR STARTER SYSTEM

1. Air Motor



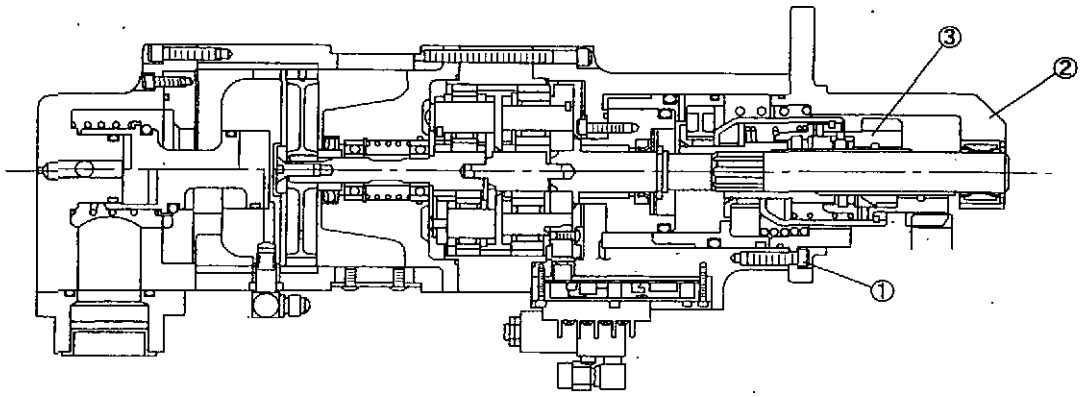
Removal of air motor

<Removal sequence>
① Cable
② Air pipe
③ Nut
④ Air motor

DISASSEMBLY, INSPECTION AND REASSEMBLY OF AIR STARTER SYSTEM

1. Air Motor

1.1 Disassembly and Reassembly of Air Motor



Disassembly and reassembly of air motor

<Disassembly sequence>
① Hexagon bolt ② Pinion case ③ Clutch assembly

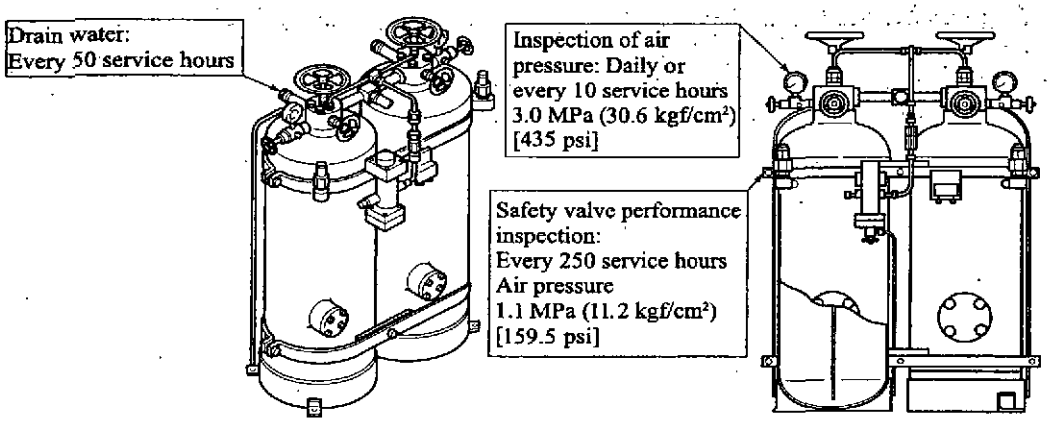
<Reassembly sequence>
③→②→①

1.2 Inspection of Air Motor

Clean the parts of the air motor, and check them for wear. Replace all worn parts.
The clutch assembly and pinion assembly must be replaced as a set if one of them is damaged or worn excessively.

2. Air Tank (for Air Motor System)

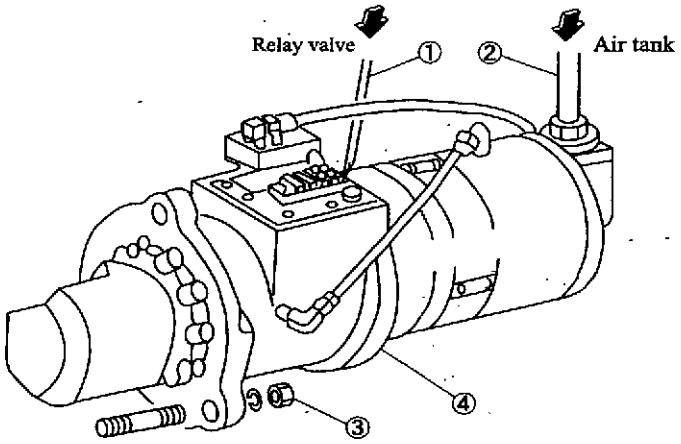
Inspection of Air Tank (for Air Motor System)



Inspection of air tank (for air motor system)

INSTALLATION OF AIR STARTER SYSTEM

1. Air Motor



Installation of air motor

< Installation sequence >

④→③→②→①

INSPECTION, ADJUSTMENT, BREAK-IN OPERATION AND PERFORMANCE TESTS

1. Engine Inspection and Adjustment

1.1 Inspection and Adjustment of Valve Clearances

Valve clearances should be inspected and adjusted when the engine is cold.

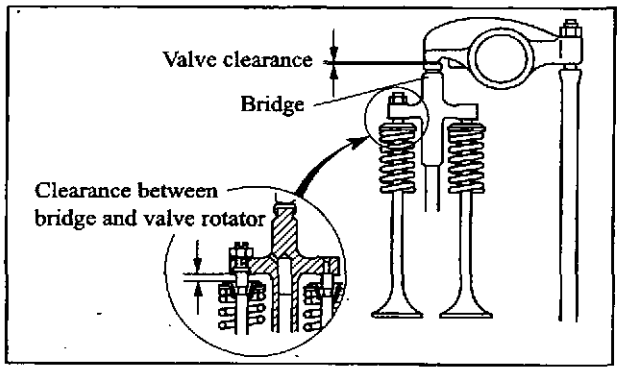
Unit mm [in.]

		Standard
Valve clearance (cold)	Inlet	0.6 [0.024]
	Exhaust	0.8 [0.031]

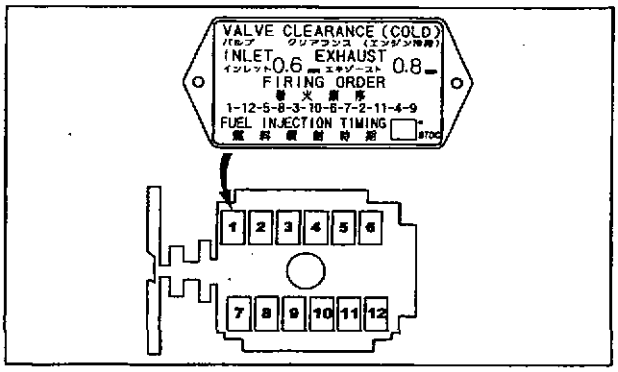
Note: (a) The bridge-to-valve-rotator clearance should be 1.5 mm [0.0591 in.] or more (standard) after the front and rear valve heights have been adjusted. If the clearance is less than the standard, grind the bridge to ensure a clearance of 1.5 mm [0.0591 in.] or more.

(b) Facing the cylinder head, the inlet valves are on the left, and the exhaust valves are the right.

(c) The valve clearance standards are also indicated on the caution plate on the No. 1 cylinder rocker cover.



Inspection of valve clearance



Valve clearance indication on engine

(1) Inspection of valve clearances

(a) Inspect the valve clearances in the firing order by turning the crankshaft 60° in the normal direction to bring each piston to top dead center in compression stroke.

Firing order

Cylinder No.	1-12-5-8-3-10-6-7-2-11-4-9

Using turning gear

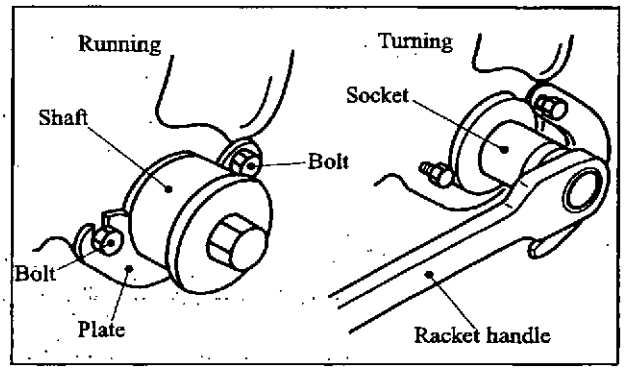
(a) Loosen the bolts, remove the plate from the slot of the shaft, then push in the shaft until it stops.

(b) Using the socket and ratchet handle, turn the shaft. Push down the ratchet handle to turn the crankshaft in the normal direction.

(c) After completing the turn, pull out the shaft, insert the plate into the slot of the shaft, then tighten the bolts. Check to make sure the plate is inserted securely into the slot of the shaft.

⚠ CAUTION

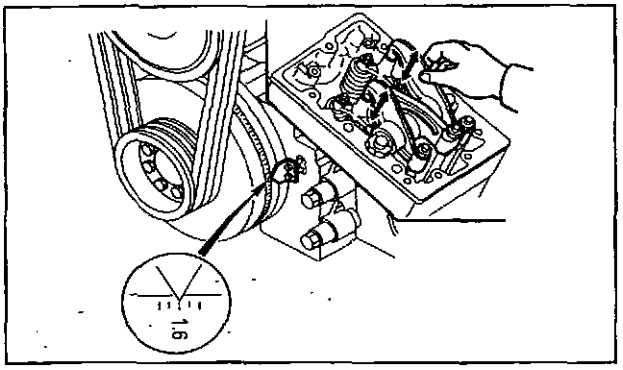
Make sure the turning gear is at the running position before starting the engine.



Using turning gear

(b) A cylinder 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.

(c) Using feeler gages, measure the clearance between each rocker arm and bridge cap.



Checking No. 1 cylinder top dead center in compression stroke

(2) Adjustment of front and rear valve heights by valve bridge

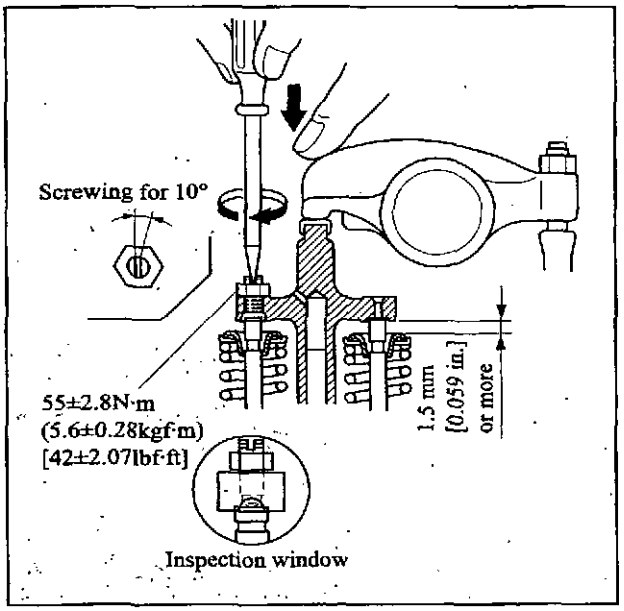
(a) Before adjusting the valve clearances, adjust the front and rear valve heights with the valve bridge (bring the bridge into contact with the front and rear valves).
If the valve seats are worn, the front and rear valve heights will differ, resulting in a gap between the valve stem top and bridge. This causes a change in the valve clearance.

(b) To adjust valve height, loosen the lock nut, and slack off the adjusting screw.

(c) Push down the rocker arm with a finger, and slowly screw in the adjusting screw until it touches the valve stem top. Then, further turn the screw 10°, and tighten the lock nut.

⚠ CAUTION

If there is no clearance between the bridge and valve rotator, they can interfere with each other, causing the valve cotters to fall off. Be sure to provide the specified clearance or more.

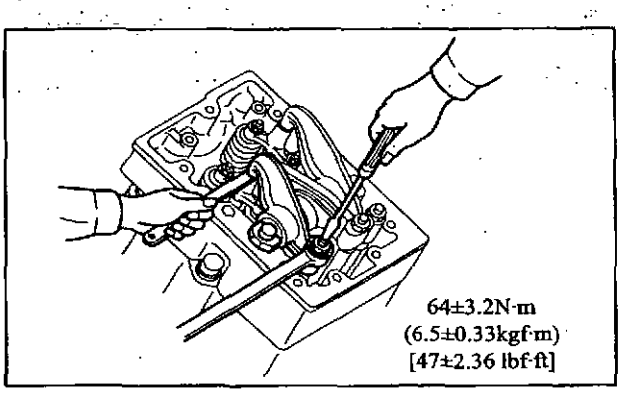


Adjustment of front and rear valve heights by valve bridge

(3) Adjustment of valve clearances

(a) Insert the feeler gage 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 gage is gripped softly between the rocker arm and bridge cap.

(b) After adjusting the clearance, tighten the lock nut, and inspect the clearance again.



Adjustment of valve clearance

1.2 Bleeding of Fuel System

⚠ WARNING

(a) When fuel overflows from the air vent plug, wipe thoroughly with a cloth. Spilled fuel is a fire hazard.
(b) After bleeding, lock the priming pump cap securely. If the cap is not locked tightly, the priming pump can be damaged, causing fuel leakage that may lead to a fire. To lock the priming pump cap, use your hand. If it is tightened with tools, excessive force may damage the pump.

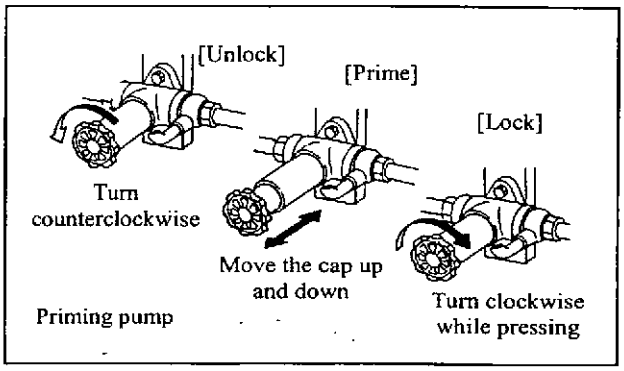
Start from the location closest to the fuel tank, and move toward the engine in order: fuel filter → fuel injection pump.

(1) Fuel filter
(a) Loosen the air vent plugs for the fuel filters (approx. 1.5 turns).
(b) Unlock the priming pump cap by turning it counterclockwise, then move the cap up and down repeatedly.
(c) When fuel flowing from the vent holes no longer contains air bubbles, tighten the air vent plugs.
(d) Follow the same procedure for both right and left fuel injection pumps.

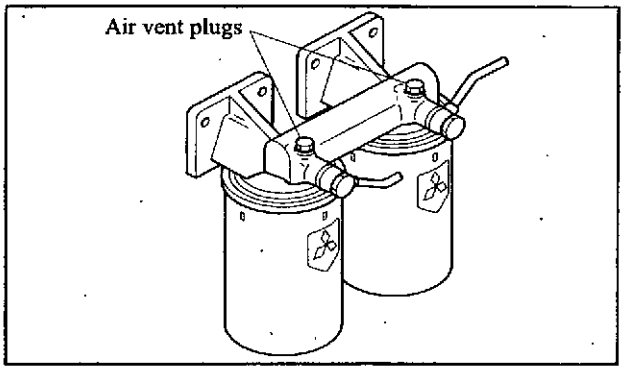
Note: To bleed air from the switch over fuel filter, follow the instruction from caution plate.

(2) Fuel pipe (return side)
(a) Loosen the air vent cock on the fuel pipe by rotating about 1.5 turns.
(b) Move the priming pump cap back and forth repeatedly.
(c) When there are no air bubbles in the fuel flowing from the air vent cock, press the priming pump cap and turn the cap clockwise.
(d) Tighten the air vent cock.

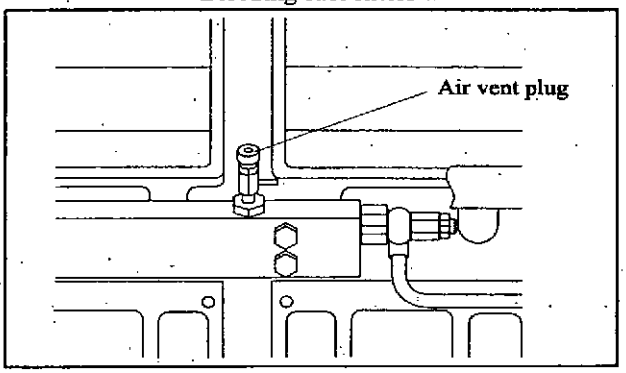
Note: Closing all air vent plugs before locking the priming pump cap disallows the priming pump cap from returning to the original position due to feed pump pressure.



Using the priming pump



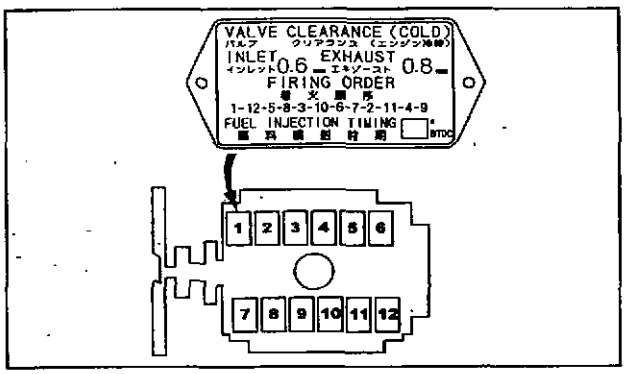
Bleeding fuel filters



Bleeding fuel return pipe

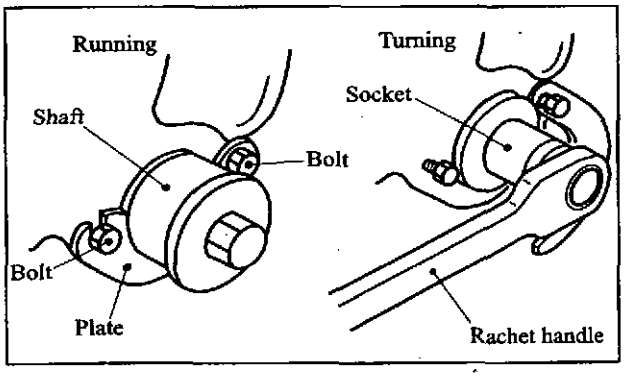
1.3 Inspection and Adjustment of Fuel Injection Timing

(1) Injection timing and its indication location
Since the fuel injection timing varies depending on the engine output, rated speed and other specifications, be sure to check the caution plate on the No. 1 rocker cover.



Location of fuel injection timing indication

(2) Checking No. 1 cylinder top dead center in compression stroke
(a) Using a ratchet handle, rotate the turning gear in the normal direction (clockwise when viewed from the front of the engine).
Pushing the ratchet down turns the shaft in the normal direction.

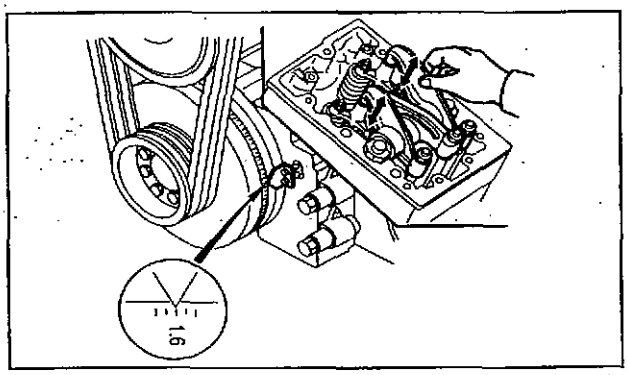


Using turning gear

(b) Stop turning when the stamped No. 1, 6 on the damper aligns with the pointer.
(c) Move the rocker arms for the No. 1 cylinder up and down to make sure the pushrods are not pushing the inlet and exhaust valves off their seats.

⚠ CAUTION

Conduct the above check to make sure the piston in the No. 1 cylinder is at the top dead center, not the piston in the No. 6 cylinder.



Checking No. 1 cylinder top dead center in compression stroke

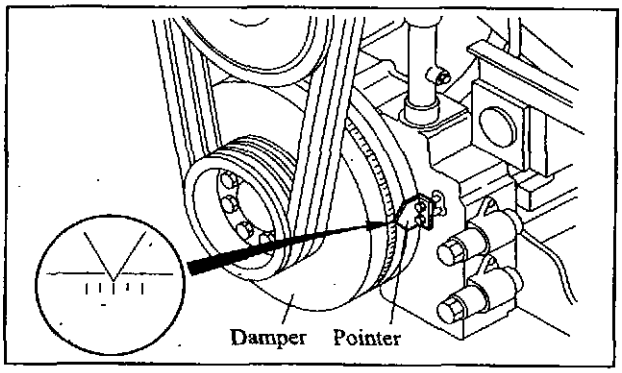
(3) Inspection of fuel injection timing

Turn the engine about 60 degrees in reverse direction, then slowly turn the engine in the forward direction until the pointer is aligned with the fuel injection timing mark (number stamped on the caution plate) on the circumference of the damper.

Then, insert the height gage into the gage stand of the injector, and confirm that the gage protrusion is aligned with the top surface of the tappet. Conduct this inspection for all cylinders.

If the protrusion of the height gage does not align with the top surface of the tappet, follow the adjustment procedure described below.

Name of special tool	Part No.
Height gage	35C91-01100



Fuel injection timing location

(4) Adjustment of fuel injection timing

⚠ CAUTION

For adjustment of the fuel injection timing of unit injectors, start with cylinder No. 1, and perform the adjustment for all cylinders.

(a) Bring the piston in No. 1 cylinder to the top dead center in compression stroke, and make sure that the pointer is properly aligned with the fuel injection timing mark (number stamped on the caution plate) on the circumference of the damper.

(b) Loosen the lock nut on the adjusting screw.

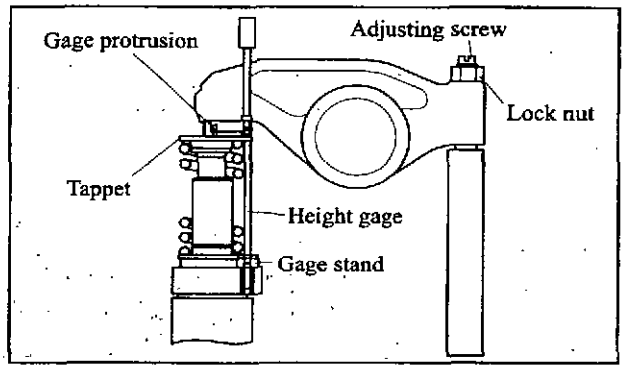
(c) Insert the height gage into the gage stand of the unit injector body, and adjust the adjusting screw so that the protrusion of the height gage is aligned with the tappet surface.

Name of special tool	Part No.
Height gage	35C91-01100

(d) When the height gage is properly aligned, secure the adjusting screw in place by tightening the lock nut.

(e) Repeat the same adjusting procedure for No. 2 and all other cylinders.

(f) To reconfirm proper adjustment, rotate the engine again (two turns), and check the fuel injection timing.



Inspection and adjustment of fuel injection timing

1.4 Inspection and Adjustment of No-Load Minimum (Idling) Speed and Maximum Speed

⚠ CAUTION

(a) The no-load minimum (idling) speed and maximum speed are set for each engine on the test bench at the factory and the set bolts are sealed. These settings must be checked and adjusted at our designated service shop.

(b) After the governor parts are adjusted, all external stoppers must be sealed.

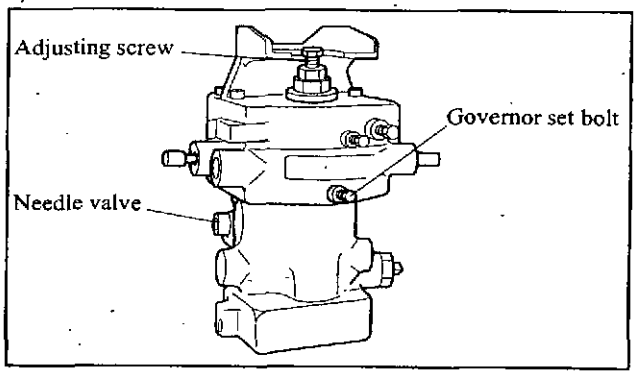
(c) Whether the seals are intact or not has important bearing on the validity of claims under warranty. Be sure to seal all the specified sections.

(d) When inspecting adjusting, be ready to operate the engine stop lever manually in case the engine overruns (engine operation at extremely high speed).

Note: Prior to inspection and adjustment, conduct a warm-up operation until the coolant and oil temperatures rise above 70°C [158°F].

1.5 Inspection and Adjustment of Governor Control (PSG)

(1) Inspection and adjustment of no-load minimum engine speed (idling)
   (a) After checking that the speed control lever is at the idling position, measure the engine speed.
   (b) If the idling speed is not within the specified range, adjust by turning the adjusting screw.



PSG governor

(2) Inspection and adjustment of no-load maximum engine speed
   (a) After setting the speed control lever to the maximum speed position, measure the engine speed.
   (b) If the maximum engine speed is not within the specified range, adjust by turning the governor set bolt.
   (c) Vary the engine speed manually to check the engine response. Also, check to make sure the engine quickly return to stable operating speed.

(3) Stopping engine hunting
   (a) If engine hunting occurs, adjust the needle valve. Turn the needle valve counterclockwise until the engine produces hunting (2 to 3 turns). Let the engine operate in this condition for about 30 seconds to release air from the governor.
   (b) Turn the needle valve clockwise slowly until hunting stops.
   (c) If the needle valve is closed too far, the engine respond to change in load becomes slow. Be sure to open the needle valve more than 1/4 turn from the fully closed position.
   (d) Seal all the set bolts.

1.6 Inspection and Adjustment of Actuator Control (DYN1)

(For DYNA8200 actuator)

(1) Adjustment of speed setting

(a) Set the power switch to OFF to stop the engine.

(b) Check the initial adjustment of each potentiometer.

"I" ····· Set the I potentiometer to 1.

"GAIN" ..... Set the GAIN potentiometer to 3.

"DROOP" ··· Turn the DROOP potentiometer fully in the counterclockwise direction in the case of isochronous operation (constant-speed operation).

For droop operation, set it to a desired position. (Max. 12 % of operation at 35°)

(c) Turn the power switch and starter switch to ON to start the engine.

(d) Adjust the SPEED potentiometer to set a desired engine speed. Note that the SPEED potentiometer can rotate 20 turns and has no stopper in the clockwise (acceleration) or counterclockwise (deceleration) directions.

(e) Set the engine to run at idling speed. (temporary adjustment)

(f) Turn off the power switch of the governor, and make sure the engine stops.

(2) Adjustment of hunting

(a) If the actuator does not stabilize (hunting does not stop), slowly turn the GAIN potentiometer counterclockwise.

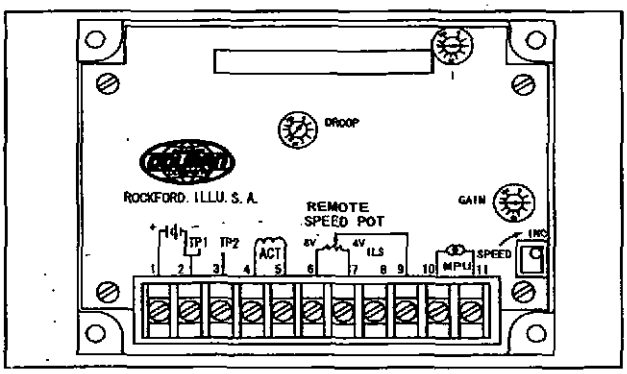
When the actuator stabilizes, operate the actuator lever in a quick motion by hand. The engine should return immediately to the initial speed without hunting.

(b) If the actuator lever is stable, slowly turn the GAIN potentiometer clockwise until hunting starts, then slowly turn it counterclockwise until hunting stops. When the actuator stabilizes, operate the actuator lever in a quick motion by hand. The engine should return immediately to the initial speed without hunting.

(3) Overshoot adjustment

(a) After setting the engine speed to the specified rpm, turn off the power switch of the governor to stop the engine.

(b) Restart the engine, if the engine speed exceeds the set rpm, turn the I potentiometer counterclockwise.



Electronic control device

(c) If it takes too long for the engine to reach the set rpm, slowly turn the I potentiometer clockwise.

(d) Since adjustment of the A, D, DROOP and GAIN potentiometers changes the speed setting slightly, use the SPEED potentiometer to accurately set the engine speed.

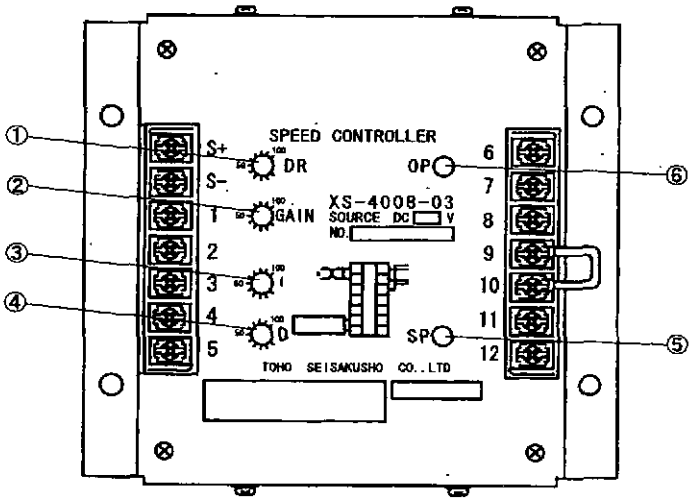
(4) Change of droop setting

If the DROOP potentiometer is turned clockwise from the previous setting after the GAIN potentiometer is adjusted with the controller, the governor may become unstable. When this happens, turn the GAIN potentiometer slightly in the clockwise direction to improve the condition.

1.7 Inspection and Adjustment of Actuator Control (Controller XS-400B)

(For SG4030 actuator)

(1) Names and functions of controls



Names and functions of controls

①DR trimmer (droop adjustment trimmer)

This trimmer is used when droop operation is necessary. After setting the specified frequency under 100% load condition, reduce the load to 0% (no-load condition). Using the difference of the engine speeds in the two operating conditions, select a droop rate. When the trimmer is turned to the right, the droop rate increases. (In a standalone operation, the DR trimmer can be set at 0%, an it does not require adjustment.)

②GAIN trimmer (variable amplification output gain adjustment trimmer)

This trimmer is used to amplify the difference between actual engine speed and set speed. When the trimmer is turned to the right, the amplification rate increases.

③I trimmer (integral adjustment trimmer)

This trimmer is used to adjust the controller's response speed when there is a deviation between the set engine speed and actual speed. When the trimmer is turned to the right, the response time becomes shorter.

④D trimmer (differential adjustment trimmer)

This function makes a prediction of the difference between the set engine speed and actual speed. When the trimmer is turned to the right, the prediction time increases.

⑤SP trimmer (engine speed setting trimmer)

Unlike other trimmers, this trimmer uses a multi-turn dial (18 turns). When the trimmer is turned to the right, the set engine speed increases.

⑥OP indicator (red LED)

This indicator lights when the controller is supplied with power and the input signal from the magnetic input exceeds 10 Hz. When the indicator is not lit, the controller is not in operation.

(2) Initial trimmer settings

The initial setting positions of the trimmers are as shown below. (Settings at the factory)

Trimmer	DR	GAIN	I	D	SP
Position	0%	20%	60%	50%	Approx. 700 min^{-1}, with 182-tooth link gear

Note 1. The above table shows trimmer positions in percentage terms. One gradation line on the trimmer equals 10%.
Note 2. The DR trimmer is set at 0%, and this results in isochronous (constant speed) operation.
Note 3. The initial settings are adjusted and changed in the engine performance test.

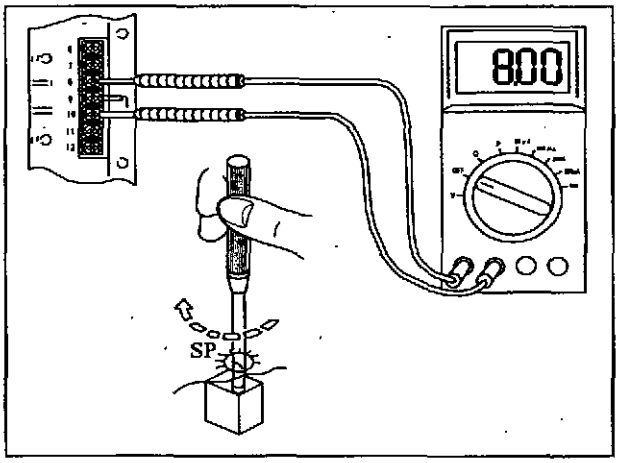
⚠ CAUTION

(a) During inspection and adjustment, always be ready to operate the engine stop lever manually in the event of an unexpected engine overrun (excessive speed increase).
(b) Reversal of the power supply polarities can result in permanent damage to the controller.

(3) Supply power
Before starting the engine, supply power to the controller, and check the voltage between terminals 8 and 10 with a voltmeter (tester). If the voltage is less than 8 VDC, the controller may be inappropriate.

⚠ CAUTION

(a) Be sure to cut off the power before connecting wires.
(b) Use shielded wires for input signal cables.
(c) Because the input signal wires can be affected by induced noise, keep them away from instrument lines, power lines and load lines.



Applying electric current

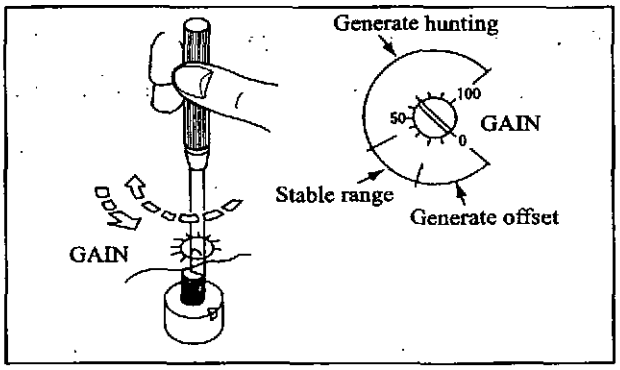
(4) Starting engine
Except when the engine runs beyond the rated speed, slowly turn the SP trimmer to the right and set the engine to the rated speed (or rated generating frequency).

⚠ CAUTION

If the engine generates excessive hunting or does not start, inspect and correct the problem by referring to the troubleshooting section.

(5) Adjustment of controller limits (rough tuning)
(a) GAIN trimmer
Slowly turn the GAIN trimmer to the right. When the engine starts to produce hunting, slowly turn the trimmer to the left until hunting stops, then further turn the trimmer 5 to 10% to the left.
If the engine does not generate hunting with the trimmer turned fully to the right, move the actuator lever by hand to cause hunting. It is recommended to set the GAIN trimmer within a range of 20 to 40%.

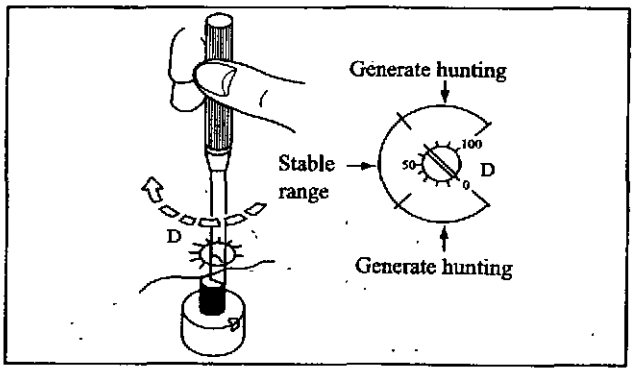
Note: When a droop rate (DR trimmer) is set, turning the GAIN trimmer to the left increases the droop rate, and turning it to the right decreases the droop rate.



GAIN trimmer

(b) D trimmer
Adjust the D trimmer by following the same procedure as for the GAIN trimmer.

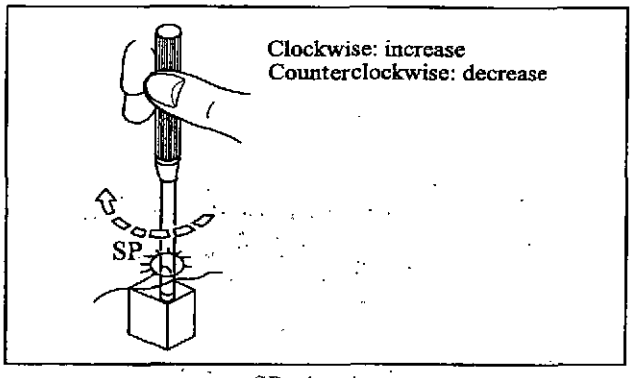
(c) SP trimmer
Since the engine speed setting changes when the GAIN and D trimmers are adjusted, set the rated engine speed again by using the SP trimmer.



D trimmer

(6) Checking engine operation under load
Slowly increase the load to the rated load (or 110% load in some cases), and make sure no hunting occurs and the engine operates properly under rated load.
If the engine does not operate under rated load, readjust the linkage to set the fuel volume properly.

(7) Adjustment of governor performance (fine tuning)
Apply about 25% load and shut it off while measuring with a frequency meter or electromagnetic oscilloscope. Conduct fine tuning according to the result of the measurement. If there is no problem in the measurement, increase the load by 1/4 at a time and check.

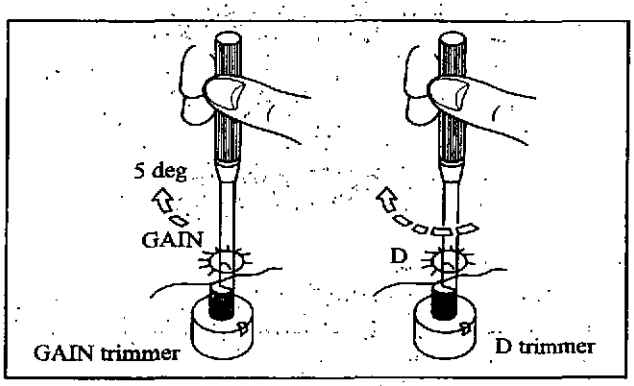


SP trimmer

(8) Reducing momentary speed variation
(a) Turn the GAIN trimmer to the right as little (approx. 5 degree) as the screwdriver recess width on the trimmer at a time, and repeat the load charge (exceeding the specified charge rate) and shut-off procedure (until the fluctuation rate falls within the specified range).

⚠ CAUTION

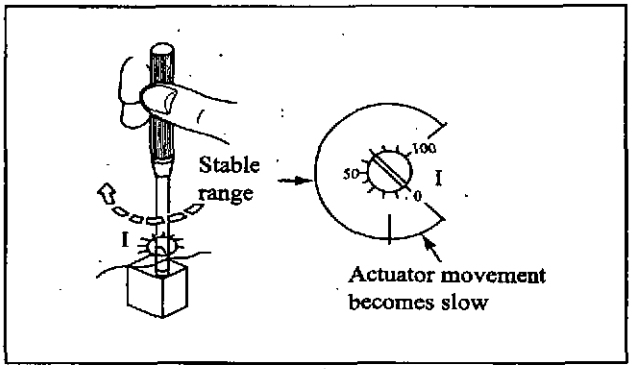
If adjusted very close to the hunting limit, external disturbance can cause hunting afterward.



Reducing momentary speed variation

(b) If the adjustment of the GAIN trimmer does not result in an improvement, turn the D trimmer to the right as little as half the graduation interval at a time, and repeat the load charge (exceeding the specified charge rate) and shut-off procedure (until the fluctuation rate falls within the specified range).

(9) Reducing stabilization time
Turn the I trimmer to the right as little as one graduation interval at a time, and repeat the load charge (exceeding the specified charge rate) and shut-off procedure.



I trimmer

⚠ CAUTION

If the I trimmer is turned excessively to the right for the purpose of shortening the stabilization time, the engine can overshoot significantly during a startup.

(10) Adjustment of droop operation

In a standalone operation, set the DR trimmer at 0%, and no adjustment is needed. If an adjustment is required, follow the procedure below.

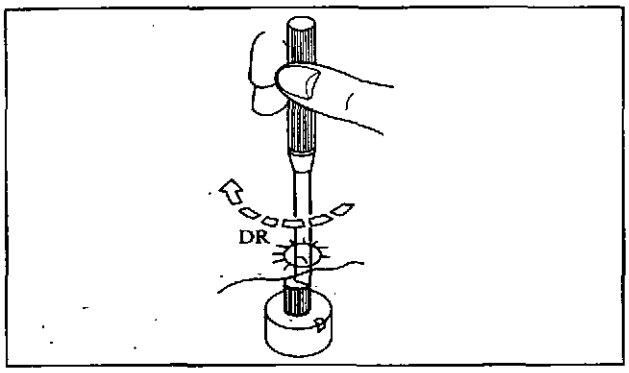
(a) Start the engine, and let it run under no load.

(b) Slowly turn the DR trimmer to the right. This normally increases the engine speed.
While adjusting the SP trimmer to maintain the target no-load maximum engine speed (rated speed + droop), set the DR trimmer to the third graduation line (30%). If the actuator load is heavy, the engine speed may drop when the DR trimmer is slowly turned to the right.

(c) Slowly increase the load to the 100% rating, and make sure that the rated engine speed is achieved. If the droop rate is insufficient, turn the DR trimmer to the right with the engine operating under no load, and repeat steps (a) through (c) to set a desired droop rate.

Note: (a) Since the controller regulates the droop using the signal representing the amount of power consumed by the actuator, the control function is affected by the actuator's hysteresis. If the lever on the engine side becomes heavy, the actuator increases the torque output, and the resulting current increase can cause a deviation of the control value.

(b) When the GAIN trimmer is turned, the droop rate changes. (Turning the GAIN trimmer to the right increases the droop rate, and vice versa.)



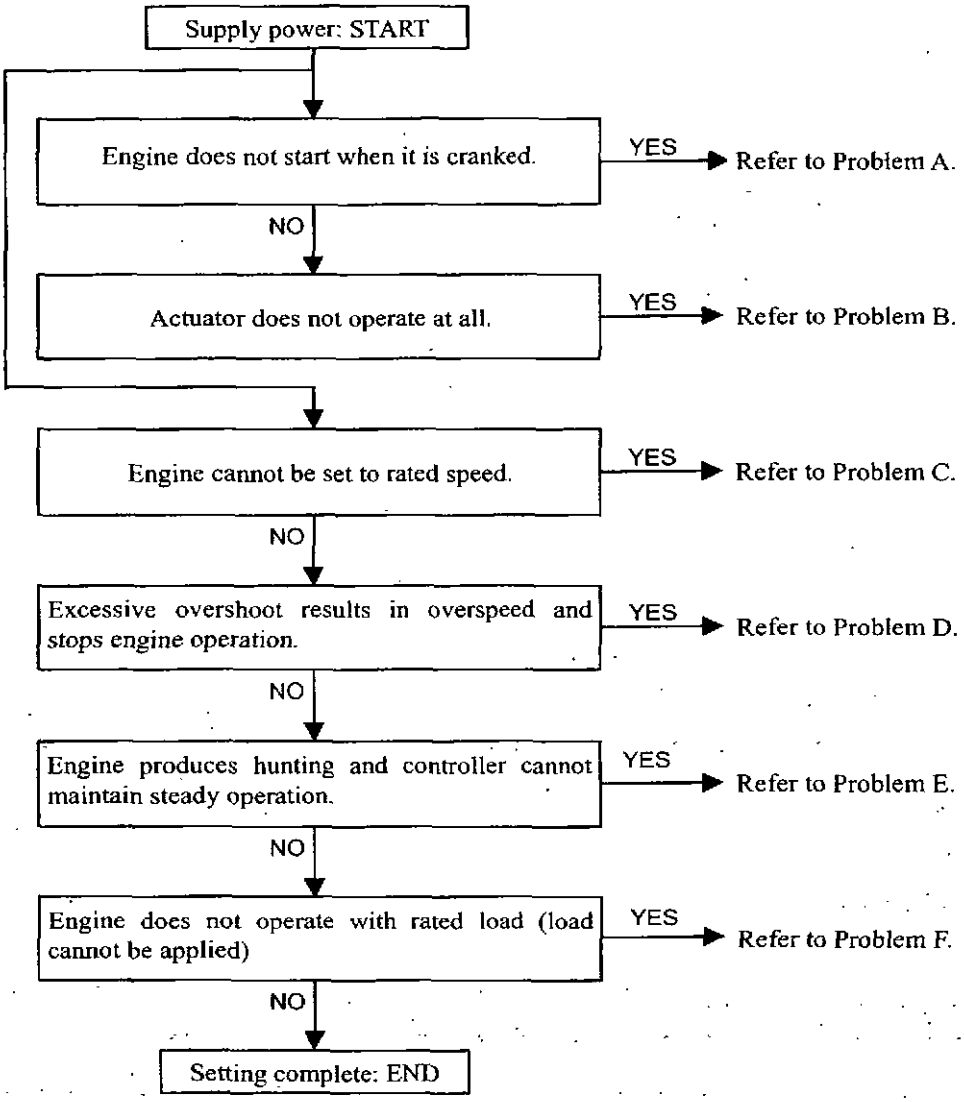
DR trimmer

(11) Inspection and adjustment of no-load minimum engine speed (idling)
  (a) Supply power to the controller.
  (b) Disconnect the wire from input terminal No. 1 of the controller.
  (c) Turn the SP trimmer (engine speed setting trimmer) fully to the left.
  (d) While operating the starter to crank the engine, slowly turn the SP trimmer to the right. When the engine starts, set the engine idling speed.
  (e) Check that the engine pressure and temperature increase. Also, check for oil and water leaks, abnormal noise, odor and vibrations.

(12) Inspection and adjustment of no-load maximum engine speed
  (a) With the engine idling, slowly turn the SP trimmer to the right to set the engine speed to the rated speed.
  (b) Conduct the same inspection as described in above (e).

1.8 Troubleshooting of Actuator Control (Controller XS-400B)

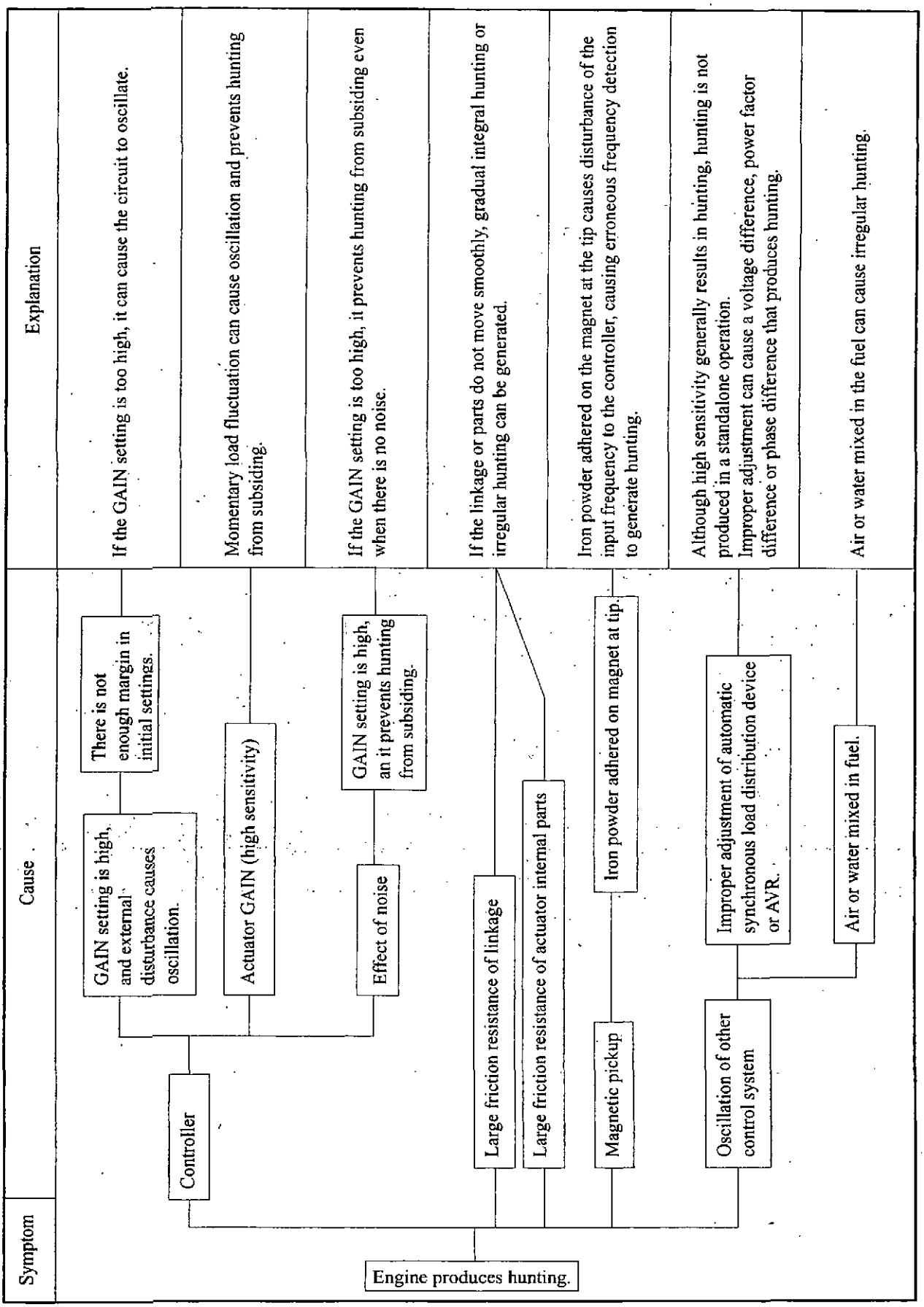
(1) Troubleshooting



Problem	Suspected cause	Check method	Remedy
A. Engine does not start when it is cranked. (Every time engine is cranked, actuator lever moves to maximum fuel supply position.)	Fuel is not supplied to the engine.	Manually control the engine.	Check the fuel system. Check the safety devices.
B. Actuator does not operate at all.	Reversed connections at terminals S+ and S−, or loose terminal screws.	Check the wire connections at terminals S+ and S−.	Connect the connections properly. replace the controller.
	The power supply voltage does not conform to the specification.	Disconnect wires from terminals S+ and S−, and measure power supply voltage with a DC voltage tester.	Supply the specified voltage. Use a thicker power supply lead cable.
	There is an open-circuit in the harness.	Disconnect wires from controller terminals 4 and 5, and check resistance. The tester should indicate approximately 3 Ω. If it indicates infinity (∞), there is an open-circuit.	Replace the harness.
	The linkage is stuck.	Move the linkage by hand to see if it moves smoothly.	Make an adjustment so the linkage moves smoothly.
	There is no signal sent from the magnetic pickup to the controller.	Check to make sure the OP lamp is lit. Crank the engine and check voltage between terminals 6 and 7.	If the measured voltage is less than 1 VAC, reset or replace the pickup.
	The actuator is malfunctioning.	Install a different actuator, and test.	Replace the actuator.
		Remove the receptacle from the actuator, and measure resistance between the actuator terminal and body. The tester should indicate infinity (∞).	If there is a short-circuit or the tester indicates resistance, replace the actuator.

Problem	Suspected cause	Check method	Remedy
B. Actuator does not operate at all.	The actuator is malfunctioning.	Measure resistance between pins A and b. If the tester indicates infinity (∞), there is an open-circuit in the coil.	Replace the actuator.
	The controller is malfunctioning. The battery capacity is too low.	If the above inspections do not find any abnormality, measure voltage between terminals 8 and 10. The tester should indicate approximately 8 VDC. If the voltage deviates from 8 VDC, there is an abnormality. Short-circuit terminals 8 and 12 using a wire. Check the actuator operation, and also measure voltage between terminals S+ and S−. If the tester indicates less than 16 VDC, the battery capacity is too low.	Replace the controller. Replace the battery. (Reference Information Lengths and diameters of wires between battery and controller, and between controller and actuator 1.25 mm² [0.0019 in²] for a length of up to 10m 3.5 mm² [0.0054 in²] for a length of up to 20 m [66 ft] 5.5 mm² [0.0085 in²] for a length of up to 30 m [98 ft])
C. Engine cannot be set to rated speed.	The trimmer or circuit board is faulty.	Make sure there is a margin in the actuator's movement in the direction toward the fully open position.	Turn the SP trimmer to the right. If the engine speed does not increase, the trimmer or circuit board is faulty.
D. Excessive overshoot results in overspeed and stops engine operation.	The I trimmer is turned too far to the right.	Turn the I trimmer to the left and set it at 40%; then recheck.	Reset the trimmer for proper adjustment of stabilization time. If the I trimmer must be turned to the right, turn the GAIN trimmer slightly to the right first.
	The SP trimmer setting is too high.	Turn the SP trimmer fully to the left, then recheck.	If overspeed results, replace the controller. If the engine speed decreases, slowly turn the SP trimmer to the right.
E. Engine produces hunting and controller cannot maintain steady operation.	The GAIN setting is too high.	Hunting occurs when the actuator lever is at 2 to 3 Hz.	Slowly turn the GAIN trimmer to the left to stop hunting. If this does not make any change, check the D trimmer.
	The D setting is too high.	Hunting occurs when the actuator lever is at 4 to 5 Hz.	Slowly turn the D trimmer to the left to stop hunting.
	The I trimmer is turned too far to the right.	The actuator vibrates in small amplitude at about 1 kHz and the rack position change is slow.	Slowly turn the I trimmer to the left to stop hunting.
F. Engine does not operate with rated speed.	There is not enough fuel supply.	Check the degree of the actuator opening.	Increase the amount of fuel supply.

(2) Causes of engine hunting

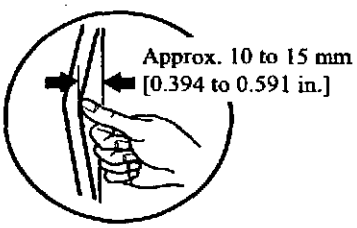


1.9 Inspection and Adjustment of V- Belt Tension

⚠ CAUTION

(a) If damage or surface separation is found on the V-belt during inspection, replace the V-belt.
(b) Keep oil and grease away from the belt, since they may cause the belt to slip and shorten the service life.
(c) Make sure the belt is not taut.

With your thumb, apply pressure (approx. 98 to 147 N (10 to 15 kgf) [22 to 33 lbf]) to the belt at the midway between the pulleys to inspect the belt tension.



Unit mm [in.]

	Standard
Belt tension (deflection)	10 to 15 [0.394 to 0.591]

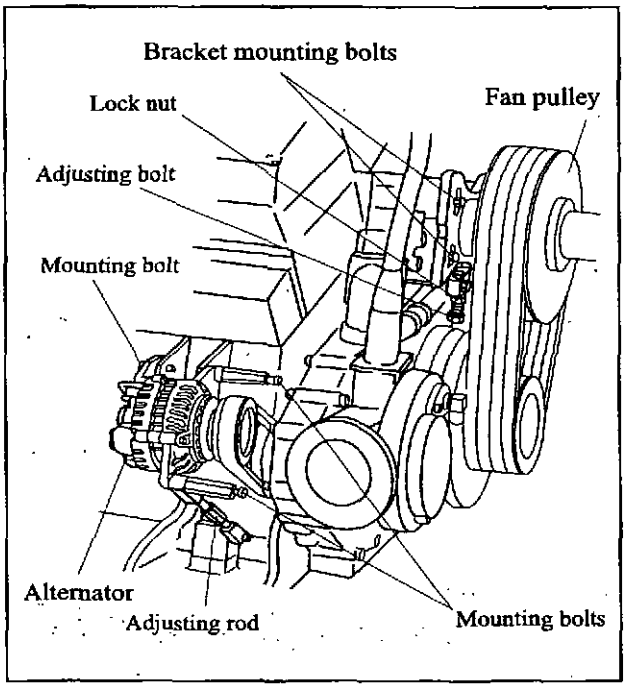
If it is not within the standard, adjust by following the procedures below.

(Alternator side)

1. Remove the belt cover of the alternator.
2. Loosen the alternator and their mounting bolts.
3. Turn the adjusting rod to adjust the belt tension.
4. Then, tighten all bolts mounting the alternator.

(Fan side)

1. Loosen fan pulley bracket mounting bolts.
2. Loosen lock nuts adjusting bolts, tighten the bolt to adjust the belt.
3. Then, fix the belt with the lock nut and tighten the bracket mounting bolt.



Inspection and adjustment of V-belt tension

2. Engine Break-In Operation

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

2.1 Starting Up

(1) Before starting the engine, check the levels of coolant, engine oil and fuel, and bleed the fuel and cooling systems.
(2) With the fuel supply cut off, operate the starter and crank the engine for about 10 seconds to circulate engine oil.
(3) Move the control lever slightly in the direction for increased fuel (do not move it to "full injection" position), then turn the starter switch key to the [START] position to start the engine.
(4) After the engine starts, let it operate at no-load minimum speed (idling).

2.2 Inspection After Starting Up

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

(1) Lubricating oil pressure should be 0.39 to 0.67 MPa (4 to 7 kgf/cm^2) [56.89 to 99.56 psi] (at rated engine speed), and more than 0.20 to 0.29 MPa (2 to 3 kgf/cm^2) [28.45 to 42.68 psi] (at idling).
(2) Coolant temperature should be 65 to 85°C [149 to 185°F].
(3) Lubricating oil temperature should be 70 to 110°C [158 to 230°F].
(4) Check for leakage of oil, coolant and fuel, especially oil leakage from turbocharger lubricating oil pipe connections.
(5) Knocking should stop when the coolant temperature rises. The engine should not produce any other abnormal noise.
(6) Check for exhaust color and abnormal odors.

2.3 Break-In Period

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

Break-in operation time

	Engine speed (min^{-1})	Load (kW [PS])	Time (min)
1	Idling speed	No load	5
2	1000	No load	5
3	1200	No load	10
4	Rated speed (Varies depending on engine specifications)	25%	10
5		50%	10
6		75%	30
7		100%	20

2.4 Inspection and Adjustment After Break-In Operation

(a) Adjustment of valve clearances
(b) Adjustment of injection timing
(c) Re-tightening external bolts and nuts

3. Performance Tests

There are various performance test procedures. The following describes the procedures specified in "Earth moving machinery - Engines - Part 1: Test code of net power (JIS D0006-1)" and "Earth moving machinery - Engines - Part 2: Standard format of specifications and testing methods of diesel engines (JIS D0006-2)."
Other test items may be required in some applications. All test results should be evaluated comprehensively in order to determine the engine performance.

3.1 Engine Equipment Condition

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

3.2 Test Items and Purposes

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

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

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

3.3 Other Inspections

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

3.4 Engine Output Adjustment

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

(1) Standard atmospheric conditions:
Base temperature: 298 K (25°C) [77°F]
Atmospheric pressure: 100 kPa [750 mmHg]
Dry atmospheric pressure: 99 kPa [743 mmHg]

(2) Calculation of corrected power
Multiply the measured brake power or torque by the calculated diesel engine correction factor to obtain a corrected value.

Corrected output=Correction factor (α_c)× Measured brake power

・Atmospheric conditions during test

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

Dry atmospheric pressure(P): 80 kPa (600 mmHg)≦P≦110 kPa (825 mmHg)

(3) Calculation of correction factor (αc)

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

(a) Calculation of atmospheric factor (*fa*)

① Natural aspiration engine and engine with mechanically driven air charger

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

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

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

③Turbocharged engine with air-to-liquid cooler

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

(b) Calculation of engine factor (*fm*)

$fm=0.036\ qc-1.14$

qc: Corrected fuel supply volume

$$①qc=\frac{q}{r}$$

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

$z=120000$(4-cycle engine)

r: Ratio between pressure at turbocharger or air cooler outlet and atmospheric pressure
($r=1$ for natural aspiration engine)

②Applicable range of engine factor (*fm*)

$37.2\leqq qc\leqq 65$ mg/(ℓ-cycle)

・$qc\leqq 37.2$ mg/(ℓ-cycle) : $fm=0.2$ (constant)
・65 mg/(ℓ-cycle)$\leqq qc$: $fm=1.2$ (constant)

(c) Range of correction equation use

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

$0.9\leqq\alpha_c\leqq 1.1$.

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

OTHERS

Disassembly and Reassembly of General Parts

1.1 Oil Seals

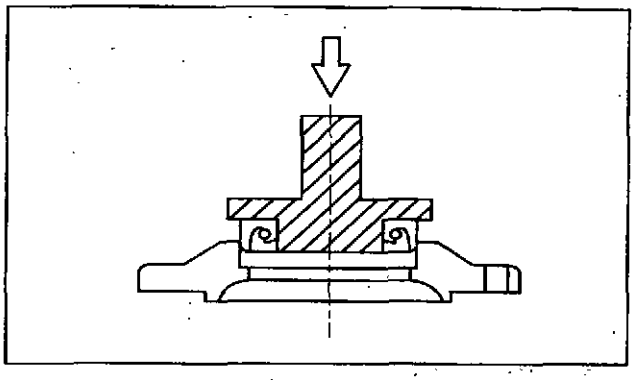
When installing oil seals, observe the following.

Installation of oil seals to housings

(a) Check the seal lip for scratches and damage, and be sure to position the lip correctly.

(b) Apply a small amount of grease to the periphery (housing contact surface) of the oil seal before installation.

(c) Use an oil seal driver that guides the seal lip and presses the seal periphery, as shown in the diagram on the right. Striking the oil seal directly with a hammer causes seal damage and results in oil leaks.

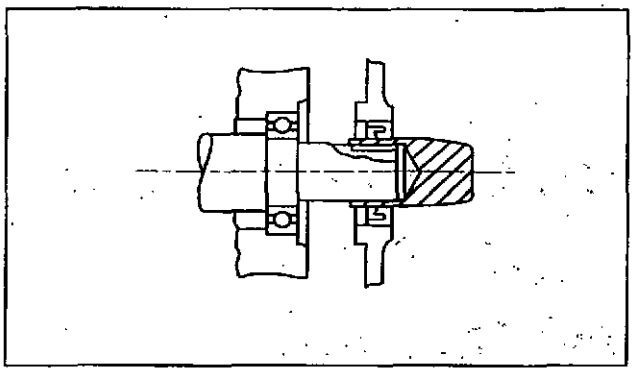


Oil seal driver

Installation of oil seals to shafts

(a) Apply grease to the oil seal lip.

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

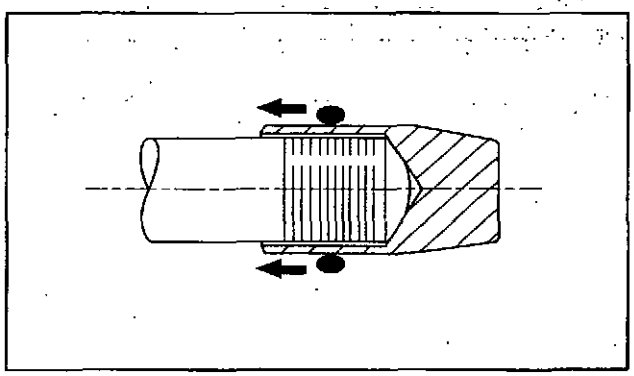


Oil seal guide

1.2 O-rings

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

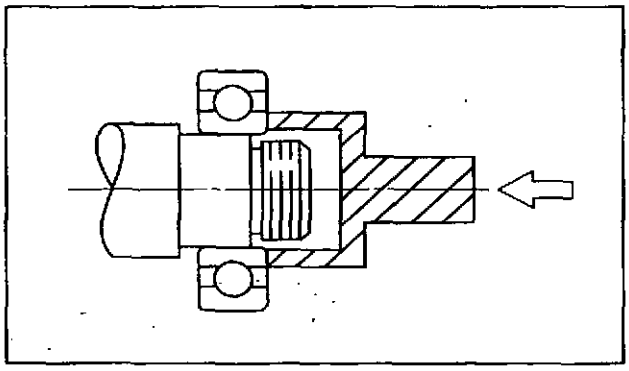
Be sure to apply a small amount of grease to the O-ring before installation.



O-ring guide

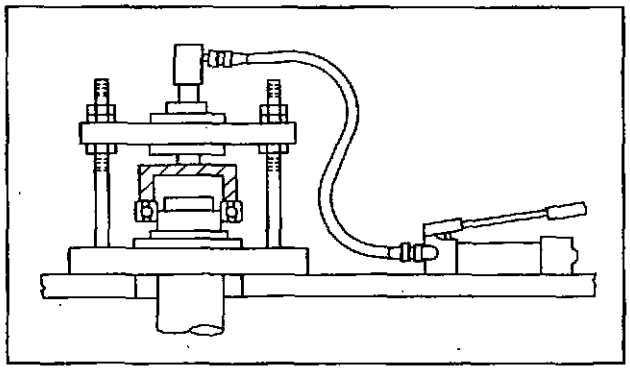
1.3 Bearings

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



Bearing driver

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



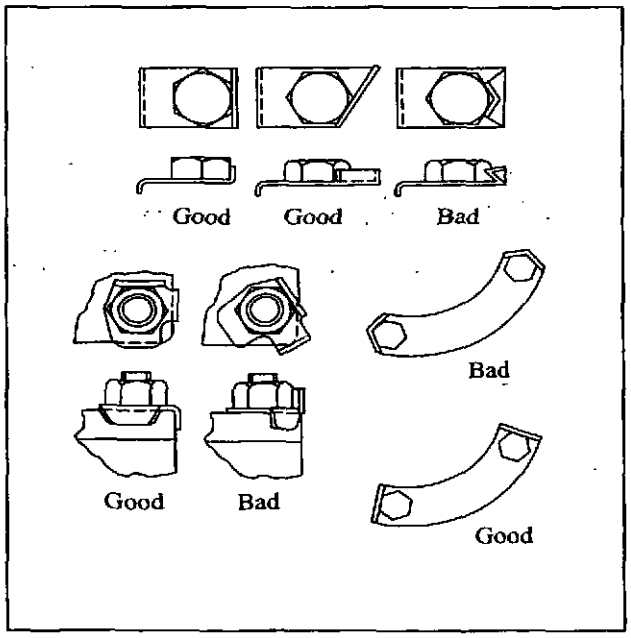
Using press for bearing installation

1.4 Lock Plates

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

1.5 Split Pins and Spring Pins

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



Bending lock plate

ENGINE INSPECTION RECORD SHEET (SH SERIES)

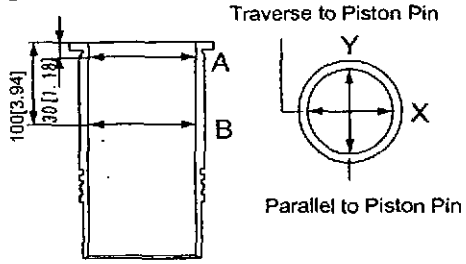
1. Measurement of Cylinder Liner Bore Diameter
2. Measurement of Cylinder Liner Collar Protrusion
3. Measurement of Valve Guide Inside Diameter and Valve Stem Diameter
4. Measurement of Valve Sinkage, Seat Width and Valve Margin
5. Measurement of Distortion of Cylinder Head Bottom Surfaces
6. Measurement of Connecting Rod Bushing Inside Diameter and Connecting Rod Big-End Bore Diameter
7. Measurement of Rocker Bushing Inside Diameter and Rocker Shaft Diameter
8. Measurement of Piston Pin Bore Diameter and Piston Pin Diameter
9. Measurement of Valve Clearance
10. Measurement of Injection Pressure of Unit Injector Nozzle
11. Measurement of Camshaft Bushing Inside Diameter and Camshaft Journal Diameter (Right Side)
12. Measurement of Camshaft Bushing Inside Diameter and Camshaft Journal Diameter (Left Side)
13. Measurement of Crankshaft End Play

INSPECTION RECORD SHEET

	S H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Cylinder Liner Bore Diameter			UNIT	mm [in.]

Measuring Locations



Standard

	Nominal Value	Standard	Limit
Cylinder Liner Bore Diameter	ϕ150 [5.91]	150.000 to 150.040 [5.9055 to 5.90708]	150.140 [5.9110]

Measured Value

Part's Name		Cylinder Liner Bore Diameter		Part's Name		Cylinder Liner Bore Diameter	
No.	Direction	A	B	No.	Direction	A	B
1	X			7	X		
	Y				Y		
2	X			8	X		
	Y				Y		
3	X			9	X		
	Y				Y		
4	X			10	X		
	Y				Y		
5	X			11	X		
	Y				Y		
6	X			12	X		
	Y				Y		

REMARK	Approved By	Checked By	Person In Charge

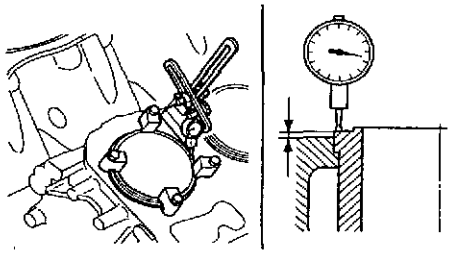
No.2

INSPECTION RECORD SHEET

	S H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Cylinder Liner Collar Protrusion			UNIT	mm [in.]

Measuring Locations



Standard

	Standard
Cylinder Liner Collar Protrusion	0.10 to 0.19 [0.0039 to 0.0075]

Measured Value

Part's Name	Cylinder Liner Collar Protrusion				
No.	A	B	C	D	Average Value
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

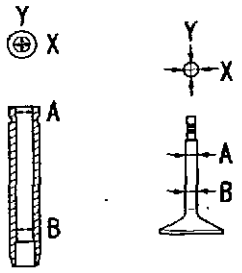
REMARK	Approved By	Checked By	Person In Charge

INSPECTION RECORD SHEET

	S H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Valve Guide Inside Diameter and Valve Stem Diameter (1/2)			UNIT	mm [in.]

Measuring Locations



Standard

	Nominal Value	Standard	Limit
Valve Guide Inside Diameter (Same for Inlet and Exhaust)	ϕ10 [0.39]	10.000 to 10.015 [0.39370 to 0.39429]	10.060 [0.39606]
Valve Stem Diameter (Same for Inlet and Exhaust)	ϕ10 [0.39]	9.940 to 9.960 [0.39134 to 0.39213]	9.910 [0.39016]

Measured Value

Part's Name			Valve Guide Inside Diameter				Valve Stem Diameter				Clearance			
No.	Direction		A		B		A		B		A		B	
			X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	Inlet	①												
		②												
	Ex-haust	①												
		②												
2	Inlet	①												
		②												
	Ex-haust	①												
		②												
3	Inlet	①												
		②												
	Ex-haust	①												
		②												
4	Inlet	①												
		②												
	Ex-haust	①												
		②												
5	Inlet	①												
		②												
	Ex-haust	①												
		②												
6	Inlet	①												
		②												
	Ex-haust	①												
		②												

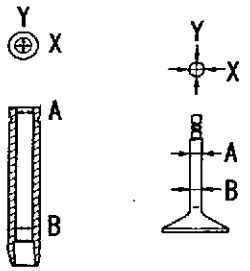
REMARK	Approved By	Checked By	Person In Charge

INSPECTION RECORD SHEET

	S H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Valve Guide Inside Diameter and Valve Stem Diameter (2/2)			UNIT	mm [in.]

Measuring Locations



Standard

	Nominal Value	Standard	Limit
Valve Guide Inside Diameter (Same for Inlet and Exhaust)	ϕ10 [0.39]	10.000 to 10.015 [0.39370 to 0.39429]	10.060 [0.39606]
Valve Stem Diameter (Same for Inlet and Exhaust)	ϕ10 [0.39]	9.940 to 9.960 [0.39134 to 0.39213]	9.910 [0.39016]

Measured Value

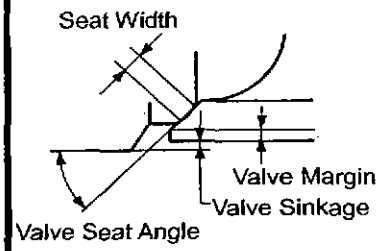
Part's Name			Valve Guide Inside Diameter				Valve Stem Diameter				Clearance			
No.	Direction		A		B		A		B		A		B	
			X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
7	Inlet	①												
		②												
	Ex-haust	①												
		②												
8	Inlet	①												
		②												
	Ex-haust	①												
		②												
9	Inlet	①												
		②												
	Ex-haust	①												
		②												
10	Inlet	①												
		②												
	Ex-haust	①												
		②												
11	Inlet	①												
		②												
	Ex-haust	①												
		②												
12	Inlet	①												
		②												
	Ex-haust	①												
		②												

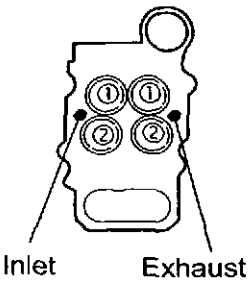
REMARK	Approved By	Checked By	Person In Charge

INSPECTION RECORD SHEET

					S H
Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Valve Sinkage, Seat Width and Valve Margin (1/2)			UNIT	mm [in.]

Measuring Locations





Standard

		Standard	Limit
Valve seat (same for Inlet and Exhaust)	Valve Seat Angle	30°	
	Valve Sinkage	-0.1 to 0.1 [-0.004 to 0.004]	1.0 [0.039]
	Seat Width	2.15 to 2.45 [0.0846 to 0.0965]	2.8 [0.110]
	Valve Margin	2.8 to 3.2 [0.110 to 0.126]	Refacing permissible up to 2.5 [0.098]

Measured Value

Part's Name №	Valve		Valve Seat Angle	Valve Sinkage	Seat Width	Part's Name №	Valve		Valve Seat Angle	Valve Sinkage	Seat Width
1	Inlet	①				5	Inlet	①			
		②						②			
	Ex-haust	①					Ex-haust	①			
		②						②			
2	Inlet	①				6	Inlet	①			
		②						②			
	Ex-haust	①					Ex-haust	①			
		②						②			
3	Inlet	①				7	Inlet	①			
		②						②			
	Ex-haust	①					Ex-haust	①			
		②						②			
4	Inlet	①				8	Inlet	①			
		②						②			
	Ex-haust	①					Ex-haust	①			
		②						②			

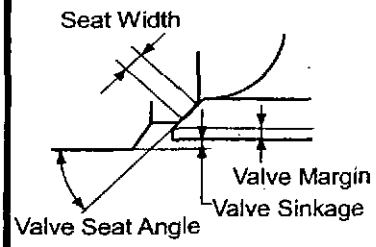
REMARK	Approved By	Checked By	Person In Charge

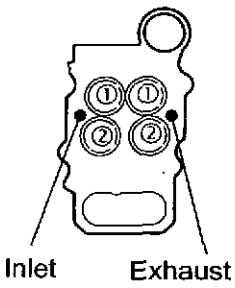
INSPECTION RECORD SHEET

S H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Valve Sinkage, Seat Width and Valve Margin (2/2)			UNIT	mm [in.]

Measuring Locations





Standard

		Standard	Limit
Valve seat (same for Inlet and Exhaust)	Valve Seat Angle	30°	
	Valve Sinkage	-0.1 to 0.1 [-0.004 to 0.004]	1.0 [0.039]
	Seat Width	2.15 to 2.45 [0.0846 to 0.0965]	2.8 [0.110]
	Valve Margin	2.8 to 3.2 [0.110 to 0.126]	Refacing permissible up to 2.5 [0.098]

Measured Value

Part's Name No.	Valve		Valve Seat Angle	Valve Sinkage	Seat Width	Part's Name No.	Valve		Valve Seat Angle	Valve Sinkage	Seat Width
9	Inlet	①				13	Inlet	①			
		②						②			
	Exhaust	①					Exhaust	①			
		②						②			
10	Inlet	①				14	Inlet	①			
		②						②			
	Exhaust	①					Exhaust	①			
		②						②			
11	Inlet	①				15	Inlet	①			
		②						②			
	Exhaust	①					Exhaust	①			
		②						②			
12	Inlet	①				16	Inlet	①			
		②						②			
	Exhaust	①					Exhaust	①			
		②						②			

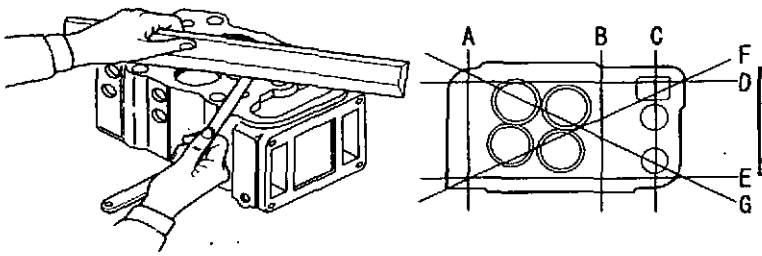
REMARK	Approved By	Checked By	Person In Charge

INSPECTION RECORD SHEET

	S H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Distortion of Cylinder Head Bottom Surfaces			UNIT	mm [in.]

Measuring Locations



Standard

	Standard	Limit
Distortion of Cylinder Head Bottom Surfaces	0.03 [0.0012] or less	0.50 [0.0197]

Measured Value

Part's Name	Distortion of Cylinder Head Bottom Surfaces						
No.	A	B	C	D	E	F	G
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							

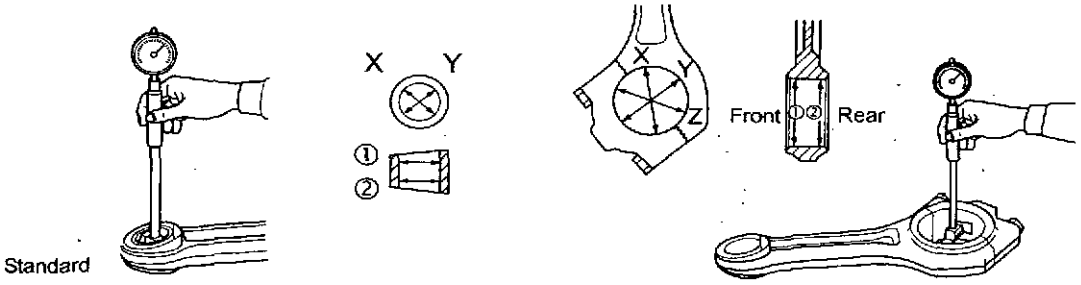
REMARK	Approved By	Checked By	Person In Charge

INSPECTION RECORD SHEET

	S H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Connecting Rod Bushing Inside Diameter and Connecting Rod Big-End Bore Diameter (1/2)			UNIT	mm [in.]

Measuring Locations



Standard

	Nominal Value	Standard	Limit
Connecting Rod Bushing Inside Diameter	ϕ58 [2.28]	58.020 to 58.040 [2.28425 to 2.28503]	58.070 [2.28622]
Connecting Rod Big-End Bore Diameter	ϕ110 [4.33]	110.000 to 110.022 [4.33070 to 4.33157]	110.047 [4.33255]

Measured Value

Part's Name		Connecting Rod Bushing Inside Diameter		Connecting Rod Big-End Bore Diameter		
№	Direction	X	Y	X	Y	Z
1	①					
	②					
2	①					
	②					
3	①					
	②					
4	①					
	②					
5	①					
	②					
6	①					
	②					

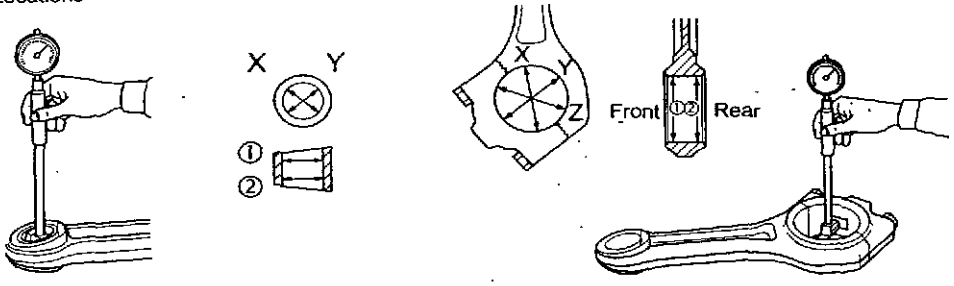
REMARK	Approved By	Checked By	Person In Charge

INSPECTION RECORD SHEET

	S H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Connecting Rod Bushing Inside Diameter and Connecting Rod Big-End Bore Diameter (2/2)			UNIT	mm [in.]

Measuring Locations



Standard

	Nominal Value	Standard	Limit
Connecting Rod Bushing Inside Diameter	ϕ58 [2.28]	58.020 to 58.040 [2.28425 to 2.28503]	58.070 [2.28622]
Connecting Rod Big-End Bore Diameter	ϕ110 [4.33]	110.000 to 110.022 [4.33070 to 4.33157]	110.047 [4.33255]

Measured Value

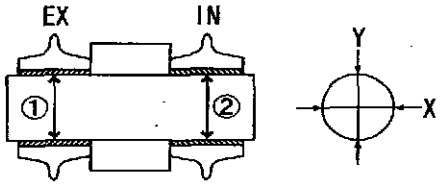
Part's Name		Connecting Rod Bushing Inside Diameter		Connecting Rod Big-End Bore Diameter		
No.	Direction	X	Y	X	Y	Z
7	①					
	②					
8	①					
	②					
9	①					
	②					
10	①					
	②					
11	①					
	②					
12	①					
	②					

REMARK	Approved By	Checked By	Person In Charge

INSPECTION RECORD SHEET

					S H
Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Rocker Bushing Inside Diameter and Rocker Shaft Diameter (1/2)			UNIT	mm [in.]

Measuring Locations



Standard

	Nominal Value	Standard	Limit
Rocker Bushing Inside Diameter	ϕ44 [1.734]	44.000 to 44.075 [1.734 to 1.735]	44.125 [1.737]
Rocker Shaft Diameter	ϕ44 [1.734]	43.975 to 43.991 [1.731 to 1.733]	43.030 [1.694]

Measured Value

Part's Name		Rocker Bushing Inside Diameter		Rocker Shaft Diameter		Clearance	
No.	Direction	X	Y	X	Y	Max.	Min.
1	①						
	②						
2	①						
	②						
3	①						
	②						
4	①						
	②						
5	①						
	②						
6	①						
	②						

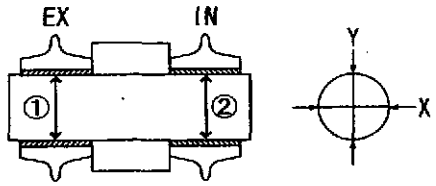
REMARK	Approved By	Checked By	Person In Charge

INSPECTION RECORD SHEET

	S H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Rocker Bushing Inside Diameter and Rocker Shaft Diameter (2/2)			UNIT	mm [in.]

Measuring Locations



Standard

	Nominal Value	Standard	Limit
Rocker Bushing Inside Diameter	ϕ44 [1.734]	44.000 to 44.075 [1.734 to 1.735]	44.125 [1.737]
Rocker Shaft Diameter	ϕ44 [1.734]	43.975 to 43.991 [1.731 to 1.733]	43.030 [1.694]

Measured Value

Part's Name		Rocker Bushing Inside Diameter		Rocker Shaft Diameter		Clearance	
No.	Direction	X	Y	X	Y	Max.	Min.
7	①						
	②						
8	①						
	②						
9	①						
	②						
10	①						
	②						
11	①						
	②						
12	①						
	②						

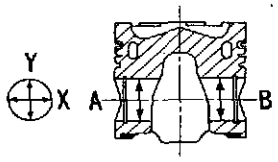
REMARK	Approved By	Checked By	Person In Charge

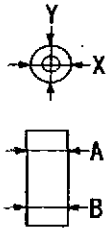
INSPECTION RECORD SHEET

S. H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Piston Pin Bore Diameter and Piston Pin Diameter (1/2)			UNIT	mm [in.]

Measuring Locations





Standard

	Nominal Value	Standard	Limit
Piston Pin Bore Diameter	ϕ58 [2.28]	58.002 to 58.012 [2.28393 to 2.28354]	58.020 [2.28425]
Piston Pin Diameter	ϕ58 [2.28]	57.987 to 58.000 [2.28295 to 2.28346]	57.970 [2.28228]

Measured Value

Part's Name		Piston Pin Bore Diameter		Piston Pin Diameter		Clearance	
No.	Direction	X	Y	X	Y	Max.	Min.
1	A						
	B						
2	A						
	B						
3	A						
	B						
4	A						
	B						
5	A						
	B						
6	A						
	B						

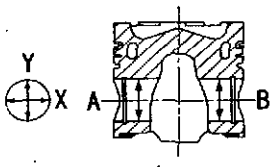
REMARK	Approved By	Checked By	Person In Charge

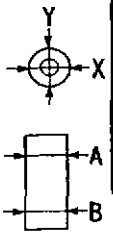
INSPECTION RECORD SHEET

	S H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Piston Pin Bore Diameter and Piston Pin Diameter (2/2)			UNIT	mm [in.]

Measuring Locations





Standard

	Nominal Value	Standard	Limit
Piston Pin Bore Diameter	ϕ58 [2.28]	58.002 to 58.012 [2.28393 to 2.28354]	58.020 [2.28425]
Piston Pin Diameter	ϕ58 [2.28]	57.987 to 58.000 [2.28295 to 2.28346]	57.970 [2.28228]

Measured Value

Part's Name		Piston Pin Bore Diameter		Piston Pin Diameter		Clearance	
No.	Direction	X	Y	X	Y	Max.	Min.
7	A						
	B						
8	A						
	B						
9	A						
	B						
10	A						
	B						
11	A						
	B						
12	A						
	B						

REMARK	Approved By	Checked By	Person In Charge

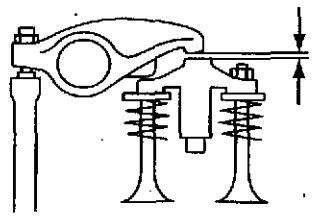
No.9

INSPECTION RECORD SHEET

S	H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Valve Clearance			UNIT	mm [in.]

Measuring Locations



Standard

		Standard
Valve Clearance (A) (When Cold)	Inlet	0.6 [0.024]
	Exhaust	0.8 [0.031]

Measured Value

No.		Valve Clearance		No.		Valve Clearance	
		Inlet	Exhaust			Inlet	Exhaust
1	Before Adjustment			7	Before Adjustment		
	After Adjustment				After Adjustment		
2	Before Adjustment			8	Before Adjustment		
	After Adjustment				After Adjustment		
3	Before Adjustment			9	Before Adjustment		
	After Adjustment				After Adjustment		
4	Before Adjustment			10	Before Adjustment		
	After Adjustment				After Adjustment		
5	Before Adjustment			11	Before Adjustment		
	After Adjustment				After Adjustment		
6	Before Adjustment			12	Before Adjustment		
	After Adjustment				After Adjustment		

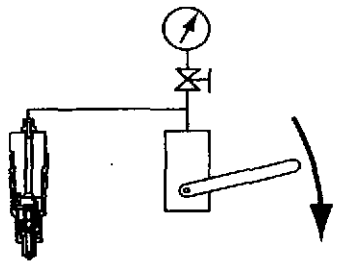
REMARK	Approved By	Checked By	Person In Charge

INSPECTION RECORD SHEET

S	H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Injection Pressure of Unit Injector Nozzle			UNIT	MPa (kgf/cm²) [psi]

Measuring Locations



Standard

	Nominal Value	Standard
Injection Pressure	29.42 (300) [4268]	28.93 to 30.89 (295 to 315) [4196 to 4481]

Measured Value

No.	Injection Pressure Before Adjustment	Service Hours (h)	Injection Pressure After Adjustment	No.	Injection Pressure Before Adjustment	Service Hours (h)	Injection Pressure After Adjustment
1				7			
2				8			
3				9			
4				10			
5				11			
6				12			

REMARK	Approved By	Checked By	Person In Charge

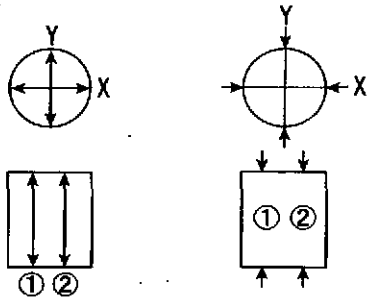
No.11

INSPECTION RECORD SHEET

S H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Camshaft Bushing Inside Diameter and Camshaft Journal Diameter (Right Side)			UNIT	mm [in.]

Measuring Locations



Standard

	Nominal Value	Standard	Limit
Camshaft Bushing Inside Diameter	ϕ100 [3.94]	100.000 to 100.115 [3.94 to 3.945]	100.160 [3.946]
Camshaft Journal Diameter	ϕ100 [3.94]	99.92 to 99.94 [3.937 to 3.938]	99.86 [3.934]

Measured Value

Part's Name		Camshaft Bushing Inside Diameter		Camshaft Journal Diameter		Clearance	
No.	Direction	X	Y	X	Y	Max.	Min.
1	①						
	②						
2	①						
	②						
3	①						
	②						
4	①						
	②						
5	①						
	②						
6	①						
	②						
7	①						
	②						

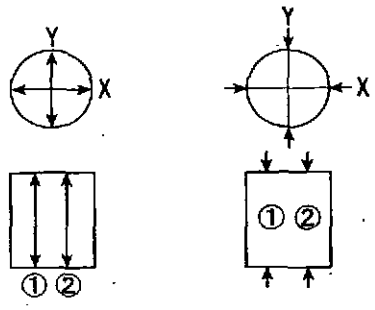
REMARK	Approved By	Checked By	Person In Charge

INSPECTION RECORD SHEET

	S H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Camshaft Bushing Inside Diameter and Camshaft Journal Diameter (Left Side)			UNIT	mm [in.]

Measuring Locations



Standard

	Nominal Value	Standard	Limit
Camshaft Bushing Inside Diameter	ϕ100 [3.94]	100.000 to 100.115 [3.94 to 3.945]	100.160 [3.946]
Camshaft Journal Diameter	ϕ100 [3.94]	99.92 to 99.94 [3.937 to 3.938]	99.86 [3.934]

Measured Value

Part's Name		Camshaft Bushing Inside Diameter		Camshaft Journal Diameter		Clearance	
No.	Direction	X	Y	X	Y	Max.	Min.
1	①						
	②						
2	①						
	②						
3	①						
	②						
4	①						
	②						
5	①						
	②						
6	①						
	②						
7	①						
	②						

REMARK	Approved By	Checked By	Person In Charge

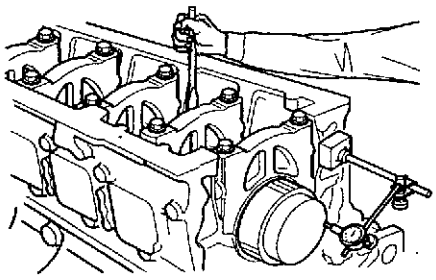
No.13

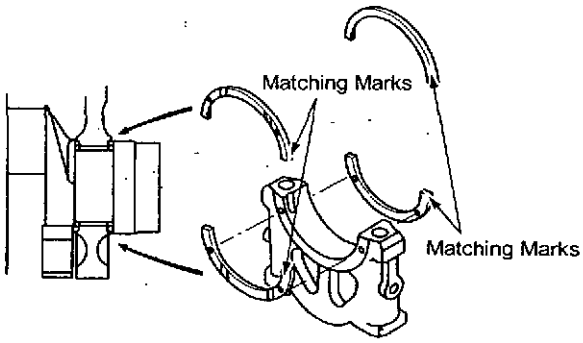
INSPECTION RECORD SHEET

	S H

Company		Engine Model		DATE	
		Serial No.			
Inspection Point	Measurement of Crankshaft End Play			UNIT	mm [in.]

Measuring Locations





Standard

	Standard	Limit
Measurement of Crankshaft End Play	0.20 to 0.40 [0.0079 to 0.0157]	0.50 [0.0197]

Measured Value

During Disassembly	After Reassembly

REMARK	Approved By	Checked By	Person In Charge

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