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SERVICE MANUAL

S12A2-Y2PTAW

for EPA Tier2

Pub. No. 99266-A2100

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MITSUBISHI DIESEL ENGINE

S12A2-Y2PTAW

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MITSUBISHI
HEAVY INDUSTRIES, LTD.

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INTRODUCTION

This service manual describes the specifications and the maintenance and adjustment procedures of the S12A2-Y2PTAW Diesel Engine that has met the exhaust emission regulations of the Environmental Protection Agency (EPA) of the United States.

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

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

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

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How to use this manual

In this service manual, the S12A2-Y2PTAW Diesel Engine specifications, maintenance standards, maintenance standards and adjustment procedure as well as service procedures such as disassembly, inspection, repair and reassembly are arranged in groups for quick reference.
A short summary of each Group is given in the General Contents, and there is also a table of contents at the beginning of each Group.
Regarding engine operation and periodical maintenance, refer to the Operation & Maintenance Manual. For component parts and ordering of service parts, refer to the Parts Catalogue. Structure and function of the engine are described in various training manuals.
There are separate manuals for the fuel injection pump and governor.

CAUTION

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

Methods of presentation

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

DANGER

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

WARNING

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

CAUTION

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

CAUTION

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

Note:

Indicates important information or information useful for operation or maintenance of the engine.

Terms used in this manual

Nominal

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

Standard

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

Limit

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

Abbreviations

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

Units of measurement

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

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

Safety Cautions

⚠ WARNING

Fire and explosion

Keep flames away

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

Keep surrounding area tidy and clean

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

Avoid accessing crankcase until engine cools

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

Care about fuel, oil and exhaust gas leakage

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

Use explosion-proof lighting apparatus

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

Prevent electrical wires from short-circuiting

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

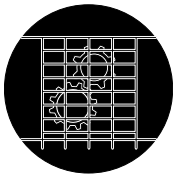
Keep fire extinguishers and first-aid kit handy

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

⚠ WARNING

Stay clear of all rotating and moving parts

Install protective covers on rotating parts



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

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

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

Never remove protective covers.

Ensure safety of neighboring people before starting engine

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

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

Stay clear of moving parts during engine running

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

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

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

Lockout and Tagout

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

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

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

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

Keep engine stopped during servicing

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

Always restore engine turning tools after use

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

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

⚠ WARNING

Be careful of burns

Do not touch the engine during or immediately after operation

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

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

Slowly and carefully open radiator cap

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

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

Close the radiator cap tightly without fail.

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

Add coolant only after the coolant temperature dropped

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

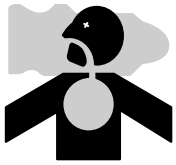
Never remove heat shields

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

⚠ WARNING

Be careful of exhaust fume poisoning

Operate engine in well-ventilated area



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

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

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

⚠ WARNING

Protect ears from noises

Wear ear plugs

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

⚠ WARNING

Be careful of falling down

Lift engine correctly

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

Do not climb onto the engine

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

Establish firm scaffold during work

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

⚠ CAUTION

Be careful of handling fuel, engine oil and LLC

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

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

Handle LLC (long life coolant) carefully

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

Proper disposal of waste oil and coolant (LLC)

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

⚠ CAUTION

Service battery

Handle the battery correctly

- Never use flames or allow sparks to generate near the battery. The battery releases flammable hydrogen gas and oxygen gas. Any flames or sparks in the vicinity could cause an explosion.
- Do not use the battery the fluid level of which is lowered below the lower limit line. Sustained use of the battery could result in an explosion.
- Do not short the battery terminals with a tool or other metal object.
- When disconnecting battery cables, always remove the cable from the negative (-) terminal first. When reconnecting the cables, attach the cable to the positive (+) terminal first.
- Charge the battery in a well-ventilated area, with all filling hole plugs removed.
- Make sure the cable clamps are securely installed on the battery terminals. A loose cable clamp can cause sparks that may result in an explosion.
- Before servicing electrical components or conducting electric welding, set the battery switch to the [Open/OFF] position or disconnect the cable from the negative (-) battery terminal to cut off the electrical current.
- Electrolyte (battery fluid) contains dilute sulfuric acid. Careless handling of the battery can lead to the loss of sight and/or skin burns. Also, keep the battery fluid off the mouth.
- Wear protective goggles and rubber gloves when working with the battery (when adding water, charging, etc.).
- If electrolyte is spilled onto the skin or clothing, immediately wash it away with lots of water. Use soap to thoroughly clean.
- The battery fluid can cause blindness if splashing into eyes. If it gets into eyes, immediately flush it away with plenty of clean fresh water, and seek immediate medical attention.
- If the battery fluid is accidentally swallowed, gargle with plenty of water, then drink lots of water, and seek immediate medical attention.

⚠ CAUTION

When abnormality occurs

Stop overheated engine after cooling run

Even if the engine comes to overheat, do not stop the engine immediately. Abrupt stopping of an overheated engine can cause the coolant temperature to rise, resulting in seized engine parts. If the engine comes to overheat, run the engine at low idling speed (cooling operation), and stop the engine after the coolant temperature lowers sufficiently.

Do not add coolant immediately after stopping the engine. Adding coolant to a hot engine can cause the cylinder heads to crack due to sudden change in temperature. Add coolant little by little after the engine cools down to room temperature.

Avoid immediate restart after abnormal stop

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

Avoid continuous engine operation with too low oil pressure

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

Stop the engine immediately if the fan belt breaks

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

⚠ CAUTION

Other cautions

Modification of engine prohibited

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

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

Never break the seals

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

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

Pre-operational check and periodic inspection/maintenance

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

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

Break-in operation

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

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

Warming-up operation

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

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

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

Avoid engine operations in a overload condition

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

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

Cooling operation before stopping engine

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

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

During cooling operation, check the engine for abnormalities.

Protection of engine against water entry

Do not allow rainwater, etc. to enter the engine through the air inlet or exhaust openings.

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

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

Maintenance of air cleaner or pre-cleaner

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

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

Observe safety rules at work site

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

Do not operate the engine if you are feeling ill.

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

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

Work clothing and protective gear

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

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

Use of tools optimum for each work

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

Avoidance of prolonged time of starter operation

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

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

Do not turn off battery switch during operation

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

Cautionary instructions for transporting engine

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

Avoid continuous engine operation in a low load condition

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

Ventilation of engine room

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

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

Avoid contact with high-pressured fuel

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

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

⚠ CAUTION

About warning labels

Maintenance of warning labels

Make sure all warning/caution labels are legible.

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

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

Replace damaged or fractured labels with new ones.

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

To obtain replacement warning labels, contact a Mitsubishi dealer.

Warning labeles

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GENERAL

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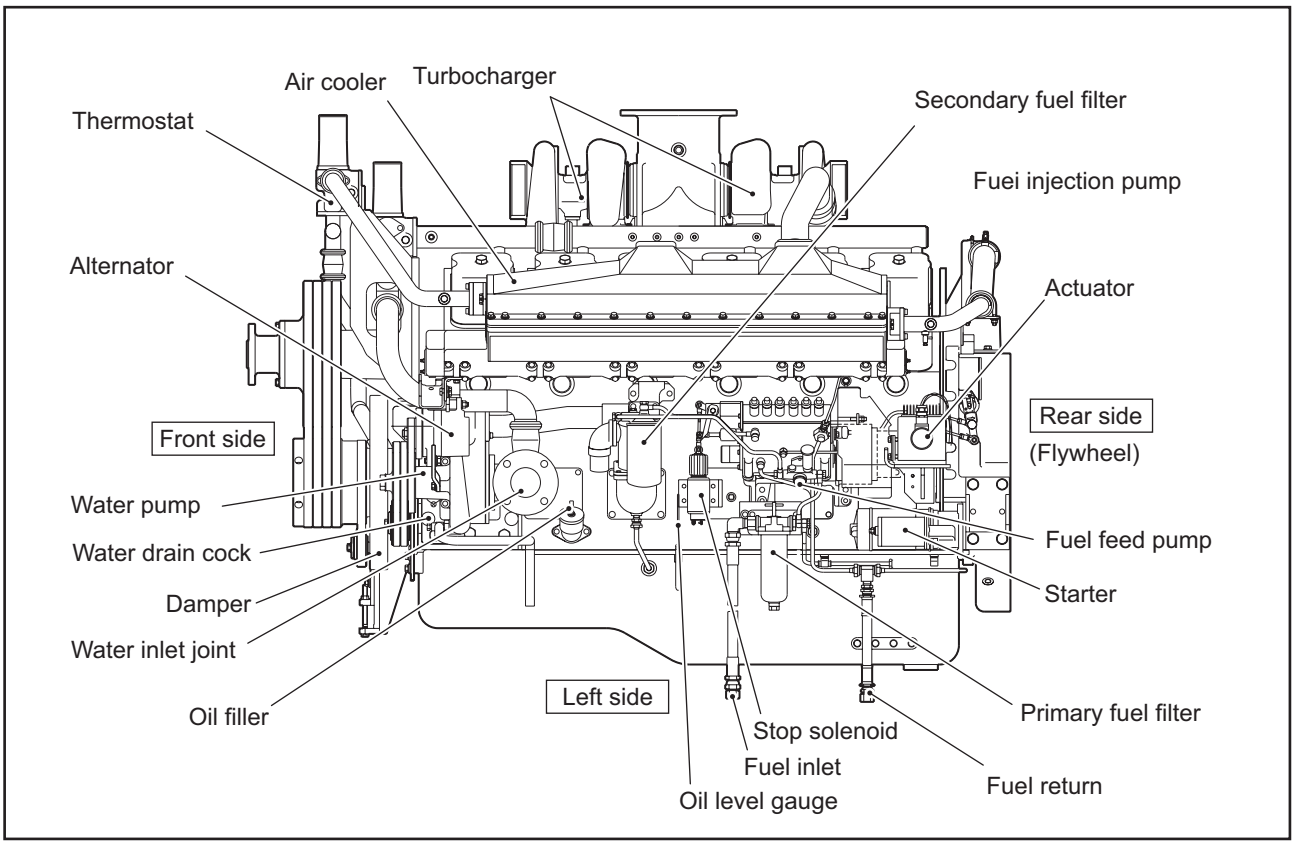
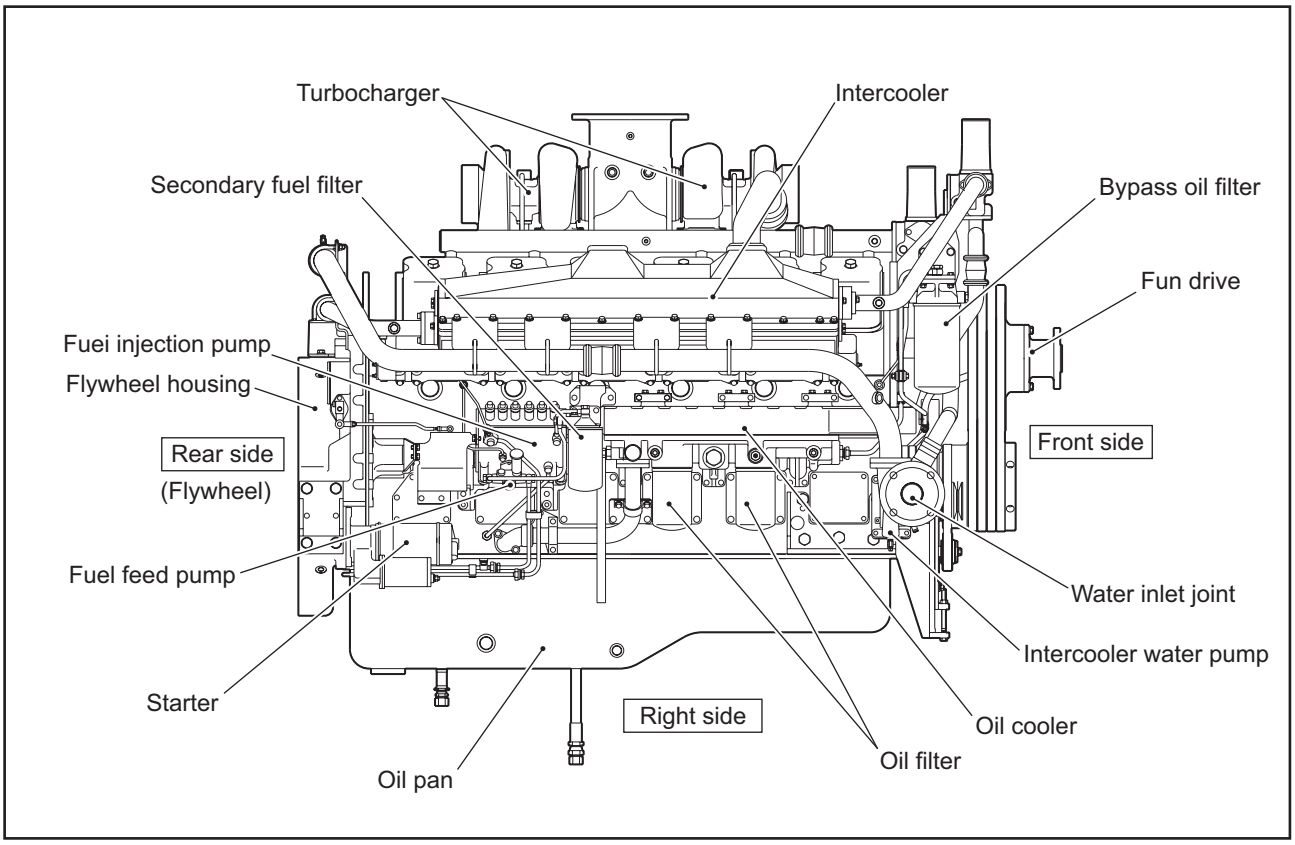
1. External view



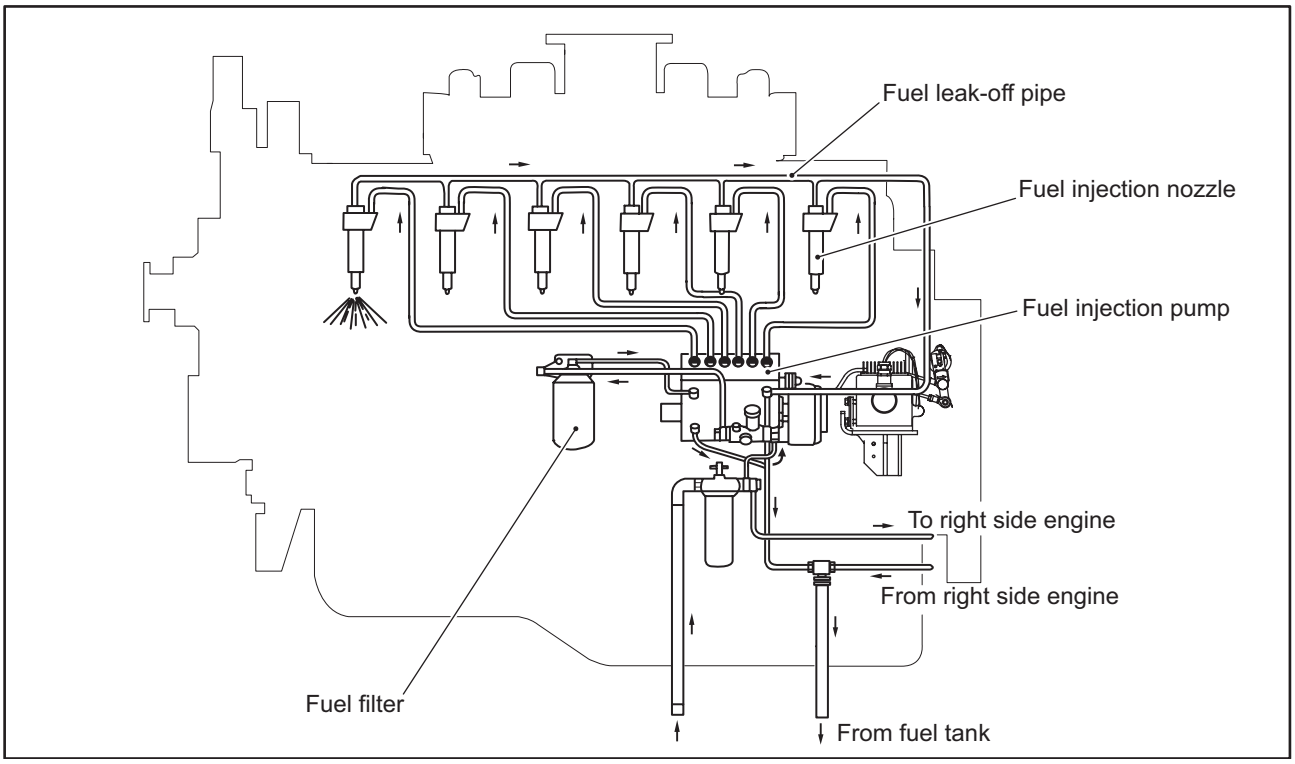
Left side view of the engine



Right side view of the engine

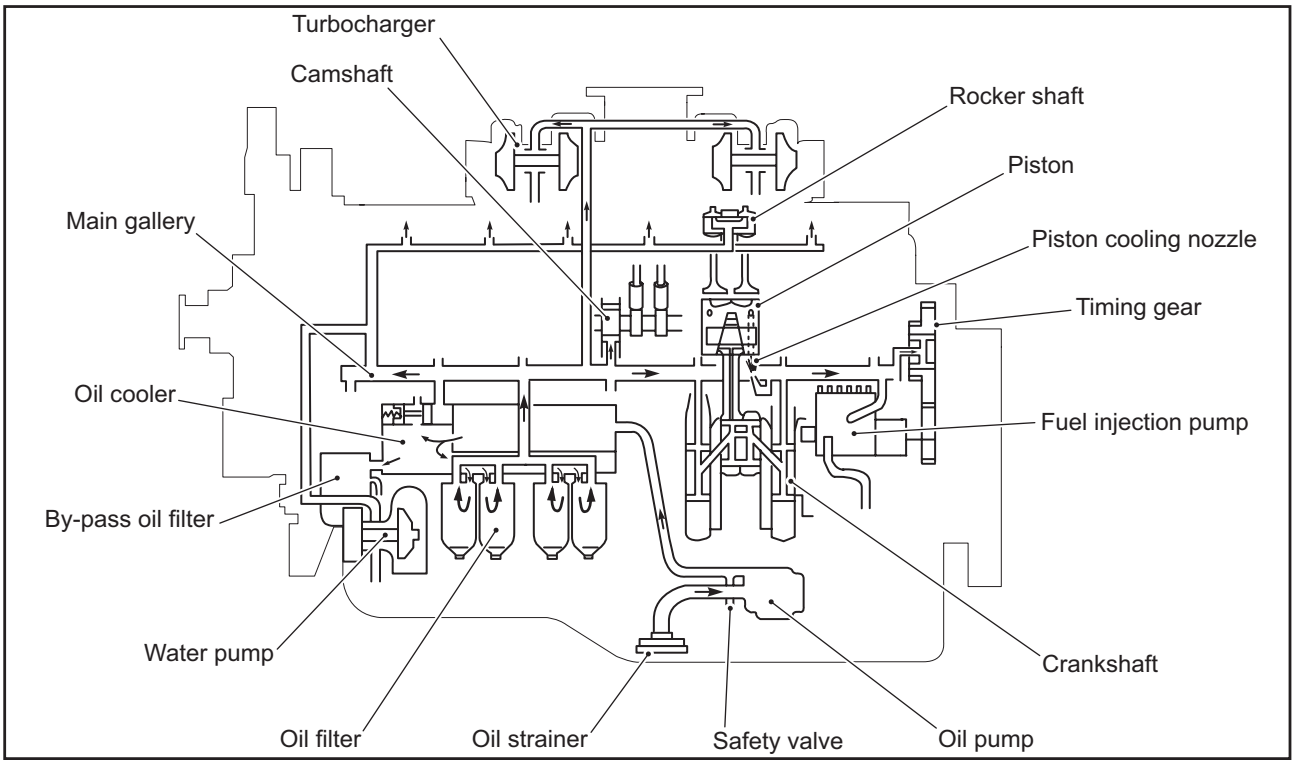
2. System flow diagrams

2.1 Fuel system - flow diagram



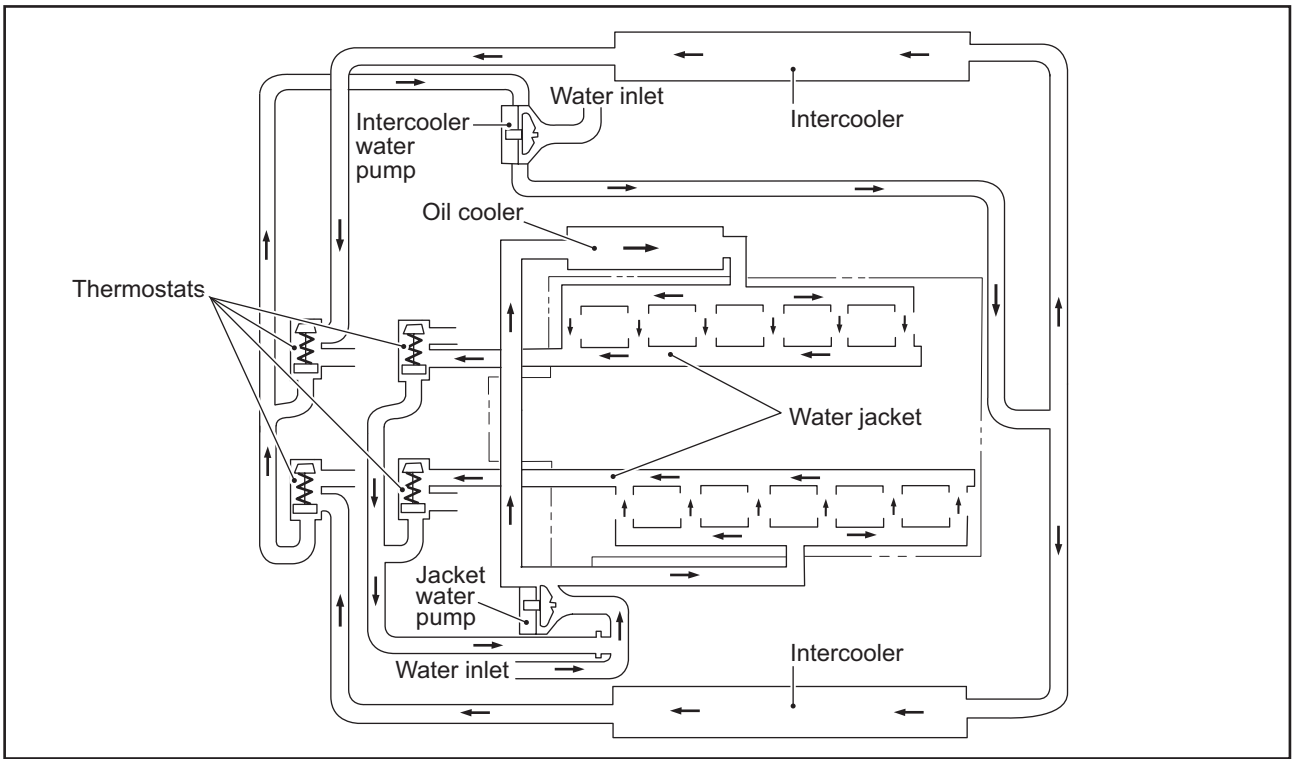
Fuel system - flow diagram

2.2 Lubrication system - flow diagram



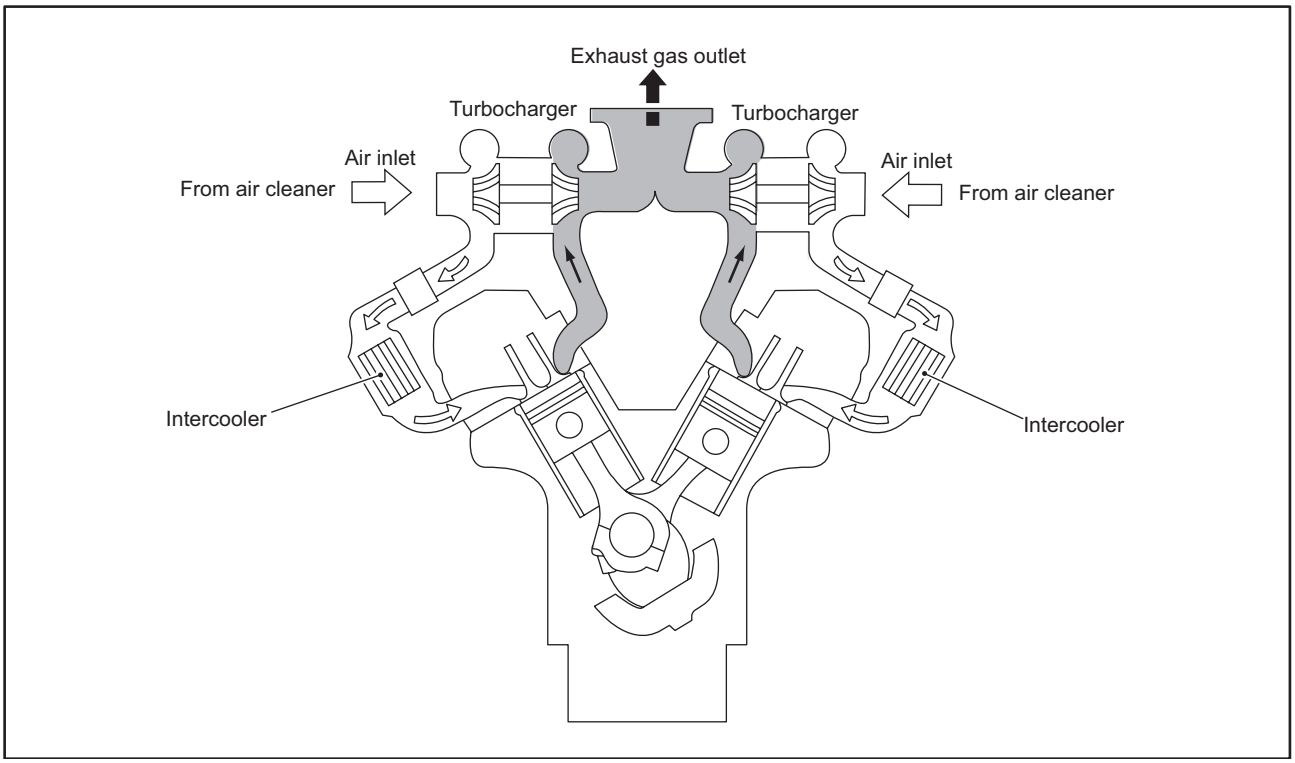
Lubrication system - flow diagram

2.3 Cooling system - flow diagram



Cooling system - flow diagram

2.4 Inlet and exhaust system - flow diagram



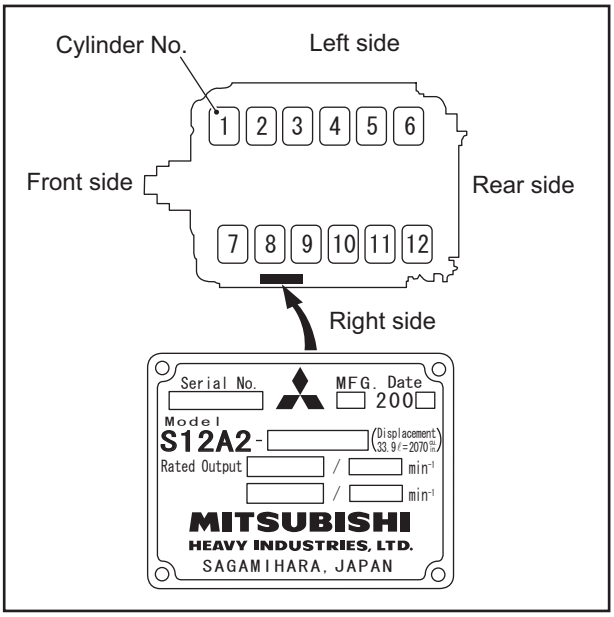
Inlet and exhaust system - flow diagram

3. Engine serial number location

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

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

The numbers shown in the illustration mean the cylinder numbers.



Nameplate location

4. Main specification

Table 1-1 Main specification(1 / 3)

Engine type				S12A2-Y2PTAW
Major specifications	Model			Water-cooled, 4-stroke cycle, turbocharged diesel with air-cooled intercooler
	No. of cylinders - arrangement			12-V
	Combustion type			Direct injection
	Valve mechanism			Overhead
	Cylinder bore × stroke			150 × 160 mm [5.906 × 6.2992 in.]
	Displacement			33.93 L [2070.53 cu in.]
	Compression ratio			15.3 : 1
	Fuel			Diesel fuel (ASTM, D975 No.1-D, No.2-D)
	Firing order			1-12-5-8-3-10-6-7-2-11-4-9
	Rotation of direction			Counterclockwise as viewed from flywheel
	Dimensions (without fan)	Length		2104 mm [82.83 in.]
		Width		1556 mm [61.26 in.]
		Height		1542 mm [60.71 in.]
	Weight (Dry)			3380 kg [7452 lb]
Engine main parts	Cylinder liner	Type		Wet type
	No. of piston rings	Compression rings Oil ring		Compression rings: 2 Oil ring (w/expander): 1
	Valve timing	Inlet valve	Open	BTDC 55°
			Close	ABDC 65°
		Exhaust valve	Open	BBDC 65°
			Close	ATDC 55°
	Engine support method			4 - point support
	Starting system			Electric - starter
Inlet and exhaust system	Turbocharger	Type		TD10
		No. of units		2
Lubrication system	Lubricating method			Forced circulation type (oil pump pressure feed type)
	Engine oil	Specification		Class CD or CF oil (API service classification)
		Capacity		Engine total: 120 L [32 U.S.gal.] approx.
	Oil pump	Type		Gear pump
		Delivery capacity		375 L [99 U.S.gal] / min (at engine speed of 1800 min^{-1})
	Relief valve	Type		Main gallery pressure detection type
		Valve opening pressure		0.49 to 0.69 MPa {5.0 to 7.0 kgf/cm²} [71.3 to 99.58 psi]
	Oil cooler	Type		Water-cooled, multi-plate type
	Oil filter	Type		Cartridge paper-element type, filtration rating 20µn
	Bypass oil filter	Type		Cartridge paper-element type, filtration rating 2µn
	Oil filter alarm	Type		Piston valve type, built-in electric contact points
		Injection pressure		0.22 to 0.26 MPa {2.3 to 2.7 kgf/cm²} [32.72 to 38.41 psi] (Contacting pressure: 0.14 to 0.17 MPa {1.5 to 1.8 kgf/cm²} [21.34 to 25.61 psi])
	Oil cooler bypass valve	Valve opening pressure		0.44 ± 0.05 MPa {4.5 ± 0.5 kgf/cm²} [64 ± 7.1 psi]
	Safety valve	Valve opening pressure		1.42 MPa {14.5 kgf/cm²} [206 psi]

Table 1-1 Main specification(2 / 3)

Engine type			S12A2-Y2PTAW
Cooling system	Cooling method		Water-cooled, forced circulation
	Coolant capacity (engine)		Approx. 86 L [23 U.S.gal]
	Water pump	Type	Centrifugal type
		Delivery capacity	1120 L [296 U.S.gal] / min (at engine speed of 1800 min^{-1})
	Water pump belt	Type	Raw edge cog B belt (NR-1)
		Manufacturer	Mitsuboshi Belting, Ltd.
		Outside circumference	1420 mm [56 in.]
	2-way water pump	Type	Centrifugal type
		Delivery capacity	500 L [132 U.S.gal] / min (at engine speed of 1800 min^{-1})
	2-way water pump belt	Type	Raw edge cog C belt (NR-1)
		Manufacturer	Mitsuboshi Belting, Ltd.
		Outside circumference	1660 mm [65 in.]
	Thermostat (water pump)	Type	Wax type
		Temperature at which valve starts opening	71 ± 2°C [160 ± 3.6°F]
	Thermostat (2-way water pump)	Type	Wax type
		Temperature at which valve starts opening	35 ± 2°C [95 ± 3.6°F]
	Fan belt	Type	Low enge cog C belt (NR-1)
		Manufacturer	Mitsuboshi Belting, Ltd.
		Outside circumference	1710 mm [67 in.]
Fuel system	Injection pump	Model (abbreviation)	NP-PE6P / S7S (S7S)
		Manufacturer	Bosch Corporation
		Plunger outside diameter	13 mm [0.51 in.]
		Plunger lead	Clockwise, 40 lead on both sides
		Cam lift	12 mm [0.47 in.]
	Feed pump	Model	NP-FP / KD-P7S
		Manufacturer	Bosch Corporation
		Cam lift	4 mm [0.157 in.]
	Governor and actuator	Control system	(Electric) Woodward PROACT- Ⅱ
	Injection nozzle	Model	Hole type
		Manufacturer	Bosch Corporation
		No. of spray holes	8
		Spray hole diameter	ø 0.23 mm [0.0091 in.]
		Spray angle	158°
		Valve opening pressure	29.4 MPa {300 kgf/cm^2} [4267 psi]
	Fuel filter		Primary: Wire element type Secondary: Paper element type

Table 1-1 Main specification(3 / 3)

Engine type			S12A2-Y2PTAW
Electrical system	Voltage - polarity		24 V - Negative (-) ground
	Starter	Manufacturer	Nikko Electric Industry Co., Ltd.
		Piston mesh type	Pinion shift
		Output	24 V-7.5 kW
		No. of units	2
	Alternator	Type	3-phase alternating-current generator, built-in IC regulator
		Manufacturer	Mitsubishi Electric Corporation
		Output	24V - 30A
		Rated output generating speed	Hot 5000 min^{-1} or less (at 27V, 30A)
		Regulated voltage	28.5 ± 0.5V
	Magnetic relay (two starters for parallel operation)	Manufacturer	Nikko Electric Industry Co., Ltd
		Nominal voltage	24V
		Rating	30 sec.
		Operating voltage	8 to 24V
		Operating interval (at 24 V)	1 ON - OFF cycle between SS and SW 2.5 to 3.0 sec.
		Allowable temperature	-30 to +80°C [-54 to +144°F]
		Grounding system	2-wire system
	Alternator belt	Type	Low edge cog B belt (NR-1)
		Manufacturer	Mitsuboshi belting, Ltd.
		Outside circumference	830 mm [33 in.]

5. Tips on disassembling and reassembling

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

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

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

CAUTION

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

5.1 Disassembling

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

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

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

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

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

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

5.2 Reassembling

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

(2) Use correct tools and instruments.

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

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

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

CAUTION

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

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

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1. Maintenance service data

1.1 General

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

Inspection point		Nominal	Standard	Limit	Remark
Maximum rotation speed (based on rated rotation speed)			5 to 10 %	15 %	Rated rotation speed is stamped on the nameplate.
Compression pressure (at 120 to 200 min^{-1})			2.35 MPa {24 kgf/cm²} [341 psi] minimum	1.86 MPa {19 kgf/cm²} [270 psi] (lower limit)	When both oil and water temperatures are at 20 to 30°C [68 to 86°F]
Lubricating oil pressure	At rated speed		0.49 to 0.69 MPa {5 to 7 kgf/cm²} [71 to 99 psi]	0.39 MPa {4.0 kgf/cm²} [57 psi] (lower limit)	Oil temperature at 60 to 70°C [140 to 158°F]
	At idling		0.20 to 0.29 MPa {2.0 to 3.0 kgf/cm²} [28 to 43 psi]	0.10 MPa {1.0 kgf/cm²} [14 psi] (lower limit)	
Valve timing	Inlet valve opens		BTDC 11°		With 2 [0.088] clearance held on valve side in cold condition. Values for checking valve timing. Different from actual valve opening and closing timing.
	Inlet valve closed		ABDC 21°		
	Exhaust valve opens		BBDC 21°		
	Exhaust valve closed		ATDC 11°		
Valve clearance	Inlet		0.4 [0.016]		When engine is cold
	Gas, exhaust		0.5 [0.020]		
Ignition timing (before TDC)			± 1° (crank angle)		Varies depending on engine specifications (Indicated on caution plate on No.1 rocker cover)

1.2 Basic engine

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

Inspection point			Nominal	Standard	Limit	Remark
Rocker	Rocker bushing inside diameter		ø 32 [1.26]	32.000 to 32.040 [1.2598 to 1.2614]	32.100 [1.2638]	
	Rocker shaft outside diameter		ø 32 [1.26]	31.975 to 31.991 [1.2589 to 1.2595]	31.950 [1.2579]	
Valve	Valve stem outside diameter	Inlet	ø 10 [0.39]	9.940 to 9.960 [0.3913 to 0.3921]	9.910 [0.3902]	
		Exhaust		9.910 to 9.930 [0.3902 to 0.3909]	9.880 [0.3890]	
	Valve guide inside diameter		ø 10 [0.39]	10.000 to 10.015 [0.3937 to 0.3943]	10.060 [0.3961]	Same for both inlet and exhaust valves

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

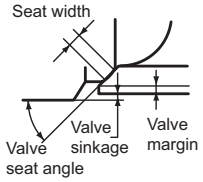
Inspection point			Nominal	Standard	Limit	Remark
Valve seat and valve	Valve seat angle			30°		
	Valve sinkage		0	-0.2 to 0.2 [-0.008 to 0.008]	0.5 [0.020]	
	Seat width	Inlet	2.08 [0.08]	1.93 to 2.23 [0.0760 to 0.0878]	2.5 [0.0984]	
		Exhaust	1.85 [0.07]	1.70 to 2.00 [0.0669 to 0.0787]	2.3 [0.0906]	
	Valve margin	Inlet	2.9 [0.11]	2.7 to 3.1 [0.106 to 0.122]	Up to 2.0 [0.079] when refaced	
		Exhaust	3.0 [0.12]	2.9 to 3.1 [0.114 to 0.122]		
	Clearance between inside diameter of cylinder head bore and outside diameter of valve seat	Inlet	ø 58 [2.28]	-0.070 to -0.130 [-0.0028 to -0.0051]		Minus sign (-) prefixed indicates the interference fit.
		Exhaust	ø 54 [2.13]			
Inlet and exhaust valve springs	Free length			67.5 [2.657]	66.2 [2.606]	
	Perpendicularity			θ = 1.0° or les s Δ = 1.2 [0.047] or less Lf = 67.5 [2.657]	Δ = 1.5 [0.059] over entire length	
	Mounting length/load			60.0 [2.362] / 259 to 286 N {26.41 to 29.16 kgf} [58.2 to 64.3 lbf]		
Pushrod	Runout			0.50 [0.0197] or less		TIR
Cylinder head	Distortion of bottom surface			0.03 [0.0012] or less	0.50 [0.0197]	Slightly reface.
Cylinder liners	Cylinder inside diameter		ø 150 [5.91]	150.000 to 150.040 [5.9055 to 5.9071]	150.140 [5.9110]	
	Circularity			0.02 [0.0008] or less		
	Cylindericity			0.02 [0.0008] or less		
	Perpendicularity of flange bottom surface to cylinder liner longitudinal centerline			0.03 [0.0012] or less		
	Cylinder liner flange protrusion above crankcase top surface			0.10 to 0.19 [0.0039 to 0.0075]		
	Thickness of cylinder liner flange			12.15 to 12.19 [0.4783 to 0.4799]		
	Height of cylinder liner top ridge			0.16 to 0.24 [0.0063 to 0.0094]		

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

Inspection point			Nominal	Standard	Limit	Remark
Piston	Outside diameter (at piston skirt)		ø 150 [5.91]	149.78 to 149.82 [5.8968 to 5.8984]	149.68 [5.8929]	Measured perpendicular to piston pin
	Weight difference in one engine			30 g [1 oz.] or less		
	Piston ring side clearance (with a new ring inserted)	No.1 compression	3.16 [0.12]	0.124 to 0.154 [0.0049 to 0.0061]	0.200 [0.0079]	
		No.2 compression	2.69 [0.11]	0.114 to 0.144 [0.0045 to 0.0057]	0.150 [0.0059]	
		Oil	5.00 [0.20]	0.050 to 0.090 [0.0020 to 0.0035]	0.150 [0.0059]	
	Pin bore diameter		ø 58 [2.28]	58.002 to 58.012 [2.2835 to 2.2839]	58.020 [2.2842]	
	Protrusion			0.38 to 0.89 [0.0150 to 0.0350]		
Cylinder head gasket	Thickness when tightened		1.8 [0.07]	1.7 to 1.9 [0.0669 to 0.0748]		
Pistons and cylinder heads	Clearance between piston and cylinder head			0.81 to 1.43 [0.0319 to 0.0563]		
Piston rings	End gap	No.1 compression		0.6 to 0.8 [0.024 to 0.031]	2.0 [0.079]	If no gauge is available, use a cylinder bore, where appoximate values can be obtained.
		No.2 compression		0.5 to 0.7 [0.0020 to 0.028]	2.0 [0.079]	
		Oil		0.5 to 0.7 [0.0020 to 0.028]	2.0 [0.079]	
Piston pins	Outside diameter		ø 58 [2.28]	57.987 to 58.000 [2.2829 to 2.2835]	57.970 [2.2823]	
Connecting rods	Bushing inside diameter		ø 58 [2.28]	58.020 to 58.040 [2.2842 to 2.2850]	58.070 [2.2862]	
	Bend and twist of connecting rod			0.05/100 [0.0020/3.94] or less		
	End play		54 [2.13]	0.60 to 0.90 [0.0240 to 0.0354]	1.00 [0.0394]	
	Big end bore diameter (measured with rod combined with cap)		ø 110 [4.33]	110.000 to 110.022 [4.3307 to 4.3316]	110.047 [4.3326]	Circularity (Max. dia. − Min. dia.) < 0.100 [0.0039]
Connecting rod bearing	Thickness at center	STD	3.000 [0.1181]	2.987 to 3.000 [0.1176 to 0.1181]	2.950 [0.1161]	Replace bearings before limit is reached. Regrind crankpins and use next undersize bearings if limit is exceeded.
		-0.25 [-0.01]	3.125 [0.1230]	3.112 to 3.125 [0.1225 to 0.1230]	3.075 [0.1211]	
		-0.50 [-0.02]	3.250 [0.1280]	3.237 to 3.250 [0.1274 to 0.1280]	3.200 [0.1260]	
		-0.75 [-0.03]	3.375 [0.1329]	3.362 to 3.375 [0.1324 to 0.1329]	3.325 [0.1310]	
		-1.00 [-0.04]	3.500 [0.1378]	3.487 to 3.500 [0.1373 to 0.1378]	3.450 [0.1358]	
Flywheel	Face runout			0.28 [0.0110] or less		
	Radial runout			0.13 [0.0051] or less		
Damper	Face runout			0.5 [0.020] or less	1.5 [0.059]	Replace with new part every 16000 operation hours.
	Radial runout			0.5 [0.020] or less	1.5 [0.059]	

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

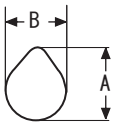
Inspection point				Nominal	Standard	Limit	Remark
Accessory drive	Inside diameter of bearing fitting bore in drive case			ø 72 [2.83]	71.988 to 72.018 [2.8342 to 2.8353]		
				ø 90 [3.54]	89.985 to 90.020 [3.5425 to 3.5435]		
	Bearing	Small	Inside diameter	ø 35 [1.38]	34.985 to 35.003 [1.3774 to 1.3781]		
			Outside diameter	ø 72 [2.83]	71.983 to 72.004 [2.8340 to 2.8348]		
		Large	Inside diameter	ø 40 [1.57]	39.985 to 40.003 [1.5742 to 1.5749]		
			Outside diameter	ø 90 [3.54]	89.980 to 90.005 [3.5425 to 3.5435]		
	Outside diameter of drive shaft bearing journal			ø 35 [1.38]	35.002 to 35.013 [1.3780 to 1.3785]		
				ø 40 [1.57]	40.002 to 40.013 [1.5749 to 1.5753]		
Timing gears	Backlash				0.12 to 0.18 [0.0047 to 0.0071]	0.50 [0.0197]	Replace gears.
	Idler bushing inside diameter			ø 50 [1.97]	50.000 to 50.025 [1.9685 to 1.9695]	50.060 [1.9709]	
	Idler shaft outside diameter			ø 50 [1.97]	49.950 to 49.975 [1.9665 to 1.9675]	49.900 [1.9646]	
	End play of idler gear				0.20 to 0.40 [0.0079 to 0.0157]	0.60 [0.0236]	
Camshaft	Cam lobe height (longer dia. - shorter dia.)			7.60 [0.299]	7.54 to 7.64 [0.2968 to 0.3008]	6.79 [0.2673]	
	Runout				0.10 [0.0039] or less	0.16 [0.0063]	Repair or replace
	Journal outside diameter	No.1 journal		ø 64 [2.52]	63.920 to 63.940 [2.5165 to 2.5173]	63.870 [2.5146]	
		No.2 to No.7 journals		ø 68 [2.68]	67.920 to 67.940 [2.6740 to 2.6748]	67.870 [2.6720]	
	Camshaft bushing inside diameter (as installed in crankcase)	No.1 journal		ø 64 [2.52]	64.000 to 64.030 [2.5197 to 2.5209]	64.090 [2.5232]	
		No.2 to No.7 journals		ø 68 [2.68]	68.000 to 68.030 [2.6772 to 2.6783]	68.090 [2.6807]	
	End play				0.20 to 0.30 [0.0080 to 0.0120]	0.40 [0.0160]	Replace thrust plate.

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

Inspection point			Nominal	Standard	Limit	Remark
Crankshaft	Crankpin outside diameter		ø 104 [4.10]	103.900 to 103.920 [4.0905 to 4.0913]	103.860 [4.0890]	Replace bearings with undersize ones if limit is exceeded.
	Crankshaft journal outside diameter		ø 130 [5.12]	129.880 to 129.900 [5.1134 to 5.1142]	129.840 [5.1118]	
	Distance between centers of journal and crankpin		80 [3.15]	79.000 to 80.100 [3.1102 to 3.1535]		
	Parallelism of journal and crankpin			0.01 [0.0004] or less	0.03 [0.0012]	
	Circularity of journal and crankpin (difference between max. and min. diameters)			0.01 [0.0004] or less	0.03 [0.0012]	Repair
	Out-of-Cylindericity (taper) of journal and crankpin (difference between max. and min. diameters)			0.01 [0.0004] or less	0.03 [0.0012]	
	Fillet radius at journals and crankpins		R7 [0.28]	6.8 to 7.0 [0.2680 to 0.2760]		
	Hardness of crankpins and journals			Hv $>$ 620		
	Finish accuracy			Ra0.2 μ m [0.008 μ in.]		
	Angular deviation between pins			±0.3°		
	Runout			0.08 [0.0031] or less	0.20 [0.0079]	Repair or replace
	End play		58 [2.28]	0.200 to 0.395 [0.0079 to 0.0156]	0.500 [0.0197] +1.18 [+0.0465] when width of crank journal is as rated	Replace thrust plates before limit is reached. If limit is exceeded, use one of following oversize thrust plates; +0.25 [+0.01], +0.50 [+0.02], +0.75 [+0.03]
Main bearing	Thickness at center	STD	3.500 [0.1378]	3.482 to 3.500 [0.1371 to 0.1378]	3.450 [0.1358]	Replace bearings before limit is reached. Regrind crank journals and use next undersize bearings if limit is exceeded.
		-0.25 [-0.01]	3.625 [0.1427]	3.607 to 3.625 [0.1420 to 0.1427]	3.575 [0.1407]	
		-0.50 [-0.02]	3.750 [0.1476]	3.732 to 3.750 [0.1469 to 0.1476]	3.700 [0.1457]	
		-0.75 [-0.03]	3.875 [0.1526]	3.857 to 3.875 [0.1519 to 0.1526]	3.825 [0.1506]	
		-1.00 [-0.04]	4.000 [0.1575]	3.982 to 4.000 [0.1568 to 0.1575]	3.950 [0.1555]	
Crankcase	Depth of counterbore			12.00 to 12.05 [0.4724 to 0.4744]		
	Distortion of top surface			0.05 [0.0020] or less	0.2 [0.0079]	Slightly reface.
	Inside diameter of main bearing fitting bore		ø 137 [5.39]	137.000 to 137.025 [5.3940 to 5.3950]	137.045 [5.3955]	

1.3 Fuel system

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

Inspection point		Nominal	Standard	Limit	Remark
Injection nozzle	Injection starting pressure		29.4 MPa {300 kgf/cm²} [4267 psi]		Limit 29.9 to 30.7 MPa {305 to 313 kgf/cm²} [4337 to 4453 psi]
	Spray cone angle	158°			Hand-operated tester

1.4 Lubrication system

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

Inspection point			Nominal	Standard	Limit	Remark
Oil pump	Backlash	Between oil pump gear and crank-shaft gear		0.120 to 0.180 [0.0047 to 0.0071]	0.50 [0.0197]	
		Between drive gear and driven gear		0.100 to 0.200 [0.0039 to 0.0079]	0.400 [0.0157]	
	Side clearance between gear teeth and case bore			0.150 to 0.230 [0.0059 to 0.0091]	Tip clearance 0.350 [0.0138]	
	End clearance between gear width and case depth			0.130 to 0.200 [0.0051 to 0.0080]	0.250 [0.0098]	
	Gear shaft diameter		ø 34 [1.34]	33.944 to 33.960 [1.3364 to 1.3370]	33.920 [1.3354]	
	Bushing inside diameter			34.000 to 34.025 [1.3386 to 1.3396]	34.055 [1.3410]	
Oil cooler bypass valve	Valve opening pressure			0.44 ± 0.05 MPa {4.5 ± 0.5 kgf/cm²} [64 ± 7 psi]		
Relief valve	Valve opening pressure			0.49 ± 0.69 MPa {5.0 to 7.0 kgf/cm²} [71 ± 100 psi]		
Oil filter alarm	Lamp lighting pressure			0.15 to 0.18 MPa {1.5 to 1.8 kgf/cm²} [21.3 to 25.6 psi]		Oil pressure changes 6.86 kPa {0.07 kgf/cm²} [1.00 psi] with 1 [0.039] shim thickness change.
Safety valve	Spring installation length/load			97 [3.82]/118N {12 kgf} [26.4 lbf]		

1.5 Cooling system

Table 2-5 Maintenance service data table - Cooling system (1 / 2) Unit: mm [in.]

Inspection point				Nominal	Standard	Limit	Remark
Water pump	Inside diameter of bearing fitting bore in case			ø 62 [2.44]	61.988 to 62.018 [2.4405 to 2.4420]		
				ø 72 [2.84]	71.988 to 72.018 [2.8342 to 2.8353]		
	Bearing	Small	Inside diameter	ø 30 [1.18]	29.988 to 30.000 [1.1806 to 1.1811]		
			Outside diameter	ø 62 [2.44]	61.987 to 62.000 [2.4404 to 2.4409]		
		Large	Inside diameter	ø 30 [1.18]	29.988 to 30.000 [1.1806 to 1.1811]		
			Outside diameter	ø 72 [2.84]	71.987 to 72.000 [2.8341 to 2.8346]		
	Outside diameter of shaft bearing journal			ø 30 [1.18]	30.002 to 30.011 [1.1812 to 1.1820]		
	Clearance on impeller front end				0.6 to 1.4 [0.0240 to 0.0551]		
	Clearance on impeller rear end				1.0 [0.0393]		
2-way water pump	Inside diameter of bearing fitting bore in case			ø 62 [2.44]	61.988 to 62.018 [2.4405 to 2.4420]		
	Case bearing bore diameter			ø 68 [2.68]	67.961 to 67.991 [2.6756 to 2.6768]		
	Bearing		Inside diameter	ø 28 [1.10]	27.990 to 28.000 [1.1020 to 1.1024]		
			Outside diameter	ø 68 [2.68]	67.987 to 68.000 [2.6766 to 2.6772]		
	Shaft bearing journal diameter			ø 28 [1.10]	28.002 to 28.015 [1.1024 to 1.1030]		
	Vane front face clearance			0.8 [0.031]	0.5 to 1.1 [0.020 to 0.043]		
Water pump belt tension pully	Inside diameter of pulley in which bearing is fitted			ø 80 [3.15]	79.961 to 79.991 [3.1481 to 3.1492]		
	Bearing		Inside diameter	ø 35 [1.38]	34.988 to 35.000 [1.3775 to 1.3780]		
			Outside diameter	ø 80 [3.15]	79.987 to 80.000 [3.1491 to 3.1496]		
	Outside diameter of shaft on which bearing is fitted			ø35 [1.38]	34.984 to 35.000 [1.3773 to 1.3780]		
2-way water pump belt tension pulley	Inside diameter of pulley in which bearing is fitted			ø 52 [2.05]	51.970 to 51.995 [2.0461 to 2.0470]		
	Bearing		Inside diameter	ø 20 [0.79]	19.988 to 20.000 [0.7869 to 0.7874]		
			Outside diameter	ø 52 [2.05]	52.988 to 52.000 [2.0861 to 2.0472]		
	Shaft bearing journal diameter			ø 20 [0.79]	19.988 to 20.000 [0.7869 to 0.7874]		

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

Inspection point				Nominal	Standard	Limit	Remark
Thermostat	71°C rating	Temperature at which valve starts opening	Primary	71°C [159.8°F]	71 ± 2°C [160 ± 3.6°F]		Check at atmospheric pressure
			Secondary	74°C [165.2°F]	74 ± 2°C [160 ± 3.6°F]		
		Temperature at which valve lift is 10 [0.39] or more			85°C [185°F]		
	35°C rating	Temperature at which valve starts opening	Primary	35°C [95°F]	35 ± 2°C [95 ± 3.6°F]		Check at atmospheric pressure
			Secondary	38°C [100°F]	38 ± 2°C [100 ± 3.6°F]		
		Temperature at which valve lift is 10 [0.39] or more			50°C [122°F]		
Fan drive	Bearing bore diameter			ø 100 [3.94]	99.987 to 100.022 [3.9365 to 3.9379]		
				ø 110 [4.33]	109.987 to 110.022 [4.3302 to 4.3316]		
	Bearing	Small	Inside diameter	ø 45 [1.77]	44.988 to 45.000 [1.7712 to 1.7717]		
			Outside diameter	ø 100 [3.94]	99.985 to 100.000 [3.9364 to 3.9370]		
		Large	Inside diameter	ø 40 [1.57]	39.988 to 40.000 [1.5743 to 1.5748]		
			Outside diameter	ø 110 [4.33]	109.985 to 110.000 [4.3301 to 4.3307]		
	Shaft bearing journal diameter			ø 40 [1.57]	40.002 to 40.013 [1.5749 to 1.5753]		
				ø 45 [1.77]	45.002 to 45.013 [1.1717 to 1.7722]		

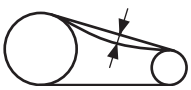
1.6 Inlet and exhaust system

Table 2-6 Maintenance service data table - Inlet and exhaust system Unit: mm [in.]

Inspection point			Nominal	Standard	Limit	Remark
Turbocharger	Inside diameter of bearing-fitted section of housing				30.006 [1.1813]	
	Bearing	Outside diameter			29.876 [1.1762]	
		Inside diameter			18.050 [0.7106]	
		Length			17.440 [0.6866]	
	Shaft & turbine wheel	Journal diameter			17.996 [0.7085]	
		Shaft deflection			0.015 [0.0006]	
	Piston ring end gap				0.05 to 0.25 [0.0020 to 0.0098]	Piston ring fitted in insert
	Shaft & turbine wheel and turbine housing clearance			0.29 to 0.91 [0.0114 to 0.0358]		
	Shaft & turbine wheel in the axial direction play			0.075 to 0.135 [0.0030 to 0.0053]		
	Turbine backplate and back side of the shaft & turbine wheel clearance			0.65 to 1.25 [0.0256 to 0.0492]		

1.7 Electrical system

Table 2-7 Maintenance service data table - Electrical system Unit: mm [in.]

Inspection point				Nominal	Standard	Limit	Remark
Starter	Commutator	Diameter		ø 43 [1.69]		ø 42 [1.65]	
		Runout			0.06 [0.0024] less or	0.10 [0.0039]	
		Mica depth			0.7 to 0.9 [0.028 to 0.035]	0.2 [0.008]	
	Height of brush				22 to 23 [0.87 to 0.91]	13.5 [0.53]	
	Tension of brush springs			44.13 N (4.5 kgf) [9.9 lbf]	39.23 to 49.03 N (4.0 to 5.0 kgf) [8.8 to 11.0 lbf]	39.23 N (4.0 kgf) [8.81 lbf]	
	Armature	Diameter of shaft front side		ø 20 [0.79]	20.002 to 20.011 [0.7875 to 0.7878]		Replace armature.
		Diameter of shaft rear side		ø 14 [0.55]	13.941 to 13.968 [0.5489 to 0.5499]		
		Shaft runout			0.05 [0.0024]		1/2 value of runout
	Pinion shaft	Shaft diameteron rear side		ø 30 [1.18]	30.002 to 30.011 [1.1812 to 1.18120]		
		Shaft diameteron front side		ø 19 [0.75]	18.900 to 18.940 [0.7441 to 0.7457]		
	Armature end play				0.2 to 0.6 [0.008 to 0.024]		
	Measurement of pinion shaft end play				0.2 to 0.8 [0.008 to 0.031]		
Alternator	Output char-acteristics	Rotating speed	1500 min^{-1}		104A or more		
			2500 min^{-1}		154A or more		
			5000 min^{-1}		143A or more (when hot)		
	Regulated voltage(Alternator 5000 min^{-1}, load 5A or more)				28.5 ± 0.5V		
	Field coil resistance (at 20°C [68°F])				3.8 to 4.5 Ω		
	Brush length				23 [0.91]	8 [0.32]	
	Alternator drive belt tension				10 to 15 [0.39 to 0.59]		When pressed with thumb as shown in the right diagram. 98 to147 N {10 to 15 kgf} [22 to 33 lbf]) 

2. Tightening torque table

2.1 Major bolt tightening torque

2.1.1 Basic engine

Table 2-8 Tightening torque list - Basic engine

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Cylinder head	M20 × 2.5	392 ± 20	40 ± 2.0	289 ± 14.5	[Wet] 2-step tightening method (Note a)
Rocker cover	M12 × 1.25	13 to 17	1.3 to 1.7	9 to 12	
Rocker shaft bracket	M12 × 1.75	49 ± 2.5	5 ± 0.25	36 ± 1.8	
Rocker arm (lock nuts)	M12 × 1.25	64 ± 6.4	6.5 ± 0.65	47 ± 4.7	
Bridge (lock nuts)	M10 × 1.25	55 ± 5.5	5.6 ± 0.56	41 ± 4.1	
Camshaft gear (lock nut)	M30 × 1.5	294 ± 15	30 ± 1.5	217 ± 10.8	Left-hand threads
Main bearing caps (Note b)	M24 × 3.0	588 ± 29.4	60 ± 3.0	434 ± 21.7	[Wet] (Note b)
Main bearing cap (side bolts)	M16 × 2.0	147 ± 7.4	15 ± 0.75	108 ± 5.4	[Wet] (Note b)
Piston cooling nozzle	M12 × 1.75	34 ± 3.4	3.5 ± 0.35	25.3 ± 2.53	(Note c)
Timing gear case	M12 × 1.75	98 ± 4.9	10 ± 0.5	72 ± 3.6	
	M16 × 1.5	255 ± 12.8	26 ± 1.3	188 ± 9.4	
Rear plate	M12 × 1.25	98 ± 4.9	10 ± 0.5	72.3 ± 3.6	
Oil pan	M10 × 1.5	39 ± 3.9	4 ± 0.4	29 ± 2.9	
Front mounting bracket	M20 × 1.5	392 ± 20	40 ± 2.0	289 ± 14.5	
Rear mounting bracket	M18 × 2.5	245 ± 12	25 ± 1.3	181 ± 9.4	
Flywheel	M22 × 1.5	539 ± 27	55 ± 2.8	398 ± 20.3	[Wet]
Damper and crankshaft pulley	M22 × 1.5	539 ± 25	55 ± 2.5	398 ± 18	[Wet]
Idler gear	M10 × 1.25	39 ± 3.9	4 ± 0.4	29 ± 2.9	
Idler shaft	M12 × 1.75	54 ± 2.7	5.5 ± 0.28	39.8 ± 2.03	
Injection pump gear (nut)	M30 × 1.5	294 ± 15	30 ± 1.5	217 ± 10.8	

Connecting rod bearing caps

Torque method (2-step tightening method)	Angle method (2-step tightening method)
343 ± 17 N·m {35 ± 1.8 kgf·m} [253 ± 13 lbf·ft]	Snug torque 147 ± 7.4 N·m {15 ± 0.75 kgf·m} [108 ± 5.41 lbf·ft] → 45 ± 3°

Note: (a) To tighten cylinder head bolts according to the angle method, follow the sequence described below.
1.Tighten to snug torque of 118 ± 5.9 N·m {12 ± 0.6 kgf·m} [87 ± 4.3 lbf·ft] (short bolt) or 196 ± 9.8 N·m {20 ± 1.0 kgf·m} [145 ± 7.2 lbf·ft] (long bolt).
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.
1.Tighten the main bearing cap bolts to the specified torque.
2.Tighten the side bolts on the right side of the engine to the specified torque.
3.Tighten the side bolts on the left side of the engine to the specified torque.

(c) To tighten piston cooling nozzles to the specified torque, be sure to use a torque wrench. Tightening without the use of a torque wrench could result in excessive tightening force, and this could cause check valve malfunctions and lead to seizing of pistons due to insufficient supply of lubricating oil during engine operation.

(d) When [Wet] is indicated, apply engine oil to the threads and bearing surfaces of the bolts and nuts.

2.1.2 Inlet and exhaust system

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

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Exhaust manifold	M10 × 1.5	59 to 69	6 to 7	43 to 50	
Turbocharger compressor wheel (nut)	M9 × 1	-	-	-	Note left-handedthread
Turbocharger V-clamp	M6-1/4 UNF	7.8 to 9.8	0.8 to 1.0	5.8 to 7.2	

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

2.1.3 Fuel system

Table 2-10 Tightening torque list - Fuel system

Description		Threads Dia × Pitch (mm)	Torque			Remark
			N·m	kgf·m	lbf·ft	
Fuel injection pump bracket		M10 × 1.5	58 ± 5.8	5.9 ± 0.59	43 ± 4.3	
Fuel injection pump		M10 × 1.5	58 ± 2.9	5.9 ± 0.3	43 ± 2.2	
Drive side coupling		M12 × 1.25	83 to 93	8.5 to 9.5	61.5 to 68.7	Tightening slit area
Laminated plate		M12 × 1.75	83 to 93	8.5 to 9.5	61.5 to 68.7	
Fuel rack control lever		M8 × 1.25	25 ± 2.5	2.5 ± 0.25	18.1 ± 1.8	2-step tightening method
Fuel feed pump inlet		M14 × 1.5	25 to 29	2.5 to 3.0	18.1 to 21.7	
Fuel injection nozzle retaining nut		M19 × 0.75	59 to 78	6 to 8	43 to 58	
Fuel injection nozzle inlet connector		M14 × 1.5	69 to 79	7 to 8	51 to 58	
Fuel injection nozzle connector		M10 × 1.0	29 to 39	3 to 4	22 to 29	
Fuel injection nozzle holder eyebolt		M10 × 1.0	15 to 20	1.5 to 2	11 to 14	
Fuel injection nozzle gland (nut)		M12 × 1.25	59 ± 2.9	6 ± 0.3	43 ± 2.2	
Fuel filter air priming plug		M8 × 1.25	8 to 10	0.8 to 1.0	6 to 7	
Fuel injection pump stay	Install of fuel injection pump	M14 × 1.5	34 ± 3.4	3.5 ± 0.35	25 ± 2.5	
	Install of crankcase	M10 × 1.5	58 ± 5.8	5.9 ± 0.59	43 ± 4.3	
	Connect to stay	M12 × 1.25	108 ± 11	11 ± 1.1	80 ± 8.0	

2.1.4 Lubrication system

Table 2-11 Tightening torque list - Lubrication system

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Oil pump gear (nut)	M27 × 1.5	294 ± 15	30 ± 1.5	217 ± 11	

2.1.5 Cooling system

Table 2-12 Tightening torque list - Cooling system

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Water pump impeller	M22 × 1.5	196 ± 20	20 ± 2.0	114.7 ± 14.5	
Water pump pulley	M24 × 1.5	245 ± 25	25 ± 2.5	181 ± 18.4	
2-way water pump pulley (nut)	M20 × 1.5	112 ± 4.9	11.5 ± 0.5	83 ± 3.6	
Water pump tension pulley (thrust plate)	M12 × 1.25	98	10	72	Jacket water pump side
Water pump tension pulley (thrust plate)	M12 × 1.25	98	10	72	2-way water pump side

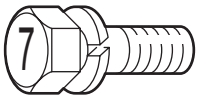
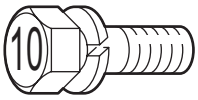
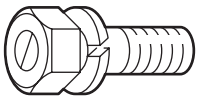
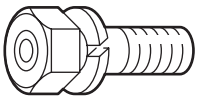
2.1.6 Electrical system

Table 2-13 Tightening torque list - Electrical system

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Starter B terminal	M10 × 1.25	19.6 to 25.5	2.0 to 2.6	14.5 to 18.8	
Alternator pulley (nut)	M20 × 1.5	132 to 162	13.5 to 16.5	97.6 to 119.3	

2.2 Standard bolt and nut tightening torque

Table 2-14 Standard bolt and nut tightening torque

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

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

2.3 Standard eyebolt tightening torque

Table 2-15 Standard eyebolt tightening torque

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

(Dry)

2.4 Standard union nut tightening torque

Table 2-16 Standard union nut tightening torque

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

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

2.5 High-pressure fuel injection pipe tightening torque

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

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

(Dry)

SERVICE TOOLS

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

1. Special tools

Table 3-1 Special tools (1 / 5)

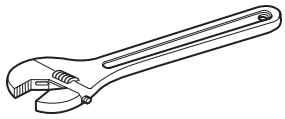
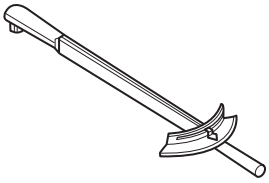
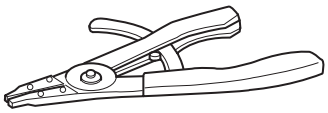
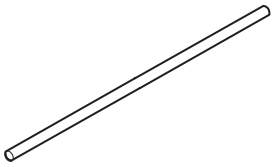
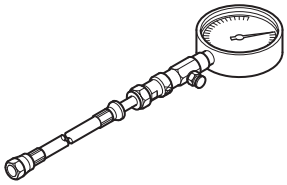
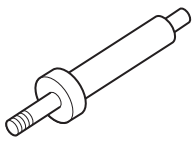
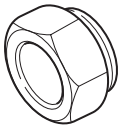
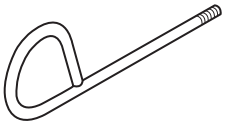
Maintenance item	Tool name/Part No.	Shape	Use
General	Adjustable wrench F9611-15000		Max. open width: 20mm [0.79 in.]
	Torque wrench 32191-03100		Range applicable: 0 to 539 N·m {0 to 55 kgf·m} [0 to 398 lbf·ft]
	Ring pliers 45191-08400		Snap ring removal/installation
	Turning bar 37191-03100		Engine turning
Inspection for overhaul need, and testing	Compression gauge 35A91-03100		Compression pressure measurement
	Gauge adapter 36291-02200		Compression pressure measurement U5/8, Thread: 18
	Connector 32061-31700		Compression pressure testing
	Screw pin 32061-31800		Overspeed testing

Table 3-1 Special tools (2 / 5)

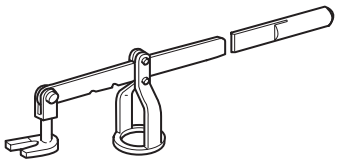
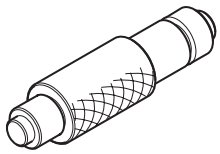
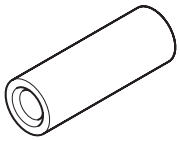
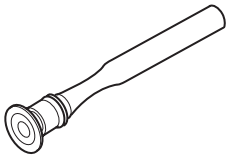
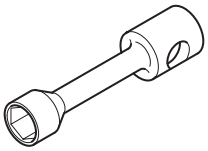
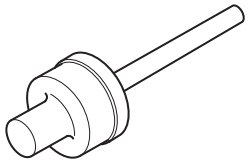
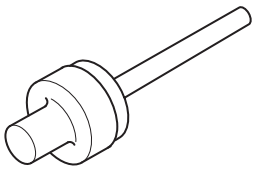
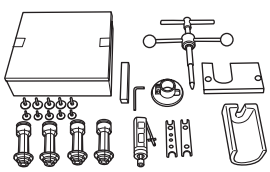
Maintenance item	Tool name/Part No.	Shape	Use
Cylinder head and valve mechanism	Valve spring pusher 33591-04500		Inlet, exhaust, prechamber gas valve spring removal/installation Length of handle plate: 600mm [23.6 in.]
	Rocker bushing puller 32591-02600		Rocker busing replacement
	Guide & seal installer 32591-10300		Valve guide and stem seal installation
	Valve lapper 30091-08800		Valve lapping
	Socket wrench 32591-01100		Cylinder head bolt removal/installation
	Inlet valve seat caulking tool 35A91-05010		Inlet valve seat installation
	Exhaust valve seat caulking tool 35A91-05020		Exhaust valve seat installation
	Valve seat puller 32591-04200		Valve seat removal

Table 3-1 Special tools (3 / 5)

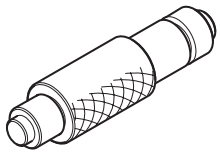
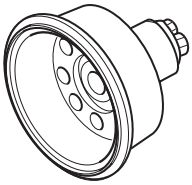
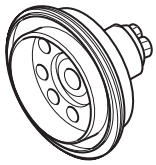
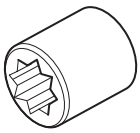
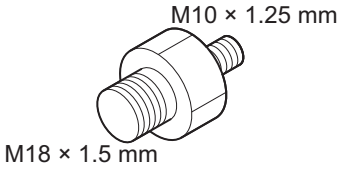
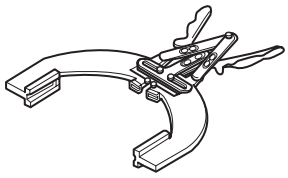
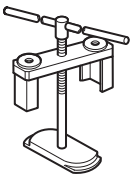
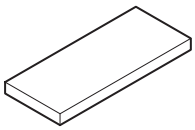
Maintenance item	Tool name/Part No.	Shape	Use
Front cover, flywheel and camshaft	Idler bushing puller 32591-02500		Idler bushing replacement
	Front seal installer assembly 32691-00042		Front oil seal insert
	Rear seal installer assembly 32591-07012		Rear oil seal insert
	Socket 32591-02800		Camshaft connector removal/installation
Crankcase	Adapter 32591-04300		Main bearing cap removal
Cylinder liner, piston, connecting rod	Ring expander 37191-03200		Piston ring removal/installation
	Cylinder liner remover 32591-04100		Cylinder liner removal
	Projection plate 37598-09201		Crankcase liner bore counter boring

Table 3-1 Special tools (4 / 5)

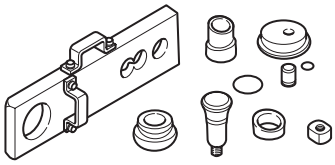
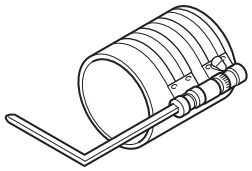
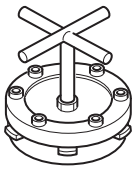
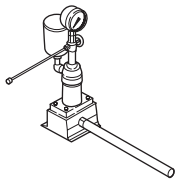
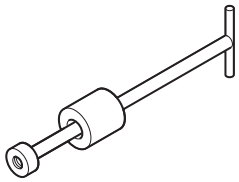
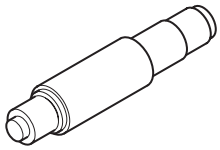
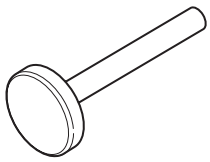
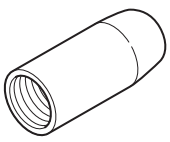
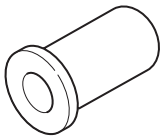
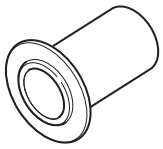
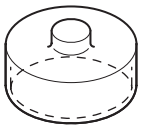
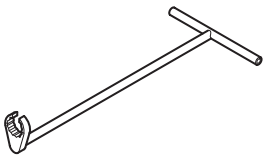
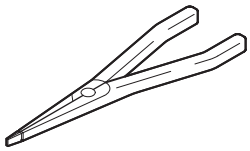
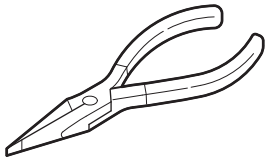
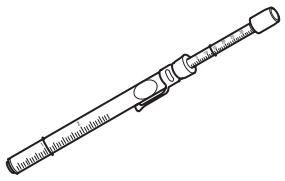
Maintenance item	Tool name/Part No.	Shape	Use
Cylinder liner, piston, connecting rod	Connecting rod bushing installer 32591-18010		Connecting rod bushing replacement
	Piston installer 37191-07100		Piston installation
	Crankcase grinder 32591-04050		Cylinder liner support ridge of crankcase adjustment
Fuel injection nozzle	Nozzle tester 04239-00050		Injection nozzle opening pressure measurement
	Nozzle remover 36291-00900		Injection nozzle removal
Oil pump	Oil pump bishing puller 32691-02700		Oil pump bushing installation/ removal
Water pump	Oil seal installer 32591-03200		Water pump oil seal installation
	Thread cover 37191-06600		Water pump shaft installation

Table 3-1 Special tools (5 / 5)

Maintenance item	Tool name/Part No.	Shape	Use
Water pump	Bearing installer 32591-03600		Water pump bearing installation
	Oil seal installer 32591-03100		Water pump seal installation
	Unit seal installer		Water pump unit seal ring installation
	Wrench 32691-01200		Water pump oil drain pipe installation/removal
Turbocharger	Plyer 49160-90101		Snap ring (49162-23200) installation/removal
	Plyer 49160-90201		Snap ring (49181-22300) installation/removal
Alternator	V-belt gauge 32591-09100		V-belt deflection measurement

DETERMINATION OF OVERHAUL

1. Determining overhaul timing 4-2

2. Testing compression pressure 4-3

1. Determining overhaul timing

CAUTION

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

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

In most cases, the engine should be overhauled when the compression pressure of the engine becomes low. An increase in engine oil consumption and blow-by gas are also considered to evaluate the engine condition. Besides, such symptoms as a decrease in output, increase in fuel consumption, decrease in oil pressure, difficulty of engine starting and increase in noise are also considered for judging the overhaul timing, although those symptoms are often affected by other causes, and are not always effective to judge the overhaul timing. Decreased compression pressure shows a variety of symptoms and engine conditions, thus making it difficult to accurately determine when the engine needs an overhaul. The following shows typical problems caused by reduced compression pressure.

(1) Decreased output power
(2) Increased fuel consumption
(3) Increased engine oil consumption
(4) Increased blow-by gas through the breather due to worn cylinder liners and piston rings (Visually check the blow-by amount)
(5) Increased gas leakage due to poor seating of inlet and exhaust valves
(6) Difficulty in starting
(7) Increased noise from engine parts
(8) Abnormal exhaust color after warm-up operation

The engine can exhibit these conditions in various combinations. Some of these problems are directly caused by worn engine parts, while others are not. Phenomena described in items (2) and (6) will result from improper fuel injection volume, fuel injection timing, worn plunger, faulty nozzles and also faulty conditions of electrical devices such as battery and starter. The most valid reason to overhaul an engine is a decrease in compression pressure due to worn cylinder liners and pistons, as described in item (4). In addition to this item, it is reasonable to take other problems into consideration for making the total judgment.

2. Testing compression pressure

CAUTION

(a) Measure all cylinders for compression pressure. Do not measure only one cylinder and make assumption about the other cylinders as it will lead to a wrong conclusion.

(b) Compression pressure varies depending on the engine speed. When measuring the compression pressure, be sure to measure the engine speed as well.

(c) It is important to regularly check the compression pressure so that you can tell the change with time.

(1) Disconnect the main harness from the relay connector.

(2) Disconnect the high pressure pump solenoid connector from the high pressure pump solenoid sensor.

(3) Select a cylinder, and remove the injector in the cylinder. (Each cylinder is tested one at a time.)

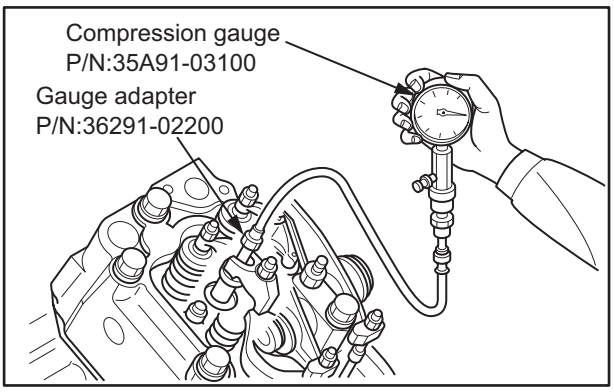
(4) Install a gauge adapter in the same location that the injector was mounted, and install a compression gauge to the gauge adapter.

(5) Start the engine using starter. With the engine running at specified speed, read the compression gauge.

(6) If the measured value is at the limit or below, overhaul the engine.

Item	Standard	Limit
Compression pressure	2.35 MPa {24 kgf/cm²} [341 psi] or more	1.86 MPa {19 kgf/cm²} [270 psi] or more

Note: Measure the compression pressure with the engine running at 120 to 200 min^{-1}.



Testing compression pressure

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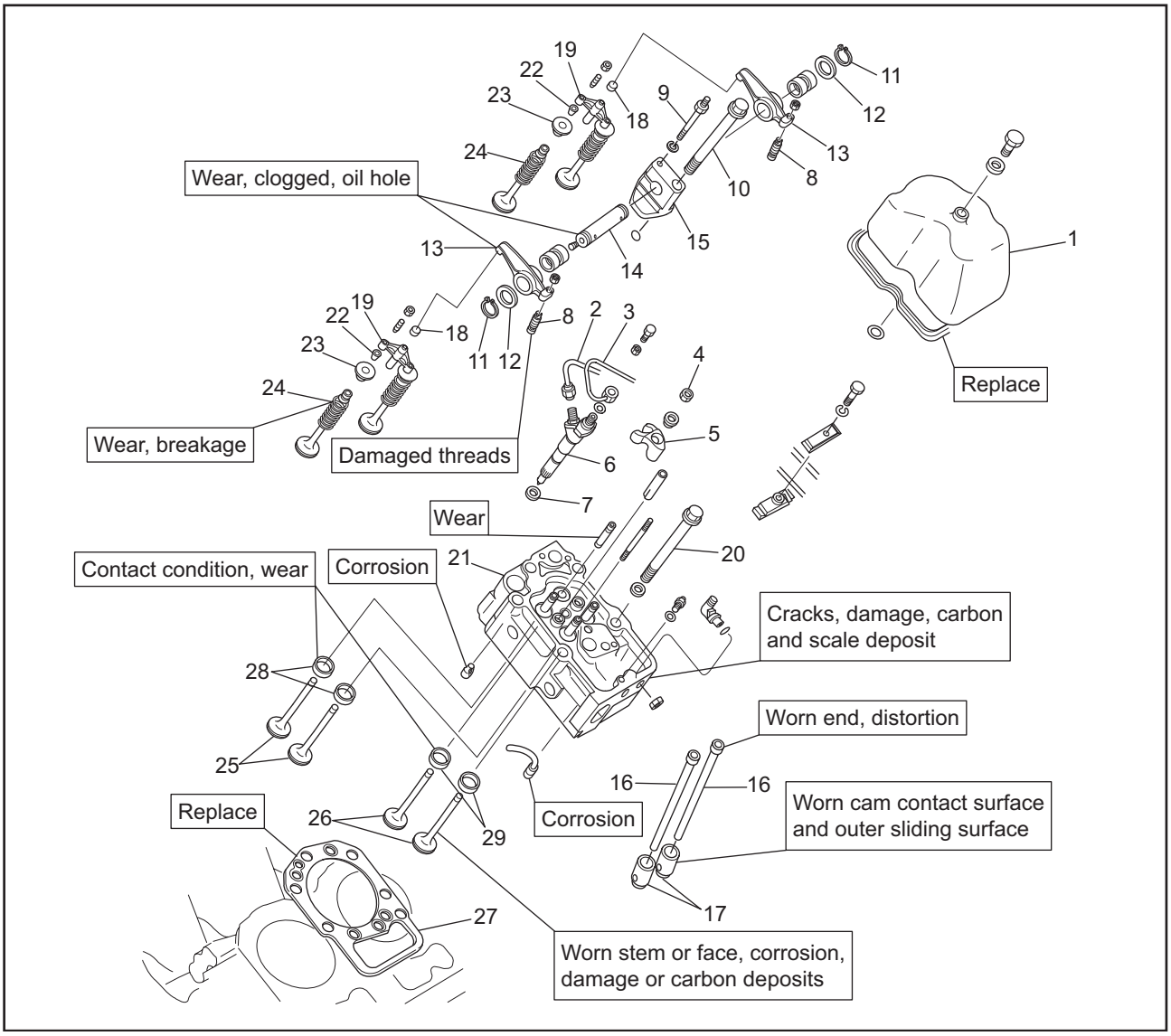
1. Disassembling and inspecting cylinder heads and valve mechanism



Disassembling and inspecting cylinder heads and valve mechanism

Disassembling sequence

1	Rocker cover	11	Snap ring	21	Cylinder head (weight: approx. 29 kg [64 lb])
2	Fuel injection pipe	12	Washer	22	Valve cotter
3	Fuel leak-off pipe	13	Rocker	23	Valve rotator
4	Nut and washer	14	Rocker shaft	24	Valve spring
5	Nozzle gland	15	Rocker shaft bracket	25	Inlet valve
6	Injection nozzle assembly	16	Pushrod	26	Exhaust valve
7	Gasket	17	Tappet	27	Cylinder head gasket
8	Adjusting screw	18	Bridge cap	28	Inlet valve seat
9	Bolt	19	Valve bridge	29	Exhaust valve seat
10	Cylinder head bolt (long)	20	Cylinder head bolt (short)		

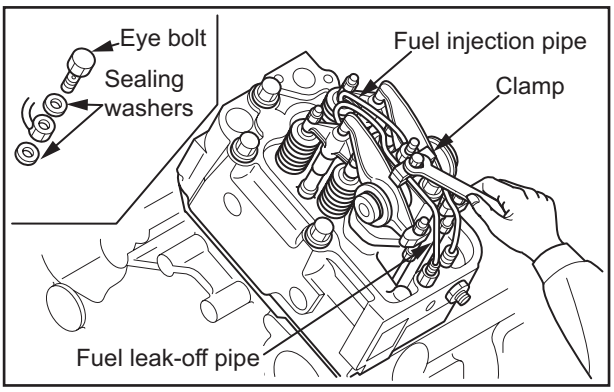
CAUTION

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

1.1 Removing fuel injection pipes

(1) Remove the clamp, and disconnect the fuel injection pipe.

(2) Remove the eye bolt of the fuel injection nozzle to disconnect the fuel injection pipe. In doing so, remove the sealing washers and keep them together to avoid the risk of losing.



Removing fuel injection pipe

1.2 Removing fuel injection nozzle

⚠ CAUTION

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

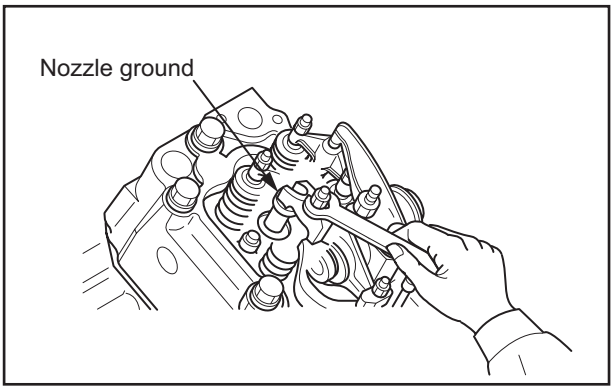
CAUTION

Wipe dust off the nozzle assembly, and prevent dust from entering the cylinder head when the nozzle holder is removed. Keep the nozzle and the fuel pipe together, and handle the nozzle with care to avoid damage to the nozzle tip.

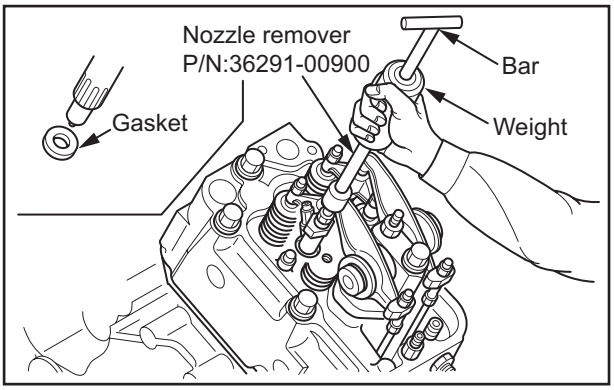
(1) Remove the nozzle gland.

(2) Using the nozzle remover, pull out the nozzle holder.

(3) Remove the remaining gasket from inside the cylinder head.



Removing nozzle ground



Removing fuel injection nozzle

1.3 Removing rocker shaft assembly

⚠ CAUTION

Always loosen shorter bolts first. Failing to do so may cause the damage to the rocker shaft bracket.

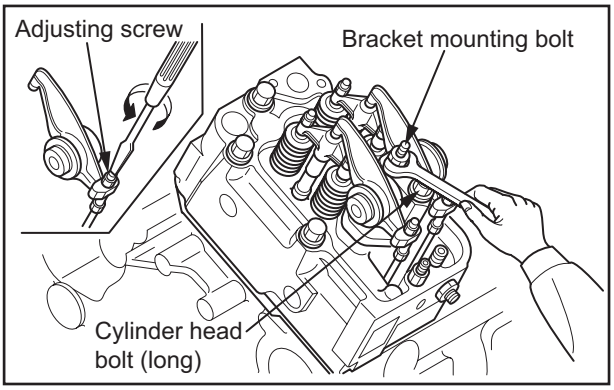
(1) Loosen the rocker arm adjusting screws by rotating about one turn.

(2) Loosen the shorter rocker bracket bolts first.

(3) Then, loosen the longer rocker bracket bolts.

(4) Remove the rokcer bracket bolts, and remove the rocker shaft assembly from the cylinder head.

(5) Remove push rods.



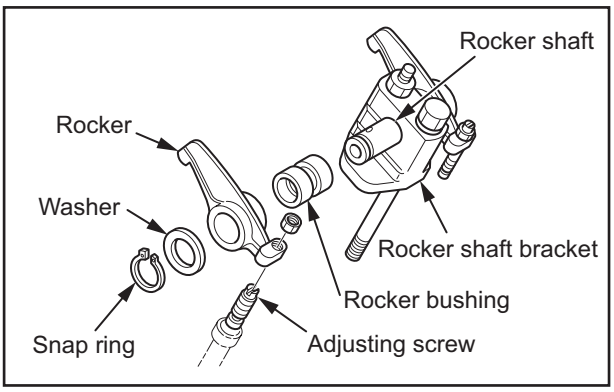
Removing rocker assembly and pushrod

1.4 Removing rocker shaft assembly

(1) Loosen the rocker arm adjusting screw by about one turn.

(2) Loosen the rocker stay bolts and remove the rocker shaft assembly.

Note: When removing the rocker shaft assembly, remove it together with the rocker stay bolts, and keep them together for reassembling.

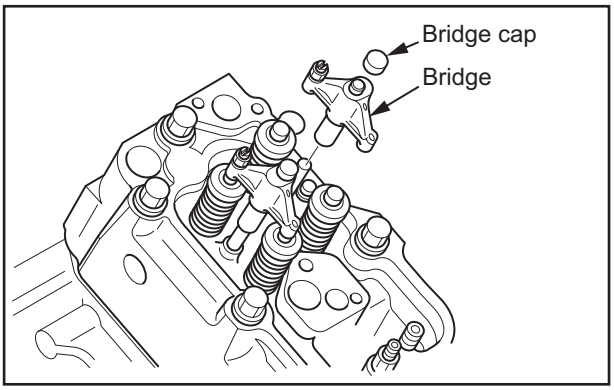


Removing rocker shaft assembly

1.5 Removing valve bridge

Remove the valve bridge and bridge cap.

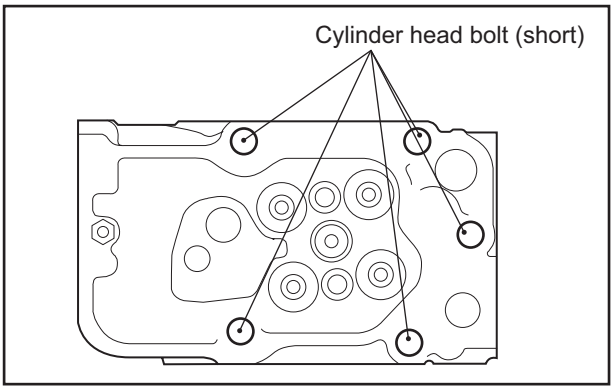
Note: Be careful not to drop bridge caps into the crankcase through the pushrod holes.



Removing valve bridge

1.6 Removing cylinder head bolt

Remove the cylinder head bolt (short).



Removing cylinder head bolt

1.7 Removing cylinder head assemblies

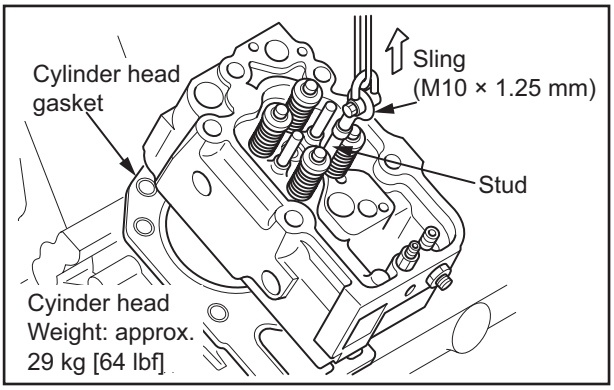
CAUTION

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

(1) Attach a sling to the nozzle holder tightening stud of the cylinder head.

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

(3) Remove the cylinder head gasket.

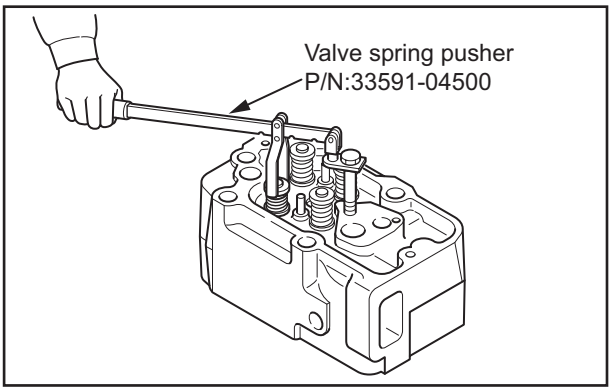


Removing cylinder head assembly

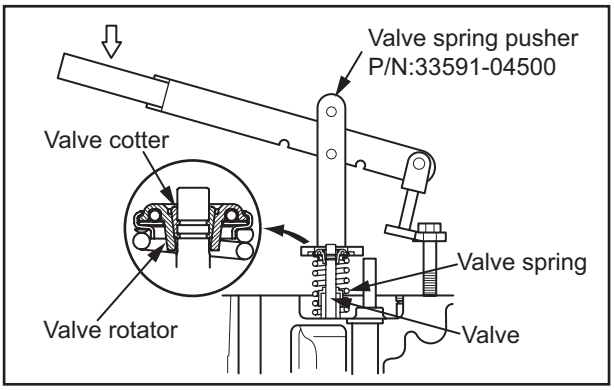
1.8 Removing valve and valve spring

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

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



Removing valve and valve spring (1)

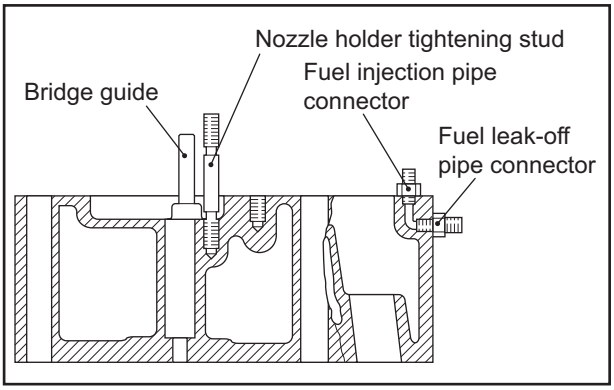


Removing valve and valve spring (2)

1.9 Removing stud and guide

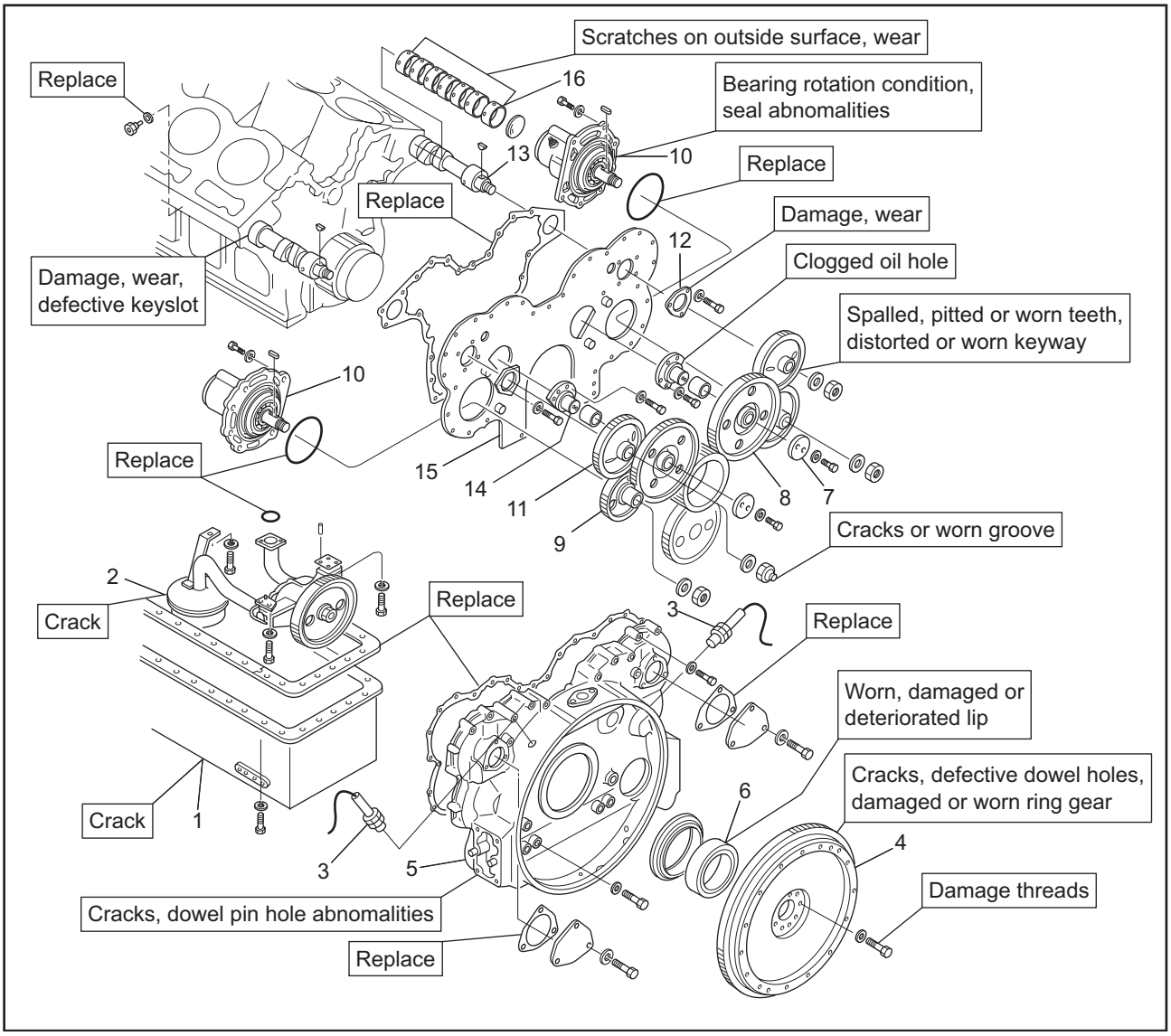
Do not remove the following parts from the cylinder head unless it is necessary. If any of these parts are removed, apply thread lock agent to the threads in the bolt holes, and install new parts.

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



Removing stud and connector

2. Disassembling and inspecting flywheel, timing gears and camshafts



Disassembling and inspecting flywheel, timing gears and camshafts

Disassembling sequence

1 Oil pan
2 Oil strainer, oil pipe and oil pump
3 Pickup
4 Flywheel (weight: approx. 83 kg [183 lb])
5 Timing gear case (weight: approx. 110 kg [243 lb])
6 Oil seal
7 Thrust plate
8 Idler gear
9 Injection pump gear
10 Accessory drive (See the "Fuel System" section for disassembly, inspection and reassembly.)
11 Camshaft gear
12 Thrust plate
13 Camshaft (weight: approx. 25 kg [55 lb])
14 Idler shaft
15 Rear plate
16 Camshaft bushing

CAUTION

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

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

2.1 Removing flywheel

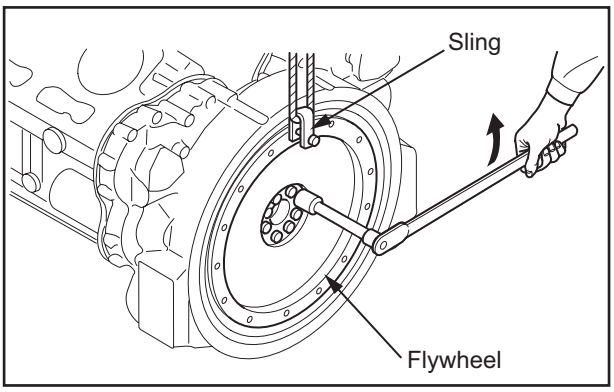
⚠ CAUTION

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

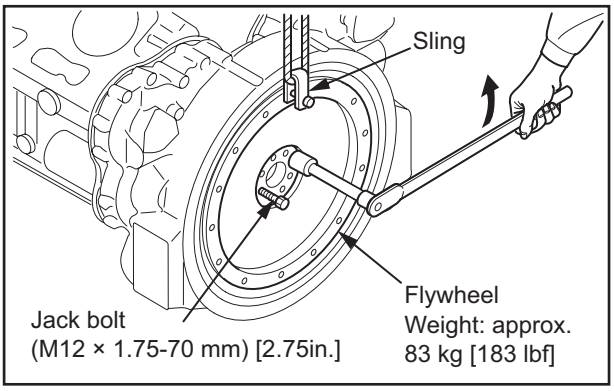
CAUTION

(a) Be sure to remove the pickups before removing the flywheel.
(b) Use jack bolts with convex and round ends. Do not use jack bolts with sharp edge, as they may cause damage to the surface of crankshaft.

(1) Attach a lifting sling to the flywheel to prevent from falling out.
(2) Remove the flywheel mounting bolts.
(3) Screw two jack bolts evenly into bolt holes, and remove the flywheel.



Removing flywheel (1)



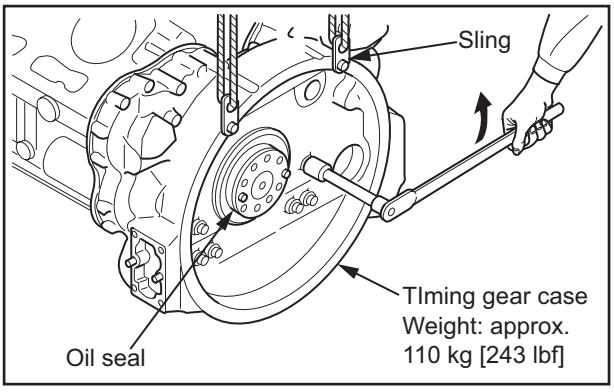
Removing flywheel (2)

2.2 Removing timing gear case

⚠ CAUTION

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

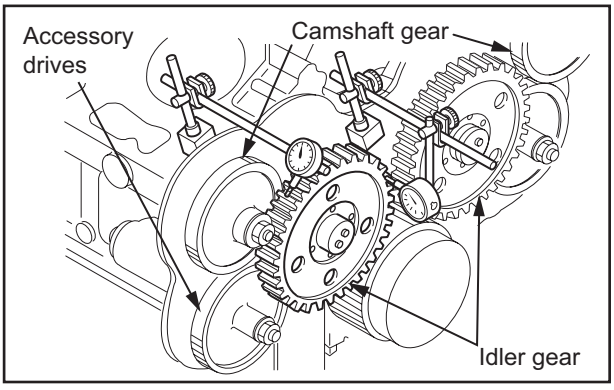
(1) Attach a lifting sling to the timing gear case to prevent it from falling out.
(2) Remove the timing gear case mounting bolts.
(3) While lifting and supporting the timing gear case, remove the timing gear case by sliding it out until the gear case is disengaged from the dowel pins. Be careful not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



Removing timing gear case

2.3 Measuring timing gear backlash and end play

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

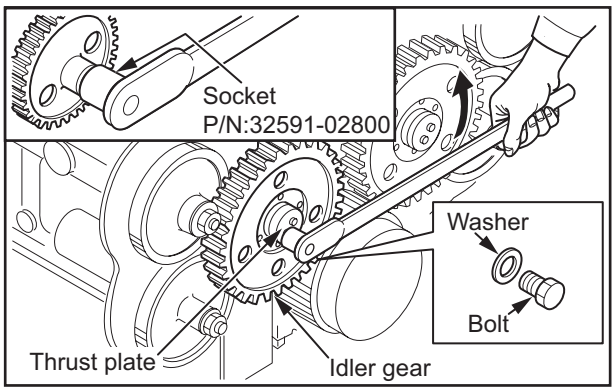


Measuring timing gear backlash end play

2.4 Removing idler gears

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

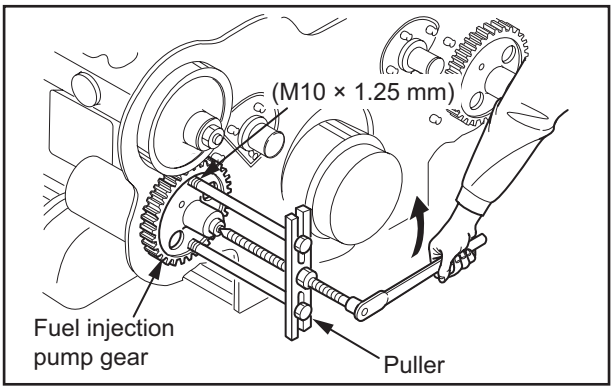
Note: When removing the bolts, take care not to lose the washers.



Removing idler gears

2.5 Removing fuel injection pump gear

Remove the mounting nut, and with a puller inserted into threaded holes of fuel injection gear, remove the fuel injection pump gear.

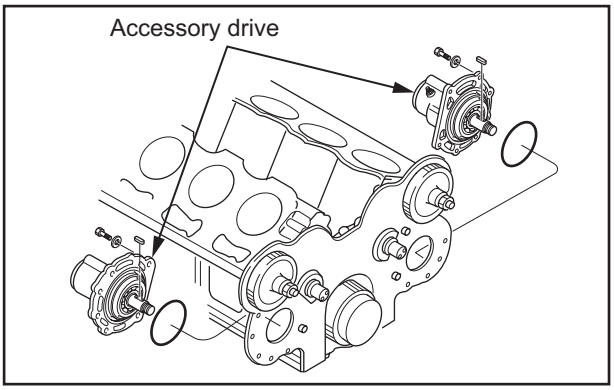


Removing fuel injection pump gear

2.6 Removing accessory drives

Unscrew the accessory drive mounting bolts, and dismount the accessory drive from the rear plate. Be careful not to damage the gear teeth.

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



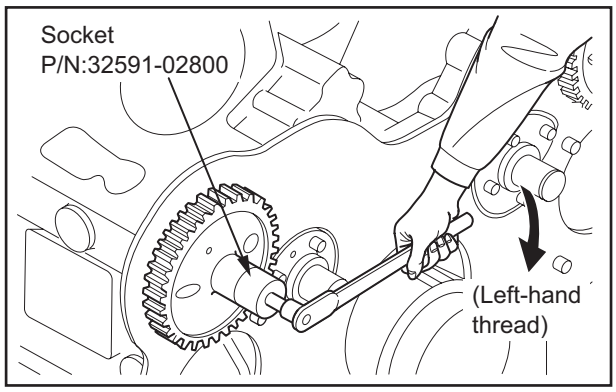
Removing accessory drives

2.7 Removing camshaft gear

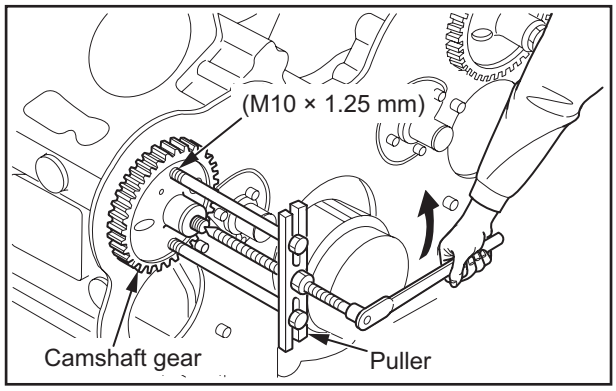
CAUTION

The camshaft gear mounting nuts are left-hand threaded. Be sure to turn them clockwise to loosen them.

(1) Using the socket remove the nuts (left-hand threads).
(2) Remove the camshaft gear with the puller using the threads in the gear.



Removing camshaft gears (1)



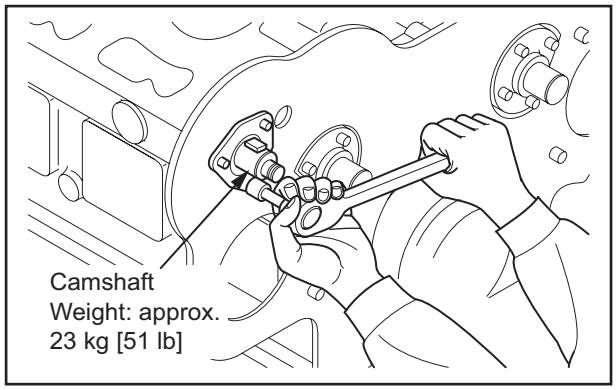
Removing camshaft gears (2)

2.8 Removing camshafts

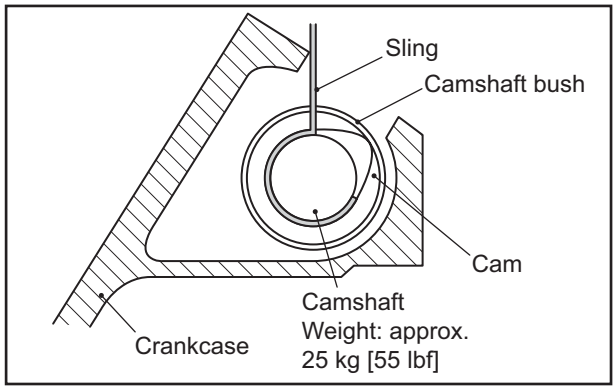
CAUTION

When removing the camshaft, be careful not to damage the camshaft cam and bushing.

(1) Unscrew the thrust plate mounting bolts, and dismount the thrust plate.
(2) Support the camshaft with a sling from the top of the crankcase, and remove the camshaft from the crankcase.



Removing camshafts (1)



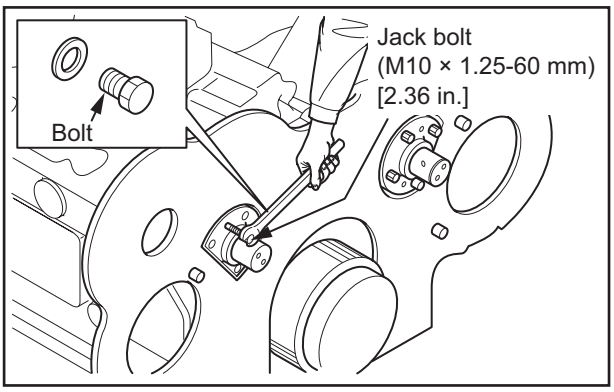
Removing camshafts (2)

2.9 Removing idler shafts

CAUTION

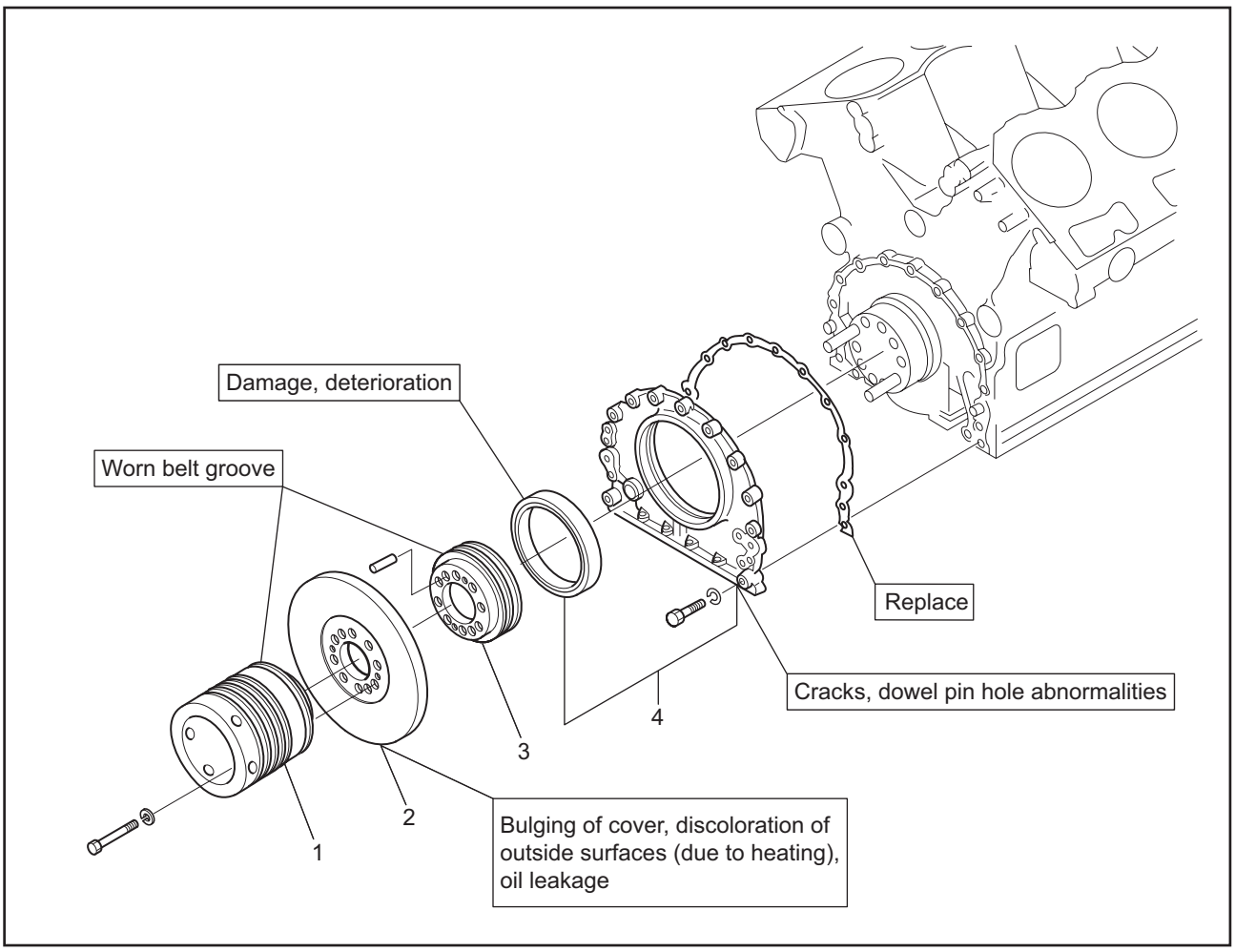
Use jack bolts with convex and round end. Do not use jack bolts with sharp edge, as they could cause damage to the surface of crankcase.

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



Removing idler shafts

3. Disassembling and inspecting damper and front cover



Disassembling and inspecting damper and front cover

Disassembling sequence

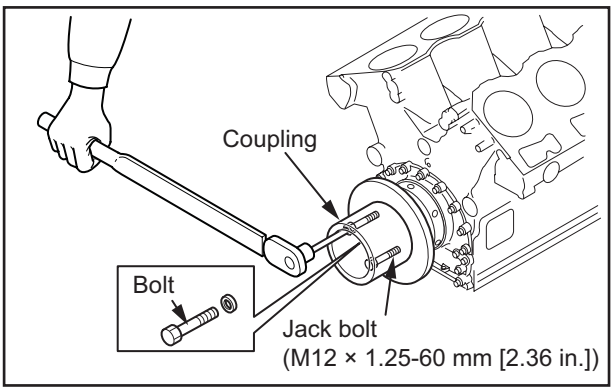
1 Coupling
2 Damper (weight: approx. 56 kg [123 lb])
3 Crankshaft pulley
4 Front cover, oil seal

3.1 Removing fan pulley

CAUTION

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

Remove the coupling mounting bolts, evenly in the holes for removing the fan pulley. Using the jack bolts, remove the coupling.



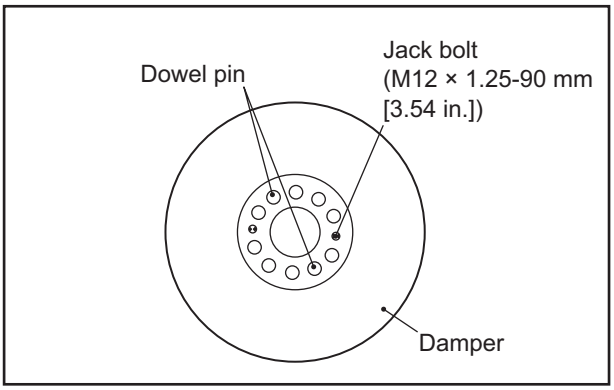
Removing fan pulley

3.2 Removing damper

CAUTION

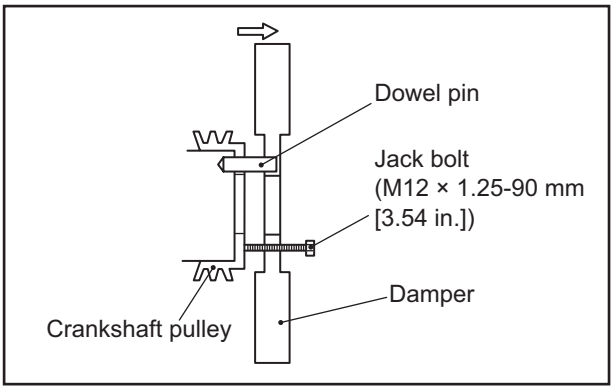
Use jack bolts with convex and round end. Do not use jack bolts with sharp edge, as they could cause damage to the surface of crankshaft pulley.

(1) Screw the set bolts evenly in the damper (front) pullout holes, and pull out the damper (front) to such a degree that it does not come off the dowel pins.



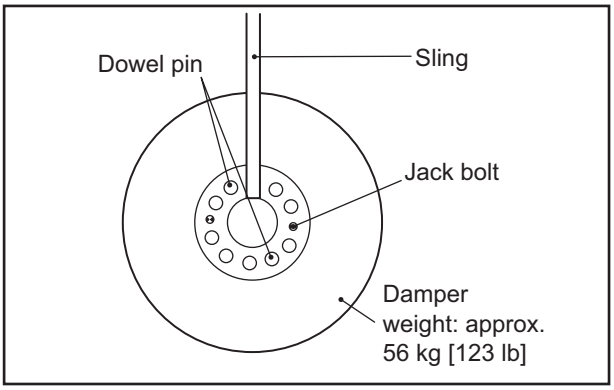
Removing damper (1)

(2) Pass the hanging strap through the center hole in the damper (front). Using the hanging strap, suspend the damper (front) with a crane or the like.



Removing damper (2)

(3) Screw in the damper (front) jack bolts further and remove the damper (front) held in suspension.



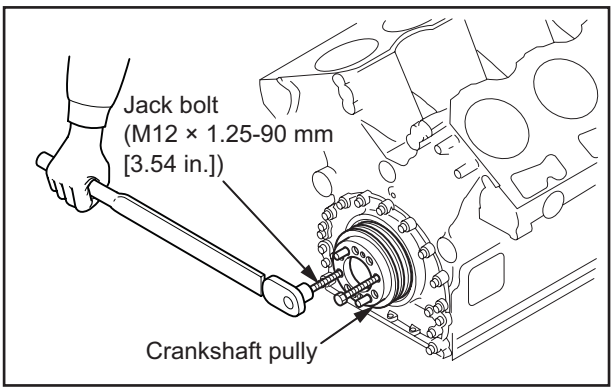
Removing damper (3)

3.3 Removing crankshaft pulley

CAUTION

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

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



Removing crankshaft pulley

3.4 Removing front cover

CAUTION

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

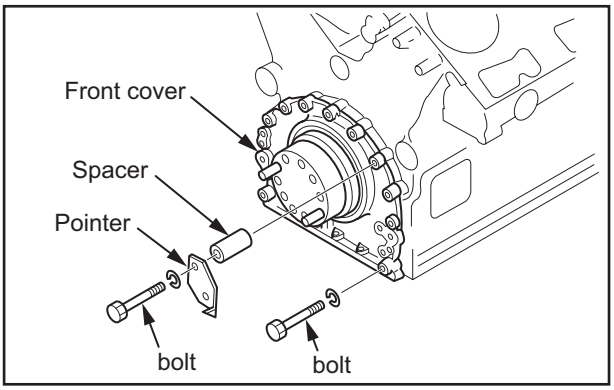
When removing the front cover, take care not to damage the lip surface of the oil seal.

(1) Remove the pointer and spacer from the front cover.

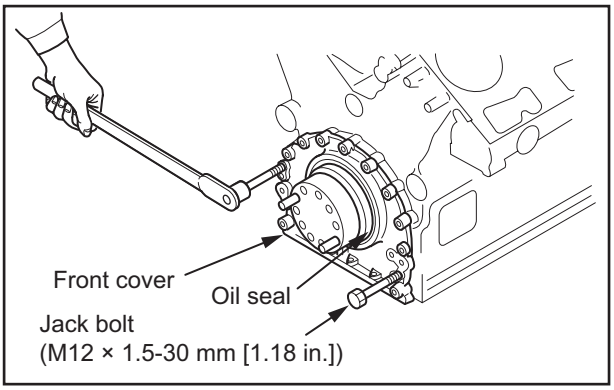
(2) Unscrew the front cover mounting bolts.

(3) Screw two jack bolts evenly in the holes to remove the front cover.

(4) Do not remove the oil seal unless it is damaged, and when you change the oil seal, you should also replace the slinger installed on the crankshaft.

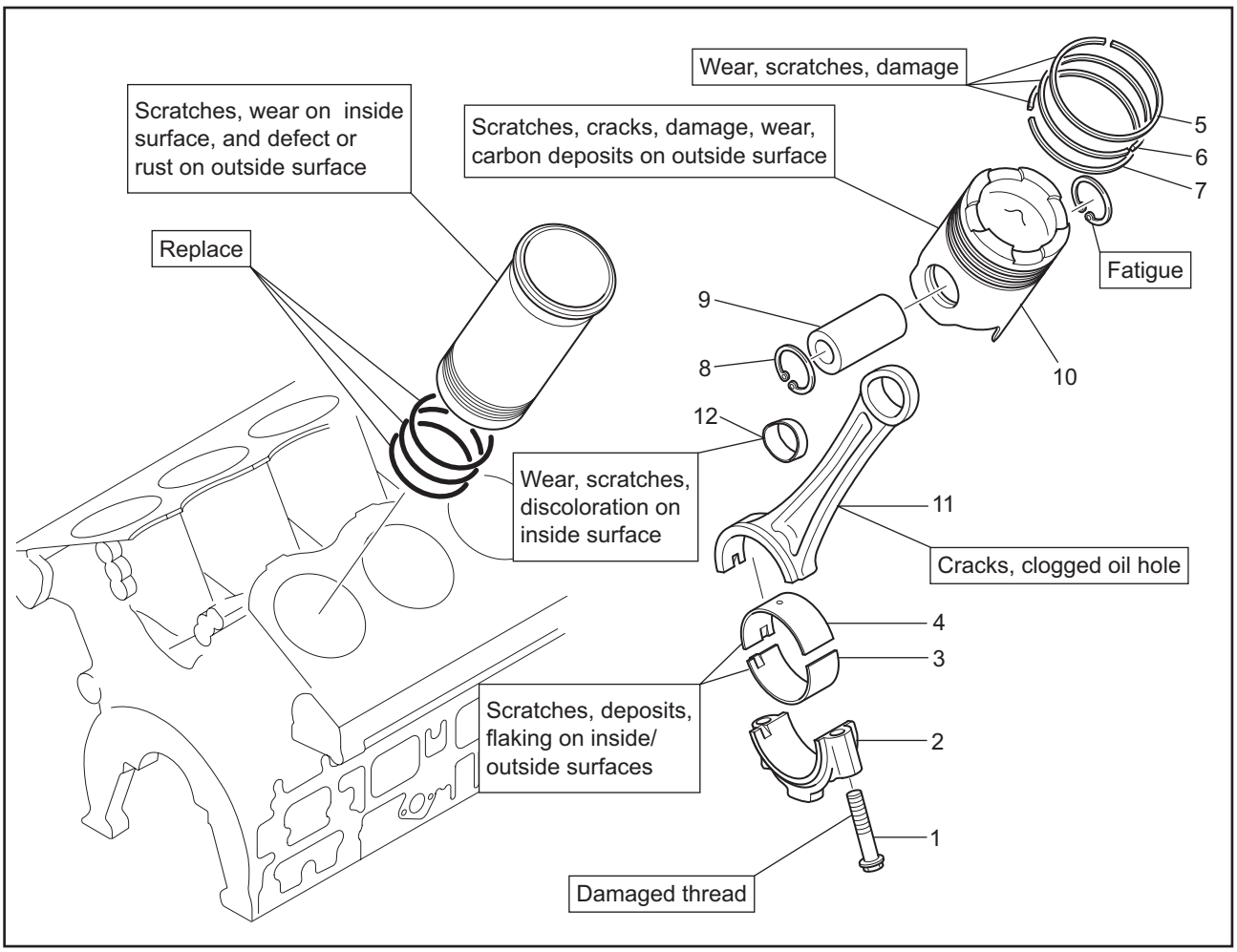


Removing front cover (1)



Removing front cover (2)

4. Disassembling and inspecting cylinder liners, pistons and connecting rods



Disassembling and inspecting cylinder liners, pistons and connecting rods

Disassembling sequence

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

CAUTION

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

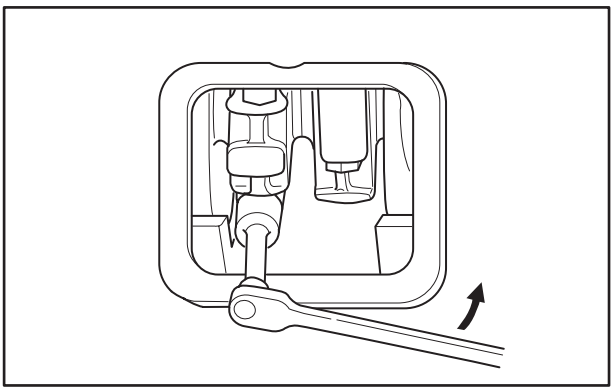
Unless out designated parts are used, the exhaust emission regulations cannot be met.

4.1 Removing connecting rod cap

Using a socket wrench, remove the connecting rod bolts through the inspection window on the side of the crankcase, and remove the connecting rod cap and connecting rod bearings.

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

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



Removing connecting rod cap

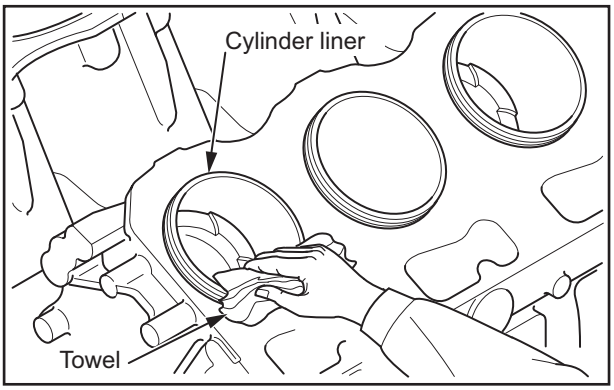
4.2 Removing ash deposits from the upper part of cylinder liner

CAUTION

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

Using a cloth or oil paper, remove ash deposits from the upper part of the cylinder liner.

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



Removing ash deposits from the upper part of cylinder liners

4.3 Pulling out pistons

⚠ CAUTION

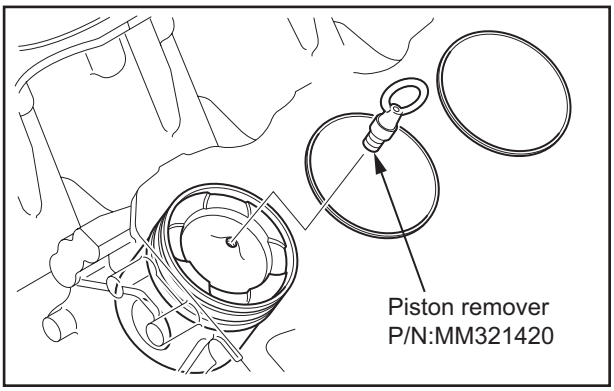
When holding the connecting rod with your hand to prevent it from swinging, be very careful, as you may suffer hand injuries from accidental movement of the connecting rod.

CAUTION

(a) When pulling out the piston, be careful not to drop the upper connecting rod bearing. Dropping the upper connecting rod bearing will cause damage to the cylinder liner and the crankshaft.
(b) Use care not to damage the cylinder liner by the swing of the connecting rod when pulling out the piston and connecting rod from the cylinder liner.
(c) When only a few pistons are left in the cylinders, the crankshaft tends to turn by itself. Be sure to hold the crankshaft to prevent it from turning while removing pistons.

(1) Turn the crankshaft to bring the piston to approximately 50° after top dead center.
(2) Attach the piston remover (special tool) to the top of the piston.
(3) Wrap a cloth around the bar, and insert the tip of the bar under the big end of the connecting rod. Then push the bar downwards using the crank pin as a fulcrum to raise the piston slightly.

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



Pulling out pistons

4.4 Removing piston ring

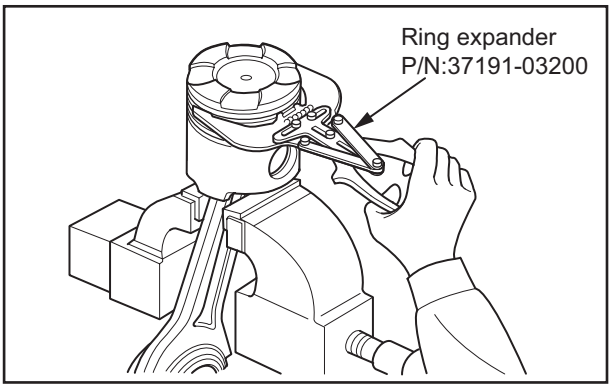
⚠ CAUTION

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

CAUTION

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

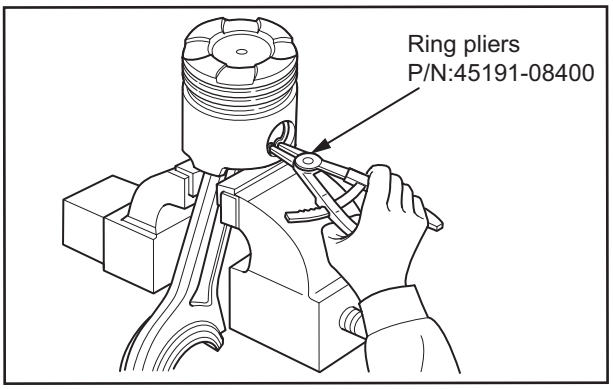
Hold the piston and connecting rod in a vise, and remove the piston ring using a ring expander.



Removing piston ring

4.5 Removing piston pin and piston

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



Removing piston pin and pistons

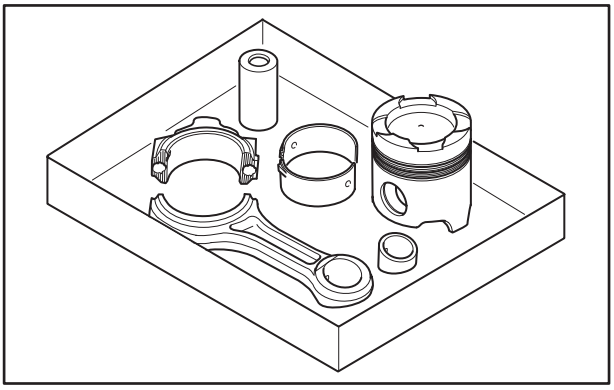
(2) Using a wooden block and mallet, remove the piston pin, and separate the piston from the connecting rod.

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

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

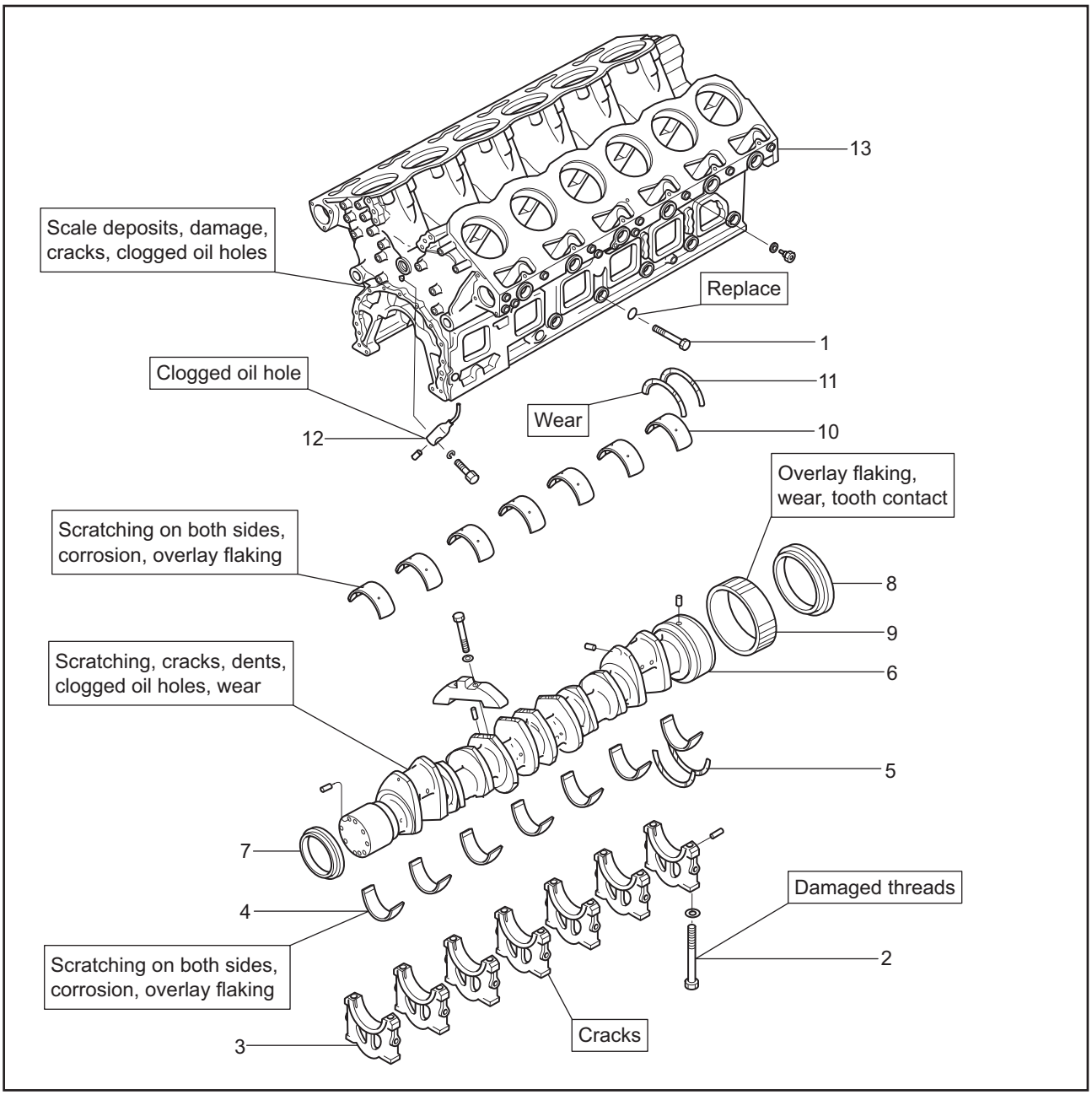
(c) Place removed pistons, piston pins, connecting rods, connecting rod bearings and connecting rod caps, not on the ground directly but on pallets or the like.

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



Keeping pistons in order after disassembling

5. Disassembling and inspecting crankcase, crankshaft and main bearing



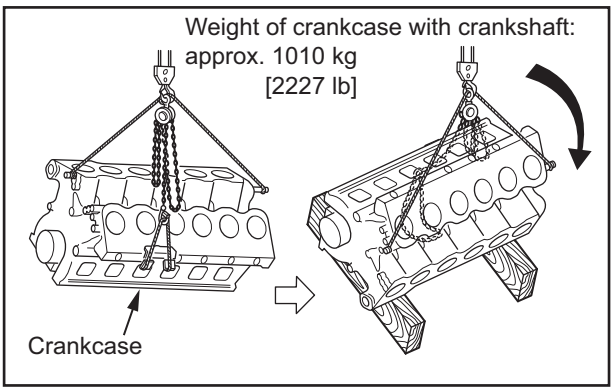
Disassembling and inspecting crankcase, crankshaft and main bearing

Disassembling sequence

1 Main bearing cap bolt
2 Side bolt
3 Main bearing cap
4 Main bearing (lower)
5 Thrust plate
6 Crankshaft
7 Sleeve
8 Slinger
9 Crankshaft gear
(6 to 9 weight: Approx. 300 kg [661 lb])
10 Main bearing (upper)
11 Thrust plate
12 Piston cooling nozzle
13 Crankcase
(1 to 13 weight: Approx. 1010 kg [2227 lb])

5.1 Inverting crankcase

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

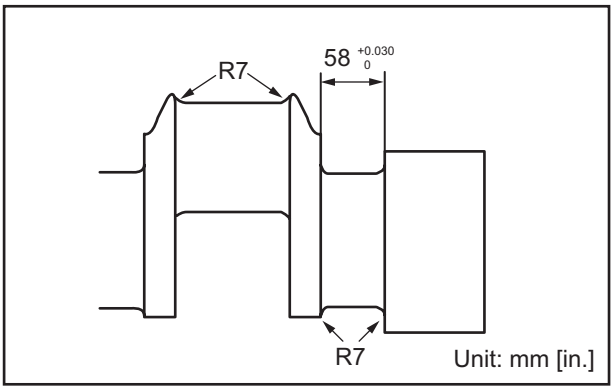


Inverting crankcase

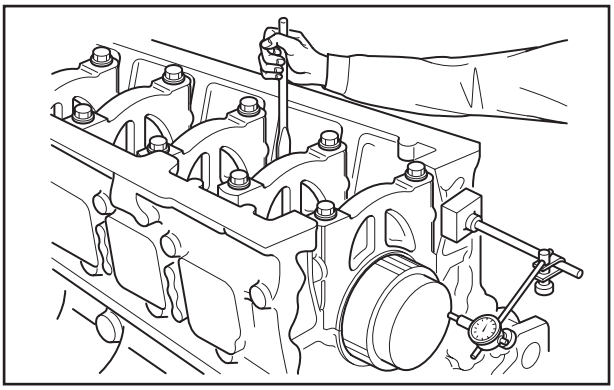
5.2 Measuring crankshaft end play

Measure the crankshaft end play (difference between the crankshaft thrust journal width and the width of the bearing cap assembled with thrust plates).

Item	Standard	Limit
Crankshaft end play	0.200 to 0.395 mm [0.0080 to 0.0160 in.]	0.500 mm [0.0200 in.]



Crankshaft thrust journal width



Measuring crankshaft end play

5.3 Removing main bearing cap

⚠ CAUTION

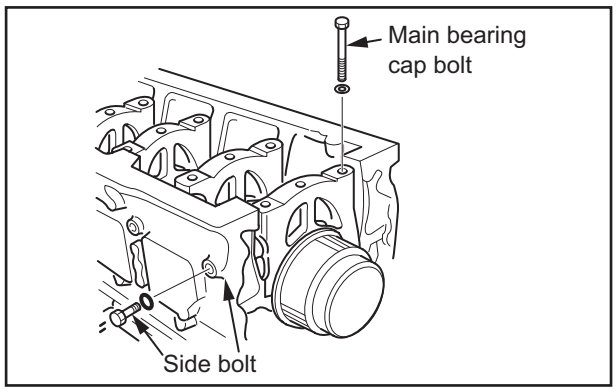
When removing the main bearing cap with a nozzle remover, take care not to get caught your fingers between the weight and the bar of the nozzle remover.

CAUTION

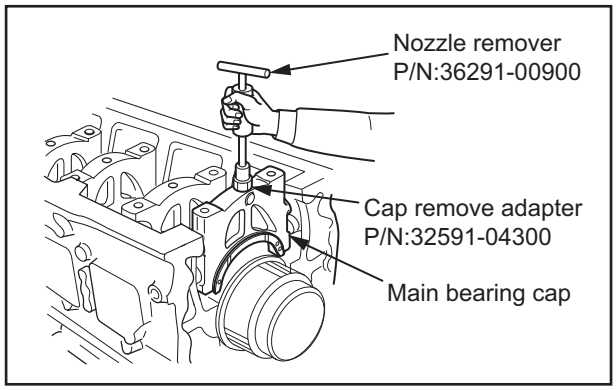
When lifting the main bearing cap away from the crankcase, be careful to not damage the lower main bearing or the lower thrust plate that are attached to the cap. Also be careful not to drop those parts, which may damage the crankshaft.

When removing the No. 7 main bearing cap, take care not to damage the thrust plate on both sides.

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



Removing main bearing cap (1)



Removing main bearing cap (2)

5.4 Removing crankshaft

CAUTION

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

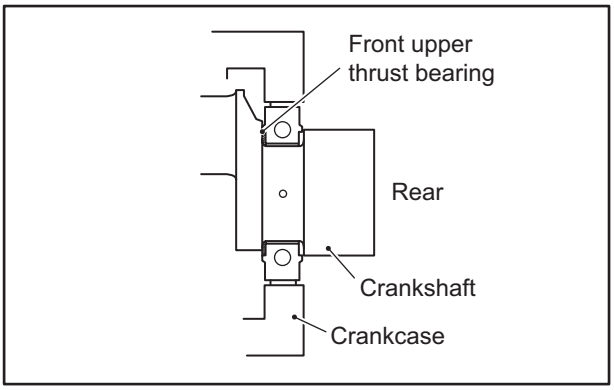
When placing the crankshaft onto a pallet or other stands, be careful not to damage the crankshaft. Once placed on a pallet, the crankshaft should be locked in place to prevent it from turning.

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

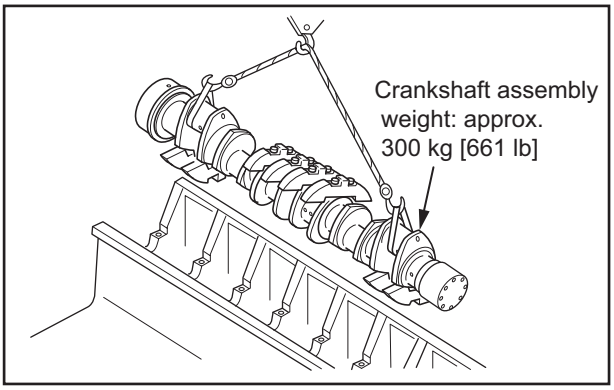
(2) Keeping the crankshaft in a horizontal position, slowly raise the crankshaft.

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

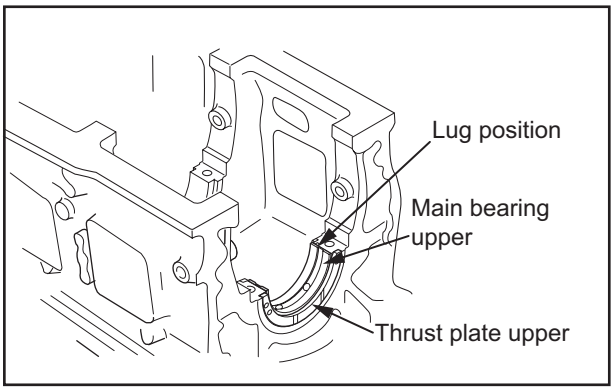
(3) Remove the upper main bearing from the crankcase, paying attention to the lug position, and remove the upper thrust plate on the rear side.



Removing crankshaft (1)



Removing crankshaft (2)



Removing crankshaft (3)

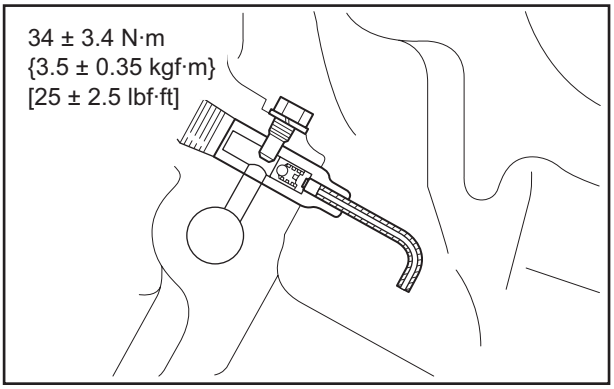
5.5 Removing piston cooling nozzle

CAUTION

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

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

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



Removing piston cooling nozzle

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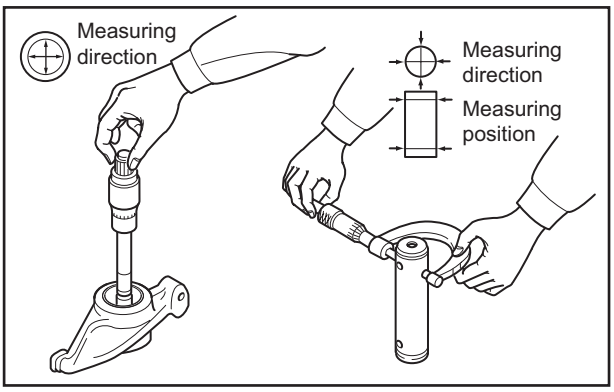
1. Inspecting and repairing cylinder heads and valve mechanism

1.1 Measuring rocker bushing inside diameter and rocker shaft outside diameter

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

Items	Nominal	Standard	Limit
Rocker bushing inside diameter	ø 32 mm [1.26 in.]	32.000 to 32.040 mm [1.2598 to 1.2614 in.]	32.100 mm [1.2638 in.]
Rocker shaft outside diameter	ø 32 mm [1.26 in.]	31.975 to 31.991 mm [1.2589 to 1.2595 in.]	31.950 mm [1.2579 in.]



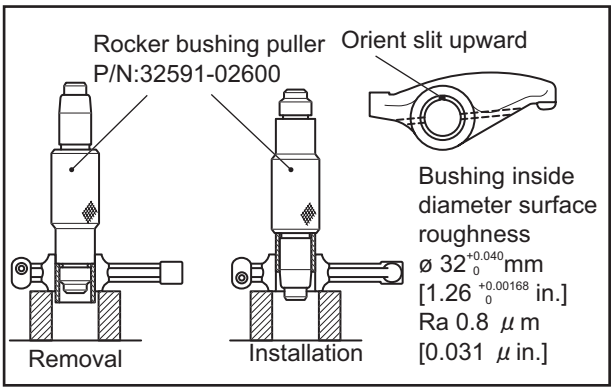
Measuring rocker arm inside diameter and rocker shaft diameter

1.2 Replacing rocker bushing

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

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

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



Replacing rocker bushing

1.3 Inspecting and replacing nozzle gland stud and bridge guide

Replace the nozzle ground stud or bridge guides with new ones if they exhibit a defect such as excessive wear or damage.

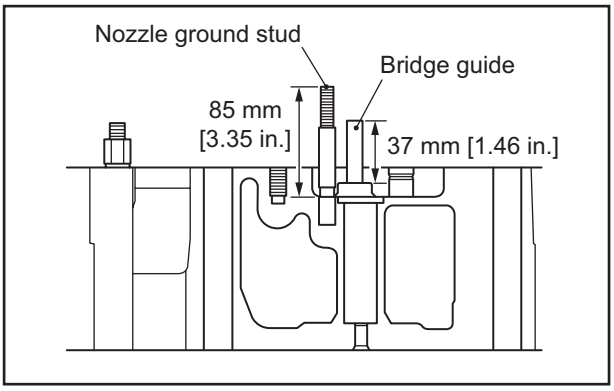
Note: Do not remove the nozzle ground stud and bridge guides from the cylinder head unless they are defective.

(1) Installation of nozzle ground stud

When replacing the nozzle ground stud, install the new nozzle ground stud so that the distance between its mounting surface and end becomes 85 mm [3.35 in.].

(2) Installation of bridge guides

When replacing the bridge guides, install the new bridge guides so that the distance between their mounting surface and end becomes 37 mm[1.46in.].

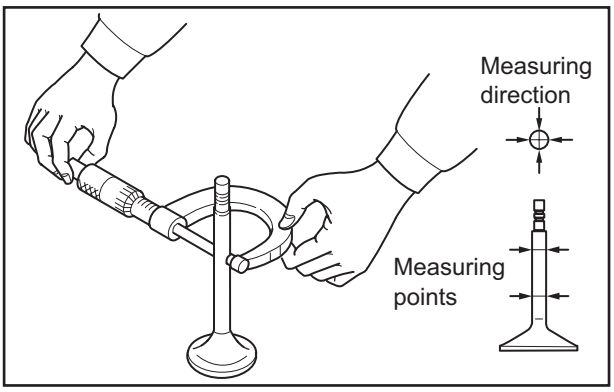


Inspecting and replacing nozzle gland stud and bridge guide

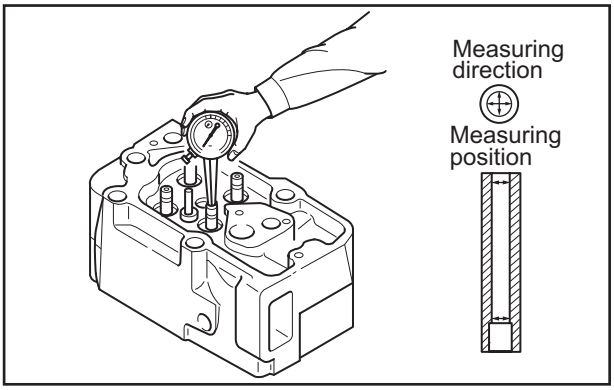
1.4 Measuring valve stem outside diameter and valve guide inside diameter

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

Item		Nominal	Standard	Limit
Valve stem outside diameter	Inlet	ø 10 mm [0.39 in.]	9.940 to 9.960 mm [0.3913 to 0.3921 in.]	9.910 mm [0.3902 in.]
	Exhaust	ø 10 mm [0.39 in.]	9.910 to 9.930 mm [0.3902 to 0.3909 in.]	9.880 mm [0.3890 in.]
Valve guide inside diameter		ø 10 mm [0.39 in.]	10.000 to 10.015 mm [0.3937 to 0.3943 in.]	10.060 mm [0.3961 in.]



Measuring valve stem diameter



Measuring valve guide inside diameter

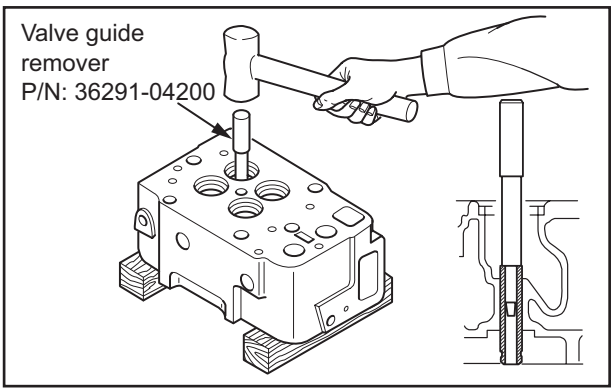
1.5 Replacing valve guide and stem seal

CAUTION

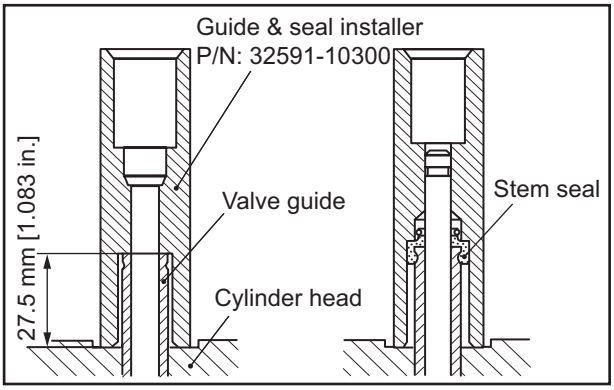
(a) The valve guide must be inserted to the specified depth. Be sure to use the guide/stem seal installer when press-fitting the valve guide.
(b) Do not apply oil or liquid gasket to the stem seal inside that comes in contact with the valve guide.
(c) Always replace the seam seal with a new one once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

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

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



Removing valve guide



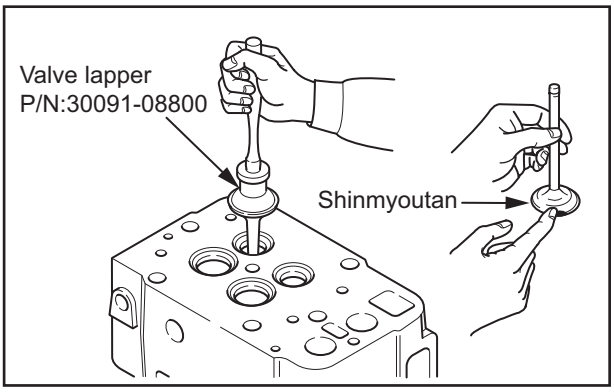
Installing valve guide and stem seal

1.6 Inspecting valve face

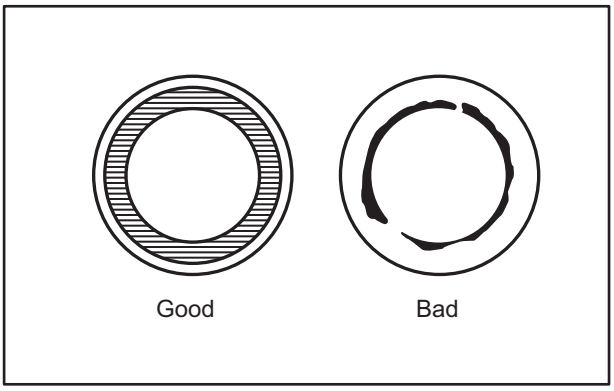
Apply a thin coat of Shinmyoutan or equivalent lead-free coloring paste on the valve face, and strike the valve face against the valve seat using a valve lapper to check for contact condition. If the contact is not even, or any defects are found, or if the limit is exceeded, reface or replace the valve.

Note: (a) Inspect the valve face after the valve guide is repaired or replaced.
(b) Do not rotate the valve when pressing the valve face coated with Shinmyoutan or equivalent lead-free dye against the valve seat.
(c) Always lap the valve and valve seat after the valve has been refaced or replaced.

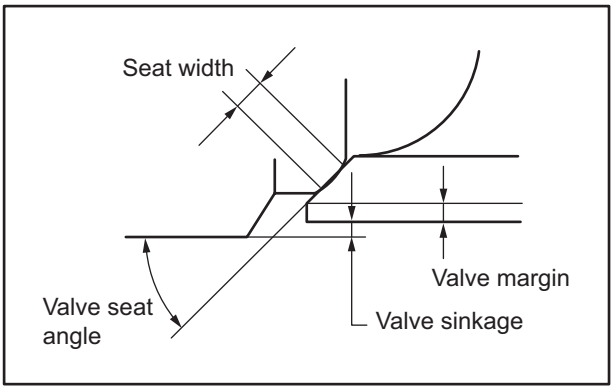
Item			Standard	Limit
Valve seat	Valve seat angle		30°	-
	Valve sinkage		-0.2 to 0.2 mm [-0.008 to 0.008 in.]	0.5 mm [0.020 in.]
	Seat width	Inlet	1.93 to 2.23 mm [0.0760 to 0.0878 in.]	2.5 mm [0.0984 in.]
		Exhaust	1.70 to 2.00 mm [0.0669 to 0.0787 in.]	2.3 mm [0.0906 in.]
Valve margin		Inlet	2.7 to 3.1 mm [0.106 to 0.122 in.]	Refacing permissible up to 2.0 mm [0.079 in.]
		Exhaust	2.9 to 3.1 mm [0.114 to 0.122 in.]	



Inspecting valve face



Contact condition between valve seat and valve

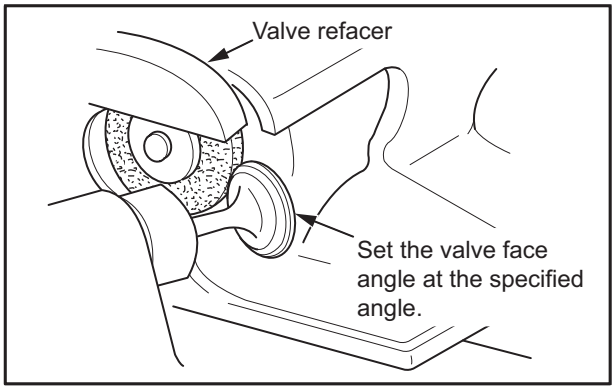


Contact of valve seat and valve

1.7 Refacing valve face

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

Note: (a) Grind the valve face using the valve refacer at the specified angle.
(b) Secure the valve margin width equal to or greater than the limit. If the dimensions after refacing does not meet the specified values, replace the valve with a new one.



Refacing valve face

1.8 Refacing valve seat

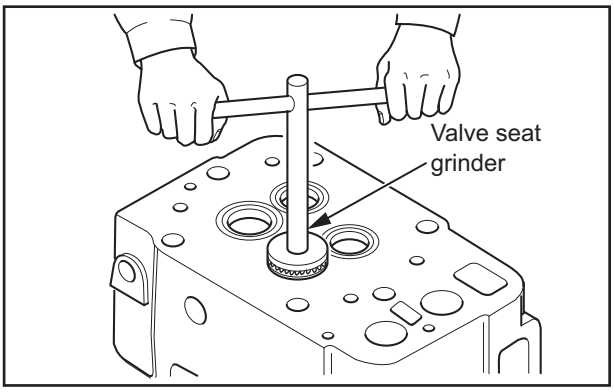
(1) Use the valve seat cutter or valve seat grinder to reface the valve seat. After refacing, sand the valve seat lightly using 400 grit sandpaper, inserting it between the cutter and valve seat.

(2) Lap the valve in the valve seat.

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

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

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



Refacing valve seat

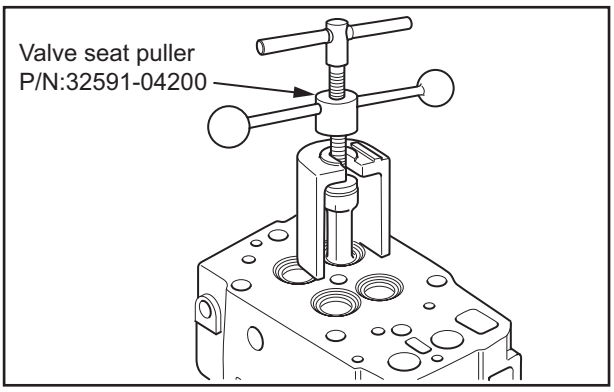
1.9 Replacing valve seat

CAUTION

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

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

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



Removing valve seat using valve seat puller

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

Item		Nominal	Standard
Clearance between inside diameter of cylinder head bore and outside diameter of valve seat	Inlet	ø 58 mm [2.28 in.]	-0.070 to -0.130 mm [-0.0028 to -0.0051 in.]
	Exhaust	ø 54 mm [2.13 in.]	-0.070 to -0.130 mm [-0.0028 to -0.0051 in.]

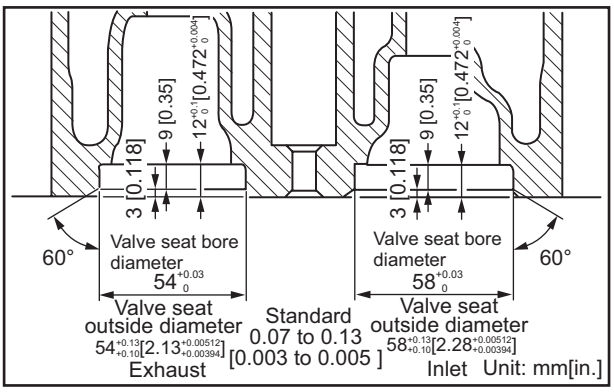
Note: (a) Standard values prefixed by a minus sign indicate the interference.
(b) Use a standard valve seat insert if the clearance meets the standard.
(c) Use an oversize valve seat insert if the clearance is out of the standard.
(d) The selection of an oversize valve seat must be made according to the inside diameter of the valve seat fitting bore in the cylinder head.

Valve seat fitting bore diameter		Oversize valve seat outside diameter
Inlet	58.030 to 58.060 mm [2.2846 to 2.2858 in.]	$58\ ^{+0.160}_{+0.130}$ mm [$2.28\ ^{+0.0063}_{+0.0051}$ mm]
	58.060 to 58.090 mm [2.2858 to 2.2870 in.]	$58\ ^{+0.190}_{+0.160}$ mm [$2.28\ ^{+0.0075}_{+0.0063}$ mm]
Exhaust	54.030 to 54.060 mm [2.1272 to 2.1283 in.]	$58\ ^{+0.160}_{+0.130}$ mm [$2.28\ ^{+0.0063}_{+0.0051}$ mm]
	54.060 to 54.090 mm [2.1283 to 2.1295 in.]	$58\ ^{+0.190}_{+0.160}$ mm [$2.28\ ^{+0.0075}_{+0.0063}$ mm]

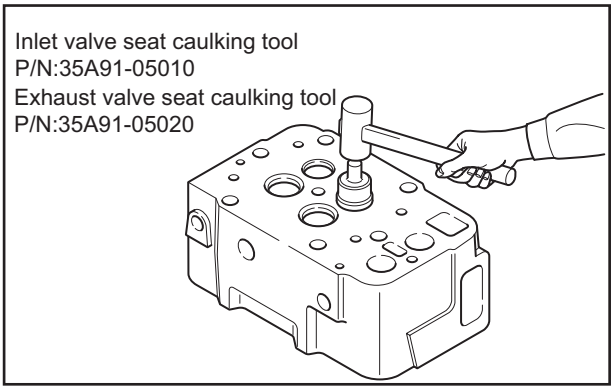
Note: Check to confirm that the specified interference is secured, even when an oversize valve seat insert is used.

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

(4) Install the valve seat into the cylinder head using a valve seat caulking tool.



Valve seat bore



Driving in valve seat

1.10 Lapping valve and valve seat

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

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

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

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

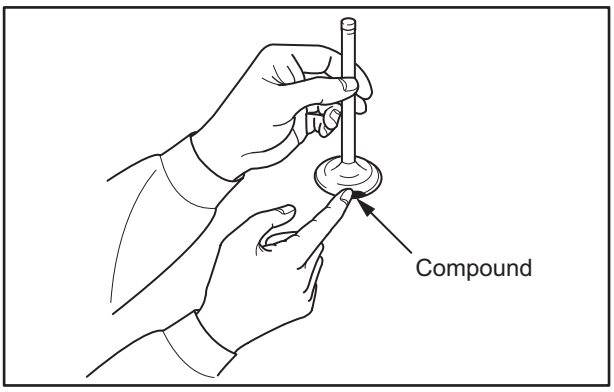
(c) Use medium-grain compound (120 to 150 mesh) for initial lapping, then use fine-grain compound (200 mesh or finer) for finishing.

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

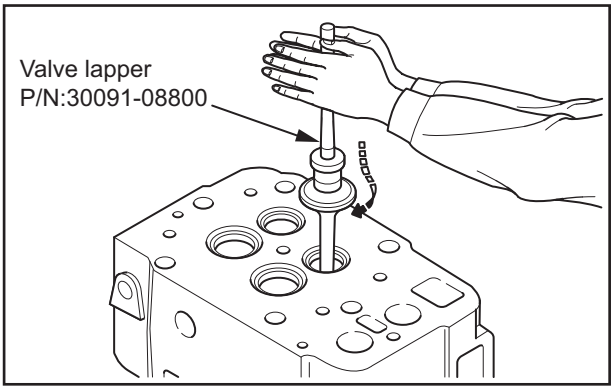
(3) Wash off the compound using diesel fuel.

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

(5) Check valve-to-seat contact.



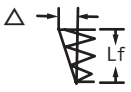
Applying compound to valve face

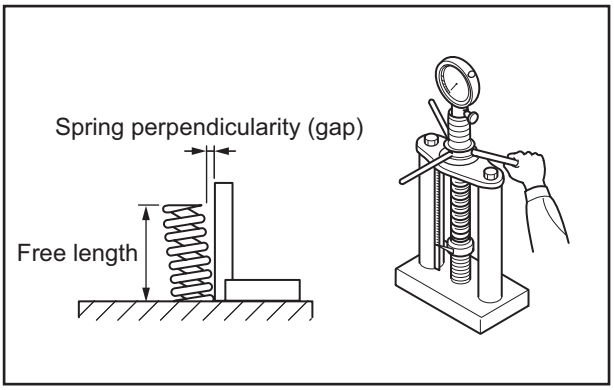


Lapping valve and valve seat

1.11 Measuring perpendicularity and free length of valve spring

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

Item	Standard	Limit
Free length	67.5 mm [2.657 in.]	66.2 mm [2.606 in.]
Squareness	 θ =1.0° maximum Δ (gap) = 1.2 mm maximum [0.047 in.] Lf = 67.5 mm [2.657 in.]	Over entire length Δ = 1.5 mm [0.059 in.]
Set length/ set force	60.0 mm [2.362 in.]/259 to 286 N {26.41 to 29.16 kgf} [58.2 to 64.3 lbf]	-



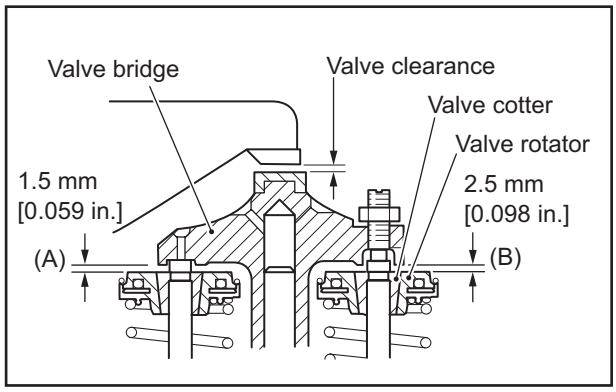
Measuring perpendicularity and free length of spring

1.12 Inspecting clearance between valve bridge and cotter/rotator

(1) After having adjusted valve heights using valve bridge screws, measure the clearance between the valve bridge and the rotator. If the clearance is less than the standard, replace the valve with a new one to secure the standard clearance.

(2) Check the bridge cap for wear. If it is significantly worn out, replace the bridge cap.

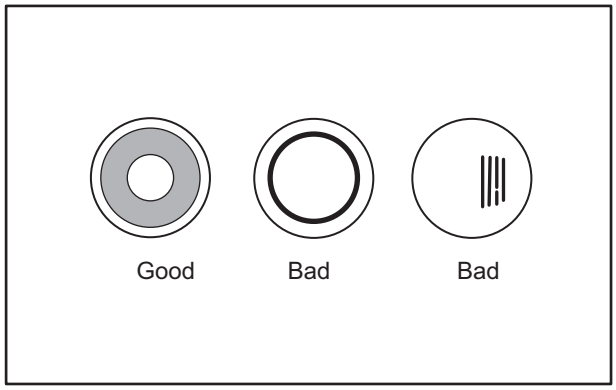
(3) Check the valve rotator for rotation. If any defect is found, replace the valve rotator.



Inspecting clearance between valve bridge and cotter/rotator

1.13 Inspecting tappet

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

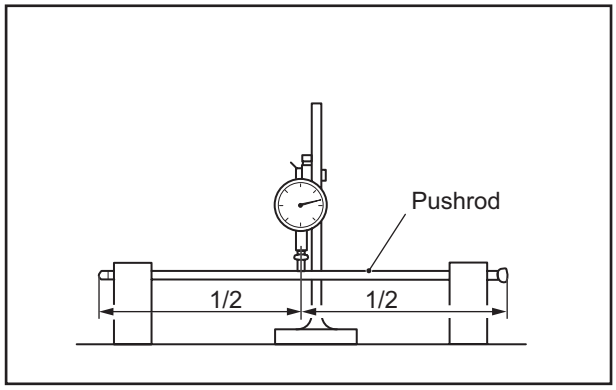


Contact surface of tappet and cam

1.14 Measuring pushrod runout

Measure the runout of each pushrod. Replace if the limit is exceeded.

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



Measuring pushrod runout

1.15 Measuring distortion of cylinder head bottom face

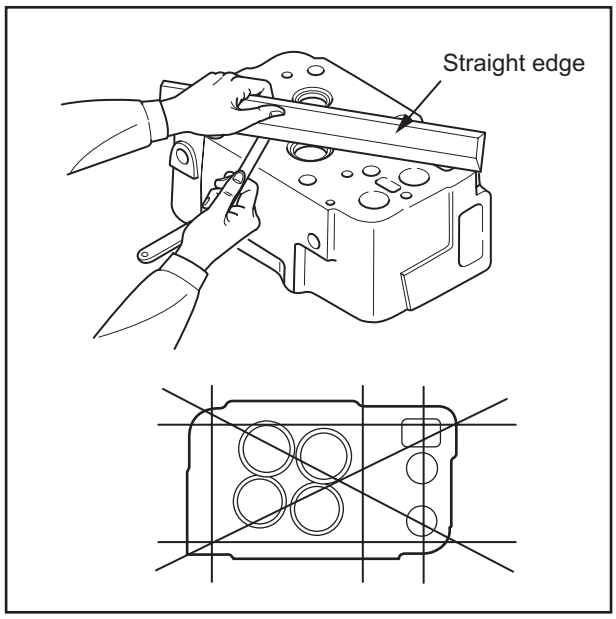
CAUTION

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

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

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

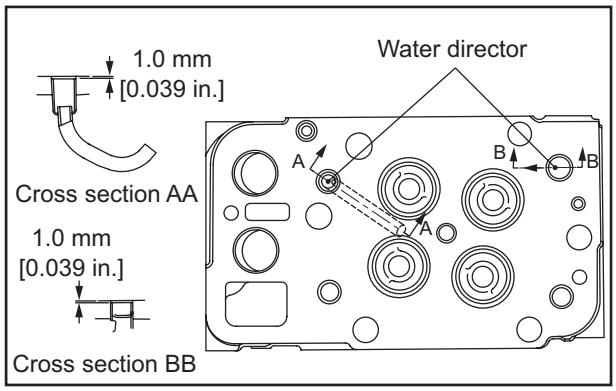
Item	Standard	Limit
Bottom surface distortion	0.03 mm [0.0012 in.] or less	0.50 mm [0.0197 in.]



Measuring distortion of the bottom surface of the cylinder head

1.16 Inspecting water director

Inspect the water director. If it is corroded, replace it. To insert the water director, gently tap the water director using a soft-head mallet to press-fit into the position at a depth of 1.0 mm [0.039 in.] from the bottom face of the cylinder head. The mounting orientation (window position) should be as shown in the illustration.



Installation direction of water director

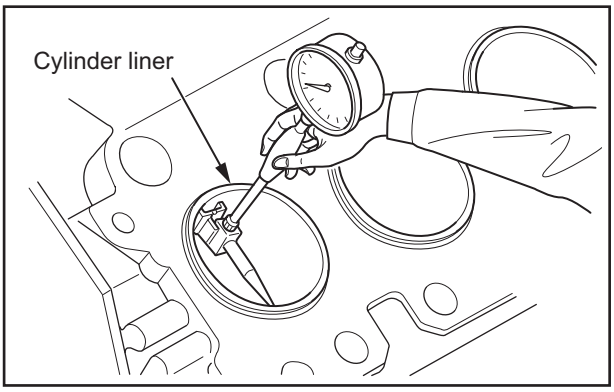
2. Inspecting and repairing cylinder liners, pistons and connecting rods

2.1 Measuring cylinder liner inside diameter

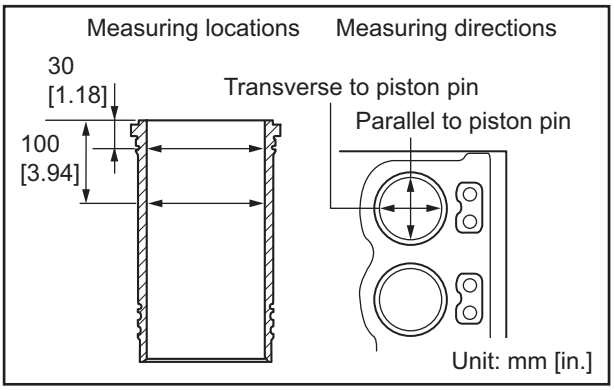
Measure the inside diameter of the cylinder liners at two levels each, i.e., upper (with much stepped wear) and middle levels, in both directions parallel to and perpendicular to the piston pin direction.

Replace the cylinder liner if the limit is exceeded.

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



Measuring cylinder liner inside diameter



Cylinder liner dimension measuring position

2.2 Measuring cylinder liner flange protrusion

CAUTION

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

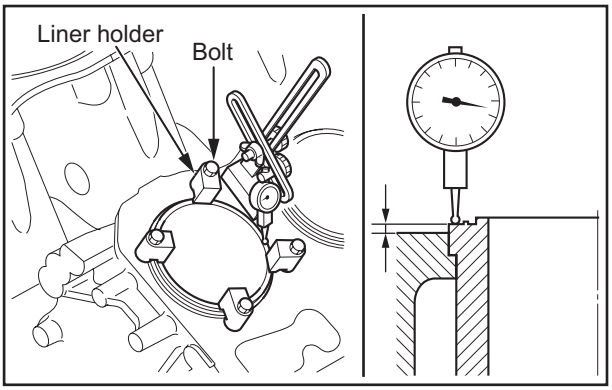
Measure the cylinder liner flange protrusion at each cylinder.

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

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

2.2.1 When cylinder liner is not replaced

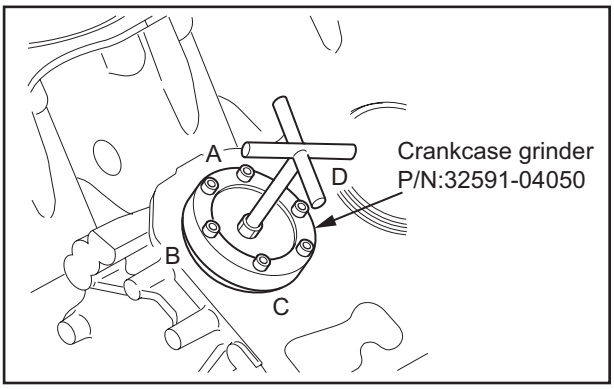
(1) Make sure that the top surface of crankcase and the upper end of cylinder liner are clean before measurement.
(2) Attach the liner holders on equally spaced 4 locations of the cylinder liner upper rim and tighten the bolts of the holders evenly to press the cylinder liner against the crankcase top surface.
(3) Apply the dial gauge plunger to the top surface of the crankcase, and zero the dial gauge.
(4) Measure the flange protrusion at four locations on the top of the cylinder liner, and obtain the mean value.
(5) If the mean value of the protrusion is smaller than the standard, insert a shim under the cylinder liner flange.



Measuring cylinder liner collar protrusion

2.2.2 When cylinder liner is replaced

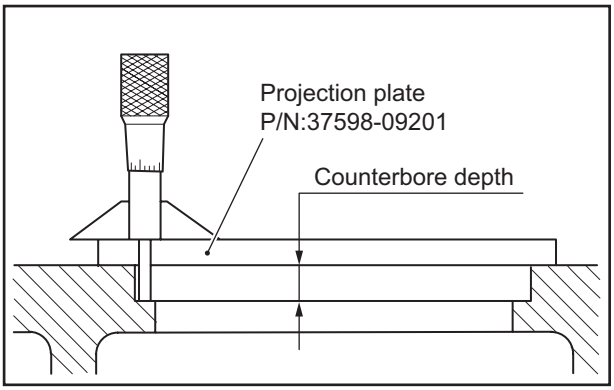
(1) Remove the old cylinder liner, and check the cylinder liner seating surface on the crankcase.
(2) If there is any evidence of uneven contact, grind the seating surface using the crankcase grinder such that the difference in depth at points A, B, C and D is less than 0.05 mm [0.0020 in.].



Refacing crankcase counterbore depth

(3) Measure the depth of the counterbore in the crankcase. Because of the possibility of the crankcase top surface distortion, use a projection plate when measuring.
(4) Calculate the mean value of the 4 measurements at points A, B, C and D.
(5) Measure the thickness of the projection plate (standard: 15 mm [0.59 in.]). Determine the actual counterbore depth from the top surface of the crankcase by subtracting the projection plate thickness from the counterbore depth measurement.

Item	Standard
Crankcase counterbore depth	12.00 to 12.05 mm [0.4724 to 0.4744 in.]



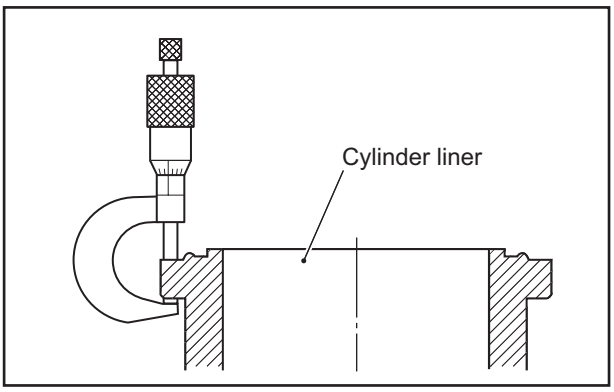
Measuring crankcase counterbore depth

(6) Measure the thickness of the cylinder liner flange.

Item	Standard
Thickness of cylinder liner flange	12.15 to 12.19 mm [0.4783 to 0.4799 in.]

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

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



Thickness of cylinder liner collar

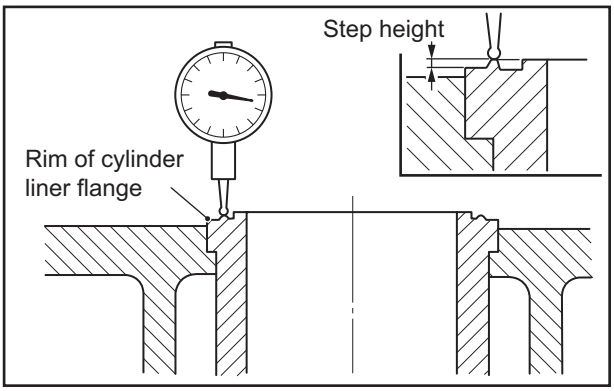
2.2.3 Measuring cylinder liner top ridge height

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

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

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

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



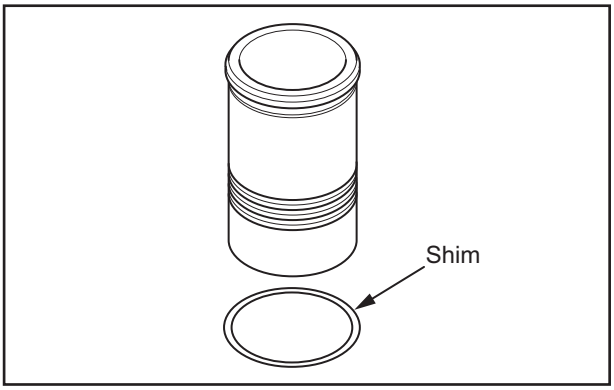
Measuring cylinder liner top ridge height

2.2.4 Inserting cylinder liner shim

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

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

Shim thickness	Part No.
0.05 mm [0.0020 in.]	35A07-07500
0.10 mm [0.0039 in.]	35A07-07100
0.15 mm [0.0059 in.]	35A07-07600
0.20 mm [0.0079 in.]	35A07-07200
0.25 mm [0.0098 in.]	35A07-07700
0.30 mm [0.0118 in.]	35A07-07300
0.40 mm [0.0157 in.]	35A07-07400



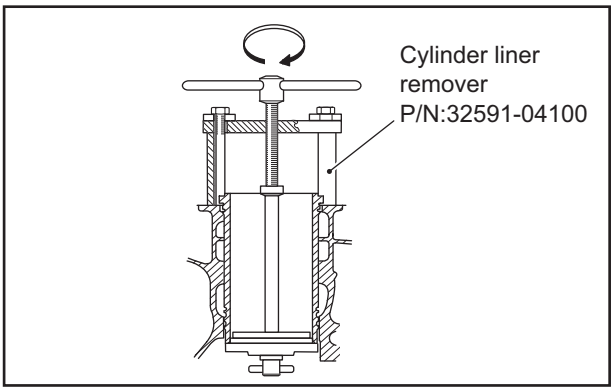
Inserting cylinder liner shim

2.3 Replacing cylinder liner

CAUTION

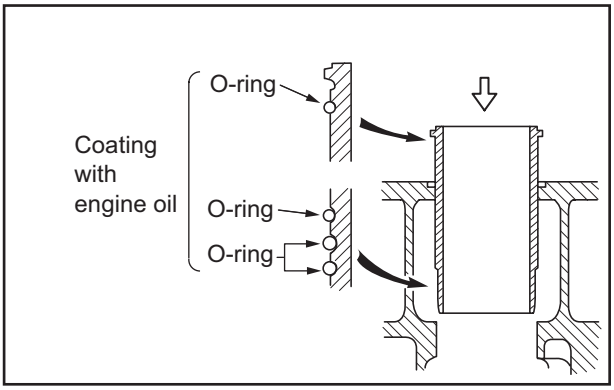
Apply engine oil to the O-rings to prevent them from twisting.

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



Removing cylinder liner

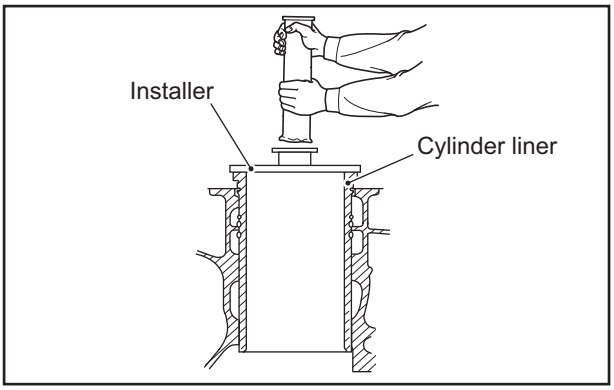
(2) Install new O-rings to the new cylinder liner.



Installing cylinder liner O-ring

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

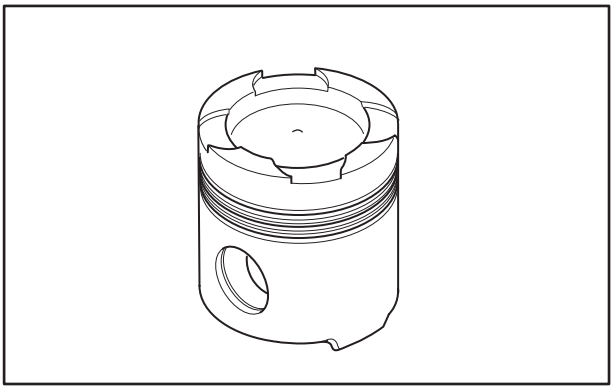
Note: (a) After the installation, conduct a water-pressure leak test to check for air-tightness.
(b) Check the cylinder liner flange protrusion from the crankcase top surface.



Installing cylinder liner

2.4 Visual inspection of piston

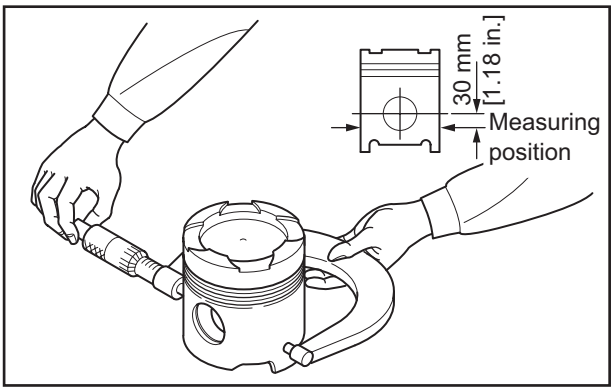
Check the combustion surface of the piston and the piston pin bore. If any defect is found, replace the piston with a new one.



Inspecting piston visually

2.5 Measuring piston outside diameter

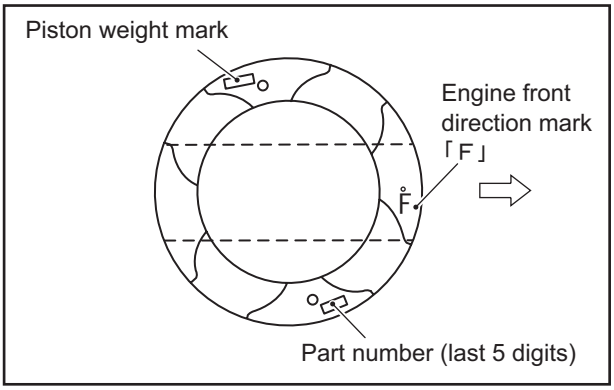
(1) Measure the piston outside diameter of the piston skirt at right angles to the piston pin. If it is less than the limit, replace the piston with a new piston. When replacing piston, be sure to select a piston so that the piston weight difference in one engine is kept within the permissible range.



Measuring piston outside diameter

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

Item	Nominal	Standard	Limit
Piston outside diameter	ø 150 mm [5.91 in.]	149.78 to 149.82 mm [5.8968 to 5.8984 in.]	149.68 mm [5.8929 in.]
Piston weight difference	-	In one engine 30 g [1 oz.] or less	-



Piston weight stamp location

2.6 Measuring clearance between piston ring groove and piston ring

CAUTION

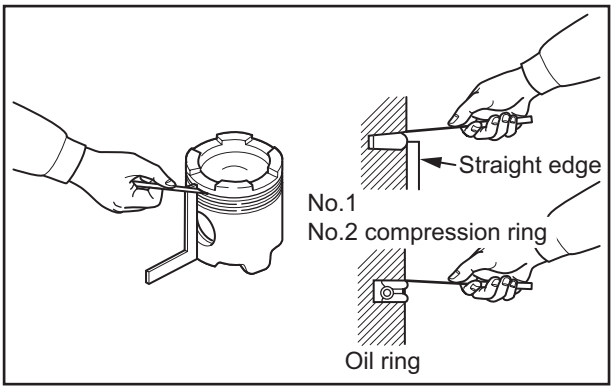
Remove ash deposits from pistons and check the entire circumference of the piston.

(1) Remove all deposits from each ring groove.

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

Fit a piston ring the thickness of which is known into the appropriate ring groove. Hold a straight edge against the ring and measure the clearance between the ring and ring groove using a feeler gauge.

Replace the piston if the limit is exceeded.



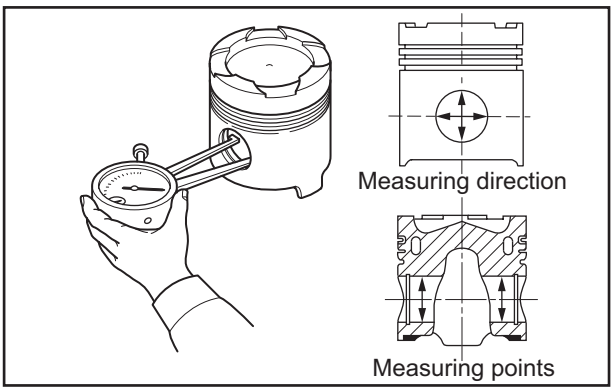
Inspecting piston ring groove

Item		Nominal	Standard	Limit
Piston ring side clearance (when a new ring installed)	No.1 compression	3.16 mm [0.12 in.]	0.124 to 0.154 mm [0.0049 to 0.0061 in.]	0.200 mm [0.0079 in.]
	No.2 compression	2.69 mm [0.11 in.]	0.114 to 0.144 mm [0.0045 to 0.0057 in.]	0.150 mm [0.0059 in.]
	Oil	5.00 mm [0.20 in.]	0.050 to 0.090 mm [0.0020 to 0.0035 in.]	0.150 mm [0.0059 in.]

2.7 Measuring piston pin bore

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

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



Measuring piston pin bore

2.8 Measuring piston protrusion

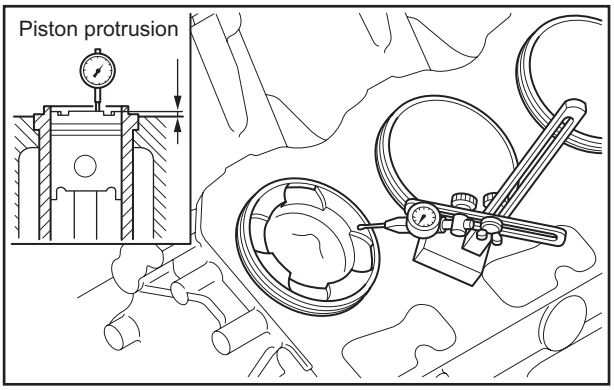
CAUTION

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

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

(1) Bring the piston to the top dead center.
(2) Apply the dial gauge plunger to the top surface of the crankcase, and zero the dial gauge.
(3) Measure the protrusion at four points on the piston head, and calculate the mean value.

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



Measuring piston protrusion

Item	Standard
Piston protrusion	0.38 to 0.89 mm [0.015 to 0.035 in.]
Thickness when tightened (cylinder head gasket)	1.7 to 1.9 mm [0.0669 to 0.0748 in.]
Clearance between piston and cylinder head	0.81 to 1.43 mm [0.0320 to 0.0563 in.]

2.9 Standard for piston ring replacement

CAUTION

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

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

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

2.9.1 Visual inspection of piston ring

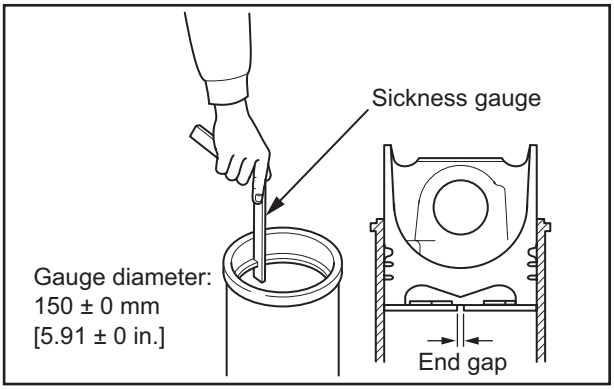
Check sliding parts for injurious seizures, sticking, abnormal wear and plating peeling due to carbon biting. If any defect is found, replace piston rings with new ones.

2.9.2 Measuring piston ring end gap

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

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

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



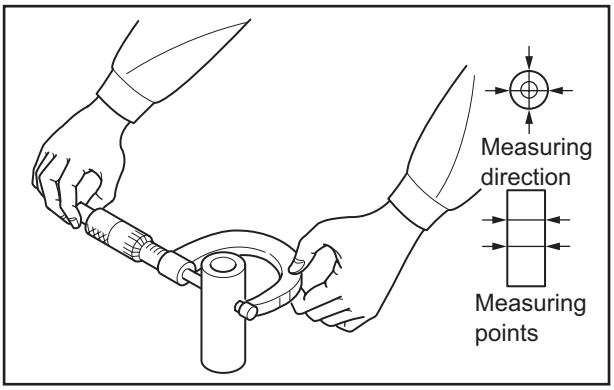
Measuring piston ring end gap

2.10 Measuring piston pin outside diameter

Measure the piston pin outside diameter.

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

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

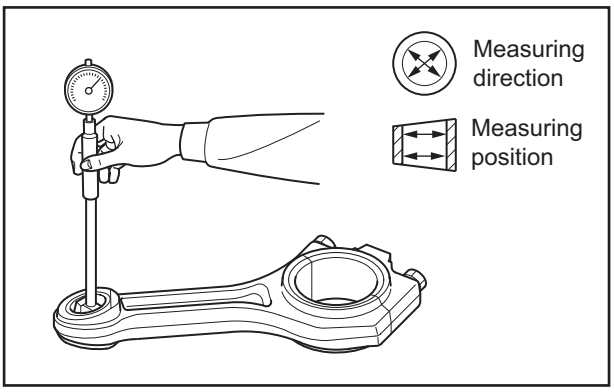


Measuring piston pin outside diameter

2.11 Measuring connecting rod bushing inside diameter

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

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



Measuring connecting rod bushing inside diameter

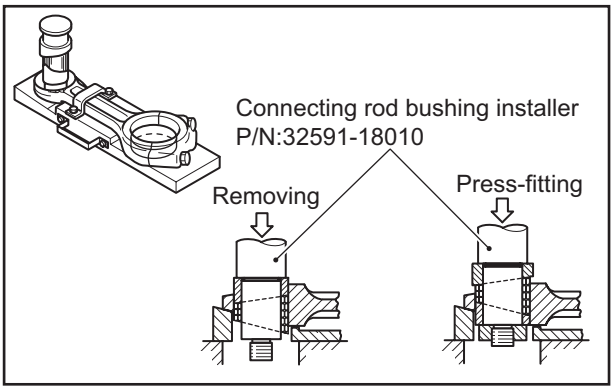
2.12 Replacing connecting rod bushing

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

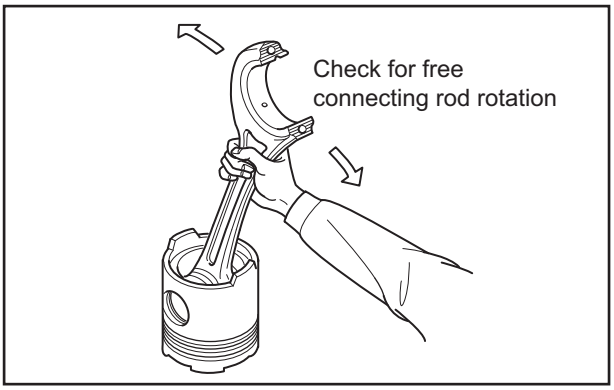
(2) Align the oil hole in the bushing with that in the connecting rod.

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

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



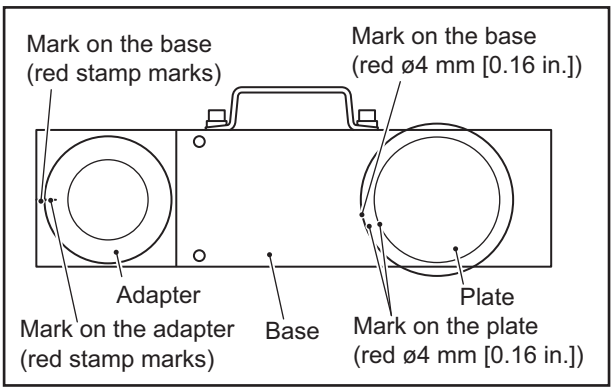
Replacing connecting rod bushing



Inspecting connecting rod movement

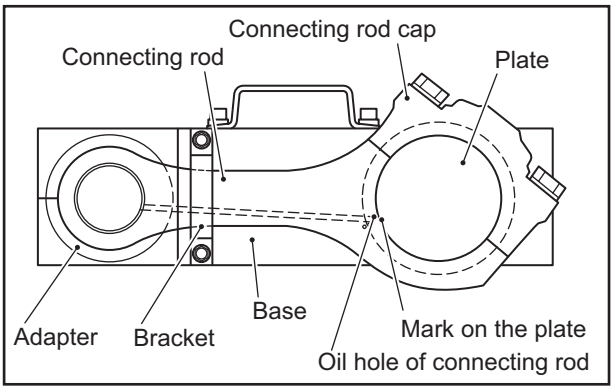
2.12.1 Usage of connecting rod bushing installer

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



Usage of connecting rod bushing installer (1)

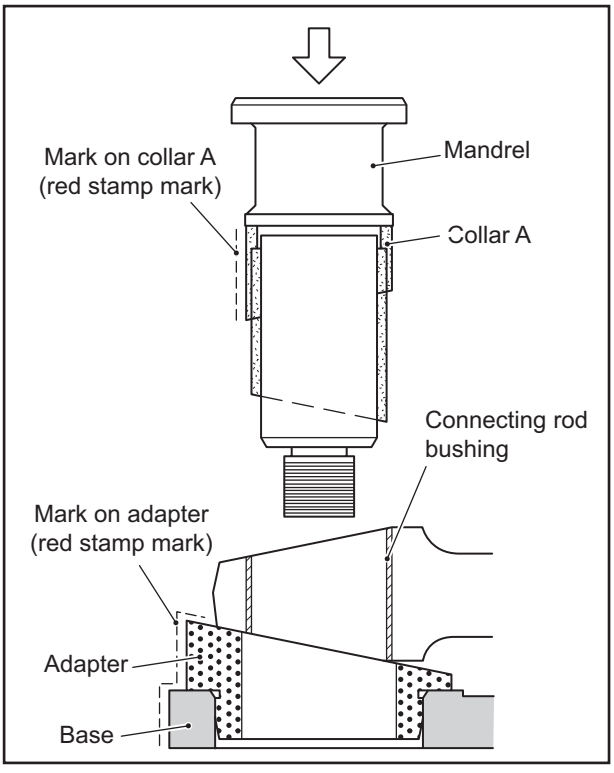
(3) Assemble the connecting rod to the connecting rod cap without fitting the connecting rod bearing.
(4) Install the connecting rod assembly on the base while aligning the oil hole in the connecting rod big end with the match mark (ø 4 mm [0.16 in.] red dot) for the plate and the connecting rod small end with the adapter.
(5) Secure the connecting rod in place with the bracket.



Usage of connecting rod bushing installer (2)

2.12.2 Removing connecting rod bushing

(1) Lubricate the inside surface of the connecting rod bushing with engine oil.
(2) Attach the collar A to the mandrel and insert the assembly into the connecting rod bushing while aligning the match mark (red scribed line) on the collar A with that on the adapter.
(3) Using a press, apply pressure slowly on the head of the mandrel to force out the connecting rod bushing.



Usage of connecting rod bushing installer (3)

2.12.3 Press-fitting connecting rod bushing

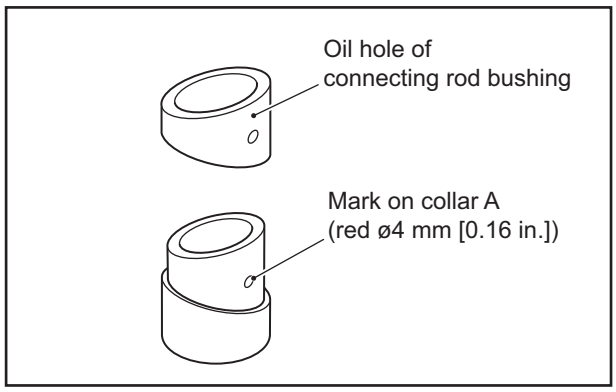
CAUTION

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

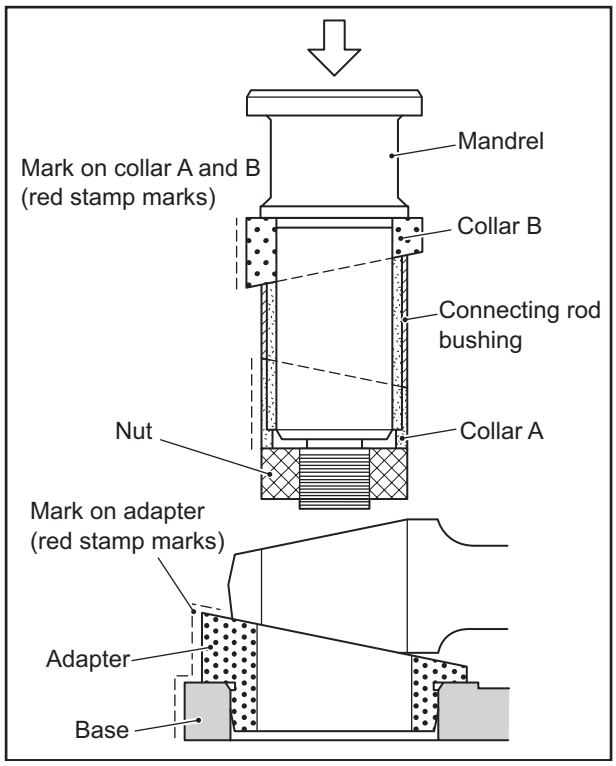
(b) Be sure to confirm that the oil hole in the connecting rod bushing is in alignment with the match mark (ø 4 mm [0.16 in.] red dot) on collar A.

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

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

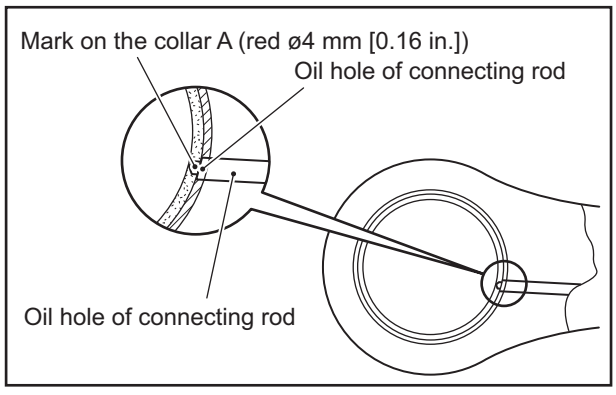


Usage of connecting rod bushing installer (4)



Usage of connecting rod bushing installer (5)

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



Usage of connecting rod bushing installer (6)

2.13 Inspecting connecting rod bend and twist

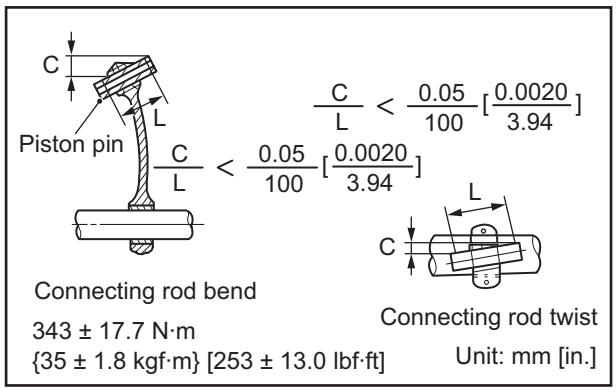
(1) Measure the dimensions of C and L in the illustration to check bend and twist of the connecting rod. Straighten the connecting rod with a press to meet the standard.
If the standard is exceeded after correction, replace the connecting rod with a new one.

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

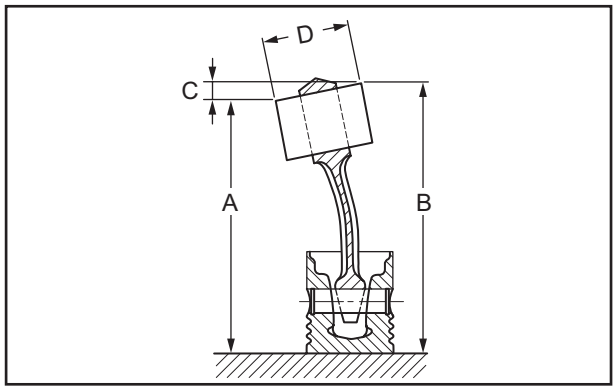
Note: Before checking bend, tighten the connecting rod cap to the specified torque.

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

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



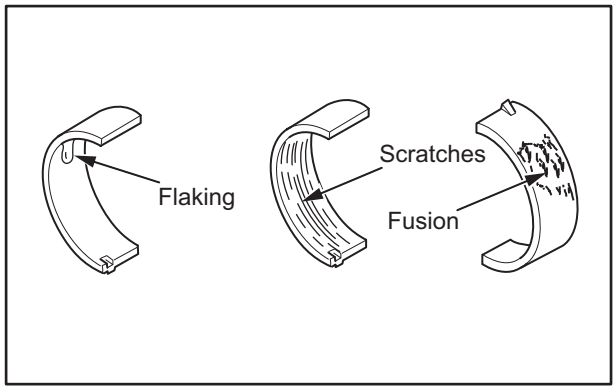
Inspecting connecting rod bend and twist



Measuring connecting rod bend

2.14 Inspecting connecting rod bearing

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

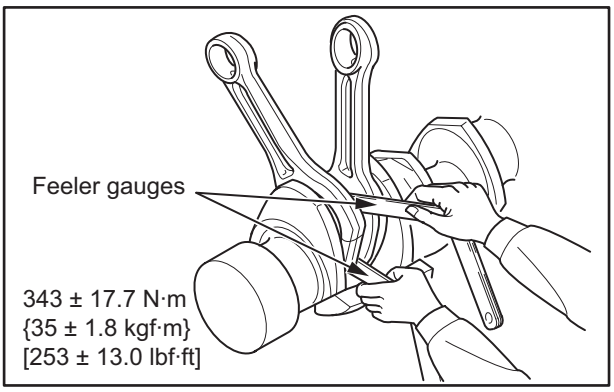


Inspecting connecting rod bearing

2.15 Measuring connecting rod end play

(1) Install the connecting rods onto the respective crankpins and tighten the connecting rod cap bolts to the specified torque.
(2) Measure the clearance to the crank arm (end play) at two positions (above and below the crankpin).
(3) If the limit is exceeded, replace the connecting rod with a new one.

Item	Nominal	Standard	Limit
Connecting rod end play	54 mm [2.13 in.]	0.60 to 0.90 mm [0.0240 to 0.0354 in.]	1.00 mm [0.0394 in.]



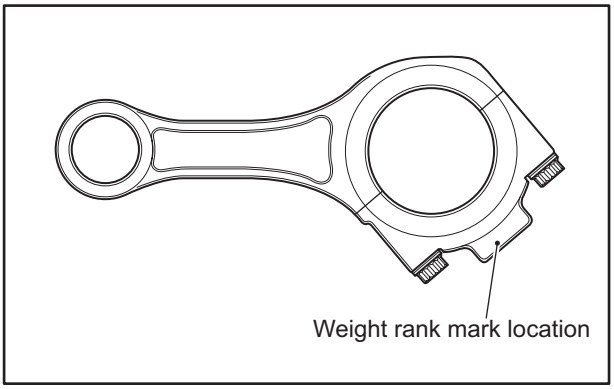
Measuring connecting rod end play

2.16 Weight difference of connecting rod assembly in one engine

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

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

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



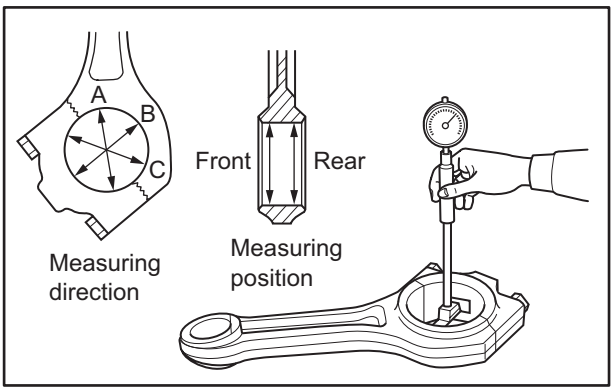
Connecting rod weight rank mark position

2.17 Measuring connecting rod big end bore diameter and roundness

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

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

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



Measuring connecting rod big-end bore diameter

2.18 Inspecting serrated portion of connecting rod big end

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

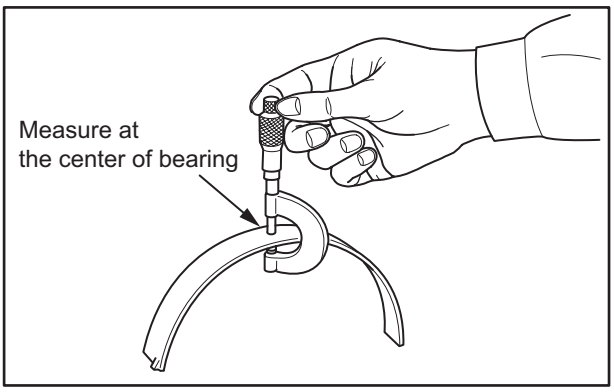
2.19 Measuring connecting rod bearing thickness

Measure the thickness of each bearing shell at its center.

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

Note: Replacement bearings are available in four undersizes:
-0.25, -0.50, -0.75 mm and -1.00 mm

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



Measuring main bearing thickness

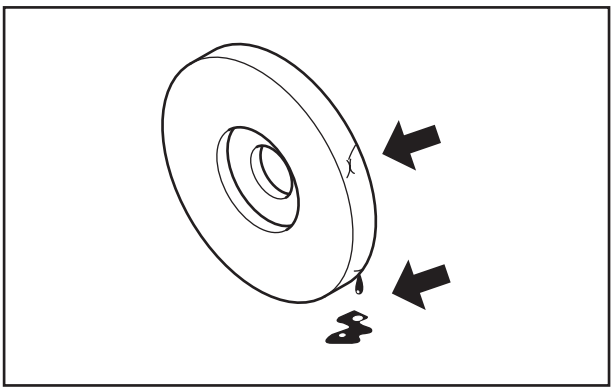
3. Inspecting and repairing damper and crankshaft pulley

3.1 Inspecting damper

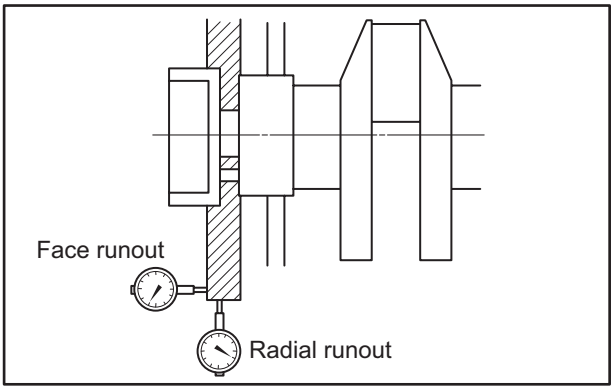
(1) Check the damper for cracks around the outer periphery, swelling and/or cracks in the end plate, silicone oil leakage and discoloration and separation of coating due to thermal effect.
If any defect is found, replace the damper with a new one.

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

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



Inspecting damper visually



Measuring damper face and radial runouts

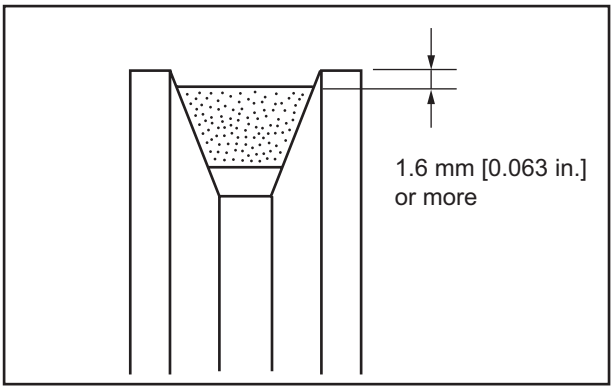
3.2 Inspecting crankshaft pulley

Check the V-belt groove in the pulley for wear.

(1) Check the sinkage of the V-belt.

(2) Fit a new V-belt in the pulley groove so that V-belt becomes taut.

(3) Replace the pulley with a new one if the V-belt sinks more than 1.6 mm [0.063 in.] below the pulley rim.



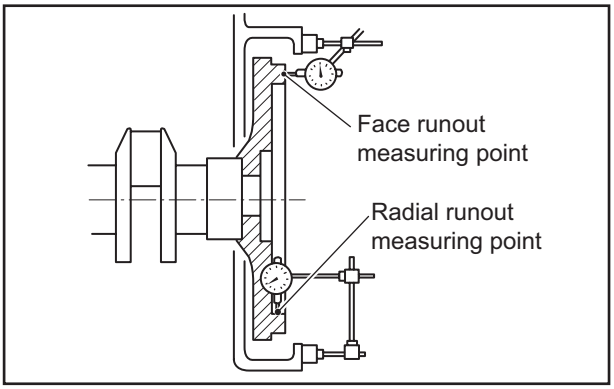
Inspecting V-belt groove wear

4. Inspecting and repairing flywheel, timing gears and camshafts

4.1 Measuring flywheel face and radial runouts

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

Item	Standard
Face runout	0.285 mm [0.0112 in.] or less
Radial runout	0.127 mm [0.0050 in.] or less

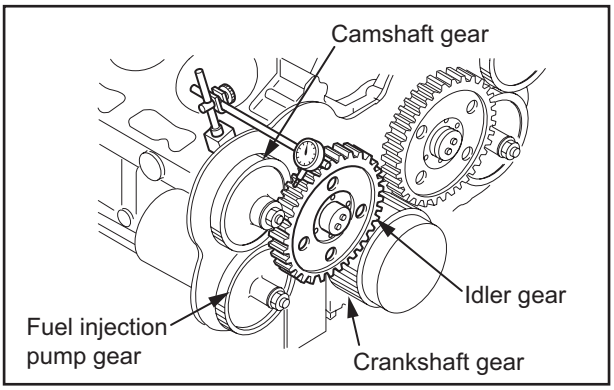


Measuring flywheel face and radial runouts

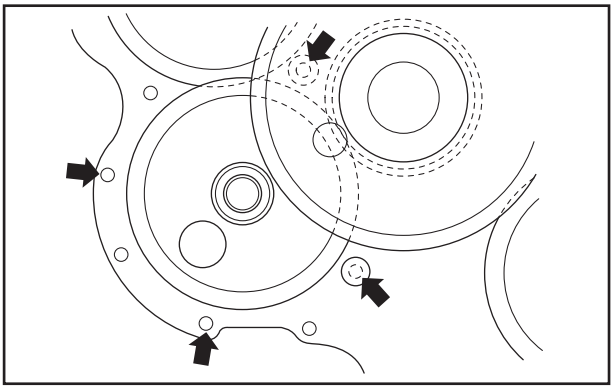
4.2 Measuring timing gear backlash

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

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



Measuring timing gear backlash (1)

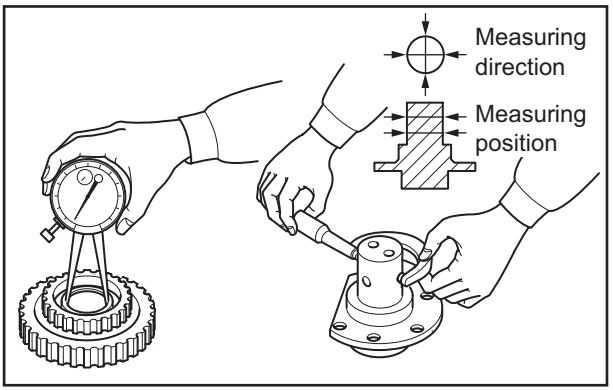


Measuring timing gear backlash (2)

4.3 Measuring idler bushing inside diameter and idler shaft outside diameter

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

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

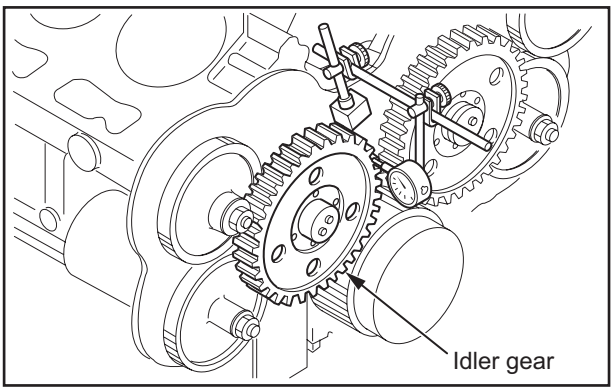


Measuring idler bushing inside diameter and idler shaft outside diameter

4.4 Measuring idler gear end play

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

Item	Standard	Limit
End play of idler gear	0.20 to 0.40 mm [0.0079 to 0.0157 in.]	0.60 mm [0.0236 in.]



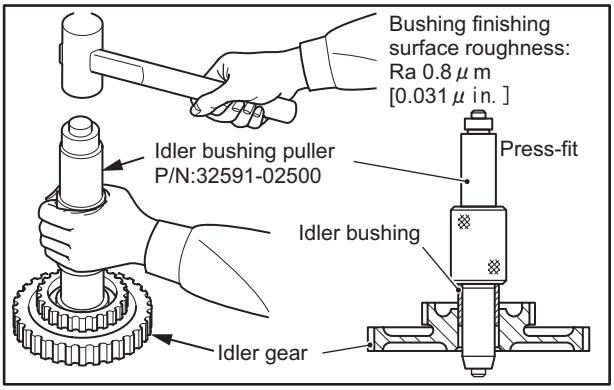
Measuring idler gear end play

4.5 Replacing idler bushing

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

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

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

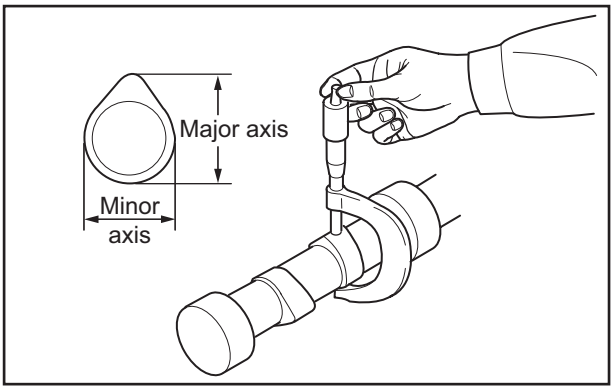


Replacing idler bushing

4.6 Measuring cam lift

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

Item	Standard	Limit
Cam lobe lift (major axis - minor axis)	7.54 to 7.64 mm [0.2968 to 0.3008 in.]	6.79 mm [0.2673 in.]



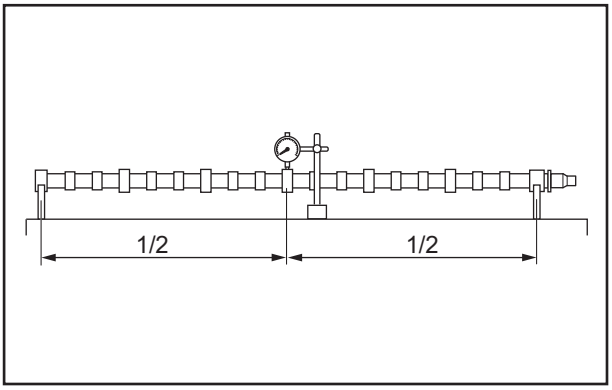
Measuring cam lift

4.7 Measuring camshaft runout

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

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

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

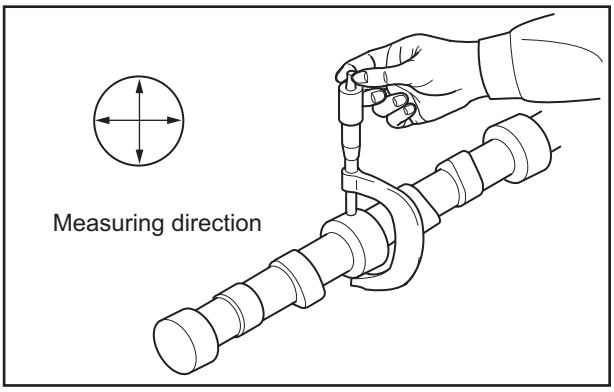


Measuring camshaft runot

4.8 Measuring camshaft journal outside diameter

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

Item		Nominal	Standard	Limit
Camshaft journal outside diameter	No.1 journal	ø 64 mm [2.52 in.]	63.920 to 63.940 mm [2.5165 to 2.5173 in.]	63.870 mm [2.5146 in.]
	No.2 to No.7 journals	ø 68 mm [2.68 in.]	67.920 to 67.940 mm [2.6740 to 2.6748 in.]	67.870 mm [2.6720 in.]



Measuring camshaft journal outside diameter

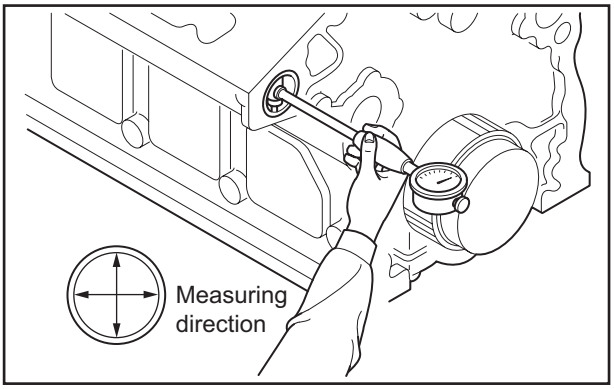
4.9 Inspecting camshaft bushing

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

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

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

Item	Nominal	Standard	Limit
Camshaft bushing inside diameter	ø 68 mm [2.68 in.]	68.000 to 68.030 mm [2.6772 to 2.6783 in,]	68.090 mm [2.6807 in.]
(Only for No.1 journal)	ø 64 mm [2.52 in.]	64.000 to 64.030 mm [2.5197 to 2.5209 in.]	64.090 mm [2.5232 in.]



Measuring camshaft bushing inside diameter

4.10 Replacing camshaft bushings

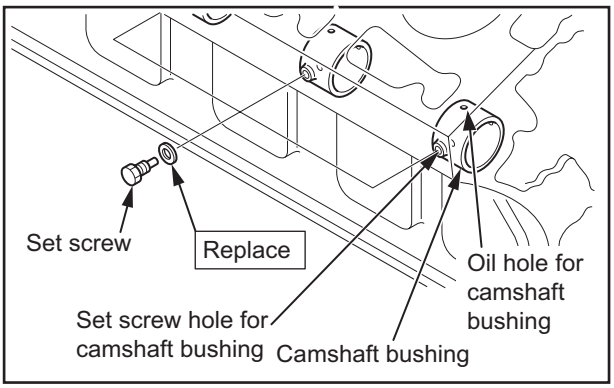
CAUTION

(a) Before tightening the set screw, be sure to check that the set screw is in alignment with the set screw hole in the camshaft bushing.
Make sure that the oil hole in the bushing is in alignment with that in the oil gallery.

(b) Always replace the sealing washer with a new one once it is removed.

(1) Remove the set screws from the side of the crankcase and then remove the camshaft bushings.

(2) Arrange new camshaft bushings as shown at right, then secure them with the set screws.

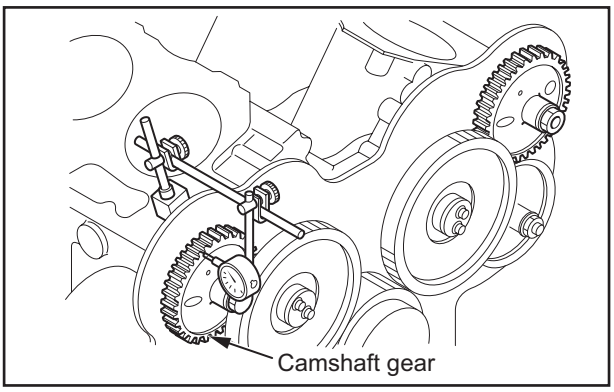


Replacing camshaft bushing

4.11 Measuring camshaft end play

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

Item	Standard	Limit
Camshaft end play	0.20 to 0.30 mm [0.0080 to 0.0120 in.]	0.40 mm [0.0157 in.]



Measuring camshaft end play

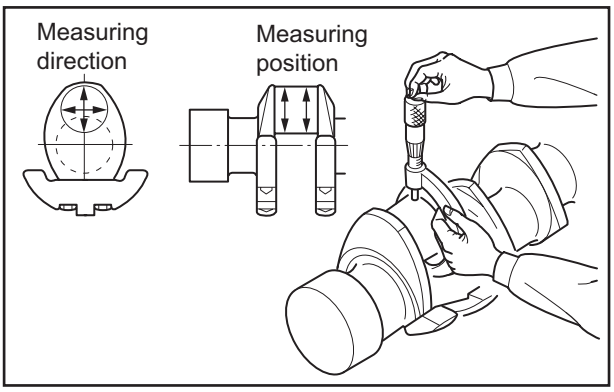
5. Inspecting and repairing crankcase, crankshaft and main bearing

5.1 Measuring crankshaft crankpin and journal outside diameters

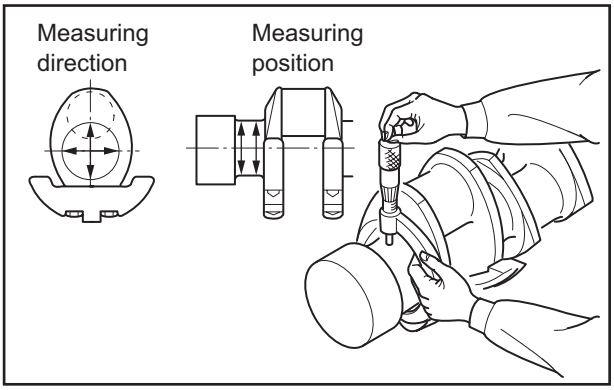
(1) Measure the outside diameter of the crankpins and crank journals. If the limit is exceeded, grind the pin or journal to fit the diameter of the next undersize bearing.

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

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



Measuring crankpin diameter



Measuring crankshaft journal outside diameter

Item			Nominal	Standard	Limit
Crank pin outside diameter			ø 104 mm [4.10 in.]	103.900 to 103.920 mm [4.0905 to 4.0913 in.]	103.860 mm [4.0890 in.]
Crankshaft journal outside diameter			ø 130 mm [5.12 in.]	129.880 to 129.900 mm [5.1134 to 5.1142 in.]	129.840 mm [5.1118 in.]
Distance between centers of journal and crankpin			80 mm [3.15 in.]	79.900 to 80.100 mm [3.1102 to 3.1535 in.]	-
Crank-pin and journal	Parallelism		-	Deviation of 0.01 mm [0.0004 in.] or less over entire pin length	0.03 mm [0.0012 in.]
	Out-of-roundness		-	0.01 mm [0.0004 in.] or less in diameter difference	0.03 mm [0.0012 in.]
	cylindericity		-	0.01 mm [0.0004 in.] or less in diameter difference	0.03 mm [0.0012 in.]
	Fillet radius	Pin	R7 [0.28 in.]	6.8 to 7.0 mm [0.2680 to 0.2760 in.]	-
		Journal	R7 [0.28 in.]	6.8 to 7.0 mm [0.2680 to 0.2760 in.]	-
	Hardness		-	Hv > 620	-
	Finish accuracy		-	Ra 0.2 µm [0.008 µin.]	-
Angular deviation between pins			-	± 0.3°	-

5.2 Grinding crankshaft

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

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

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

Grinding dimensions for undersize crankshaft

Grinding parts	Under-size	Finish dimension	Out-of-round-ness	Cylin-dericity
Crankpin diameter	0.25 mm [0.01 in.]	103.65 to 103.67 mm [4.0807 to 4.0815 in.]	0.01 mm [0.0004 in.] or less in diameter difference	0.01 mm [0.0004 in.] or less in diameter difference
	0.50 mm [0.02 in.]	103.40 to 103.42 mm [4.0709 to 4.0716 in.]		
	0.75 mm [0.03 in.]	103.15 to 103.17 mm [4.0610 to 4.0618 in.]		
	1.00 mm [0.04 in.]	102.90 to 102.92 mm [4.0512 to 4.0520 in.]		
Crankshaft journal outside diameter	0.25 mm [0.01 in.]	129.63 to 129.65 mm [5.1035 to 5.1043 in.]		
	0.50 mm [0.02 in.]	129.38 to 129.40 mm [5.094 to 5.0945 in.]		
	0.75 mm [0.03 in.]	129.13 to 129.15 mm [5.080 to 5.0846 in.]		
	1.00 mm [0.04 in.]	128.88 to 128.90 mm [5.074 to 5.0748 in.]		

5.3 Measuring crankshaft end play

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

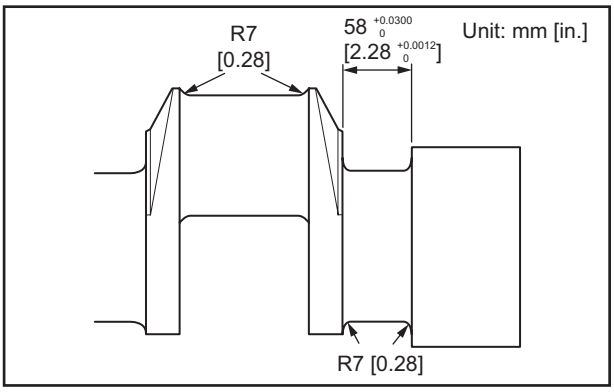
(2) If the limit is still exceeded after a new thrust plate has been installed, use an oversize thrust plate.

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

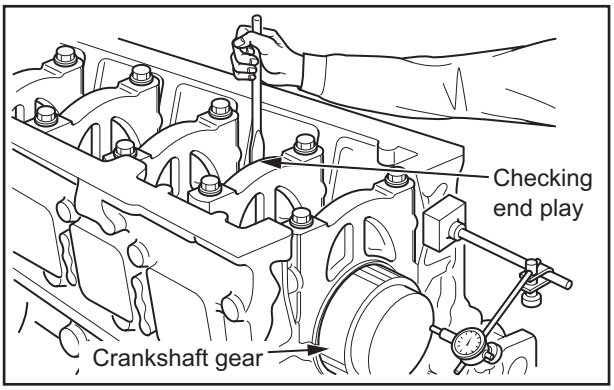
Item	Standard	Limit
Crankshaft end play	0.200 to 0.395 mm [0.0079 to 0.0156 in.]	0.500 mm [0.0197 in.]

Note: If use of oversized thrust plates brings the end play below the standard value, grind the crankshaft thrust journal as appropriately as possible.

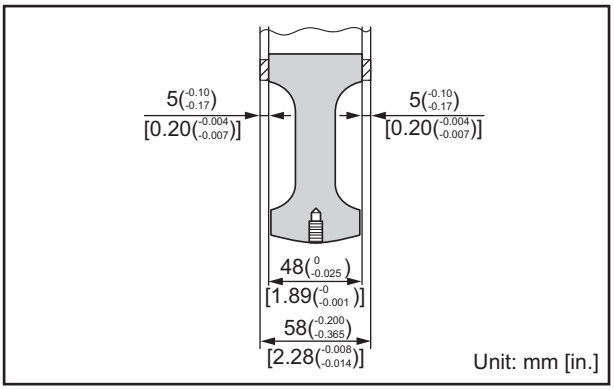
Measure of over size	O.S. plates for rear only.	O.S. plates for rear only front.	Toler-ance
+0.25 mm O.S.	58.25 mm [2.2933 in.]	58.500 mm [2.6303 in.]	$^{+0.03}_{0}$ mm [$^{+0.0012}_{0}$ in.]
+0.50 mm O.S.	58.50 mm [2.3031 in.]	59.00 mm [2.3288 in.]	
+0.75 mm O.S.	58.75 mm [2.3130 in.]	59.50 mm [2.3425 in.]	



Width of crankshaft thrust bearing surface



Measuring crankshaft end play



Thrust plate dimensions

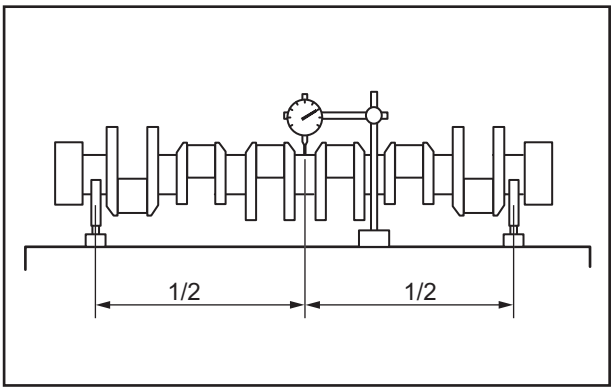
5.4 Measuring crankshaft runout

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

If the limit is exceeded, replace the crankshaft.

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

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



Measuring crankshaft runout

5.5 Replacing front oil seal

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

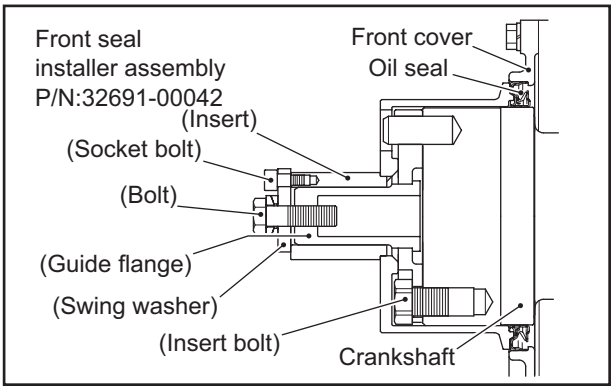
(1) Install the guide to the seal installer.

(2) Apply engine oil to the oil seal lip, and place the oil seal lip in the seal installer.

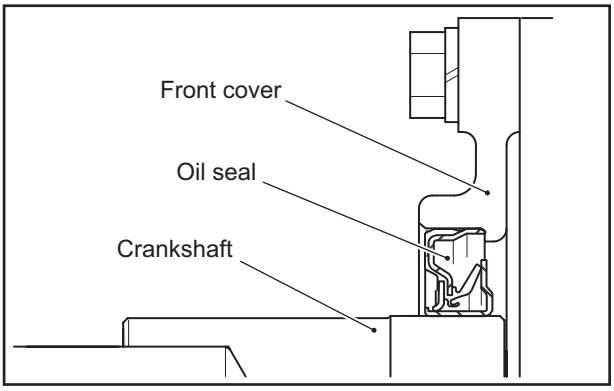
(3) Clean the oil seal contacting surface, and install the front seal installer with the oil seal to the crankshaft.

(4) Tighten the bolt until the seal installer contacts the guide.

Note: The position of oil seal is where the installer contacts the guide.



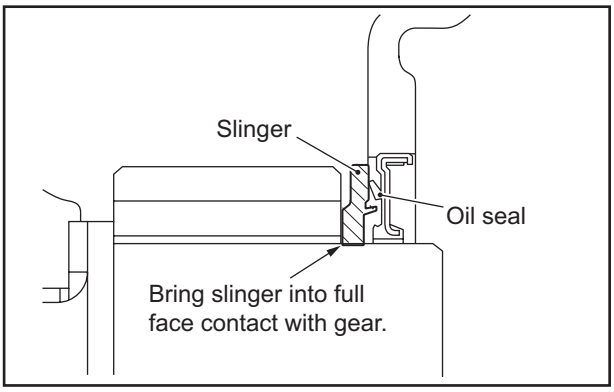
Replacing front oil seal (1)



Replacing front oil seal (2)

5.6 Replacing rear oil seal slinger

Inspect the rear oil seal slinger. If any abnormalities that could lead to oil leak are found, replace the slinger with a new one as instructed below.

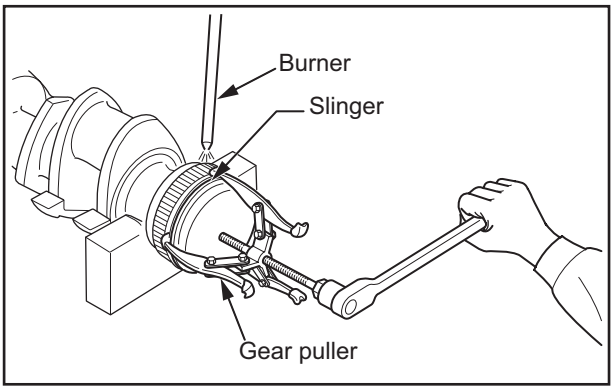


Replacing rear oil seal slinger

5.6.1 Removing oil seal slinger

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

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

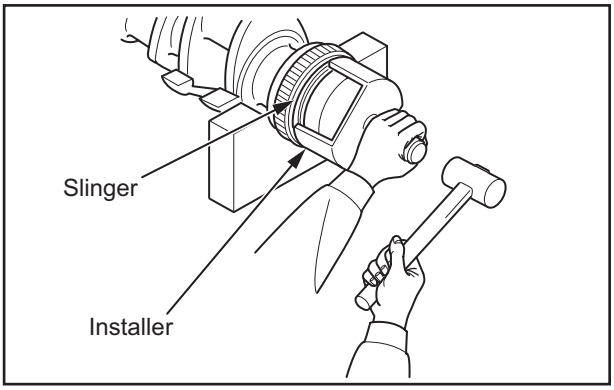


Removing oil seal slinger

5.6.2 Installing oil seal slinger

Heat a new slinger to a temperature of at least 110°C [230°F] and fit it onto the tip of the installer. Then, drive the slinger onto the crankshaft until it is firmly attached to the gear.

If it stops halfway up to the gear, tap the installer on the center or the shoulder using a copper hammer.



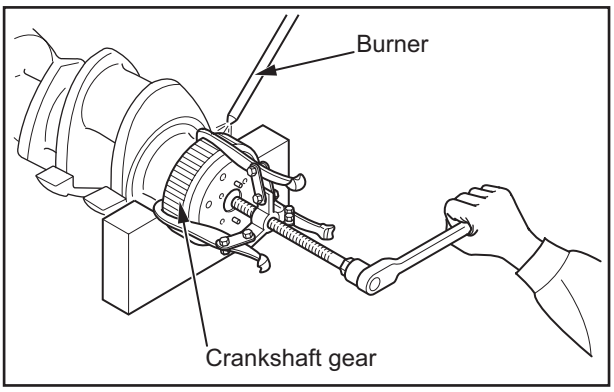
Installing oil seal slinger

5.7 Replacing crankshaft gear

5.7.1 Removing crankshaft gear

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

Note: (a) Do not strike on the gear to remove it.
(b) Do not heat the gear for longer than necessary.



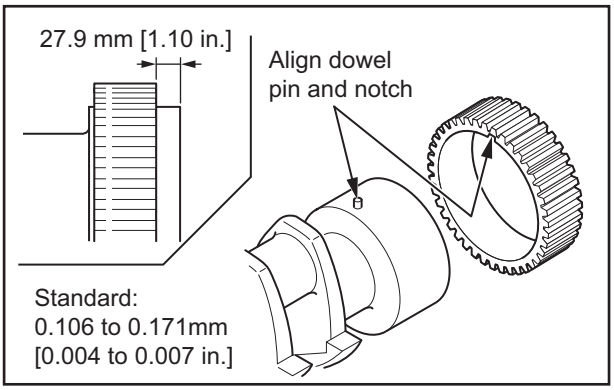
Replacing crankshaft gear

5.7.2 Installing crankshaft gear

CAUTION

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

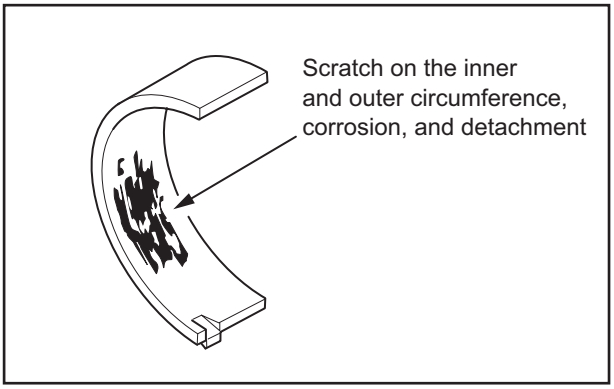
(1) Before installing the crankshaft gear, measure the crankshaft diameter and the bore diameter of the crankshaft gear to confirm that the specified amount of interference is assured.
(2) Heat the crankshaft gear to a temperature of 180 to 200°C [356 to 392°F]. Position the crankshaft gear such that its notch is aligned with the dowel pin on the crankshaft, and tap the end face of the gear lightly with a copper hammer to fit the gear into position.



Installing crankshaft gear

5.8 Inspecting main bearing surface

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



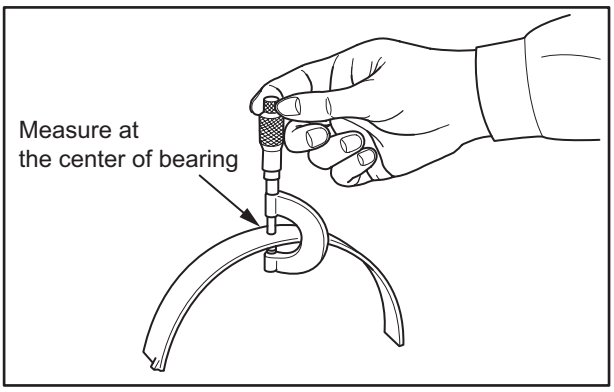
Inspecting main bearing surfaces

5.9 Measuring thickness of main bearing shell

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

Item		Nominal	Standard	Limit
Thickness of main bearing shell at center	STD	3.500 mm [0.1378 in.]	3.482 to 3.500 mm [0.1371 to 0.1378 in.]	3.450 mm [0.1358 in.]
	-0.25 mm [-0.01 in.]	3.625 mm [0.1427 in.]	3.607 to 3.625 mm [0.1420 to 0.1427 in.]	3.575 mm [0.1407 in.]
	-0.50 mm [-0.02 in.]	3.750 mm [0.1476 in.]	3.732 to 3.750 mm [0.1469 to 0.1476 in.]	3.700 mm [0.1457 in.]
	-0.75 mm [-0.03 in.]	3.875 mm [0.1526 in.]	3.857 to 3.875 mm [0.1519 to 0.1526 in.]	3.825 mm [0.1506 in.]
	-1.00 mm [-0.04 in.]	4.000 mm [0.1575 in.]	3.982 to 4.000 mm [0.1568 to 0.1575 in.]	3.950 mm [0.1555 in.]

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



Measuring main bearing thicknesss

5.10 Replacing main bearing

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

5.11 Measuring crankcase top surface distortion

CAUTION

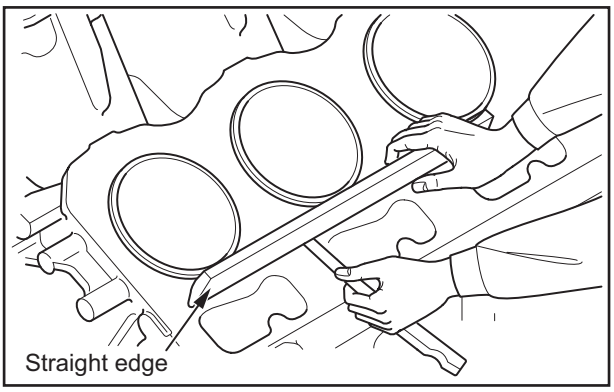
Refacing of cylinder head should be kept to an absolute minimum.

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

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

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

Item	Standard	Limit
Distortion of crankcase top surface	0.05 mm [0.0020 in.] or less	0.20 mm [0.0079 in.]



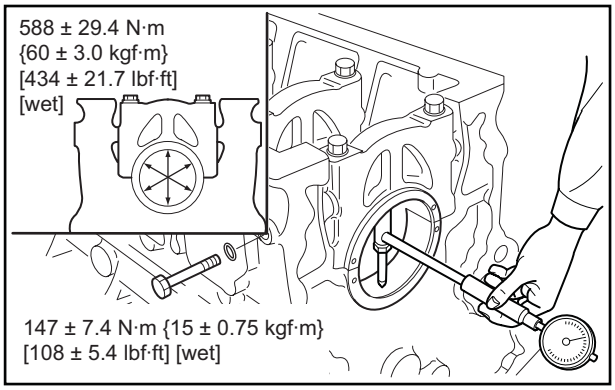
Measuring crankcase top surface distortion

5.12 Measuring main bearing fitting bore

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

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

Item	Nominal	Standard	Limit
Measuring inside diameter of main bearing housing	ø 137 mm [5.39 in.]	137.000 to 137.025 mm [5.3940 to 5.3950 in.]	137.045 mm [5.3955 in.]



Measuring main bearing fitting bore

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1. Reassembling crankcase, crankshaft and main bearings

1.1 Installing main bearing upper shells

CAUTION

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

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

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

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

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

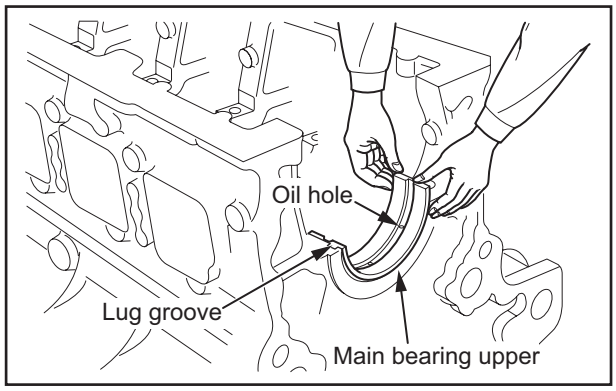
(3) Make sure that the main bearing upper and lower shells are neither damaged nor contaminated.

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

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

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

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



Installing main bearing upper shells

1.2 Installing crankshaft

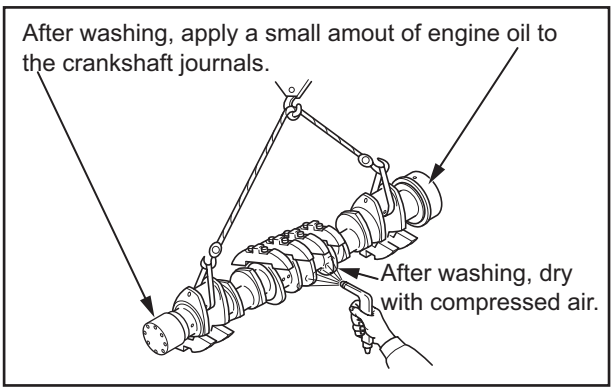
(1) Make sure that the main bearing upper shells that are installed in the crankcase bores have their inner periphery (the surface comes into contact with the journal) lubricated with an even coat of fresh engine oil.

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

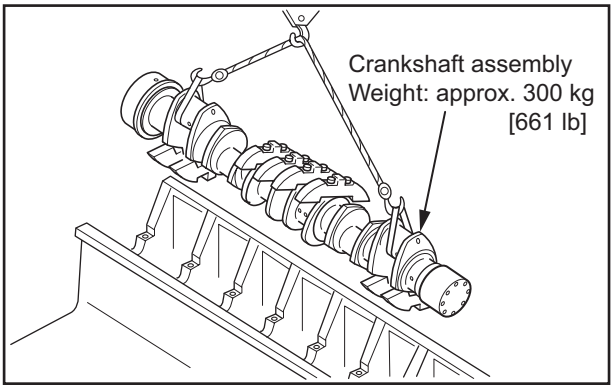
Note: When cleaning the crankshaft, pay special attention to the oil holes in the crank journals and crankpins, and make sure that they are free from any foreign matter.

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

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



Cleaning crankshaft



Installing crankshaft

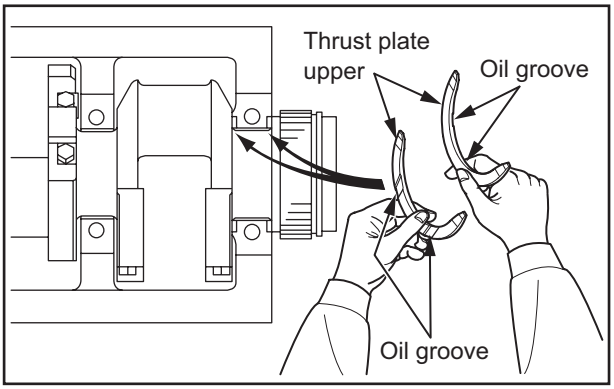
1.3 Installing upper thrust plates

CAUTION

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

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

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



Installing upper thrust plates

1.4 Installing lower main bearing and lower thrust plate

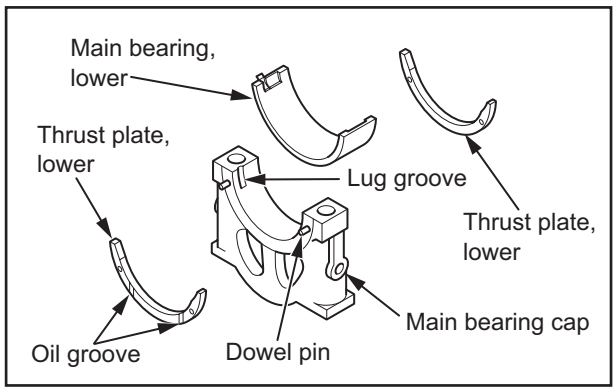
(1) Fit the main bearing lower shells in the main bearing caps while aligning their lug with the notch in the bearing cap.

Note: Make the bearing end protrusion from the bearing cap even at both ends.

(2) Apply a small quantity of engine oil to the inner surface of each main bearing lower shell.

(3) Fit the lower thrust plates on the rearmost main bearing cap while aligning their end holes with the dowel pins on the bearing cap.

Note: Install both thrust plates with the oil grooves facing outward (in a direction away from the bearing cap).



Installing lower main bearing and lower thrust plate

1.5 Installing main bearing caps

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

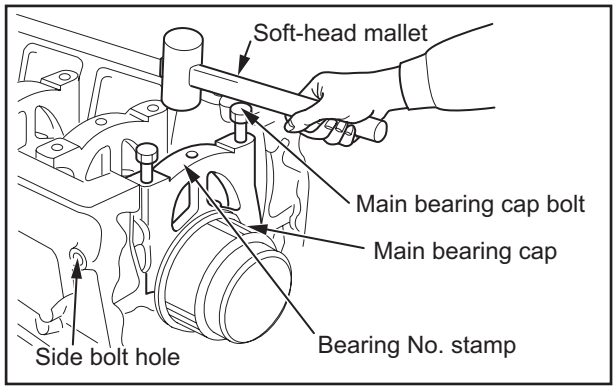
(2) Install the main bearing caps in numerical order from the front end of engine toward the rear end so that the embossed bearing number faces toward the rear end (all lug grooves are aligned in the same side).

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

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

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

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



Installing main bearing caps

1.6 Installing main bearing cap bolts

CAUTION

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

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

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

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

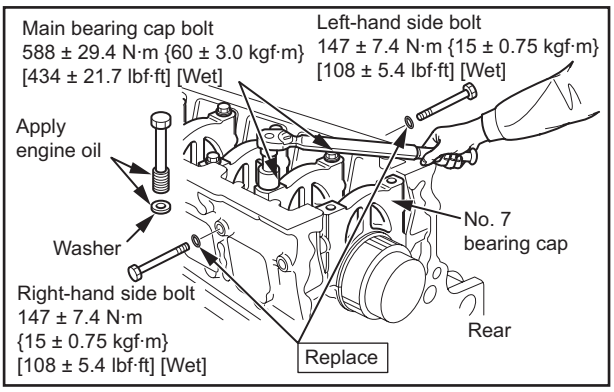
(b) Tighten the side bolts on the right side of the engine to the specified torque.

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

Note: Replace the O-rings with new ones.

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

Measure the crankshaft end play in this condition.



Installing main bearing cap bolts

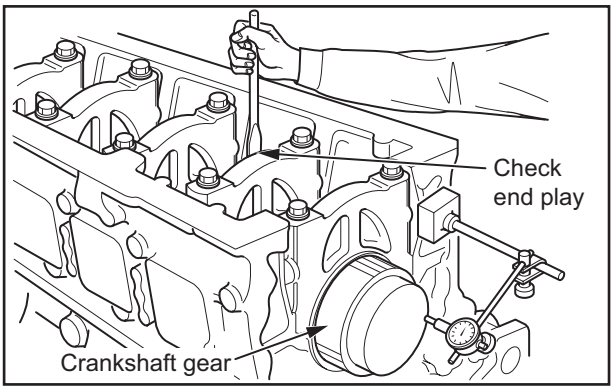
1.7 Measuring crankshaft end play

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

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

Make sure that the camshaft turns freely.

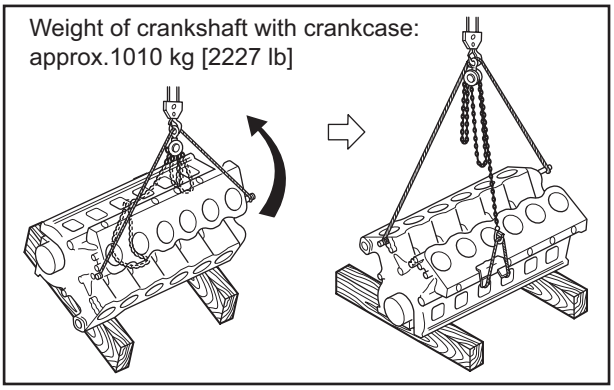
Item	Standard	Limit
Crankshaft end play	0.200 to 0.395 mm [0.0079 to 0.0156 in.]	0.500 mm [0.0197 in.]



Measuring crankshaft end play

1.8 Inverting crankcase

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



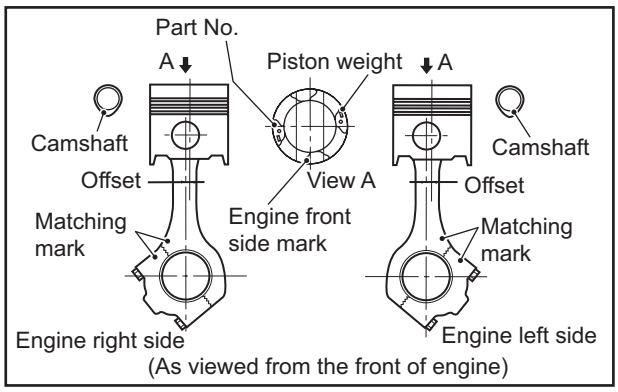
Inverting crankcase

2. Reassembling cylinder liners, pistons and connecting rods

2.1 Reassembling piston and connecting rod

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

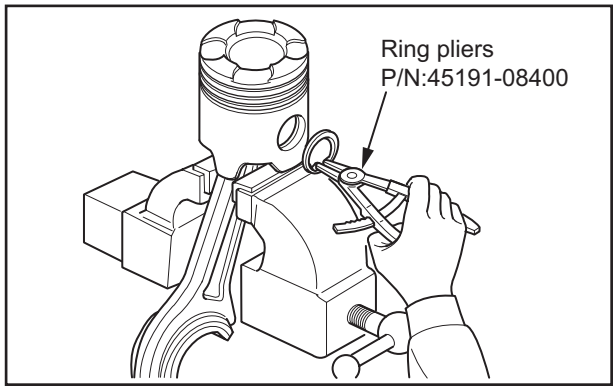
Note: The pistons and piston pins are assembled to each other in clearance fit. However, the piston pins are more easily inserted into the pistons if the pistons are warmed up with a heater or in hot water.



Alignment marks on connecting rod

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

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



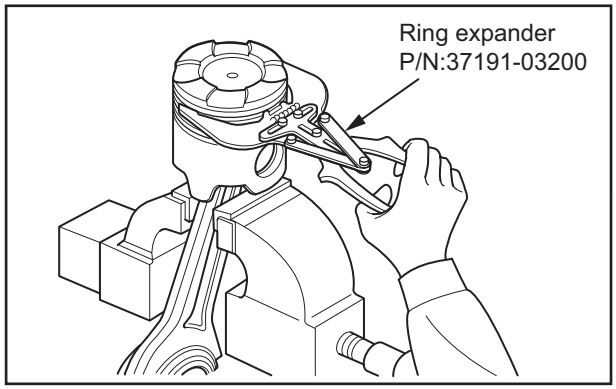
Reassembling piston and connecting rod

2.2 Installing piston

CAUTION

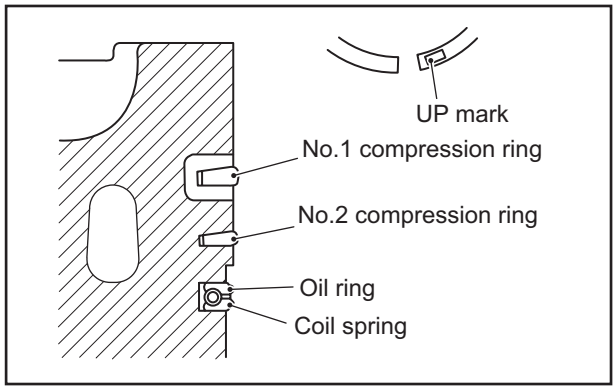
Every piston ring has a top mark such as “R” near the end gap. Install all piston rings with this mark facing upward.

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



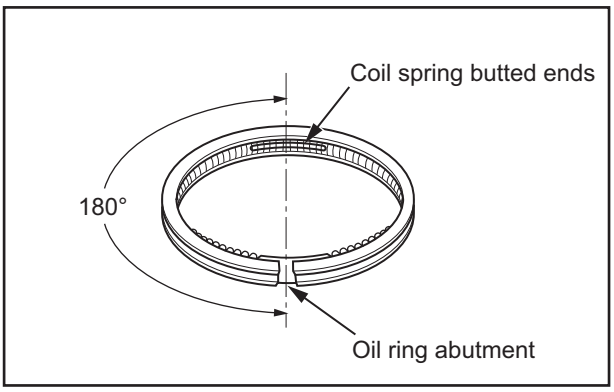
Installing piston rings

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



Piston/piston ring orientation

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

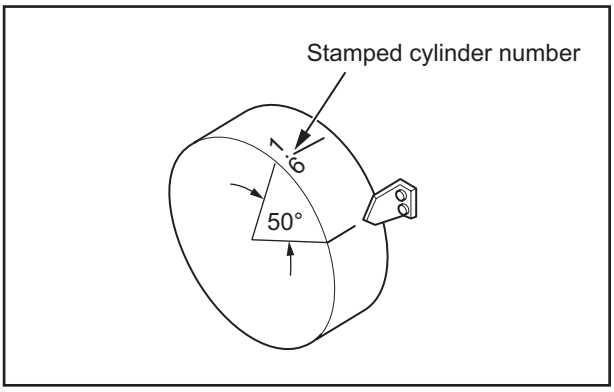


Oil ring end gap/
coil spring joint orientation

2.3 Preparation for Installing Pistons

(1) For the right bank

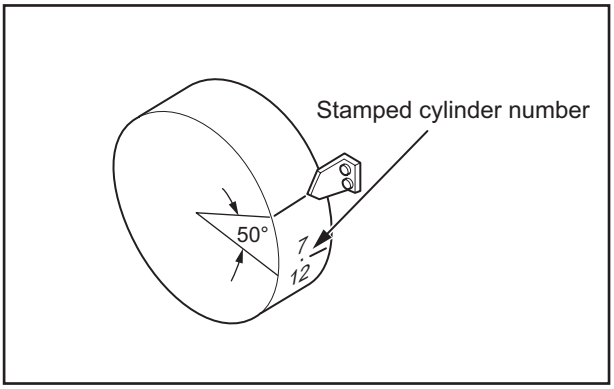
To facilitate piston installation, temporarily install the damper and the pointer. Turn the crankshaft in the normal turning direction to bring the stamped mark of the installing cylinder number to the position approximately 50° before top dead center.



Preparation for installing piston in right-bank cylinder

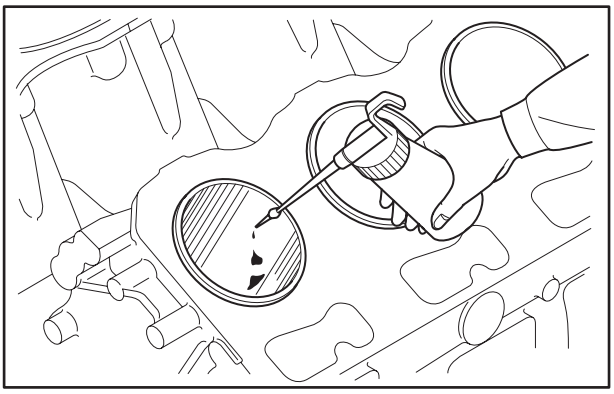
(2) For the left bank

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



Preparation for installing piston in left-bank cylinder

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



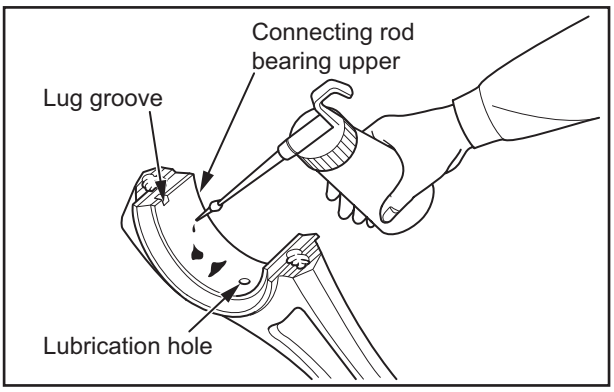
Applying engine oil to cylinder

2.4 Installing upper connecting rod bearing

CAUTION

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

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



Installing upper connecting rod bearing

2.5 Installing piston

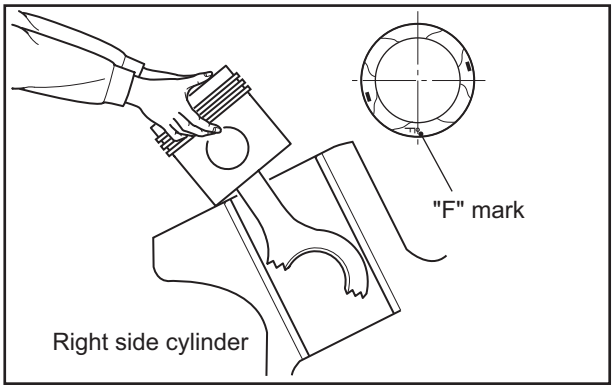
⚠ CAUTION

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

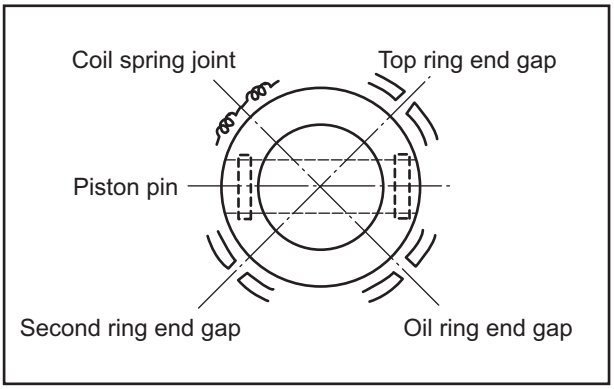
CAUTION

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

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

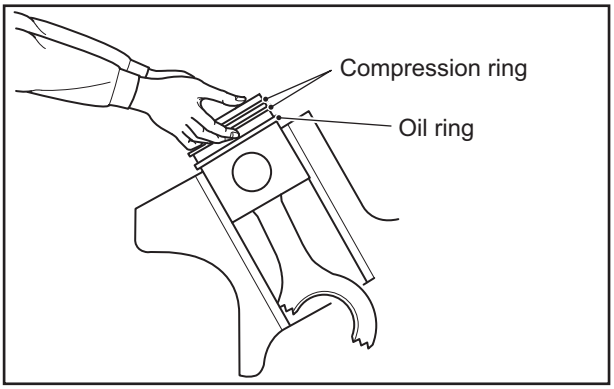


Fitting in connecting rod



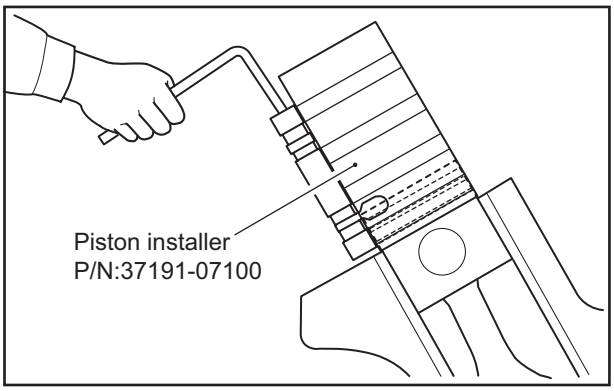
Location of piston ring end gaps

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



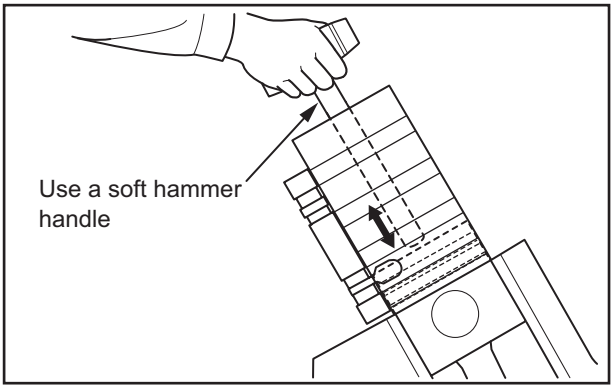
Fitting in piston skirt section

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



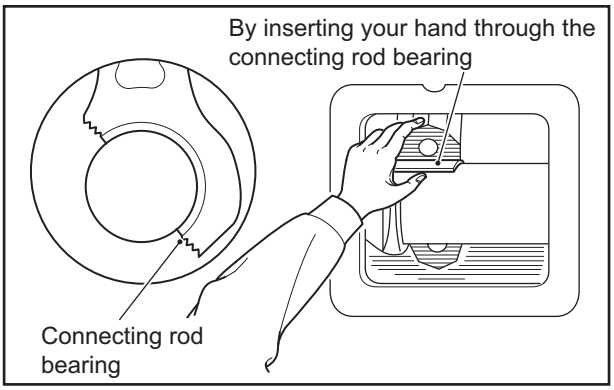
Clamping piston rings

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



Fitting in piston

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



Inspecting connecting rod bearing upper shell position

2.6 Installing connecting rod cap

CAUTION

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

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

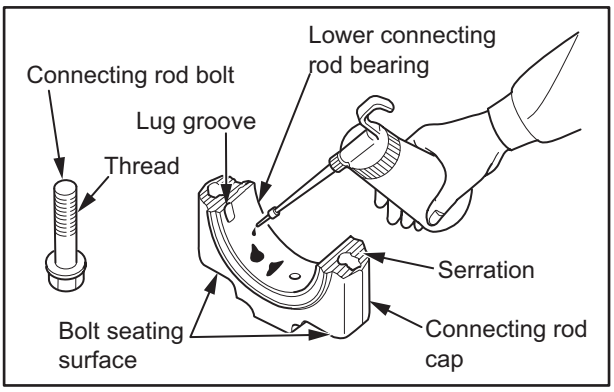
(1) Fit the connecting rod bearing lower shell in the bearing cap while aligning its lug with the notch in the bearing cap.

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

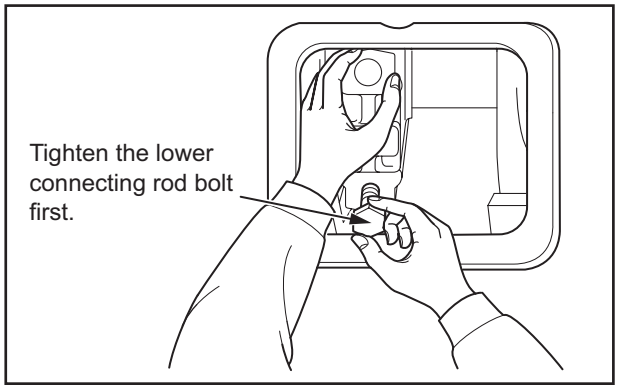
(3) Check that the match mark on the bearing cap and the match mark on the connecting rod are on the same side and in alignment, then install the connecting rod bearing cap to the connecting rod.

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

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



Installing connecting rod bearing lower shell



Temporarily tightening connecting rod bolts

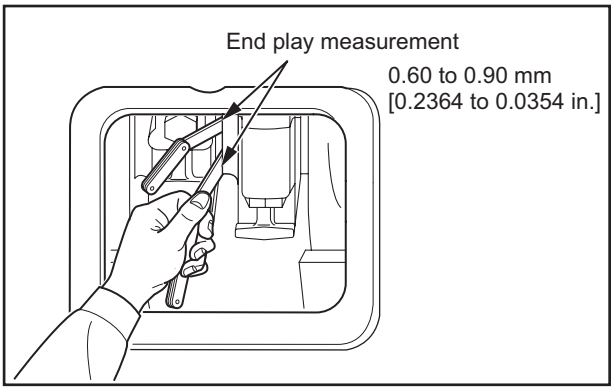
(5) With the bolts tightened loosely, measure the end play of the connecting rod to verify that the clearance is even at above and below the crankpin.

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

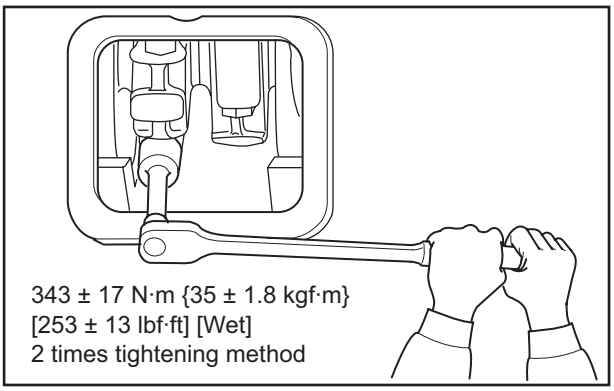
Note: When tightening the connecting rod cap bolts according to the angle method, follow the sequence described below.
(a)Tighten the bolts with a snug torque of 147±7.4 N·m {15±0.75 kgf·m} [108±5.4 lbf·ft].
(b) Further tighten them by turning 45°±3°.
(c) Loosen all bolts, and then tighten them again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

CAUTION

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



Measuring end play of connecting rod



Tightening connecting rod bolts

2.7 Measuring piston protrusion

CAUTION

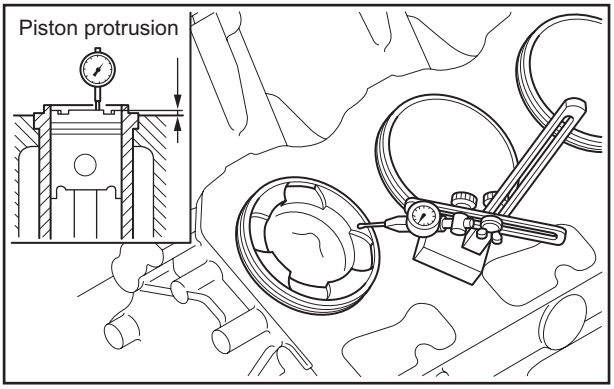
Before installing the cylinder head, measure the piston protrusion on all cylinders to verify that they are normal.

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

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

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

Item	Standard
Piston protrusion	0.38 to 0.89mm [0.0150 to 0.0350 in.]



Measuring piston protrusion

3. Reassembling flywheel, timing gears and camshafts

3.1 Installing front cover

(1) Apply sealant (Heldite) to the mating surfaces of front cover, crankcase, and oil pan, and install the packing on that portion.

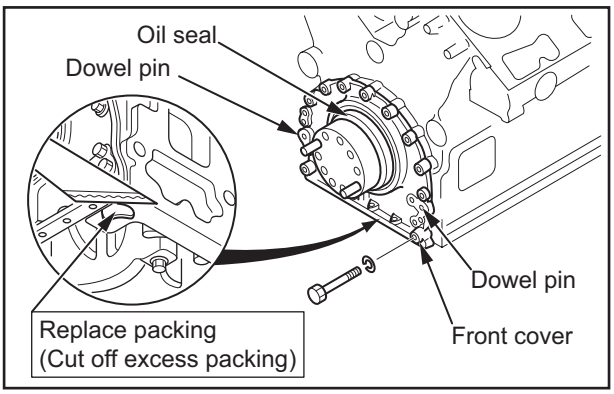
(2) Apply sealant to the packing and install the front cover thereon.

(3) If the dowel pins are worn or when the front cover is replaced, replace the dowel pins with new ones.

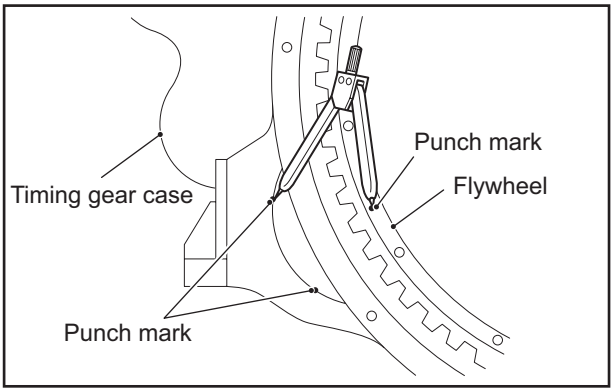
(4) Tighten the front cover mounting bolts.

(5) Install the front cover mounting bolts uniformly.

Note: When the pointer was removed or when the pointer was accidentally moved from its position, check if the piston in No.1 cylinder is at top dead center on the compression stroke or not in the following manner:
Turn the flywheel to the position where its punch mark is at the same distance from the two punch marks stamped on the flywheel housing. The No. 1 cylinder (also No. 6 cylinder) piston must be at the top dead center at this position.



Installing front cover (1)



Installing front cover (2)

3.2 Installing front oil seal

To install front oil seal, use the front oil seal installer assembly.

(1) Apply a clean engine oil evenly to the oil seal lip, and temporarily install the oil seal to the front cover.

Note: When installing oil seal, pay attention to the orientation, taking care not to damage the seal.

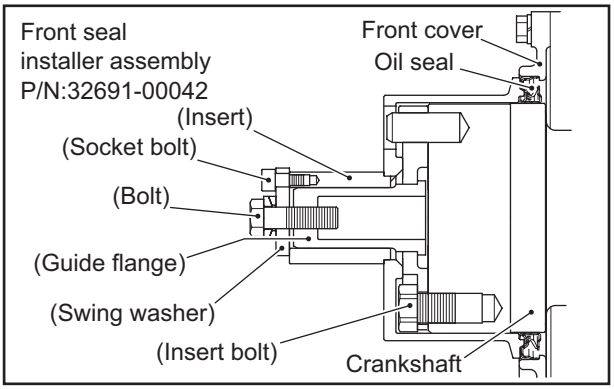
(2) Install the front guide flange onto the crankshaft, and fix it with insert bolt.

(3) Set the oil seal to the insert and install it to the guide flange.

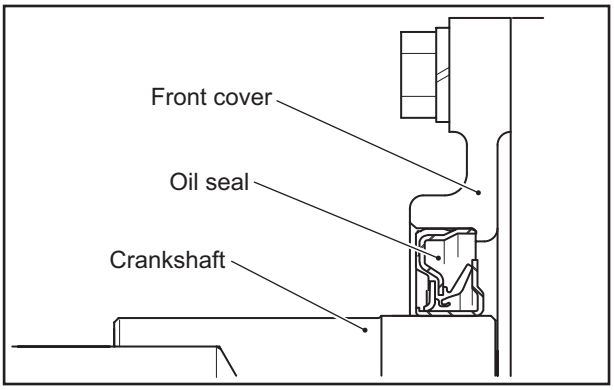
(4) Tighten the bolt attached to the insert to install the oil seal into the front cover.

(5) Loosen the socket bolt, remove the swing washer from the bolt and pull out the insert.

(6) Remove the insert bolt, and remove the guide flange from the crankshaft.



Installing front oil seal (1)



Installing front oil seal (2)

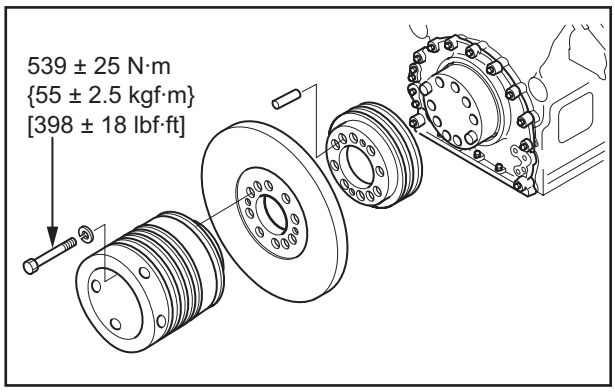
3.3 Installing coupling, damper and crankshaft pully

(1) Install the crankshaft pulley, damper and coupling in this order onto the crankshaft while aligning the dowel pin holes with the dowel pins on the crankshaft.

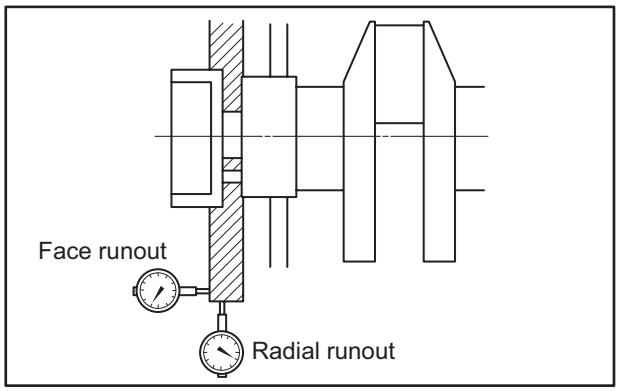
(2) Tighten the coupling mounting bolts to the specified torque.

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

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



Installing coupling, damper and crankshaft pully



Measuring damper face and radial runouts

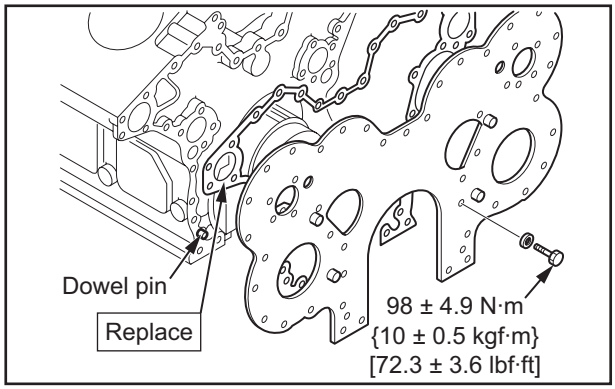
3.4 Installing rear plate

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

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

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

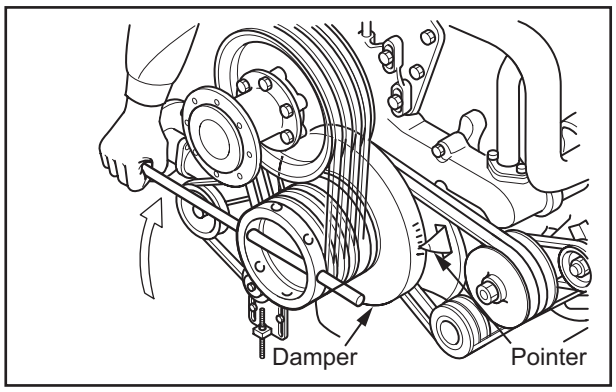
(3) Make sure that the rear plate bottom is flush with the crankcase bottom. If the packing is protruding, cut off the excess neatly.



Installing rear plate

3.5 Rotating crankshaft

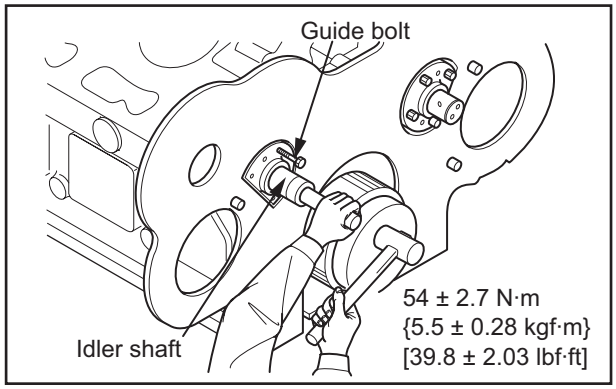
Rotate the crankshaft to bring the No.1 cylinder at the top dead center using a ratchet handle and socket.



Rotating crankshaft

3.6 Installing front idler shaft

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



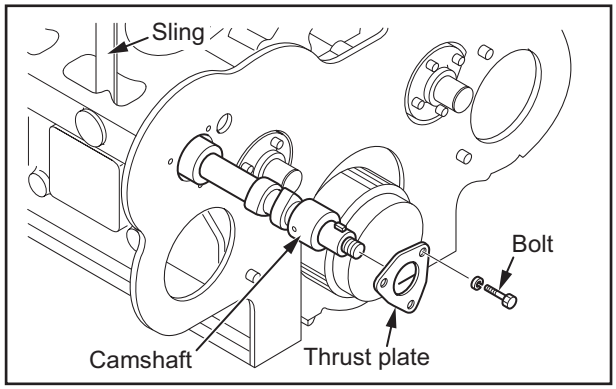
Installing idler shaft

3.7 Installing camshaft

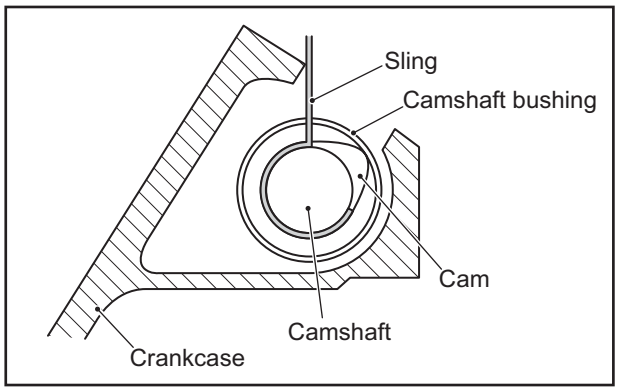
CAUTION

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

(1) Apply engine oil to the inner surface of camshaft bushing.
(2) Insert the camshaft gently to the crankcase.
(3) Install the thrust plate, and tighten the bolt to the specified torque.
(4) Make sure that each camshaft rotates freely.



Installing camshaft (1)



Installing camshaft (2)

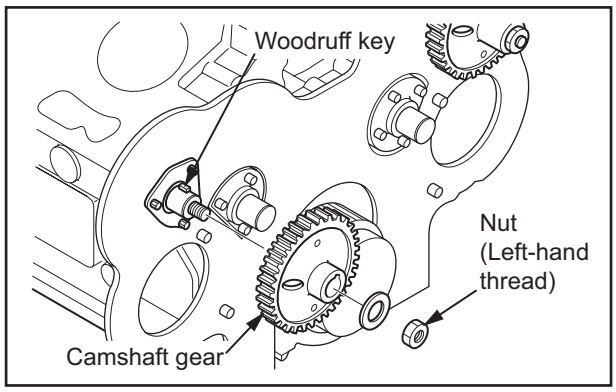
3.8 Installing camshaft gear

(1) Align the keyway in the bore with the woodruff key on the camshaft, and install the camshaft gear onto the camshaft.

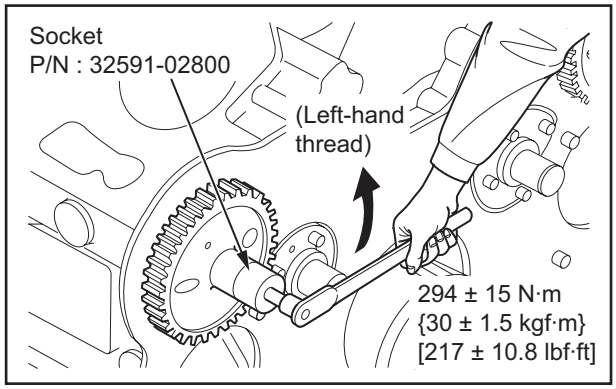
CAUTION

The mounting nut of the camshaft gear has left-hand threads, and must be turned counterclockwise to tighten.

(2) Tighten the nut to the specified torque using a socket wrench.



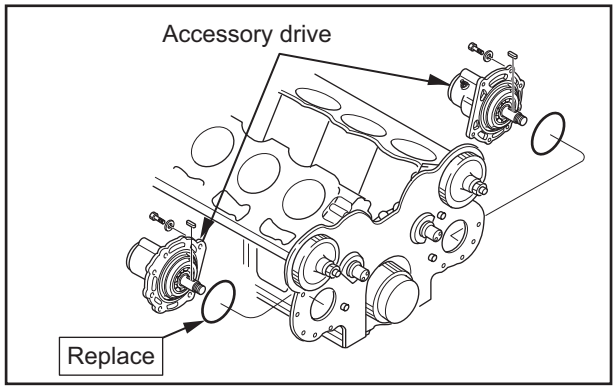
Installing camshaft gear (1)



Installing camshaft gear (2)

3.9 Installing accessory drive

Install new O-ring in the accessory drive. Install the accessory drive to the rear plate, and tighten the bolts.

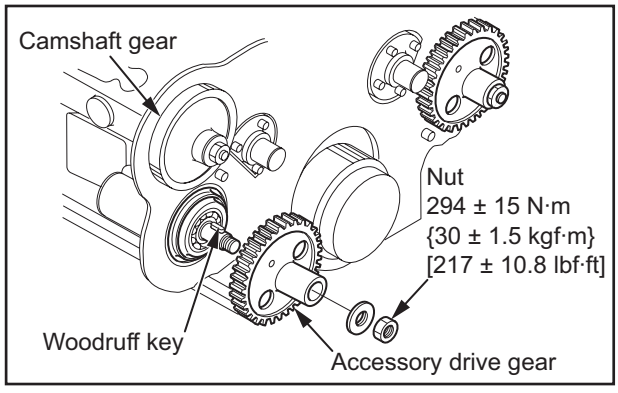


Installing accessory drive

3.10 Installing accessory drive gear

(1) Aligning with the alignment mark on camshaft gear, install the accessory drive gear to the drive shaft with Woodruff key.

(2) Tighten the nut to the specified torque.

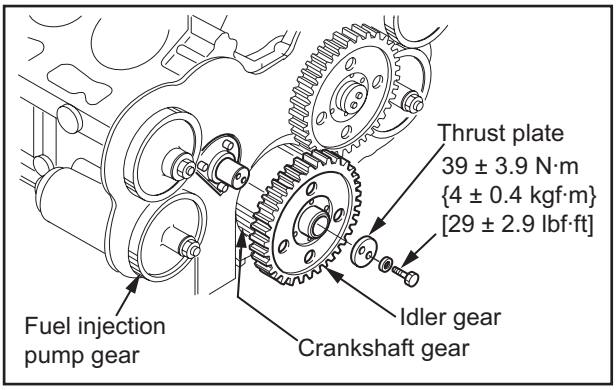


Installing accessory drive gear

3.11 Installing idler gear

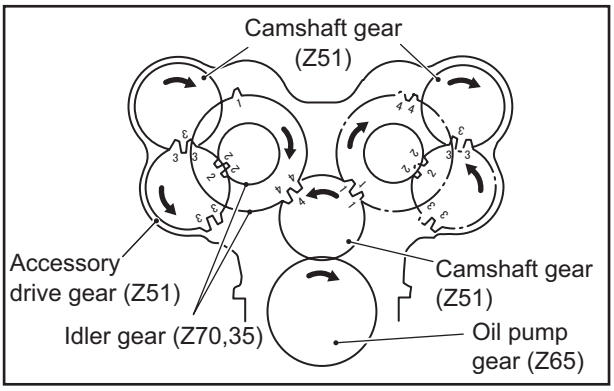
(1) Install the idler gear with its match marks aligned with the marks on the crankshaft gear and accessory drive gear.

(2) Attach the thrust plate to the idler gear and tighten the mounting bolt to the specified torque.



Installing idler gear

(3) Aling the individual match marks on the timing gears as shown in the illustration.

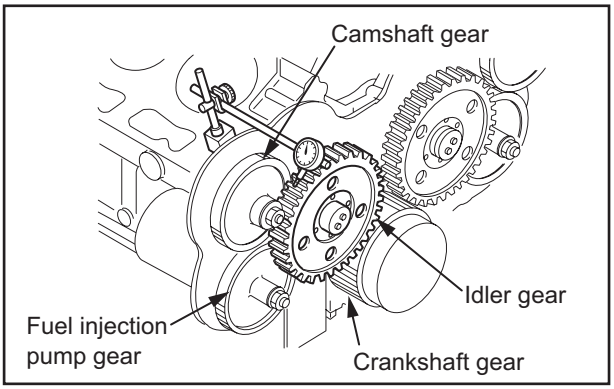


Timing gear train (viewed from flywheel) [Timing gear engagement when No.1 piston is at compression top dead center]

3.12 Measuring timing gear backlash

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

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

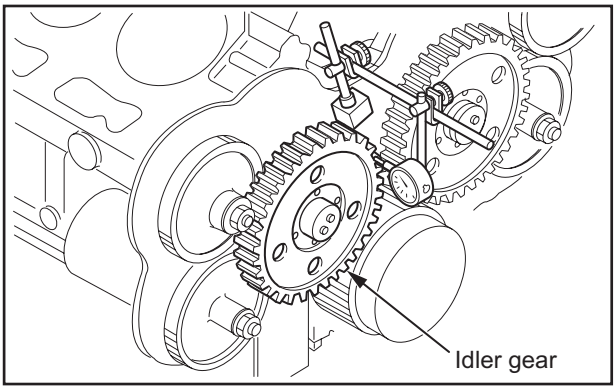


Measuring timing gear backlash

3.13 Measuring end play of idler gear

Measure the end play of the idler gear using a feeler gauge or dial gauge. If the end play exceeds the limit, replace the thrust plate with a new one.

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

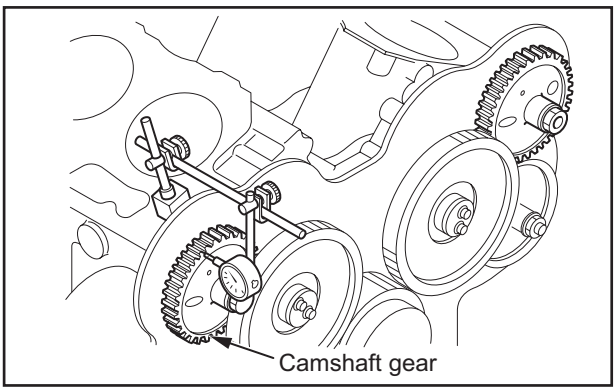


Measuring end play of idler gear

3.14 Measuring camshaft end play

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

Item	Standard	Limit
Camshaft end play	0.20 to 0.30 mm [0.0080 to 0.0120 in.]	0.40 mm [0.0157 in.]



Measuring camshaft end play

3.15 Installing timing gear case

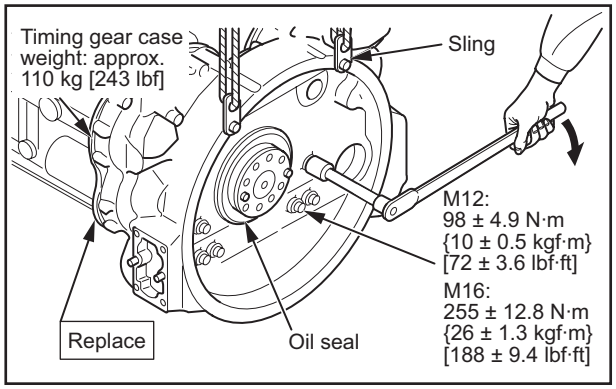
⚠ CAUTION

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

(1) Apply sealant (ThreeBond 1211 or 1207C) to the timing gear case mounting portion of the rear plate, and install the gasket on that portion.
Apply sealant (ThreeBond 1211 or 1207C) to the gasket.

(2) Attach a lifting sling to the timing gear case, and install the timing gear case to the crankcase while bringing the dowel pins and holes in alignment.

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

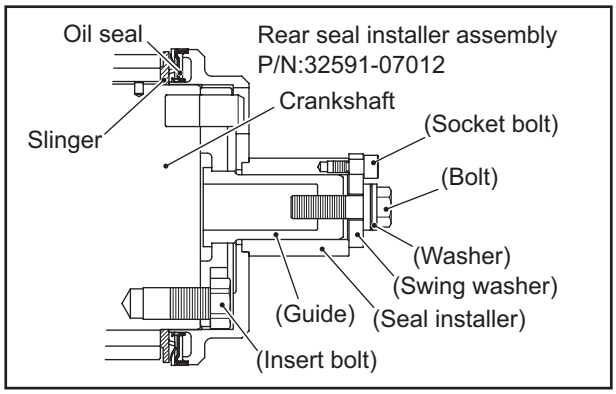


Installing timing gear case

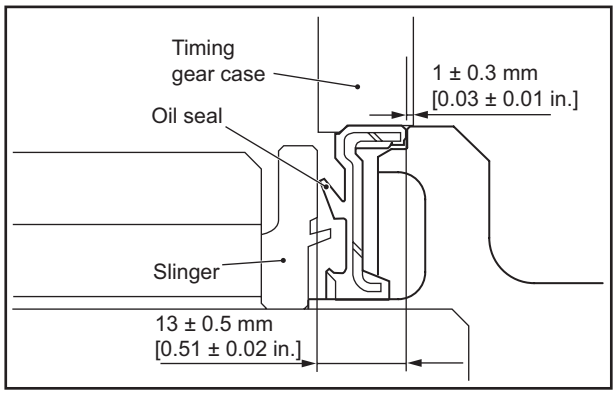
3.16 Installing rear oil seal

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

(1) Install the guide to the crankshaft rear end, and secure it with the insert bolts.
(2) Fit the oil seal to the installer and install the installer to the guide.
(3) Tighten the bolt mounted on the installer to install the oil seal into the timing gear case.
(4) Loosen the socket bolt and push the swing washer out of the bolt, then pull out the installer.
(5) Remove the insert bolts and remove the guide from the crankshaft.



Installing rear oil seal (1)



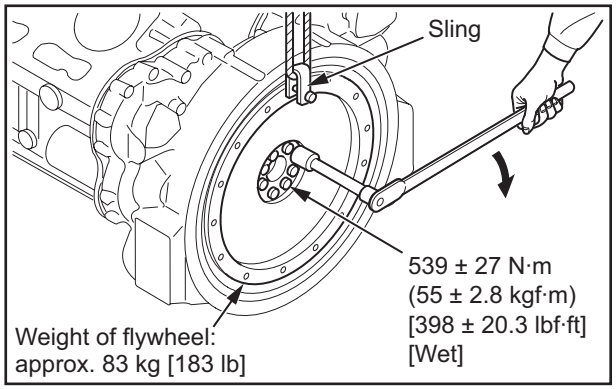
Installing rear oil seal (2)

3.17 Installing flywheel

⚠ CAUTION

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

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

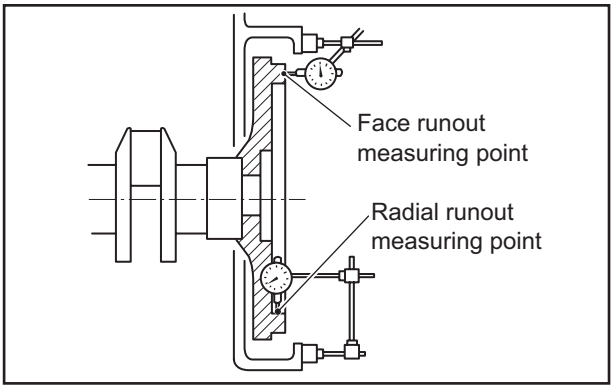


Installing flywheel

3.18 Measuring flywheel face and radial runouts

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

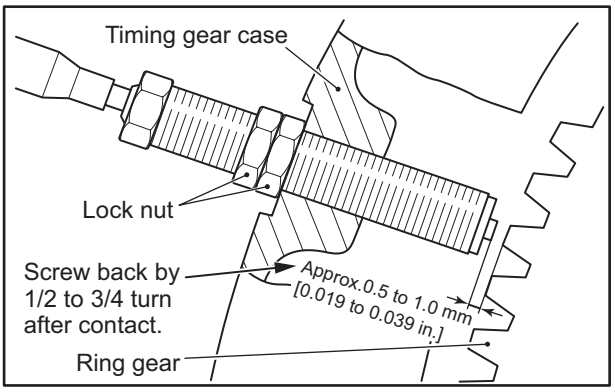
Item	Standard
Face runout	0.285 mm [0.0112 in.] or less
Radial runout	0.127 mm [0.0050 in.] or less



Measuring flywheel face and radial runouts

3.19 Installing pickup

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

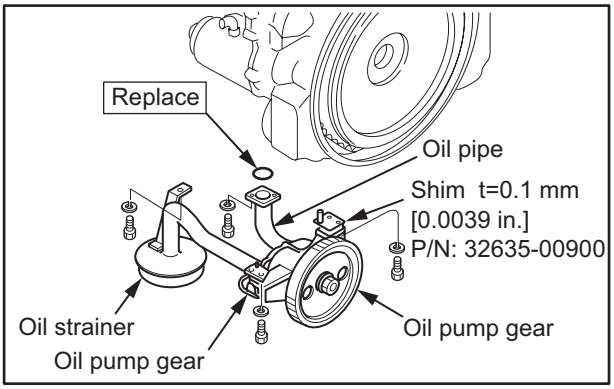


Installing pickup

3.20 Installing oil pump and oil strainer

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

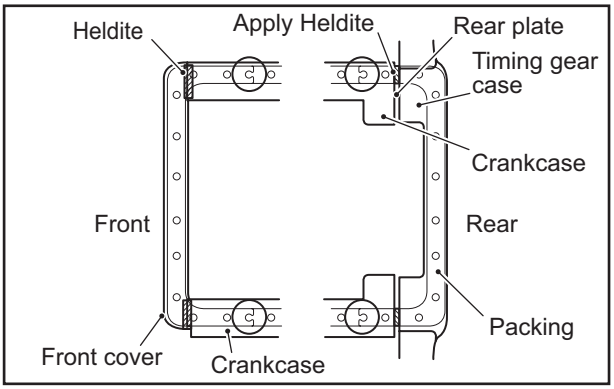
Item	Standard
Backlash between oil pump idler gear and crankshaft gear	0.12 to 0.18 mm [0.0047 to 0.0071 in.]



Installing oil pump and oil strainer

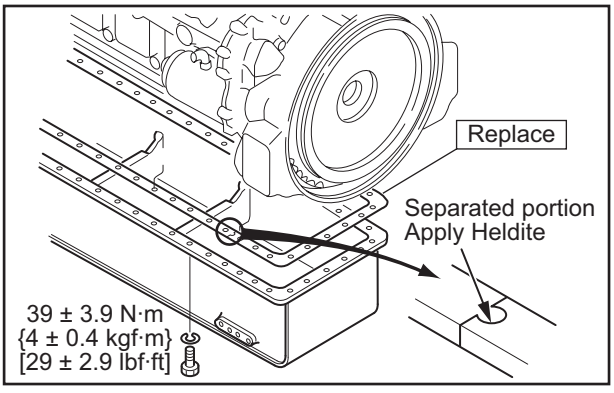
3.21 Installing oil pan

(1) Apply Heldite to the lower faying surfaces of the front cover and the crankcase.
(2) Apply Heldite to the lower faying surfaces of the crankcase, rear plate and timing gear case.



Installing oil pan (1)

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



Installing oil pan (2)

4. Reassembling cylinder heads and valve mechanism

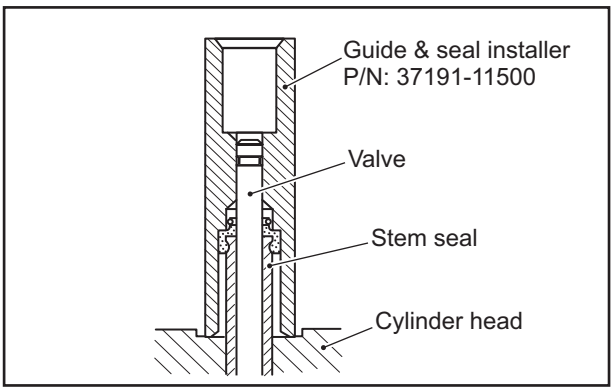
4.1 Reassembling cylinder head

CAUTION

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

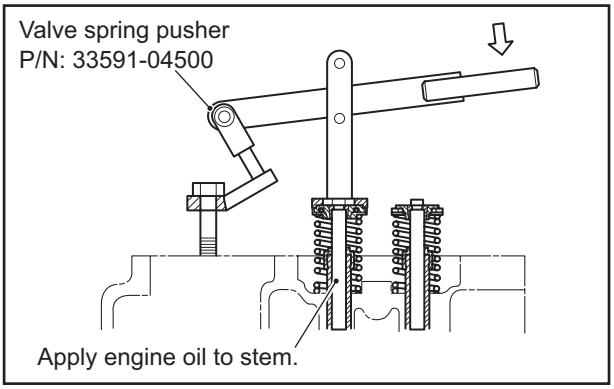
(1) Lubricate the valve stem with engine oil, then fit the valve onto the valve guide.

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



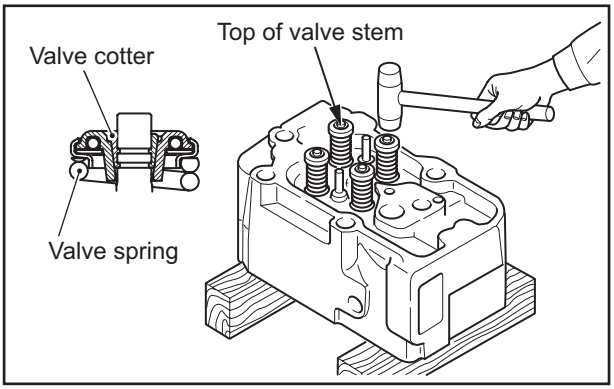
Installing stem seal

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



Installing valve cotter

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



Installing valve

4.2 Applying liquid gasket

CAUTION

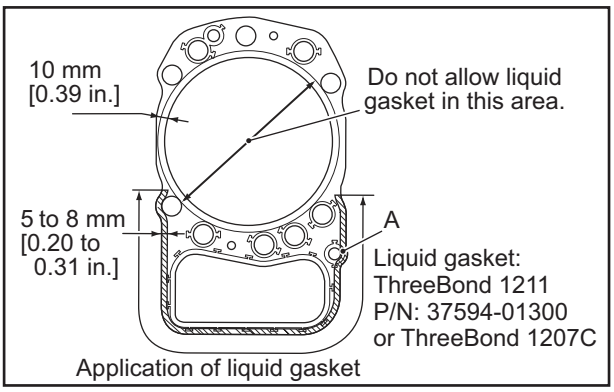
(a) Do not apply liquid gasket more than necessary. Excess liquid gasket could come into contact with O-rings, and cause deformation of O-rings. When applying gasket to portions A and B, in particular, take utmost care since there is little clearance to the O-rings.

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

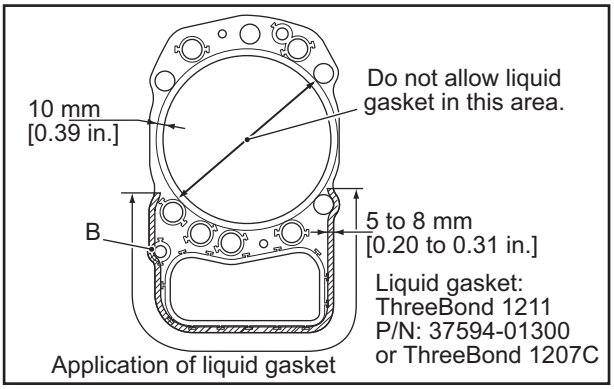
(1) Wipe off oil, grease and dirt thoroughly from the cylinder head gasket.

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

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



Liquid gasket coating area (head side)

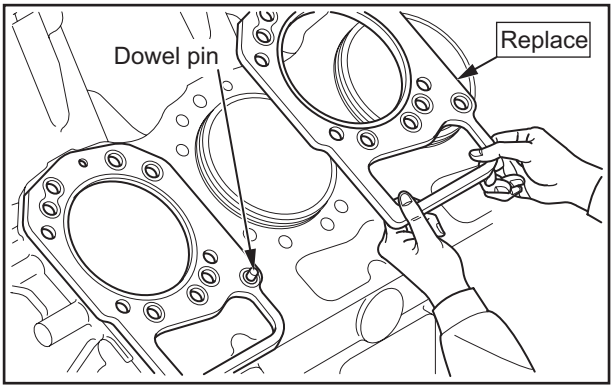


Liquid gasket coating area (crankcase side)

4.3 Installing cylinder head gasket

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

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



Installing cylinder head gasket

4.4 Installing cylinder head assembly

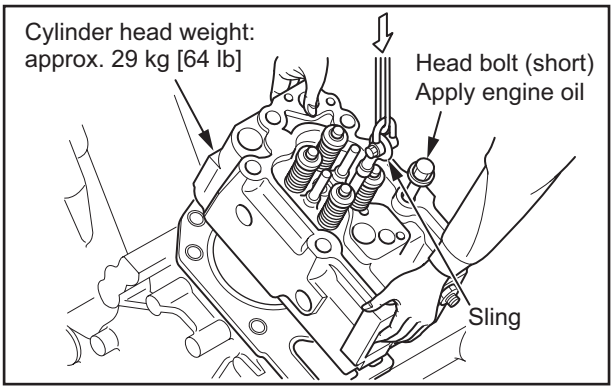
CAUTION

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

Lubricate the cylinder head bolts with engine oil, and wipe off excess oil from the cylinder head bolts before installation.

(1) Attach a sling to the nozzle holder tightening stud of the cylinder head, and lift the cylinder head assembly.

(2) Keep the cylinder head assembly slightly lifted with the dowel pins aligned with their holes, lubricate the threads of short cylinder head bolts with engine oil (except for long bolts that secure the rocker brackets), and loosely tighten the bolts.



Installing cylinder head assemblies

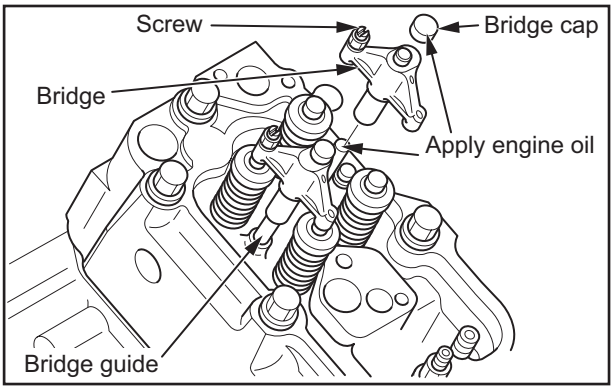
4.5 Installing bridges and bridge cap

(1) Apply engine oil to the bridge guide.

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

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

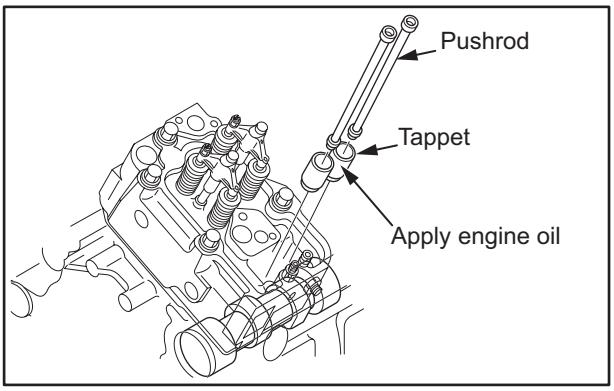
(4) Fit the bridge cap onto the bridge after applying a thin coat of engine oil to the seating surface. At this time, take care not to drop the cap inside the crankcase through the push rod hole.



Installing bridge and bridge cap

4.6 Installing pushrod and tappet

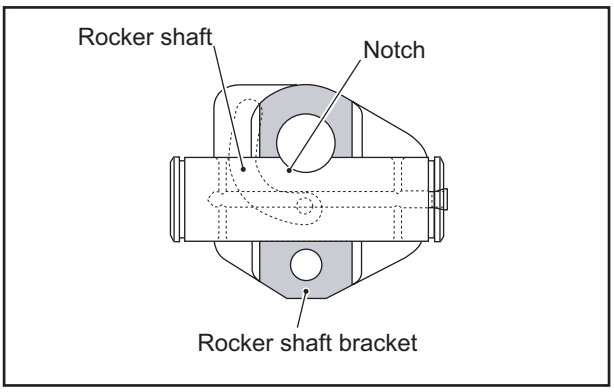
Apply engine oil to the tappet. Slowly place the tappet on the camshaft and then insert the push rod into the tappet.



Installing tappets and push rods

4.7 Reassembling rocker shaft assembly

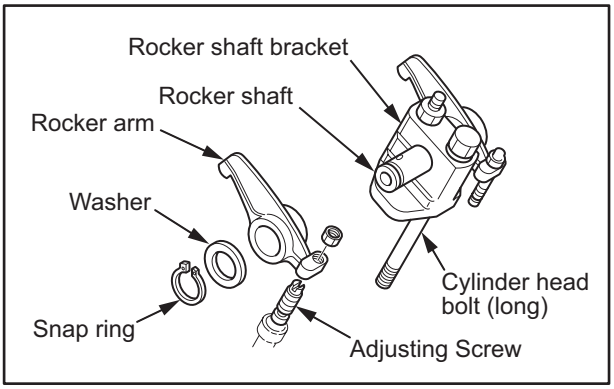
(1) Align the notch of the rocker shaft with the bolt hole in the bracket, and install the rocker shaft into the rocker shaft bracket.



Reassembling rocker shaft assembly (1)

(2) Insert the cylinder head bolt (longer one) through the rocker shaft bracket to secure the rocker shaft.

(3) Install the rocker and washer to each side of the rocker shaft bracket and secure them with a snap ring.



Reassembling rocker shaft assembly (2)

4.8 Installing rocker shaft assembly

CAUTION

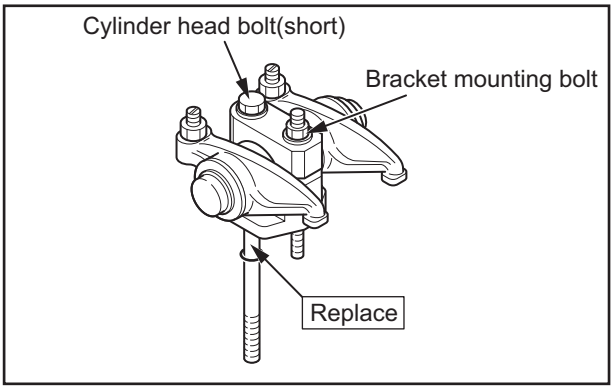
After reassembly, move the rocker arms up and down to make sure they move smoothly.

With the bracket mounting bolt loosely tightened, adjust the bracket position so that the ends of both rockers come into contact equally with the respective bridge cap tops.

Before tightening the bracket mounting bolt to the specified torque, install the cylinder head bolt that also secures the rocker bracket.

(1) Screw the bracket mounting bolt into the rocker shaft bracket.

(2) Fit a new O-ring to the cylinder head bolt and secure the rocker assembly temporarily with the cylinder head bolt.



Installing rocker shaft assembly

4.9 Tightening cylinder head bolts

For tightening cylinder head bolts, two methods are available; one according to tightening torque and one according to tightening angle.

4.9.1 Method according to tightening torque

(1) Tighten the cylinder head bolts to the specified torque in the sequence shown in the illustration.

(2) Loosen all bolts once, and tighten them again in the same manner. (2-time tightening method)

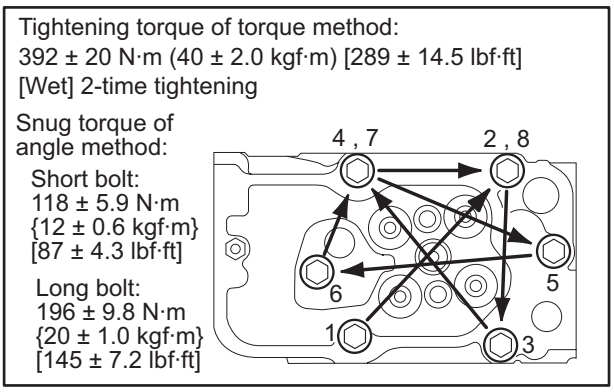
4.9.2 Method according to tightening angle

(1) Tighten the cylinder head bolts to the specified snug torque in the sequence shown in the illustration.

(2) Tighten the cylinder head bolts by turning 30±1.5° in the specified sequence.

(3) Tighten the cylinder head bolts further by turning 30 ± 1.5° in the specified sequence.(Total tightening angle of 60°±3°)

(4) Loosen all bolts once, and tighten them again by repeating the same procedure. (2-time tightening method)



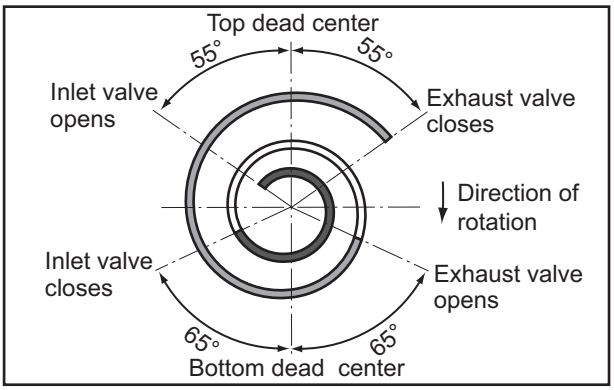
Tightening sequence of cylinder head bolts

4.10 Inspecting valve timing

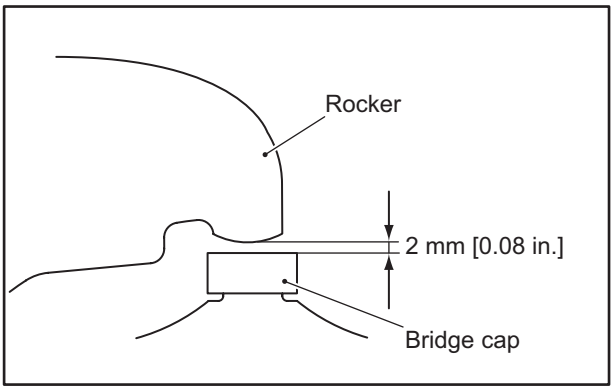
The valve timing will be set in the specified range if each gear is assembled according to the match marks. For verification, however, inspect the valve timing as follows:

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

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

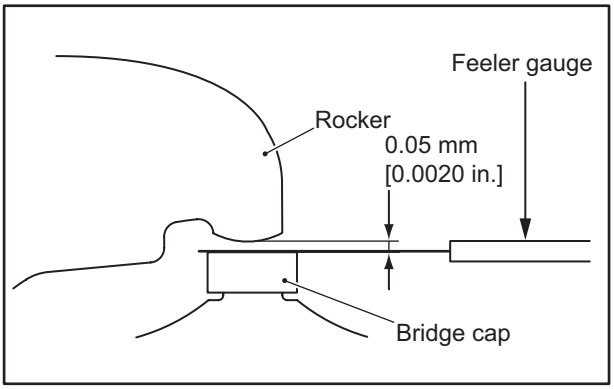


Valve timing diagram
(when valve clearance is standard value)

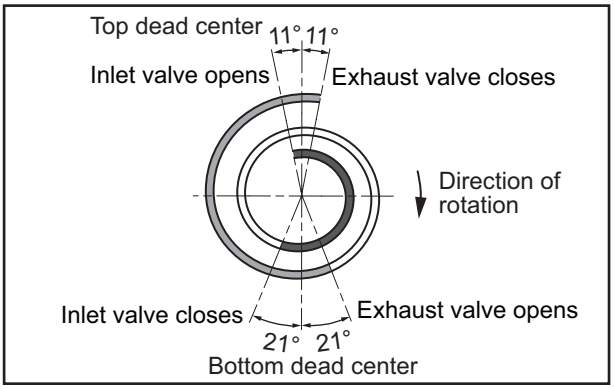


Valve clearance
(with 2 mm [0.08 in.] clearance held on valve side)

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



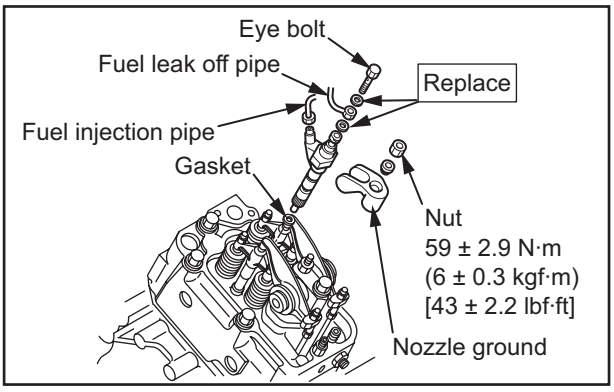
Valve clearance
(with 0.05 mm [0.002 in.] clearance held on valve side)



Inspecting valve timing
(with 2 mm [0.08 in.] clearance held on valve side)

4.11 Installing fuel injection nozzle assemblies

(1) Install the nozzle assembly in the mounting position in the cylinder head. Then, remember to put the gaskets.
(2) Temporarily install the fuel leak off pipe to which the fuel injection pipe and new sealing washer are installed.
(3) Tighten the nozzle gland mounting nut to the specified torque.



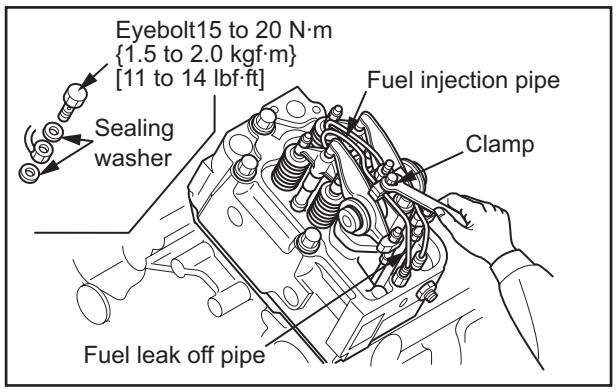
Installing fuel injection nozzle

4.12 Installing fuel pipes

(1) Fully tighten the fuel injection pipe and fuel leak off pipe.

Note: Tighten the eye bolt of the fuel leak off pipe to the specified torque.

(2) Fix the fuel pipe with the clamp.



Installing fuel pipe

4.13 Adjusting valve clearance

Adjust the valve clearance.

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

FUEL SYSTEM

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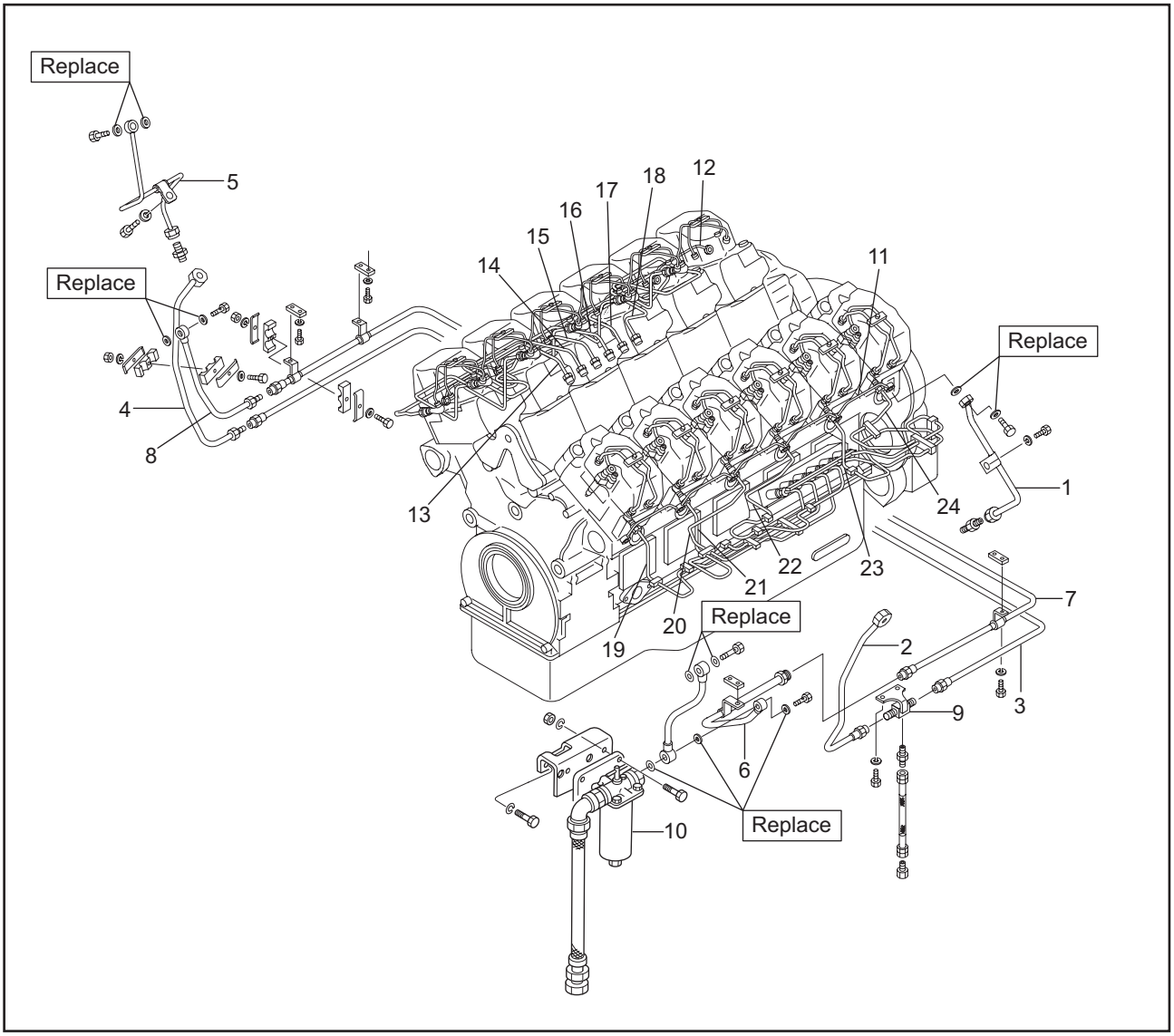
1. Removing fuel system

1.1 Removing fuel injection pipes and fuel leak-off pipes



Removing fuel injection pipes and fuel leak-off pipes

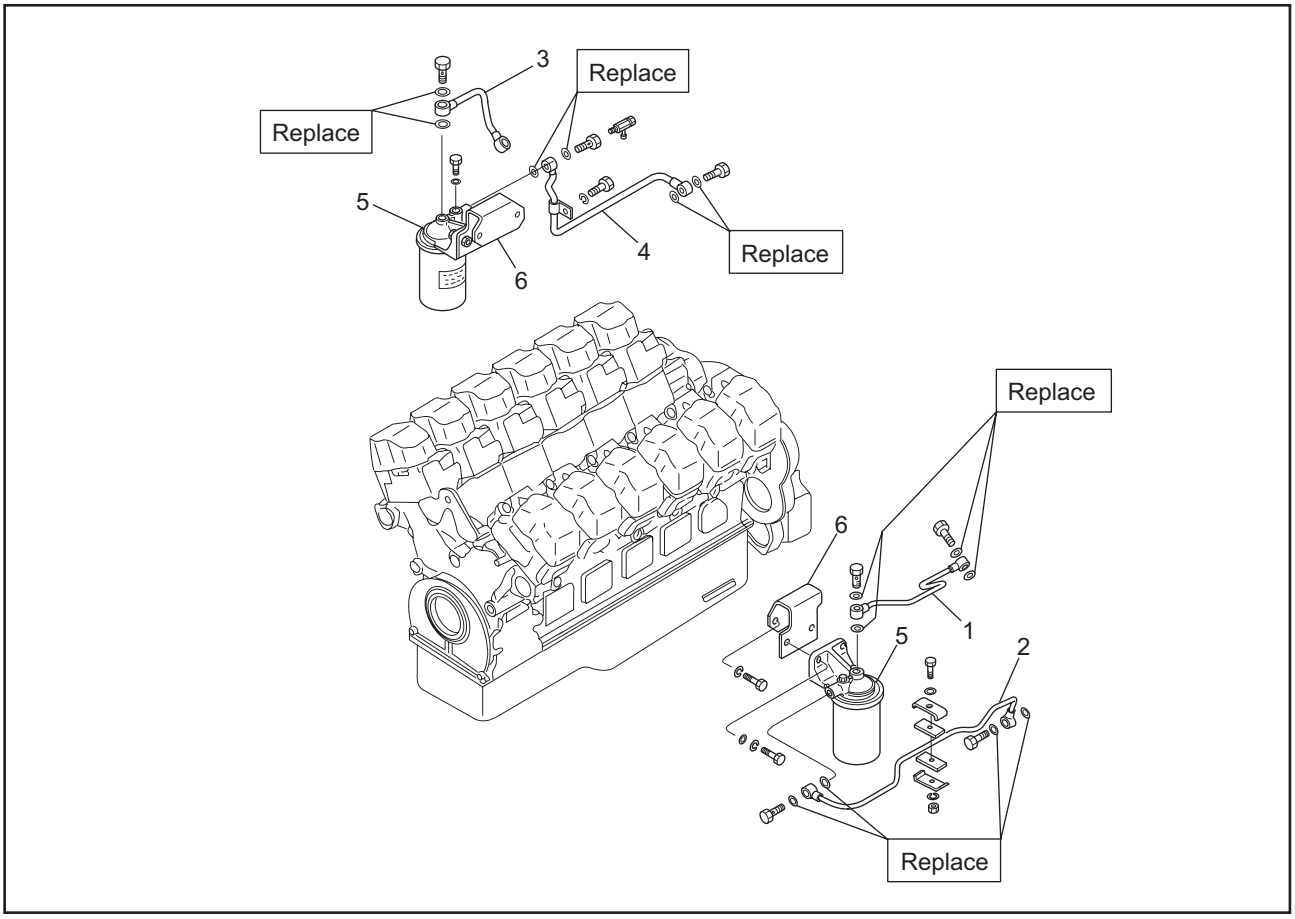
Removing sequence

1 Left side fuel leak-off pipe
2 Left side fuel leak-off pipe
3 Fuel leak-off pipe
4 Right-side fuel leak-off pipe
5 Right-side fuel leak-off pipe
6 Left side fuel pipe
7 Fuel pipe
8 Right side fuel pipe
9 Connector
10 Primary fuel filter
11 Left side fuel leak-off pipe
12 Right-side fuel leak-off pipe
13 No. 1 fuel injection pipe
14 No. 2 fuel injection pipe
15 No. 3 fuel injection pipe
16 No. 4 fuel injection pipe
17 No. 5 fuel injection pipe
18 No. 6 fuel injection pipe
19 No. 7 fuel injection pipe
20 No. 8 fuel injection pipe
21 No. 9 fuel injection pipe
22 No. 10 fuel injection pipe
23 No. 11 fuel injection pipe
24 No. 12 fuel injection pipe

CAUTION

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

1.2 Removing fuel filter and fuel pipes

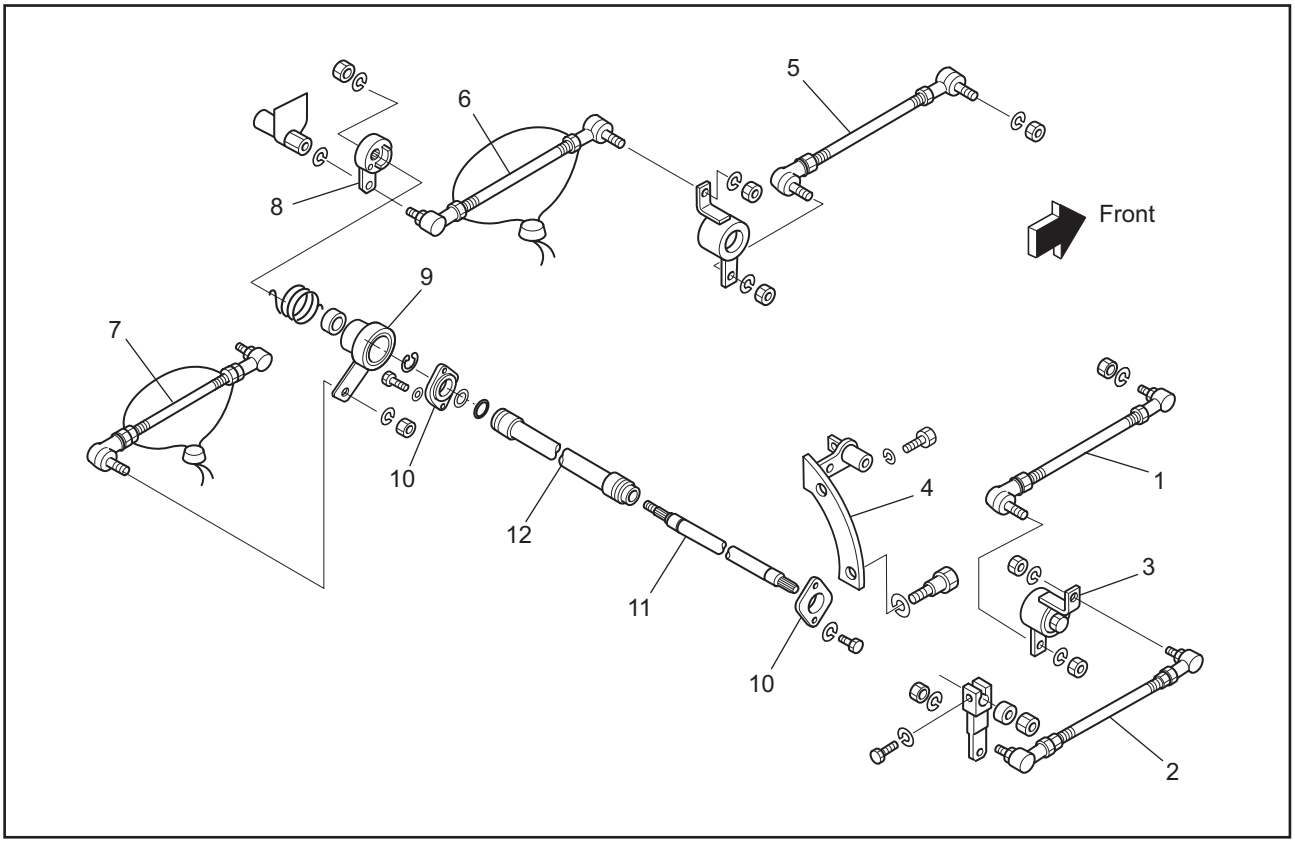


Removing fuel filter and fuel pipes

Removing sequence

1 Left side fuel pipe
2 Left side fuel pipe
3 Right side fuel pipe
4 Right side fuel pipe
5 Fuel filter assembly
6 Fuel filter bracket

1.3 Removing fuel control links

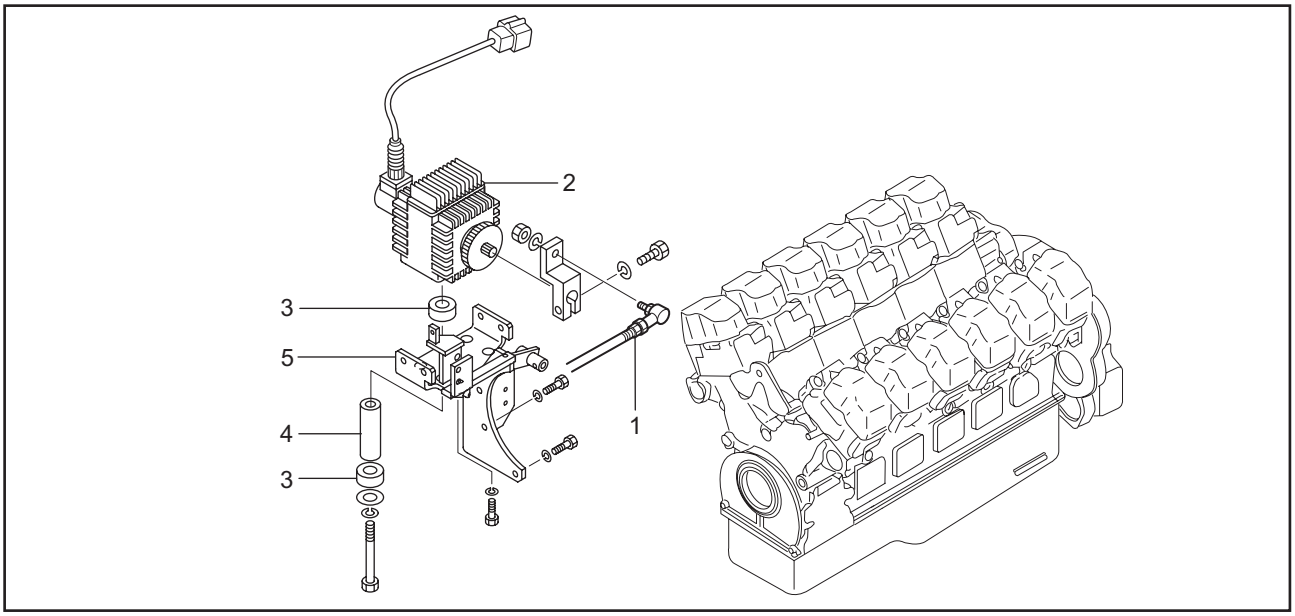


Removing fuel control links

Removing sequence

1 Right side control link B
2 Right side control link A
3 Right side lever
4 Right side stay
5 Right side control link B
6 Left side control link A
7 Actuator control link
8 Left side lever A
9 Left side lever B
10 Bearing cover
11 Control shaft
12 Timing gear case pipe

1.4 Removing actuator

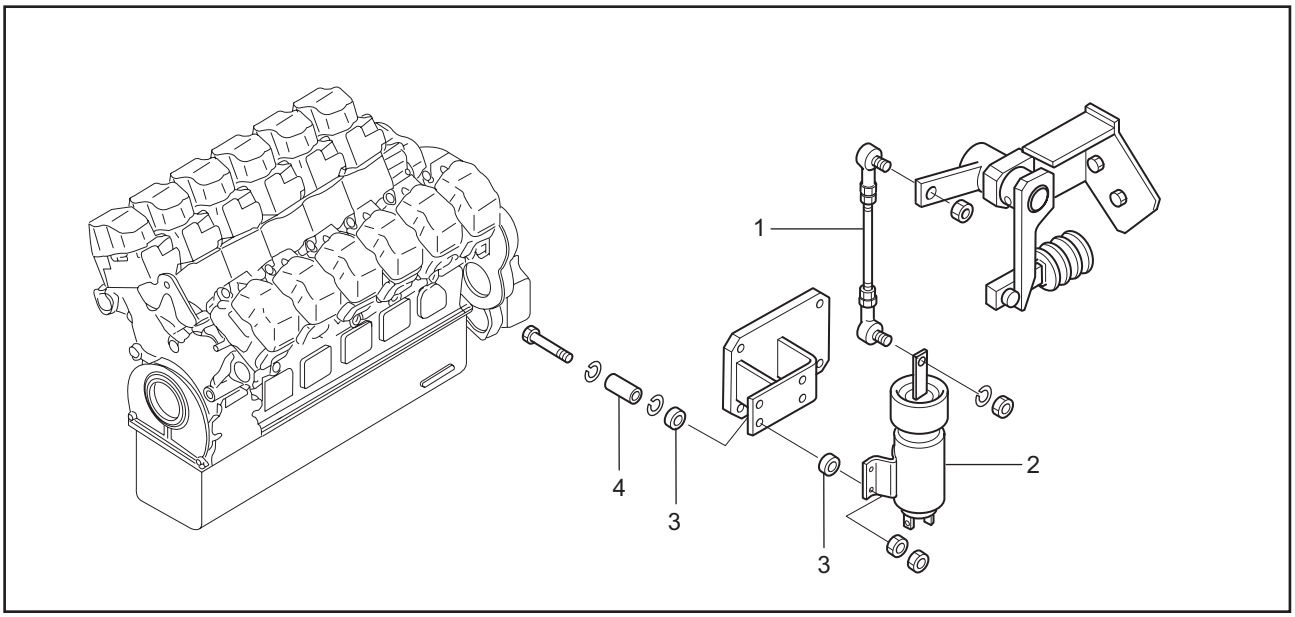


Removing actuator

Removing sequence

1 Control link
2 Actuator
3 Cushion mount
4 Spacer
5 Proact bracket

1.5 Removing stop solenoid



Removing stop solenoid

Removing sequence

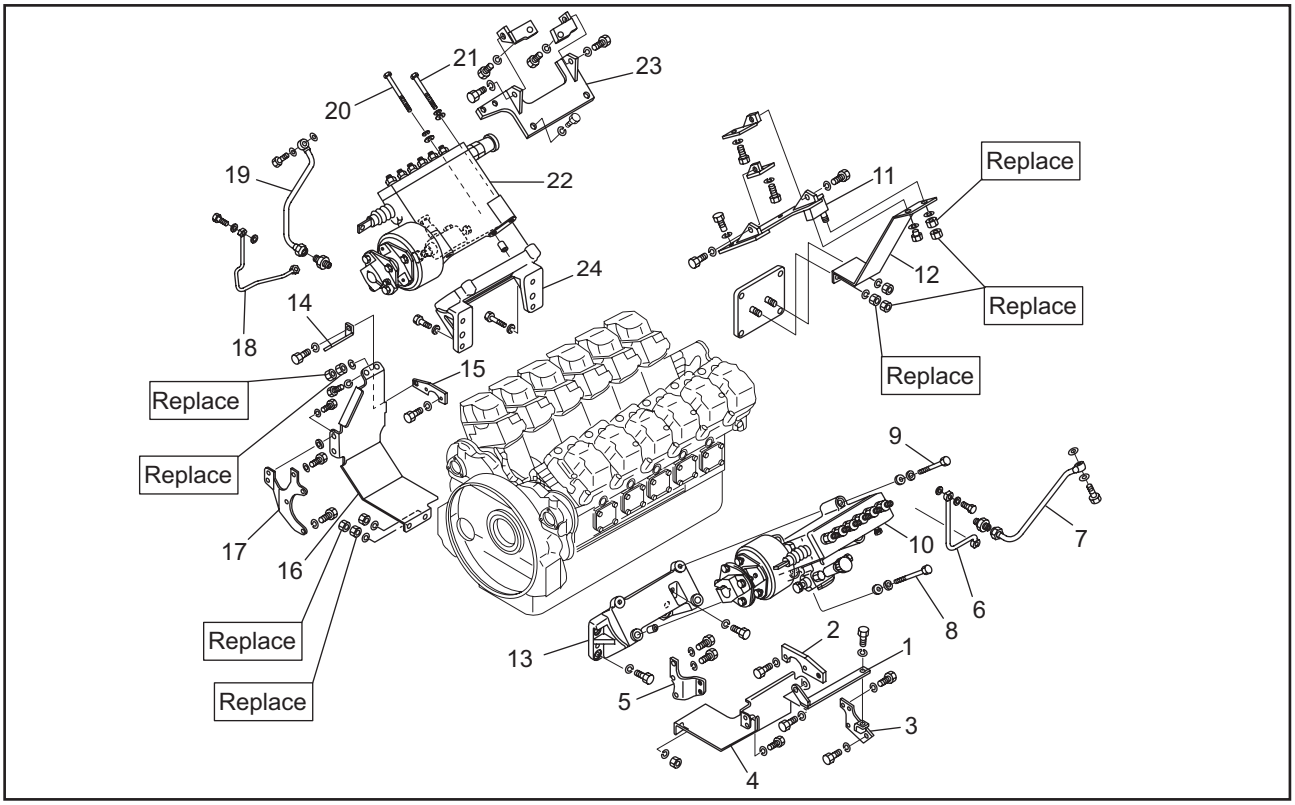
1 Control link
2 Stop solenoid
3 Cushion rubber
4 Spacer

1.6 Removing fuel injection nozzle

Using a wrench, loosen the nozzle, and remove the fuel injection nozzle and holder gasket.

Note: Using a wire or screwdriver remove the holder gasket.

1.7 Removing fuel injection pumps



Removing fuel injection pumps

Removing sequence

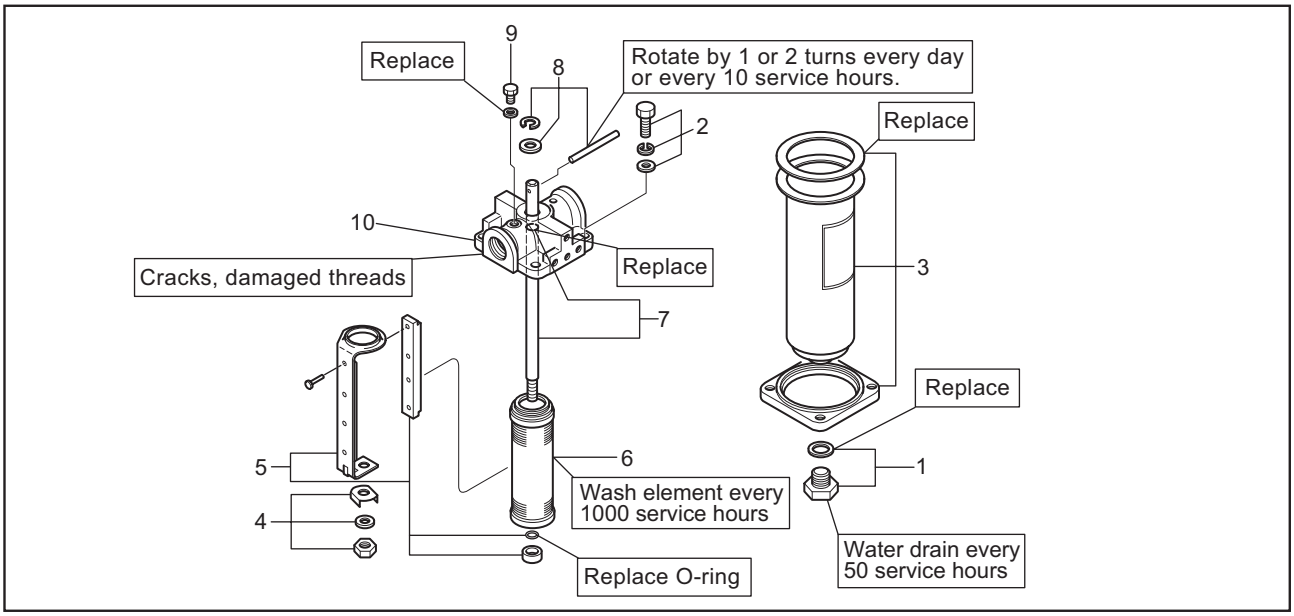
1 Right side priming stopper
2 Right side stay
3 Clamp plate
4 Coupling cover
5 Cover stay
6 Right side oil pipe
7 Right side oil drain pipe
8 Pump mounting bolt
9 Pump mounting bolt
10 Right side fuel injection pump (weight: approx. 43 kg [95 lb])
11 Right side injection pump stay
12 Right side tamper plate
13 Right side injection pump bracket
14 Left side priming stopper
15 Left side stay
16 Left side tamper plate
17 Left side cover stay
18 Left side oil pipe
19 Left side oil drain pipe
20 Pump mounting bolt
21 Pump mounting bolt
22 Left side fuel injection pump (weight: approx. 43 kg [95 lb])
23 Left side injection pump stay
24 Left side injection pump bracket

CAUTION

When removing the tamper plates at both sides, break and remove the tamper nuts because they cannot be removed in their original condition.

2. Disassembling, inspecting and reassembling fuel system

2.1 Disassembling and inspecting fuel tilter (wire element type)

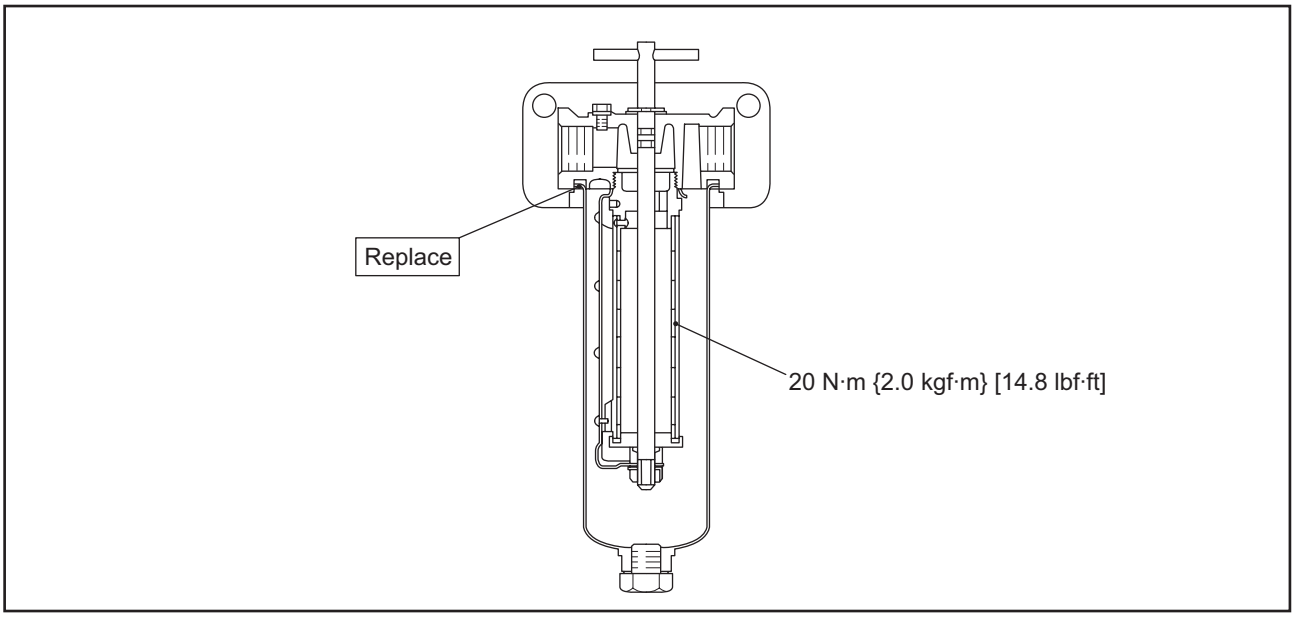


Disassembling and inspecting fuel tilter (wire element type)

Disassembling sequence

1	Plug, packing	5	Plate, scraper collar, O-ring	9	Bolt
2	Bolt, spring washer, plain washer	6	Element	10	Cover
3	Flange, lower case, packing	7	Rod, O-ring		
4	Washer, nut	8	Snap ring, washer, handle		

2.2 Reassembling fuel filter (wire element type)

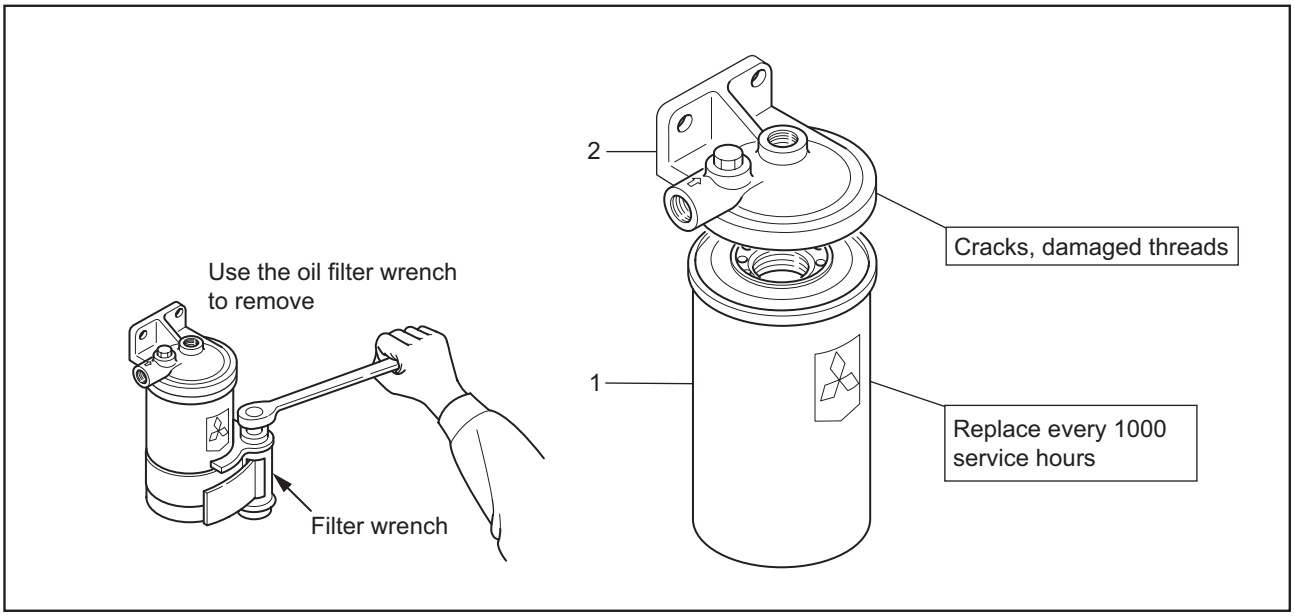


Reassembling fuel filter (wire element type)

CAUTION

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

2.3 Disassembling and inspecting fuel tilter (paper element type)

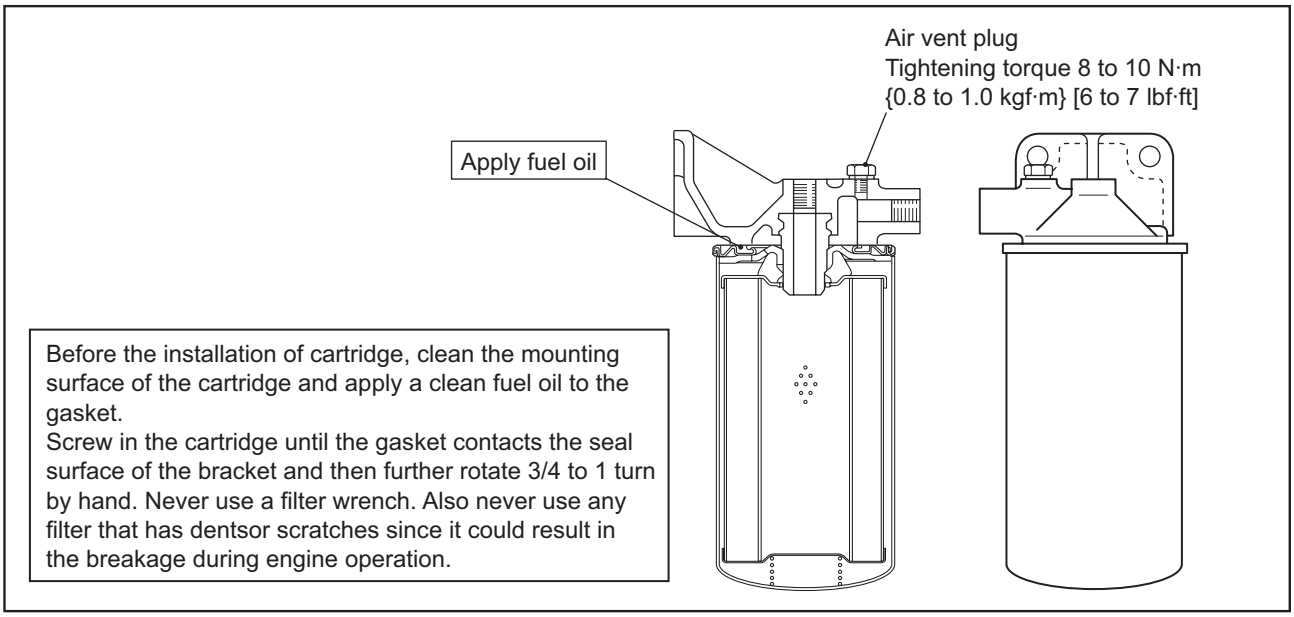


Disassembling and inspecting fuel tilter (paper element type)

Disassembling sequence

1 Cartridge filter
2 Filter bracket

2.4 Reassembling fuel filter (paper element type)

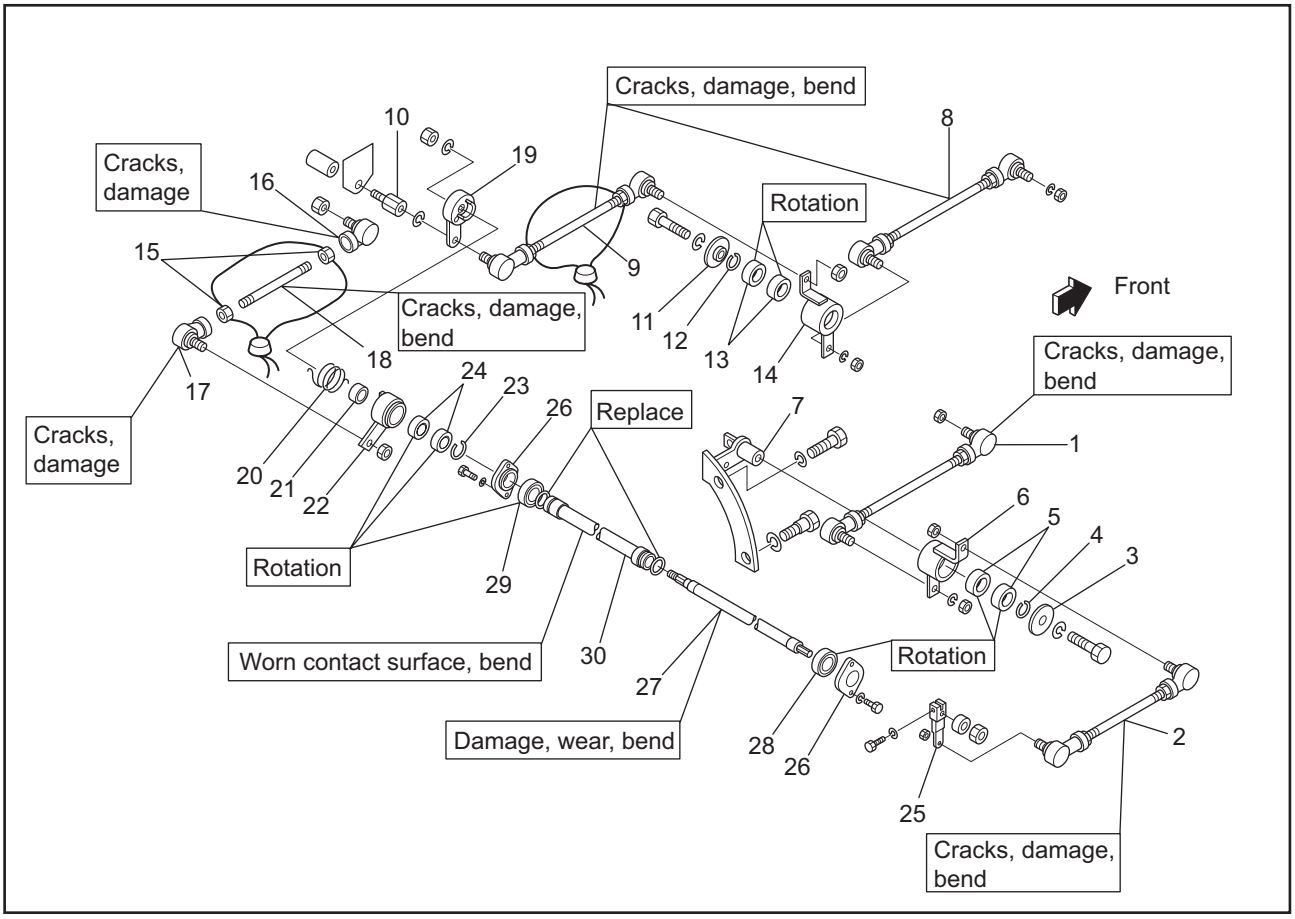


Reassembling fuel filter (paper element type)

CAUTION

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

2.5 Disassembling and inspecting fuel control links



Disassembling and inspecting fuel control links

Disassembling sequence

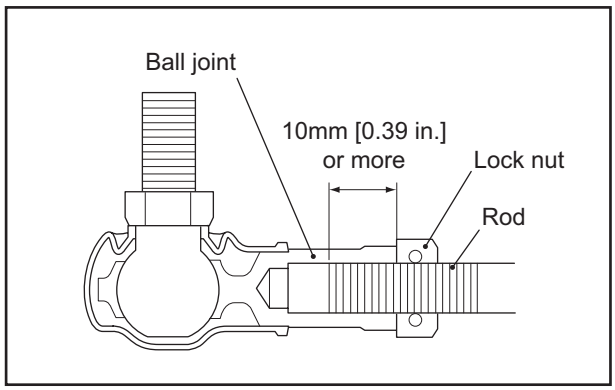
1	Right side control link	11	End plate	21	Spacer
2	Right side control link	12	Snap ring	22	Left side lever
3	End plate	13	Ball bearing	23	Snap ring
4	Snap ring	14	Left side link lever	24	Ball bearing
5	Ball bearing	15	Rock nut	25	Right side control lever
6	Right side link lever	16	Ball joint	26	Bearing cover
7	Right side stay	17	Ball joint (left thread)	27	Control shaft
8	Left side control link	18	Rod	28	Ball bearing
9	Left side control link	19	Left side lever	29	Ball bearing
10	Connector	20	Spring	30	Timing gear case pipe

2.6 Reassembling fuel control link

CAUTION

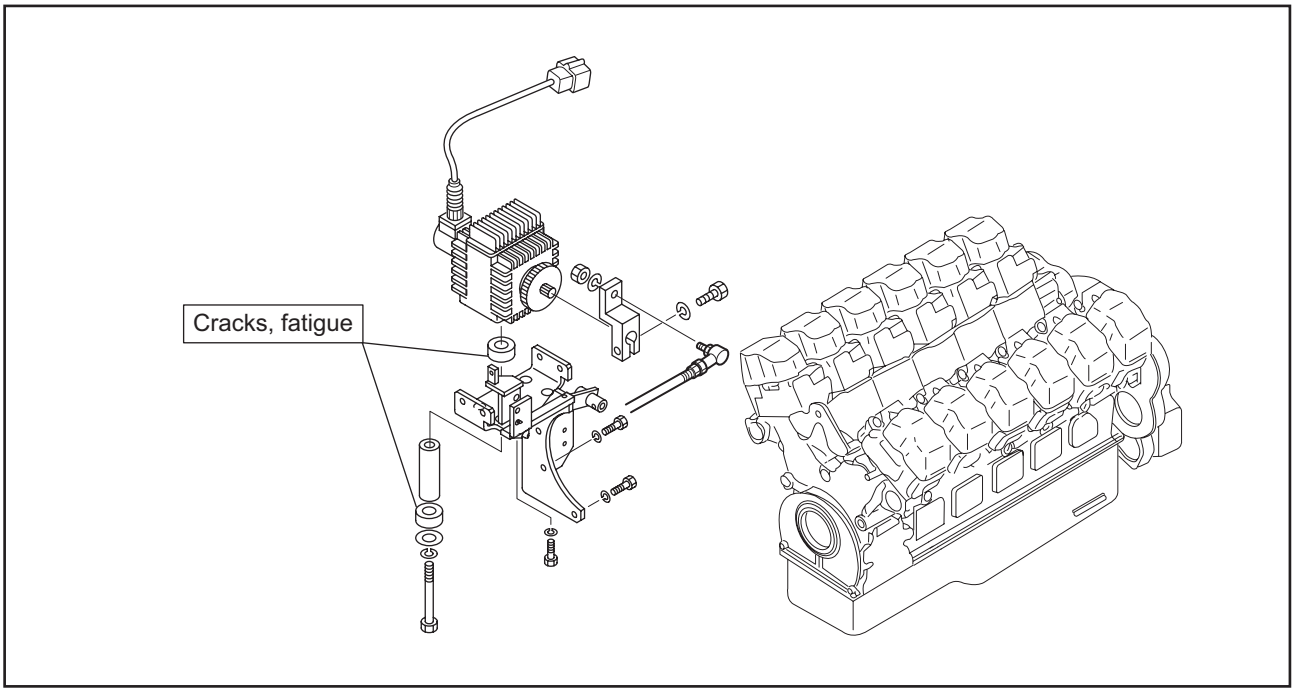
(a) The lock nuts and ball joints at both ends of the rod may be right-hand or left-hand threaded. When installing them, pay attention to their thread direction.

(b) Screw the rod 10 mm [0.39 in.] or more into the ball joint, when installing the rod in the ball joint.



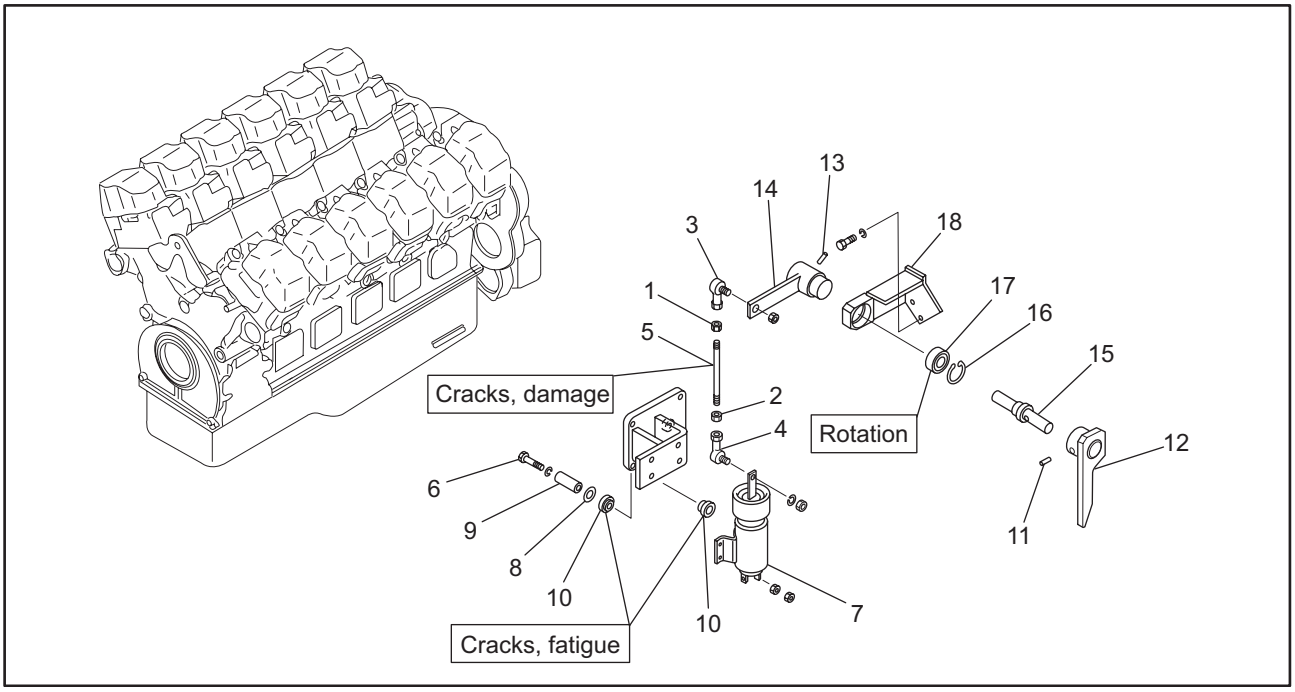
Installing ball joint

2.7 Inspecting actuator control link



Inspecting actuator control link

2.8 Disassembling and inspecting stop solenoid control link



Disassembling and inspecting stop solenoid control link

Disassembling sequence

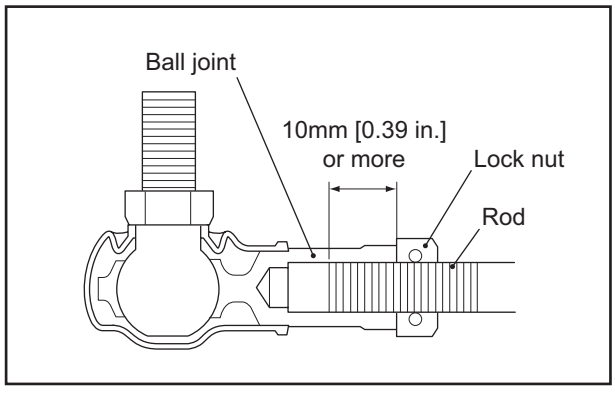
1	Jam nut	7	Stop solenoid	13	Spring pin
2	Lock nut (left thread)	8	Washer	14	Lever
3	Ball joint	9	Spacer	15	Shaft
4	Ball joint (left thread)	10	Cushion rubber	16	Snap ring
5	Rod	11	Spring pin	17	Ball bearing
6	Bolt	12	Lever	18	Support

2.9 Reassembling stop solenoid control link

CAUTION

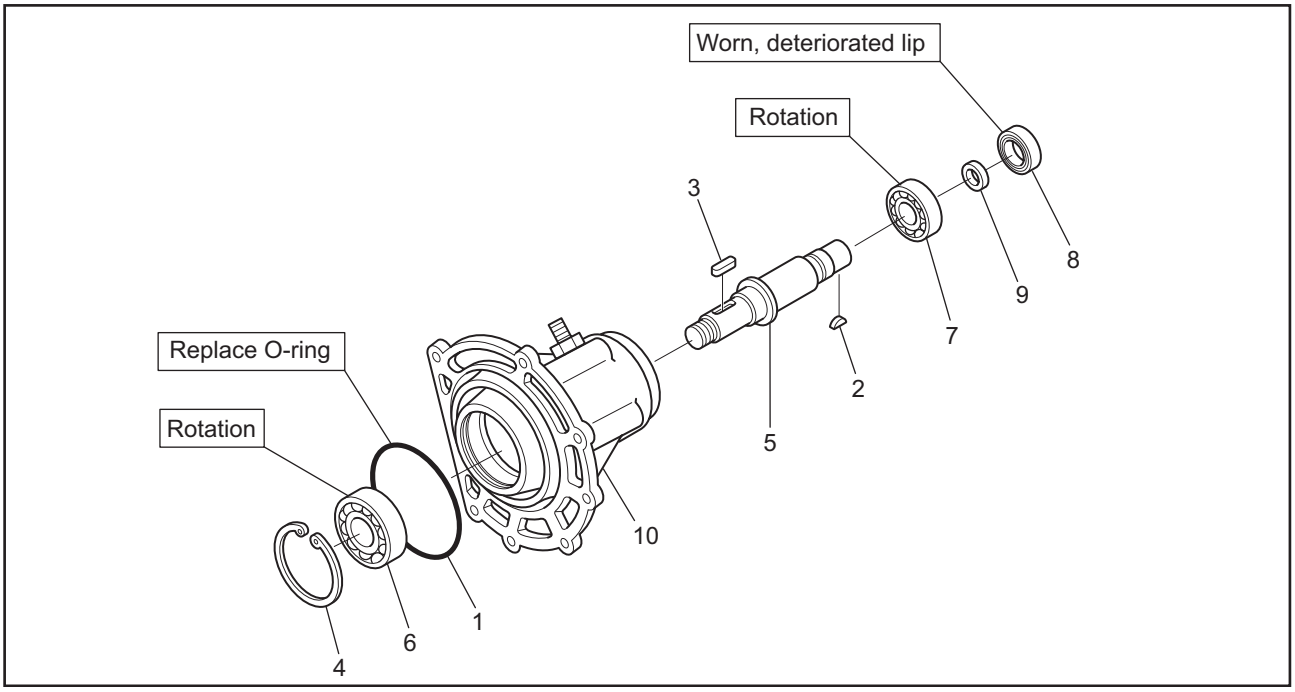
(a) The ball joint may be right-hand or left-hand threaded. When installing it, pay attention to its thread direction.

(b) Screw the rod 10 mm [0.39 in.] or more into the ball joint, when installing the rod in the ball joint.



Installing ball joint

2.10 Disassembling and inspecting accessory drive



Disassembling and inspecting accessory drive

Disassembling sequence

1 O-ring
2 Woodruff key
3 Thank key
4 Snap ring
5 Drive shaft
6 Ball bearing
7 Ball bearing
8 Oil seal
9 Sleeve
10 Drive case

2.11 Inspecting accessory drive

2.11.1 Outside and inside diameters of bearing-fitted sections

Rotate each bearing, and if it does not rotate smoothly, replace the bearing.

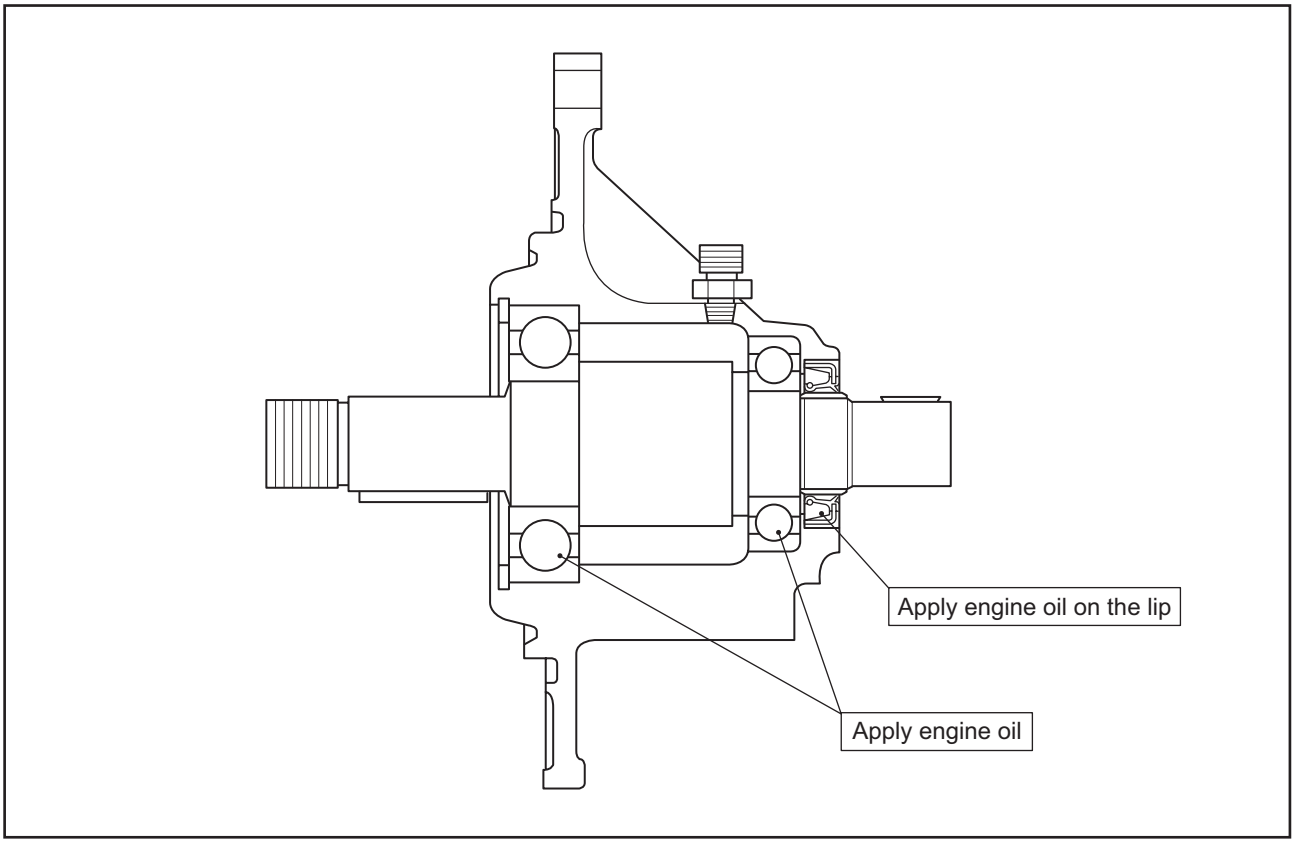
Inspect the bearing journals of the drive shaft, and replace the drive shaft if worn.

Inspect the bearing housing of the drive case, and replace the drive case if worn.

Inspect the drive shaft and oil seal, and replace if any abnormality is found.

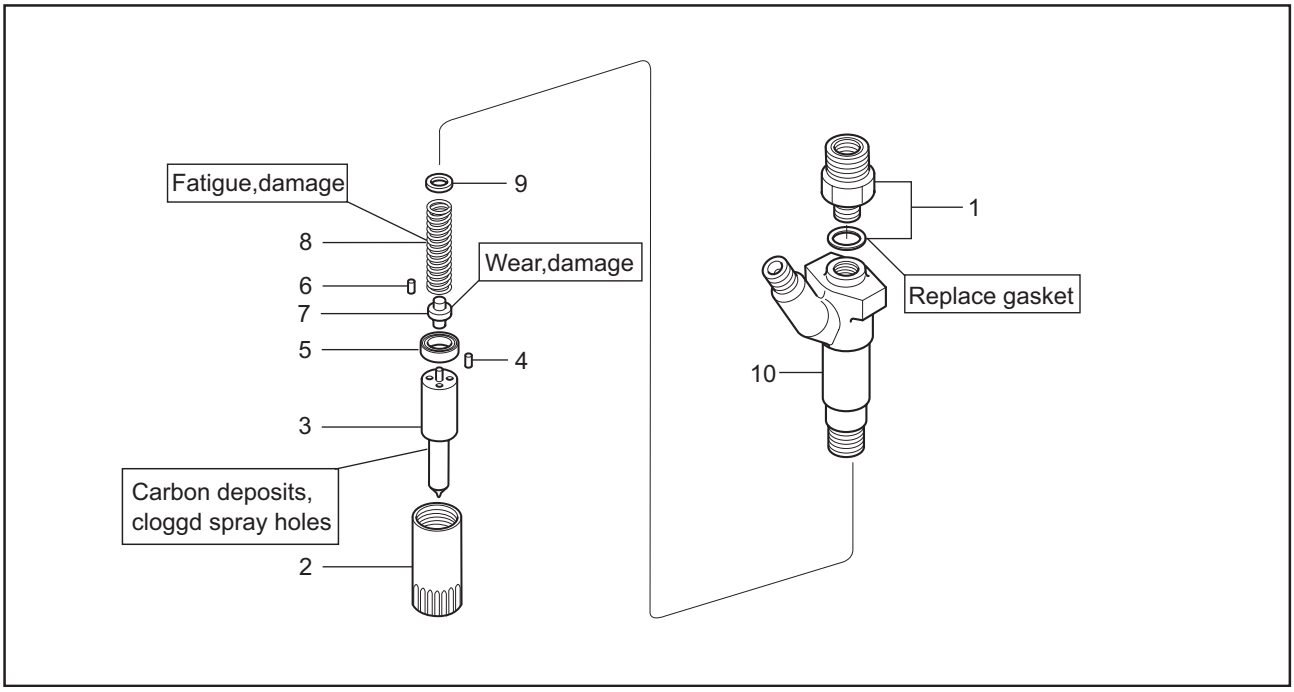
Item			Nominal	Standard
Inside diameter of bearing fitting bore in drive case			ø 72 mm [2.83 in.]	71.988 to 72.018 mm [2.8342 to 2.8353 in.]
			ø 90 mm [3.54 in.]	89.985 to 90.020 mm [3.5425 to 3.5435 in.]
Bearing	Small	Inside diameter	ø 35 mm [1.38 in.]	34.985 to 35.003 mm [1.3774 to 1.3781 in.]
		Outside diameter	ø 72 mm [2.83 in.]	71.983 to 72.004 mm [2.8340 to 2.8348 in.]
	Large	Inside diameter	ø 40 mm [1.57 in.]	39.985 to 40.003 mm [1.5742 to 1.5749 in.]
		Outside diameter	ø 90 mm [3.54 in.]	89.980 to 90.005 mm [3.5425 to 3.5435 in.]
Drive shaft bearing journal diameter			ø 35 mm [1.38 in.]	35.002 to 35.013 mm [1.3780 to 1.3785 in.]
			ø 40 mm [1.57 in.]	40.002 to 40.013 mm [1.5749 to 1.5753 in.]

2.12 Reassembling accessory drive



Reassembling accessory drive

2.13 Disassembling and inspecting fuel injection nozzles



Disassembling and inspecting fuel injection nozzles

Disassembling sequence

1 Connector and gasket
2 Retaining nut
3 Nozzle tip
4 Pin
5 Spacer
6 Pin
7 Pushrod
8 Nozzle spring
9 Shim
10 Nozzle holder body

CAUTION

When changing parts, be sure to use our designated parts, Unless our designated parts are used, the exhaust emission regulations cannnot be met.

2.14 Adjusting and inspecting of fuel injection nozzlers

2.14.1 Inspecting and adjusting fuel injection valve opening pressure

(1) Install the nozzle on the nozzle tester and operate the handle of the tester at a rate of about 1 stroke per second, and read the pressure at which fuel injection starts. Adjust the nozzle, if limit is exceeded.

Item	Standard	Limit
Valve opening pressure	29.4 MPa {300 kgf/cm²} [4267 psi]	29.9 to 30.7 MPa {305 to 313 kgf/cm²} [4337 to 4453 psi]

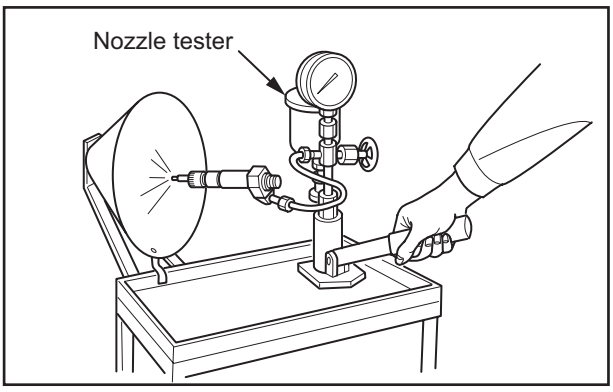
⚠ CAUTION

During injection testing, never touch the sprayed fuel.

(2) Adjust the injection starting pressure by increasing or decreasing the number of shims. The seven kinds of shims are available in thicknesses of 0.40 to 0.70 mm [0.0157 to 0.0275 in].

(3) After the adjustment, tighten the retaining nut to the specified torque of 59 to 78 N·m {6 to 8 kgf·m} [43 to 58 lbf·ft]

(4) After tightening the retaining nut to the specified torque, inspect again the injection starting pressure to see that it is as specified.



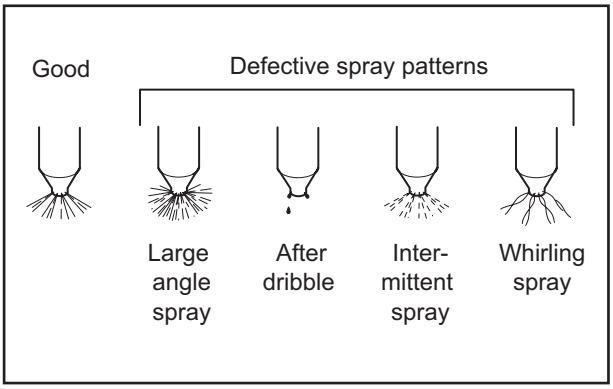
Inspecting fuel injection nozzle for injection pressure

2.14.2 Inspecting fuel spray pattern of fuel injection nozzle

(1) When adjusting the nozzle opening pressure using a nozzle tester, check for clogged nozzle hole, fuel spray pattern, and fuel dribble from the spray hole.

(2) Checking points of fuel spray pattern are as follows:
- · Fuel is injected straightly.
- · Fuel is injected in a spray of fine droplets.
- · Fuel is injected without after-dribbling.

(3) If the spray pattern is defective, clean or replace the nozzle tip.



Spray pattern of fuel injection nozzle

2.14.3 Cleaning and replacing faulty nozzle

CAUTION

When pulling out the nozzle tip, be careful not to damage the tip.

(1) Loosen the retaining nut, then remove the nozzle tip, and clean the needle valve and body.

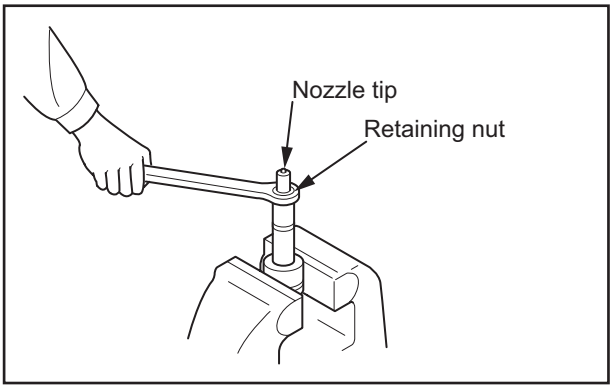
(2) Clean the nozzle tip in clean wash oil. After cleaning, assemble the needle valve and body in clean diesel fuel.

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

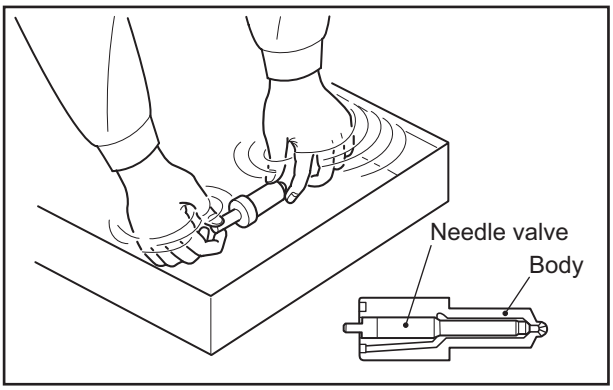
(3) Tighten the nozzle tip retaining nut to the specified torque.

(4) If the spray pattern is still faulty after cleaning and adjusting, replace the nozzle tip.

Note: When using a new nozzle tip, remove the anti-corrosive agent from the nozzle tip, and clean the nozzle tip in wash oil. Then clean the tip again in the fuel before assembly.

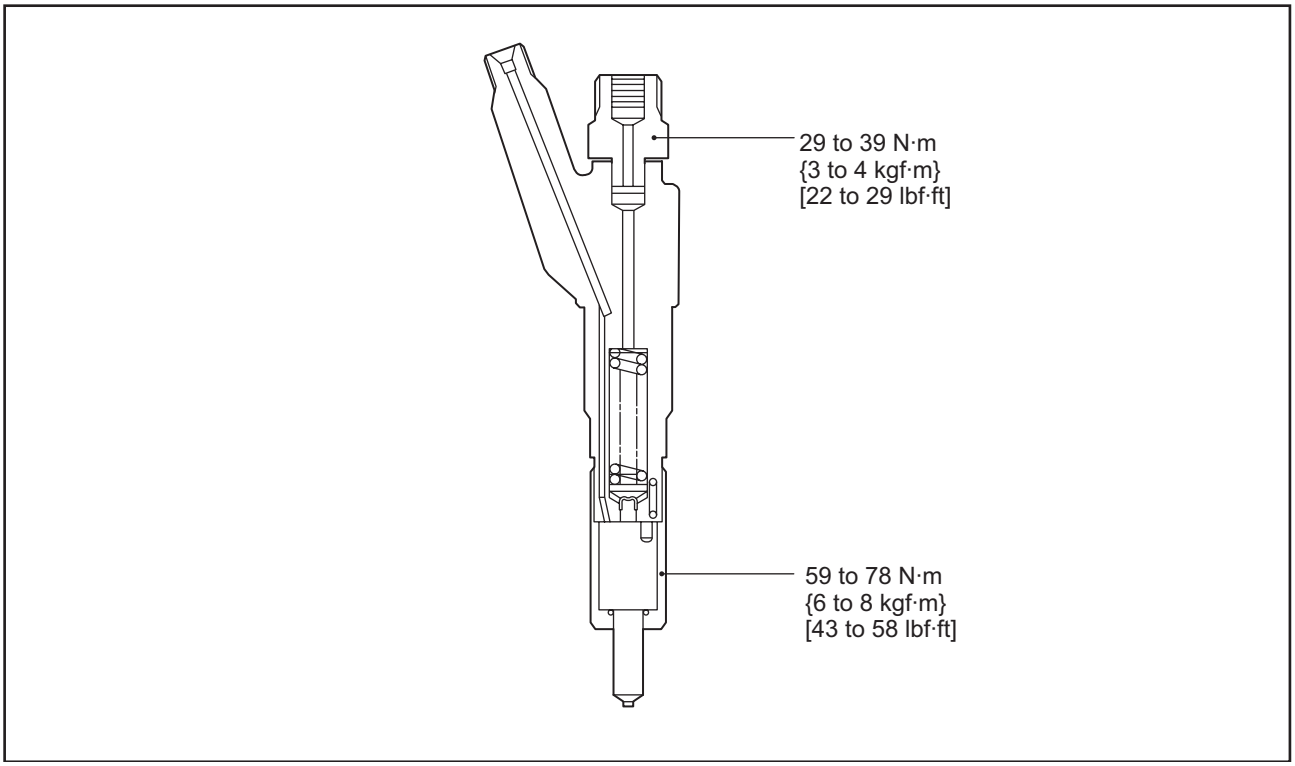


Removing fuel injection nozzle tip



Washing fuel injection nozzle tip

2.15 Reassembling fuel injection nozzle



Reassembling fuel injection nozzle

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

CAUTION

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

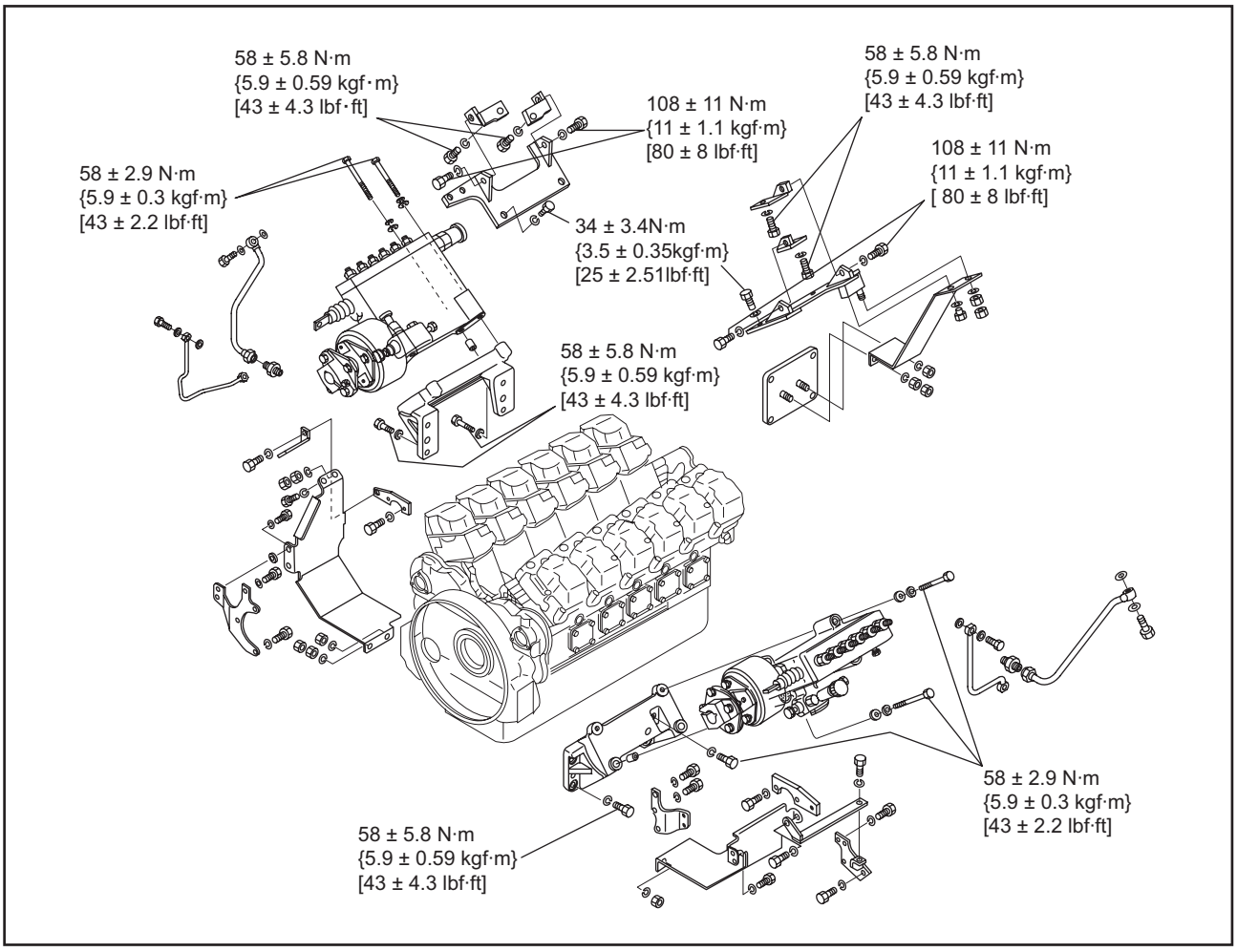
3. Installing the fuel system

3.1 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.
This procedure is described in "Inspection, adjustment, break-in operation, performance test and testing procedures".

3.2 Installing fuel injection pumps



Installing fuel injection pumps

3.2.1 Installing fuel injection pump (right side)

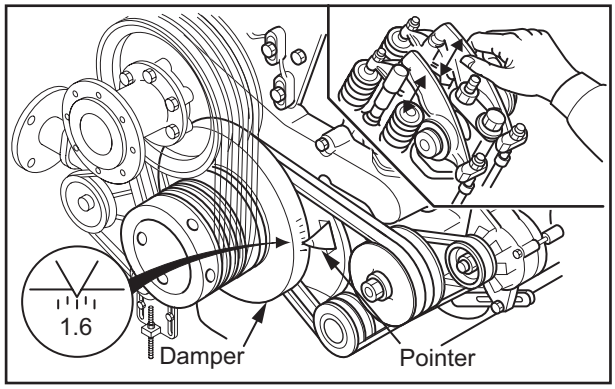
⚠ CAUTION

Be sure to check the injection start timing stamped on the caution plate on the rocker cover for the No. 1 cylinder.

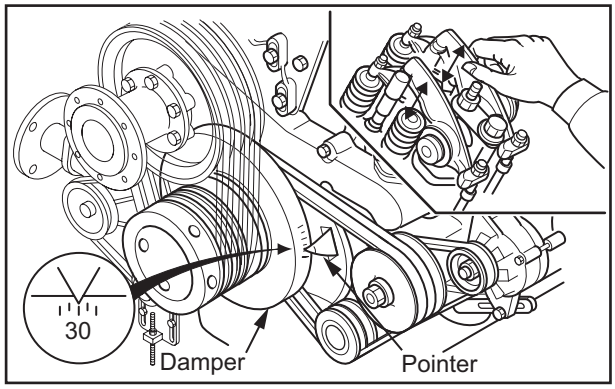
(1) Rotate the engine in the normal direction until the No. 1·6 mark stamped on the damper aligns with the pointer.

(2) Move the rockers of the inlet and exhaust valves for the No. 1 cylinder by hand to make sure that the pushrods are not pushing the inlet or exhaust valves off their seats.

(3) Turn the crankshaft about 60° in the reverse direction, then turn it in the normal direction a little at a time to align the pointer with the specified injection start timing mark on the circumference of the damper.



Determining top dead center of No.1 cylinder compression stroke

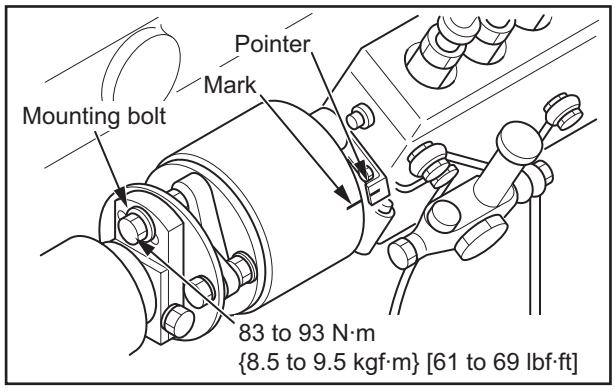


Inspecting angle of injection starting timing mark on damper circumference

(4) Install coupling to injection pump and align the pointer on the pump case with mark on the coupling.

(5) Fit the key of drive shaft into the keyway in coupling, then push in the injection pump toward the drive case. Tighten the shaft mounting bolts to the specified torque.

(6) Connect the fuel pipe, oil pipe and fuel control link to the pump.

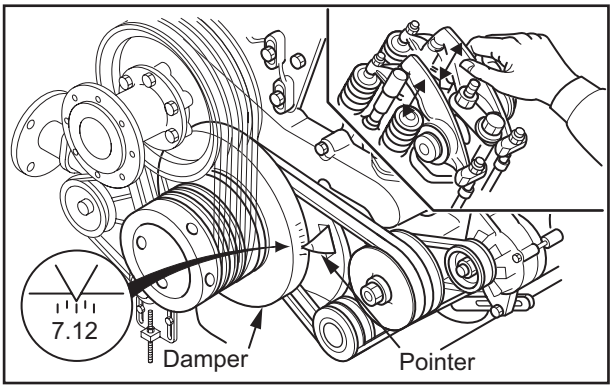


Adjusting fuel injection timing

3.2.2 Installing fuel injection pump (left side)

(1) To install the left side injection pump, align the No. 7·12 mark stamped on the damper with the pointer.
Make sure the piston in the No. 7 cylinder is at the top dead center in compression stroke by checking the inlet and exhaust valves.

(2) Adjust the injection timing by following the same procedure as for the right-side injection pump and install the injection pump, then connect the pipes and control link.

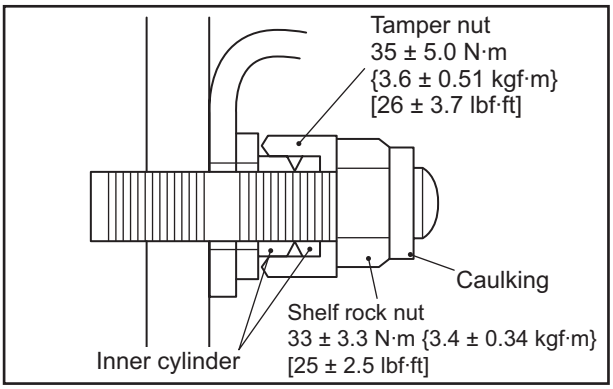


Installing fuel injection pump (left side)

3.2.3 Installing tamper nut

(1) Check that the tamper nut breaks the inner cylinder when tightened to the specified torque (inner cylinder breaking torque).

(2) Tighten the self lock nut to the specified torque, and caulking the end of the nut.

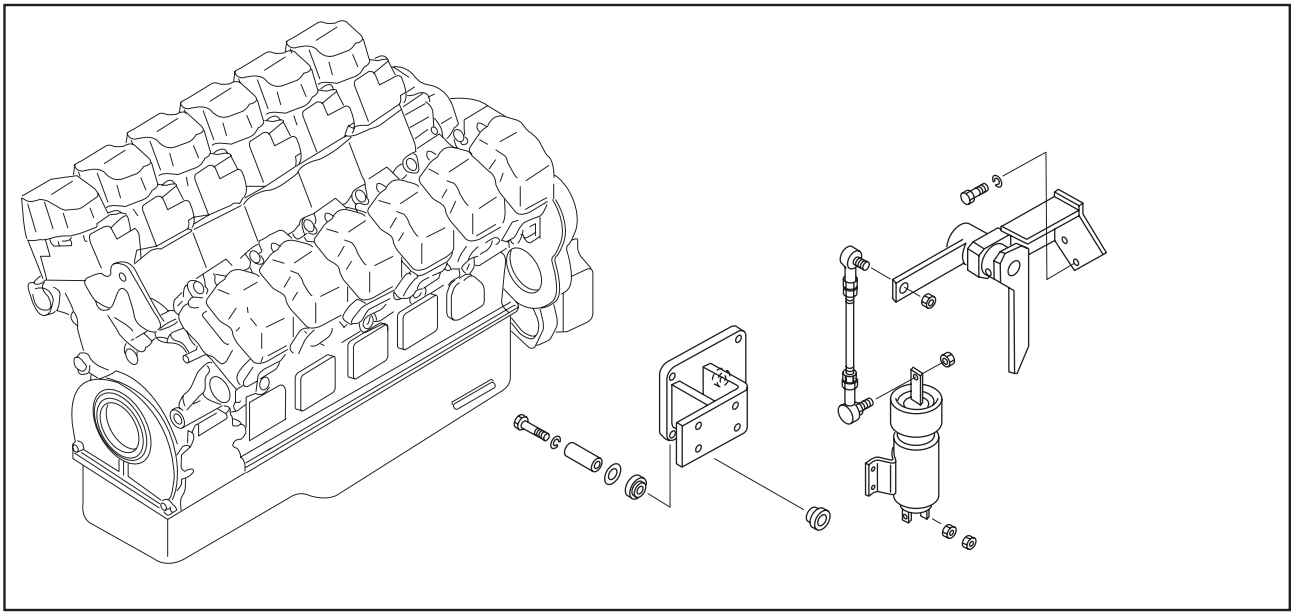


Installing tamper nut

3.3 Fuel Injection Nozzles

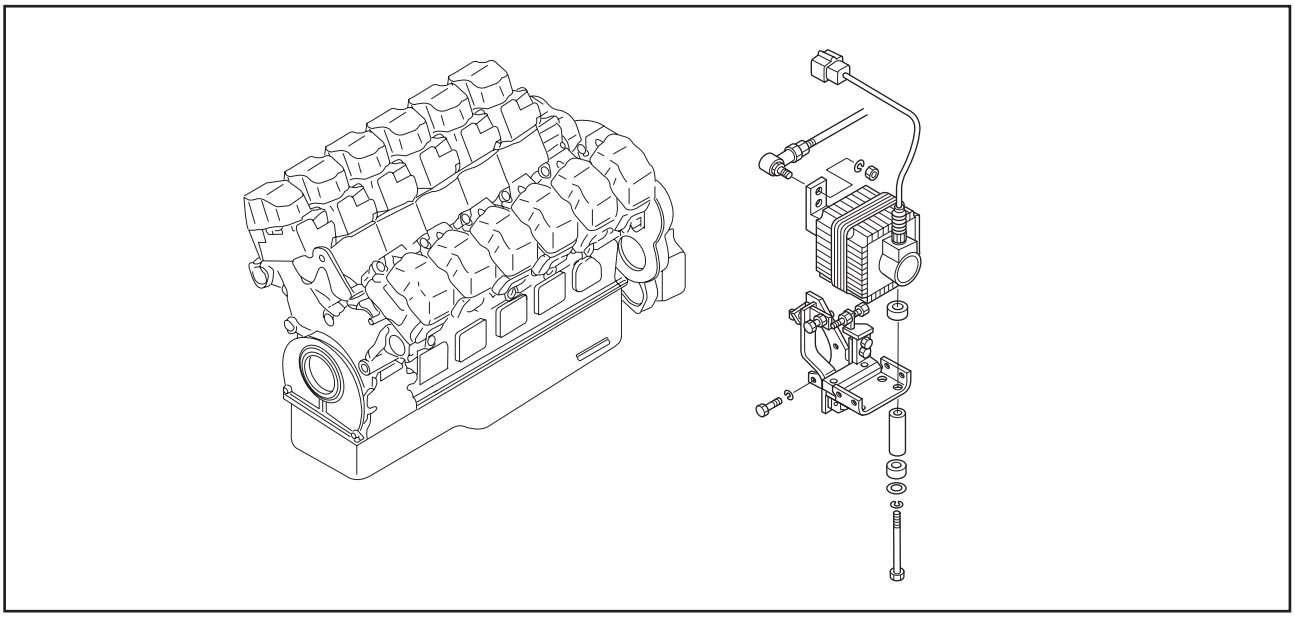
For fuel injection nozzle installation procedure, refer to the section on reassembly of engine main parts.

3.4 Installing stop solenoid



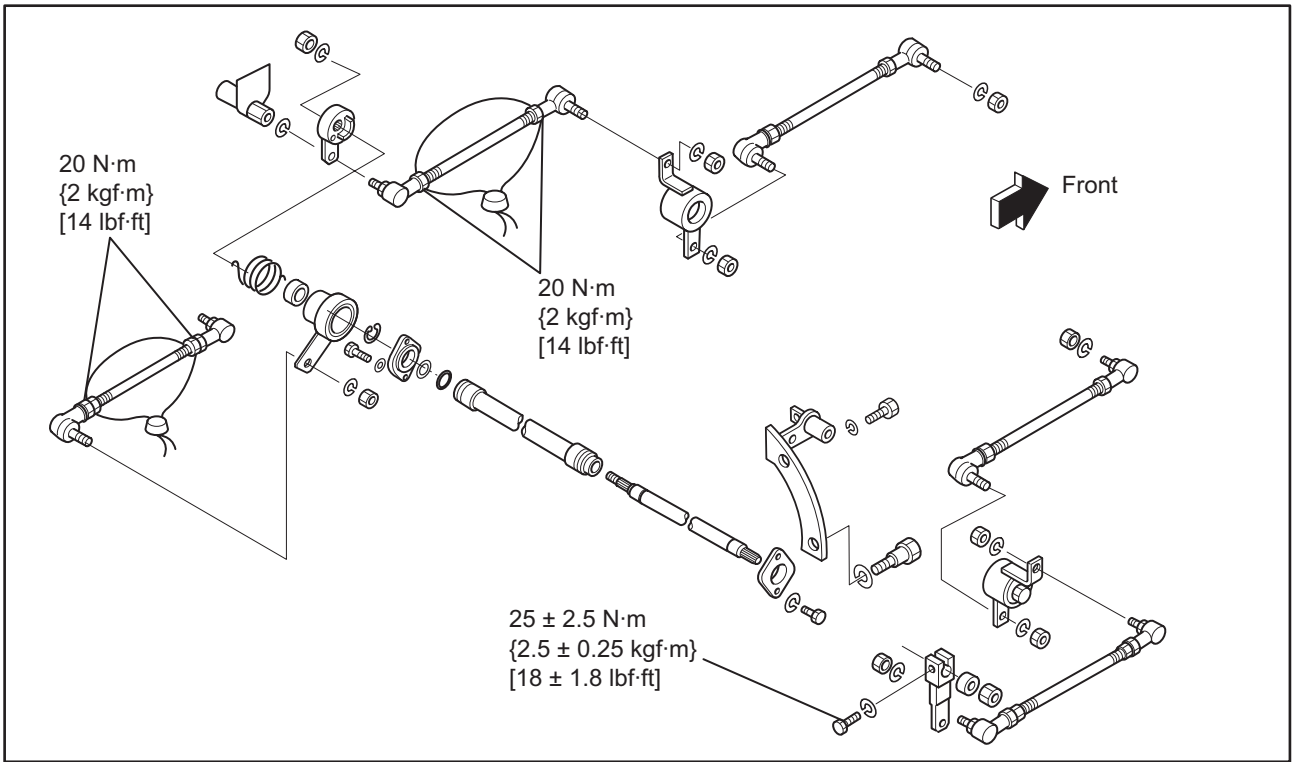
Installing stop solenoid

3.5 Installing actuator



Installing actuator

3.6 Installing fuel control links



Installing fuel control links

3.6.1 Installing fuel control and actuator

(1) Check to make sure that control rack for the injection pump on the right side is set to 0 (no injection).

(2) Connect right-side control link B to control rack and link lever.

Note: Right-side control link B is of fixed length, and the center distance between the ball joints at the ends is 126.5 ± 0.3 mm [4.980 ± 0.012 in.].

(3) Install control link A to right side lever, and install control lever to the opposite side of righe side control link.

Note: Righe side control link is of fixed length, and the center distance between the ball joints at the ends is 140.5 ± 0.3 mm [5.531 ± 0.012 in.]

(4) Install control lever to control shaft.

(5) Check to make sure that control rack for the fuel injection pump on the right side is set to "0" (no injection).

(6) Connect left side control link B to control rack and left side lever.

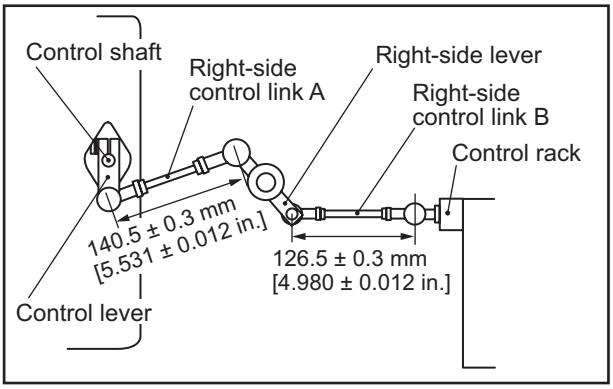
Note: Left side control link B is of fixed length, and the center distance beween the ball joints at the ends is 126.5 ± 0.3 mm [5.531 ± 0.012 in.].

(7) Install left side control link A to left link lever and left side lever A.

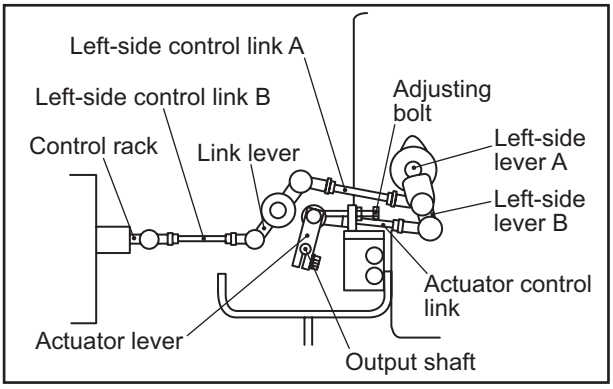
Note: Install left side control link A to that the center distance between the ball joints at the ends becomes 146 ± 0.3 mm [5.748 ± 0.012 in.].

(8) Install actuator control link to left side lever B, and install actuator lever to the opposite side of actuator control link.

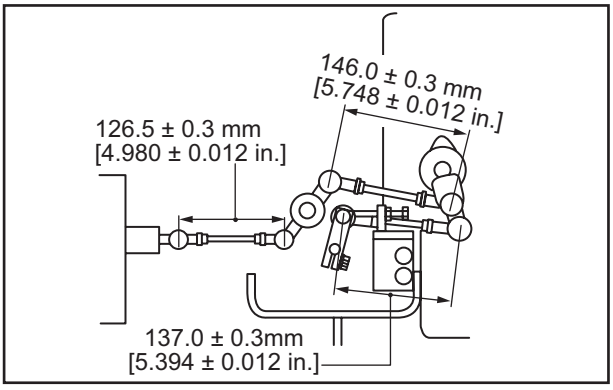
Note: Install actuator control link so that the center distance between the ball joints at the ends becomes 137 ± 0.3 mm [5.394 ± 0.012 in.].



Installing fuel control link (right side)



Installing fuel control link (left side) (1)



Installing fuel control link (left side) (2)

(9) Check that output shaft of the actuator is set to 0 (no injection), and install actuator lever to output shaft.

(10) Check that the position of control rack of the fuel injection pump and the position of output shaft of the actuator are both 0 (no injection).

If these positions are no longer 0, adjust the length of left side control link.

The tightening torque of the lock nut of left side control link is about 20 N·m {2kgf·m} [14.5 lbf·ft].

(11) Adjust with the adjusting bolt so that the control racks of the left and right fuel injection pumps project from 0 (no injection) to 2 ± 1 mm [0.079 ± 0.039 in.].

3.6.2 Adjusting stop solenoid

(1) Turn off the stop solenoid (stretched).

(2) Make adjustment so that the gap between the follower on the cancel lever B and the stop lever is 0.5 to 1.0 mm [0.02 to 0.04 in.] with the rod.

Note: The screw engagement margin for the rod and ball joint must be over 8 mm [0.32 in.] on both ends.

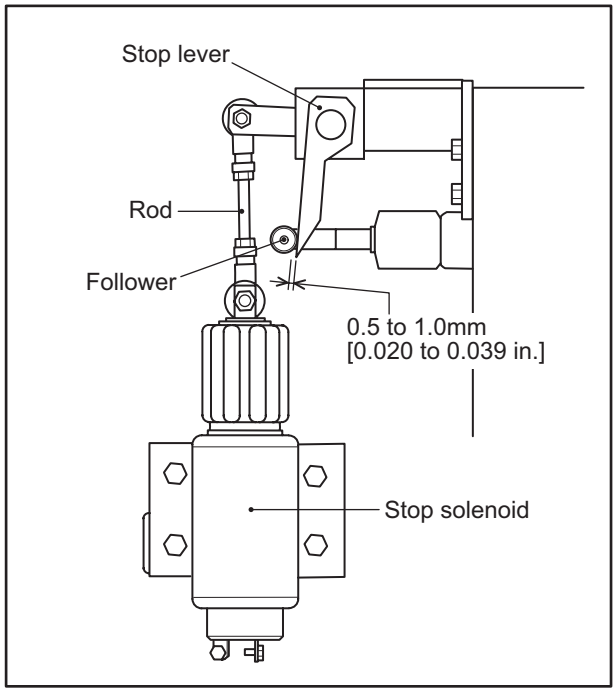
3.6.3 Stop solenoid working inspection

(1) Energize (or contract) solenoid.

(2) Idle the engine.

(3) Deenergize (on extend) solenoid.

(4) Check that the engine stops.

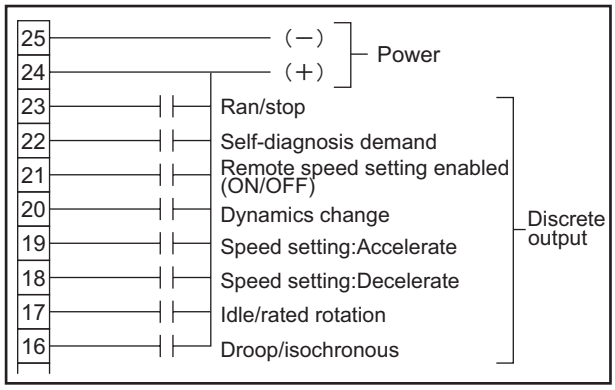


Adjusting and checking stop solenoid

4. Adjusting governor controller

CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.
Work related to the exhaust emission regulations can be conducted only at out designated service factories.



Adjusting governor controller

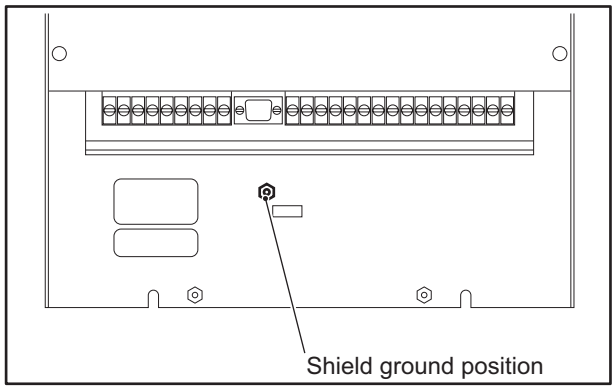
4.1 Wiring controller

(1) Wire the controller as shown on the wiring diagram. Prepare a switch box or the like so that the contract inputs to terminals 17 to 23 can be turned on and off during operation.

(2) Have the contacts of terminals 17 to 23 set as shown in the table right before the start of operation.

Con-tact No.	Name	Initial contact condi-tion	Remarks
16	Droop/isoc change hronous operation	Open	
17	Idle/rated rotation change	Open	Rated rotation in closed condition
18	Speed setting: Decrease	Open	Deceleration in closed condition
19	Speed setting: Increase	Open	Acceleration in closed condition
20	Dynamics change	Open	Rated rotation in open condition
21	Remote speed setting enabled (ON/OFF)	Open	
22	Self-diagnosis demand	Open	
23	Run/stop	Open	Run in closed condition

(3) Connect the shield wires of the actuator, rotation pickup, and boost sensor to the ground terminal of the controller.



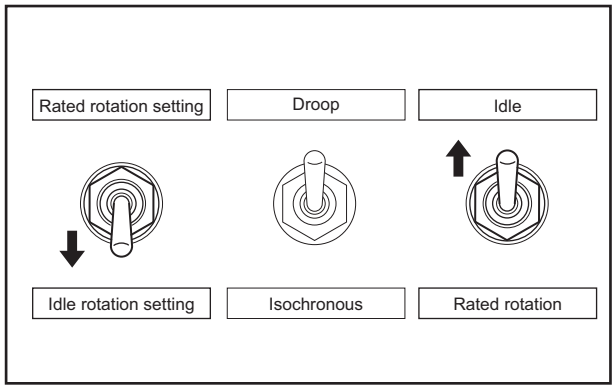
Wiring controller

4.2 Initial setting of controller

Do not change the initial set value unless otherwise required.

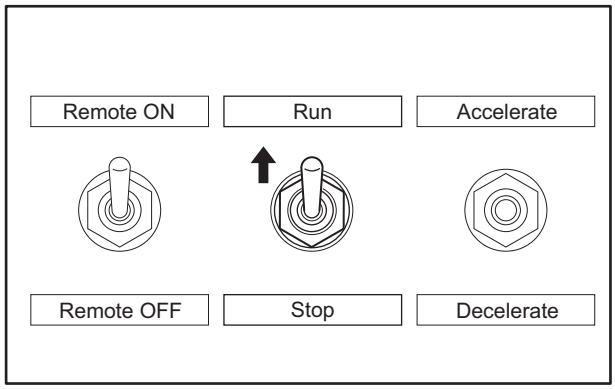
4.3 Adjusting governor during idling

(1) Turn the idle/rated rotation selector switch to "Idle" and the Dynamics selector switch to "Idle rotation setting".



Adjusting governor during idling (1)

(2) Turn the Run/Stop selector switch to "Run", and start the engine.



Adjusting governor during idling (2)

(3) Adjusting hunting

When hunting or rotational fluctuation occurs, adjust the control parameters of the controller as described below.

(a) Press the numeric key "2" of the handy programmer to select "MENU 2" of the control parameters.

(b) Press the arrow key◀ or ▶to show " Alt Gain A" in the window.

(c) Adjust the value of "Alt Gain A" with the Key△ or ▽ so that hunting or rotational fluctuation is eliminated.

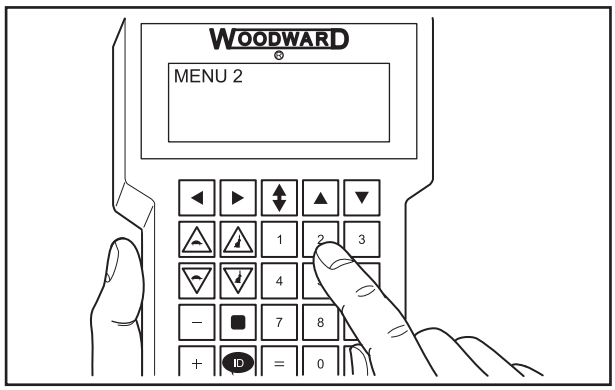
Key△ : Value slowly increases in small increments

Key▽ : Value slowly decreases in small increments

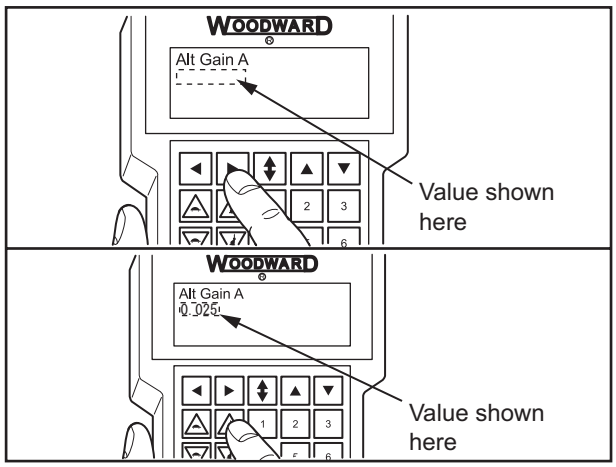
Key△ : Value rapidly increases in large increments

Key▽ : Value rapidly decreases in large increments

Set "Alt Gain A" to 0.025.



Adjusting governor during idling (3)



Adjusting governor during idling (4)

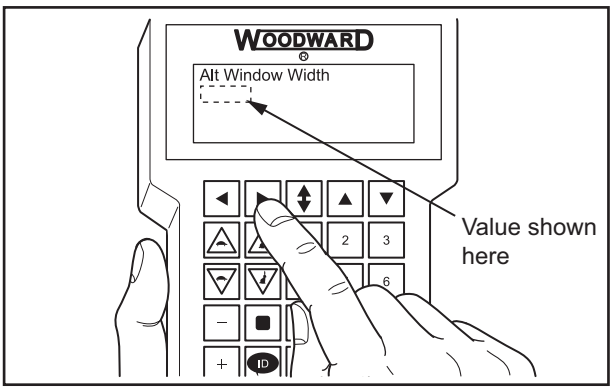
The value of "Alt Gain A" is related to hunting and rotational fluctuation as follows:

When the value of "Alt Gain A" is large, hunting increases, and rotational fluctuation decreases.

When the value of "Alt Gain A" is small, hunting decreases, and rotational fluctuation increases.

If hunting is not eliminated by the adjusting procedure described in the previous step, adjust it as described below.

(a) Press the arrow key◀ or ▶to select "Alt Window Width" or "Alt Gain Ratio".



Adjusting governor during idling (5)

(b) Adjust with the key△ or ▽.

The values of "Alt Window Width" and "Alt Gain Ratio" are related to hunting as follows:

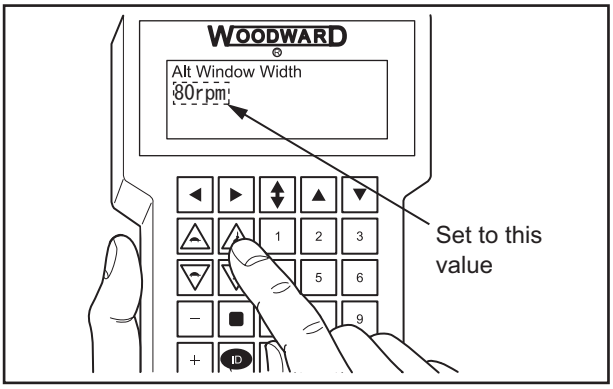
When the value of "Alt Window Width" is large, hunting decreases.When the value of "Alt Window Width" is small, hunting increases.

When the value of "Alt Gain Ratio" is small, hunting decreases. When the value of "Alt Gain Ratio" is large, hunting increases.

Note: When the value of "Alt Gain Ratio" is too small, response is too poor for the engine to start.

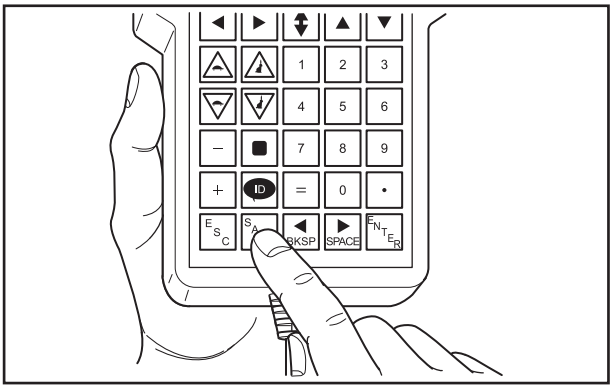
Set "Alt Window Width" to 80 rpm (min^{-1})/

Set "Alt Gain Ratio" to 4.0.



Adjusting governor during idling (6)

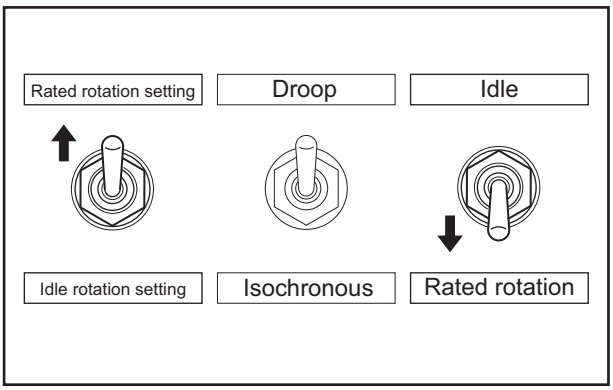
(d) After completing the adjusting procedure, press the SAVE key to store the set values.



Adjusting governor during idling (7)

4.4 Changing to rated rotation speed

When the adjustment during the idling operation is completed, turn the Idle/Rated rotation selector switch to "Rated Rotation" and the Dynamics selector switch to "Rated Rotation Setting".
The engine rotation speed rises to the rated rotation speed in a few seconds.



Changing to rated rotation speed

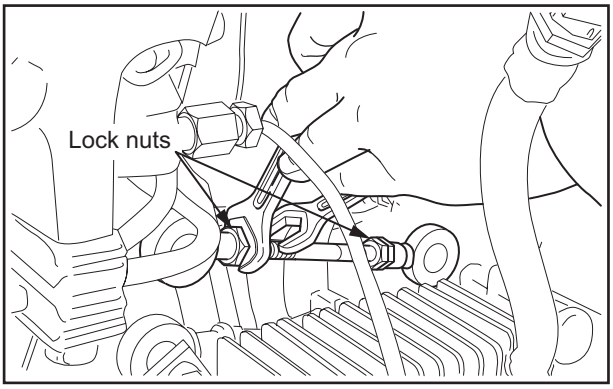
4.5 Adjustment of exhaust temperatures of right and left banks

(1) Slowly increase the load to the rated load, and operate the engine under the rated load for 5 min or more.

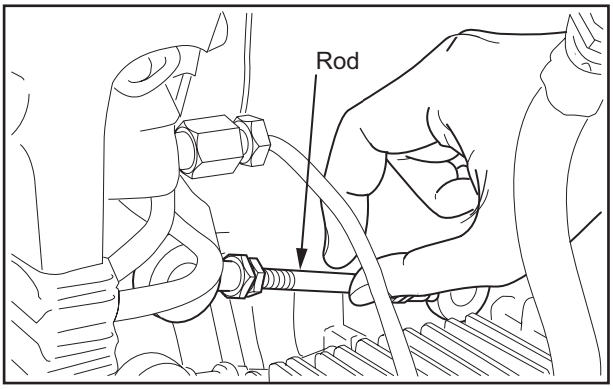
(2) Check that the turbocharger inlet temperature of the left and right banks is saturated, and measure that temperature.

(3) Adjust the exhaust temperature by changing the link length.

(a) Loosen the lock nuts.
(b) While measuring the exhaust temperature, slowly turn the rod to adjust the link length.
Adjust the exhaust temperature difference between the left and right banks to ± 20°C [68°C] at the rated load.

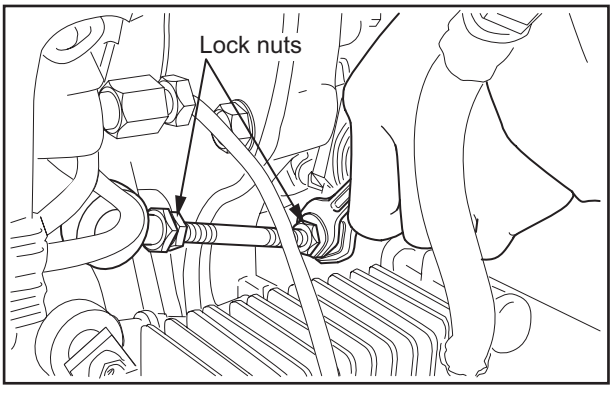


Adjusting exhaust temperature left and right bank (1)



Adjusting exhaust temperature left and right bank (2)

(c) When the adjustment is completed, tighten the lock nuts.



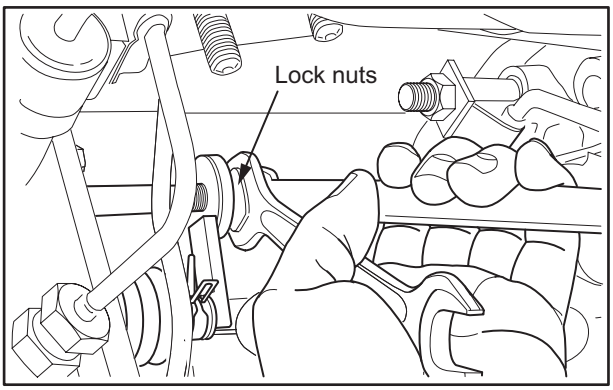
Adjusting exhaust temperature left and right banks (3)

4.6 Adjusting rack set

(1) Rack set of left pump

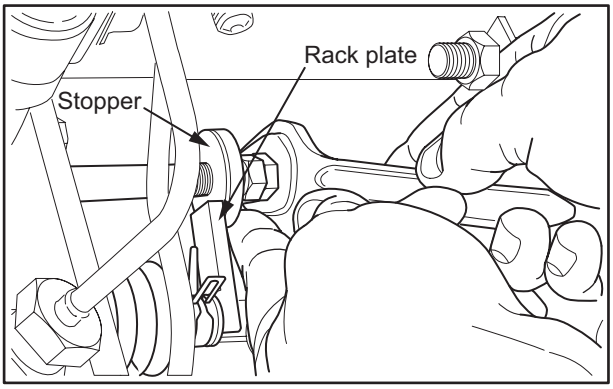
(a) While the engine is running under the rated load, move the stop lever to the maximum rotation side and hold it in that condition.

(b) Loosen the lock nut of the stopper.



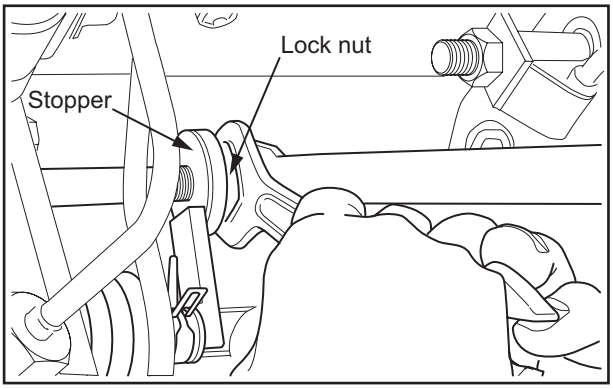
Adjusting rack set (1)

(c) Adjust the stopper so that the rack plate lightly touches the stopper.



Adjusting rack set (2)

(d) While maintaining the above-mentioned condition, tighten the lock nut to fix the stopper.

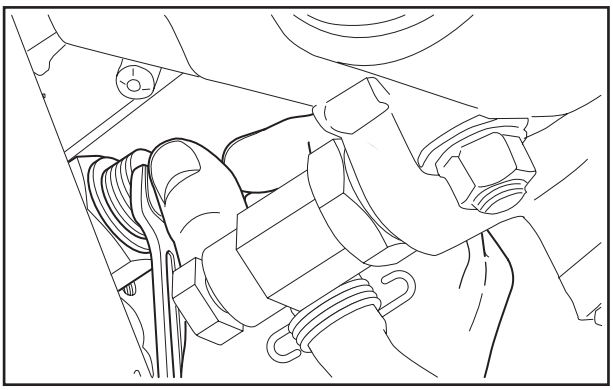


Adjusting rack set (3)

(2) Rack set of right pump

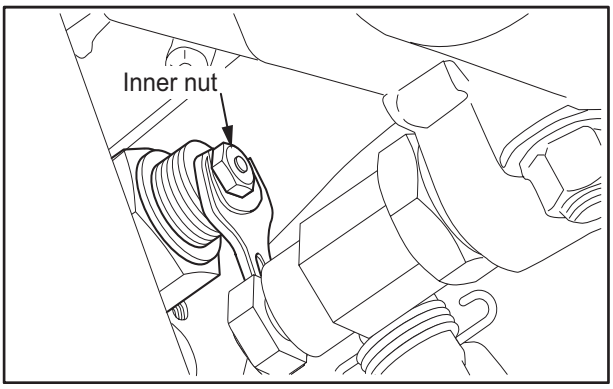
(a) While the engine is running under the rated load, move the stop lever to the maximum rotation side and hold it in that condition.

(b) Remove the cap, and loosen the outer nut of the double nuts inside.

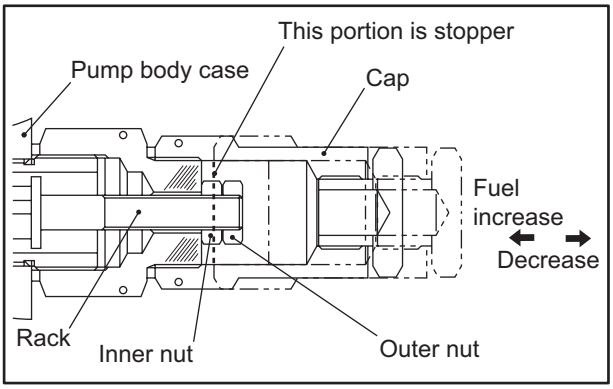


Adjusting rack set (4)

(c) Tighten or loosen the inner nut, and stop it when it clicks.

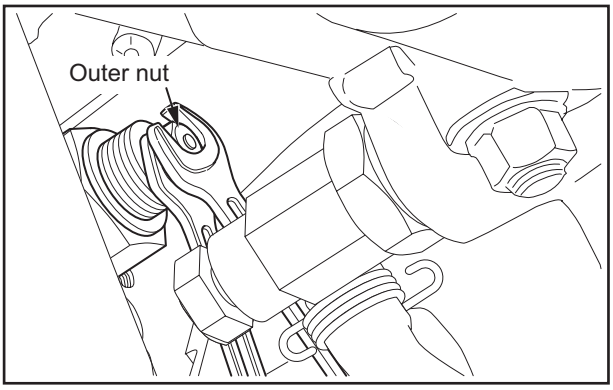


Adjusting rack set (5)



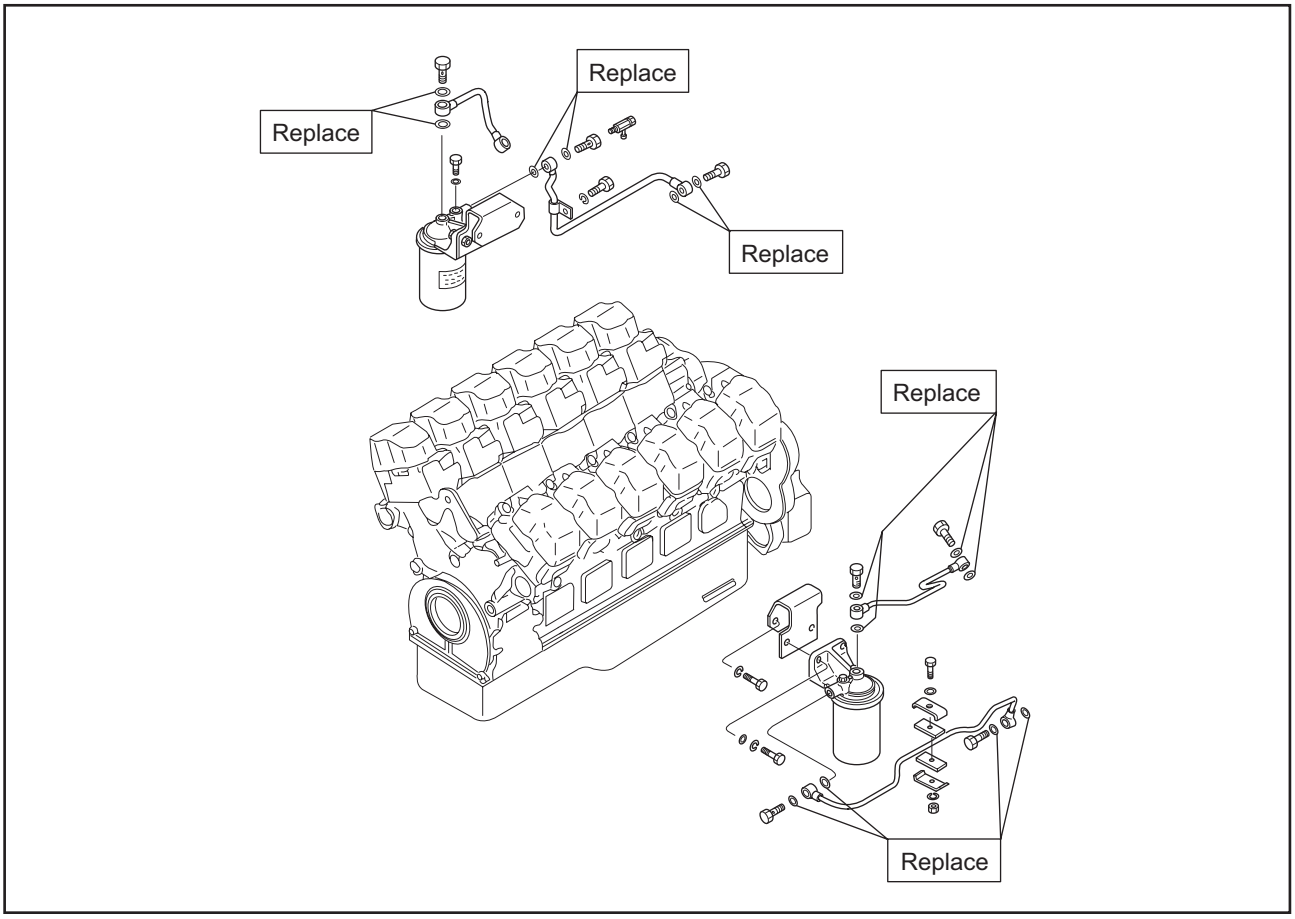
Adjusting rack set (6)

(d) While maintaining the above-mentioned condition, tighten the outer nut to fix the rack.



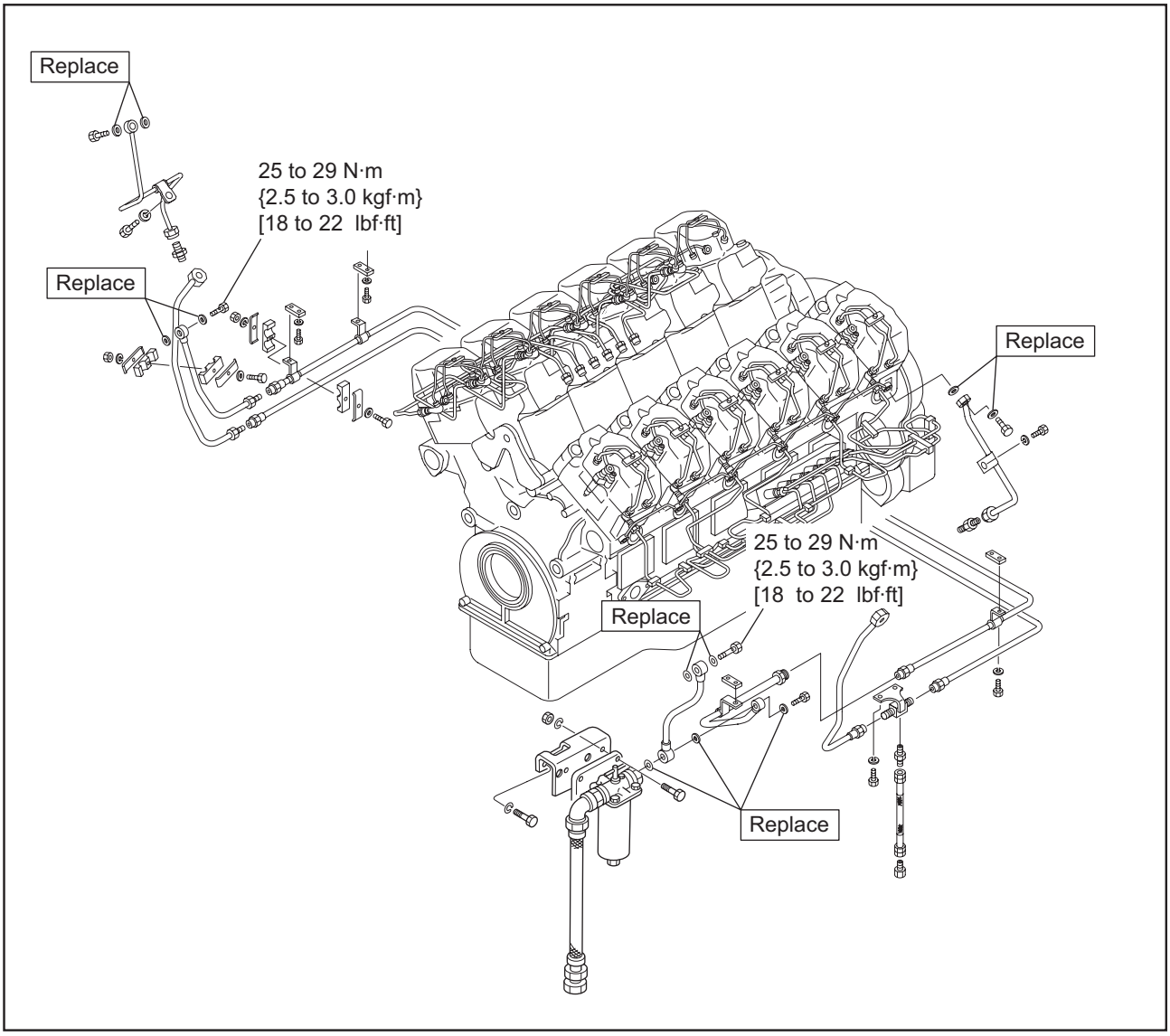
Adjusting rack set (7)

4.7 Installing fuel filters and fuel pipes



Installing fuel filters and fuel pipes

4.8 Installing fuel injection pipes and fuel leak-off pipes



Installing fuel injection pipes and fuel leak-off pipes

LUBRICATION SYSTEM

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3.2 Installing breather and oil filler 9-17
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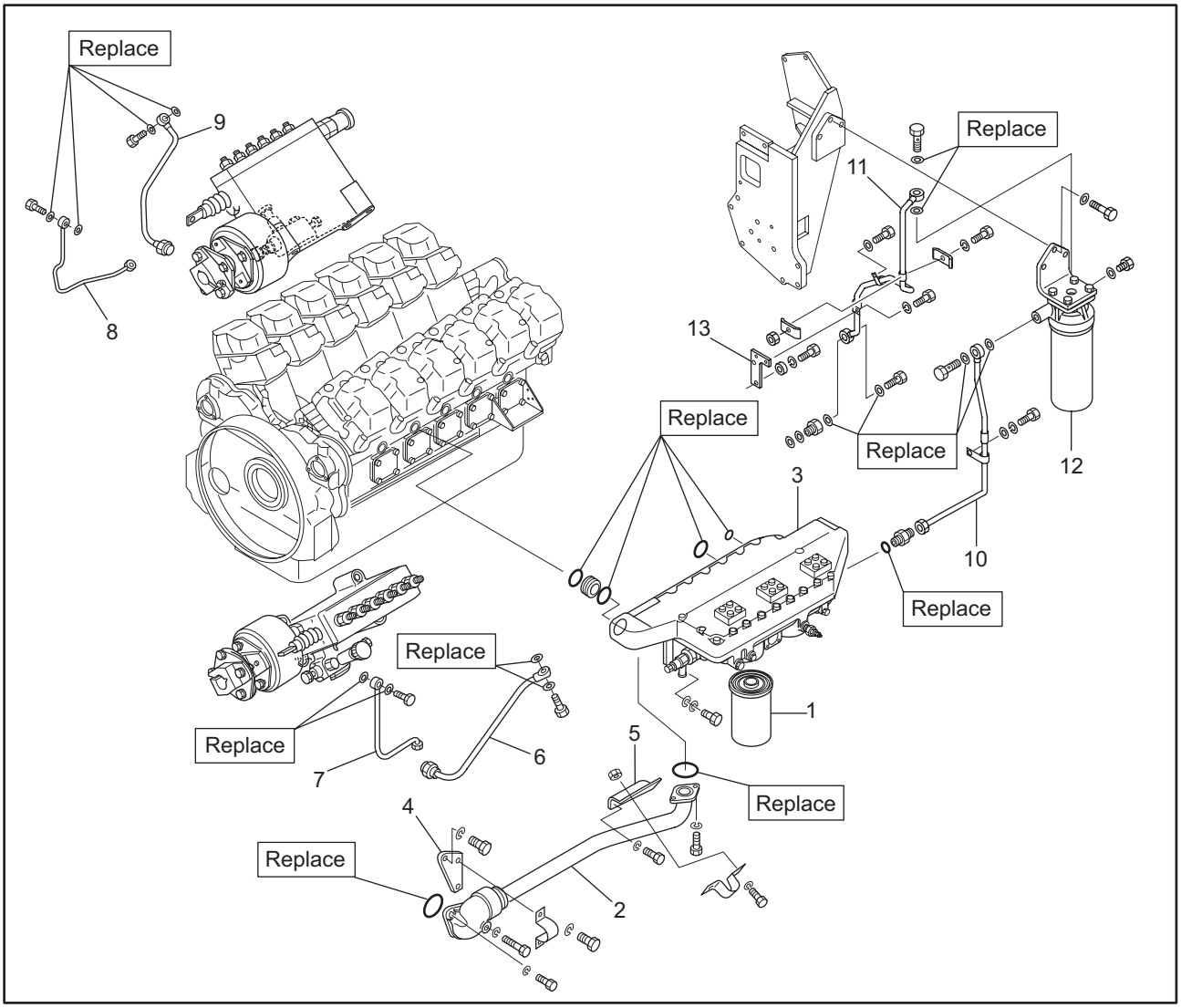
1. Removing lubrication system

1.1 Removing oil pipe, oil cooler and oil filter for fuel injection pumps

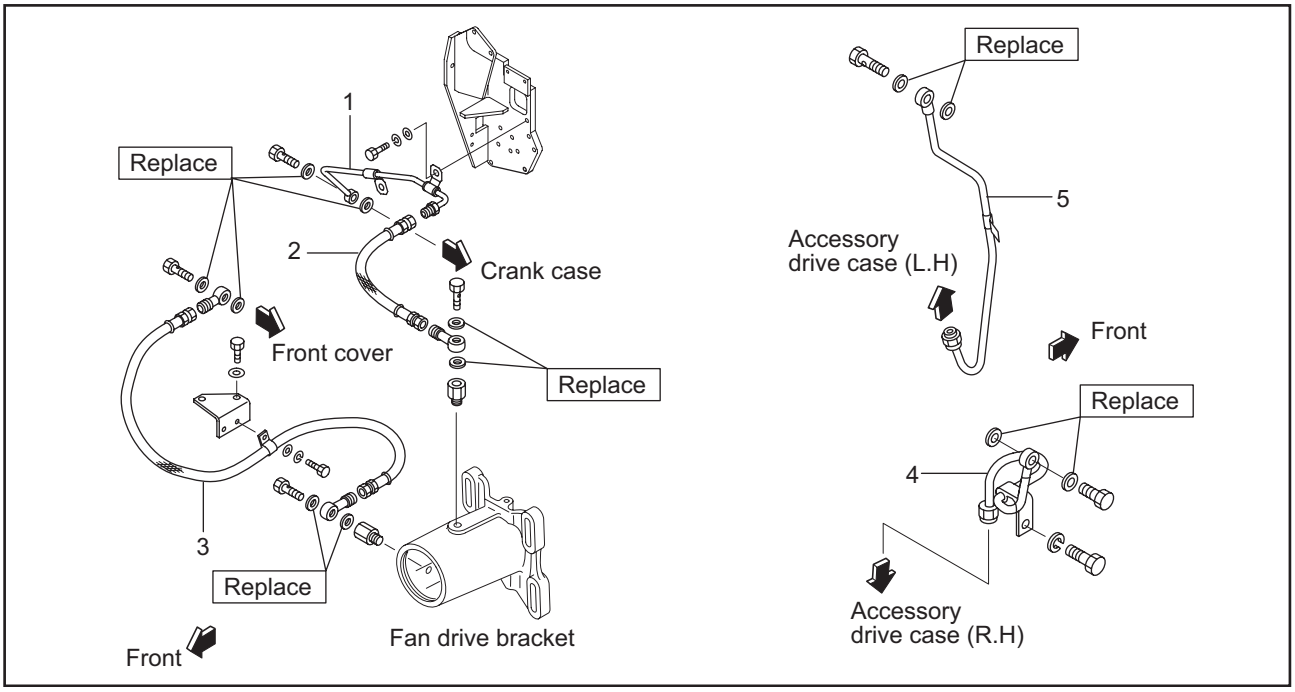


Removing oil pipe, oil cooler and oil filter for fuel injection pumps

Removing sequence

1 Oil filter element
2 Oil pipe
3 Oil cooler
4 Stay
5 Stay
6 Right side oil pipe
7 Right side oil pipe
8 Left side oil pipe
9 Left side oil pipe
10 Oil pipe
11 Oil pipe
12 Bypass oil filter assembly
13 Pipe drain stay

1.2 Removing fan drive and oil pipe for accessory drives

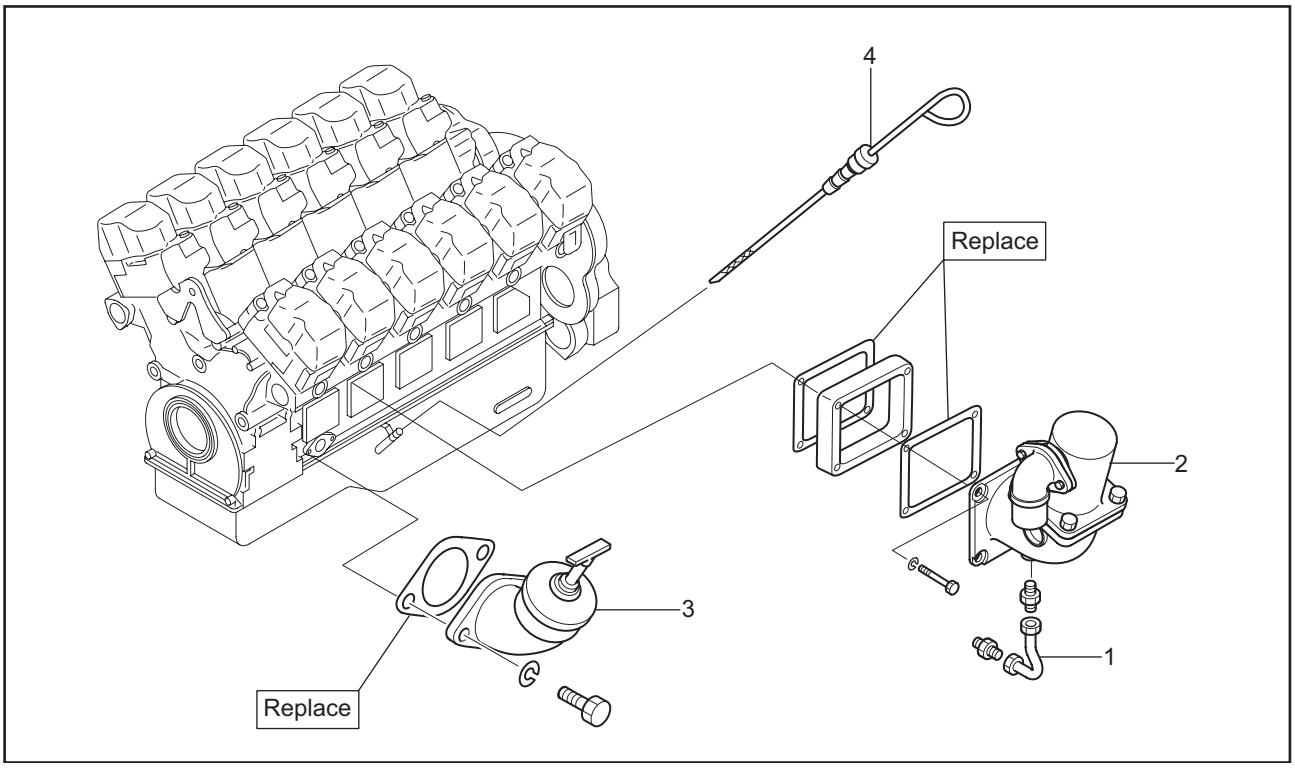


Removing fan drive and oil pipe for accessory drives

Removing sequence

1 Oil pipe for fan drive
2 Oil pipe for fan drive
3 Drain pipe for fan drive
4 Oil pipe for accessory drive (R.H)
5 Oil pipe for accessory drive (L.H)

1.3 Removing breather, oil filler and oil level gauge

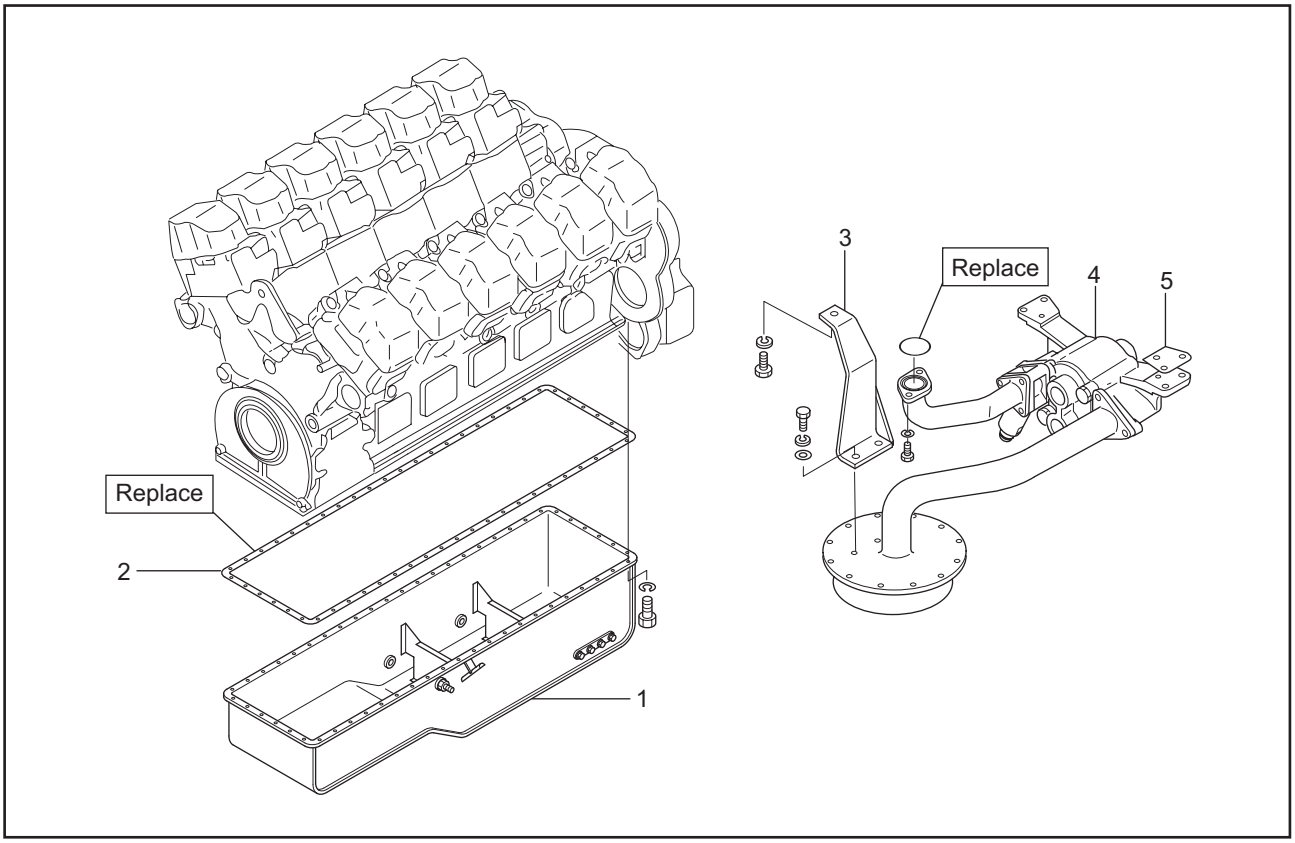


Removing breather, oil filler and oil level gauge

Removing sequence

1 Oil pipe
2 Breather
3 Oil filler
4 Oil level gauge

1.4 Removing oil pan, oil strainer and oil pump



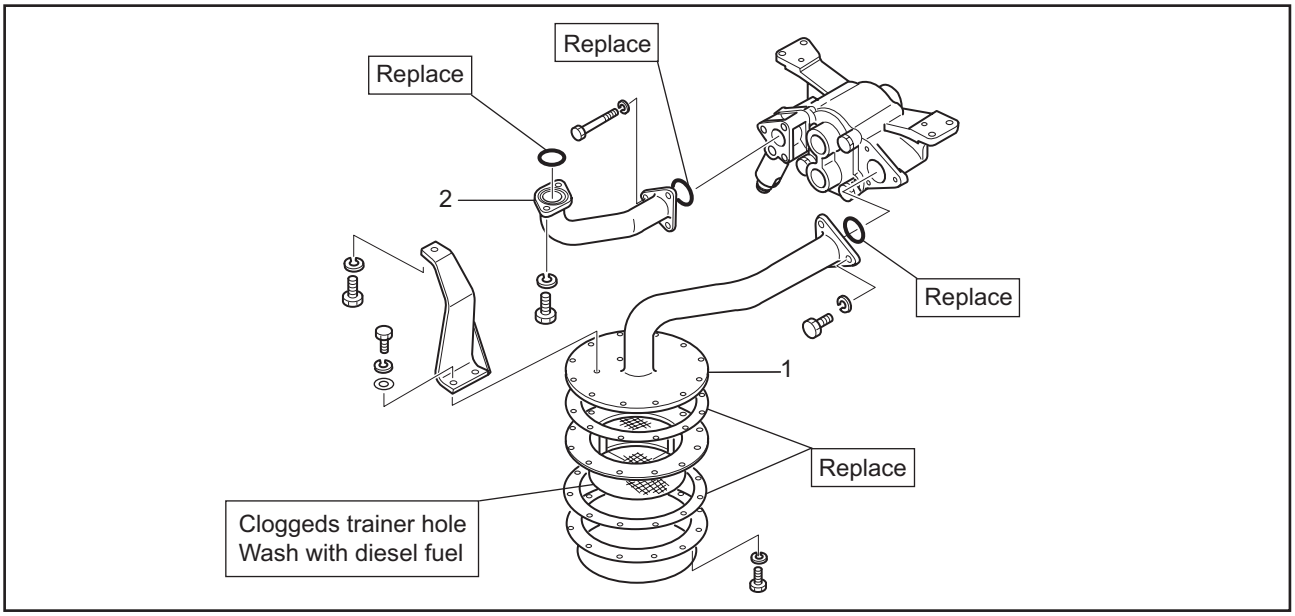
Removing oil pan, oil strainer and oil pump

Removing sequence

1 Oil pan
2 Packing
3 Oil strainer support
4 Oil pump assembly
5 Shim

2. Disassembling, inspecting and reassembling lubrication system

2.1 Disassembling and inspecting oil strainer

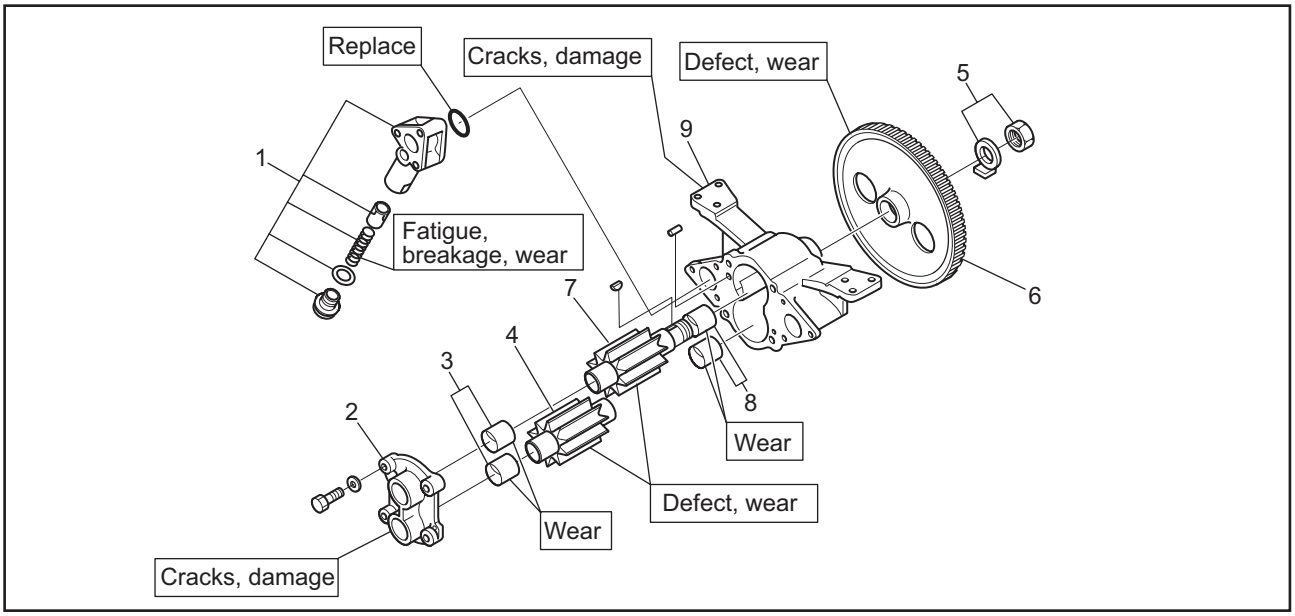


Disassembling and inspecting oil strainer

Disassembling sequence

1 Oil strainer
2 Oil pipe

2.2 Disassembling and inspecting oil pump and safety valve



Disassembling and inspecting oil pump and safety valve

Disassembling sequence

1 Safety valve assembly
2 Oil pump cover
3 Bushing
4 Driven gear
5 Nut and washer
6 Oil pump gear
7 Drive gear
8 Bushing
9 Oil pump case
10 Shim

2.3 Inspecting oil pump and safety valve

2.3.1 Measuring oil pump gear backlash

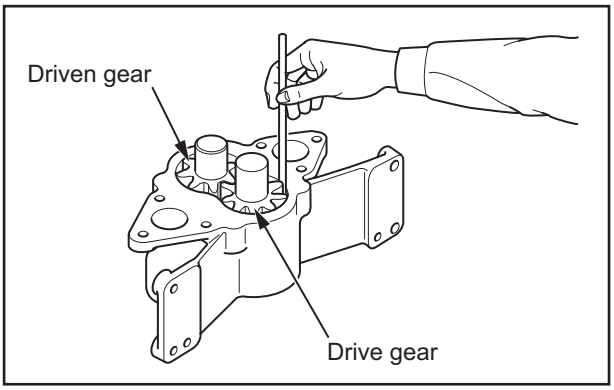
Measure gear backlash. Renew the gear(s) if the limit is exceeded.

Item	Standard	Limit
Backlash between drive and driven gears	0.100 to 0.200 mm [0.0039 to 0.0079 in.]	0.400 mm [0.0157 in.]

2.3.2 Measuring side clearance between gears and case

Measure the side clearance between gear teeth and case bore. If the limit is exceeded, replace gears or case with a new one.

Item	Standard	Limit
Side clearance between gear teeth and case bore	0.150 to 0.230 mm [0.0059 to 0.0091 in.]	0.350 mm [0.0138 in.]

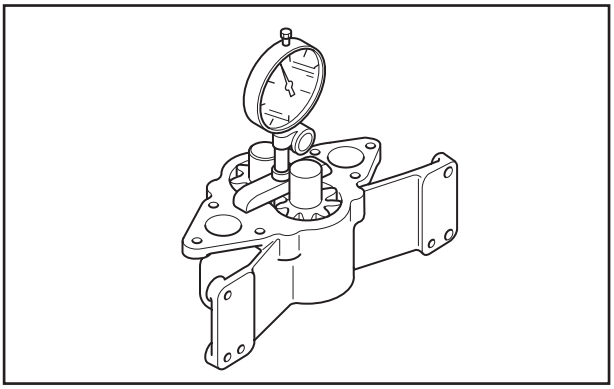


Measuring side clearance between gears and case

2.3.3 Measuring end clearance between gears and case

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

Item	Standard	Limit
End clearance between gear width and case depth	0.130 to 0.200 mm [0.0051 to 0.0080 in.]	0.250 mm [0.0098 in.]



Measuring end clearance between gears and case

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

(1) Inspect the gear teeth. If any defects are found, replace the gear with a new one.

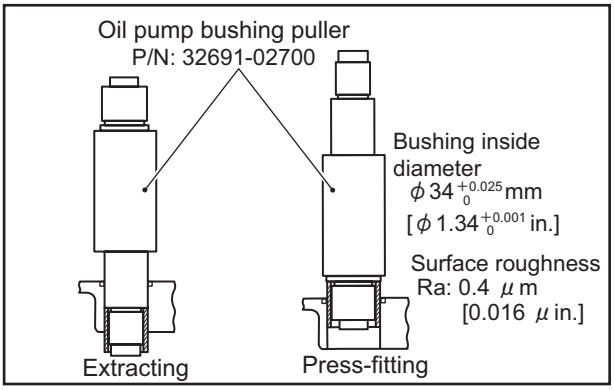
(2) Measure the drive and driven gear shaft outside diameters and the bushing inside diameter. If any of the gear and bushing combination exceeds the limit, replace it with the new set of such parts.

Item	Nominal	Standard	Limit
Gear shaft diameter	ø 34 mm [1.34 in.]	33.944 to 33.960 mm [1.3364 to1.3370 in.]	33.920 mm [1.3354 in.]
Bushing inside diameter		34.000 to 34.025 mm [1.3386 to1.3396 in.]	34.055 mm [1.3410 in.]

2.3.5 Replacing oil pump bushing

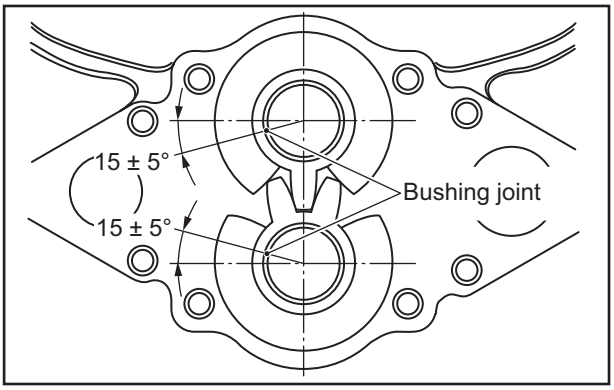
(1) Use the oil pump bushing puller to replace oil pump bushings.

(2) Remove the bushing from the oil pump only when it is practical. If it is hard to remove, replace it as an assembly with the oil pump case or oil pump cover.



Press-fitting oil pump bushing

(3) When press-fitting a bushing in the oil pump cover, orient the bushing such that its joint is positioned as illustrated (it is not aligned with the oil groove).

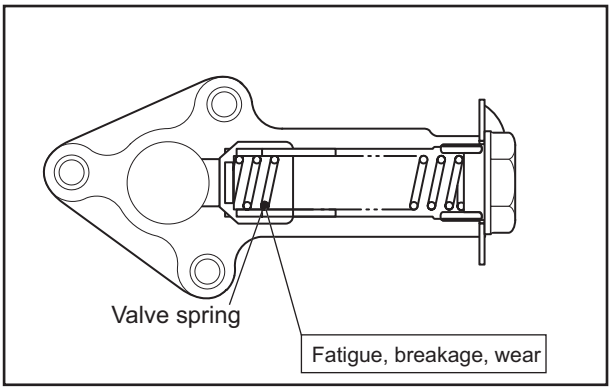


Location of oil pump bushing joint

2.3.6 Inspecting oil pump safety valve spring

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

Item	Standard
Safety valve spring installation length/load	97 mm [3.82 in.]/118N {12 kgf} [26.4 lbf]

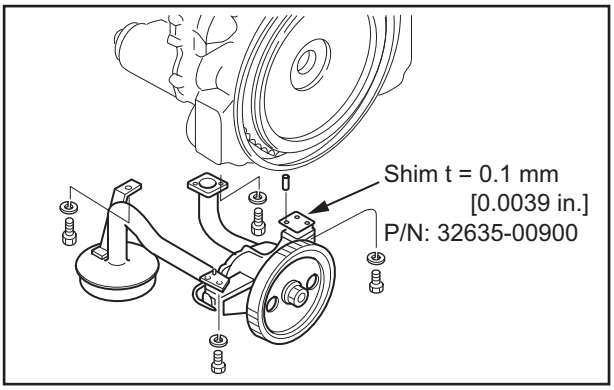


Inspecting safety valve

2.3.7 Adjusting backlash when installing oil pump

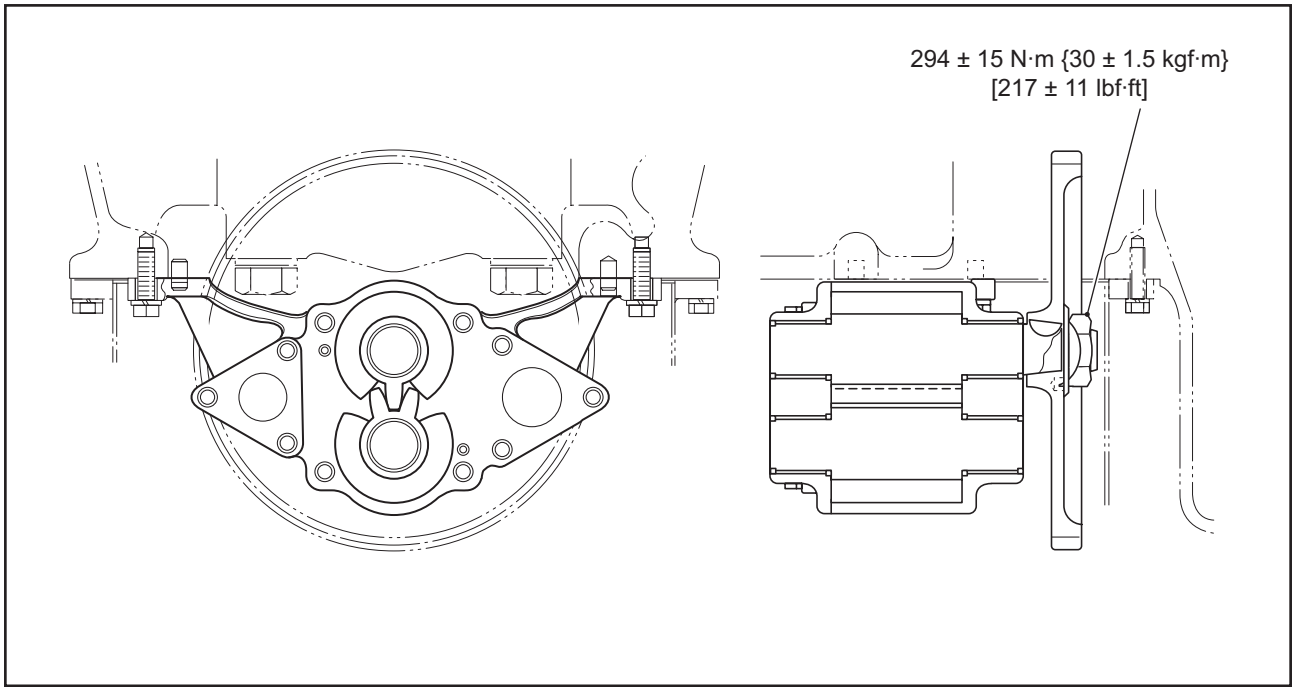
After installing the oil pump to the crankcase, measure the backlash between the crankshaft gear and oil pump idler gear. If the backlash does not confirm to the standard, adjust the backlash by inserting shim(s) under the oil pump mount.

Item	Standard
Backlash between oil pump idler gear and crankshaft gear	0.120 to 0.180 mm [0.0047 to 0.0071 in.]



Adjusting backlash when installing oil pump

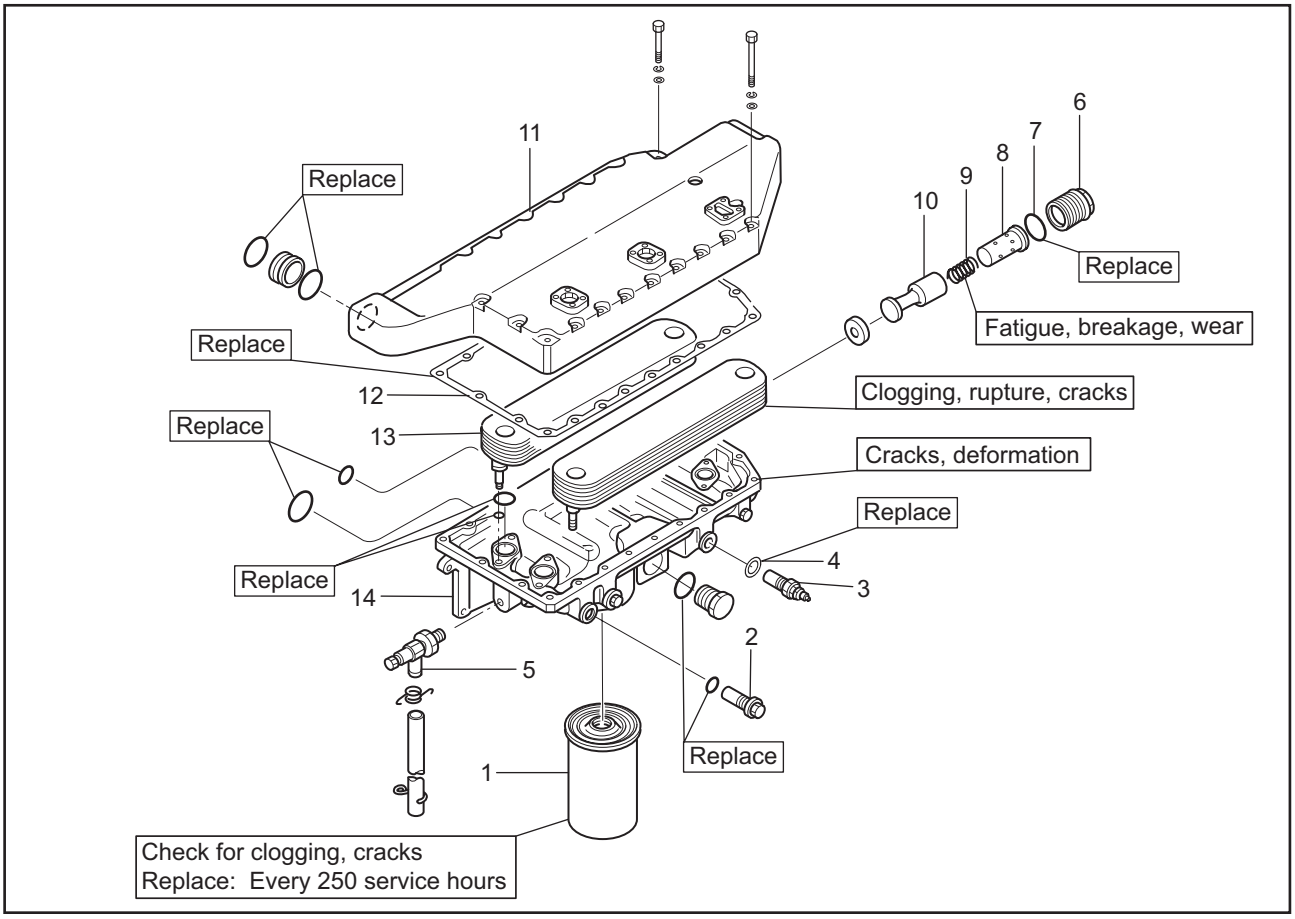
2.4 Reassembling oil pump and safety valve



Reassembling oil pump and safety valve

Note: Lubricate individual parts with engine oil during reassembly. Apply a thick coat of engine oil to the threads and seating surfaces of the nuts and bolts before tightening them.

2.5 Disassembling and inspecting oil cooler, oil filter, alarm and relief valve



Disassembling and inspecting oil cooler, oil filter, alarm and relief valve

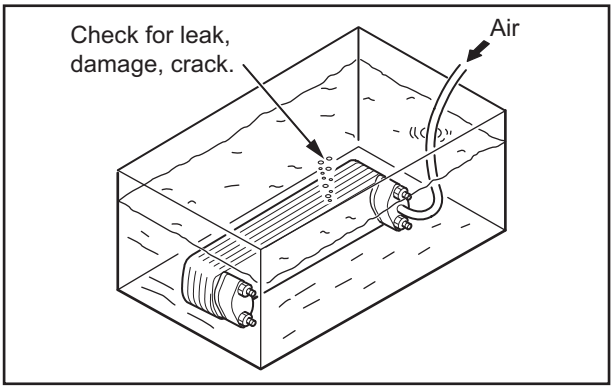
Disassembling sequence

1 Oil filter (cartridge type)
2 Bypass valve
3 Oil filter alarm
4 Sealing washer
5 Drain cock
6 Relief valve plug
7 O-ring
8 Relief valve sleeve
9 Relief valve spring
10 Relief valve
11 Oil cooler case
12 Gasket
13 Oil cooler element
14 Oil cooler cover

2.6 Inspecting oil cooler, oil filter, alarm and relief valve

2.6.1 Inspecting oil cooler

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



Inspecting oil cooler

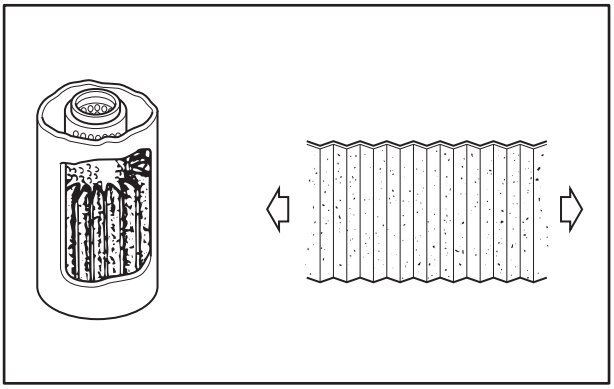
2.6.2 Inspecting bypass valve

Check the bypass valve opening pressure. If the pressure does not fall within the specified range, replace the valve with a new one.

Item	Standard
Bypass valve opening pressure	0.44 ± 0.05 MPa {4.5 ± 0.5 kgf/cm² } [64 ± 7 psi]

2.6.3 Inspecting oil filter

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



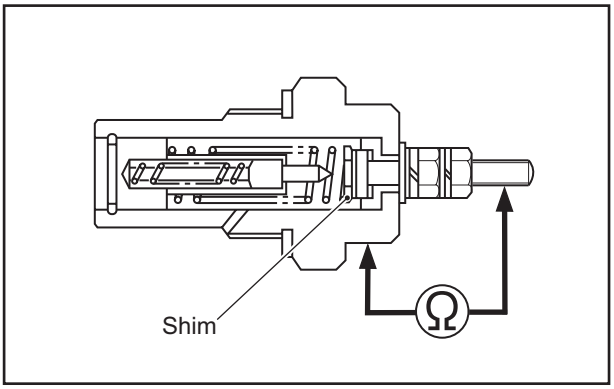
Inspecting oil filter

2.6.4 Inspecting oil filter alarm

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

(2) If the filter alarm lamp lighting pressure exceeds the standard, replace the alarm with a new one.

Item	Standard
Oil filter alarm lighting pressure	0.15 to 0.18 MPa {1.5 to 1.8 kgf/cm²} [21.3 to 25.6 psi]



Inspecting oil filter alarm

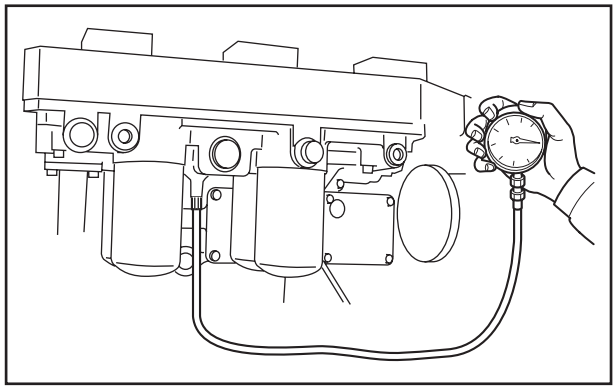
2.6.5 Measuring relief valve pressure

(1) Remove the taper plug at the bottom of oil cooler, and set a pressure gauge in that place.

(2) Run the engine until the oil temperature reaches 70 to 90 °C [158 to 194 °F].

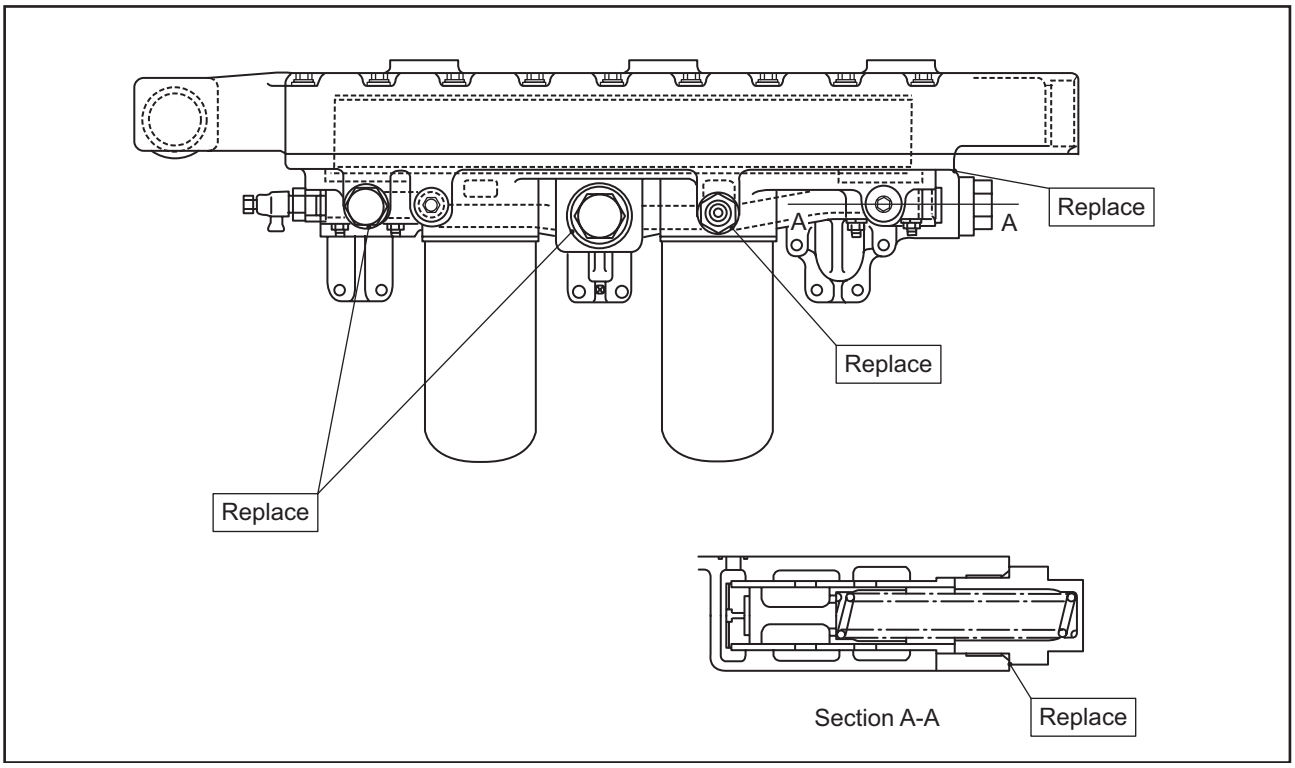
(3) Measure the oil pressure at idling and at the maximum speed respectively.

Item	Standard
Relief valve opening pressure	0.49 to 0.69 MPa {5.0 to 7.0 kgf/cm²} [71 to 100 psi]



Pressure measurement point

2.7 Reassebling oil cooler, oil filter, alarm and relief valve

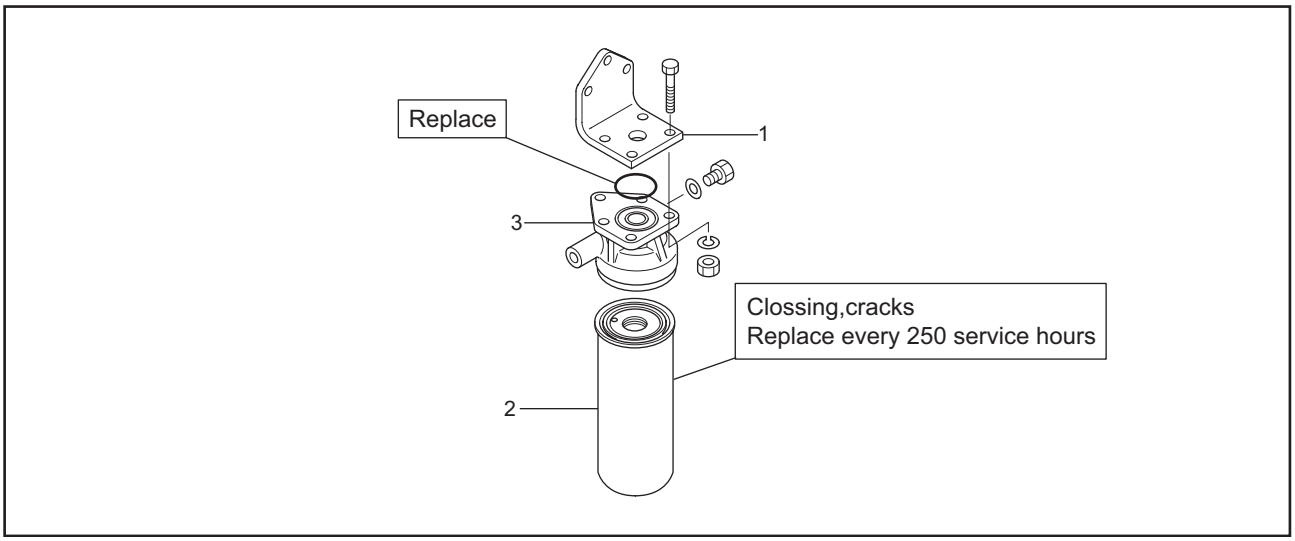


Reassebling oil cooler, oil filter, alarm and relief valve

CAUTION

Install new packings and O-rings in reassembly.

2.8 Disassembling and inspecting bypass oil filters

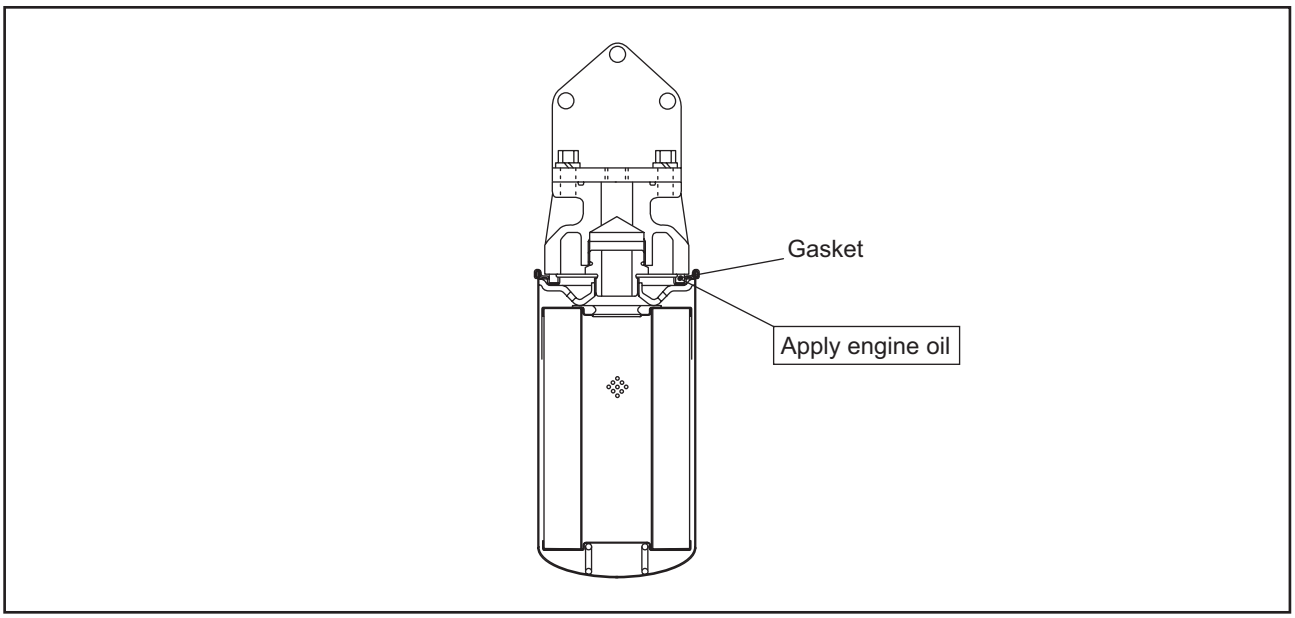


Disassembling and inspecting bypass oil filters

Disassembly sequence

1 Bracket
2 Cartridge element
3 Bracket

2.9 Reassembling bypass oil filters



Reassembling bypass oil filters

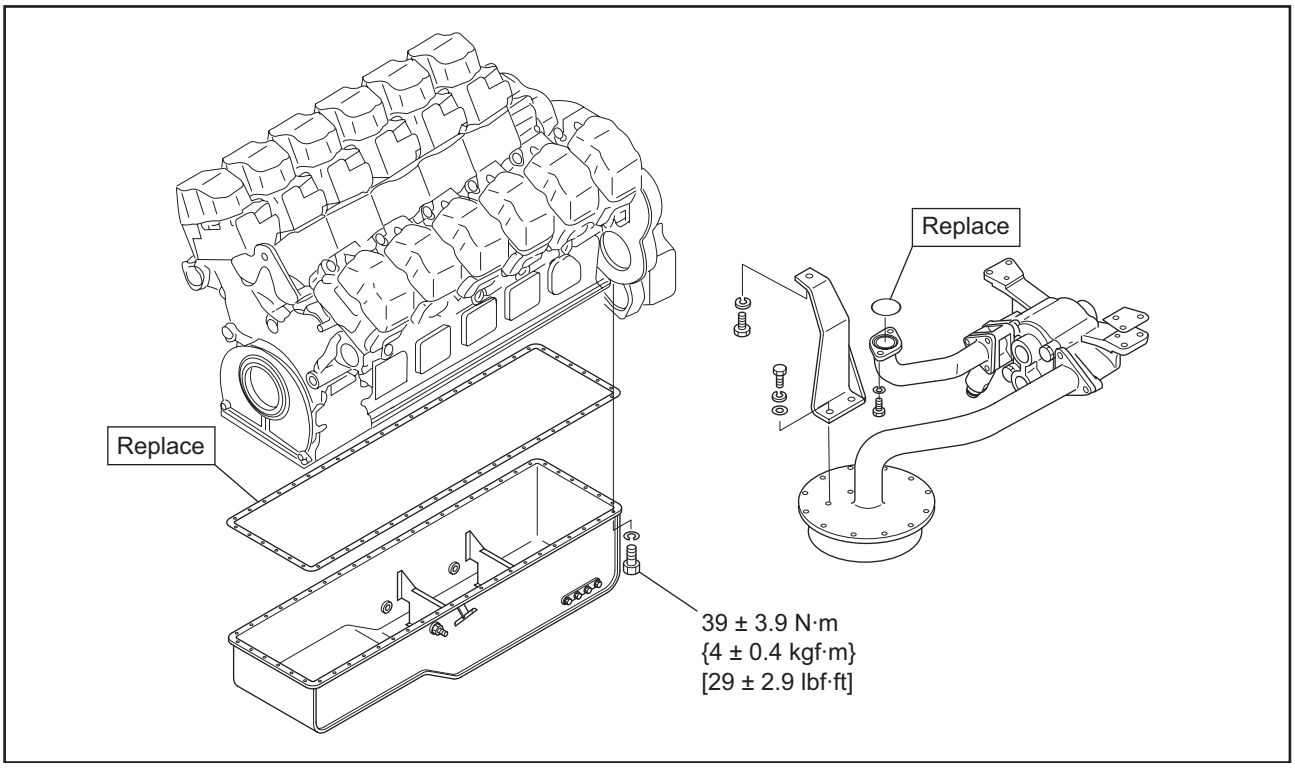
CAUTION

Tighten the cartridge oil filter by hand. Do not use a filter wrench to tighten the oil filter.

With the oil filter contacted the bracket mounting surface, tighten the filter by 3/4 to 1 turn, being careful not to dent or damage the filter surface.

3. Installing lubrication system

3.1 Installing oil pan, oil strainer and oil pump



Installing oil pan, oil strainer and oil pump

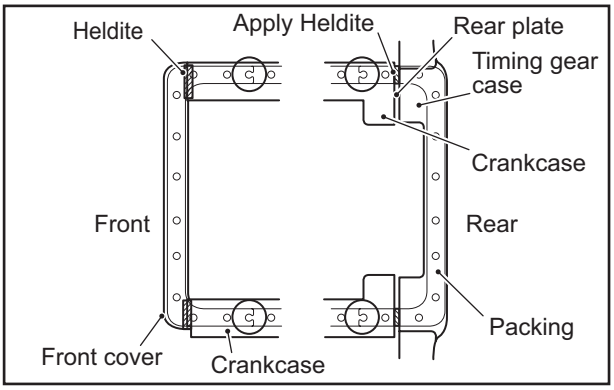
3.1.1 Installing oil pan

(1) Apply Heldite to the lower faying surfaces between the front cover and the crankcase.

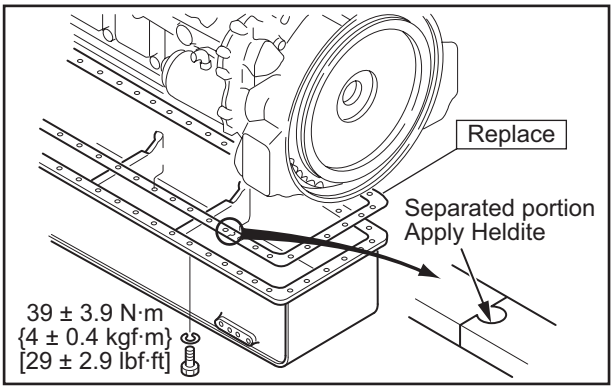
(2) Apply Heldite to the lower faying surfaces of the crankcase, rear plate and timing gear case.

(3) Apply sealant (Heldite) to the joint surfaces of separated portions (4 locations) of the oil pan packing, and install the packing to the oil pan.

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

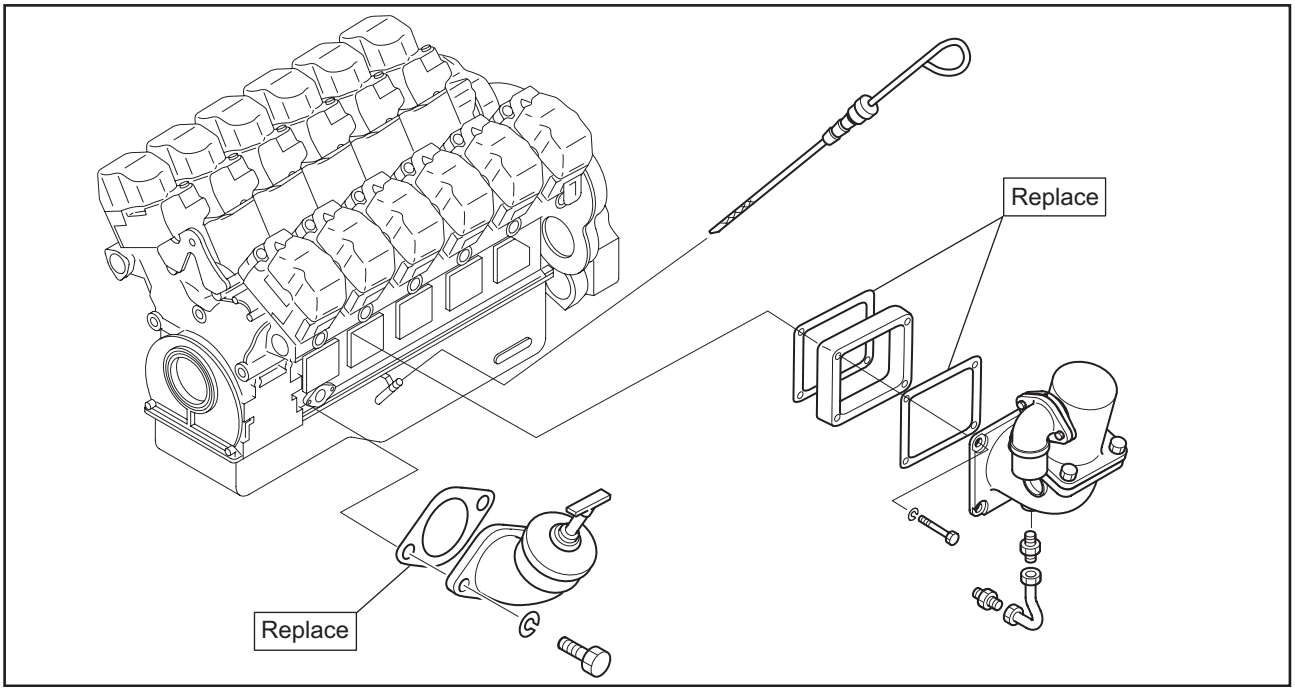


Installing oil pan (1)



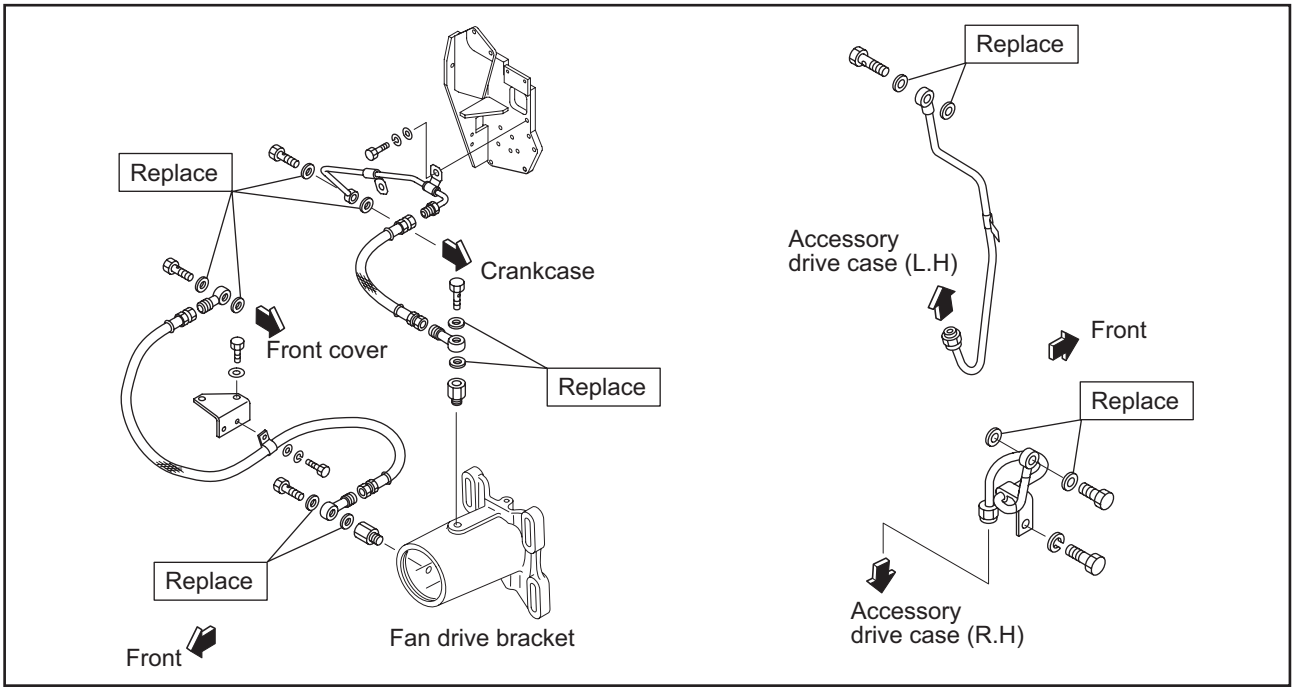
Installing oil pan (2)

3.2 Installing breather and oil filler



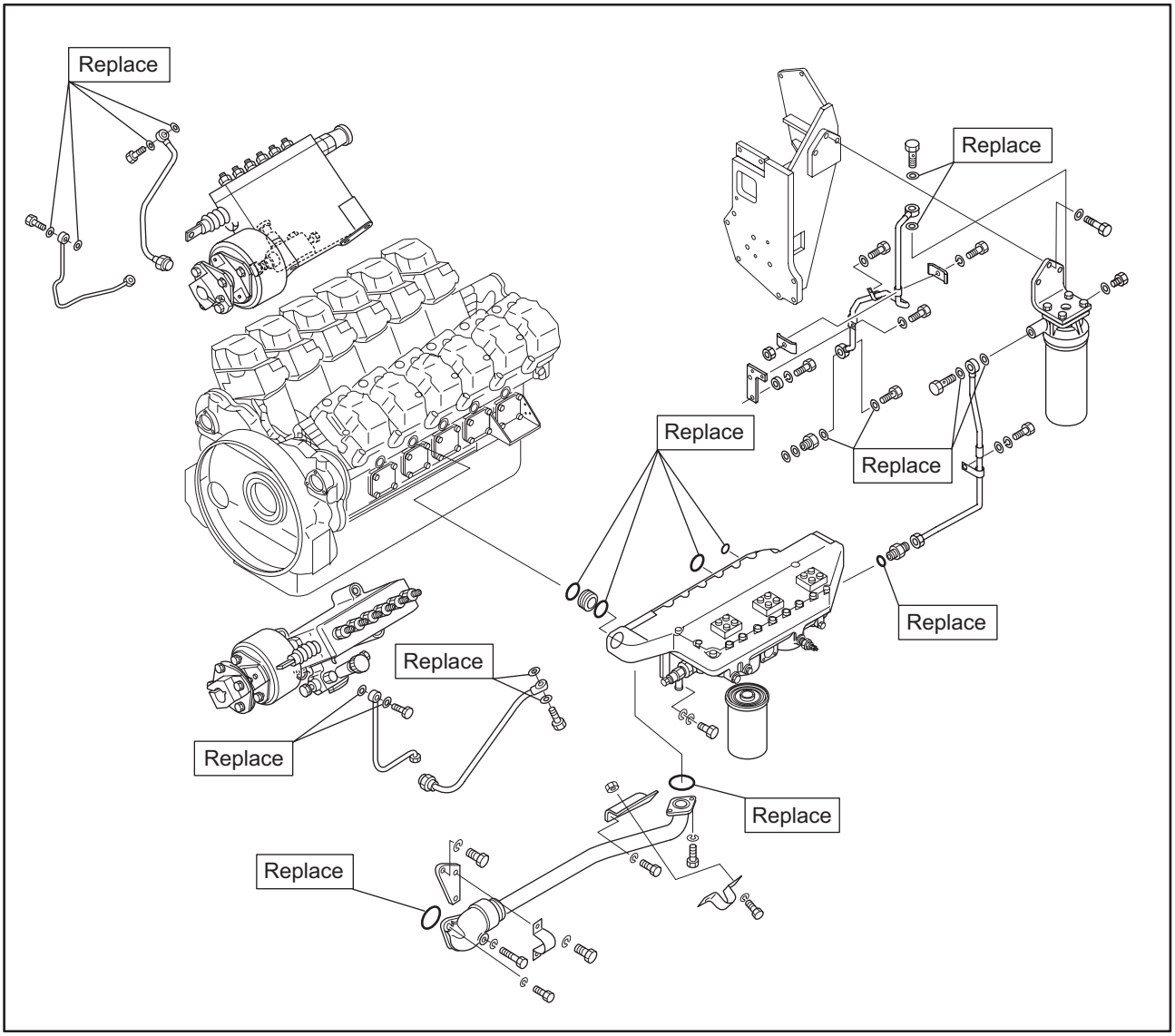
Installing breather and oil filler

3.3 Installing fan drive and oil pipe for accessory drives



Installing fan drive and oil pipe for accessory drives

3.4 Installing oil pipe, oil cooler and oil filter for fuel injection pumps



Installing oil pipe, oil cooler and oil filter for fuel injection pumps

CAUTION

Tighten the cartridge oil filter by hand. Do not use a filter wrench to tighten the oil filter.

With the oil filter contacted the bracket mounting surface, tighten the filter by 3/4 to 1 turn, being careful not to dent or damage the filter surface.

COOLING SYSTEM

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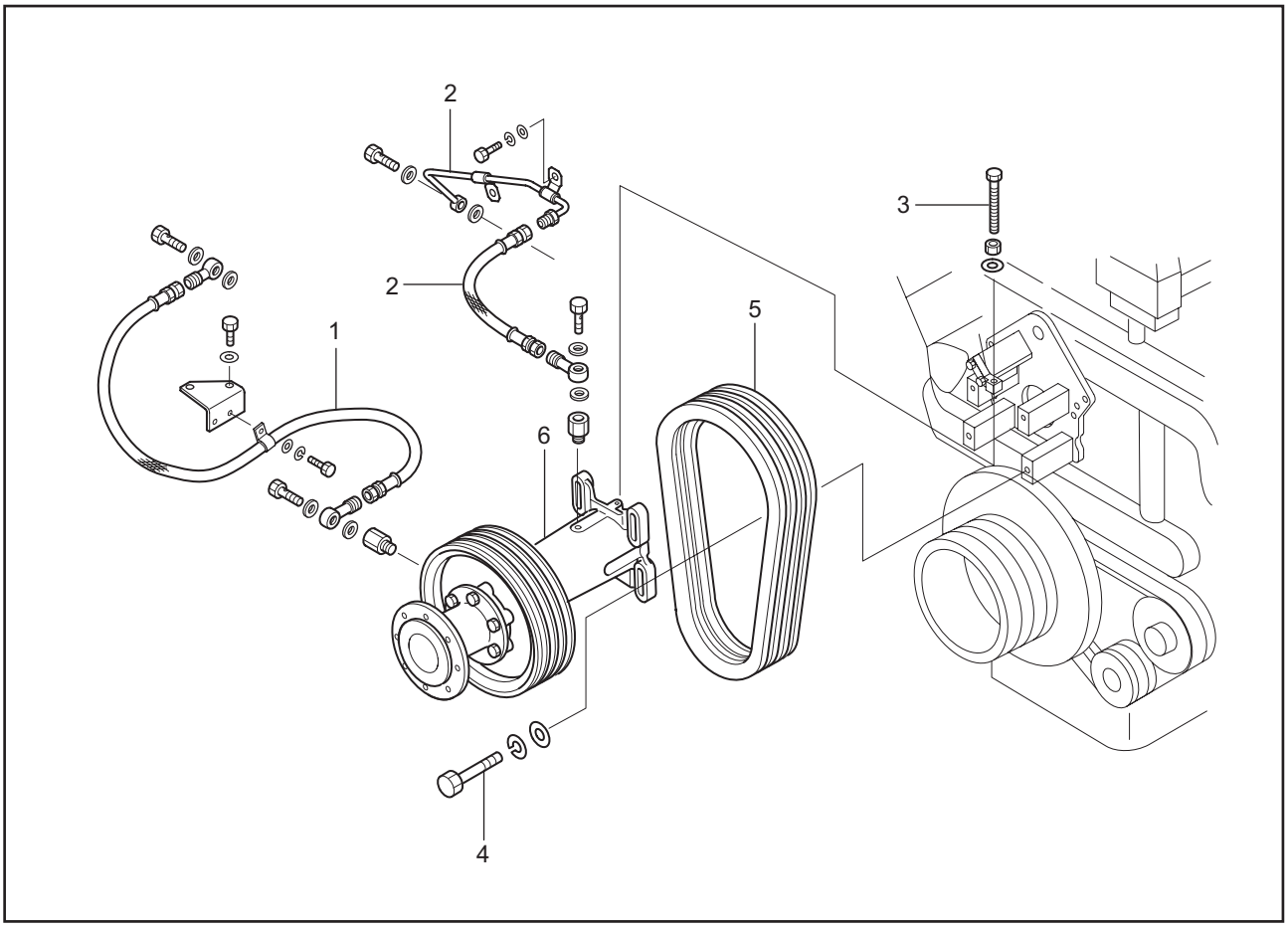
1. Removing cooling system

1.1 Removing fan drive

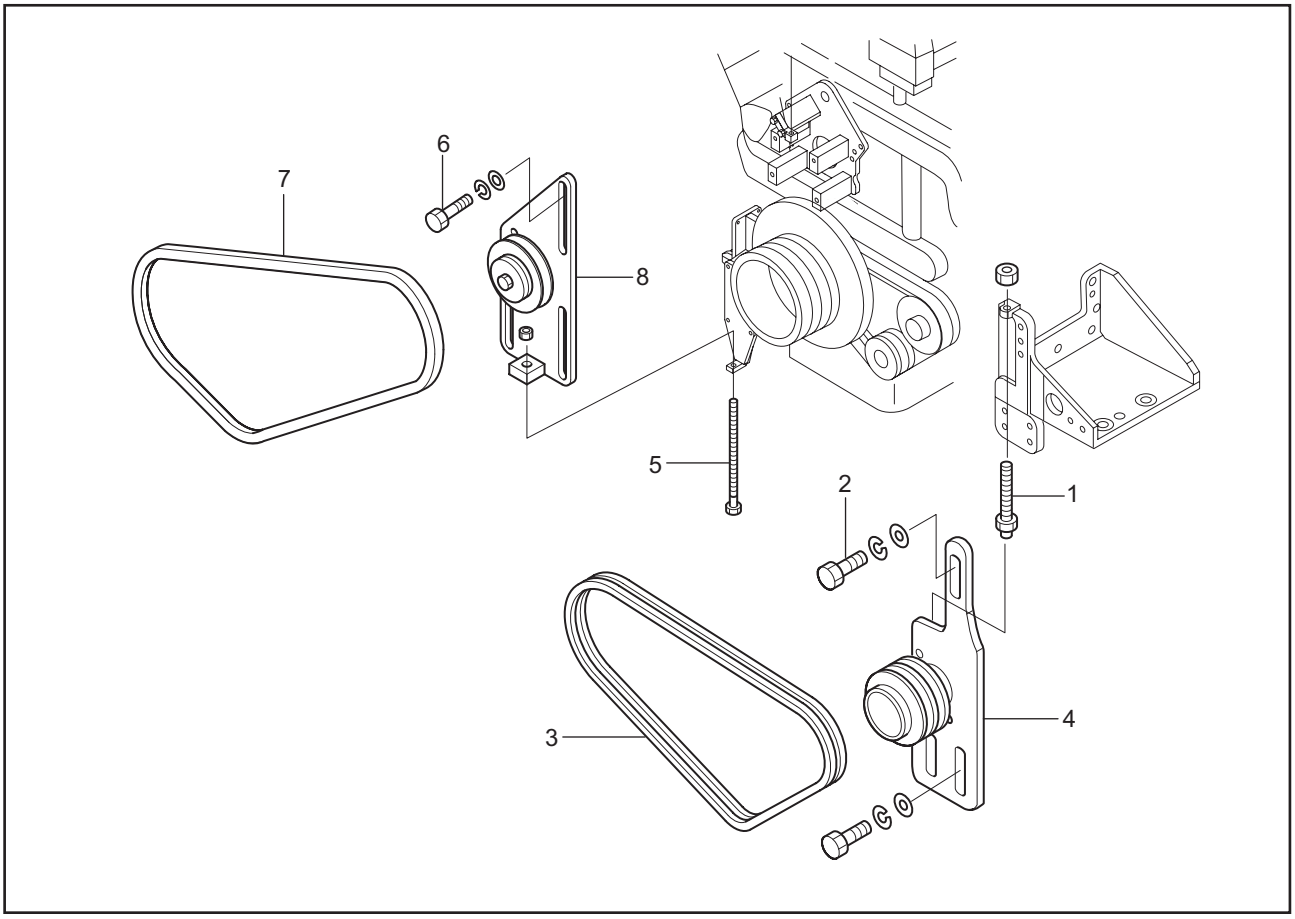


Removing fan drive

Removing sequence

1 Flexible pipe
2 Oil pipe, flexible pipe
3 Tension bolt
4 Mounting bolt
5 V-belt
6 Fan drive, fan pulley

1.2 Removing tension pulley

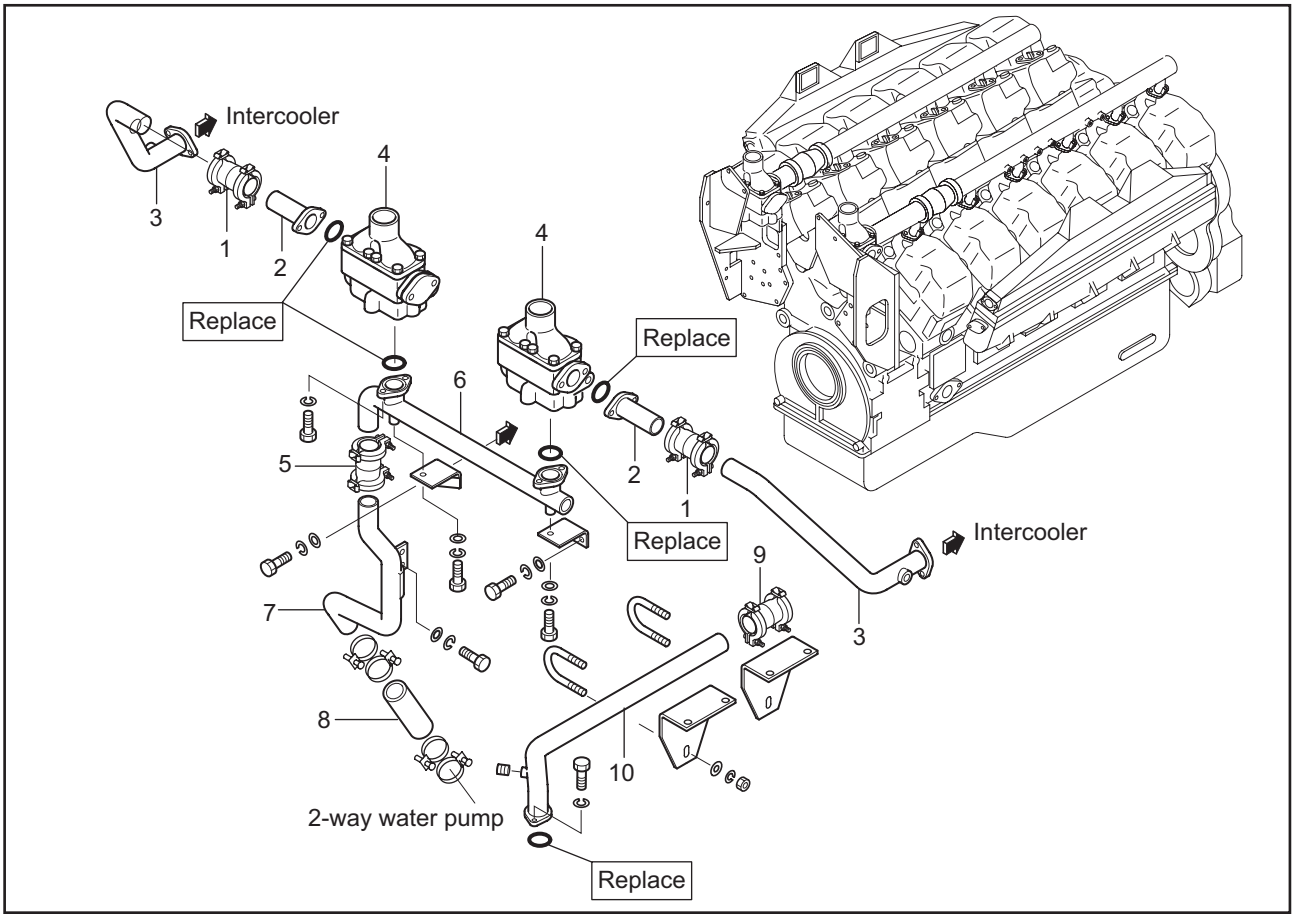


Removing tension pulley

Removing sequence

1 Tension bolt
2 Mounting bolt
3 V-belt
4 Tension pulley assembly
5 Tension bolt
6 Mounting bolt
7 V-belt
8 Tension pulley assembly

1.3 Removing thermostat and 2-way water pipe

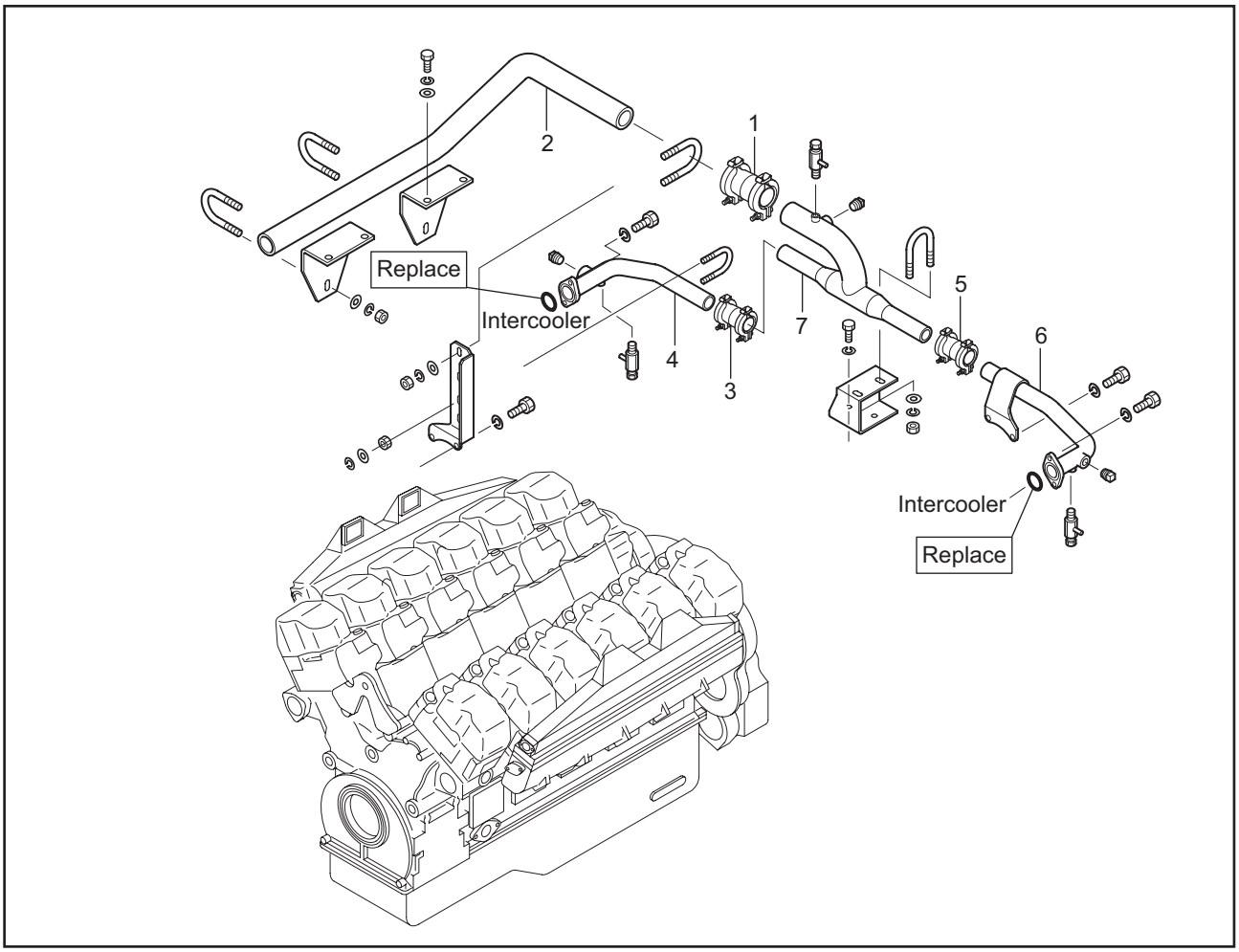


Removing thermostat and 2-way water pipe

Removing sequence

1 Coupling
2 Water pipe
3 Water pipe
4 Thermostat
5 Coupling
6 By-pass pipe
7 By-pass pipe
8 Rubber hose
9 Coupling
10 Water pump pipe

1.4 Removing 2-way water pipe

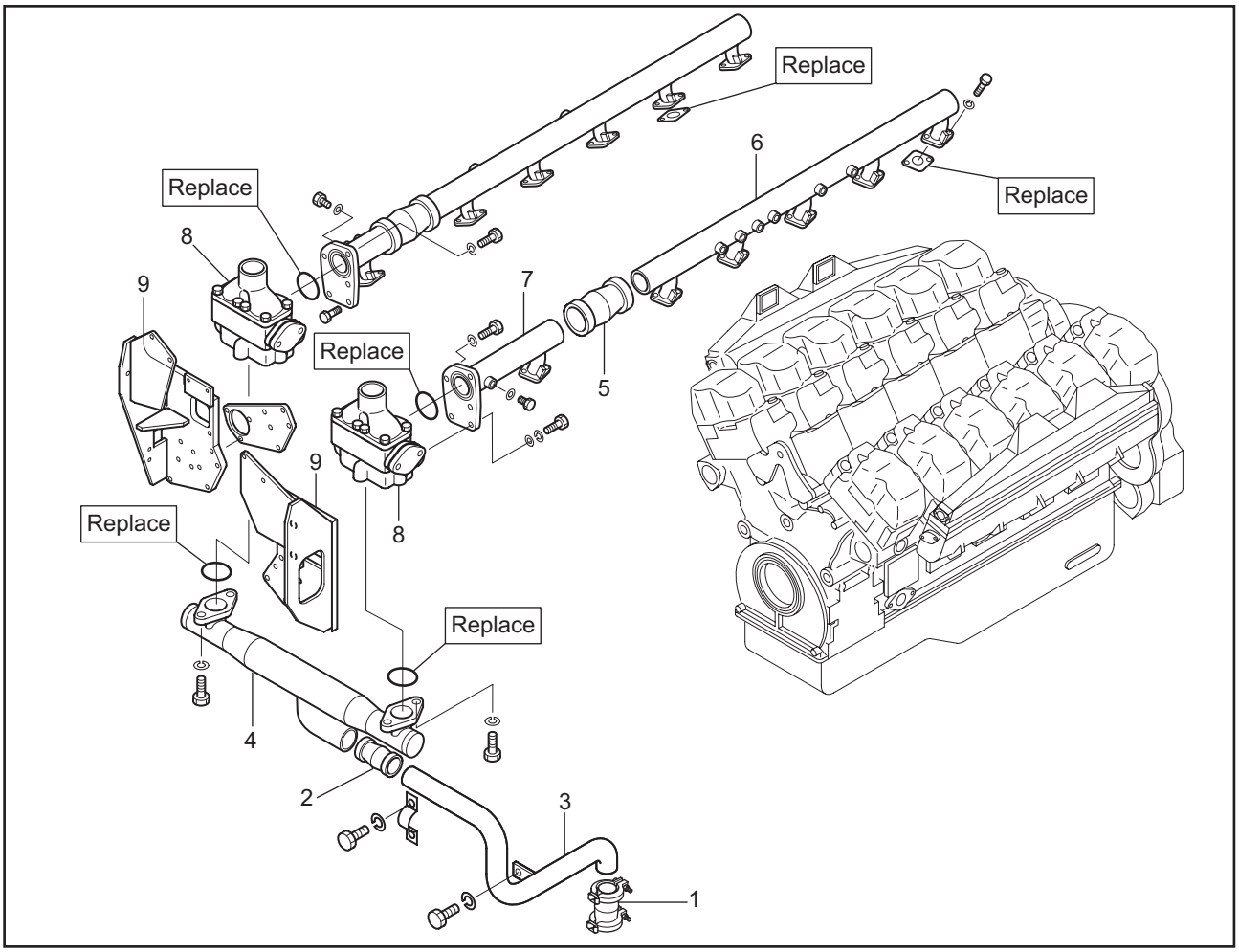


Removing 2-way water pipe

Removing sequence

1 Coupling
2 Water pipe
3 Coupling
4 Water pipe
5 Coupling
6 Water pipe
7 Water pipe

1.5 Removing thermostat and water pipe

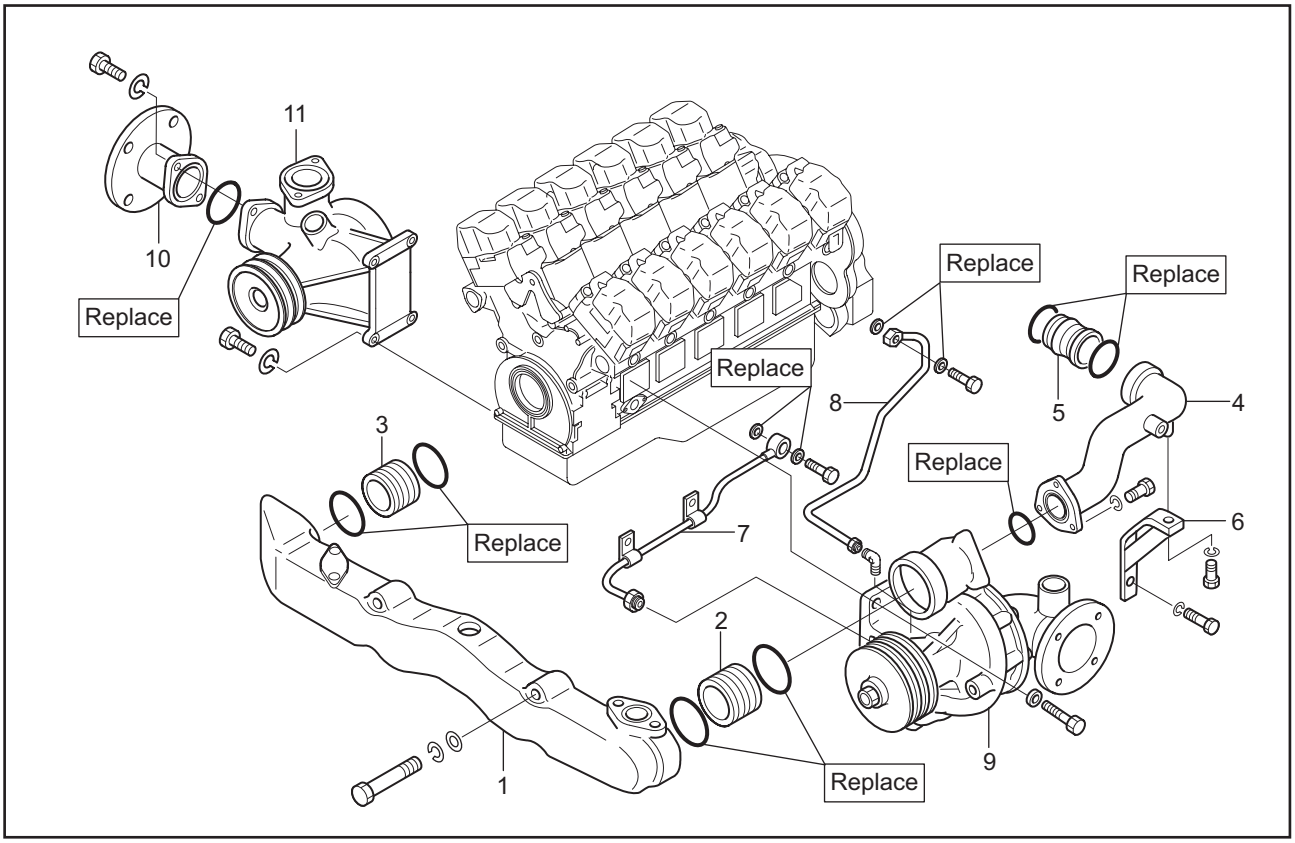


Removing thermostat and water pipe

Removing sequence

1 Coupling
2 Coupling
3 By-pass pipe
4 Water pipe
5 Coupling
6 Outlet pipe
7 Outlet pipe
8 Thermostat
9 Thermo bracket

1.6 Removing water pump and water pipe



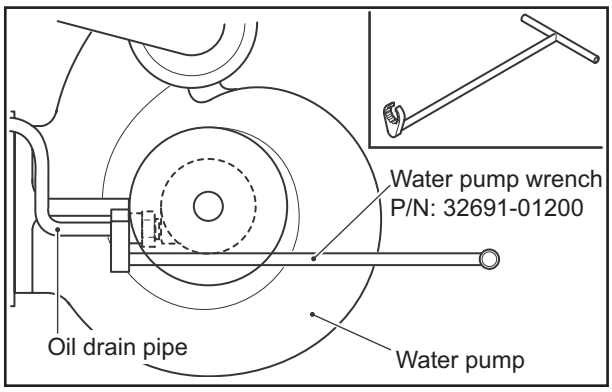
Removing water pump and water pipe

Removing sequence

1 Water pipe
2 Joint
3 Joint
4 Water pipe
5 Joint
6 Stay
7 Oil drain pipe
8 Oil pipe
9 Water pump
10 Water pump pipe
11 Water pump

1.6.1 Removing oil drain pipe

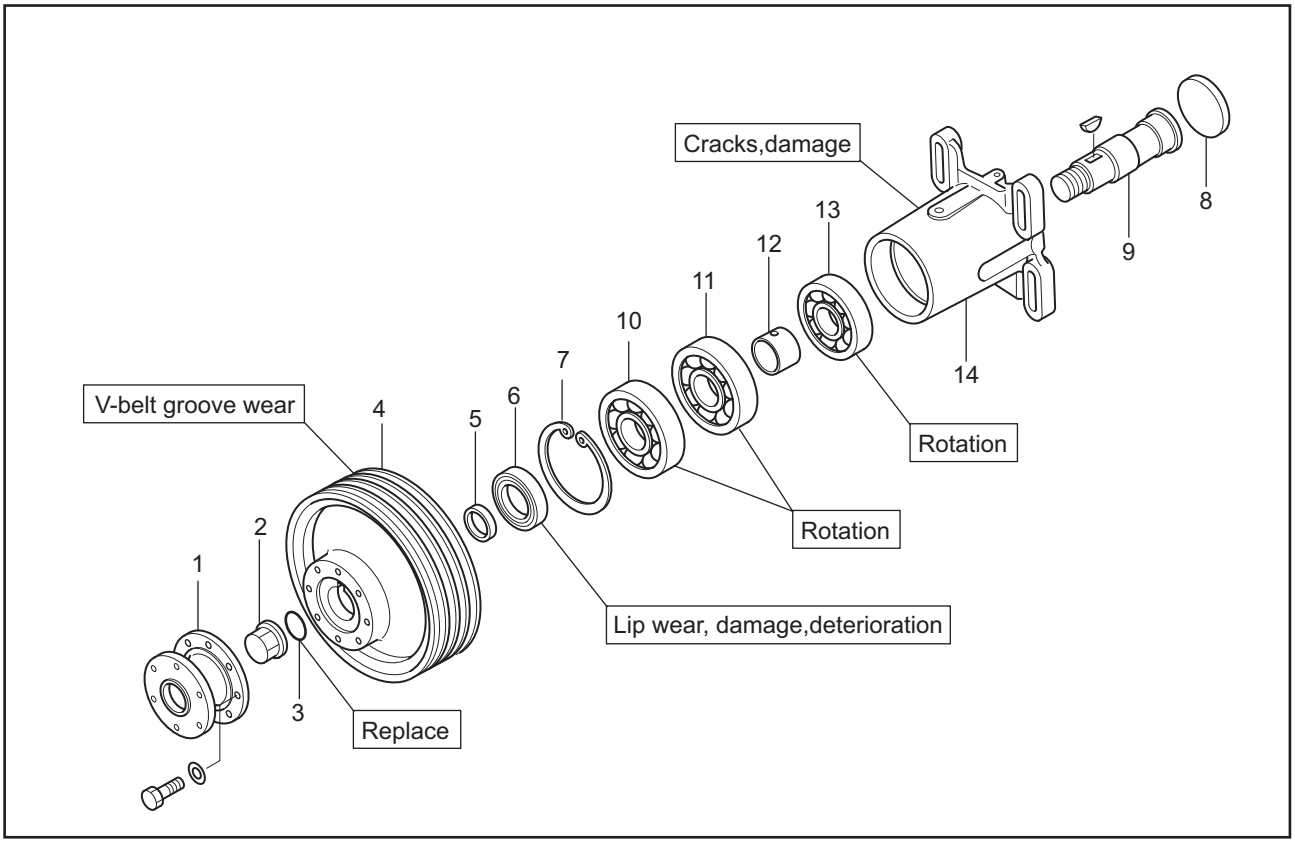
The oil drain pipe is located at a hard-to-access position behind the water pump. Use a water pump wrench to remove the pipe.



Removing oil drain pipe

2. Disassembling, inspecting and reassembling cooling system

2.1 Disassembling and inspecting fan drive



Disassembling and inspecting fan drive

Disassembling sequence

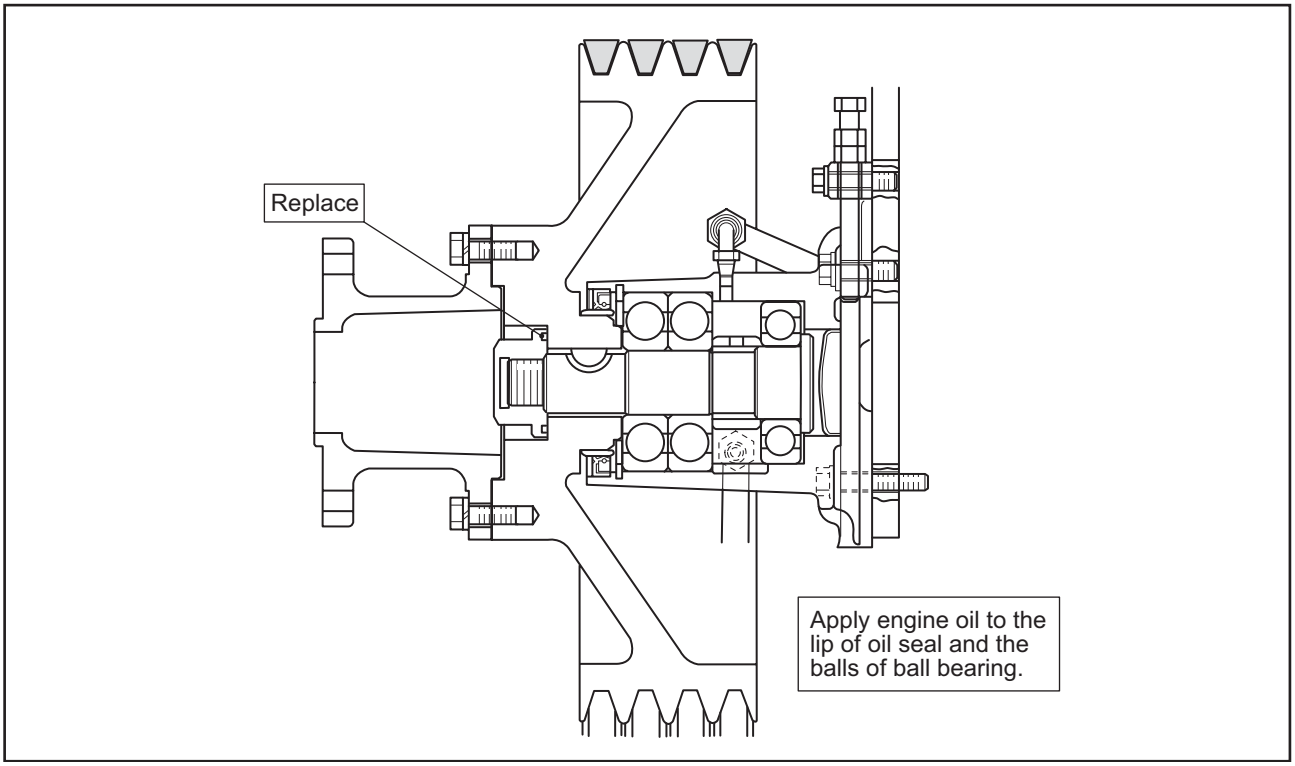
1 Fan spacer
2 Cap nut
3 O-ring
4 Fan pulley
5 Sleeve
6 Oil seal
7 Snap ring
8 Cap
9 Fan drive shaft
10 Ball bearing
11 Ball bearing
12 Spacer
13 Ball bearing
14 Drive shaft bracket

2.1.1 Inspecting fan drive

Measure the fan drive case bore and the shaft diameter at the bearing fitting portions as well as the inside and outside diameters of the bearings. If any of the measurements is out of the standard, replace the part with a new one.

			Nominal	Standard
Inside diameter of bearing fitting bore in drive case			ø 62 mm [2.44 in.]	61.988 to 62.018 mm [2.4405 to 2.4420 in.]
			ø 72 mm [2.84 in.]	71.988 to 72.018 mm [2.8342 to 2.8353 in.]
Bearing	Small	Inside diameter	ø 30 mm [2.44 in.]	29.988 to 30.000 mm [1.1806 to 1.1811 in.]
		Outside diameter	ø 62 mm [2.44 in.]	61.987 to 62.000 mm [2.4404 to 2.4409 in.]
	Large	Inside diameter	ø 30 mm [2.44 in.]	29.988 to 30.000 mm [1.1806 to 1.1811 in.]
		Outside diameter	ø 72 mm [3.45 in.]	71.987 to 72.000 mm [2.8341 to 2.8346 in.]
Outside diameter of drive shaft bearing journal			ø 30 mm [1.18 in.]	30.002 to 30.011 mm [1.1812 to 1.1820 in.]
Clearance on impeller front end				0.6 to 1.4 mm [0.0240 to 0.0551 in.]
Clearance on impeller rear end				1.0 mm [0.0393 in.]

2.2 Reassembling fan drive

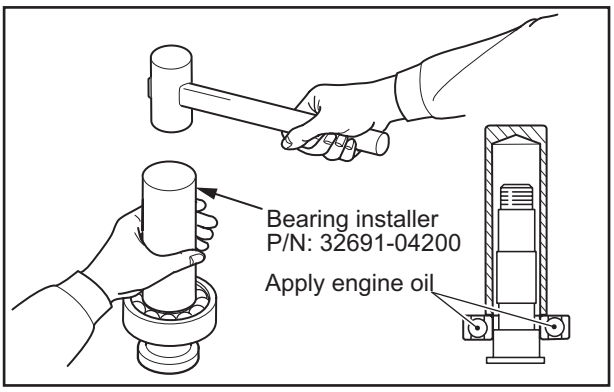


Reassembling fan drive

2.2.1 Installing inner ball bearing

(1) Apply engine oil to balls in balll bearings.

(2) Drive the ball bearing on the drive shaft using a bearing installer

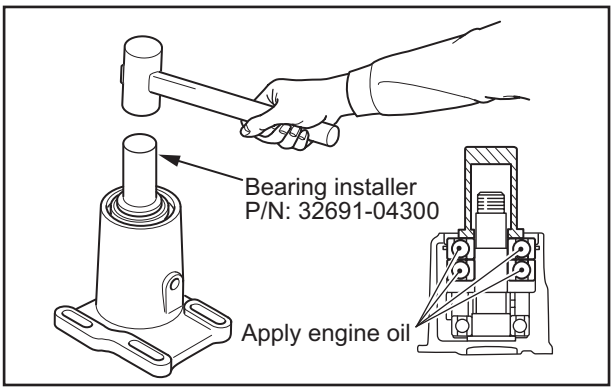


Installing inner bell bearing

2.2.2 Installing outer ball bearing

(1) Apply engine oil to balls in balls in ball bearings.

(2) Drive the drive shaft into the shaft bracket, drive the ball bearing on the drive shaft and shaft bracket using bearing installer.

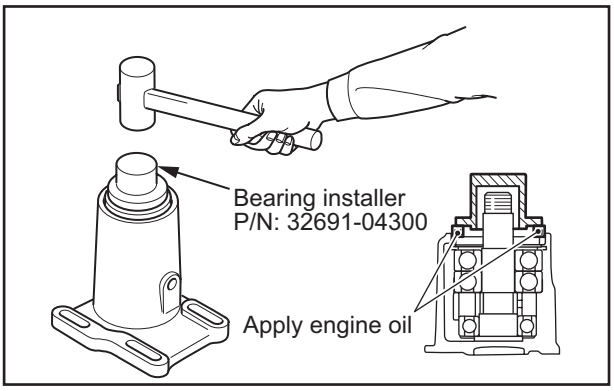


Installing outer ball bearing

2.2.3 Installing oil seal

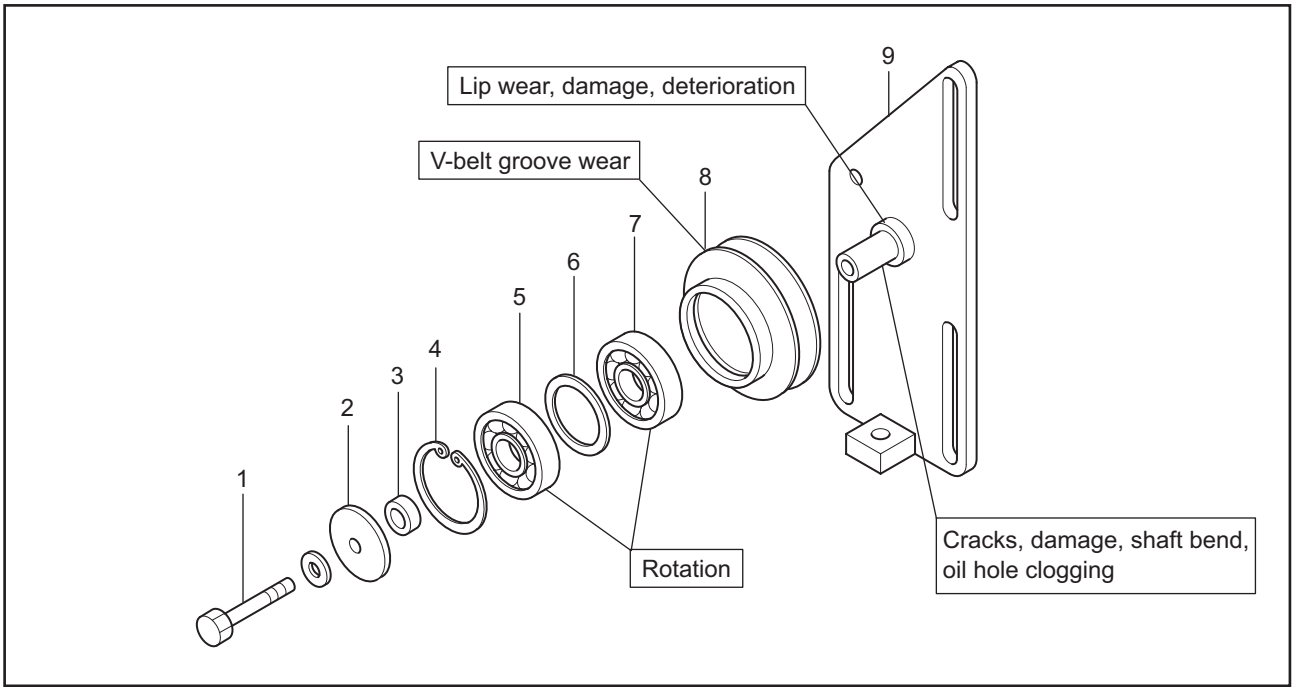
(1) Drive oil seal in the case using a oil seal installer so that the oil seal is flush with the end face of case.

(2) Apply engine oil to the oil seal lip.



Installing oil seal

2.3 Disassembling and inspecting tension pulley (2-way water pump side)



Disassembling and inspecting tension pulley

Disassembling sequence

1 Bolt
2 Thrust plate
3 Spacer
4 Snap ring
5 Ball bearing
6 Spacer
7 Ball bearing
8 Tension pulley
9 Bracket

2.3.1 Inspecting tension pulley

Check the bearing fitting portions in the tension pulley and on the shaft for wear and damage. If they are abnormally worn or damaged, replace the bearing, pulley or tension bracket.

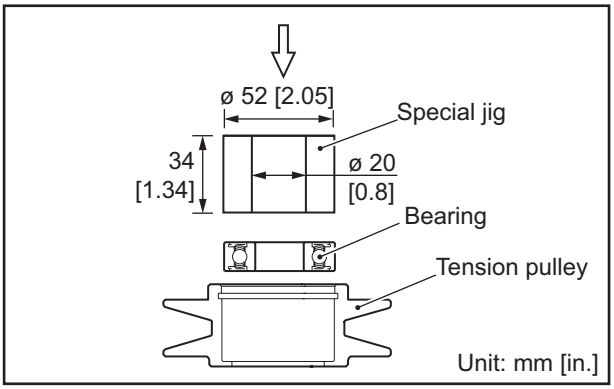
Item		Nominal	Standard
Inside diameter of tension pulley in which bearing is fitted		ø 52 mm [2.05 in.]	51.970 to 51.995 mm [2.0461 to 2.0470 in.]
Bearing	Inside diameter	ø 20 mm [0.79 in.]	19.988 to 20.000 mm [0.7869 to 0.7874 in.]
	Outside diameter	ø 52 mm [20.5 in.]	52.988 to 52.000 mm [2.0354 to 2.0591 in.]
Outside diameter of shaft on which bearing is fitted		ø 20 mm [0.79 in.]	19.988 to 20.000 mm [0.7869 to 0.7874 in.]

2.3.2 Reassembling tension pulley

(1) Apply engine oil to the bearing fitting portion in the tension pulley.

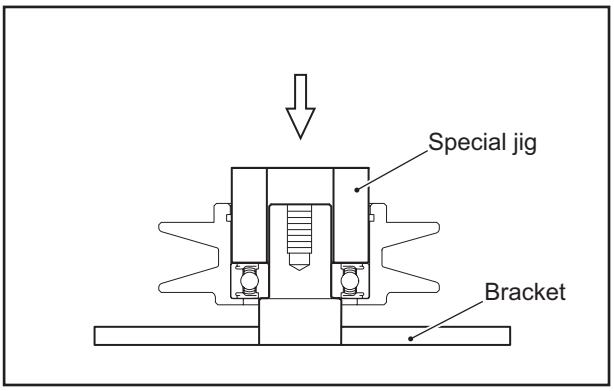
(2) Fabricate a special press-fitting jig. Fit the bearing in the tension pulley using the jig and a press.

Note: The bearing is of a grease-filled type. Do not wash the bearing.



Press-fitting inner ball bearing

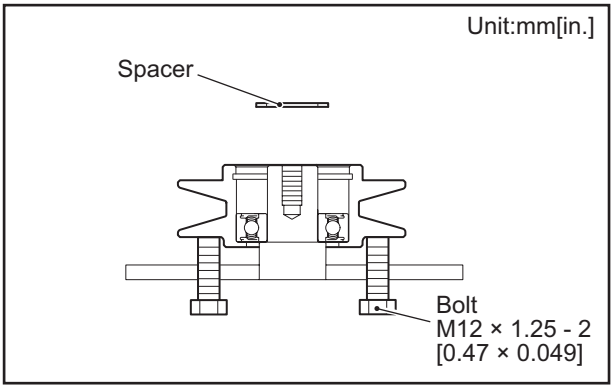
(3) Fit the inner ball bearing onto the bracket using a press.



Press-fitting tension pulley

(4) Insert the inner spacer in position.

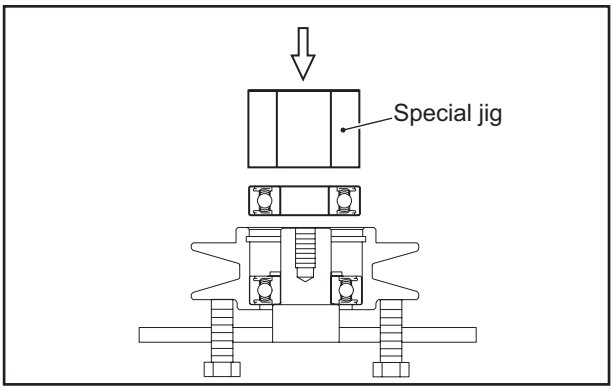
(5) Screw two bolts into the extracting bolt holes in the bracket from the inside to hold the tension pulley lightly.



Installing inner spacer

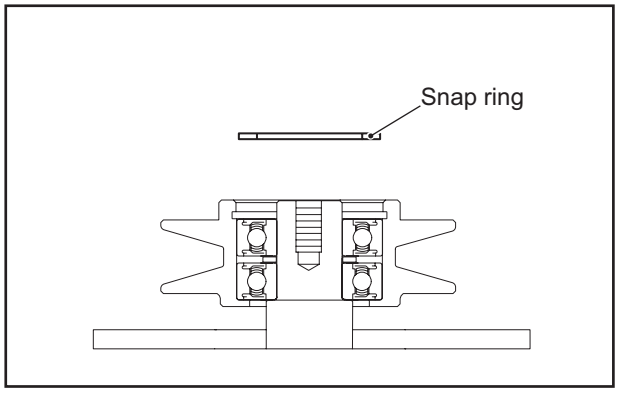
(6) Fit the outer ball bearing into the tension pulley using the special jig.

Note: For press-fitting, use a hand-press.



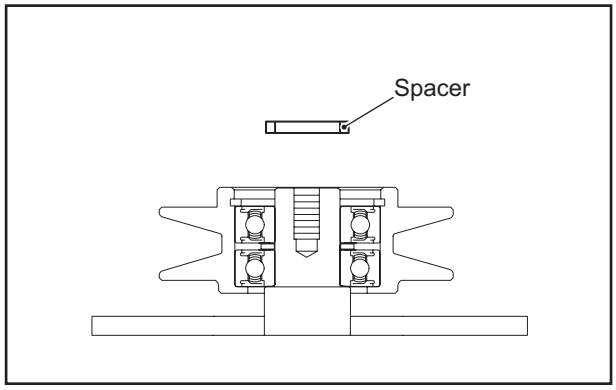
Press-fitting outer ball bearing

(7) Fit the snap ring in the ring groove inside the tension pulley.



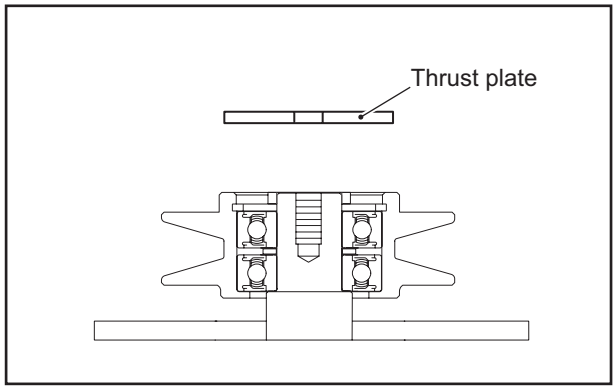
Installing snap ring

(8) Insert the outer spacer in positon



Installing outer spacer

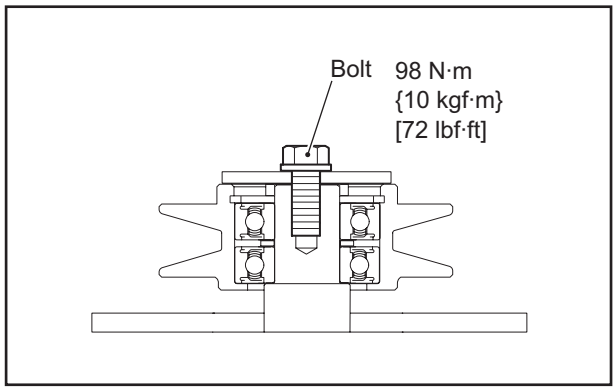
(9) Fit the thrust plate with the bolt.



Fitting thrust plate

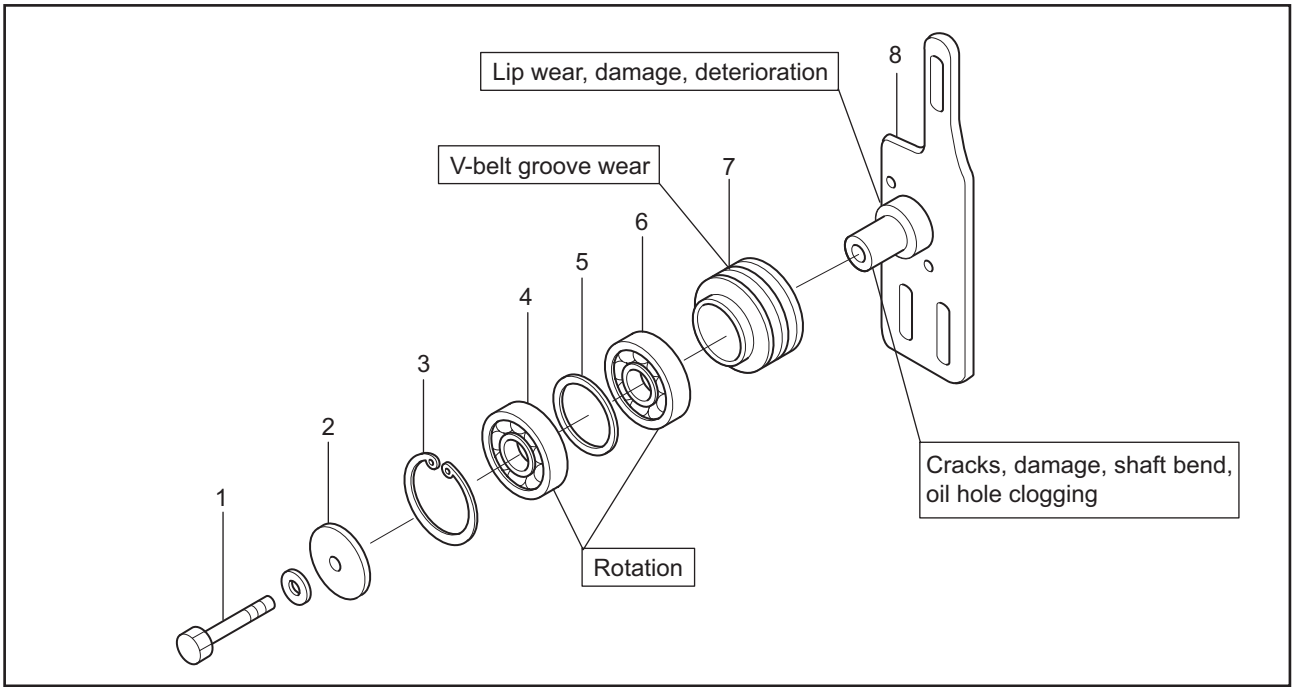
(10)Tighten the bolt to the specified torque.

Note: After reassembling, make sure that the tension pulley rotates smoothly.



Tightening bolt

2.4 Disassembling and inspecting tension pully (water pump side)



Disassembling and inspecting tension pully

Disassembling sequence

1 Bolt
2 Thrust plate
3 Snap ring
4 Ball bearing
5 Spacer
6 Ball bearing
7 Tension pulley
8 Bracket

2.4.1 Inspecting tension pulley

Check the bearing fitting portions in the tension pulley and on the shaft for wear and damage. If they are abnormally worn or damaged, replace the bearing, pulley or tension bracket.

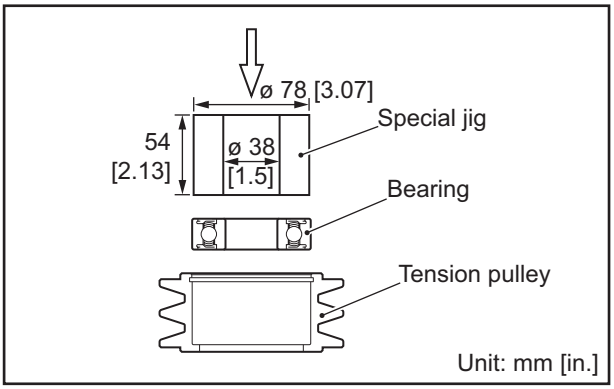
Item		Nominal	Standard
Inside diameter of tension pulley in which bearing is fitted		ø 80 mm [3.15 in.]	79.961 to 79.991 mm [3.1481 to 3.1492 in.]
Bearing	Inside diameter	ø 35 mm [1.38 in.]	34.988 to 35.000 mm [1.3775 to 1.3780 in.]
	Outside diameter	ø 80 mm [3.15 in.]	79.987 to 80.000 mm [3.1491 to 3.1496 in.]
Outside diameter of shaft on which bearing is fitted		ø 35 mm [1.38 in.]	34.984 to 35.000 mm [1.3773 to 1.3780 in.]

2.4.2 Reassembling tension pulley

(1) Apply engine oil to the bearing fitting portion in the tension pulley.

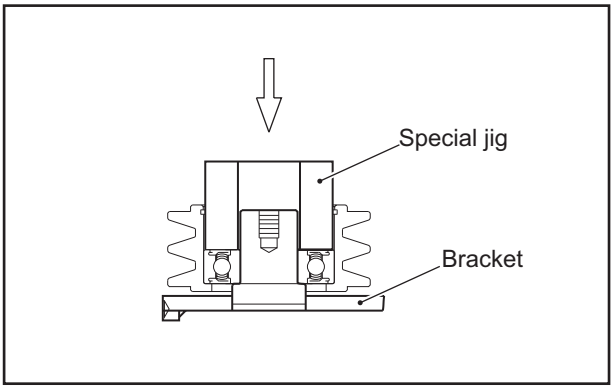
(2) Fabricate a special press-fitting jig. Fit the bearing in the tension pulley using the jig and a press.

Note: The bearing is of a grease-filled type. Do not wash the bearing.



Press-fitting inner ball bearing

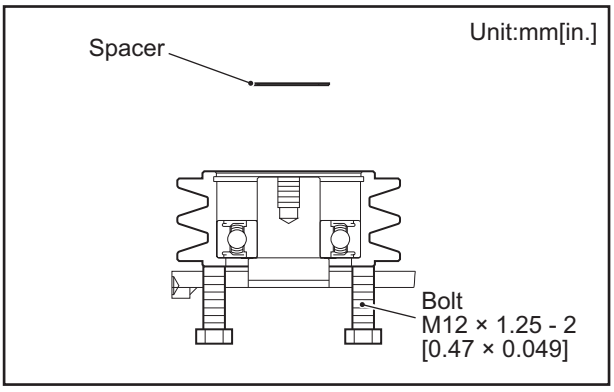
(3) Fit the inner ball bearing onto the bracket using a press.



Press-fitting tension pulley

(4) Insert the spacer in position.

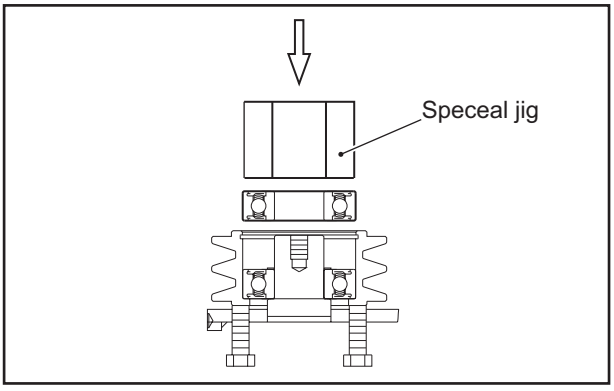
(5) Screw two bolts into the extracting bolt holes in the bracket from the inside to hold the tension pulley lightly.



Installing spacer and bolts

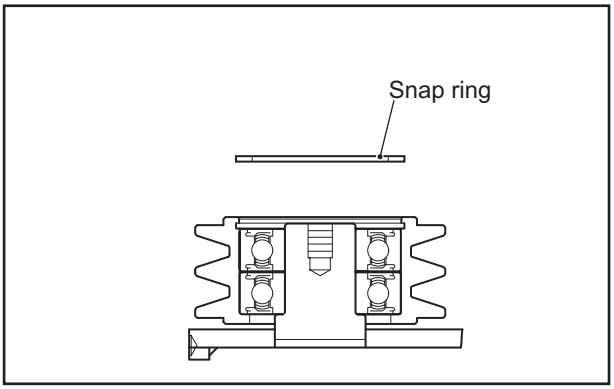
(6) Fit the outer ball bearing into the tension pulley using the special jig.

Note: For press-fitting, use a hand-press.



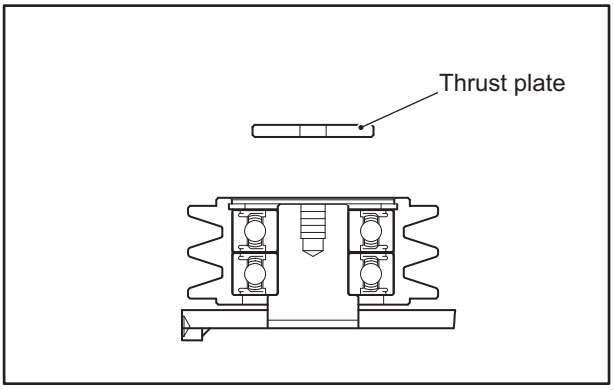
Press-fitting outer ball bearing

(7) Fit the snap ring in the ring groove inside the tension pulley.



Installing snap ring

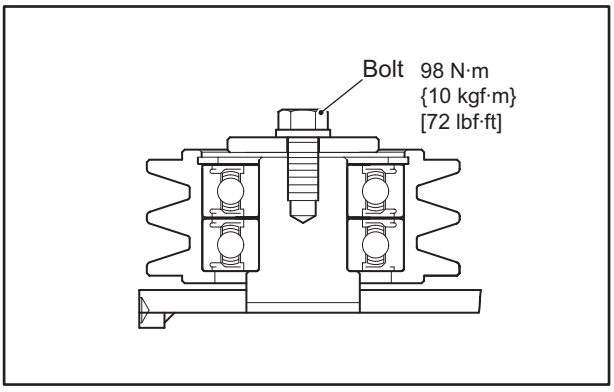
(8) Fit the thrust plate with the bolt.



Fitting thrust plate

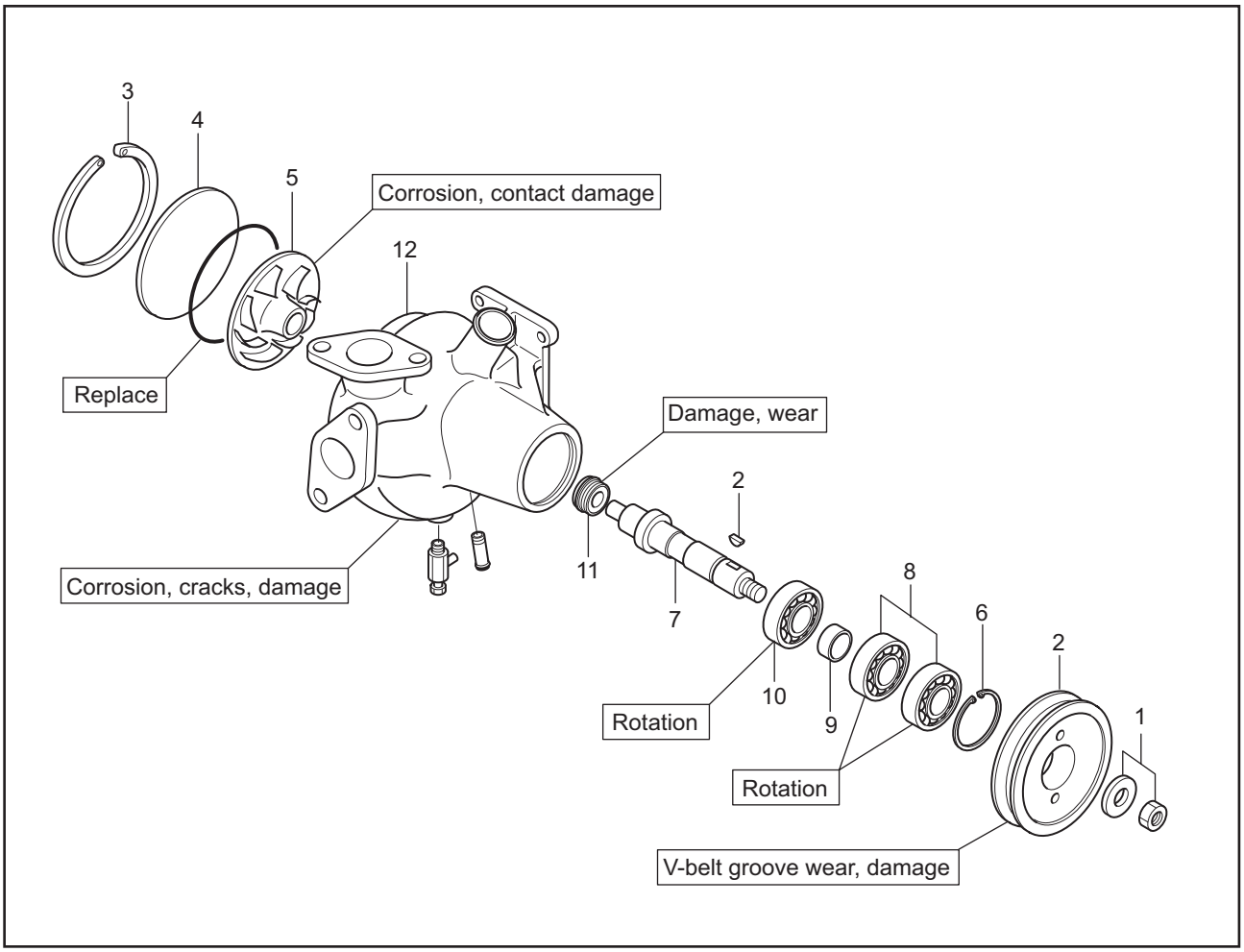
(9) Tighten the bolt to the specified torque.

Note: After reassembling, make sure that the tension pulley rotates smoothly.



Tightening bolt

2.5 Disassembling and inspecting 2-way water pump



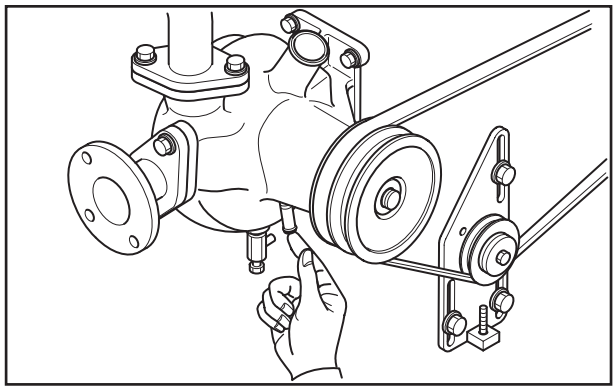
Disassembling and inspecting 2-way water pump

Disassembling sequence

1 Nut, washer
2 Water pump pulley, key
3 Snap ring
4 Cover
5 Impeller
6 Snap ring
7 Water pump shaft
8 Ball bearing
9 Spaser
10 Ball bearing
11 Unit seal
12 Water pump case

2.5.1 Inspecting water pump in installed condition

Touch the drain port in the bottom of pump case center with your fingers.
If water oozing is felt, the unit seal is probably faulty.



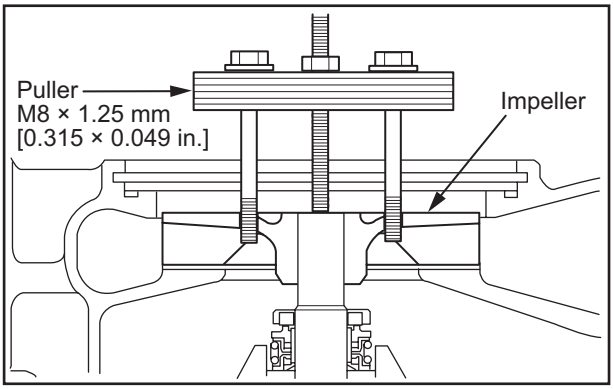
Inspecting 2-way water pump in installed condition

2.5.2 Removing impeller

CAUTION

When removing the impeller from the water pump shaft, take care not to damage the water pump shaft and the impeller.

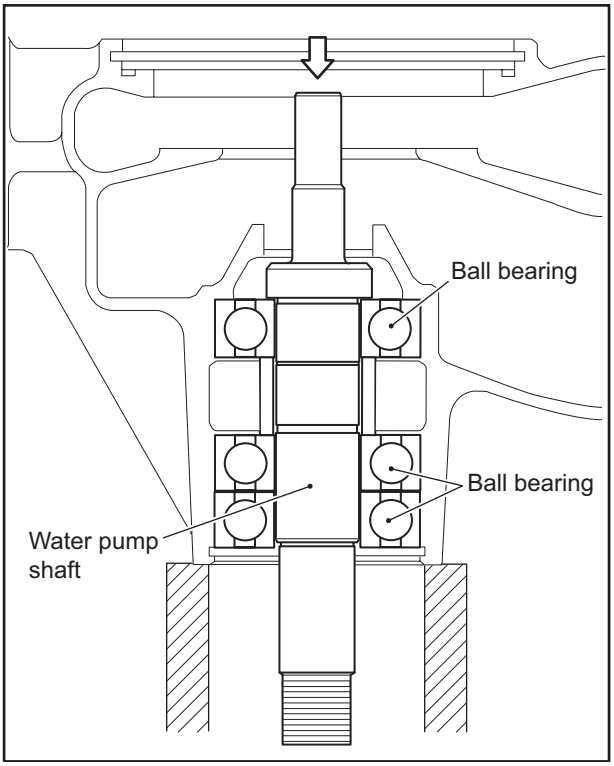
Using the puller, pull out the impeller.



Removing impeller

2.5.3 Removing water pump shaft

Remove the snap ring securing the front ball bearing. Then, remove the water pump shaft together with the ball bearings toward the pulley side by pushing on it slowly with a press or by tapping on it lightly with a soft-head hammer.



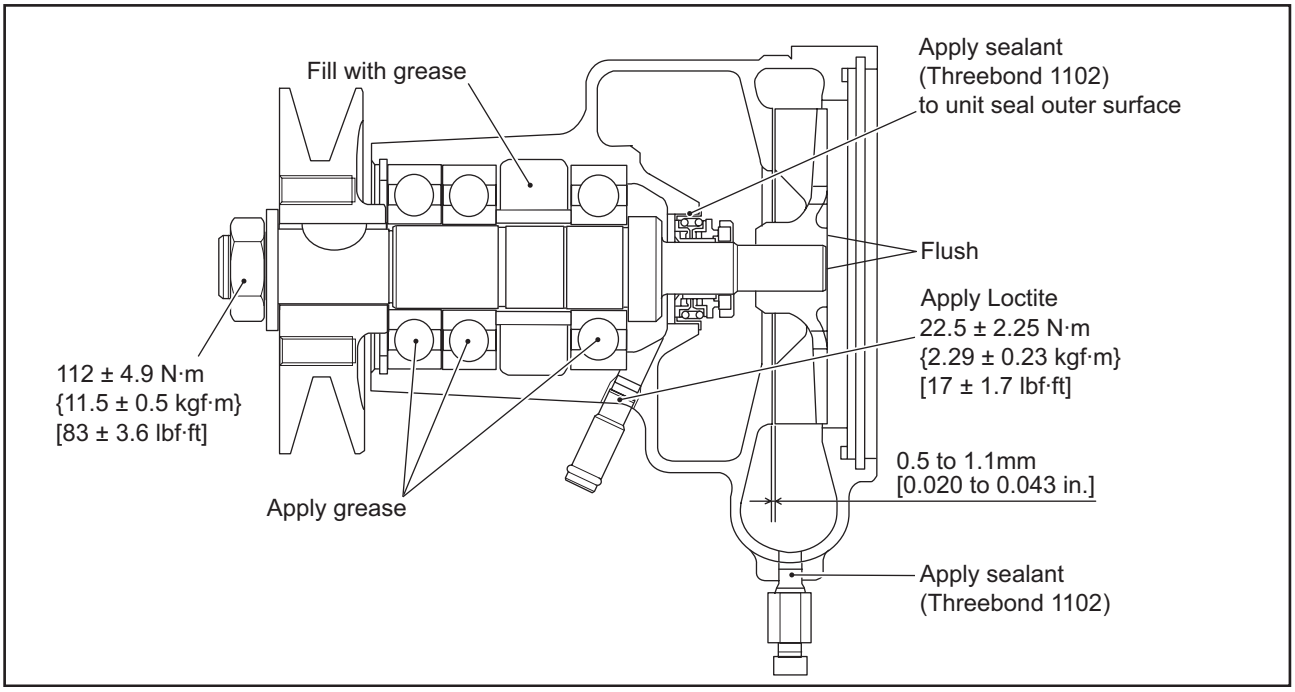
Removing water pump shaft

2.5.4 Inspecting 2-way water pump

Measure the water pump case bore and the shaft diameter at the bearing fitting portions as well as the inside and outside diameters of the bearings. If any of the measurements is out of the standard, replace the part with a new one.

Item		Nominal	Standard
Inside diameter of bearing fitting bore in case		ø 62 mm [2.44 in.]	61.988 to 62.018 mm [2.4405 to 2.4420 in.]
Case bearing bore diameter		ø 68 mm [2.68 in.]	67.961 to 67.991 mm [2.6756 to 2.6768 in.]
Bearing	Inside diameter	ø 28 mm [1.10 in.]	27.990 to 28.000 mm [1.1020 to 1.1024 in.]
	Outside diameter	ø 68 mm [2.68 in.]	67.987 to 68.000 mm [2.6766 to 2.6772 in.]
Shaft bearing journal diameter		ø 28 mm [1.10 in.]	28.002 to 28.015 mm [1.1024 to 1.1030 in.]
Clearance at the front of impeller		0.8 mm [0.031 in.]	0.5 to 1.1 mm [0.020 to 0.043 in.]

2.6 Reassembling 2-way water pump



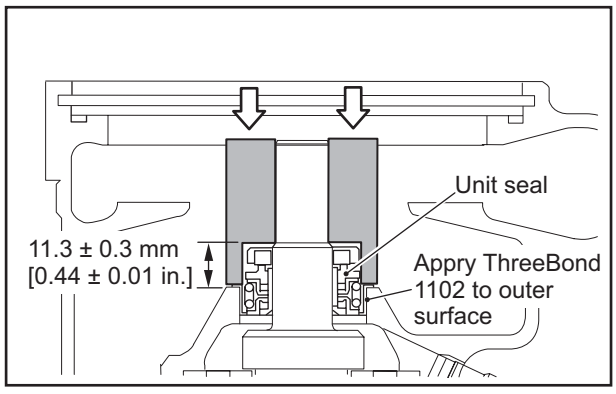
Reassembling 2-way water pump

2.6.1 Installing unit seal

(1) Apply sealant (ThreeBond 1102) to the circumference of the unit seal.

(2) Drive the unit seal into the case using a unit seal installer.

Note: Always replace the unit seal with a new one once it has been removed from the pump case.



Installing unit seal

2.6.2 Installing water pump shaft

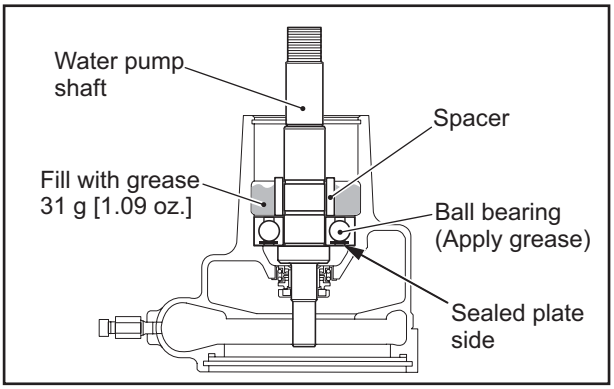
(1) Drive the ball bearing into the shaft.

Note: The ball bearing should be installed so that the shield plate is positioned on the unit seal side.

(2) Fill the ball bearing rolling section with WPH grease.

(3) Drive the shaft into the case.

(4) Install the spacer into the shaft, and fill the case with 31 g [1.09 oz.] of WPH grease.



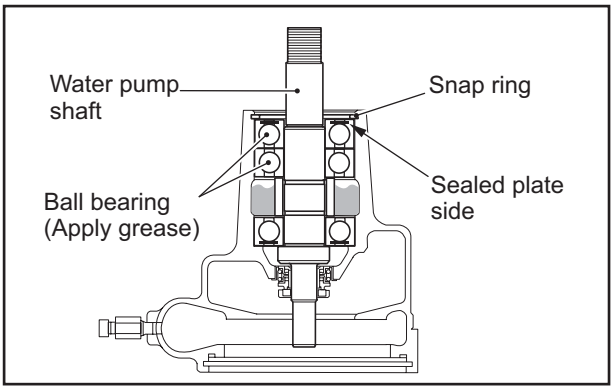
Installing water pump shaft

2.6.3 Installing ball bearing

(1) Fill the ball bearing rolling section with WPH grease, and drive the ball bearing.

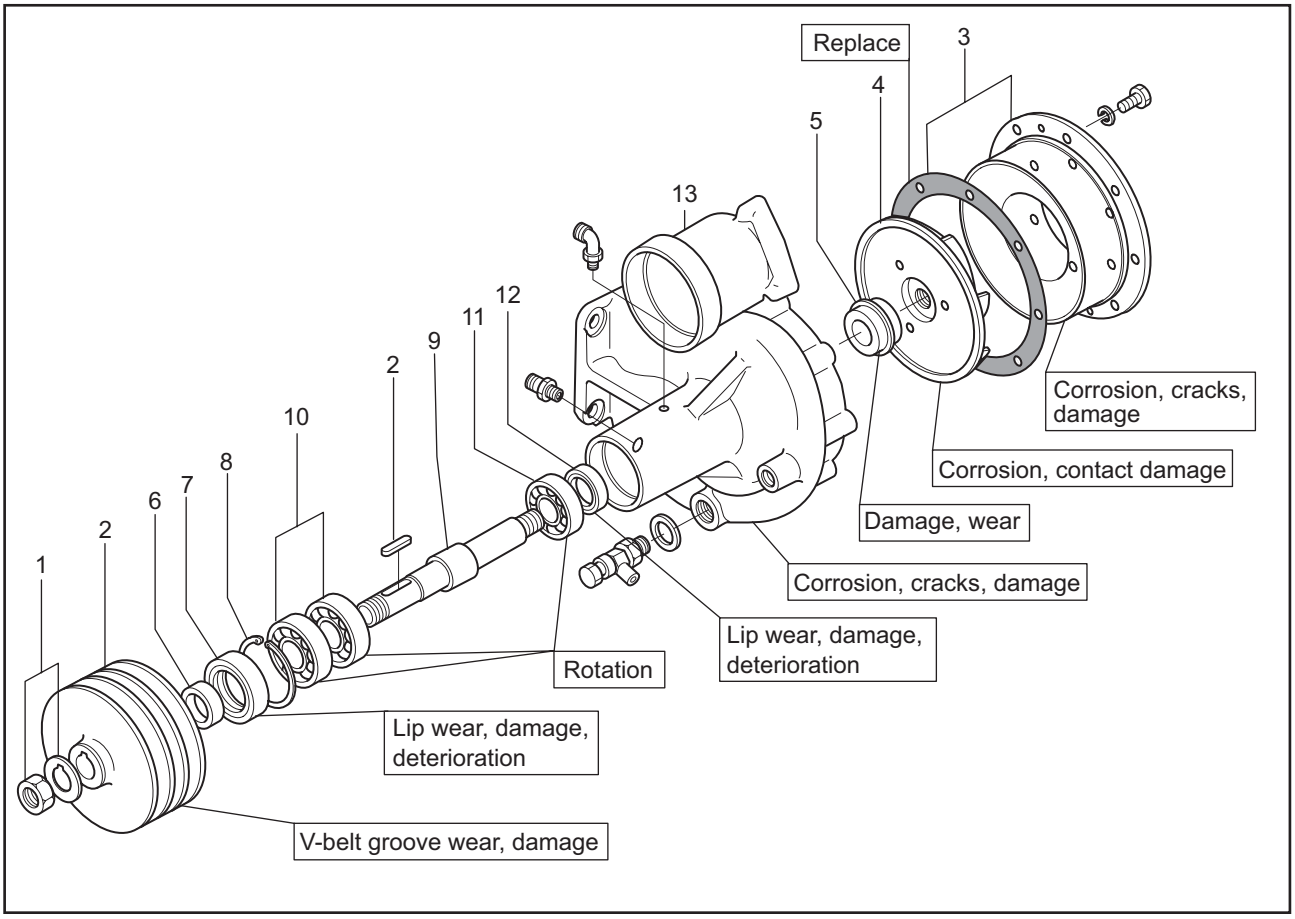
Note: The ball bearing with shield plate should be installed so that shield plate is positioned on the pulley side.

(2) Secure the ball bearing using a snap ring.



Installing ball bearing

2.7 Disassembling and inspecting water pump



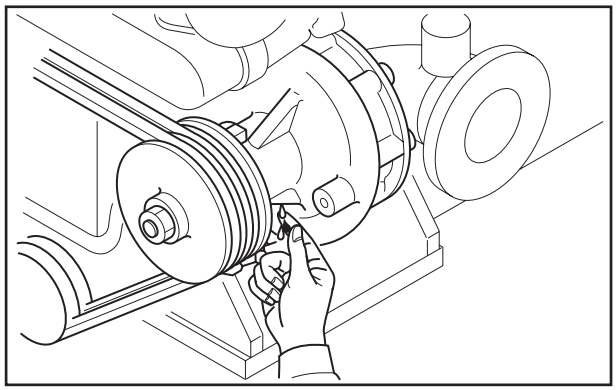
Disassembling and inspecting water pump

Disassembling sequence

1 Nut, lock washer
2 Water pump pulley, key
3 Water pump cover, packing
4 Impeller
5 Unit seal
6 Spacer
7 Oil seal
8 Snap ring
9 Water pump shaft
10 Ball bearing
11 Ball bearing
12 Oil seal
13 Water pump case

2.7.1 Inspecting water pump mounted on engine

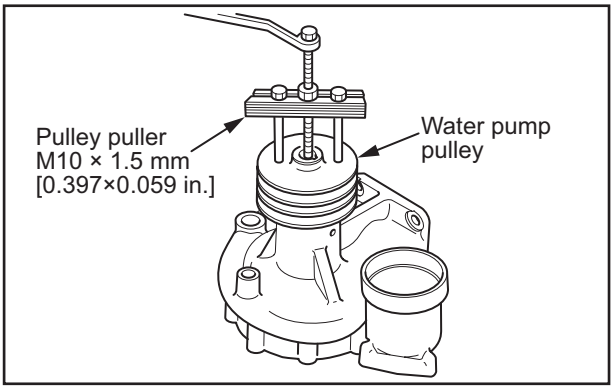
Touch the drain port located in the bottom of pump case center with your fingers.
If water oozing is felt, the unit seal is probably faulty, and if oil oozing is felt, the oil seal is probably faulty.



Inspecting water pump in installed condition

2.7.2 Removing water pump pulley

Attach the pulley puller in the water pump pulley extracting holes and remove the water pump pulley.



Removing water pump pulley

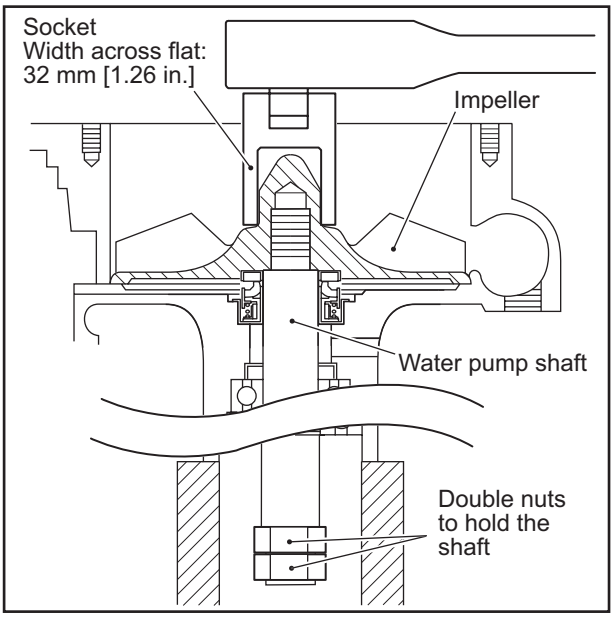
2.7.3 Removing impeller

CAUTION

When removing the impeller from the water pump shaft, take care not to damage the water pump shaft and the impeller.

(1) Fit double nuts to the water pump shaft on the opposite side to the impeller to hold the shaft.

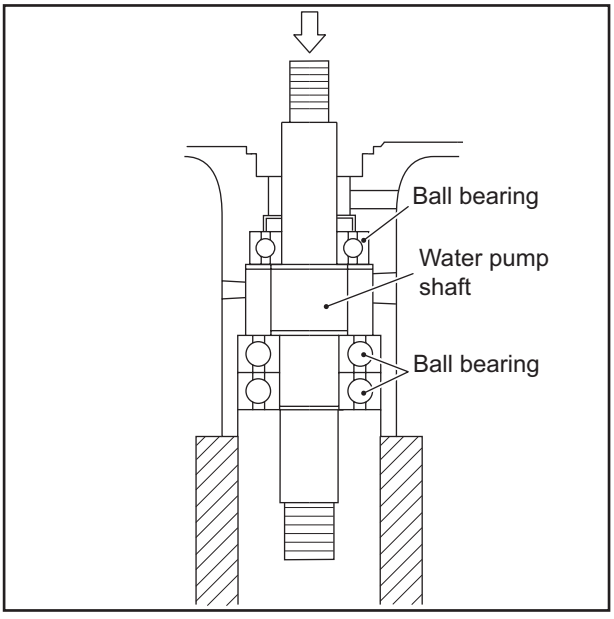
(2) Hold the double nuts with a wrench, and loosen the impeller using a socket wrench (width across flats 32 mm [1.26 inch]).



Removing impeller

2.7.4 Removing water pump shaft

Remove the snap ring securing the front ball bearing. Then, remove the water pump shaft together with the ball bearings toward the pulley side by pushing on it slowly with a press or by tapping on it lightly with a soft-head hammer.



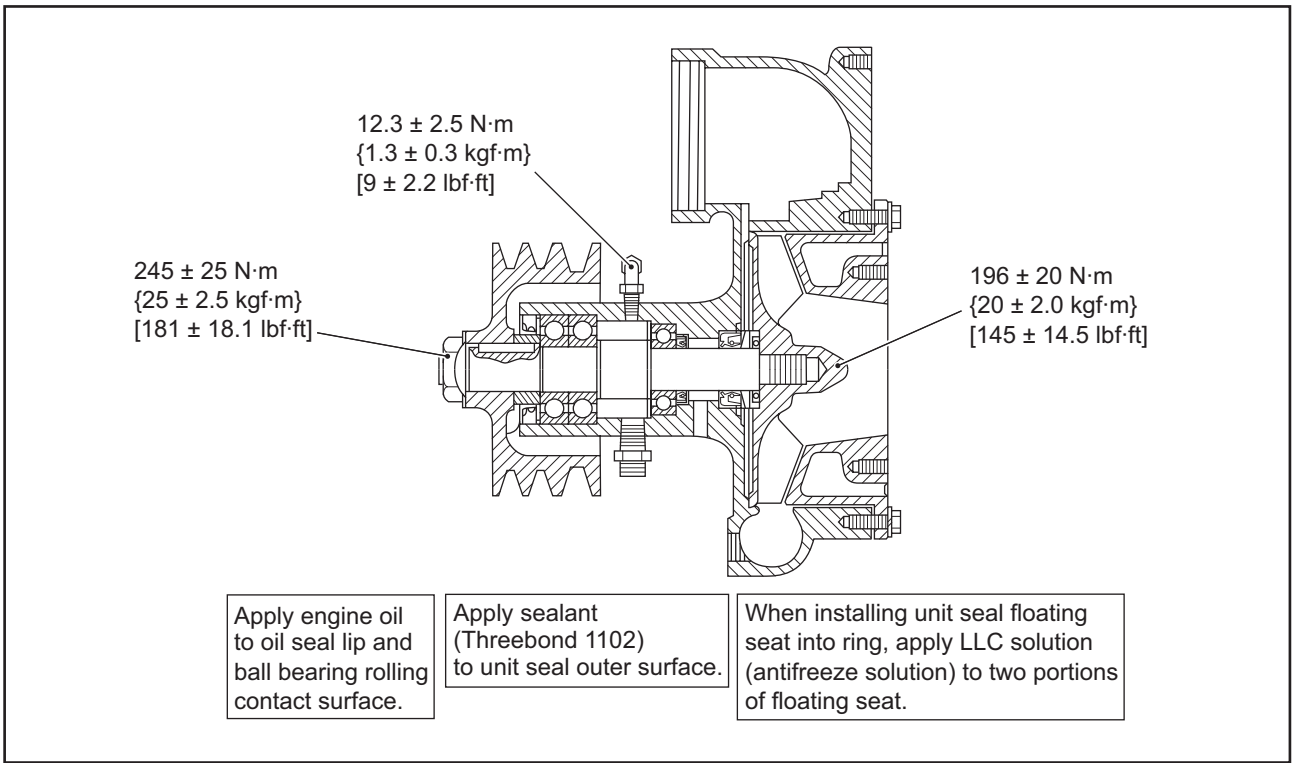
Removing water pump shaft

2.7.5 Inspecting water pump

Measure the water pump case bore and the shaft diameter at the bearing fitting portions as well as the inside and outside diameters of the bearings. If any of the measurements is out of the standard, replace with a new one.

Item			Nominal	Standard
Water pump case inside diameter at bearing fitting portion			ø62 mm [2.44 in.]	61.988 to 62.018 mm [2.4405 to 2.4420 in.]
			ø72 mm [2.84 in.]	71.988 to 72.018 mm [2.8342 to 2.8353 in.]
Bearing	Small	Inside diameter	ø30 mm [1.18 in.]	29.988 to 30.000 mm [1.1806 to 1.1811 in.]
		Outside diameter	ø62 mm [2.44 in.]	61.987 to 62.000 mm [2.4404 to 2.4409 in.]
	Large	Inside diameter	ø30 mm [1.18 in.]	29.988 to 30.000 mm [1.1806 to 1.1811 in.]
		Outside diameter	ø72 mm [2.84 in.]	71.987 to 72.000 mm [2.8341 to 2.8346 in.]
Shaft outside diameter at bearing fitting portion			ø30 mm [1.18 in.]	30.002 to 30.011 mm [1.1812 to 1.1820 in.]
Clearance on impeller front end				0.6 to 1.4 mm [0.0240 to 0.0551 in.]
Clearance on impeller rear end				1.0 mm [0.0393 in.]

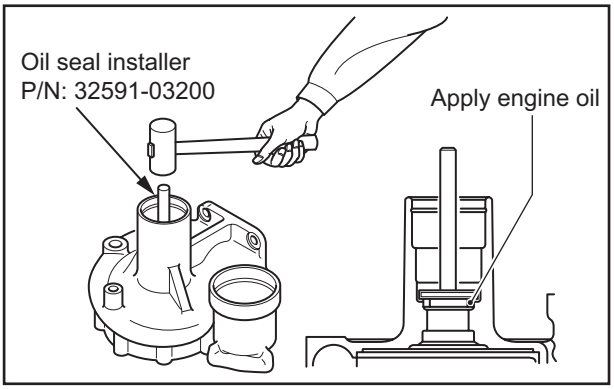
2.8 Reassembling water pump



Reassembling water pump

2.8.1 Installing inner oil seal

(1) Install oil seal in the case using a oil seal installer so that the oil seal is flush with the end face of fitting housing.
(2) Apply engine oil to oil seal lip.

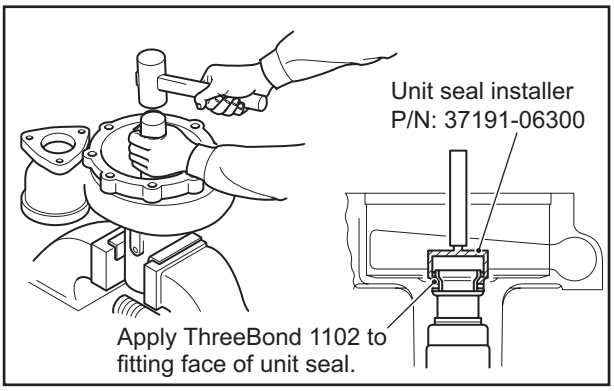


Installing inner oil seal

2.8.2 Installing unit seal

(1) Apply sealant (ThreeBond 1102) to the circumference of the unit seal.
(2) Drive the unit seal into the case using a unit seal installer.

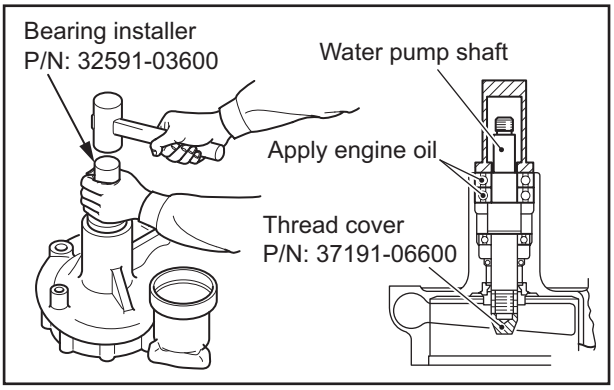
Note: Always replace the unit seal with a new one once it has been removed from the pump case.



Installing unit seal

2.8.3 Installing ball bearing

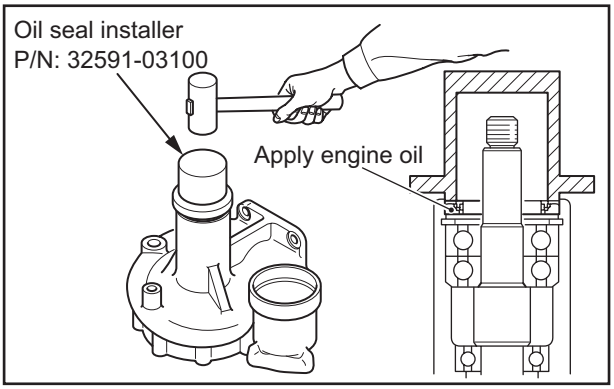
(1) Apply engine oil to balls in ball bearings.
(2) Attach the thread cover onto the pump shaft with ball bearings.
(3) Drive the pump shaft into the pump case using a bearing installer.



Installing ball bearing

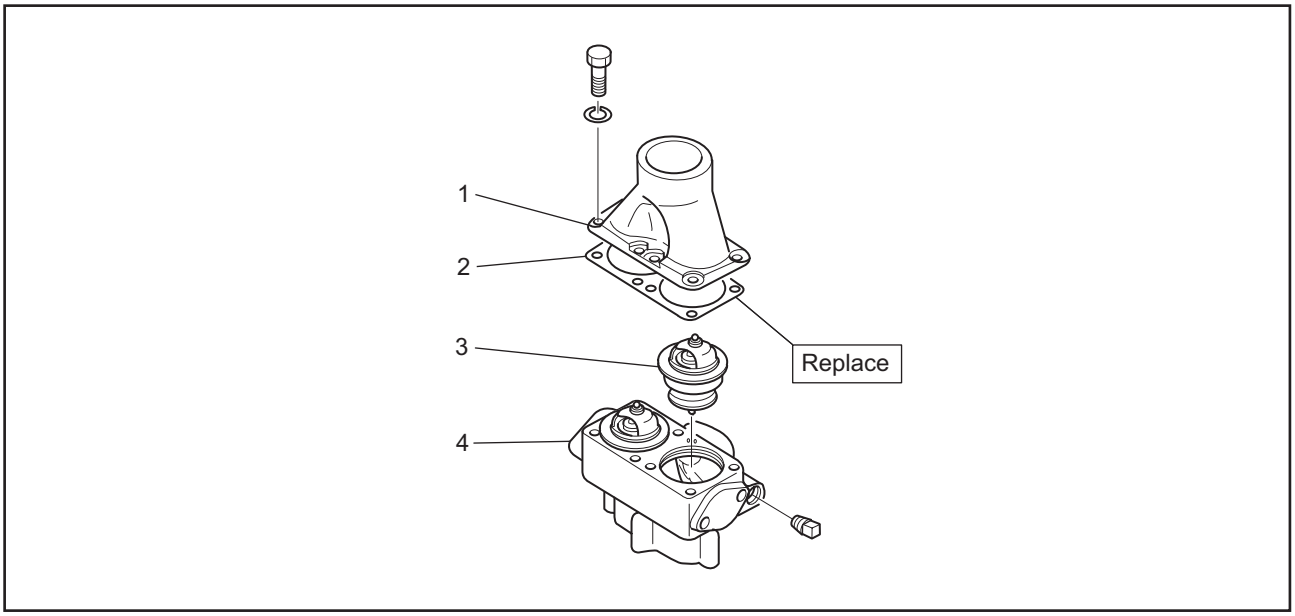
2.8.4 Installing outer oil seal

(1) Drive oil seal in the case using a oil seal installer so that the oil seal is flush with the end face of case.
(2) Apply engine oil to the oil seal lip.



Installing outer oil seal

2.9 Disassembling thermostat



Disassembling thermostat

Disassembling sequence

1 Case cover
2 Packing
3 Thermostat
4 Thermostat case

2.9.1 Inspecting thermostat

⚠ CAUTION

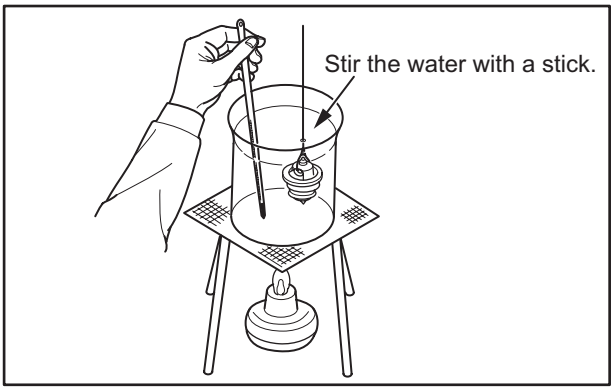
Be careful of burns or a fire when measuring temperature, as it involves a high-temperature and open flame.

To test the thermostat operation, immerse the thermostat in a container filled with water. Heat the water, while measuring the water temperature. Record the temperature at the conditions shown in the table below. If the temperatures are not within the standard range, replace the thermostat.

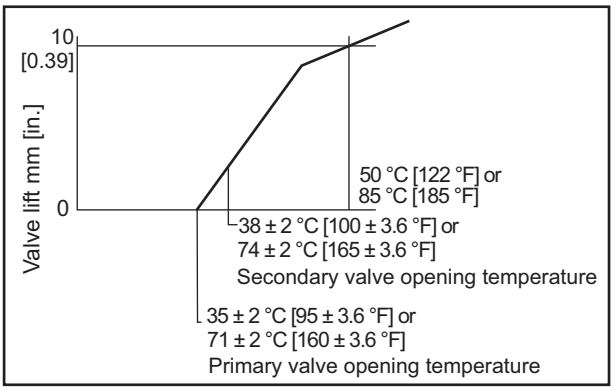
Note: (a) Stir the water in the container with a stick to ensure uniform temperature distribution.

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

Item	Standard	
	35 °C rating (2-way water side)	71 °C rating (Jacket water side)
Temperature at which primary valve starts opening	35 ± 2 °C [95 ± 3.6 °F]	71 ± 2 °C [160 ± 3.6 °F]
Temperature at which secondary valve starts opening	38 ± 2 °C [100 ± 3.6 °F]	74 ± 2 °C [165 ± 3.6 °F]
Temperature at which valve lift becomes 10 mm [0.39 in.] or more	50 °C [122 °F]	85 °C [185 °F]



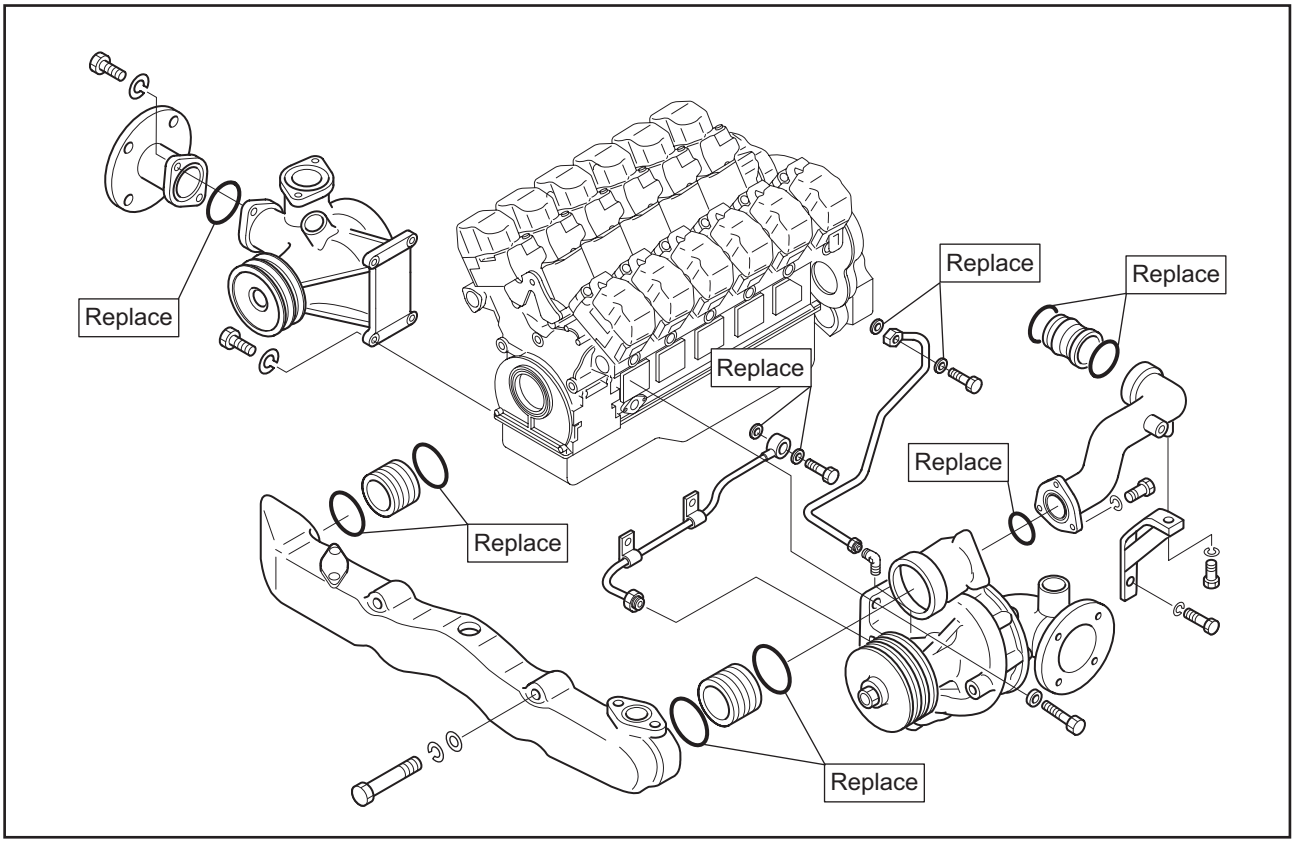
Inspecting thermostat



Thermostat motion diagram

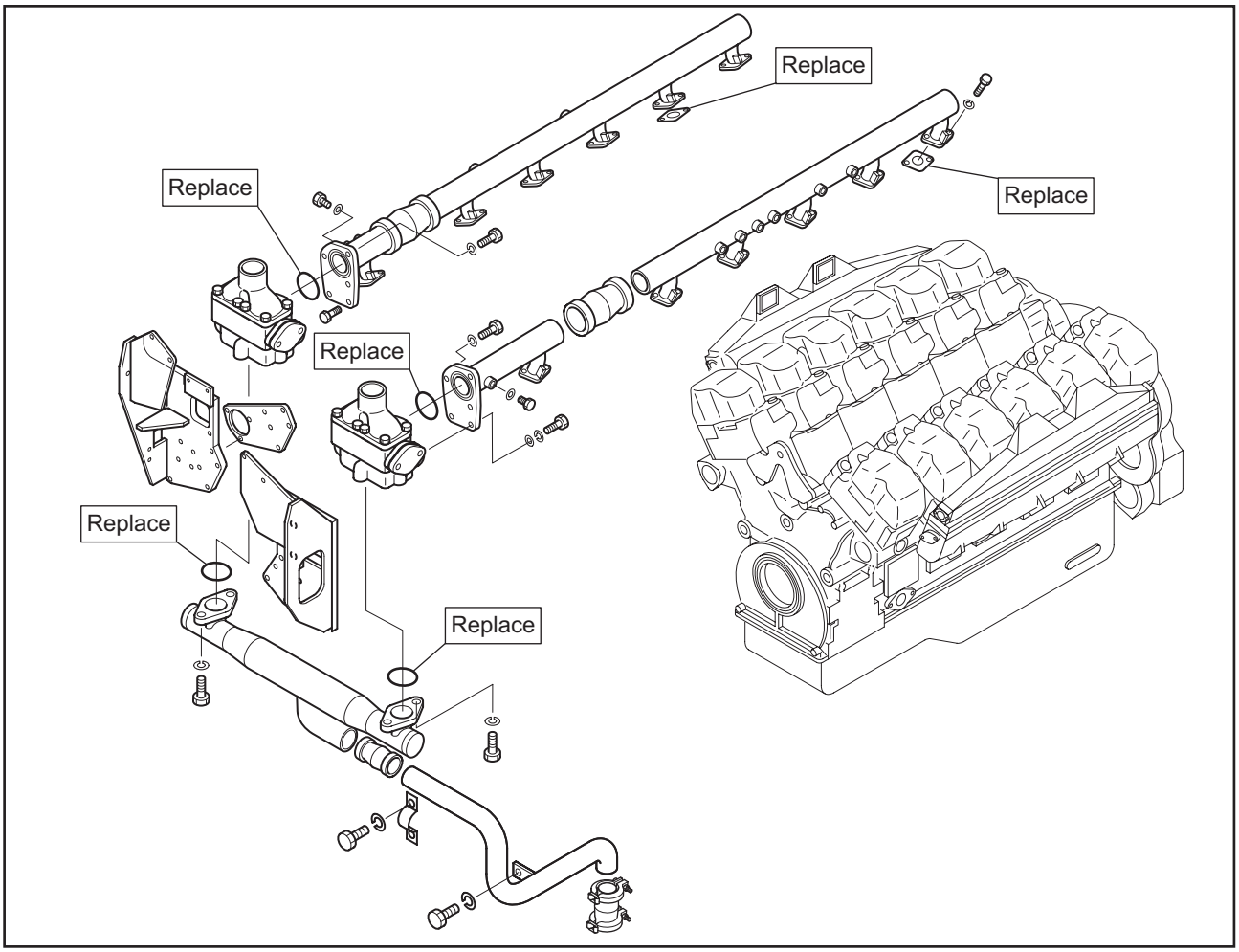
3. Installing cooling system

3.1 Installing water pump and water pipe



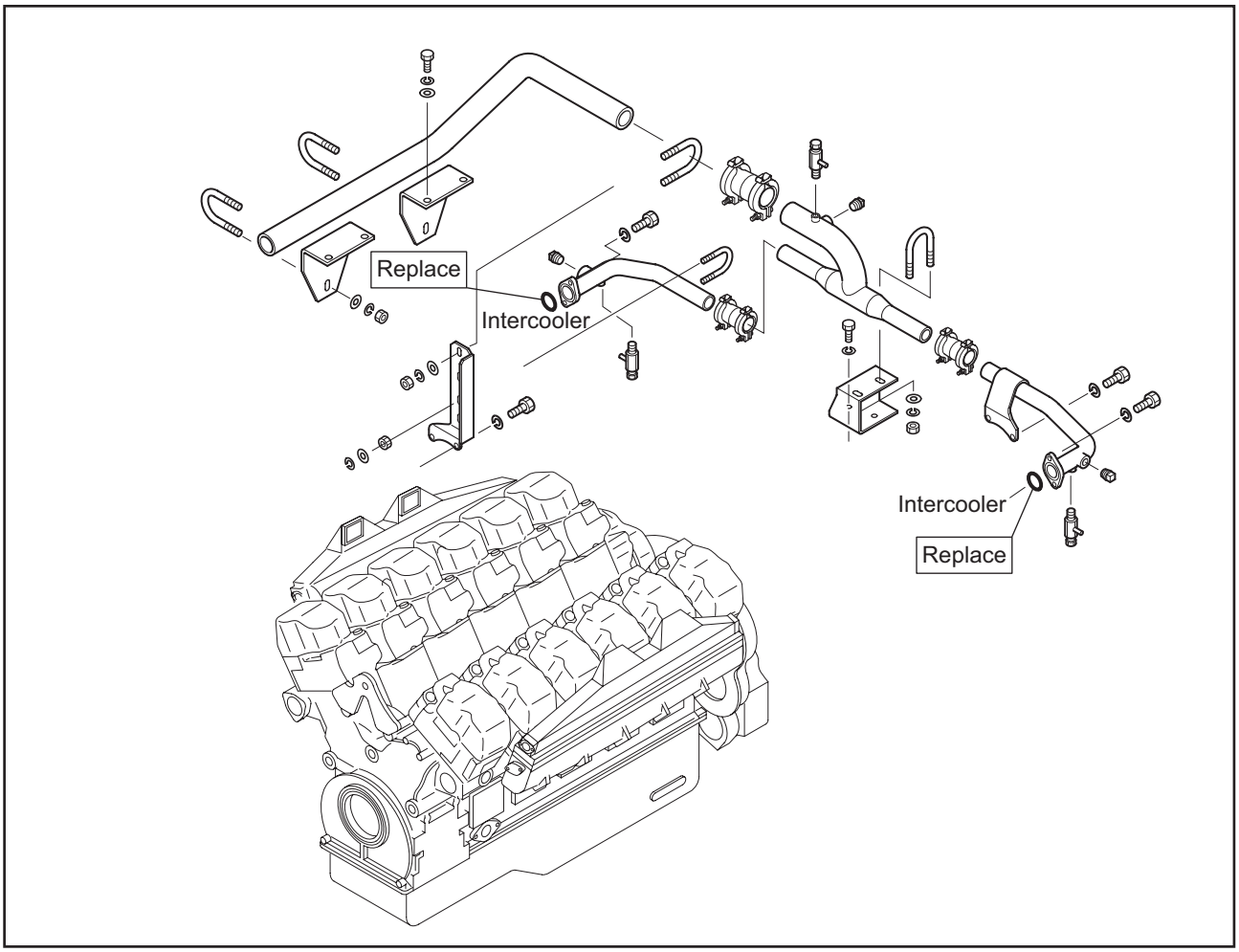
Installing water pump and water pipe

3.2 Installing thermostat and water pipe



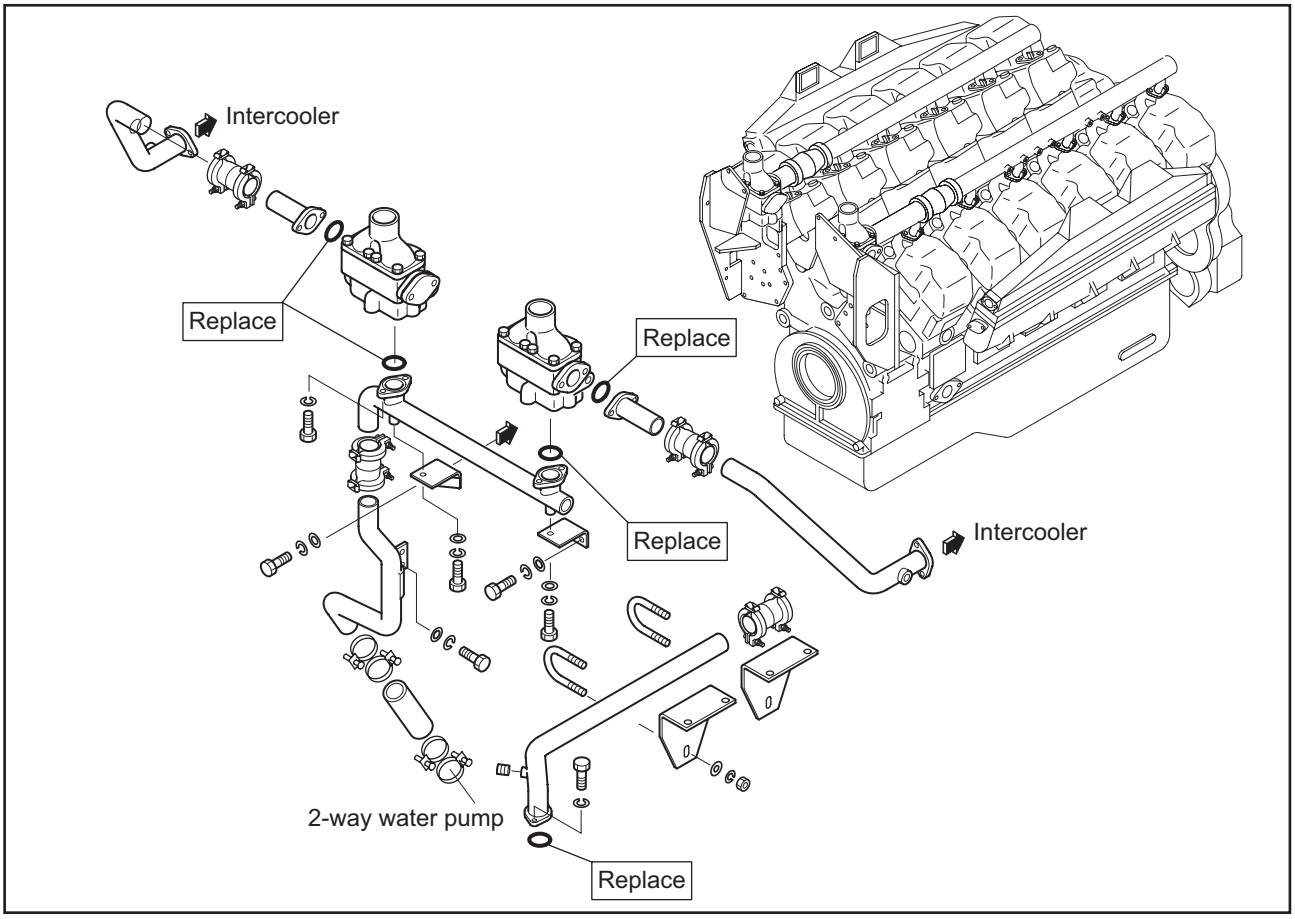
Installing thermostat and water pipe

3.3 Installing 2-way water pipe



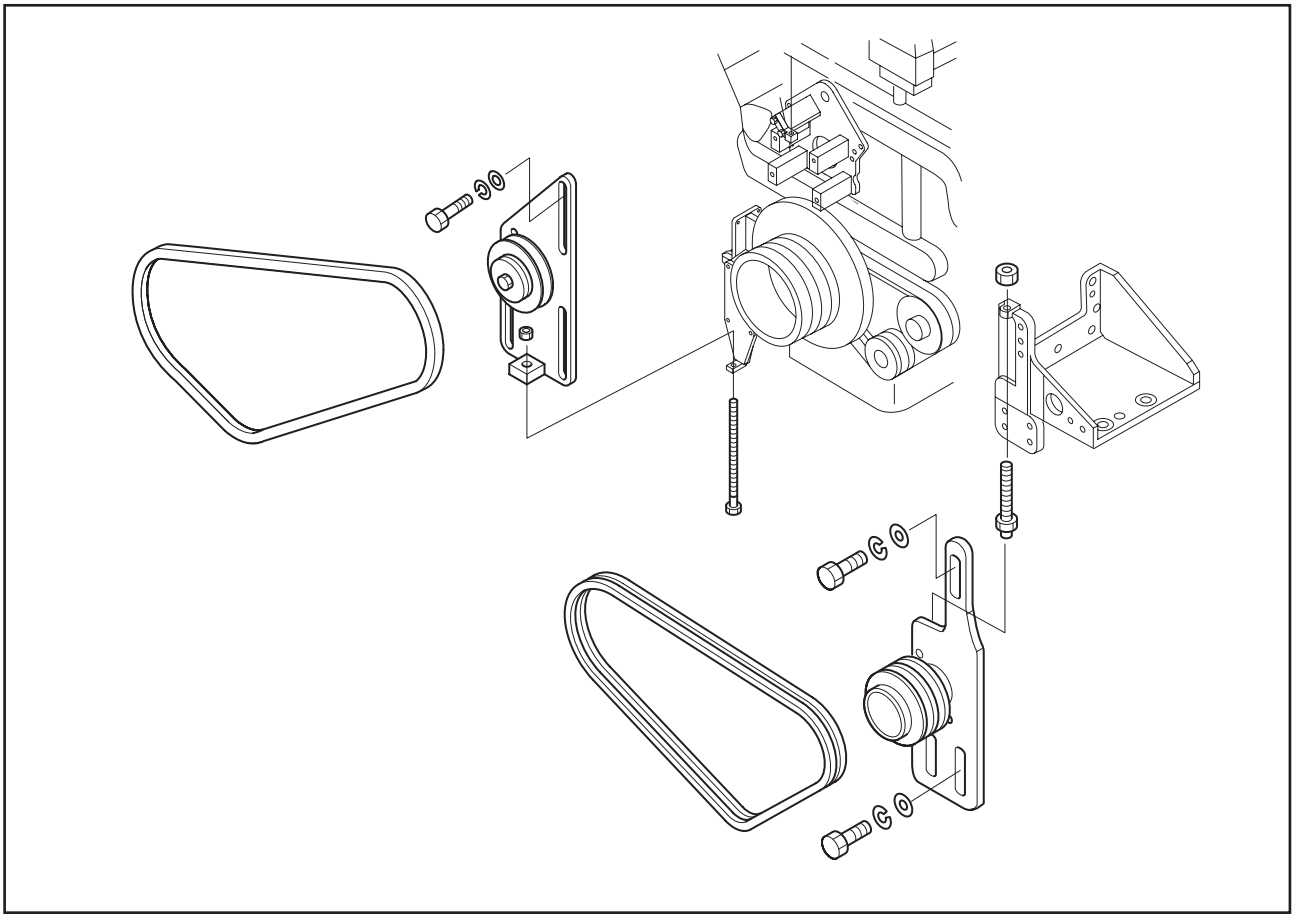
Installing 2-way water pipe

3.4 Installing thermostat and 2-way water pipe



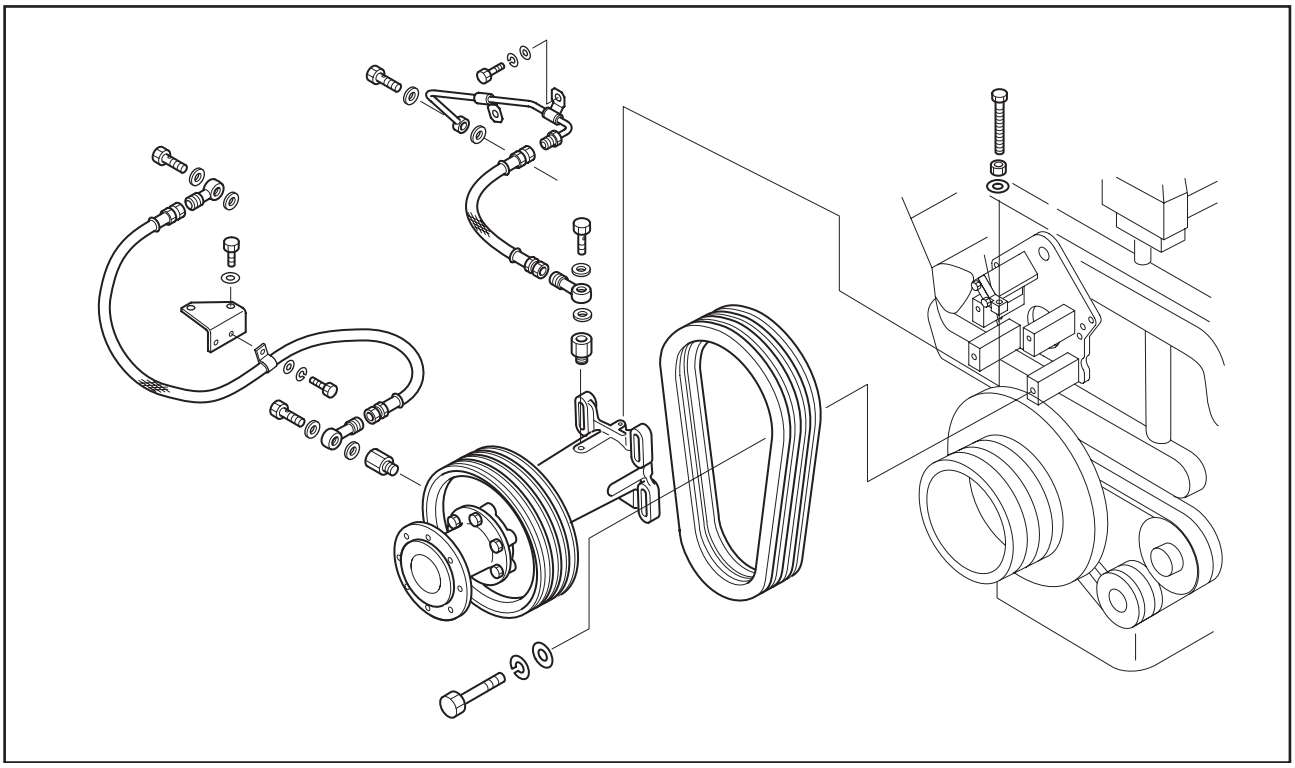
Installing thermostat and 2-way water pipe

3.5 Installing tension pully



Installing tension pully

3.6 Installing fan drive



Installing fan drive

INLET AND EXHAUST SYSTEMS

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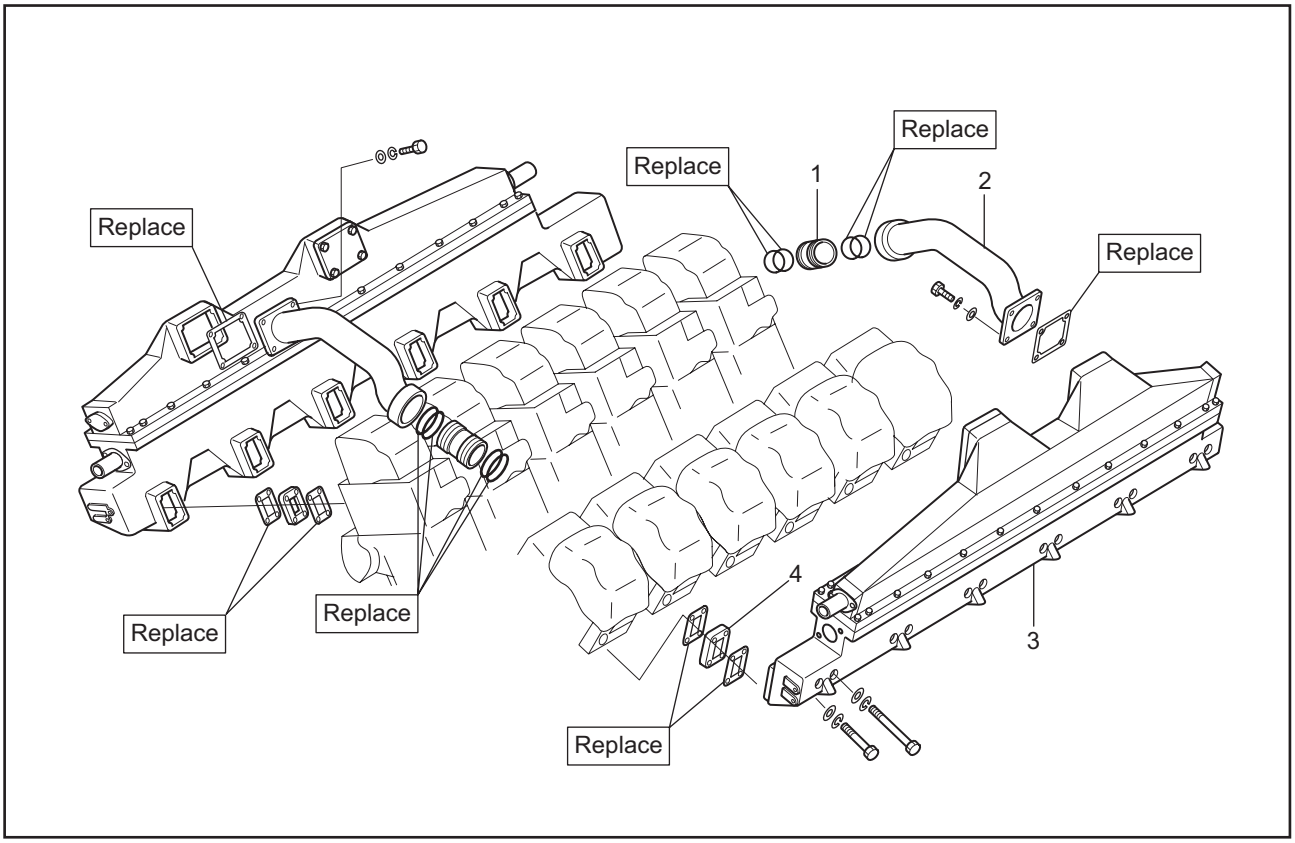
1. Removing inlet and exhaust systems

1.1 Removing intercooler assembly

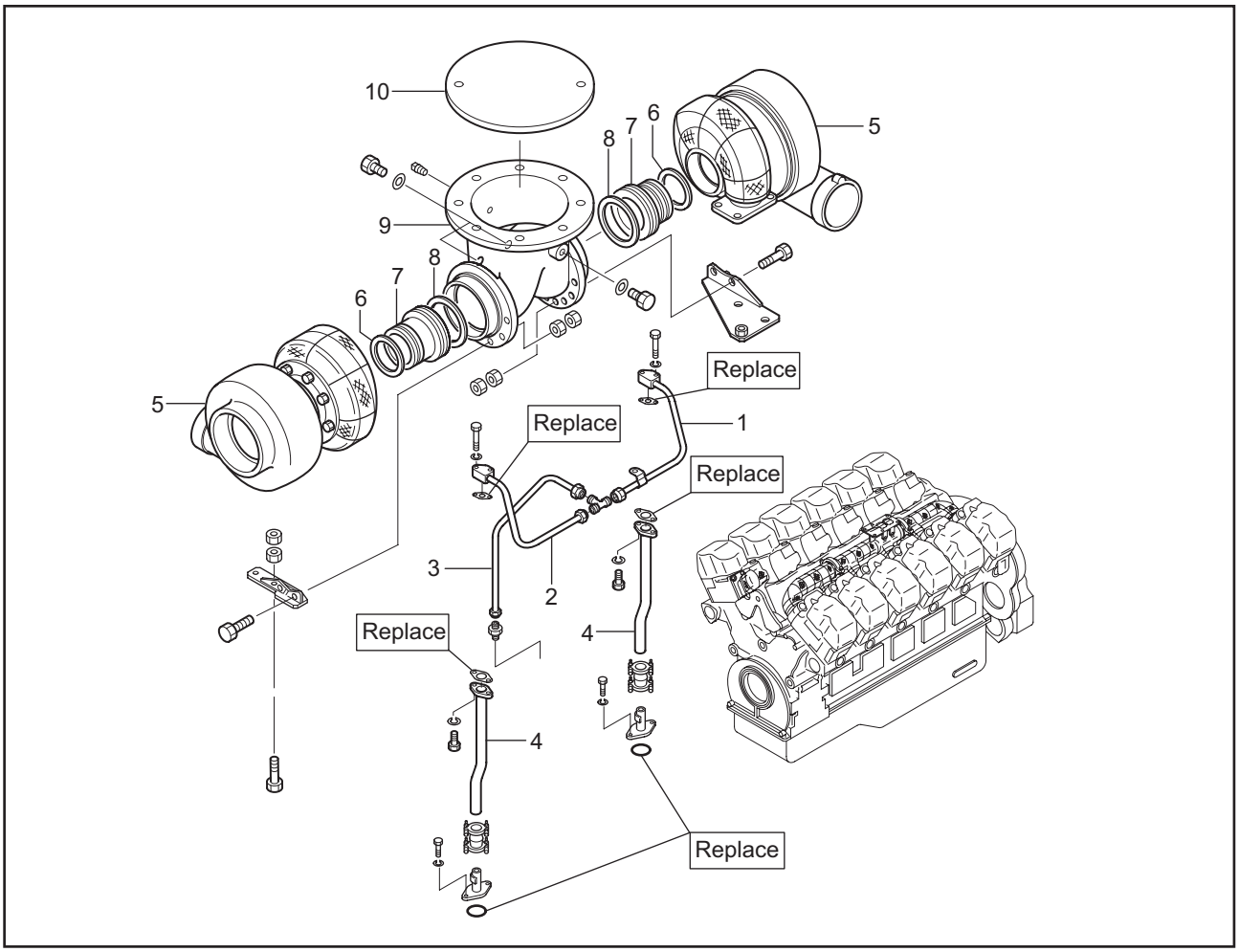


Removing intercooler assembly

Removing sequence

1 Joint
2 Inlet duct
3 Intercooler assembly
4 Spacer

1.2 Removing turbocharger, oil pipe and exhaust pipe



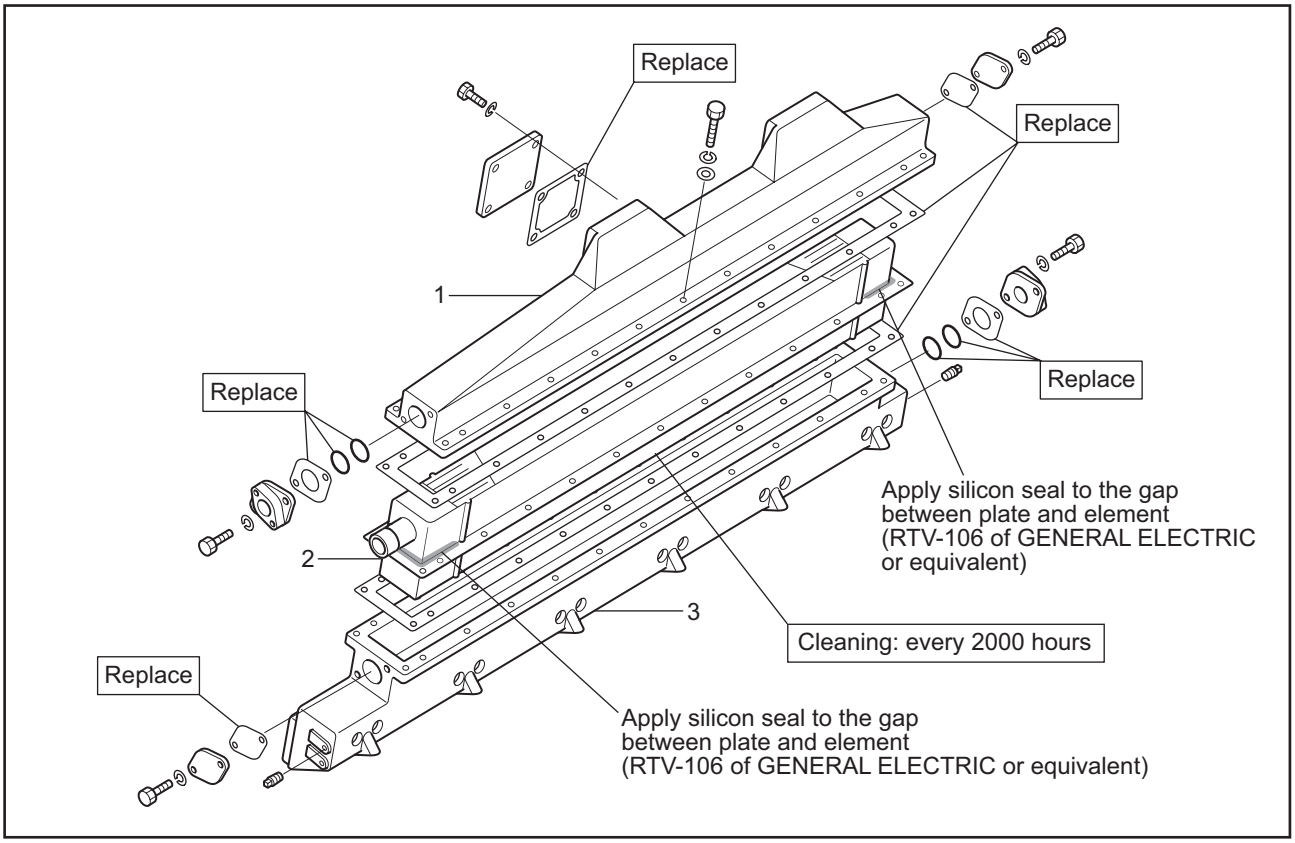
Removing turbocharger, oil pipe and exhaust pipe

Removing sequence

1 Oil pipe
2 Oil pipe
3 Oil pipe
4 Oil drain pipe
5 Turbocharger
6 Ring
7 Exhaust pipe joint
8 Ring
9 Exhaust pipe
10 Exhaust cover

2. Disassembling and inspecting inlet and exhaust systems

2.1 Disassembling and inspecting intercooler assembly



Disassembling and inspecting intercooler assembly

Disassembling sequence

1 Intercooler cover
2 Intercooler element
3 Inlet manifold

2.2 Inspecting intercooler and inlet manifold

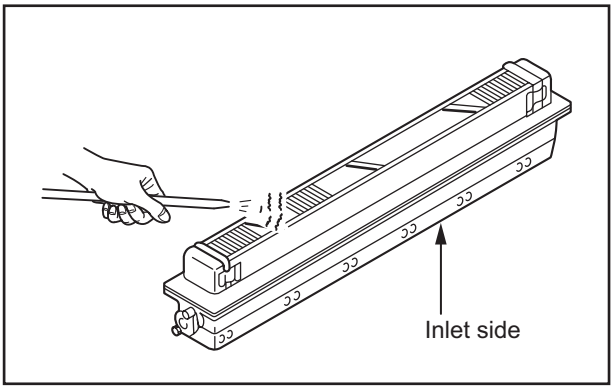
2.2.1 Cleaning intercooler

⚠ CAUTION

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

(1) To remove the accumulation of dust and dirt, blow compressed air (at a pressure of 0.29 to 0.49 MPa {3 to 5 kgf/cm²} [43 to 71 psi]) through the intercooler in the opposite direction to the normal air flow. Then, inspect for corrosion and cracks.

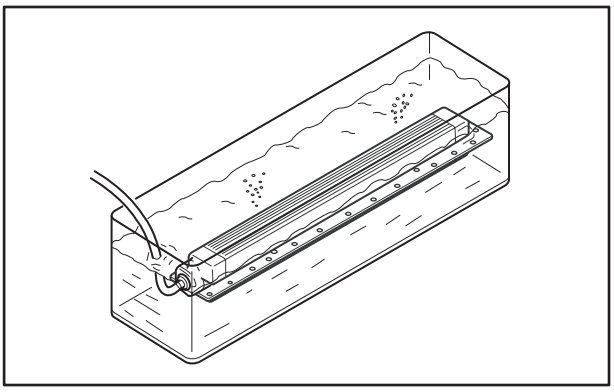
(2) Flush the coolant pipes thoroughly with water holding sodium hydroxide (caustic soda) or soda lime in solution to remove scales.



Cleaning intercooler

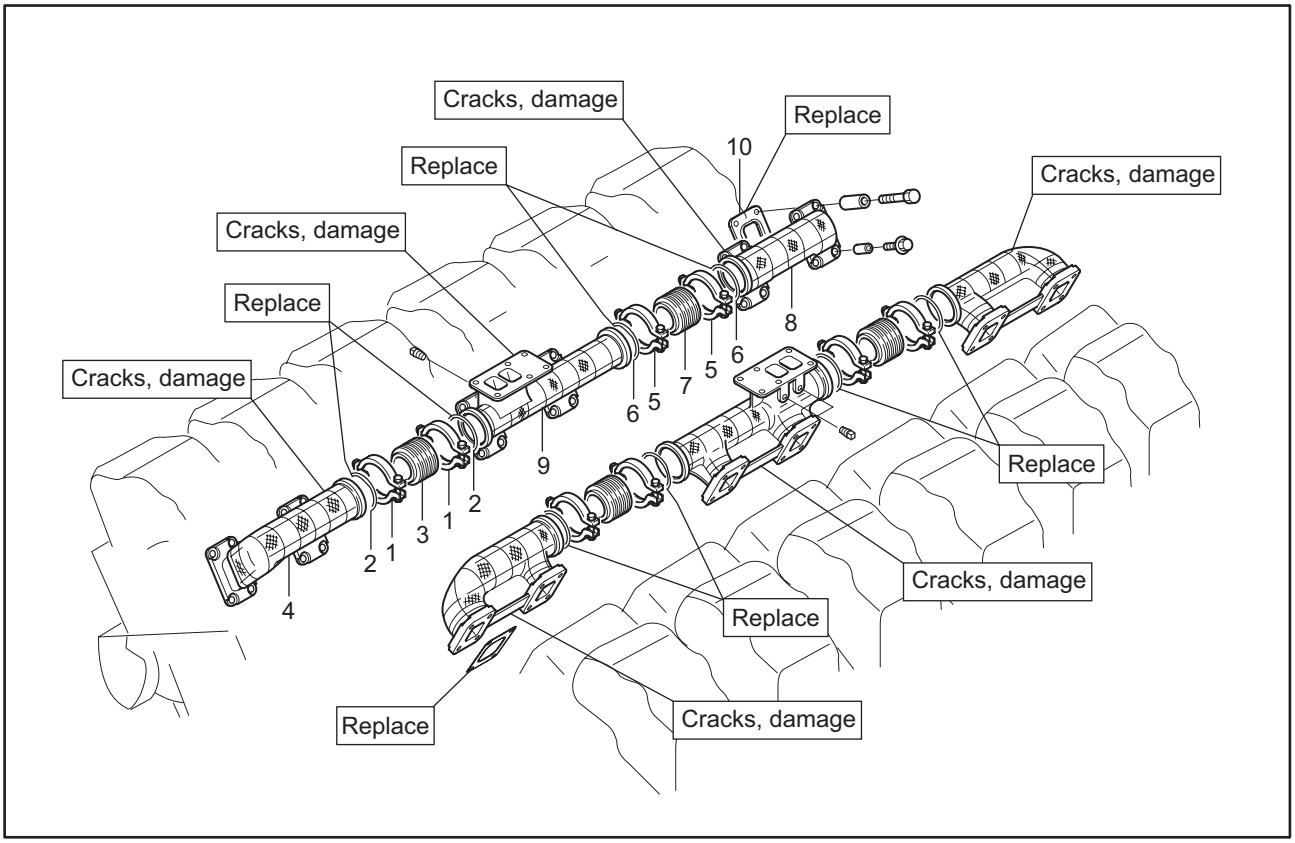
2.2.2 Inspecting intercooler for leakage

Immerse the intercooler in water. In this condition, blow compressed air (at a pressure of 0.39 MPa {4 kgf/cm²} [57 psi]) through the coolant passage and check for air leak.



Inspecting intercooler for leakage

2.3 Disassembling and inspecting exhaust manifold



Disassembling and inspecting exhaust manifold

Disassembling sequence

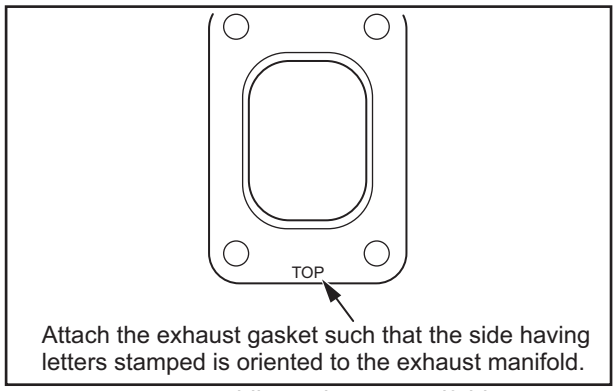
1 Coupling
2 Joint gasket
3 Flexible joint
4 Exhaust manifold
5 Coupling
6 Joint gasket
7 Flexible joint
8 Exhaust manifold
9 Exhaust manifold
10 Exhaust manifold gasket

2.4 Reassembling exhaust manifold

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

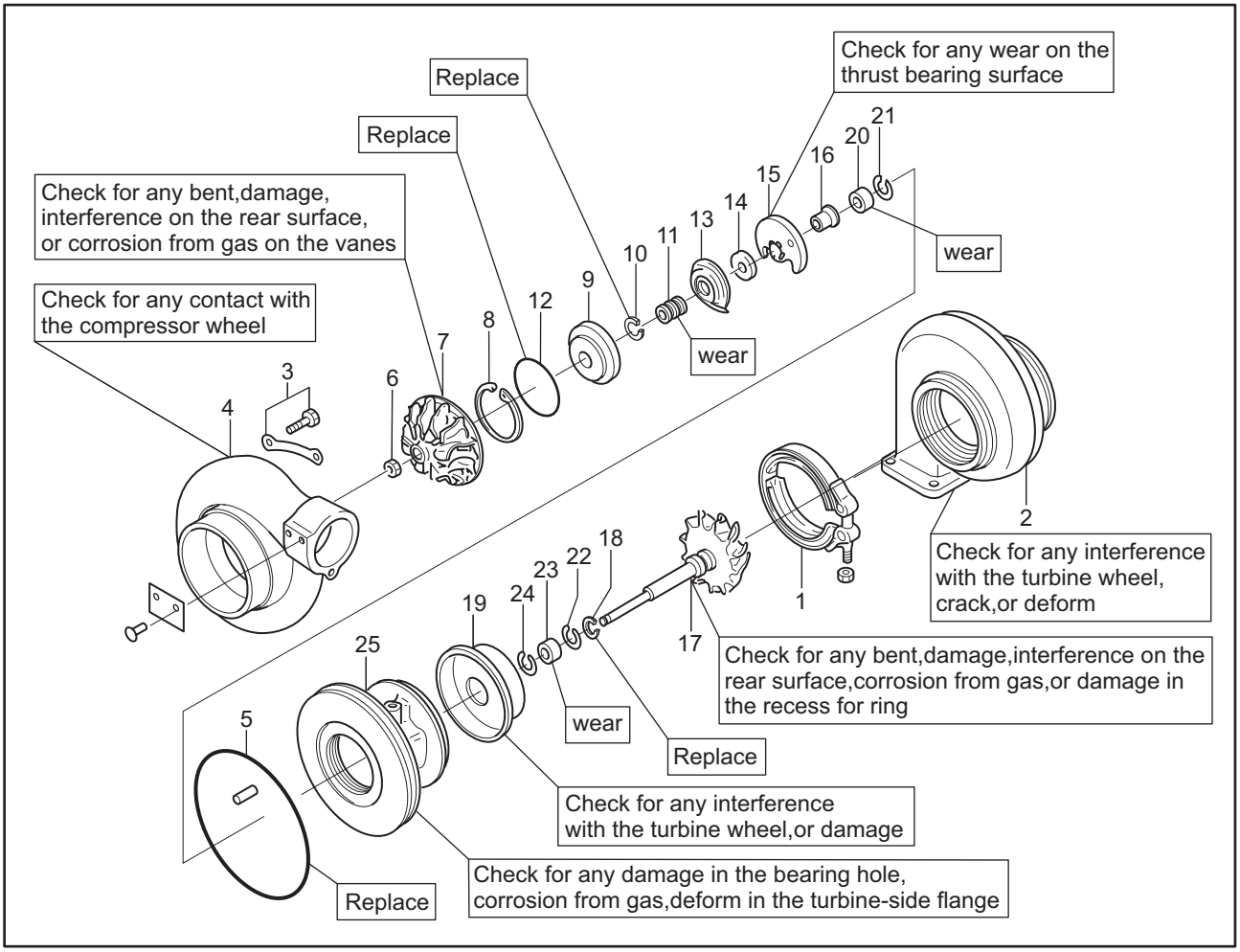
Note: (a) Attach the exhaust gasket such that the side having letters stamped is oriented to the exhaust manifold.

(b) When reassembling the exhaust manifold, always replace all pieces of the exhaust gasket with new ones.



Reassembling exhaust manifold

2.5 Disassembling and inspecting turbocharger



Disassembling and inspecting turbocharger

Disassembling sequence

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

CAUTION

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

CAUTION

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

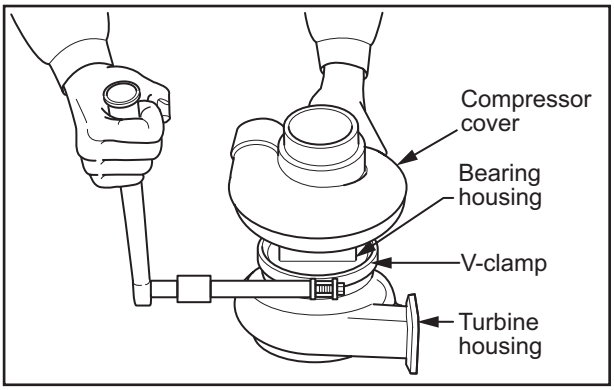
2.5.1 Removing turbine housing

⚠ CAUTION

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

(1) Use the box wrench to reduce the tension of the V-clamp.

(2) Remove V-clamp and turbine housing from turbocharger.



Removing turbine housing

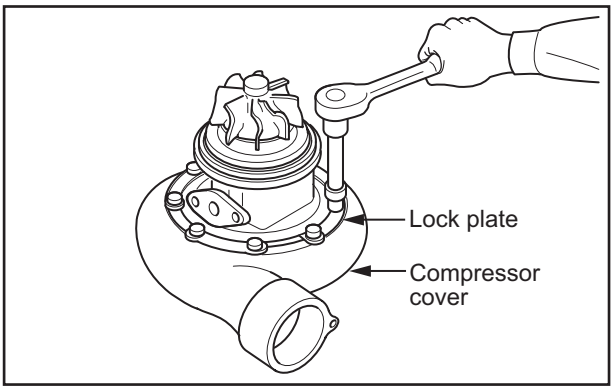
2.5.2 Removing compressor cover

⚠ CAUTION

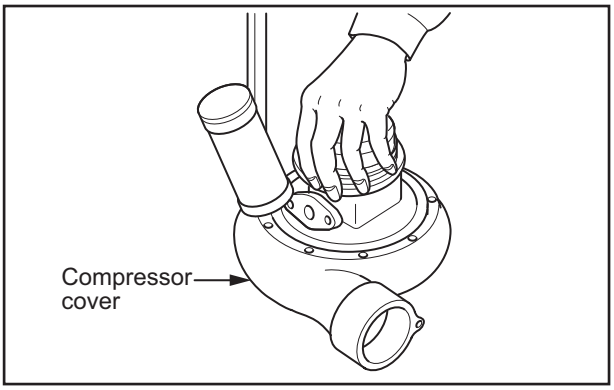
Be careful not to hit the compressor wheel against the compressor cover.

(1) Place the turbocharger on a work bench with the compressor cover facing down. Unscrew bolts, and remove lock plate.

(2) Lightly tap the entire periphery of compressor cover with a soft hammer, and remove the compressor cover. Remove O-ring from the bearing housing.



Removing compressor cover (1)



Removing compressor cover (2)

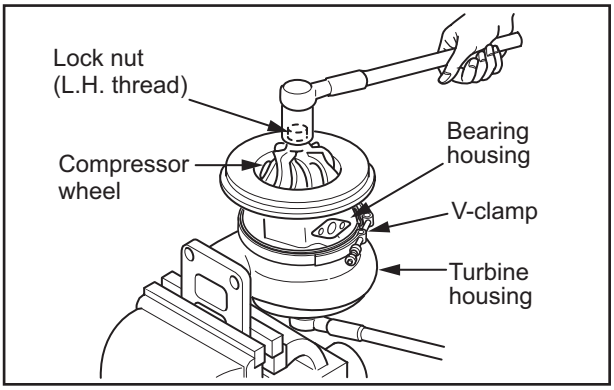
2.5.3 Removing compressor wheel

⚠ CAUTION

(a) Be careful not to hit the compressor wheel against the compressor cover.

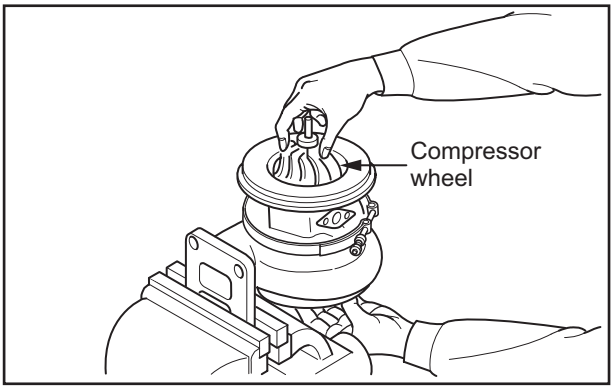
(b) Note that lock nut has left-handed threads.

(1) Hold the flange of the turbine housing in a vise. Install the bearing housing to the turbine housing with V-clamp. Hold the boss of the shaft & turbine wheel and unscrew the lock nut that holds the compressor wheel.



Removing compressor wheel (1)

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



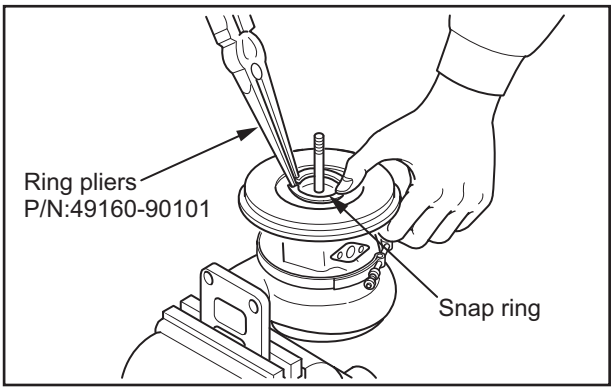
Removing compressor wheel (2)

2.5.4 Removing snap ring

⚠ CAUTION

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

Using the ring pliers, remove the snap ring.



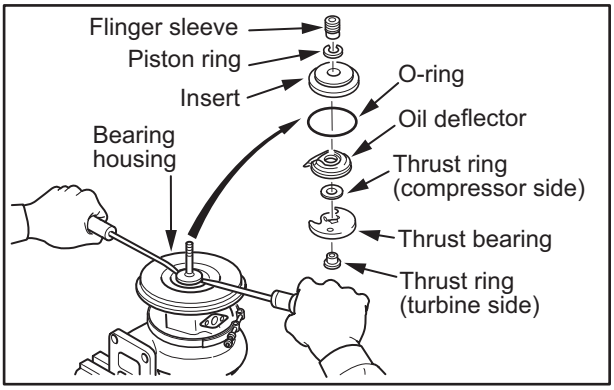
Removing snap ring

2.5.5 Removing insert and oil deflector

(1) Using two screwdrivers, gently pry out the insert from the bearing housing.

(2) Separate the flinger sleeve together with the piston ring from the insert.

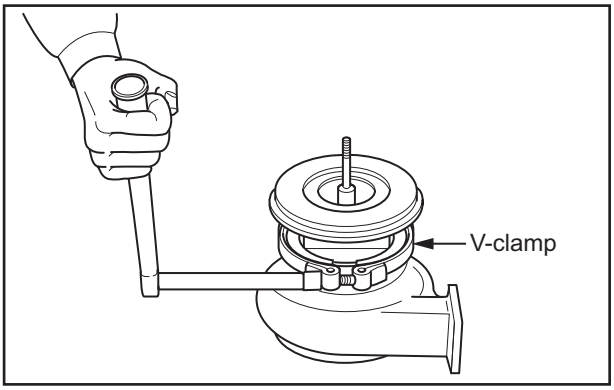
(3) Remove the following parts from the bearing housing.
O-ring
Oil deflector
Thrust ring (compressor side)
Thrust bearing
Thrust ring (turbine side)



Removing insert and oil deflector

2.5.6 Removing V-clamp

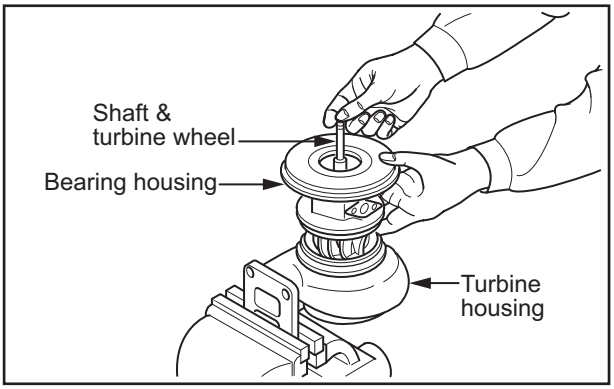
Loosen the V-clamp with a socket wrench, and dislodge the V-clamp from its clamping position.



Removing V-clamp

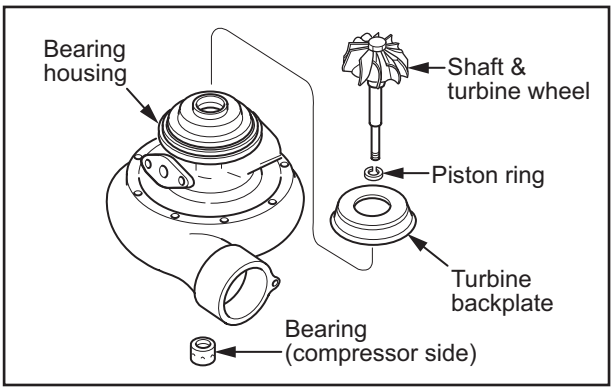
2.5.7 Removing shaft & turbine wheel

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



Removing shaft & turbine wheel (1)

(2) Turn over the bearing housing (so the turbine wheel faces up), and place it on the compressor cover. Then, remove the following parts.
Shaft & turbine wheel
Piston ring
Turbine backplate
Bearing (compressor side)



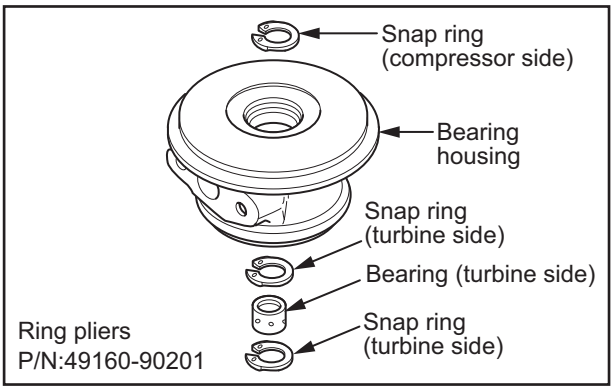
Removing shaft & turbine wheel (2)

2.5.8 Removing snap ring and bearing

⚠ CAUTION

(a) Use the pliers to remove the snap ring.
(b) Carefully remove the snap ring, making sure not to damage the inside surface of the bearing housing or the seal (turbine side) of the piston ring.

Place the bearing housing on a workbench with the compressor side facing up. Then, remove the following parts.
Snap ring (compressor side)
Bearing (turbine side)
Snap ring (turbine side)



Removing snap ring and bearing

2.6 Cleaning

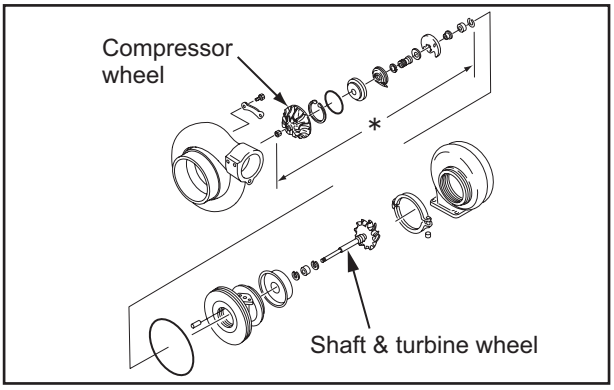
CAUTION

(a) If any commercial neutral detergent needs to be used, it must not have a corrosive nature.
(b) Exercise care not to damage any part.
(c) Where shot-blasting is necessary, cover the both end surfaces of the compressor wheel, and screws, shafts, and groove for ring of the turbine shaft & turbine wheel to protect their surfaces from being rugged or sore before the cleaning operation.

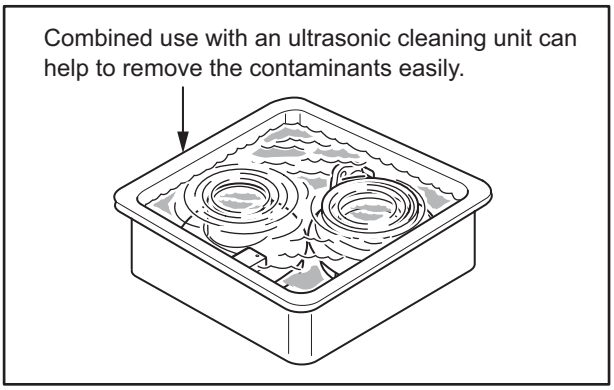
In maintenance workshops dedicated for turbocharger, it is popular to use a blasting equipment for cleaning the target parts. The alternative of this method is as follows:

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

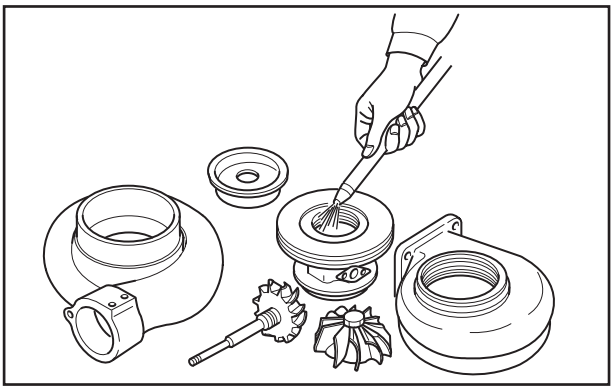
(1) Visually check the part conditions before cleaning to note any burns and abrasions, which may not be observable after cleaning.
(2) Soak the disassembled parts in the inflammable solvent (e.g. Die Cleaner T-30 manufactured by Daido Chemical Industry Corp.) to remove oil contaminants and carbon attachments. However, do not soak the O-ring, thrust bearing, and other bearings.
(3) Blow a compressed air over the either inside and outside surfaces.



Proper cleaning of turbocharger

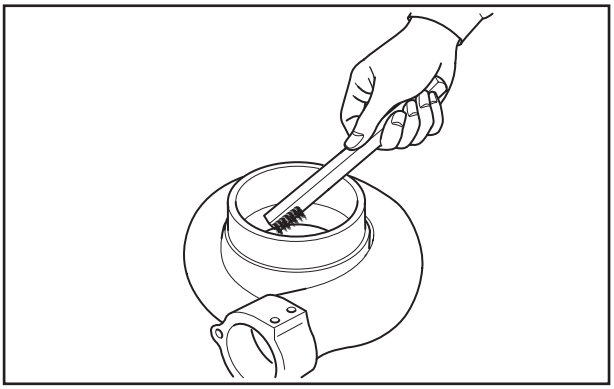


Cleaning turbocharger



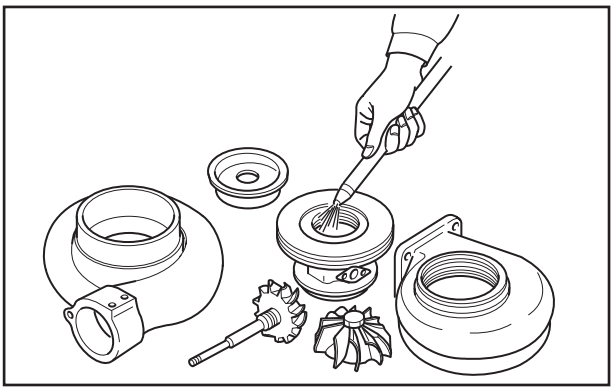
Blow compressed air onto

(4) Pick off the attachments using a plastic lever or bristle brush.



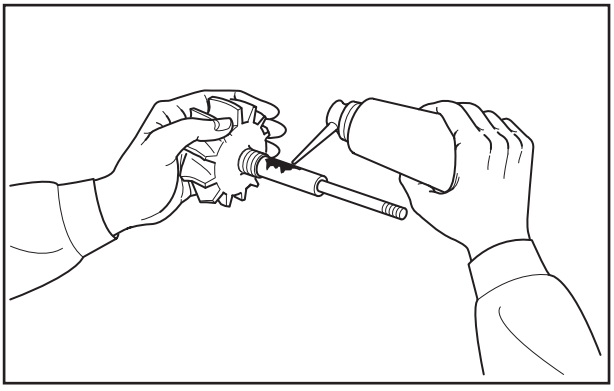
Removing carbon deposits thoroughly

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



Blow compressed air onto

Coat a clean engine oil over the surfaces of each sliding component. Should the screw, shaft, or ring-receiving groove be rusty, remove it with a puff, etc. Never use a file to abrade the surfaces.



Apply engine oil

2.7 Inspecting turbocharger

CAUTION

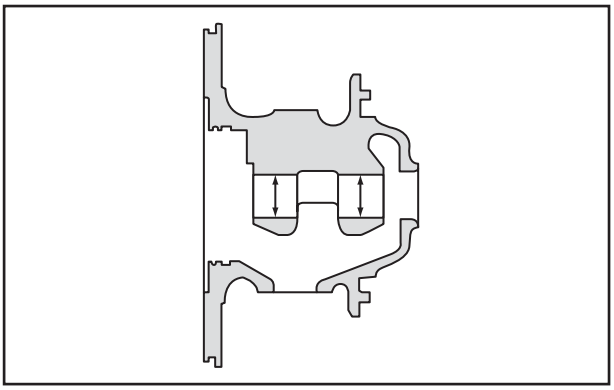
When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

2.7.1 Bearing housing

Measuring inside diameter of bearing-fitted section

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

Item	Limit
Inside diameter of bearing-fitted housing section	30.006 mm [1.1813 in.]



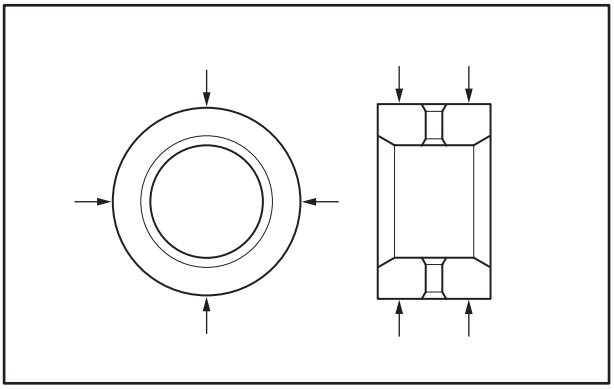
Measuring inside diameter of bearing-fitted section

2.7.2 Bearing

(1) Measuring bearing outside diameter

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

Item	Limit
Bearing outside diameter	29.876 mm [1.1762 in.]

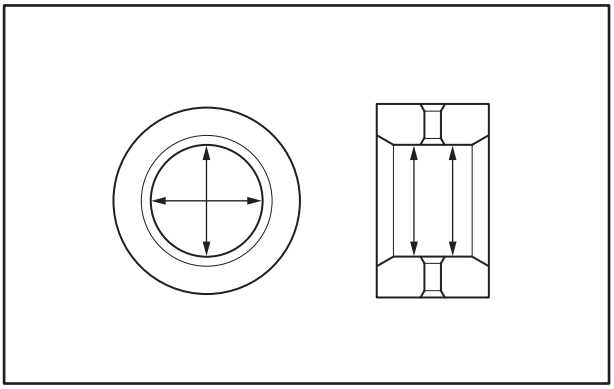


Measuring bearing outside diameter

(2) Measuring bearing inside diameter

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

Item	Limit
Bearing inside diameter	18.050 mm [0.7106 in.]

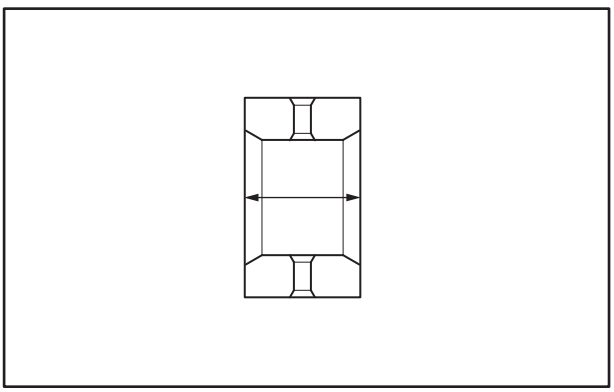


Measuring bearing inside diameter

(3) Measuring bearing length

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

Item	Limit
Bearing length	17.440 mm [0.6866 in.]



Measuring bearing length

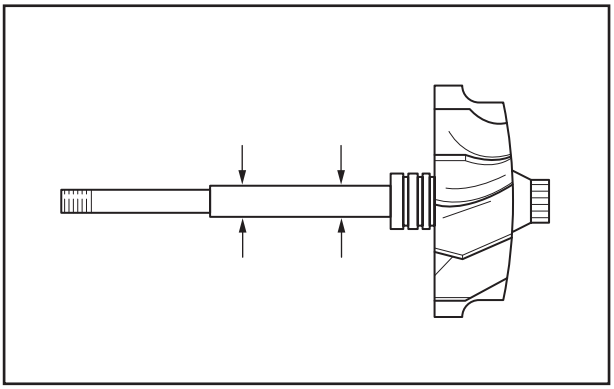
2.7.3 Shaft & turbine wheel

(1) Measuring journal diameter of the shaft & turbine wheel

If the measured diameter is less than the service limit, replace the shaft & turbine wheel.

Replace the piston ring with new one.

Item	Limit
Shaft journal diameter	17.996 mm [0.7085 in.]



Measuring journal diameter of shaft & turbine wheel

(2) Measuring shaft runout

⚠ CAUTION

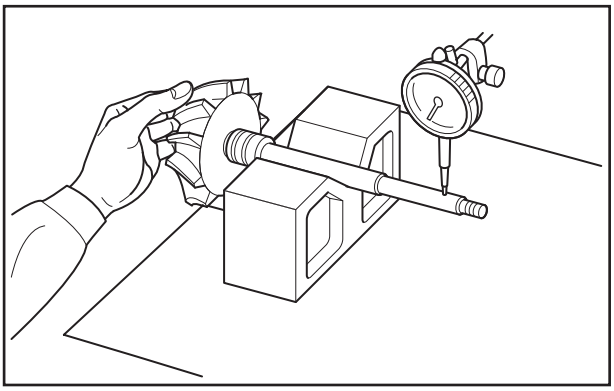
If the shaft is bent, replace. Do not attempt to correct the bend.

Set a dial gauge at a location next to the threaded section of the shaft, and measure shaft runout.

If the deviation indicated by the dial gauge exceeds the service limit, replace the shaft & turbine wheel.

If the surface of the shaft journal is rough, mount the shaft on a lathe, and gently polish the surface using #400 sandpaper and engine oil while rotating at 300 to 600 min^{-1}.

Item	Limit
Shaft runout	0.015 mm [0.0006 in.]



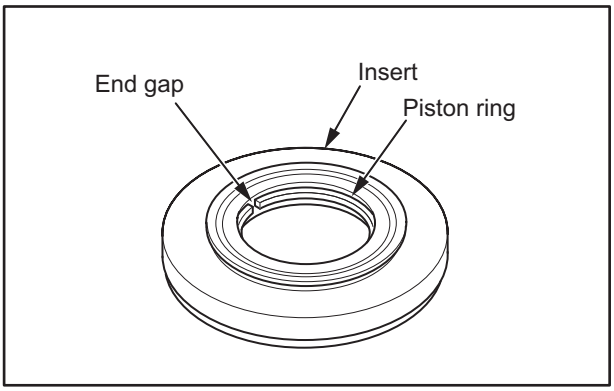
Measuring shaft deflection

2.7.4 Inspecting insert and measuring piston ring end gap

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

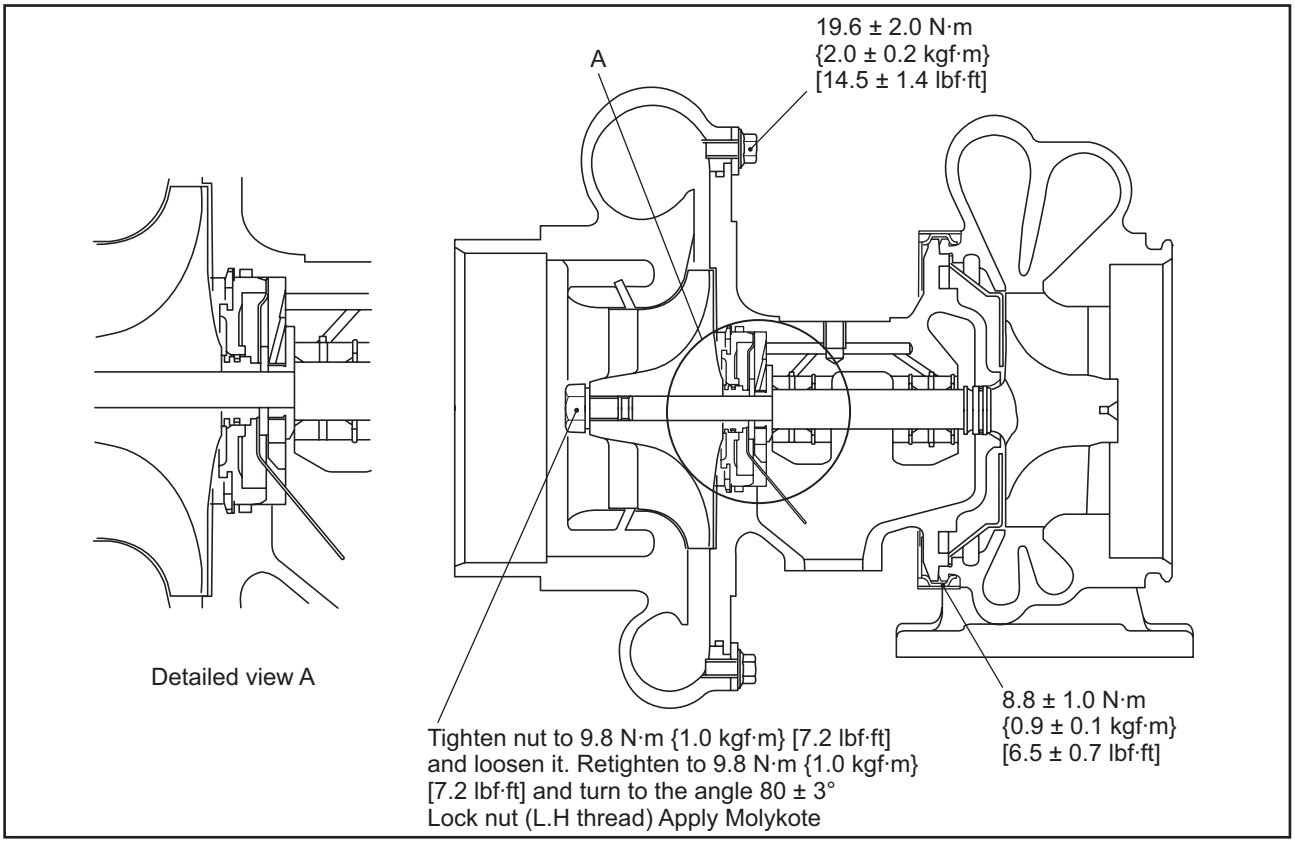
If the end gap deviates from the assembly standard, replace the insert.

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



Measuring piston ring end gap

2.8 Reassembling turbocharger



Reassembling turbocharger

CAUTION

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

CAUTION

Replace the following parts once disassembled.

Piston ring

O-ring

After installing the overhauled turbocharger on the engine, crank the engine with the starter to send lubricating oil to the moving parts in the turbocharger.

CAUTION

(a) If vanes are damaged or cracked, do not reuse the part.

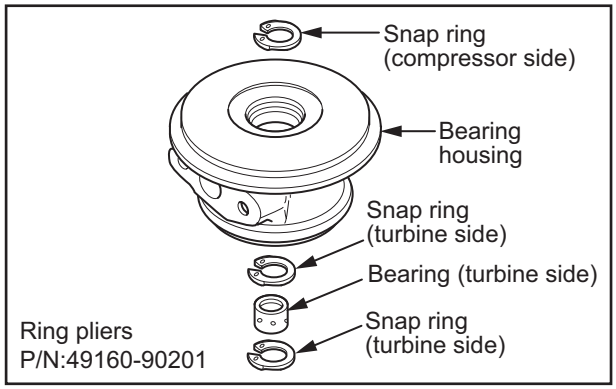
(b) If only one vane is slightly bent or scratched, the part can reused. However, do not attempt to correct the bend.

2.8.1 Installing shaft & turbine wheel and bearing

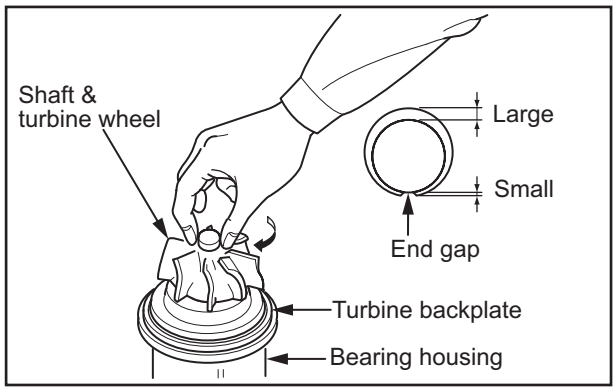
⚠ CAUTION

(a) Use the snap ring pliers to install the snap ring. After installing the snap ring, rotate the ring with a finger to make sure it rotates smoothly.
(b) Apply engine oil to the outside and inside surfaces of the bearing before installation.
(c) Do not expand the piston ring excessively or twist the ends when installing on the shaft & turbine wheel.
(d) After installing the piston ring in the ring groove, apply Molykote to the ring before assembly.
(e) The piston rings on the turbine side and compressor side are identical.
(f) Do not apply excessive force without centering the shaft properly during the installation of the shaft & turbine wheel.

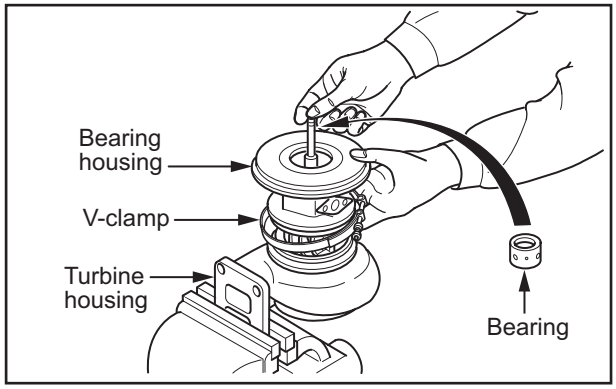
(1) Install the following parts.
Bearing housing (compressor side)
Snap ring (turbine side)
Snap ring (turbine side)
Bearing (turbine side)
Snap ring (compressor side)
(2) Place the bearing housing on the compressor cover, and install the turbine backplate.
(3) Insert the piston ring into the groove on the shaft & turbine wheel.
(4) When installing the shaft & turbine wheel mounted with the piston ring in the bearing housing, position the ring on the shaft as shown in the drawing, and insert the shaft & turbine wheel while rotating.
(5) After installing the shaft & turbine wheel, hold the shaft end and turn over the assembly so the compressor side faces up.
Then, install the bearing on the compressor side.
After the assembly was completed, mount the bearing housing on the turbine housing and tighten the bolts and clamp plates temporarily.



Installing shaft & turbine wheel and bearing (1)



Installing shaft & turbine wheel and bearing (2)

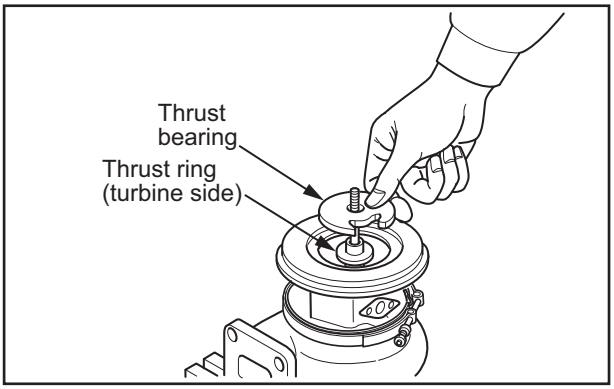


Installing shaft & turbine wheel and bearing (3)

2.8.2 Installing thrust bearing

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

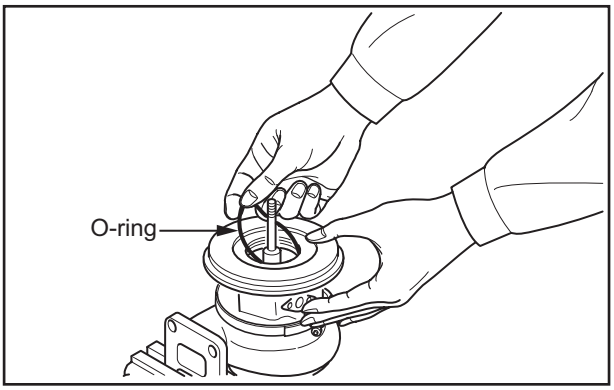
To install the thrust bearing, align the notch to the groove pin.



Installing thrust bearing

2.8.3 Installing O-ring

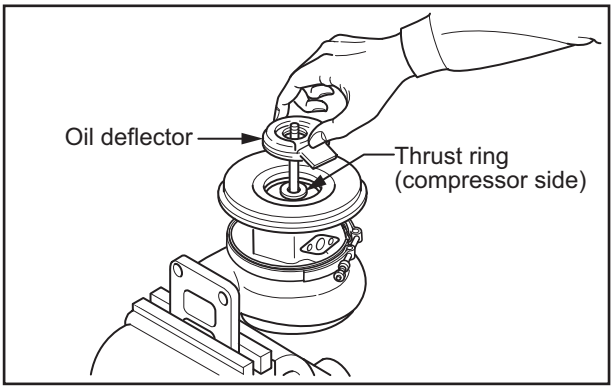
Apply grease to O-ring, and install.



Installing O-ring

2.8.4 Installing oil deflector

Apply engine oil to both sides of the thrust ring and install. Then, install the oil deflector with the baffle facing down.



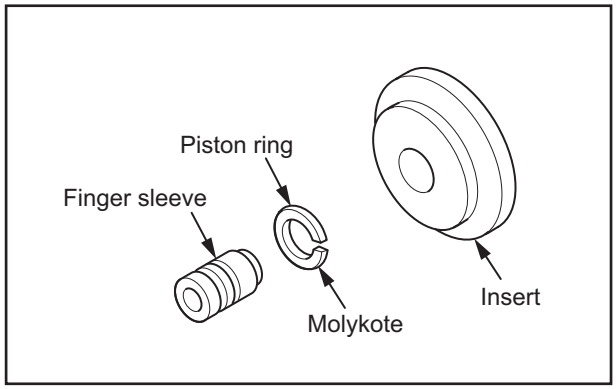
Installing oil deflector

2.8.5 Reassembling insert sub-assembly

CAUTION

(a) Do not expand the piston ring excessively or twist the ends when installing on the finger sleeve.
(b) Apply specified sealant to the piston ring installed on the flinger sleeve, then install on the insert carefully so as to avoid piston ring damage.

(1) Install the following parts to the insert.
Flinger sleeve
Piston ring
Insert
(2) After installing the above parts, install the sub-assembly in the bearing housing.



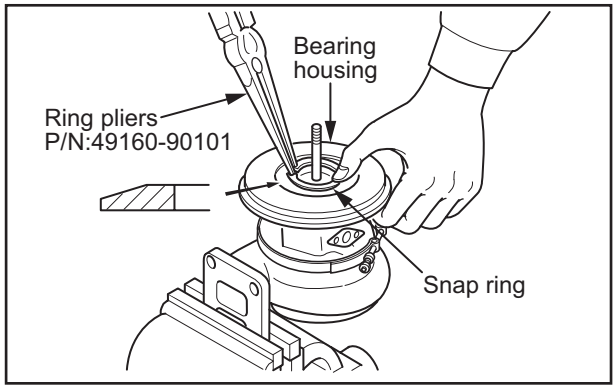
Reassembling insert sub-assembly

2.8.6 Installing snap ring

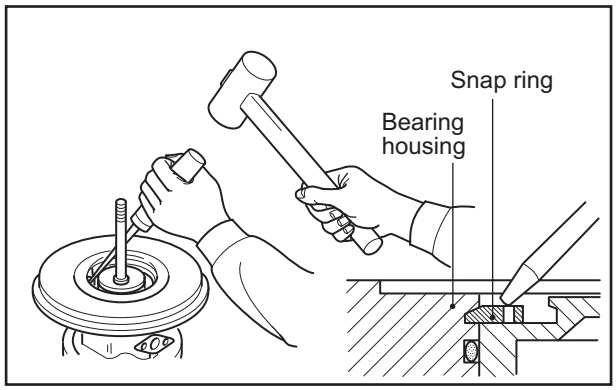
CAUTION

(a) Be sure to install the special tool snap ring in the correct direction.
(b) Lightly drive both ends of the snap ring using a screwdriver and hammer to securely insert the ring into the groove on the bearing housing.
(c) Make sure the screwdriver does not hit the bearing housing when driving the snap ring with the screw-driver and hammer.

With the tapered face facing up, install the snap ring in the bearing housing using the pliers.



Installing snap ring (1)



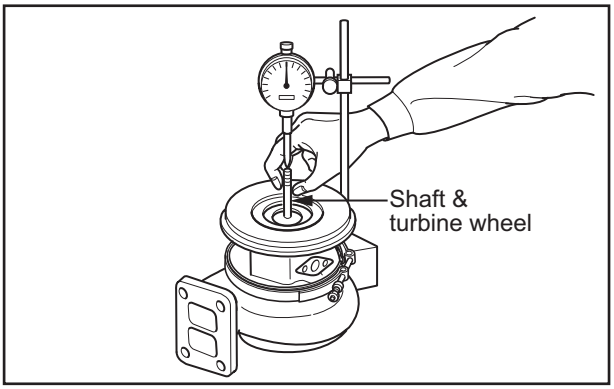
Installing snap ring (2)

2.8.7 Measuring clearance between shaft & turbine wheel and turbine housing

Set dial gauge on the end face of the shaft & turbine wheel. Read the dial gauge indication while moving the shaft & turbine wheel in the axial direction.

If the dial gauge indication deviates from the assembly standard, disassemble and locate the cause of the problem.

Item	Standard
Clearance between shaft & turbine wheel and turbine housing	0.29 to 0.91 mm [0.0114 to 0.0358 in.]



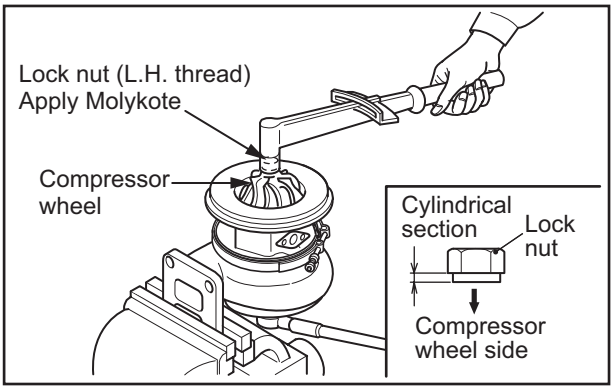
Measuring clearance between turbine wheel and turbine housing

2.8.8 Installing compressor wheel

Install the compressor wheel. Apply specified sealant to the threads of the lock nut, and tighten the nut to the specified torque.

· Lock nut tightening method

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



Installing compressor wheel

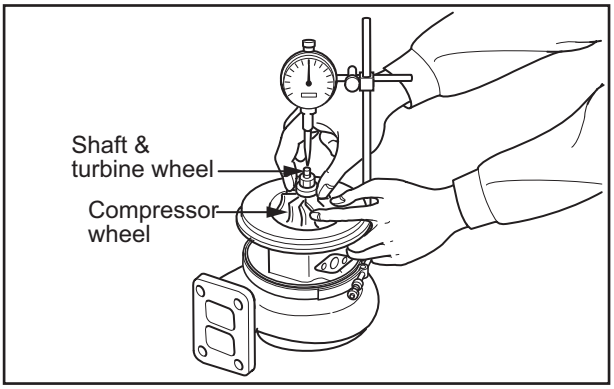
2.8.9 Measuring play of shaft & turbine wheel in axial direction

Set a dial gauge on the end face of the shaft & turbine wheel.

Measure the amount of play while moving the compressor wheel in the axial direction.

If the measured amount of play deviates from the standard value, disassemble and locate the cause of the problem.

Item	Standard
Shaft & turbine wheel end play	0.075 to 0.135 mm [0.0030 to 0.0053 in.]



Measuring play of shaft & turbine wheel in axial direction

2.8.10 Measuring clearance between turbine backplate and back side of turbine wheel

CAUTION

Be sure to use two feeler gauges, and take the measurement at vane tips.

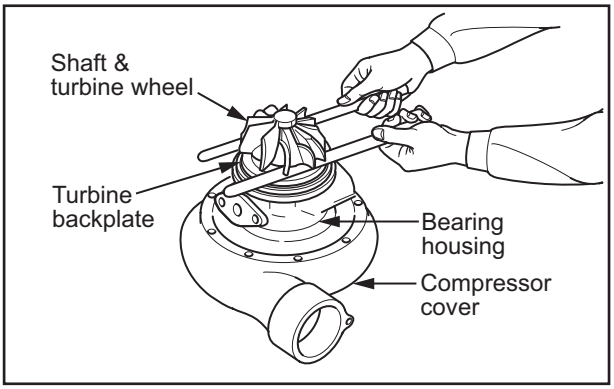
Remove the turbine housing from the bearing housing.

Install the compressor cover, and conduct the following measurement.

Using feeler gauges, measure clearance between the turbine backplate and the back side of the turbine wheel.

If the measured clearance deviates from the assembly standard, disassemble and locate the cause of the problem.

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

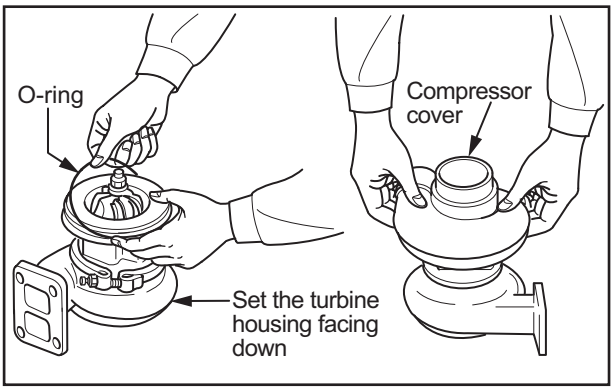


Measuring clearance berween turbine backplate and back side of turbine wheel

2.8.11 Installing the compressor cover

Place the turbocharger on a workbench with its turbine housing facing down. Apply grease to the O-ring and install the O-ring to the turbocharger.

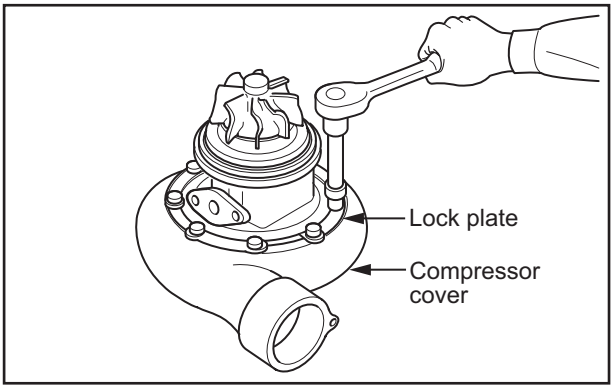
Then, while aligning the mating marks, install the compressor cover.



Installing compressor cover

2.8.12 Installing lock plate

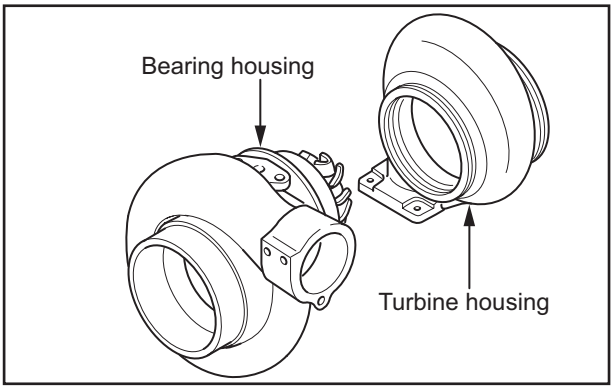
Remove the turbine housing, place the turbocharger with its compressor cover facing down, and install the lock plate to the compressor cover.



Installing lock plates

2.8.13 Installing turbine housing

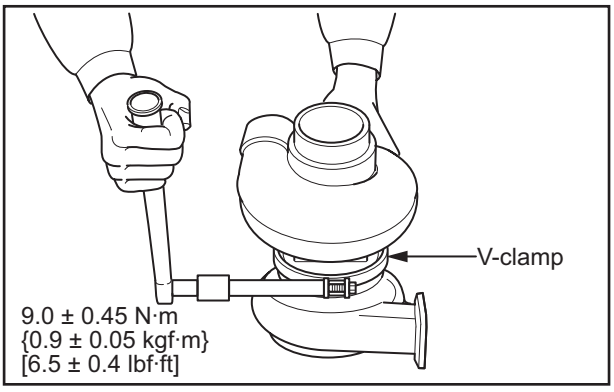
Install the turbine housing to the bearing housing by lining up the match marks put during disassembly.



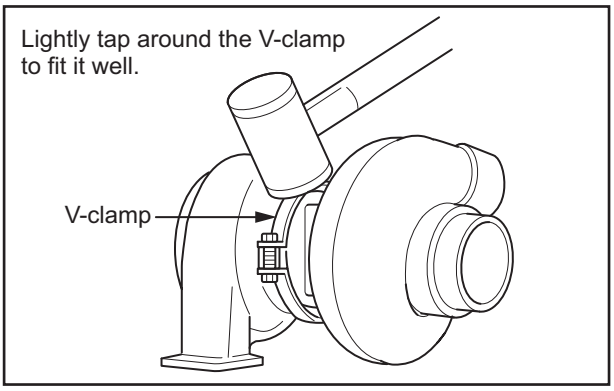
Installing turbine housing

2.8.14 Installing V-clamp

(1) Apply Molykote to the threads of the V-clamp and tighten its nut to the specified torque.
(2) Lightly tap around the V-clamp with a soft-faced hammer to fit the V-clamp well with the parts clamped.
(3) Then, retighten the V-clamp nut to the specified torque.



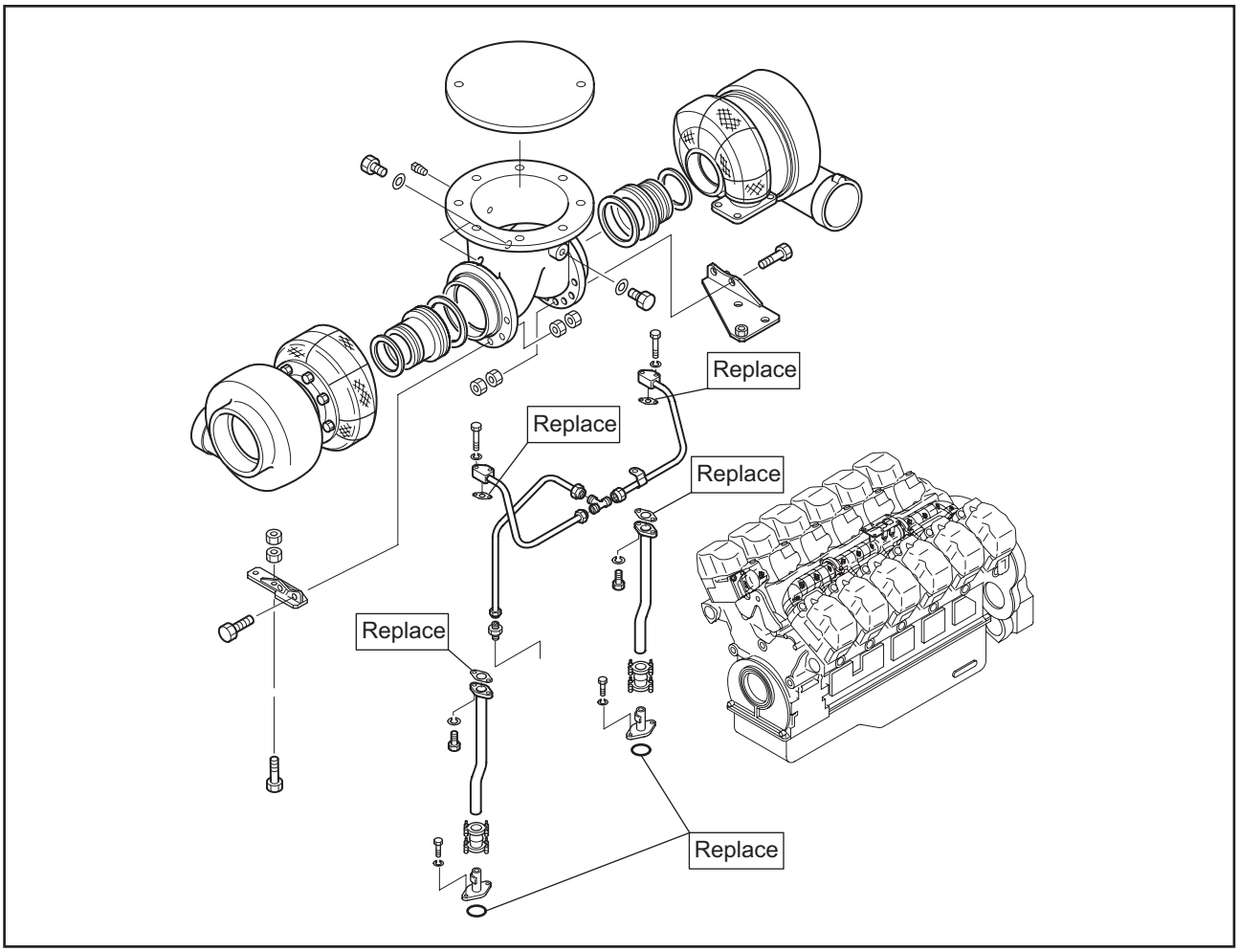
Installing V-clamp (1)



Installing V-clamp (2)

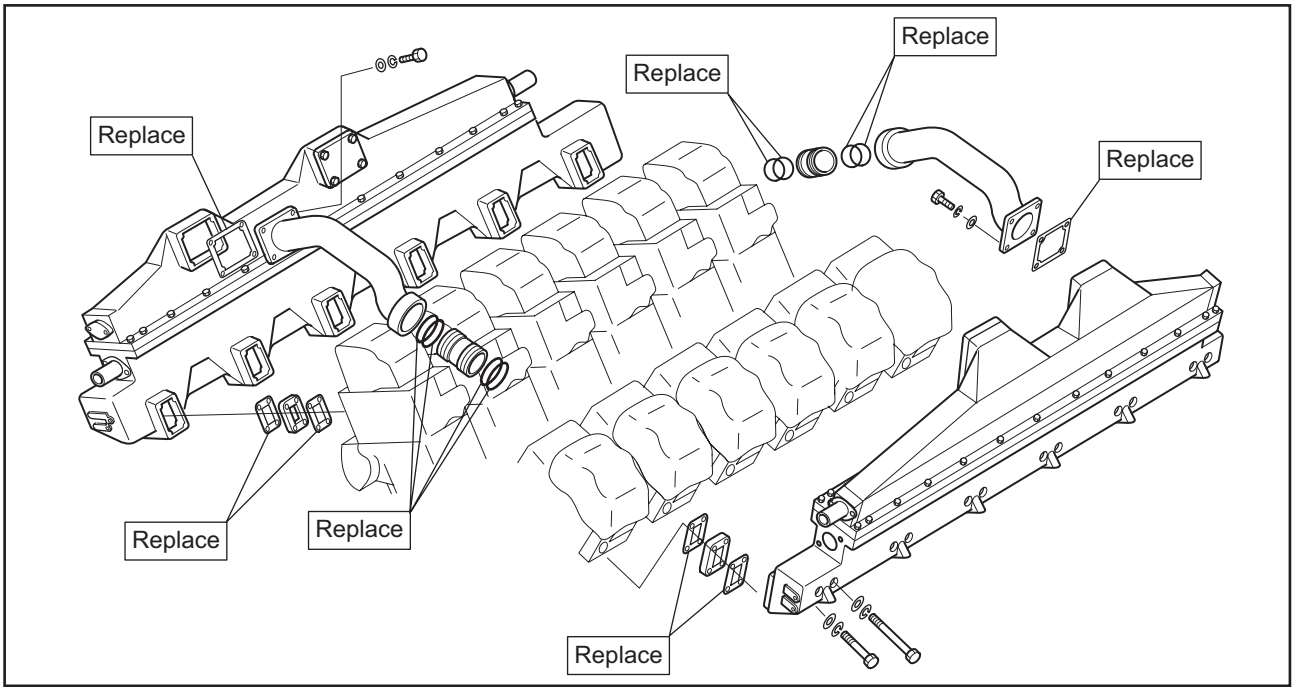
3. Installing inlet and exhaust systems

3.1 Installing turbocharger, oil pipe and exhaust pipe



Installing turbocharger, oil pipe and exhaust pipe

3.2 Installing intercooler assembly



Installing intercooler assembly

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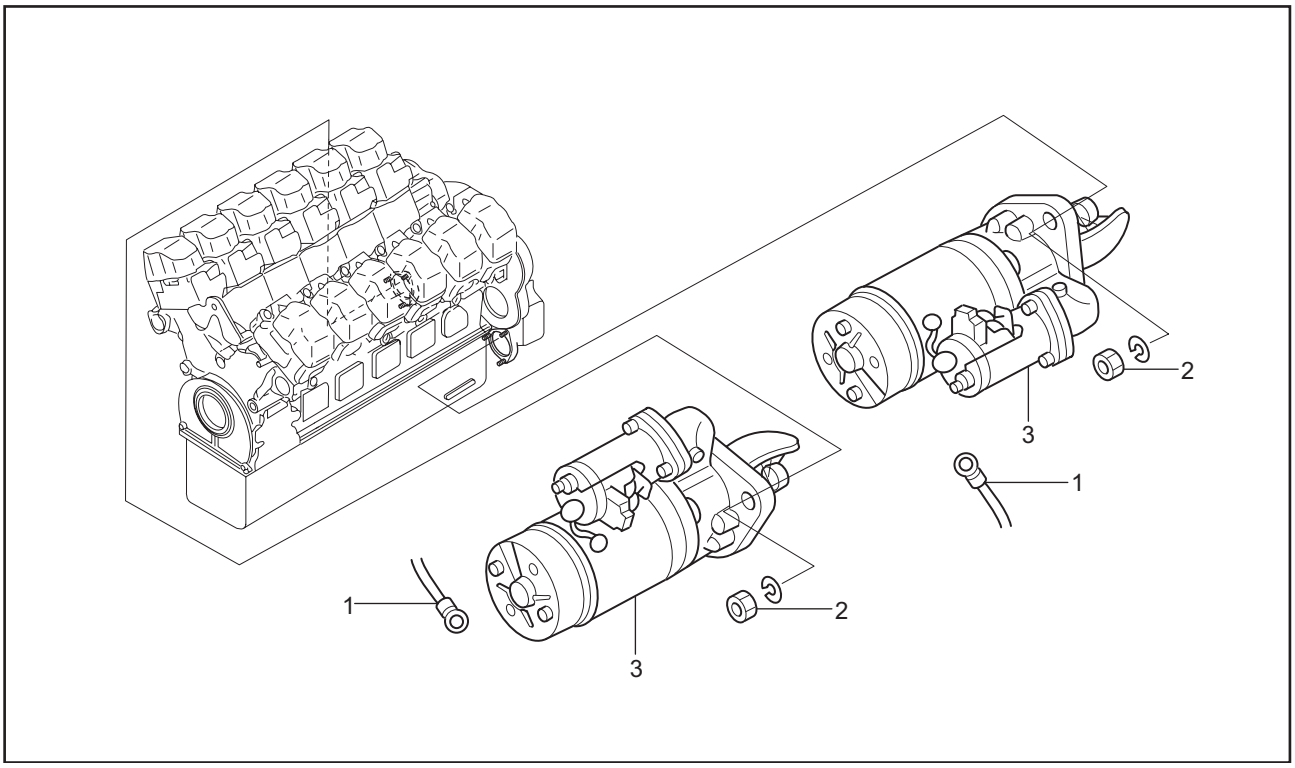
1. Removing electrical system

1.1 Removing starter



Removing starter

Removing sequence

1 Harness
2 Mounting nut
3 Starter (weight: approx. 19 kg [42 lb])

1.2 Inspection before removal of alternator

1.2.1 Inspecting alternator operation

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

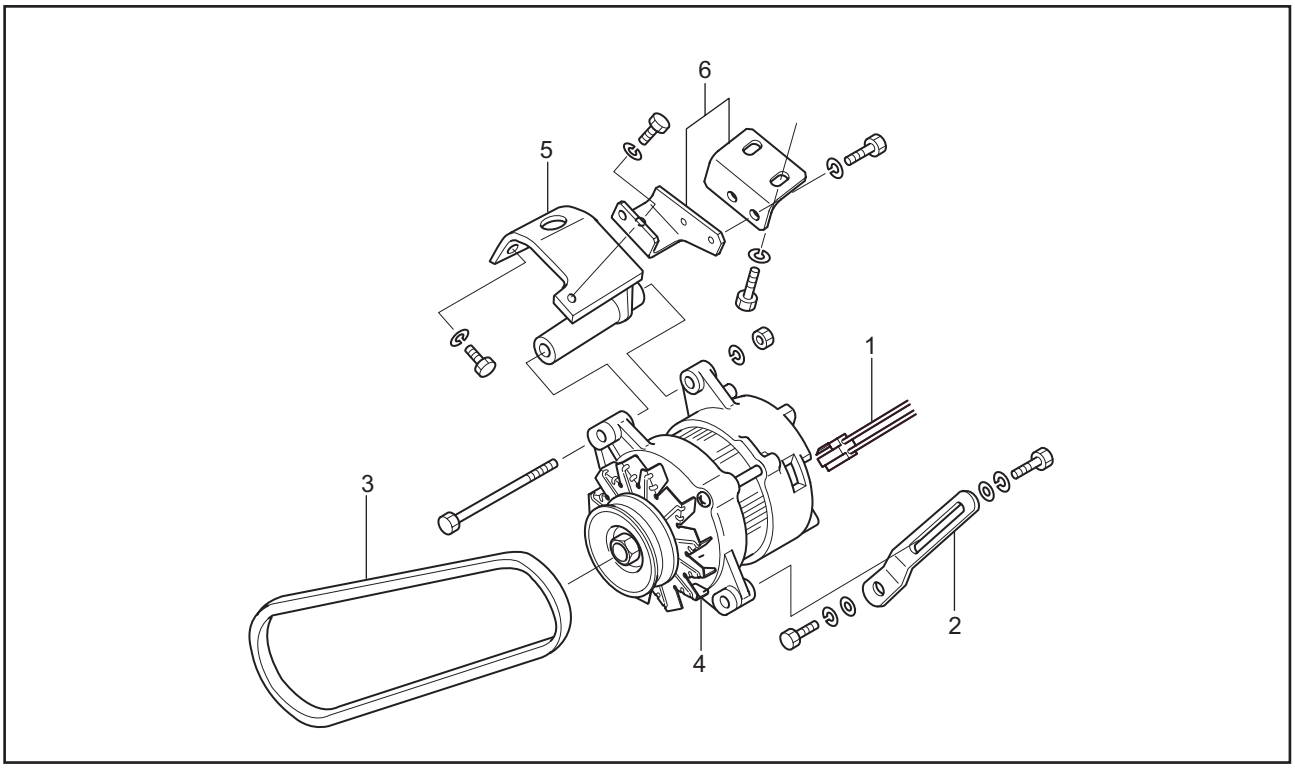
Overcharge	Adjusted value of voltage regulator is high.
	Faulty battery.
Over discharge	Low adjusted value of voltage relay.
	Faulty alternator output.
	Electric power consumption is extremely high.
	Special load is used.
	Faulty wiring.

1.2.2 Handling precaution

Improper handling could cause damage or failure to the alternator.

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

1.3 Removing alternator



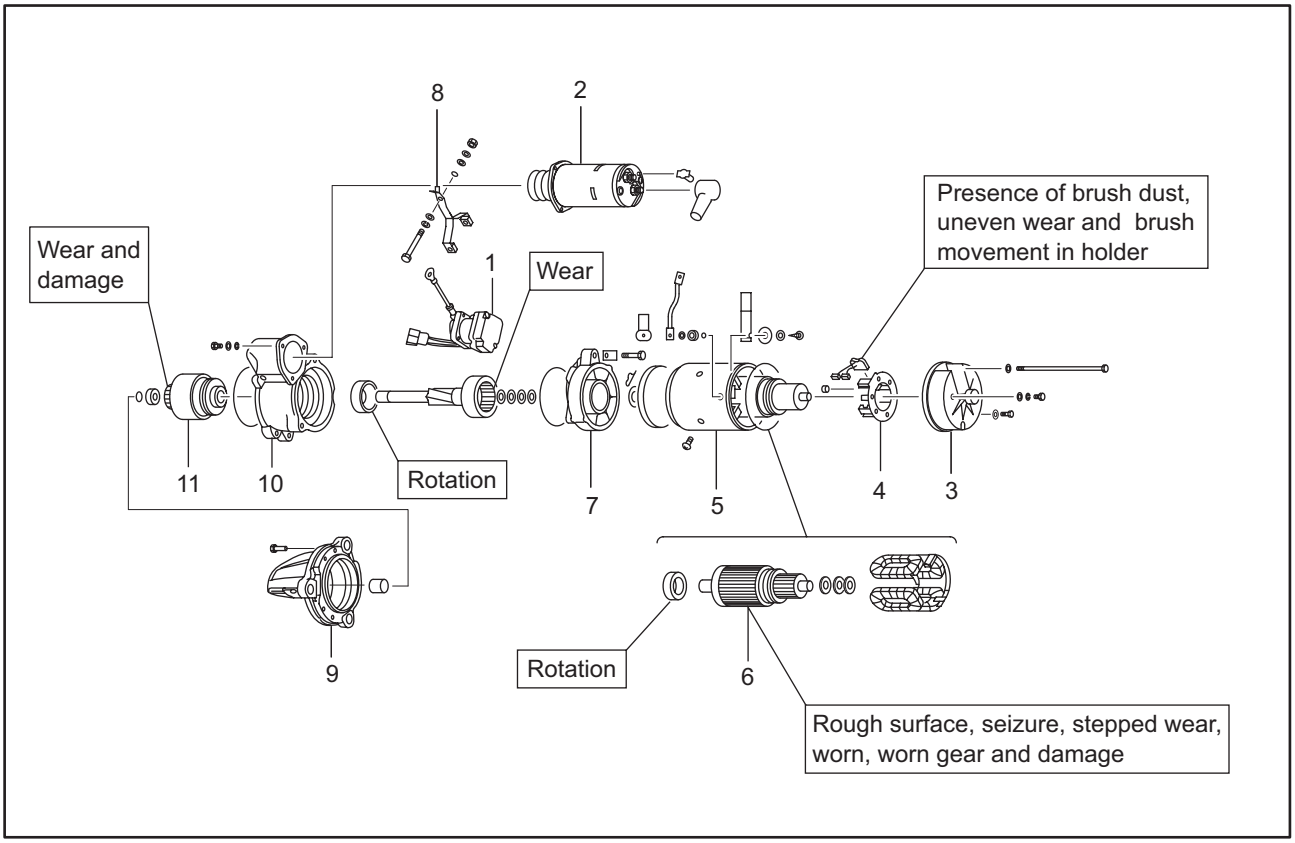
Removing alternator

Removing sequence

1 Harness
2 Adjusting plate
3 Alternator for belt
4 Alternator
5 Alternator bracket
6 Alternator stay

2. Disassembling, inspecting and reassembling electrical system

2.1 Disassembling and inspecting starter



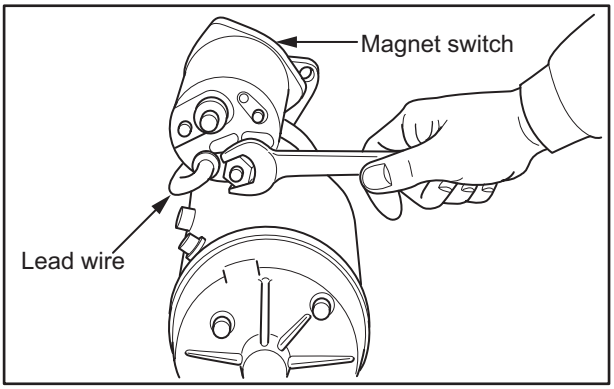
Disassembling and inspecting starter

Disassembling sequence

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

2.1.1 Removing magnetic switch

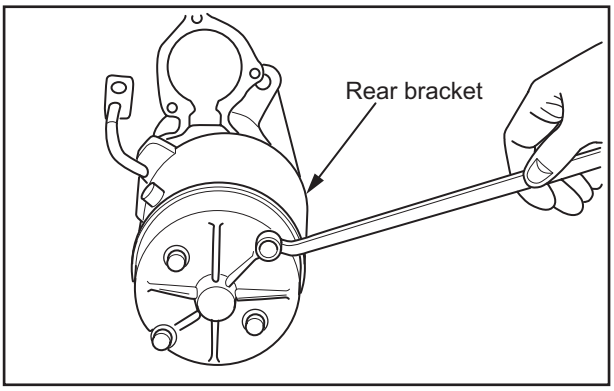
Disconnect the safety switch and lead wire, and remove the magnetic switch.



Removing magnetic switch

2.1.2 Removing rear bracket

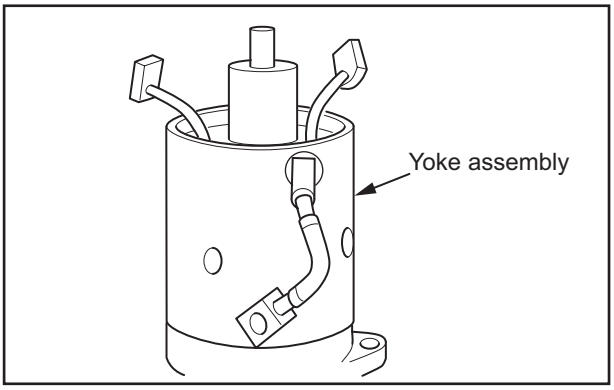
Remove the through bolts and screws of the brush holder, and then remove the rear bracket.



Removing rear bracket

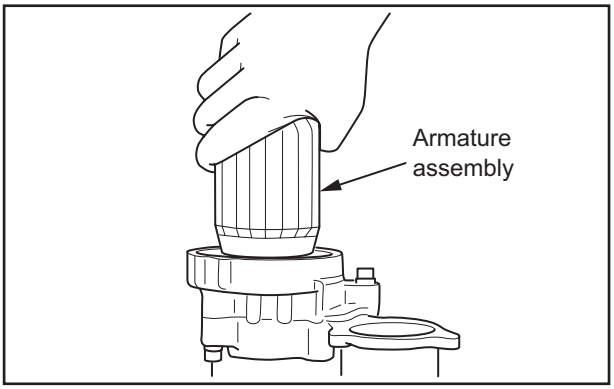
2.1.3 Removing armature and yoke assembly

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



Removing yoke assembly

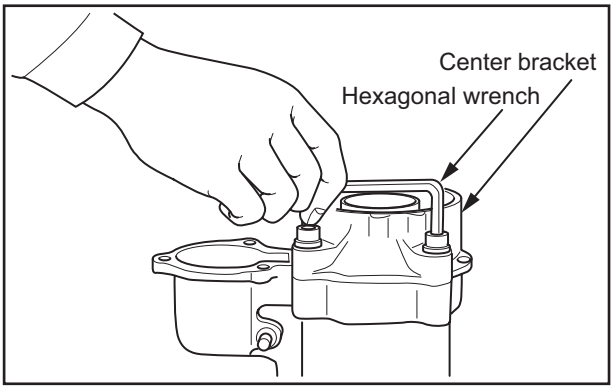
(2) Pull out the armature assembly.



Removing armature assembly

2.1.4 Removing center bracket

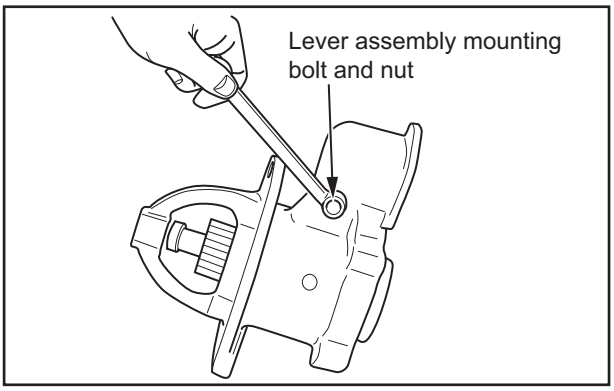
Remove the center bracket using a hexagonal wrench.



Removing center bracket

2.1.5 Removing pinion set

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

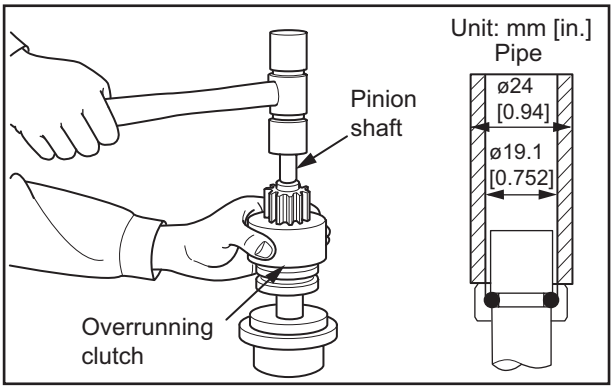


Removing lever assembly

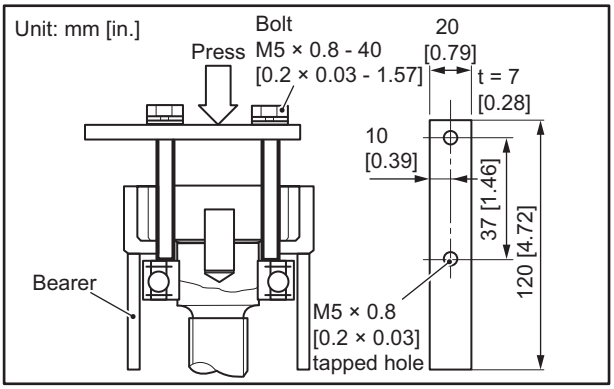
(2) Using a jig, remove the pinion stopper, then remove the overrunning clutch from the pinion shaft.

Item		Nominal	Standard	Remarks
Pinion shaft	Rear shaft outside diameter	ø 30 mm [1.18 in.]	30.002 to 30.011mm [1.1812 to 1.1820 in.]	Replace pinion shaft.
	Front shaft outside diameter	ø 19 mm [0.75 in.]	18.900 to 18.940 mm [0.7441 to 0.7457 in.]	Replace pinion shaft.

Note: To remove the shaft bearing for replacement, use a bearing puller as shown in the drawing.



Removing overrunning clutch

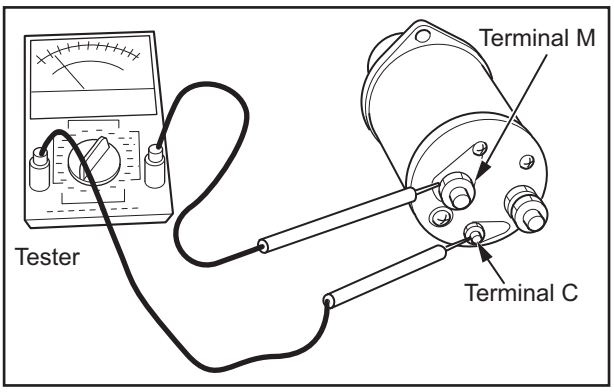


Pinion shaft bearing puller

2.2 Inspecting and repairing starter

2.2.1 Inspecting continuity of magnetic switch (between M terminal and C terminal)

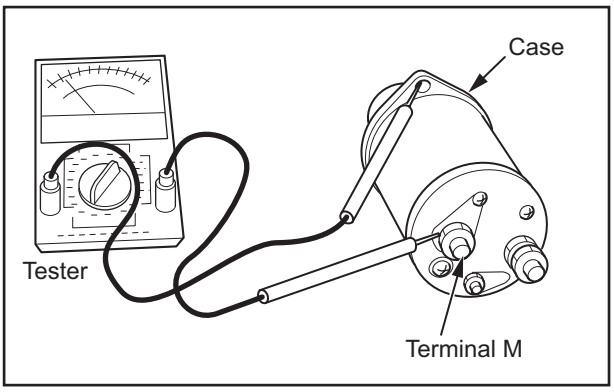
Check that there is continuity between M terminal and C terminal. If no continuity is observed, replace the magnetic switch with a new one.



Inspecting continuity of magnetic switch (between M terminal and C terminal)

2.2.2 Inspecting continuity of magnetic switch (between M terminal and case)

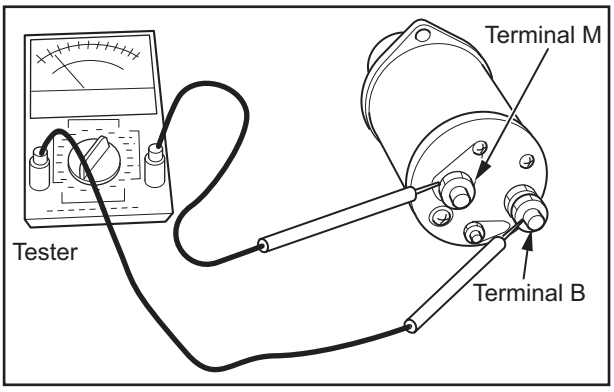
Check that there is continuity between M terminal and case. If no continuity is observed, replace the magnetic switch with a new one.



Inspecting continuity of magnetic switch (between M terminal and case)

2.2.3 Inspecting insulation of magnetic switch (between M terminal and B terminal)

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

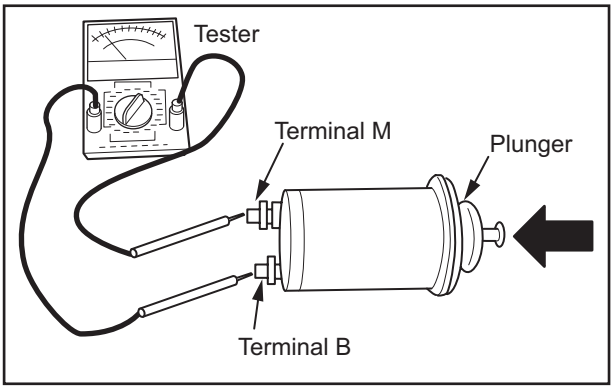


Inspecting insulation of magnetic switch (between M terminaland B terminal)

2.2.4 Inspecting continuity of magnetic switch (between M terminal and B terminal)

(1) Press the plunger until the contact point touches.

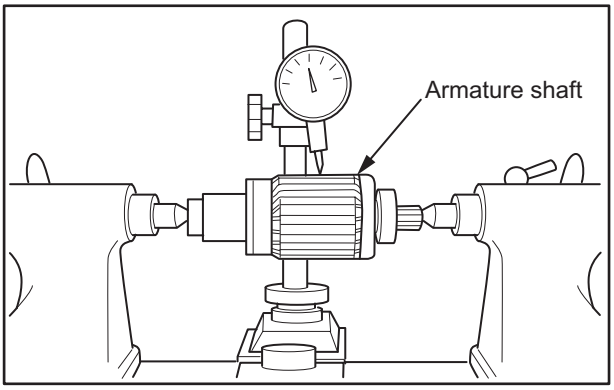
(2) Check that there is continuity between M terminal and B terminal. If no continuity is observed, replace the magnetic switch with a new one.



Inspecting continuity of magnetic switch (between M terminal and B terminal)

2.2.5 Measuring armature shaft runout

Using a dial gauge, measure the shaft runout. If the runout exceeds the standard, repair or replace the armature.



Measuring armature shaft runout

2.2.6 Measuring armature shaft bearing fitting face

Measure the diameter of armature shaft at bearing fitting face. If the measured value exceeds the standard value, replace the armature shaft with a new one.

Item	Standard
Armature shaft runout	0.05 mm [0.0020 in.] or less

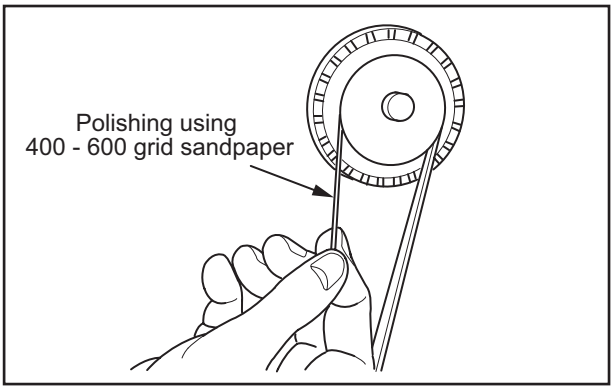
Item		Nominal	Standard
Armature	Front side shaft outside diameter	ø 20mm [0.79 in.]	20.002 to 20.011 mm [0.7875 to 0.7878 in.]
	Rear side shaft outside diameter	ø 14 mm [0.55 in.]	13.941 to 13.968 mm [0.5489 to 0.5499 in.]

2.2.7 Measuring commutator radial runout

(1) Inspect the commutator surface. If the surface is rough, polish it using a 400 to 600 grit sandpaper.

(2) Measure the commutator radial runout with a dial gauge. If the measured value exceeds the limit, replace the armature with a new one.

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



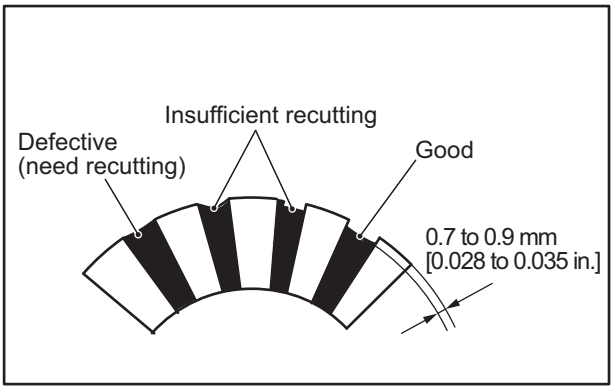
Polishing commutator surface

2.2.8 Measuring undercut depth

Measure the depth of undercutting between the commutator segments.

If the measured value is less than the limit, repair or replace with a new part.

Item	Standard	Limit
Undercutting depth	0.7 to 0.9 mm [0.028 to 0.035 in.]	0.2 mm [0.008 in.]



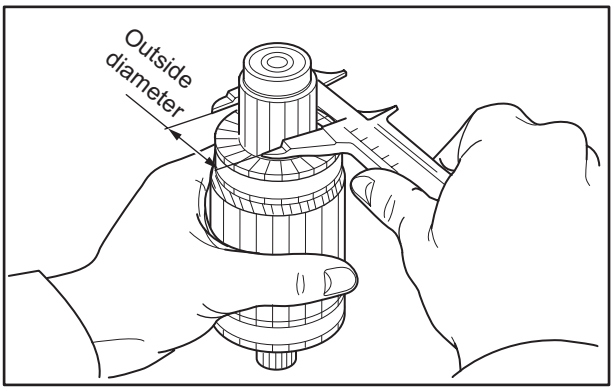
Measuring commutator mica depth

2.2.9 Measuring commutator outside diameter

Measure the commutator outside diameter.

If the measured value is less than the limit, replace the armature with a new one.

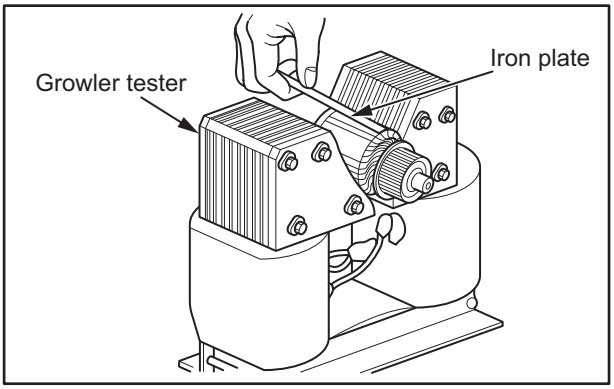
Item	Nominal	Limit
Commutator outside diameter	ø 43 mm [1.69 in.]	ø 42 mm [1.65 in.]



Measuring commutator outside diameter

2.2.10 Inspecting armature coil

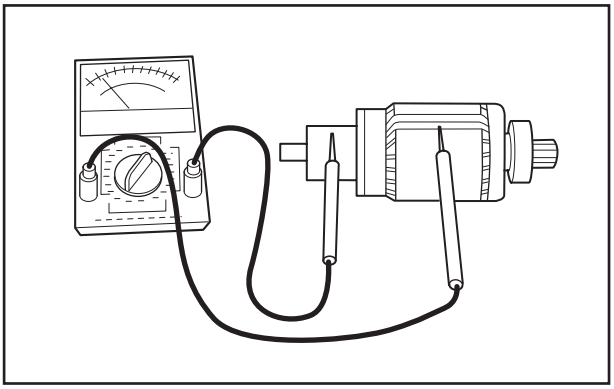
(1) Inspect the armature coil using a growler.
Hold a piece of iron plate against the armature core. If the iron plate vibrates, replace the armature with a new one.



Inspecting armature coil for short circuit

(2) Check that there is no continuity between the commutator and the shaft (core).
If any continuity is observed, replace the armature with a new one.

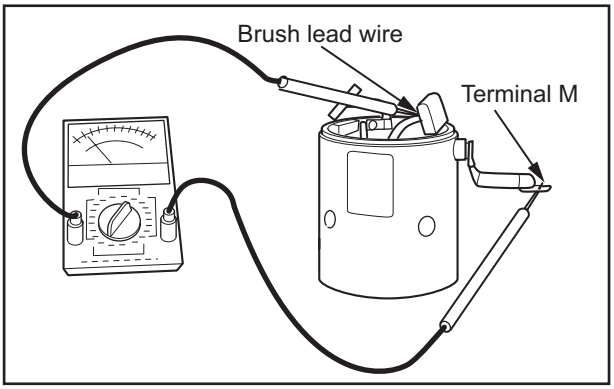
(3) Check that there is continuity between segments in various combinations.
If poor or no continuity is observed, replace the armature with a new one.



Inspecting insulation between commutator and shaft (core)

2.2.11 Inspecting continuity of yoke assembly

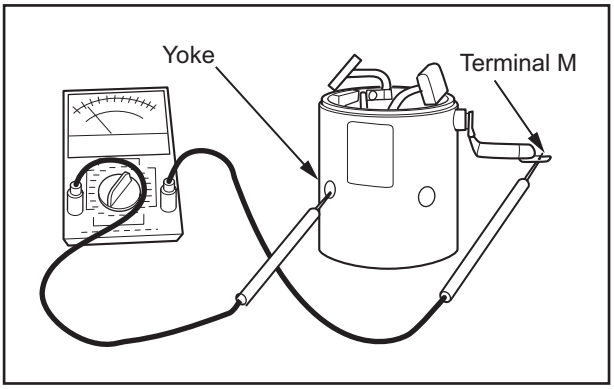
Check that there is continuity between M terminal of field coil and the lead wire for the brush. If no continuity is observed, replace the yoke assembly with a new one.



Inspecting continuity between terminal M and brush side lead

2.2.12 Inspecting insulation between field coil and yoke

Check that there is no continuity between field coil and yoke. If continuity is observed, replace the yoke assembly with a new one.



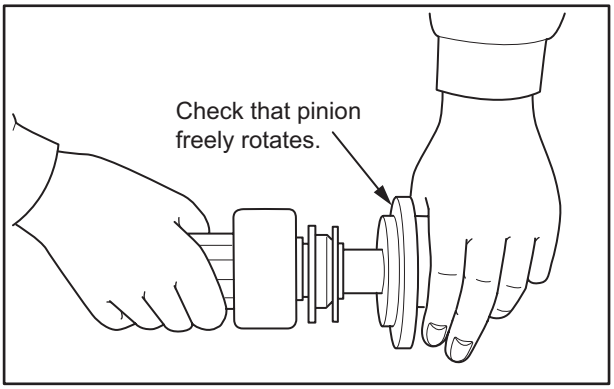
Inspecting insulation between terminal M and yoke

2.2.13 Inspecting overrunning clutch

CAUTION

Do not clean the overrunning clutch in wash oil.

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

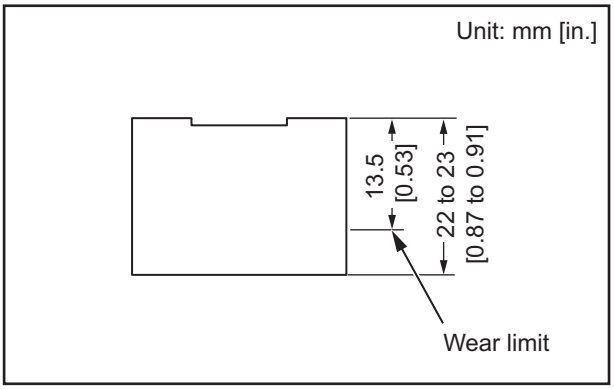


Inspecting overrunning clutch operation

2.2.14 Inspecting brushes for wear

Measure the length of the brushes. If the measured value is less than the limit, replace both the brush holder assembly and the brush assembly with new ones.

Item	Standard	Limit
Brush height	22 to 23 mm [0.87 to 0.91 in.]	13.5 mm [0.53 in.]



Inspecting brushes for wear

2.2.15 Measuring brush spring load

Using a new brush, measure the spring load at which the spring lifts from the brush. If the measured value is less than the limit, replace the spring with a new one.

Item	Standard	Limit
Spring load (when brush is installed)	39.23 to 49.03 N {4.0 to 5.0 kgf} [8.8 to 11.0 lbf]	Less than 39.23 N {4.0 kgf} [8.8 lbf]

2.3 Inspecting safety switch

CAUTION

When connecting the battery, be sure to connect the battery in correct polarity.

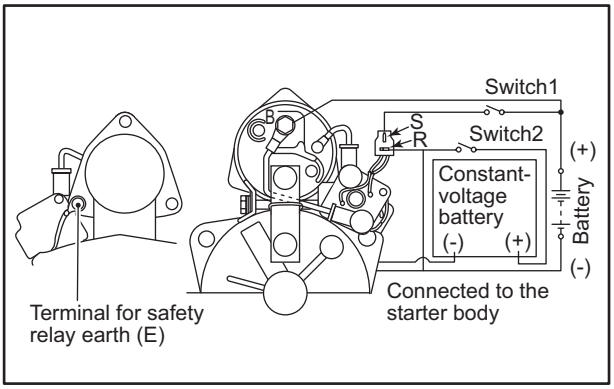
Connect the components as shown and check the operation of starter and safety switch.

(1) Connect the terminal R to the battery negative terminal.

(2) Turn on the switch and check if the starter operates (rotates).

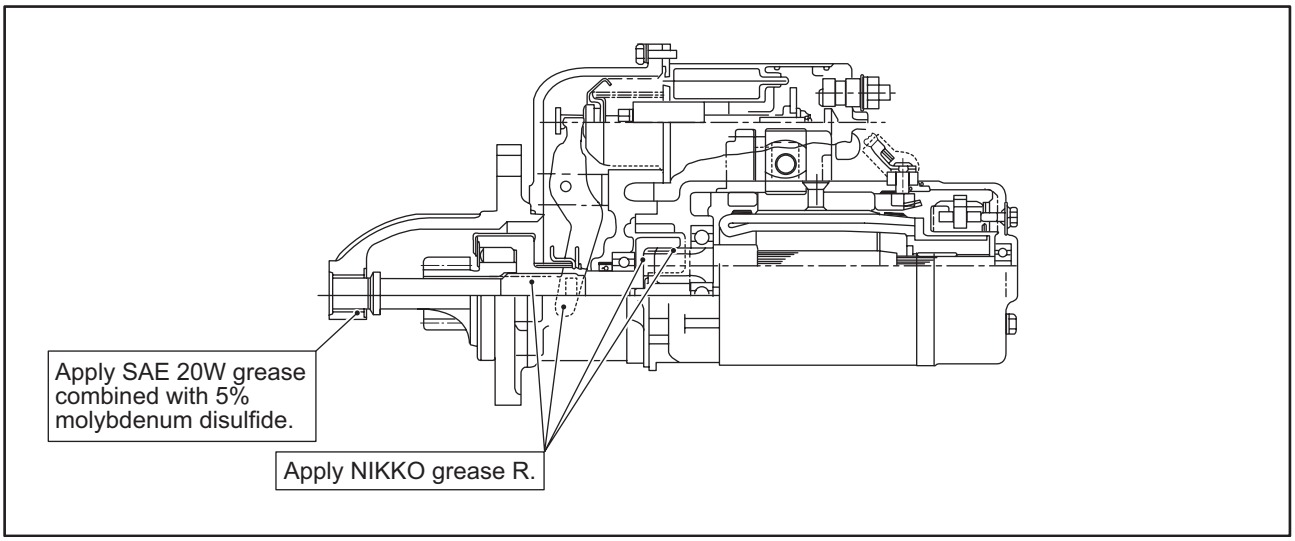
(3) While operating the starter, disconnect the terminal R from the battery negative terminal and connect the terminal R to the battery positive terminal. Check if the starter stops.

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



Inspecting safety switch

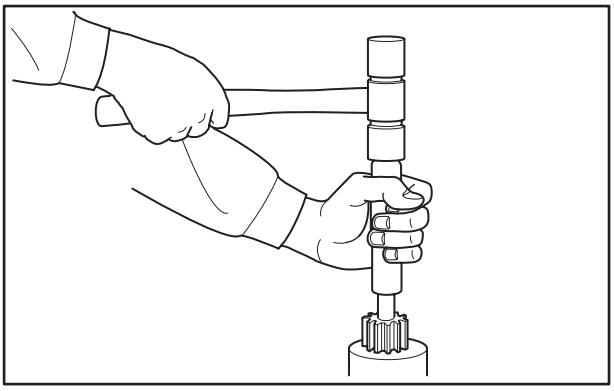
2.4 Installing starter



Installing starter

2.4.1 Installing pinion shaft

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

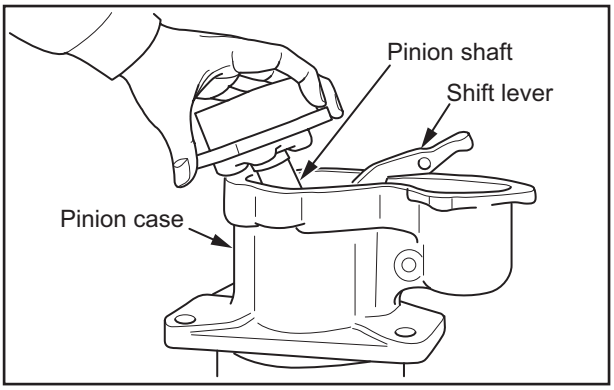


Installing pinion shaft

2.4.2 Installing lever and pinion shaft

(1) Install the shift lever and pinion shaft to the front bracket while aligning the mark on the shift lever with the mark on the bracket.

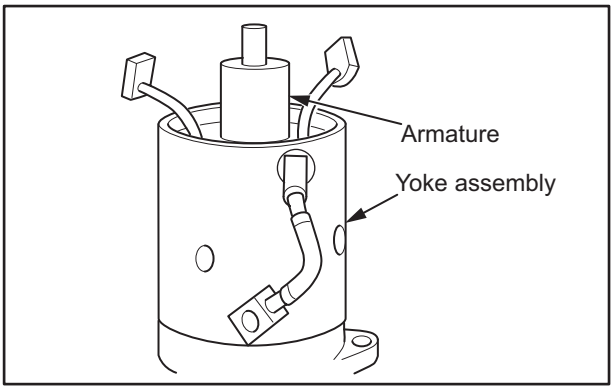
(2) Coat the internal gear of the pinion shaft with a liberal amount of Nikko Grease R.



Reassembling lever and pinion shaft

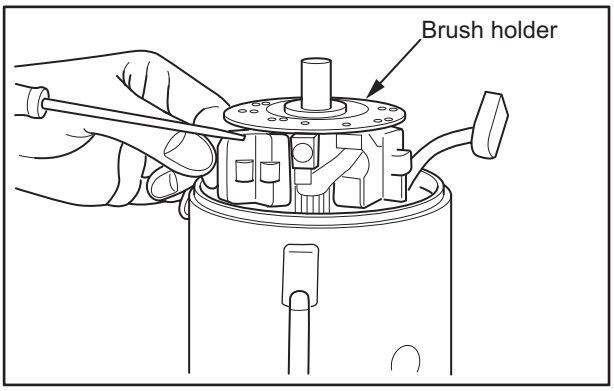
2.4.3 Installing armature, yoke, brush and brush holder

(1) Align the knock pin with the center bracket and reassemble the armature to the yoke.



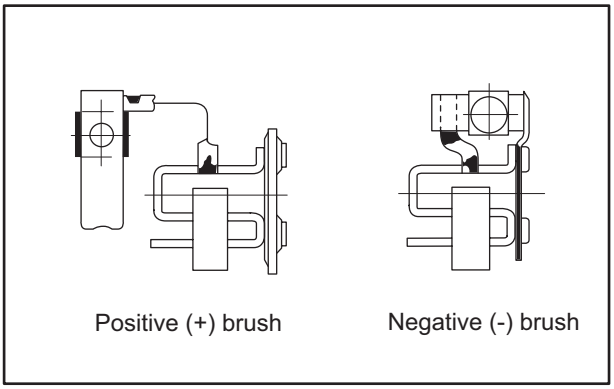
Reassembling armature and yoke

(2) Reassemble the brush holder and brushes.



Reassembling brush holder and brushes

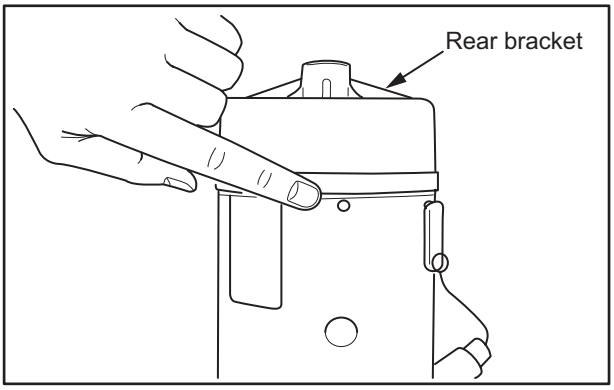
Note: Install the positive (+) and negative (-) brushes as shown in the illustration on the right.



Reassembling positive (+) and negative (-) brushes

2.4.4 Installing rear bracket

Reassemble the rear bracket to the yoke with the alignment marks in alignment. Secure the brush holder with screws and then tighten the through bolts.

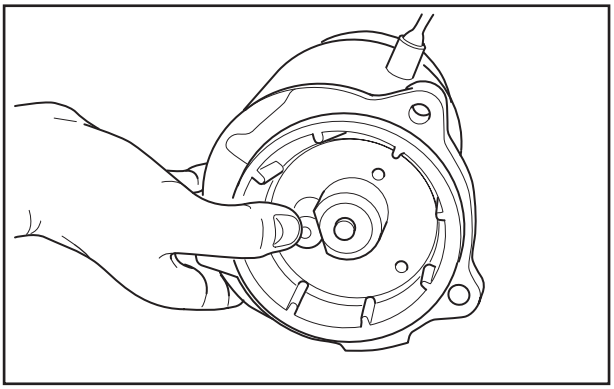


Installing rear bracket

2.4.5 Measuring armature end play

Measure the armature end play. If the measured value is out of tolerance, adjust the end play at the rear.

Item	Standard
Armature end play	0.2 to 0.6 mm [0.008 to 0.024 in.]

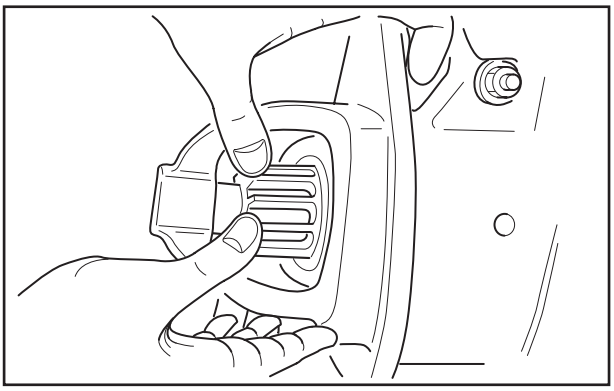


Measuring armature end play

2.4.6 Measuring pinion shaft end play

Measure the pinion shaft end play. If the measurement is out of tolerance, adjust the end play at the internal gear side.

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



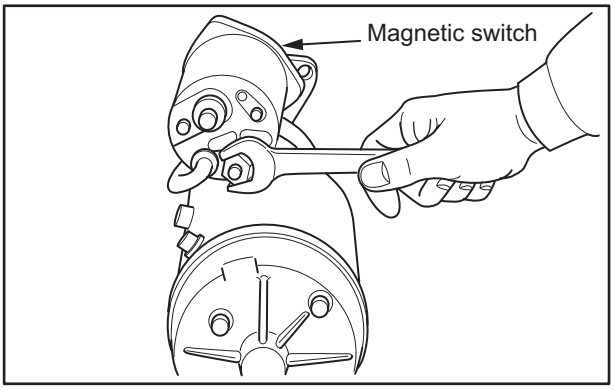
Measuring pinion shaft end play

2.4.7 Installing magnetic switch

(1) Install the magnetic switch and tighten the screws.
(2) Connect the lead to the terminal M and secure it with the fixing nut.

2.4.8 Installing safety switch

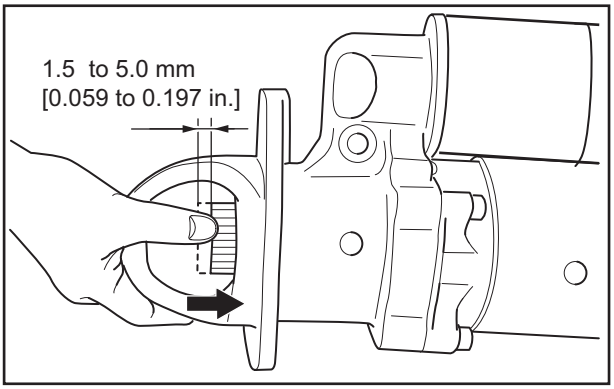
(1) Tighten the lead wire.
(2) Install the safety switch.



Installing magnetic switch

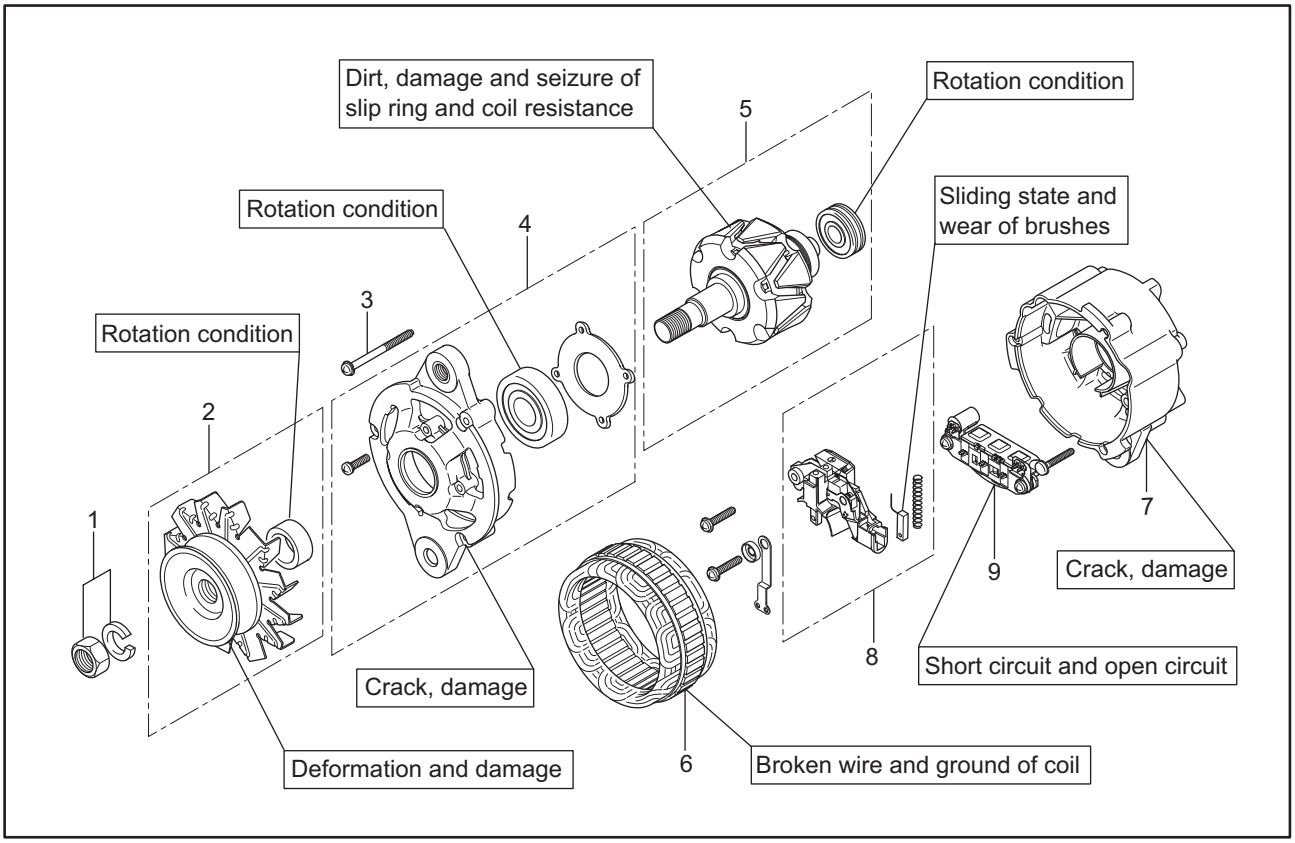
2.4.9 Measuring pinion gear retraction length

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



Measuring pinion gear retraction

2.5 Disassembling and inspecting alternator



Disassembling and inspecting alternator

Disassembling sequence

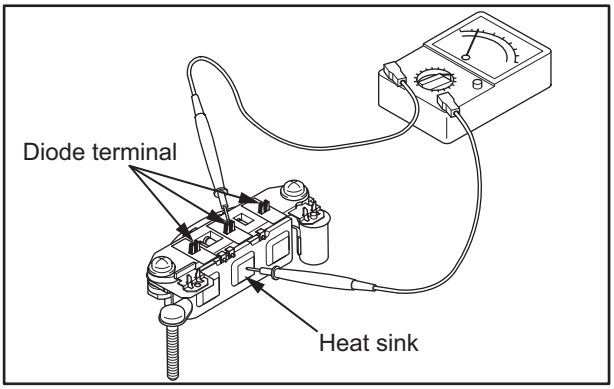
1 Nut, spring washer
2 Pulley assembly
3 Set screw
4 Front bracket assembly
5 Rotor assembly
6 Stator
7 Rear bracket
8 Regulator assembly
9 Rectifier assembly

2.6 Inspecting and repairing alternator

2.6.1 Inspecting rectifier

Check that diodes in a rectifier function properly. To check, measure both negative (-) and positive (+) resistance alternately twice. If both infinite negative and infinite positive resistances are observed, the diode is open-circuited. If measured value is close to 0 Ω, the diode is short-circuited. In either case, replace the rectifier with a new one.

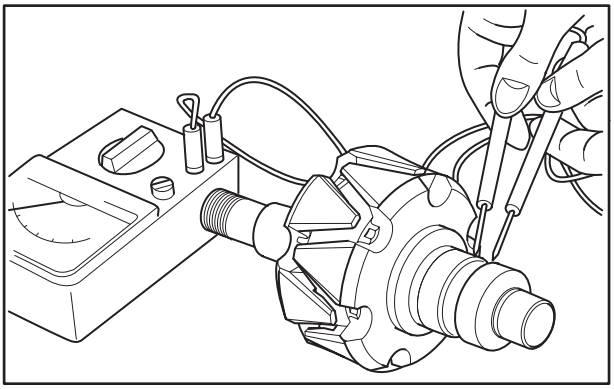
Note: Use a wide measuring range as much as possible. The current flow during test is significantly lower than the current that normally flows in the rectifier, by which the accurate resistance may not be measured using a tester, and this tendency is noticeable if the measuring range is small.



Inspecting rectifier

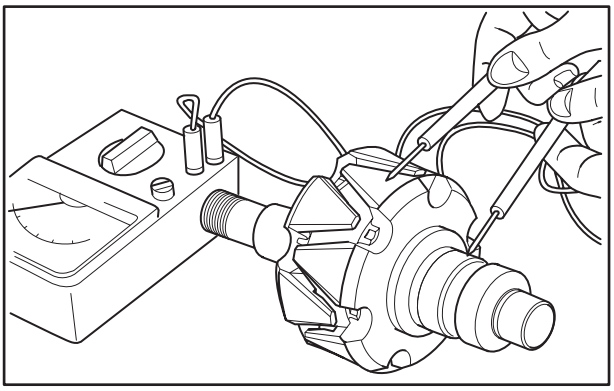
2.6.2 Inspecting rotor

(1) Check that there is continuity between slip rings. If no continuity is observed, replace the rotor with a new one.



Inspecting field coils for continuity

(2) Check that there is no continuity between the slip ring and the shaft (or the core). If continuity is observed, replace the rotor with a new one.



Inspecting field coils for frounding

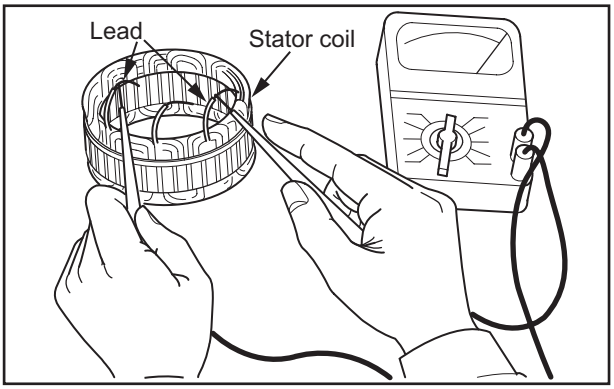
2.6.3 Inspecting stator

(1) Checking continuity between lead wires

Check that there is continuity between a pair of lead wires.

Also check that there is no continuity between a pair of lead wires and other pair of lead wires.

If defective, replace the stator.

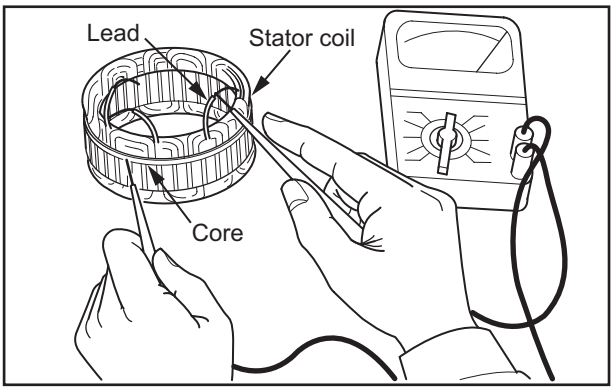


Inspecting continuity between lead wires

(2) Checking insulation between lead wire and core

Check that there is no continuity between each lead wire and the stator core. If continuity is observed, replace the stator.

Note: The core cannot be replaced as a single item.

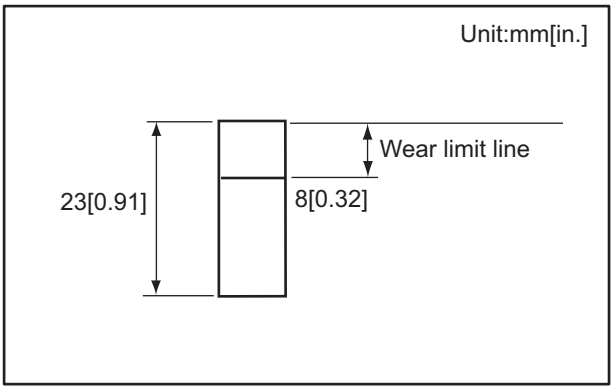


Inspecting for grounding between lead wires and core

2.6.4 Inspecting brushes for wear

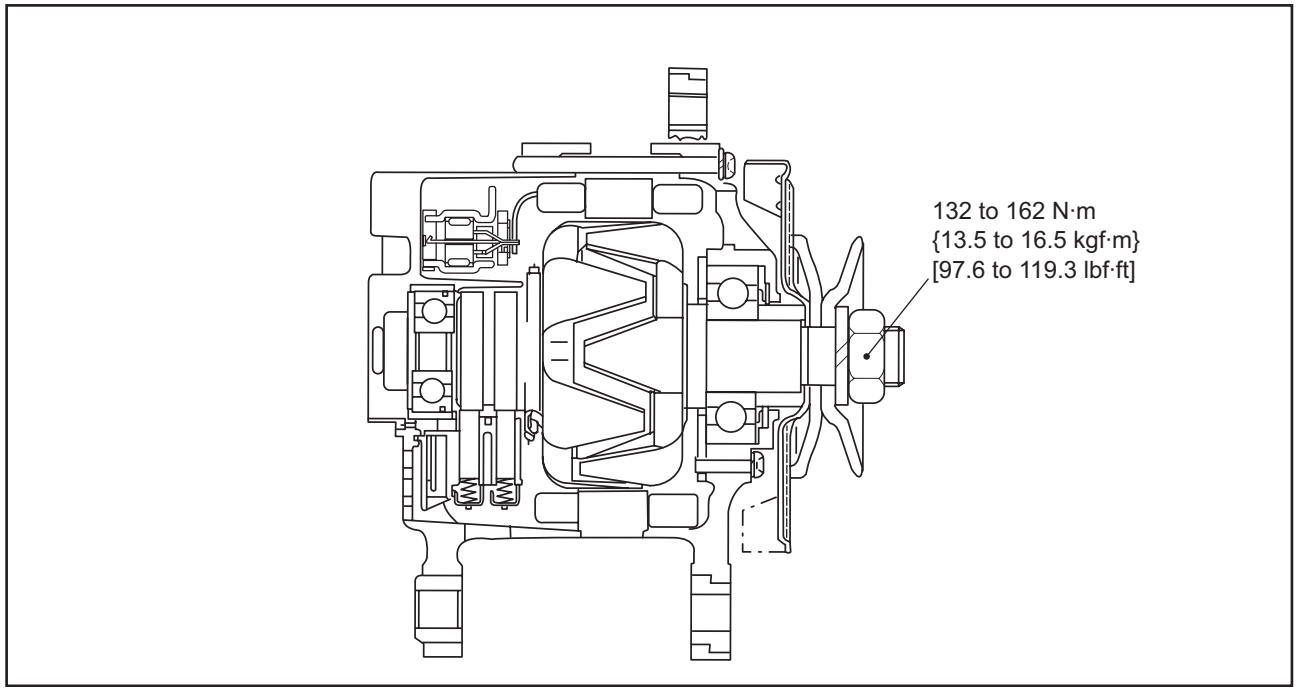
Measure the length of the brushes. If the measured value is less than the limit, replace both the brush holder assembly and the brush assembly with new ones.

Item	Standard	Limit
Brush length	23 mm [0.91 in.]	8 mm [0.32 in.]



Inspecting brushes

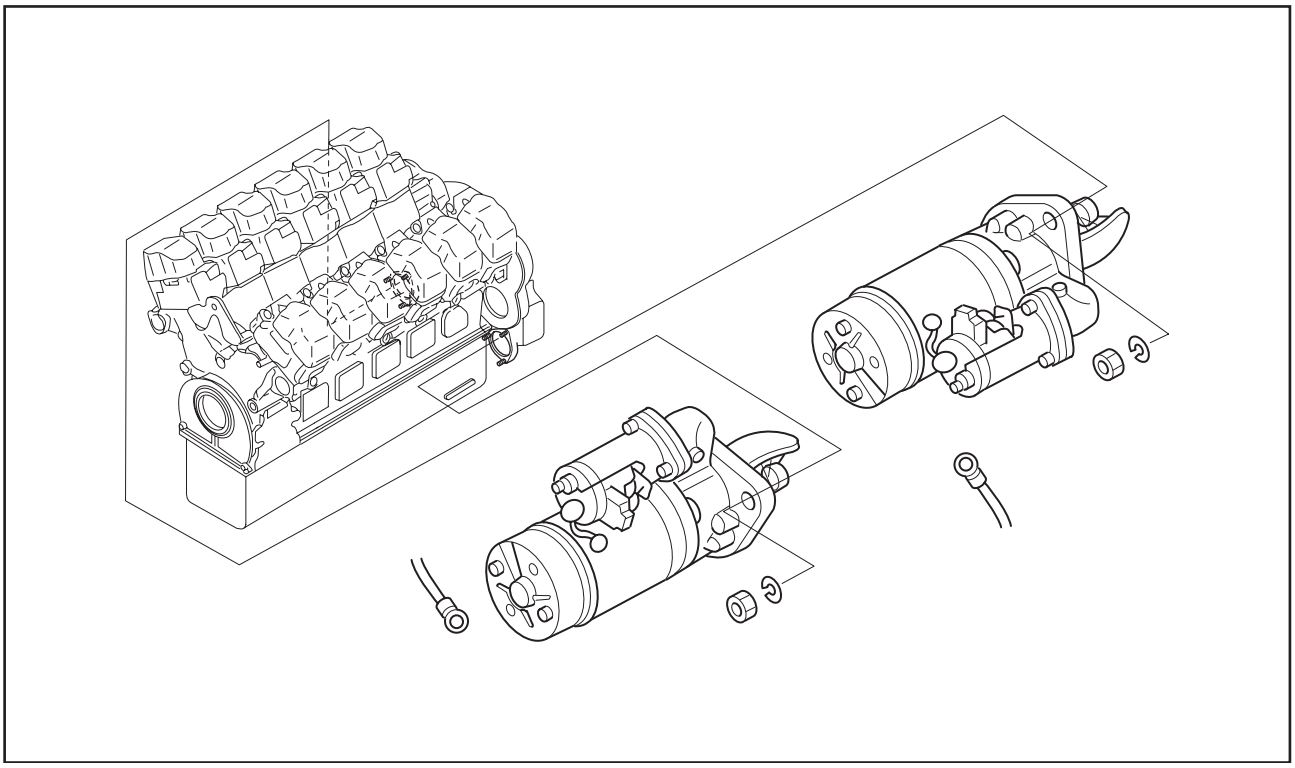
2.7 Reassembling alternator



Reassembling alternator

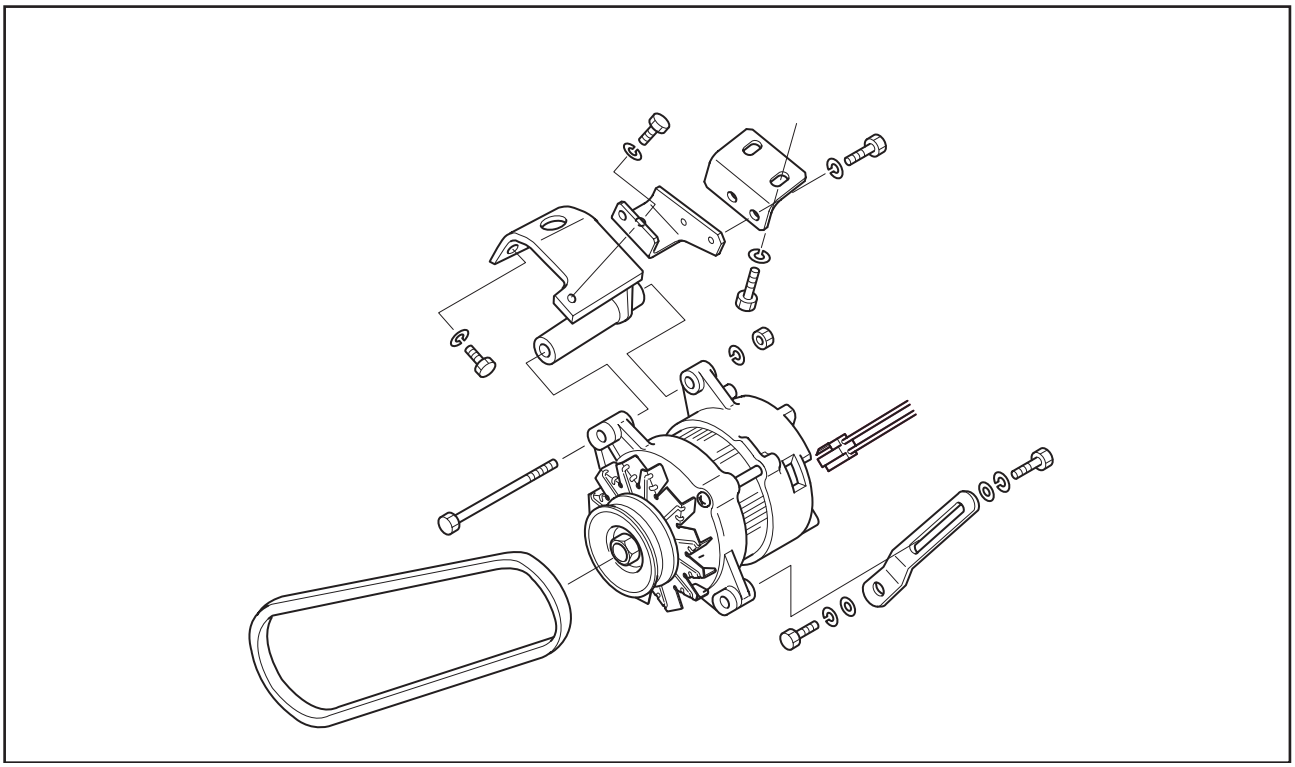
3. Installing electrical system

3.1 Installing starter



Installing starter

3.2 Installing alternator



Installing alternator

ADJUSTMENT AND OPERATION

1. Adjusting engine.....13-2
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1. Adjusting engine

1.1 Inspecting and adjusting valve clearance

Inspect and adjust the valve clearance.

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

Note: (a) The inlet values are on the left side and the exhaust values are on the right side when the cylinder head is viewed from the camshaft gear side.

(b) The valve clearance standard values are indicated on the caution plate on the No.1 cylinder rocker cover.

Item		Standard
Valve clearance	Inlet	0.4 mm [0.016 in.]
	Exhaust	0.5 mm [0.020 in.]
Clearance between bridge and valve rotator	(A)	1.5 mm [0.059 in.]
	(B)	2.5 mm [0.098 in.]

1.1.1 Inspecting clearance between bridge and valve rotator

The clearance between the bridge and the valve rotator should meet to the standard after attaining the standard height of both valves using the valve bridge.

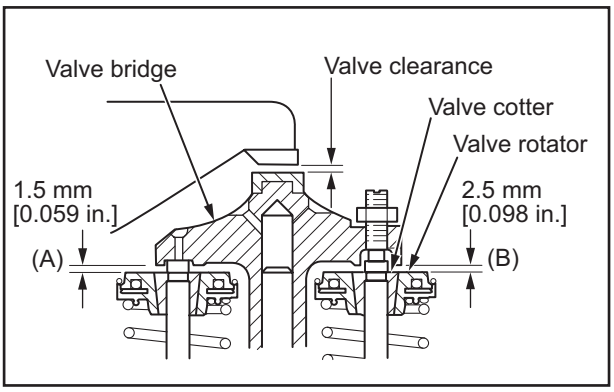
If the clearance is not within the standard, attain the standard value by grinding the bridge bottom on the screw side.

1.1.2 Inspecting valve clearance

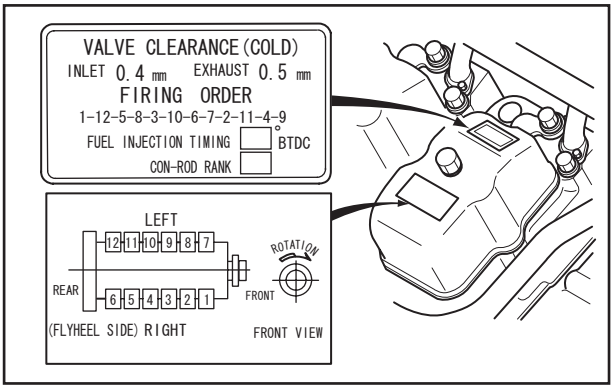
(1) Inspect the valve clearance in the firing order by turning the crankshaft in the normal direction to bring each piston to the top dead center on compression stroke.

(2) A piston is at the top dead center on compression stroke when its number that stamped on the vibration damper aligns with the pointer, and the pushrods are not pushing the inlet or exhaust valves off their seats.

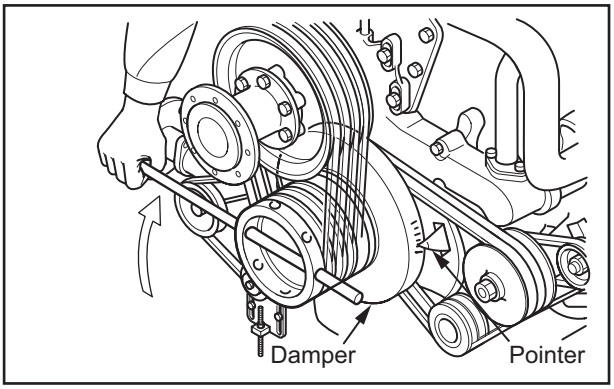
(3) Using feeler gauges, measure the clearance between each rocker arm and bridge cap.



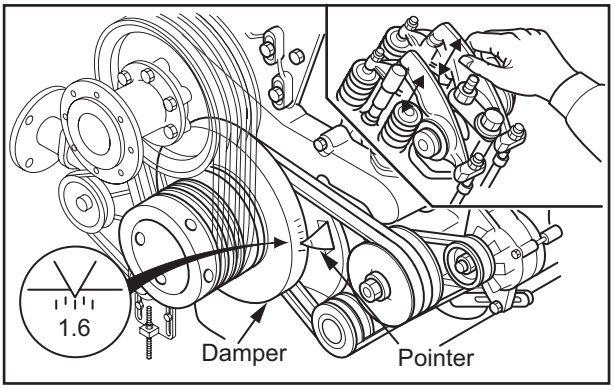
Inspecting valve clearance



Caution plate



Rotating crankshaft



Determining top dead center of No.1 cylinder compression stroke

1.1.3 Adjusting both inlet and both exhaust valve heights by valve bridge

CAUTION

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

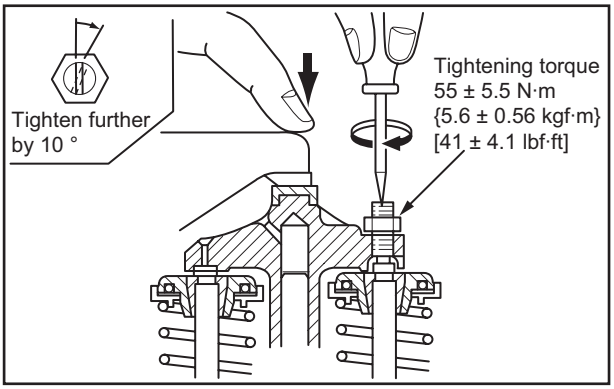
When adjusting the both inlet and both exhaust valve heights with the valve bridge, bring the piston at the top dead center on the compression stroke.

(1) Prior to the valve clearance adjustment, it is necessary to adjust the both inlet and both exhaust valve heights with the valve bridge (bringing the bridge into contact with the both inlet and both exhaust valves). If the both inlet and both exhaust valve heights are not the same, which can occur due to such conditions as valve seat wear, a clearance will be generated between the top of valve stem and the either side of bridge, resulting in the change of valve clearance.

Note: When adjusting both inlet and both exhaust valve heights using a valve bridge, be sure to bring each piston to the top dead center on the compression stroke.

(2) To adjust the valve height, loosen the rock nut and unscrew the adjusting screw.

(3) Hold the rocker arm with a finger, and slowly turn the adjusting screw until the screw contacts the top of valve stem. Then, turn the screw further, at angle of 10 degrees from the position, and tighten the rock nut.

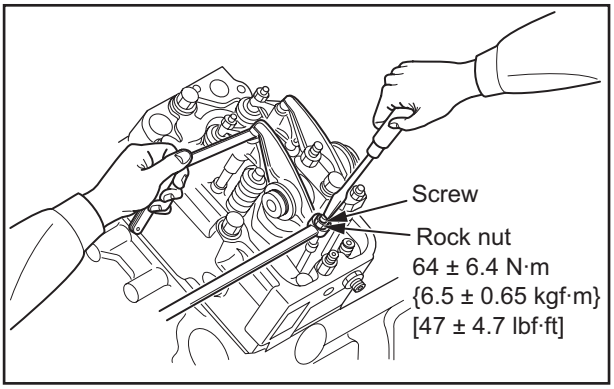


Adjusting valve height using valve bridge

1.1.4 Adjusting valve clearance

(1) Insert the feeler gauge of the specified thickness between the rocker arm and bridge cap, then adjust the clearance by turning the screw in either direction so that the gauge is gripped softly between the rocker arm and bridge cap.

(2) After adjusting the clearance, tighten the lock nut firmly, and inspect the clearance again.



Adjusting valve clearance

1.2 Bleeding air from fuel system

⚠ WARNING

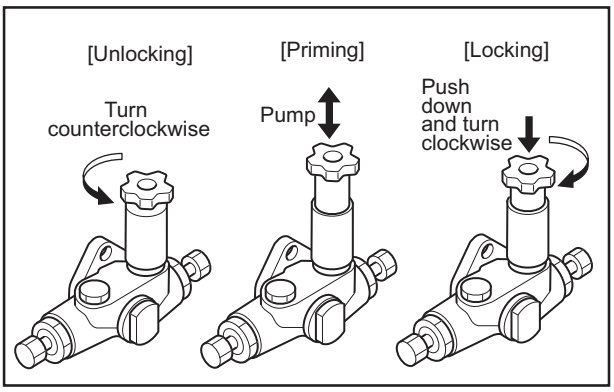
(a) Wipe off any fuel spilled from the air vent plug thoroughly with a cloth. Spilled fuel could cause fire.

(b) After bleeding air, be sure to lock priming pump cap. If the lock is not insufficient, it could cause damage to the pump and result in fire due fuel leaks. The priming pump cap must be locked in accordance with the procedure in the next page.

CAUTION

If all the air vent plugs are tightened before the priming pump cap is locked, fuel pressure acts on the priming pump, making it impossible to return the cap to the original position.

To bleed air from the fuel system, start at the place nearest to the fuel tank as follows: water separator → fuel filter → injection pump.



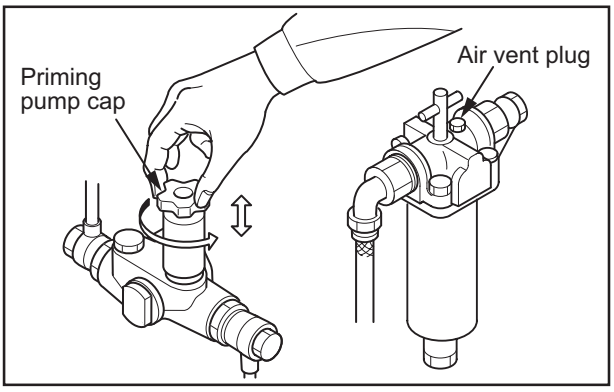
Priming pump

1.2.1 Bleeding air from fuel filter (wire-element type)

(1) Loosen air vent plug of the water separator (by rotating about 1.5 full turns).

(2) Turn priming pump cap counterclockwise to loosen, then move the priming pump cap up and down.

(3) When fuel flowing out of the air vent no longer contains air bubbles, close the air vent plug.



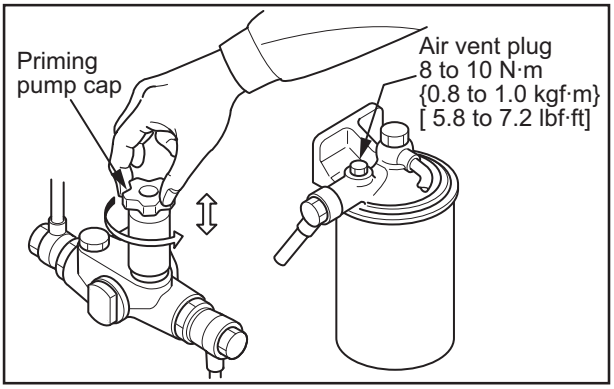
Bleeding air from fuel filter (wire-element type)

1.2.2 Bleeding air from fuel filter (paper-element type)

(1) Loosen the air vent plugs for the fuel filters. (approx. 1.5 turns)

(2) Unlock the priming pump cap by turning it counterclockwise, then move the cap up and down repeatedly.

(3) When fuel flowing from the vent holes no longer contains air bubbles, tighten the air vent plugs.

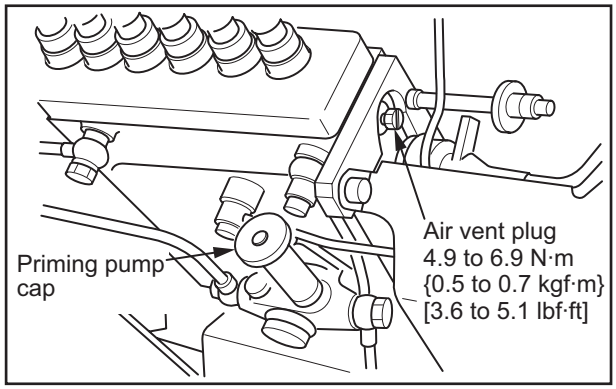


Bleeding air from fuel filter (paper-element type)

1.2.3 Bleeding air from fuel injection pump

(1) Loosen the air vent plugs for the injection pumps. (approx. 1.5 turns)
(2) Move the cap up and down repeatedly.
(3) When fuel flowing from the vent holes no longer contains air bubbles, tighten the air vent plugs. Before tightening the last air vent plug, lock the priming pump cap by turning it clockwise while pushing it down.
(4) Follow the same procedure for the fuel injection pumps on both right and left sides.

Note: (a) If all the vent plugs are tightened before the priming pump cap is locked, fuel pressure acts on the feed pump, making it impossible to return the cap to the original position.
(b) Wipe off fuel spilled from the vent holes thoroughly with a cloth.



Bleeding air from fuel injection pump

1.2.4 Clamping method of priming pump cap

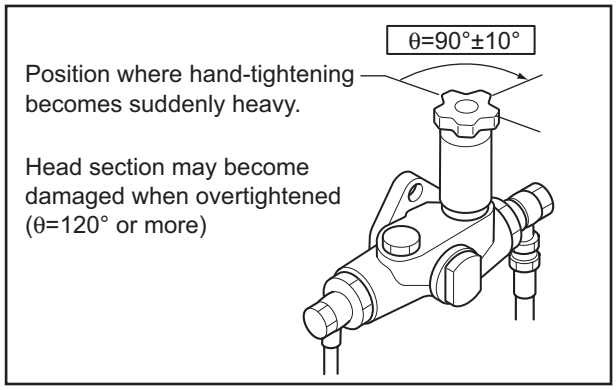
(1) Tighten the priming pump cap by hand until the tightening force suddenly increases.
(2) Mark the priming pump cap in this position to facilitate the subsequent procedure.
(3) After step (1), further turn the priming pump cap by 90 ± 10° by wrench.
(4) After tightening, make sure the priming pump head packing is not dislodged from the installation position.

Note: If the packing at the head is protruding, loosen the priming pump cap to verify there is no damage to the packing, and then tighten the cap again.
If the packing is damaged, the priming pump must be replaced. Contact your local Mitsubishi dealer.

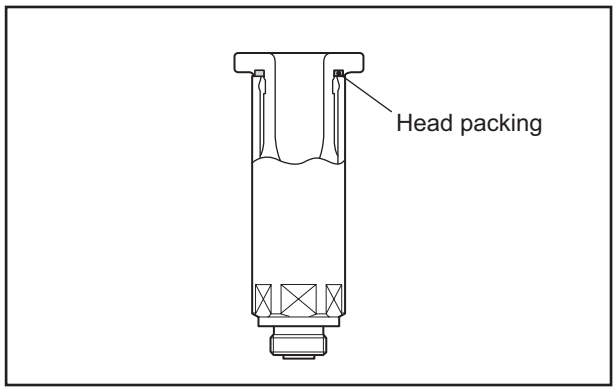
CAUTION

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

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



Clamping method of priming pump cap

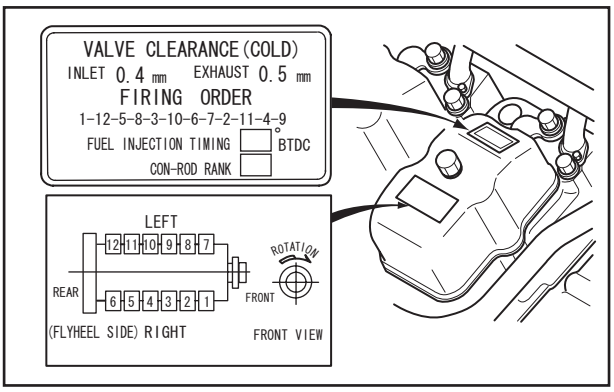


Cross section of priming pump

1.3 Inspecting and adjusting fuel injection timing (right side)

1.3.1 Injection timing and its indication location

Since the fuel injection timing varies depending on the engine output, engine speed and other specifications, be sure to check the caution plate on the No. 1 rocker cover.



Caution plate

1.3.2 Determining top dead center of No.1 cylinder compression stroke

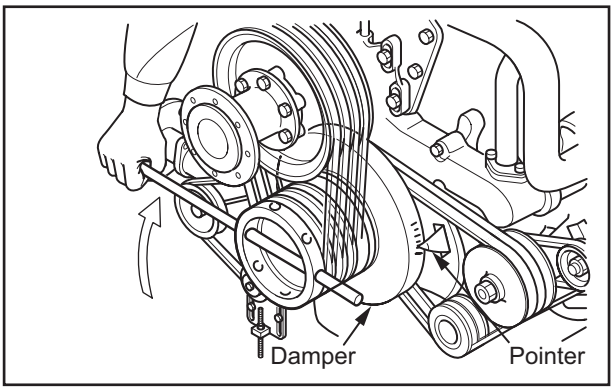
⚠ CAUTION

Be sure to check that #1 cylinder is on top dead center (TDC) of compression stroke, not on the TDC of the exhaust stroke.

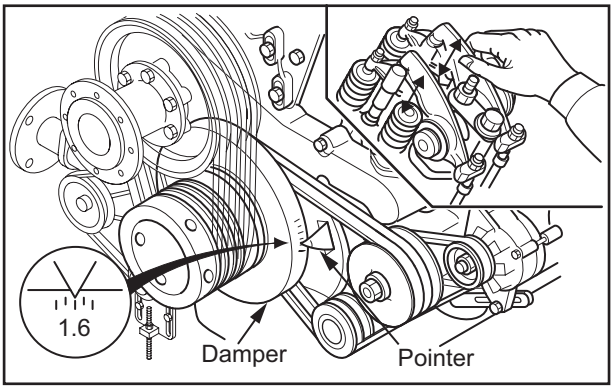
(1) Using a ratchet handle, rotate the turning gear in the normal direction (clockwise when viewed from the front of the engine).

(2) Stop turning when the cylinder number "1" stamped on the damper is aligned with the pointer.

(3) Move the rocker arms of the inlet and exhaust valves for the No. 1 cylinder up and down, and make sure that the pushrods are not pushing the inlet and exhaust valves off their seats.



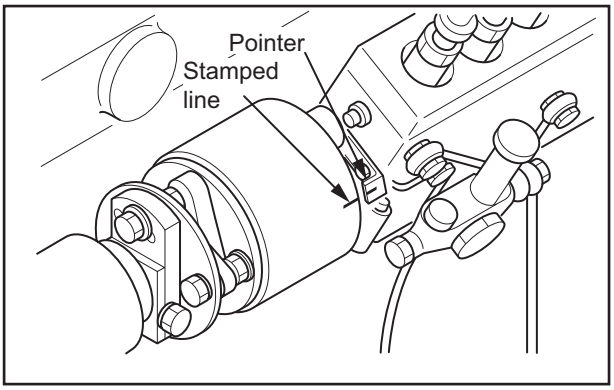
Rotating crankshaft



Determining top dead center of No.1 cylinder compression stroke

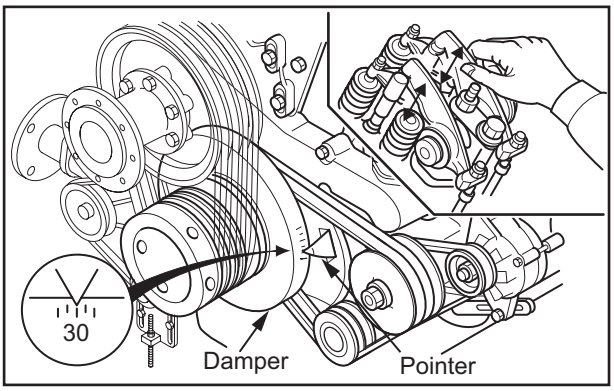
1.3.3 Inspecting fuel injection timing

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



Inspecting fuel injection timing

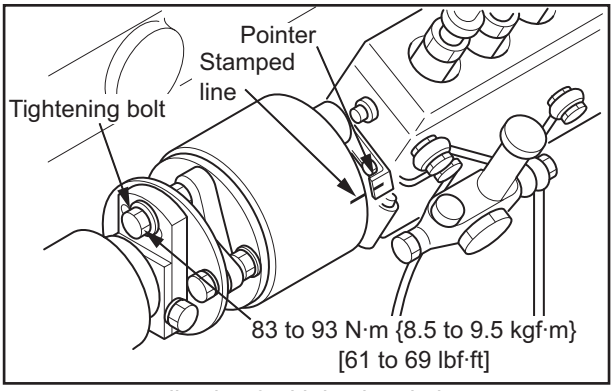
(2) Read the injection mark (degree) on the circumference of the damper indicated by the pointer on the engine. The indicated angle is the injection timing of the engine. The negative (-) mark on the angle scale and BTDC means “Before Top Dead Center.”



Inspecting angle of injection starting timing mark on damper circumference

1.3.4 Adjusting fuel injection timing

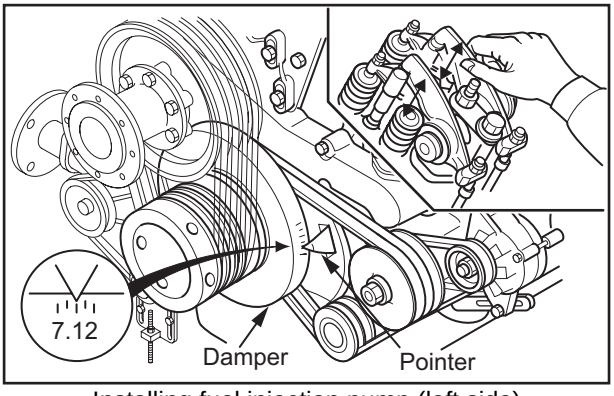
(1) Make sure the injection timing angle of No. 1 cylinder on the damper is aligned with the pointer on the engine.
(2) Loosen the two nuts for the injection pump drive coupling (laminated plate).
(3) Move the pump shaft until the line mark on the flywheel aligns with the pointer on the pump case end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



Adjusting fuel injection timing

(Fuel injection pump on left side)

The position where the stamped mark No. 7 and 12 are aligned with the pointer is the top dead center in compression stroke. The valve clearance of both the inlet and exhaust valve is the prerequisite at this time. From there the fuel injection timing is adjusted in the same procedure as the right side.



Installing fuel injection pump (left side)

2. Adjusting V-belt tension

Inspect the V-belt deflection by strongly pressing it with your thumb (force of approx. 98 to 147 N {10 to 15 kgf} [22 to 33 lbf]) at the center of the pulley-to-pulley span. The belt tension is correct if the deflection is 10 to 15mm [0.39 to 0.59 in.]. If the tension is out of standard, adjust it as follows:

When using a gauge to measure the amount of belt deflection, be sure to use the V-belt gauge.

Item	Standard
V-belt deflection	10 to 15 mm [0.39 to 0.59 in.]

• Fan pulley

(1) Loosen the fan bracket fixing bolts.

(2) Loosen the lock nut, adjust the V-belt tension by turning the adjusting bolt.

(3) Tighten the lock nut.

(4) Tighten the fan bracket fixing bolts.

• 2-way water pump side tension pulley

(1) Loosen the tension pulley fixing bolts.

(2) Loosen the lock nut, adjust the V-belt tension by turning the adjusting bolt.

(3) Tighten the lock nut.

(4) Tighten the tension pulley fixing bolts.

• Water pump side tension pulley

(1) Loosen the tension pulley fixing bolts.

(2) Loosen the lock nut, adjust the V-belt tension by turning the adjusting bolt.

(3) Tighten the lock nut.

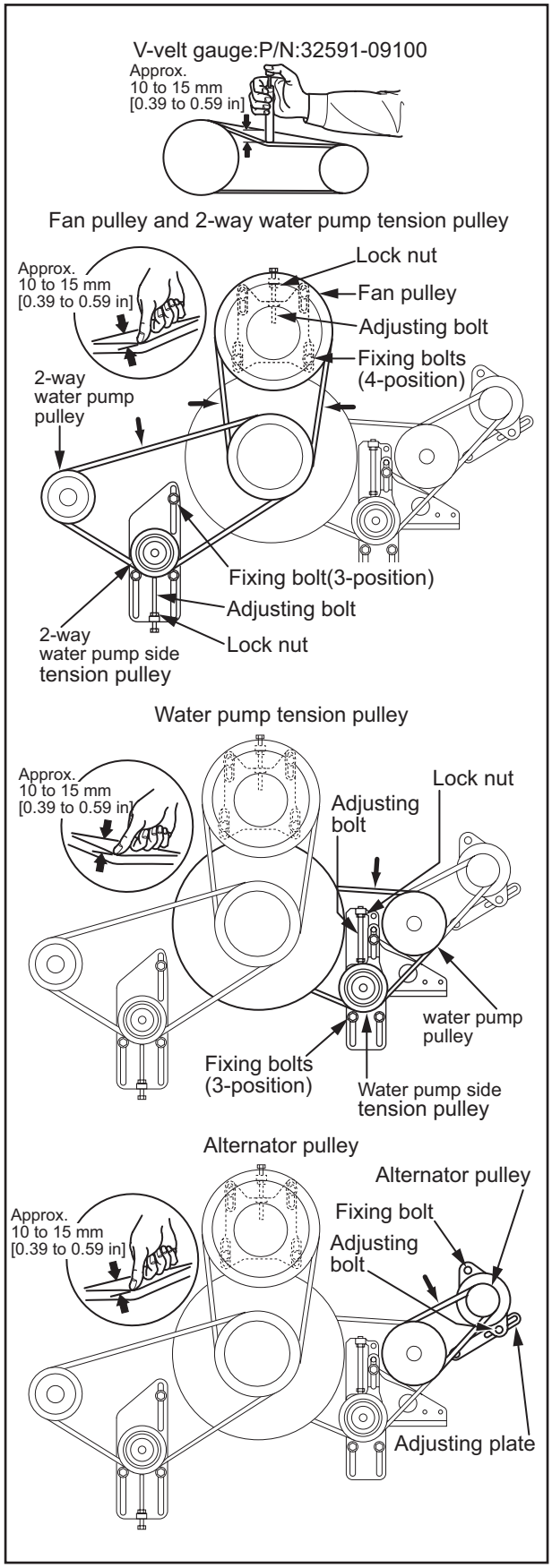
(4) Tighten the tension pulley fixing bolts.

• Alternator pulley

(1) Loosen the alternator fixing bolt and adjusting bolt.

(2) Move the alternator to opposite direction of water pump pulley, adjust the V-belt deflection properly.

(3) Tighten the alternator fixing bolt and adjusting bolt.



Adjusting V-belt tension

3. Break-in operation

After the engine is overhauled, couple the engine to the dynamometer, and run the engine for break-in operation and inspection.

3.1 Starting up

(1) Before starting the engine, check the levels of coolant, engine oil and fuel.
Bleed air from the fuel and cooling systems.
(2) Stop the fuel supply, and crank the engine with the starter for about 10 seconds to lubricate the engine.
(3) Move the control lever slightly in the fuel increase direction (but not to the "full injection" position), and then turn the starter switch key to the [START] position to start the engine.
(4) After the engine is started, adjust the control lever to let the engine operate at a minimum no-load speed (low idle speed).
(5) Turn the starter switch key to the [OFF] position and make sure that the engine is stopped.

3.2 Inspecting engine condition after starting up

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

(1) The oil pressure should be the specified value.
(2) The coolant temperature should be the specified value.
(3) Any leakage of oil, coolant and fuel must not be found. Pay special attention to oil leakage from the turbocharger lube oil pipe connections.
(4) Knocking noise should disappear as the coolant temperature rises. Check that there are no any other abnormal noises.
(5) Check for smoke color and odors.

3.3 Break-in operation time

The relationship between the load in break-in operation and the operation time is as shown below.

Break-in operation time

	Engine speed (min^{-1})		Load	Duration (min)
1	Low rotation speed	600 to 900	No-load	5
2	Medium rotation speed	1000 to 1200	No-load	5
3	High rotation speed	1400 to rated speed	No-load	10
4	Rated speed		25 %	10
5			50 %	10
6			75 %	30
7			100 %	20

Note: The table above is provided solely for reference purpose. Run the engine at appropriate speed and load for the break-in operation of your engine. Be sure to perform break-in operation after overhaul or installation.

3.4 Inspection and adjustment after break-in operation

(1) Valve clearance adjustment
(2) Ignition timing inspection
(3) Exterior bolt and nut tightness check