July 2016

SERVICE MANUAL

S4Q,S4Q2

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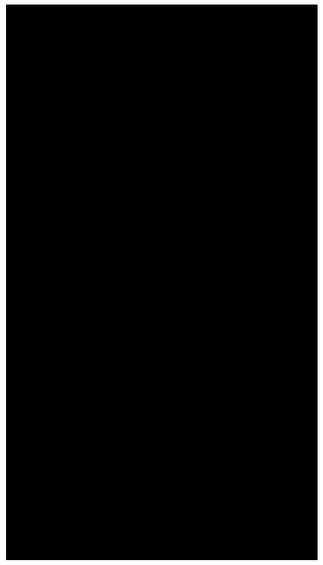

MITSUBISHI DIESEL ENGINES

S4Q,S4Q2

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MITSUBISHI HEAVY INDUSTRIES
ENGINE & TURBOCHARGER, LTD.

INTRODUCTION

This service manual describes the specifications, maintenance and service procedures for Mitsubishi diesel engines.

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

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

The contents of the manual are based on the engine models that are being produced at the time of publication. Due to improvements made thereafter, the actual engine that you work on may differ partially from the one described in this manual.

Pub.No.99619-13141

How to use this manual

This service manual consists of several Groups, which are arranged so as to allow you to make reference quickly to specifications, maintenance standards, adjustment procedures and service procedures including methods for disassembly, inspection, repair and reassembly of the Mitsubishi Diesel Engine (standard model for land use).
A short summary describing the content of each Group is given in the General Contents page, and there is also a detailed table of contents at the beginning of each Group.
Regarding the procedures for operation and periodical maintenance of the engine, refer to the Operation and Maintenance Manual. For information on the engine components and ordering of service parts, refer to the Parts Catalogue. Structure and function of the engine are described in the relevant training manuals.

Methods of presentation

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

DANGER

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

WARNING

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

CAUTION

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

CAUTION

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

Note:

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

Terms used in this manual

Nominal

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

Standard

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

Limit

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

Abbreviations

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

Units of measurement

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

- Pressure: 1 MPa = 10.197 kgf/cm^2
- Torque: 1 N·m = 0.10197 kgf·m
- Force: 1 N = 0.10197 kgf
- Horsepower: 1 kW = 1.341 HP = 1.3596 PS
- Meter of mercury: 1 kPa = 0.7 cmHg
- Meter of water: 1 kPa = 10.197 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 surrounding parts thoroughly. Such materials can cause fire or the engine to overheat. In particular, clean the top surface of the battery thoroughly. Dust can cause a short-circuit.
Always operate the engine at a position at least 1 m [3.28 ft.] away from buildings and other equipment to prevent possible fire caused by engine heat.

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.

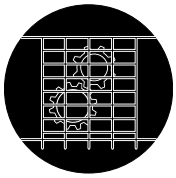
Keep fire extinguishers and first-aid kit handy

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

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.
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.

⚠ CAUTION

Be careful of handling fuel, engine oil and LLC

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

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

Handle LLC (long life coolant) carefully

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

Proper disposal of waste oil and coolant (LLC)

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

⚠ CAUTION

Service battery

Handle the battery correctly

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

⚠ CAUTION

When abnormality occurs

Stop overheated engine after cooling run

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

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

Avoid immediate restart after abnormal stop

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

Avoid continuous engine operation with too low oil pressure

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

Stop the engine immediately if the fan belt breaks

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

⚠ CAUTION

Other cautions

Modification of engine prohibited

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

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

Never break the seals

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

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

Pre-operational check and periodic inspection/maintenance

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

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

Break-in operation

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

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

Warming-up operation

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

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

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

Avoid engine operations in a overload condition

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

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

Cooling operation before stopping engine

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

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

During cooling operation, check the engine for abnormalities.

Protection of engine against water entry

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

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

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

Maintenance of air cleaner or pre-cleaner

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

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

Observe safety rules at work site

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

Do not operate the engine if you are feeling ill.

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

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

Work clothing and protective gear

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

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

Use of tools optimum for each work

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

Avoidance of prolonged time of starter operation

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

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

Do not turn off battery switch during operation

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

Cautionary instructions for transporting engine

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

Avoid continuous engine operation in a low load condition

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

Ventilation of engine room

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

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

Avoid contact with high-pressured fuel

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

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

⚠ CAUTION

About warning labels

Maintenance of warning labels

Make sure all warning/caution labels are legible.

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

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

Replace damaged or fractured labels with new ones.

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

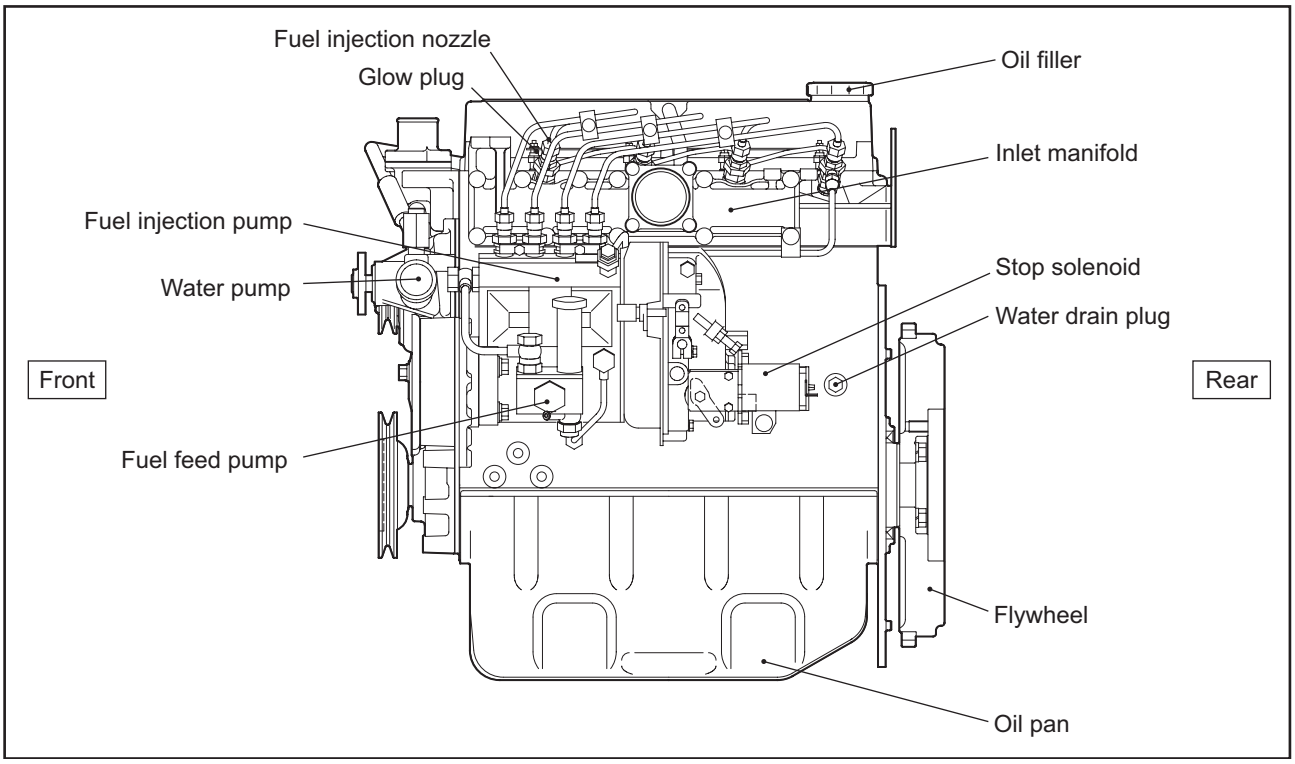
Warning labels

GENERAL CONTENTS

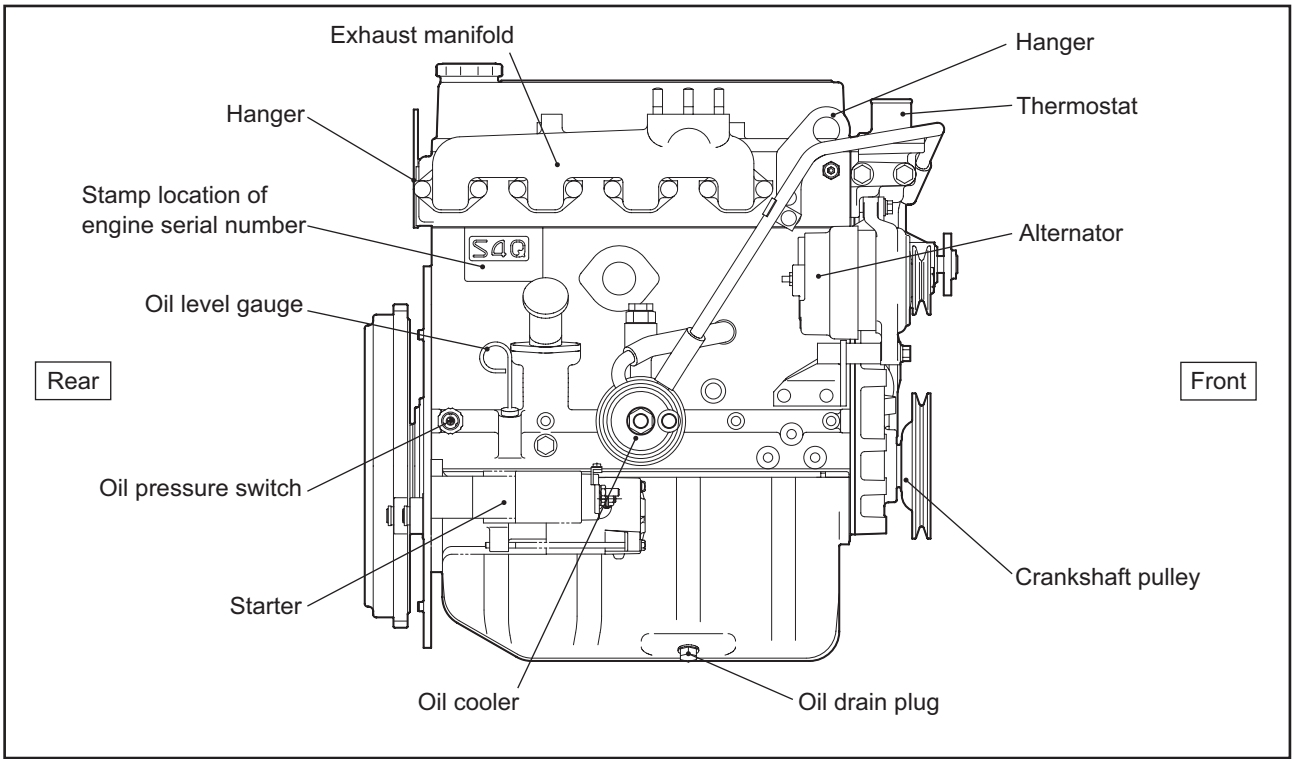
GENERAL

1. External view

1.1 In-line fuel injection pump type

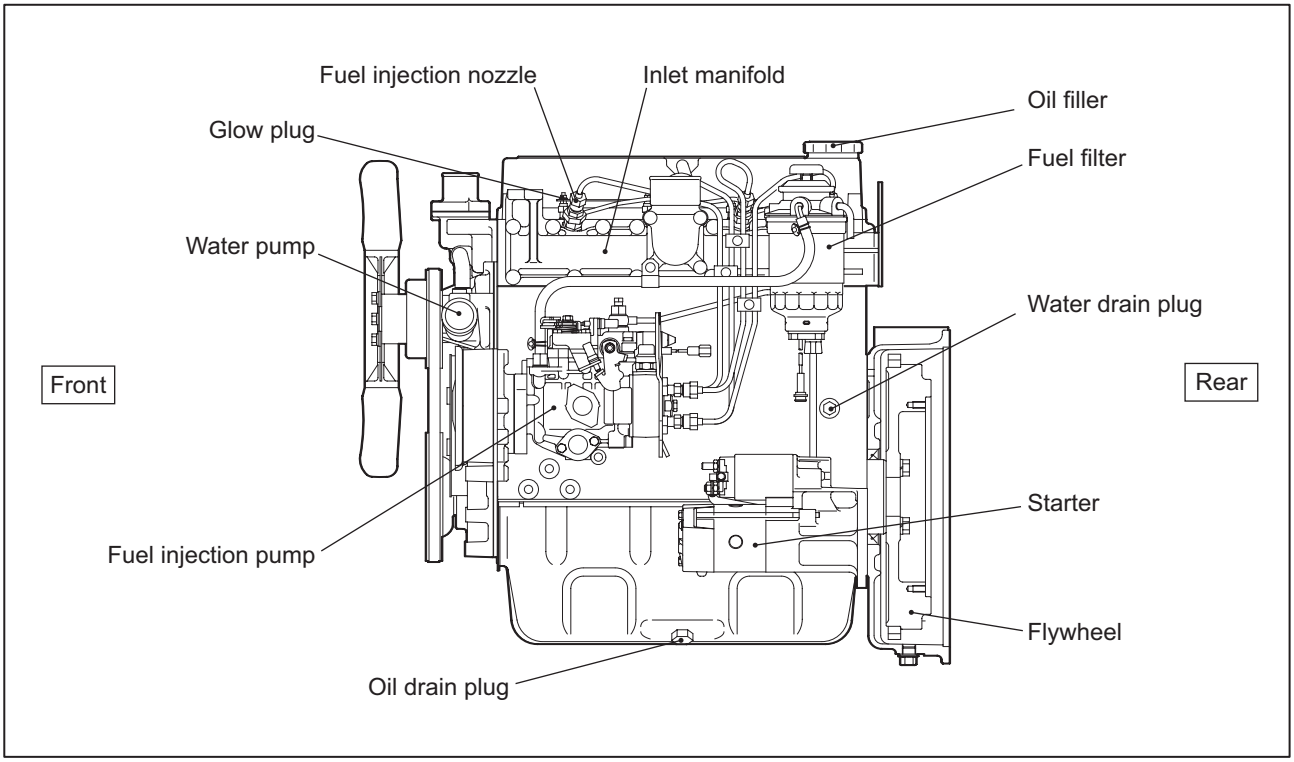


Left side of engine

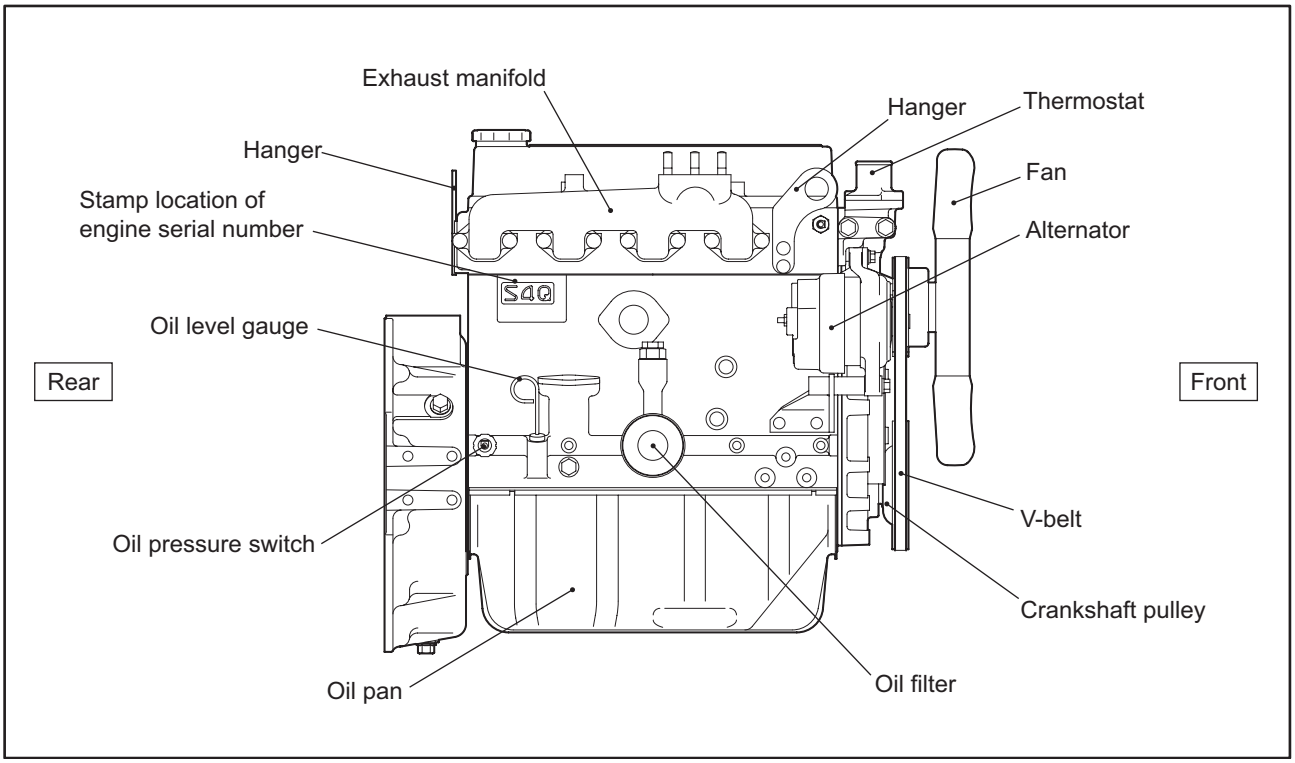


Right side of engine

1.2 Distribution fuel injection pump type



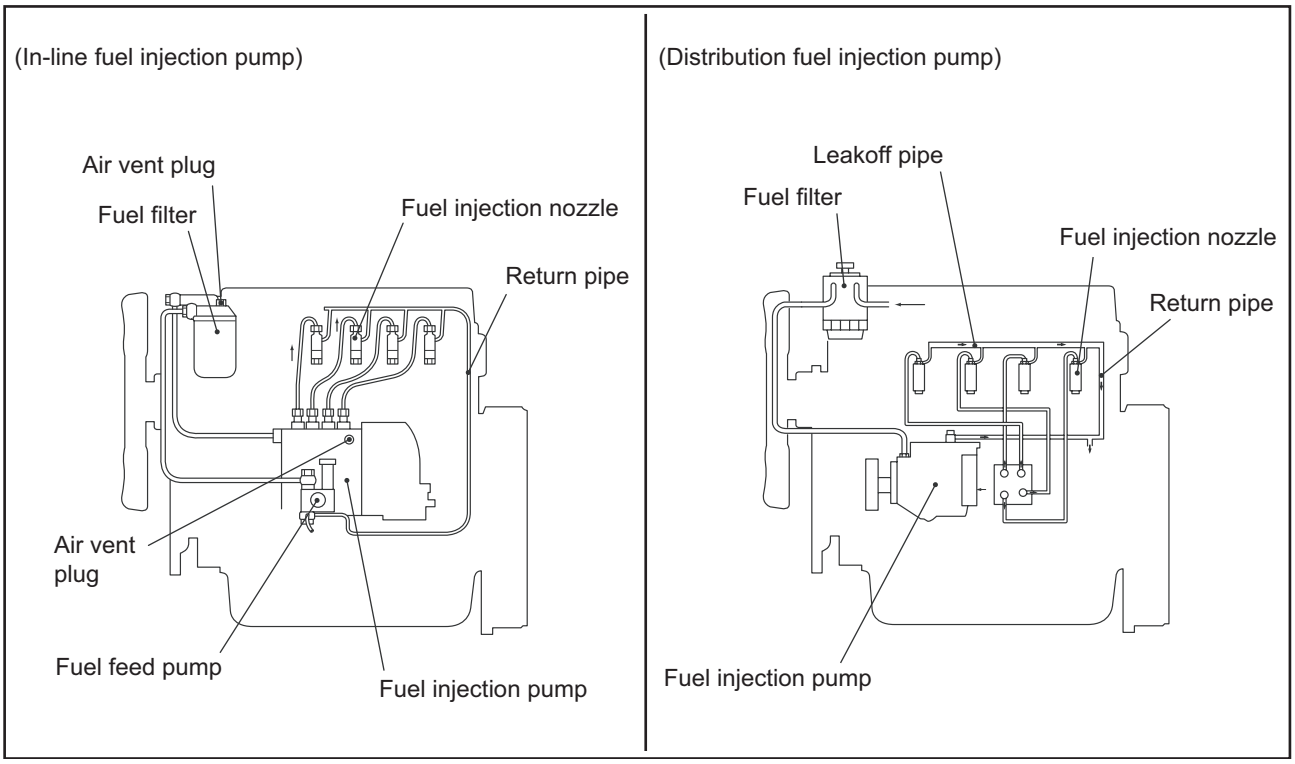
Left side of engine



Right side of engine

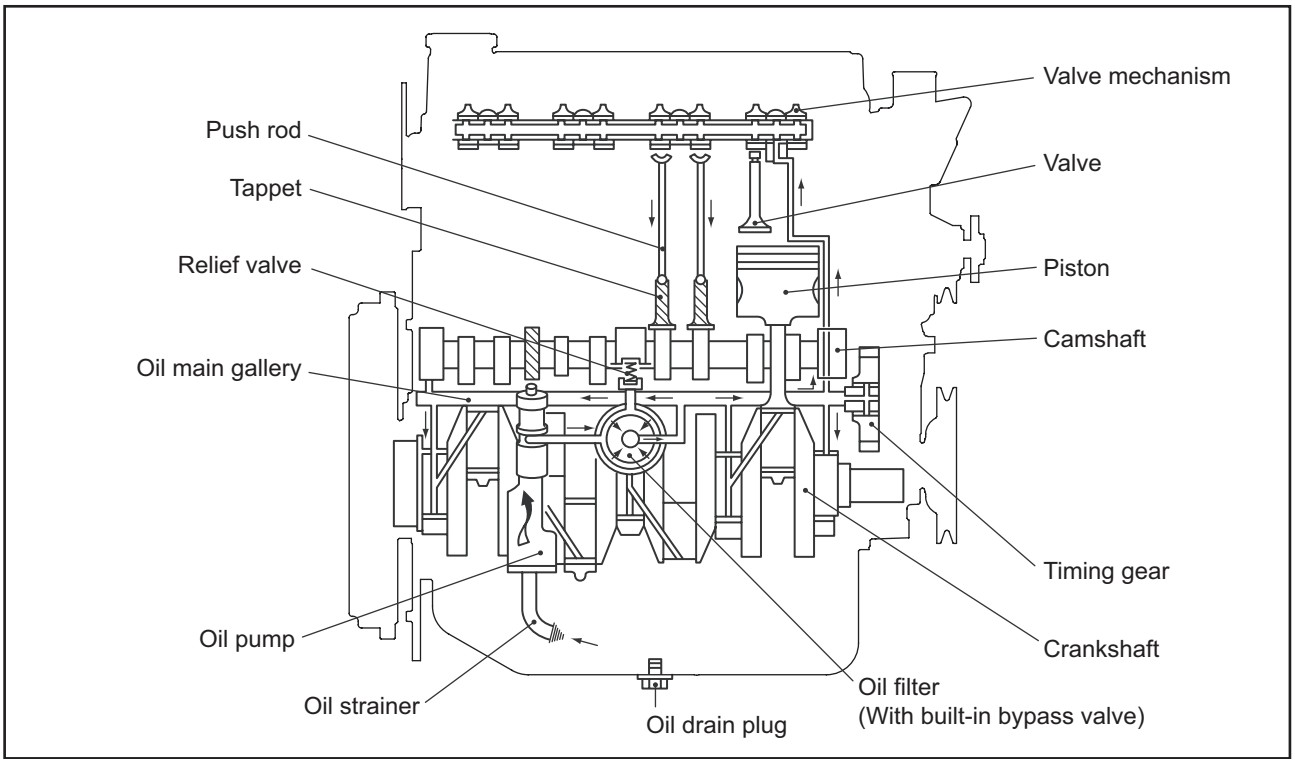
2. System flow diagrams

2.1 Fuel system - flow diagram



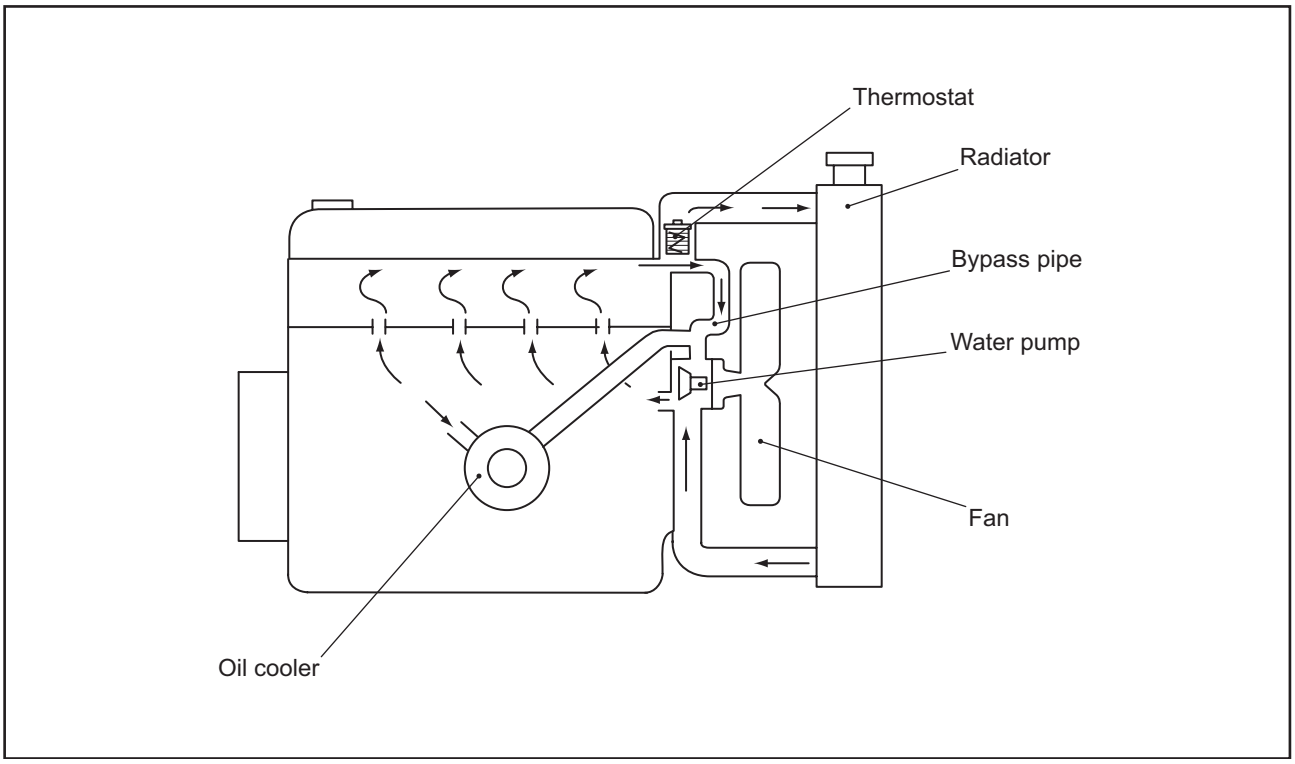
Fuel system - flow diagram

2.2 Lubrication system - flow diagram



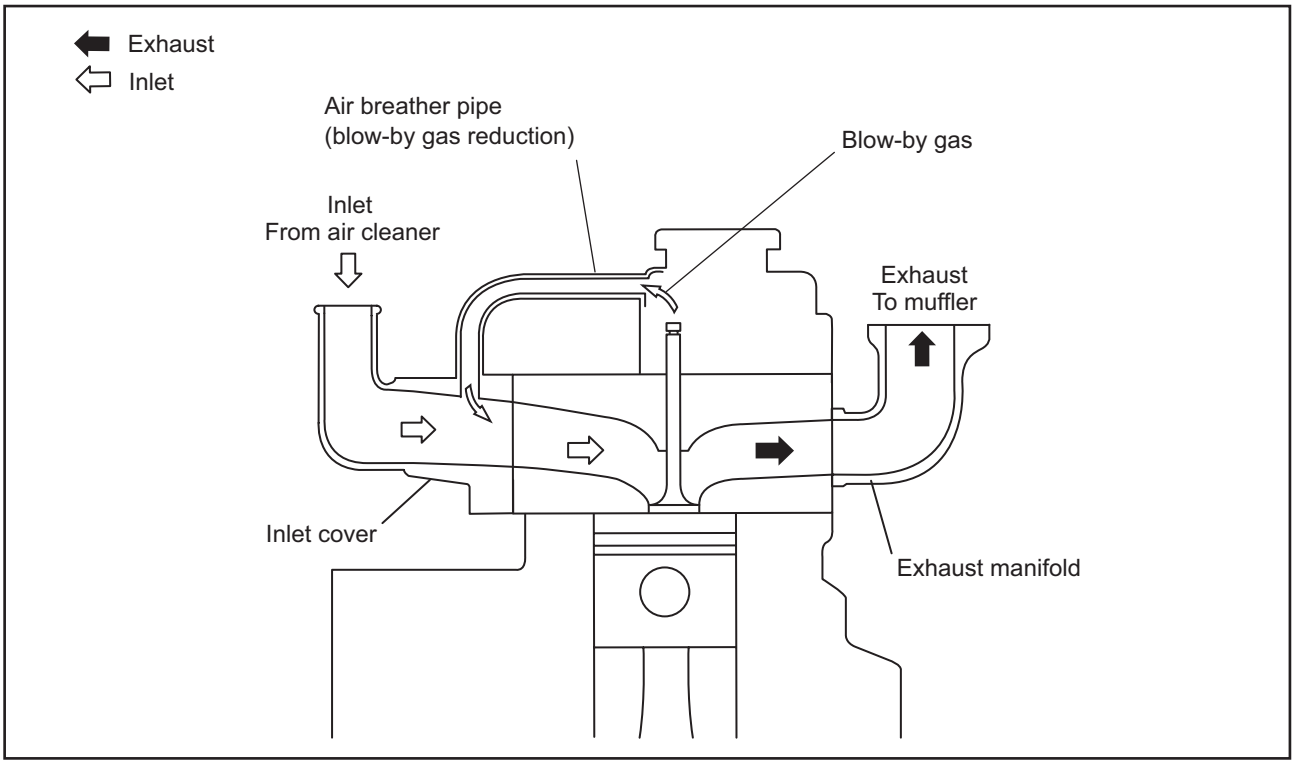
Lubrication system - flow diagram

2.3 Cooling system - flow diagram



Cooling system - flow diagram

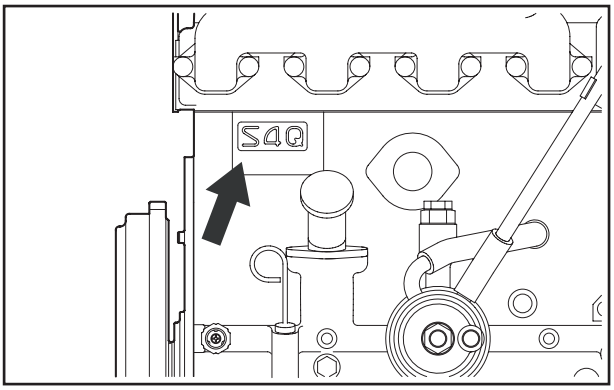
2.4 Inlet and exhaust system - flow diagram



Inlet and exhaust system - flow diagram

3. Engine serial number location

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



Stamp location of engine serial number

4. Main specifications

This specifications may differ from your engine specifications.

Table 1-1 Main specifications(1 / 3)

Engine type				S4Q	S4Q2
Main specifications	Model			Vertical type, Water-cooled, 4-stroke cycle diesel engine	
	Number and arrangement of cylinders			4 cylinder in-line	
	Combustion type			Swirl chamber type	
	Valve mechanism			Overhead	
	Cylinder bore × stroke			88 × 95 mm [3.46 × 3.74 in.]	88 × 103 mm [3.46 × 4.06 in.]
	Displacement			2.311 L [0.6 U.S.gal.]	2.505 L [0.7 U.S.gal.]
	Compression ratio			22.0 : 1	
	Fuel used			JIS K2204, Diesel oil or its equivalent (ASTM D975, etc.).	
	Firing order			1 - 3 - 4 - 2	
	Direction of rotation			Counterclockwise when viewed from flywheel	
	Dimensions	Overall length		707 mm [27.83 in.]	
		Overall width		493 mm [19.40 in.]	
		Overall height		633 mm [24.92 in.]	
	Dry weight			Approx. 195 kg [429.9 lb]	
Basic engine	Cylinder	Type		Dry (integral with cylinder block)	
	Piston ring	Number of rings		Compression rings: 2	
				Oil ring (w/expander): 1	
	Valve timing (when warm)	Inlet valve	Open	BTDC 30°	
			Close	ABDC 50°	
		Exhaust valve	Open	BBDC 74°	
			Close	ATDC 30°	
	Starting system			Electric	
	Starting aid system			Glow plug	
Fuel system	Fuel injection pump	Type		In-line (Bosch A type) or Distribution (VE type)	
		Plunger diameter		In-line: ø 6.5 [0.26 in.]mm , Distribution: ø11 mm [0.43 in.]	
	Fuel feed pump	Type		In-line pump: Pistone type Distribution pump: Vane Pump type	
	Governor	Speed control system		Centrifugal type	
		Feature		All speed	
	Fuel injection nozzle	Nozzle type		Bosch, Throttle type	
		Number of spray holes		1	
		Spray hole diameter		ø 1.0 mm [0.04 in.]	
		Spray angle		0°	
		Valve opening pressure		13.73 MPa {140 kgf/cm²} [1991 psi]	

Table 1-1 Main specifications(2 / 3)

Engine type			S4Q	S4Q2
Lubrication system	Lubricating method		Forced circulation type (pressure feed by oil pump)	
	Engine oil	Standard (API service classification)	Class CF or CH-4	
		Engine oil capacity	Shallow oil pan: approx. 5.5 L [1.45 U.S.gal.] in oil pan (Engine total: approx. 6.5 L [1.45 U.S.gal.]) Deep oil pan: approx. 7.5 L [1.98 U.S.gal.] in oil pan (Engine total: approx. 8.5 L [2.25 U.S.gal.])	
	Oil pump	Type	Trochoid	
		Discharge capacity	10.45 L [2.76 U.S.gal.]/min or more (at pump rotation of 1000 min^{-1})	
	Relief valve	Valve opening pressure	0.30 to 0.40 MPa {3 to 4 kgf/cm^2} [42.67 to 56.89 psi]	
	Oil filter	Type	Cartridge type paper element	
Cooling system	Cooling method		Water-cooled, forced circulation	
	Coolant capacity (engine)		4 L [1.06 U.S.gal.], approx.	
	Water pump	Type	Volute type centrifugal pump	
		Discharge capacity	70 L[18.49 U.S.gal]/min (Pump rotating speed 3000 min^{-1}, total pump head 2.5×10^{-2}MPa)	
	Thermostat	Type	Wax type	
		Valve opening temperature	76.5 ± 1.5 °C [169.7 ± 2.7°F]	

Table 1-1 Main specifications(3 / 3)

Engine type				S4Q	S4Q2
Electrical system	Starter	Manufacturer		Mitsubishi Electronic Corporation	
		Type		M008T70371	
		Pinion meshing type		Pinion shift	
		Output		12 V - 2.0 kW	
		Qty		1	
		Ring gear and pinion ratio		10/113	
		No-load characteristics	Voltage	11 V	
			Current	130 A or below	
			Speed	3600 r/min or more	
		Load characteristic	Voltage	7.7 V	
			Current	400 A	
			Torque	10.59 N·m {1.08 kgf·m} [7.8 lbf·ft] or more	
			Speed	1280 r/min or more	
		Load characteristics	Voltage	3 V	
			Current	1000 A or below	
			Torque	29.42 N·m {3.0 kgf·m} [21.7 lbf·ft] or more	
	Alternator	Manufacturer		Mitsubishi Electronic Corporation	
		Model number		A007T02077C	
		Output		12 V - 50 A	
		Regulated voltage		14.7 ± 0.3 V	
	Glow plug	Type		Sheathe glow plug	
		Rated voltage		DC10.5 V	

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:

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 "Tightening torque table."

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

SERVICE DATA

1. Maintenance service data

1.1 General

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

Inspection point			Nominal	Standard	Limit	Remark
Maximum rotation speed (rated rotation speed used as reference)			Varies depending on the specifications			Adjust governor setting.
Minimum rotation speed						
Compression pressure			2.94 MPa {30 kgf/cm²} [427 psi]		2.55 MPa {26 kgf/cm²} [370 psi]	When oil and water temperatures at 20 to 30°C [68 to 86°F] (150 to 200 min^{-1}) or more
Engine oil pressure	Duty run (1500 min^{-1} or more)		Reference value: 0.10 to 0.39 MPa {1 to 4 kgf/cm²} [15 to 57 psi]			Reference values of engine itself (standard specification), when oil temperature at 70 to 90°C [158 to 194°F].
	Low idling (Approx. 1000 min^{-1})		Reference value: 0.05 MPa {0.5 kgf/cm²} [7 psi] or more			
Valve timing	Inlet valve	Open	BTDC 30°	± 3°		(Crank angle)
		Close	ABDC 50°			
	Exhaust valve	Open	BBDC 74°			
		Close	ATDC 30 °			
Valve clearance (when cold)				0.25 [0.0098]		Both inlet and exhaust
Fuel injection timing			Varies depending on the specifications			
Fan belt deflection (crankshaft pulley to alternator pulley)				Applox. 13 [0.51]		Amount of deflection when pressed with the thumb firmly. (98 N {10 kgf} [72 lbf])

1.2 Basic engine

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

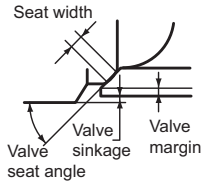
Inspection point			Nominal	Standard	Limit	Remark
Rocker	Rocker arm inside diameter		ø 19 [0.75]	19.01 to 19.03 [0.7484 to 0.7492]		
	Rocker shaft outside diameter		ø 19 [0.75]	18.98 to 19.00 [0.7472 to 0.7480]		
	Clearance between rocker arm and shaft			0.01 to 0.05 [0.0004 to 0.0020]	0.07 [0.0028]	
Valve and valve guide	Valve stem outside diameter	Inlet	ø 8 [0.31]	7.940 to 7.955 [0.3126 to 0.3132]	7.900 [0.3110]	
		Exhaust	ø 8 [0.31]	7.920 to 7.940 [0.3118 to 0.3126]	7.850 [0.3091]	
	Clearance between valve stem and guide	Inlet		0.045 to 0.075 [0.0018 to 0.0030]	0.130 [0.0051]	
		Exhaust		0.060 to 0.095 [0.0024 to 0.0037]	0.150 [0.0059]	
	Height to top of valve guide		15.5 [0.610]	15.1 to 15.6 [0.594 to 0.614]		
Valve seat	Valve seat angle		30°			
	Valve sinkage		0.8 [0.031]	0.7 to 0.9 [0.028 to 0.035]	1.3 [0.051]	
	Seat width		1.18 [0.0465]	1.04 to 1.32 [0.0409 to 0.0520]	1.6 [0.063]	
	Valve margin		1.7 [0.067]		Refacing permissible up to 1.2 [0.047]	

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

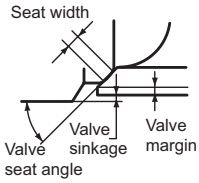
Inspection point			Nominal	Standard	Limit	Remark
Valve seat	Valve seat angle		30°			
	Valve sinkage		0.8 [0.031]	0.7 to 0.9 [0.028 to 0.035]	1.3 [0.051]	
	Seat width		1.18 [0.0465]	1.04 to 1.32 [0.0409 to 0.0520]	1.6 [0.063]	
	Valve margin		1.7 [0.067]		Refacing permissible up to 1.2 [0.047]	
Valve spring	Free length			48.85 [1.9232]	47.60 [1.8740]	
	Perpendicularity			θ = 1.5° Δ = 1.3 [0.051] Lf = 48.85 [1.9232]	Δ = 1.5 [0.059] at the end	
	Set length/set load			43 mm [1.69 in.]/ 176 to 196 N {18 to 20 kgf} [130 to 145 lbf]	43 mm [1.69 in.]/ 147 N {15 kgf} [108 lbf]	
Push rod	Runout			0.3 [0.012] or less		Runout (dial gaule reading) when pushrod is supported along center line of spherical surface at either end.
Cylinder head	Distortion of bottom face			0.05 [0.0020] or less	0.20 [0.0079]	Reface minimum thickness.
	Compressed thickness of gasket		1.3 [0.0512]	1.27 to 1.37 [0.0500 to 0.0539]		
Piston	Outside diameter	STD	87.970 [3.4634]	87.955 to 87.985 [3.4628 to 3.4640]	87.770 [3.4555]	14 [0.55] upper from the bottom right angle to the piston pin.
		0.25 [-0.0098] OS	88.220 [3.4732]	88.205 to 88.235 [3.4726 to 3.4738]	88.020 [3.4653]	
		0.50 [-0.0197] OS	88.470 [3.4831]	88.455 to 88.485 [3.4825 to 3.4837]	88.270 [3.4752]	
	Protrusion from crankcase			0.13 to 0.60 [0.0051 to 0.0236]		Bearing clearance check.
	Weight difference in one engine			5 g [0.20 oz.] or less		
Piston ring	Clearance between piston ring and ring groove	No.1 compression ring		0.060 to 0.100 [0.0024 to 0.0039]	0.200 [0.0079]	Use the piston with replacing the piston rings until reaching the limits. when reaching the limits, replace the piston.
		No.2 compression ring		0.045 to 0.080 [0.0018 to 0.0031]	0.150 [0.0059]	
		Oil ring		0.025 to 0.065 [0.0010 to 0.0026]	0.150 [0.0059]	
	Closed gap of ring	No.1, 2 compression rings		0.25 to 0.40 [0.0098 to 0.0157]	1.50 [0.0591]	
		Oil ring		0.30 to 0.50 [0.0118 to 0.0197]	1.50 [0.0591]	

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

Inspection point		Nominal	Standard	Limit	Remark
Piston pin	Piston pin hole inside diameter	ø 28 [1.10]	28.000 to 28.010 [1.1024 to 1.1028]		
	Outside diameter	ø 28 [1.10]	27.994 to 28.000 [1.1021 to 1.1024]		
	Clearance between piston pin hole and piston pin		0.000 to 0.016 [0.0000 to 0.0006]	0.050 [0.0020]	Use the piston with replacing the piston pin until reaching the limits. when reaching the limits, replace the piston.
Connecting rod	Bushing inside diameter	ø 28 [1.10]	28.020 to 28.045 [1.1031 to 1.1041]		
	Clearance between piston pin		0.020 to 0.051 [0.0008 to 0.0020]	0.080 [0.0031]	Replace the piston and bushing (Ream if necessary)
	Clearance between crankpin and connecting rod bearing (oil clearance)		0.030 to 0.095 [0.0012 to 0.0037]	0.200 [0.0079]	Use connecting rod with replacing bearing until reaching the limit. when exceeding the limit, re-gring the crankpin and replace the bearing with under size.
	Bend and twist		0.05/100 [0.0020/3.94] or less	0.15/100 [0.0059/3.94]	
	End play		0.15 to 0.35 [0.0059 to 0.0138]	0.50 [0.0197]	Replace connecting rod.
	Connecting rod bearing inside diameter	ø 58 [2.28]	58.000 to 58.045 [2.2835 to 2.2852]		
Exhaust manifold	Distortion of manifold		0.15 [0.0059] or less		
Idler gear	Clearance between shaft and bushing		0.025 to 0.075 [0.0010 to 0.0030]	0.100 [0.0039]	Replace bushing.
	End play		0.05 to 0.20 [0.0020 to 0.0079]	0.35 [0.0138]	Replace thrust plate.
Timing gear backlash	Crankshaft gear to idler gear		0.03 to 0.16 [0.0012 to 0.0063]	0.25 [0.0098]	Replace gear.
	Idler gear to camshaft gear		0.04 to 0.17 [0.0016 to 0.0067]	0.25 [0.0098]	
	Idler gear to fuel injection pump gear		0.03 to 0.18 [0.0012 to 0.0071]	0.25 [0.0098]	

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

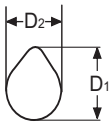
Inspection point				Nominal	Standard	Limit	Remark
Camshaft	Cam lift (D_1 - D_2)	Inlet		Major axis $46.916^{+0.1}_{-0.3}$ [$1.8471^{+0.004}_{-0.012}$]	Major axis - minor axis = 6.684 [0.2631]	Major axis - minor axis = 6.184 [0.2435]	
		Exhaust		Major axis $45.944^{+0.1}_{-0.3}$ [$1.8088^{+0.004}_{-0.012}$]	Major axis - minor axis = 7.344 [0.2891]	Major axis - minor axis = 6.844 [0.2694]	
	Runout				0.04 [0.0016] or less	0.10 [0.0039]	Repaor the runout, or replace.
	Journal outside diameter		No.1, No.2	ø 54 [2.13]	53.94 to 53.96 [2.1236 to 2.1244]	53.90 [2.1220]	
			No.3	ø 53 [2.09]	52.94 to 52.96 [2.0842 to 2.0850]	52.90 [2.0827]	
	Circularity of journal				0.02 [0.0008] or less		
	Cylindericity of journal				0.02 [0.0008] or less		
	Clearance between camshaft journal outside diameter and crankcase hole inside diameter.				0.07 to 0.11 [0.0028 to 0.0043]	0.15 [0.0059]	
	Camshaft hole inside diameter		No.1, No.2	ø 54 [2.13]	54.03 to 54.05 [2.1272 to 2.1279]		
			No.3	ø 53 [2.09]	53.03 to 53.05 [2.0878 to 2.0886]		
	Circularity of camshaft hole				0.02 [0.0008] or less		
	Camshaft hole coaxiality				0.05 [0.0020] or less		
	End play			5 [0.20]	0.10 to 0.25 [0.0039 to 0.0098]	0.30 [0.0118]	Replace thrust plate.
Tappet	Tappet hole inside diameter			ø 14 [0.55]	14.000 to 14.018 [0.5512 to 0.5519]	14.100 [0.5551]	
	Clearance between crankcase				0.016 to 0.052 [0.0006 to 0.0020]	0.080 [0.0031]	

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 58 [2.28]	57.950 to 57.970 [2.2815 to 2.2823]		
	Crankpin journal outside diameter		ø 65 [2.56]	64.965 to 64.985 [2.5577 to 2.5585]		
	Distance between centers of journal and crankpin		51.5 [2.028]	51.46 to 51.54 [2.0260 to 2.0291]		
	Parallelism between journal and crankpin			Pin maximum defection: 0.01 [0.0004] or less		
	Roundness of journals and crankpins			0.01 [0.0004] or less	0.03 [0.0012]	
	Cylindericity of journals and crankpins			0.01 [0.0004] or less	0.03 [0.0012]	
	Fillet radius of pin		R3 [0.12]	±0.2 [0.008]		
	Fillet radius of journals		R3 [0.12]	±0.2 [0.008]		
	Runout (TIR)			0.04 [0.0016] or less	0.10 [0.0039]	TIR
	End play			0.100 to 0.204 [0.0039 to 0.0080]	0.300 [0.0118]	
Main bearing	Crankcase hole (main bearing lower hole)	Inside diameter	ø 69 [2.72]	69.000 to 69.019 [2.7165 to 2.7173]		When main bearing cap is tightened.
		Circularity		0.02 [0.0008] or less		
		Coaxiality		0.05 [0.0020] or less		
	Clearance between main bearing and crankshaft journal (oil clearance)			0.035 to 0.085 [0.0014 to 0.0033]	0.200 [0.0079]	
	Thrust bearing width (cap width)		23 [0.91]	22.979 to 23.000 [0.9047 to 0.9055]		
Crankcase	Flatness of top surface			0.05 [0.0020] or less	0.20 [0.0079]	Reface minimum thickness.
	Cylinder inside diameter	STD	88 [3.46]	88.000 to 88.035 [3.4646 to 3.4659]	Standard value +0.2 [+0.008]	
		0.25 [-0.0098] OS	88.25 [3.4744]	88.250 to 88.285 [3.4744 to 3.4758]		
		0.50 [-0.0197] OS	88.50 [3.4842]	88.500 to 88.535 [3.4842 to 3.4856]		
	Cylindricality of cylinder inside diameter			0.015 [0.0006] or less		

1.3 Fuel system

Table 2-3 Maintenance service data table - Fuel system

Inspection point		Nominal	Standard	Limit	Remark
Fuel injection nozzle	Valve opening pressure	13.73 MPa {140 kgf/cm²} [1991 psi]	13.93 to 14.71 MPa {142 to 150 kgf/cm²} [2020 to 2133 psi]		Standard is a value of new parts.
	Spray cone angle	0°			Check nozzle with a hand tester (at fuel oil temperature 20°C [68°F]). Replace the nozzle tip if the spray pattern is still bad after washing in clean fuel oil.
	Nozzle valve seat oil sealing	Seat shall hold a test pressure lower than valve opening pressure by 1.96 MPa {20 kgf/cm²} [285 psi] for 10 seconds.			Wash in clean fuel oil or replace nozzle tip.

1.4 Lubrication system

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

Inspection point		Nominal	Standard	Limit	Remark
Oil pump	Rotor, case and end play		0.04 to 0.09 [0.0016 to 0.0035]	0.15 [0.0059]	
	Clearance between outer rotor and inner rotor		0.13 to 0.15 [0.0051 to 0.0059]	0.20 [0.0079]	
	Clearance between outer rotor and case		0.20 to 0.28 [0.0079 to 0.0110]	0.50 [0.0197]	
	Shaft outside diameter	ø 13 [0.51]	12.985 to 13.000 [0.5112 to 0.5118]		
	Clearance between shaft and case		0.032 to 0.074 [0.0013 to 0.0029]		
Relief valve	Valve opening pressure	0.34 MPa {3.5 kgf/cm²} [49.78 psi]	0.3 to 0.4 MPa {3 to 4 kgf/cm²} [42.67 to 56.89 psi]		

1.5 Cooling system

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

Inspection point		Nominal	Standard	Limit	Remark
Water pump	Interference thread between case and bearing unit		0.017 to 0.064 [0.0007 to 0.0025]		
Thermostat	Temperature at which valve starts opening	76.5°C [170°F]	75 to 78°C [167 to 172°F]		
	Temperature at which valve lift is 8 [0.32], minimum		90°C [194°F]		

1.6 Electrical system

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

Inspection point			Nominal	Standard	Limit	Remark
Starter	Commutator	Diameter	ø 32 [1.26]		31.4 [1.236]	
		Runout			0.10 [0.004]	
		Mica depth		0.5 [0.020]	0.2 [0.008]	
	Brush leight			17.5 [0.6890]	11 [0.4331]	
	Tension of brush springs		31 N {3.2 kgf} [23.1 lbf]	26.7 to 36.1 N {2.7 to 3.7 kgf} [20 to 27 lbf]	14.7 N {1.5 kgf} [11 lbf]	
	Pinion shaft thrust gap			0.5 [0.020] or lower		0 [0.00] lower limit
	Pinion gap			0.5 to 2.0 [0.020 to 0.079]		
	No-load characteristics	Voltage (V)		11		When the tip of the pinion is fixed at 2mm [0.08in.] away from stop position,voltage is 8V or less.
		Armature current (A)		130 or less		
		Rotational speed (min^{-1})		3600 or more		
Alternator	Brush spring tension			4.8 to 6.0 N {0.5 to 0.6 kgf} [3.6 to 4.3 lbf]	2.2 N {0.2 kgf} [1.4 lbf]	
	Brush leight			18.5 [0.728]	5.0 [0.197]	
	Resistance between slip rings		2.8 Ω	2.6 to 3.0 Ω		at 20°C [68°F]
	Spring ring outside diameter			ø 22.7 [0.894]	22.1 [0.870]	

2. Tightening torque table

2.1 Major bolt tightening torque

2.1.1 Basic engine

Table 2-7 Tightening torque table - Basic engine

Description		Threads Dia × Pitch (mm)	Torque			Remark
			N·m	kgf·m	lbf·ft	
Cylinder head bolt		12 × 1.75	118 ± 5	12 ± 0.5	87 ± 3.6	
Cylinder head plug		16 × 1.5	44 ± 5	4.5 ± 0.5	33 ± 3.6	
Rocker cover		8 × 1.25	12 ± 1	1.2 ± 0.1	9 ± 0.7	
Adjusting screw nut		8 × 1.25	20 ± 2	2 ± 0.2	14 ± 1.4	
Rocker shaft bracket (short)		8 × 1.25	11.3 ± 1.5	1.15 ± 0.15	8 ± 1.1	
Rocker shaft bracket (long)		8 × 1.25	15 ± 2	1.5 ± 0.2	11 ± 1.4	
Main bearing cap		12 × 1.75	83 ± 5	8.5 ± 0.5	61 ± 3.6	
Connecting rod cap		10 × 1.0	54 ± 5	5.5 ± 0.5	40 ± 3.6	
Flywheel		12 × 1.25	83 ± 5	8.5 ± 0.5	61 ± 3.6	
Camshaft thrust plate		8 × 1.25	12 ± 1	1.2 ± 0.1	9 ± 0.7	
Front plate		8 × 1.25	12 ± 1	1.2 ± 0.1	9 ± 0.7	
Timing gear case cover		8 × 1.25	12 ± 1	1.2 ± 0.1	9 ± 0.7	
Crankshaft pulley		24 × 1.5	392 ± 10	40 ± 1	289 ± 7.2	
Flywheel housing		10 × 1.25	60 ± 6	6.1 ± 0.6	44 ± 4.3	
Rear plate stud		10 × 1.25	24 ± 2	2.4 ± 0.2	17 ± 1.4	
Tachometer L joint union nut	Resin gasket	22 × 1.5	29 ± 3	3 ± 0.3	22 ± 2.2	
	Copper gasket		20 ± 3	2 ± 0.3	14 ± 2.2	

2.1.2 Fuel system

Table 2-8 Tightening torque table - Fuel system

Description		Threads Dia × Pitch (mm)	Torque			Remark
			N·m	kgf·m	lbf·ft	
Fuel injection nozzle		20 × 1.5	59 ± 6	6 ± 0.6	43 ± 4.3	
Fuel injection nozzle retaining nut		16 × 0.75	36.8 ± 2.45	3.75 ± 0.25	27 ± 1.8	
Fuel leak off pipe mounting nut		12 × 1.5	23 ± 2	2.3 ± 0.2	17 ± 1.4	
Fuel injection pump gear	Distribution, CAV	14 × 1.5	81 ± 5	8.3 ± 0.5	60 ± 3.6	
	Distribution, VE	12 × 1.75	64 ± 5	6.5 ± 0.5	47 ± 3.6	
Fuel injection pipe nut		12 × 1.5	29 ± 3	3 ± 0.3	22 ± 2.2	
Fuel return pipe nut		10 × 1.25	20 ± 2	2 ± 0.2	14 ± 1.4	
Fuel injection pump fuel eye bolt		14 × 1.5	17 ± 2	1.75 ± 0.2	13 ± 1.4	
Fuel injection pump over flow valve		12 × 1.5	17 ± 2	1.75 ± 0.2	13 ± 1.4	
Fuel injection pump lubrication pipe (flare)		12 × 1.0	19 ± 3	1.95 ± 0.3	14 ± 2.2	
Fuel injection pump lubrication pipe (nipple)		14 × 1.5	29 ± 3	3 ± 0.3	22 ± 2.2	
Fuel injection pump lubrication connector		R1/8	25 ± 2	2.5 ± 0.2	18 ± 1.4	
Fuel injection pump lubrication eye bolt		10 × 1.0	10 ± 2.5	1.05 ± 0.25	8 ± 1.8	
Separate oil filter connector		20 × 1.5	39 ± 5	3 ± 0.5	22 ± 3.6	

2.1.3 Lubrication system

Table 2-9 Tightening torque table - Lubrication system

Description		Threads Dia × Pitch (mm)	Torque			Remark
			N·m	kgf·m	lbf·ft	
Oil pan mounting bolt	Press oil pan	8 × 1.25	8 ± 1	0.8 ± 0.1	6 ± 0.7	
	Cast oil pan	8 × 1.25	30 ± 3	3.1 ± 0.3	22 ± 2.2	
Oil pan drain plug		14 × 1.5	39 ± 5	4 ± 0.5	29 ± 3.6	
Oil pan drain cock		14 × 1.5	34 ± 5	3.5 ± 0.5	25 ± 3.6	
Oil filter bracket eye bolt		20 × 1.5	39 ± 5	4 ± 0.5	29 ± 3.6	
Oil filter		20 × 1.5	12 ± 1	1.2 ± 0.1	9 ± 0.7	
Oil filter shaft		20 × 1.5	49 ± 5	5 ± 0.5	36 ± 3.6	
Oil cooler connector		20 × 1.5	69 ± 10	7 ± 1	51 ± 7.2	
Oil relief valve		22 × 1.5	49 ± 5	5 ± 0.5	36 ± 3.6	
Oil pump set bolt		12 × 1.75	34 ± 4	3.5 ± 0.4	25 ± 2.9	
Oil pressure switch		PT 1/8	29.4	3.0	22	
Oil relief valve plug		18 × 1.5	44 ± 5	4.5 ± 0.5	33 ± 3.6	

2.1.4 Cooling system

Table 2-10 Tightening torque table - Cooling system

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Water drain plug	1/4 - 18 NPTF	39 ± 4	4 ± 0.4	29 ± 2.9	
Hose clamp	-	1.37 ± 0.2	0.14 ± 0.02	1 ± 0.1	
Thermoswitch	16 × 1.5	23 ± 2	2.3 ± 0.2	17 ± 1.4	

2.1.5 Electrical system

Table 2-11 Tightening torque table - Electrical system

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Glow plug (Engine body)	10 × 1.25	18 ± 2	1.8 ± 0.2	13 ± 1.4	
Glow plug (terminal)	4 × 0.7	1.3 ± 0.2	0.13 ± 0.02	0.9 ± 0.1	
Starter terminal B	8 × 1.25	11 ± 1	1.1 ± 0.1	8 ± 0.7	
Starter terminal S	5 × 0.8	3.3 ± 0.8	0.34 ± 0.08	2.5 ± 0.6	

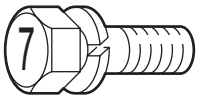
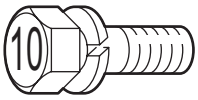
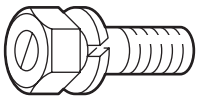
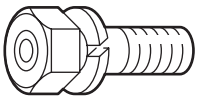
2.1.6 Inlet and exhaust systems

Table 2-12 Tightening torque table - Inlet and exhaust systems

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Exhaust manifold	8 × 1.25	30 ± 3	3.1 ± 0.3	22 ± 2.2	
Inlet hose clamp	-	7 ± 1	0.7 ± 0.1	5 ± 0.7	
Turbo air hose board clamp	-	6 ± 1	0.6 ± 0.1	4 ± 0.7	Length of the 23 mm [0.90 in.]
	-	7 ± 1	0.7 ± 0.1	5 ± 0.7	Length of the 33 mm [1.30 in.]

2.2 Standard bolt and nut tightening torque

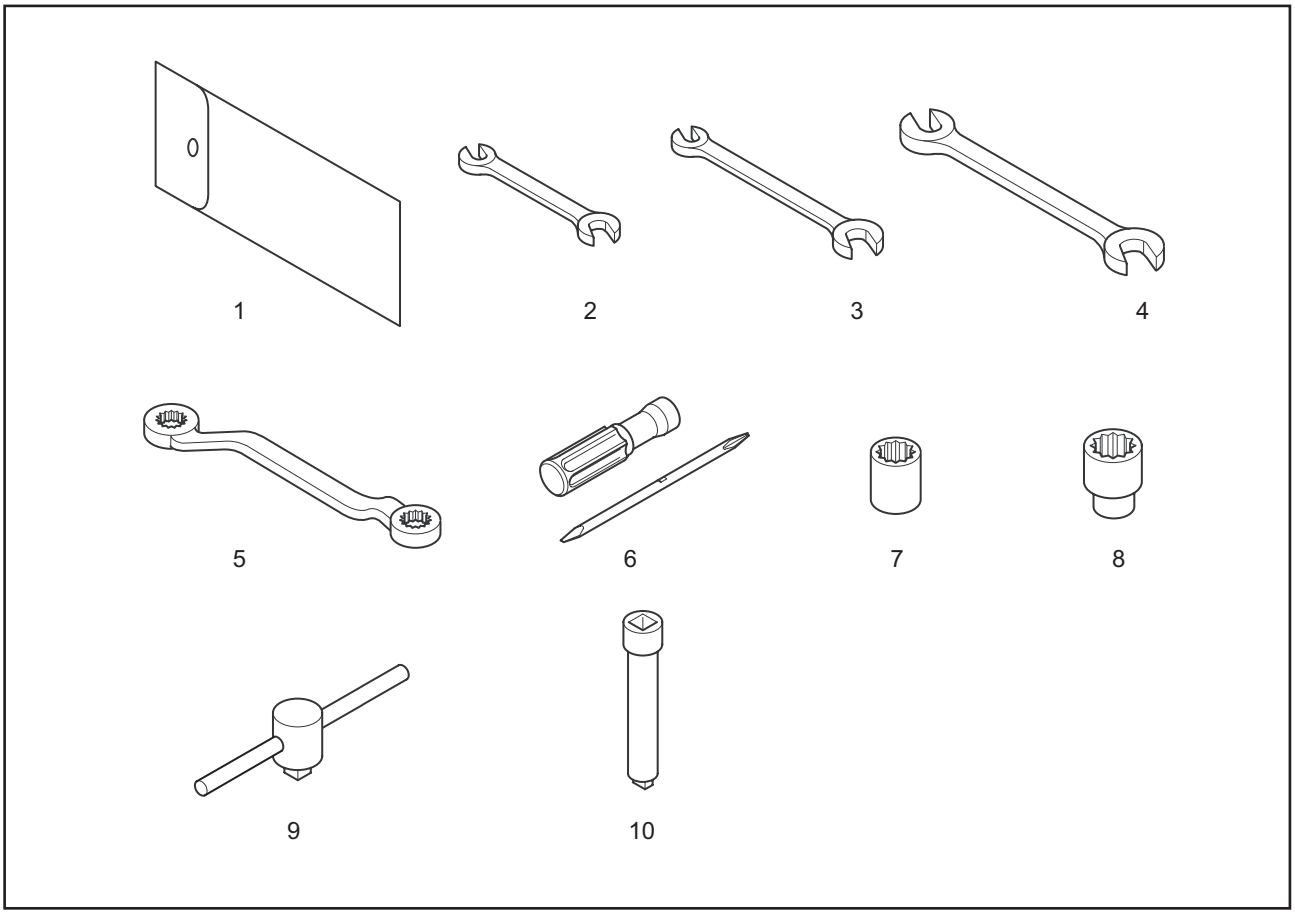
Table 2-13 Standard bolt and nut tightening torque

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)

SERVICE TOOLS

1. General tools



General tools

Table 3-1 General tool list

No.	Tool name	Part No.	Use
-	Tool set	32A91-00010	Includes parts No.1 through 10
1	Tool bag	34491-01102	
2	Spanner	F9600-10012	Width across flats: 10 × 12 mm [0.39 × 0.47 in.]
3	Spanner	F9600-14017	Width across flats: 14 × 17 mm [0.55 × 0.67 in.]
4	Spanner	F9600-22024	Width across flats: 22 × 24 mm [0.87 × 0.94 in.]
5	Wrench	F9612-12014	Width across flats: 12 × 14 mm [0.47 × 0.55 in.]
6	Screw driver	91267-00201	(+), (-)
7	Socket	F9614-17000	Width across flats: 17 mm [0.67 in.]
8	Socket	F9614-19000	Width across flats: 19 mm [0.75 in.]
9	Handle	F9618-25000	
10	Extension bar	F9615-15000	

2. Special tool

Table 3-2 Special tool list (1 / 3)

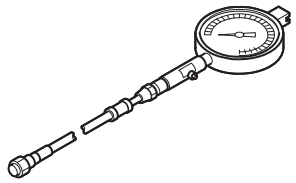
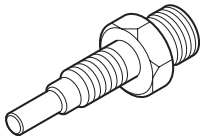
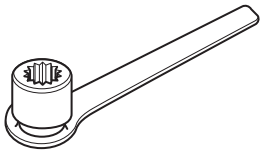
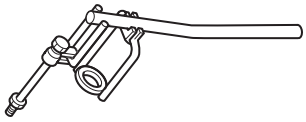
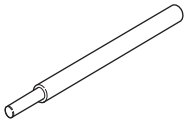
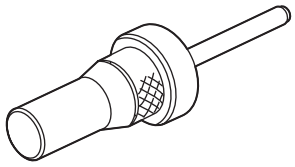
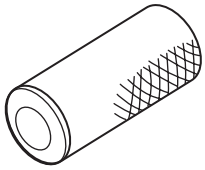
Tool name	Part No.	Shape	Use
Compression gauge	33391-02100		Engine compression pressure measuring 0 to 7 MPa {0 to 71.4 kgf/cm²} [0 to 1015.54 psi]
Gauge adapter	30691-21100		Engine compression pressure measuring
Turnine handle	30691-21800		Engine turning
Valve spring pusher	30691-04500		Valve spring removal/installation
Valve guide remover	32A91-00300		Valve guide removal
Valve sheet insert caulking tool	Inlet: 30691-02700 Exhaust: 30691-02800		Valve seat installation
Stem seal installer	32C91-10400		Stem seal installation

Table 3-2 Special tool list (2 / 3)

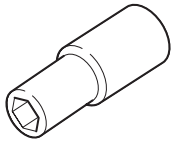
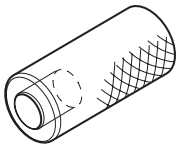
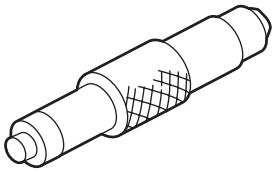
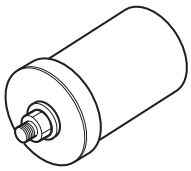
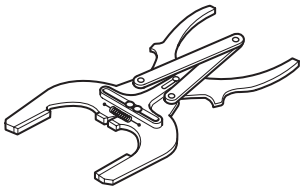
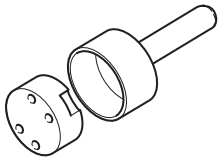
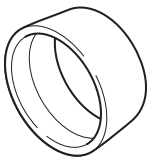
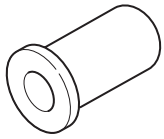
Tool name	Part No.	Shape	Use
Socket	34491-00300		Rocker bracket installation, camshaft thrust plate removal/ installation
Valve guide installer	32C91-00300		Valve guide installation
Idler bushing puller	30691-51900		Idler bushing removal/installation
Idler shaft puller	MH061077		Idler shaft removal
Piston ring pliers	31391-12900		Piston ring removal/installation
Oil seal sleeve installer set	30691-13010		Oil seal sleeve installation of crankshaft rear side
Piston guide	30691-58100		Piston installation

Table 3-2 Special tool list (3 / 3)

Tool name	Part No.	Shape	Use
Front oil seal installer	32C91-00500		Front oil seal installation

DETERMINATION OF OVERHAUL

1. Determining overhaul timing

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

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

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

2. Testing compression pressure

CAUTION

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

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

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

(d) On the new engine or overhauled engine, the compression pressure rises temporary due to breaking-in condition of the piston rings and the valve seats. But it drops later due to the wear of these parts.

(1) Remove the glow plugs from all cylinders.

(2) Attach the compression gauge adapter to the cylinder, and connect compression gauge.

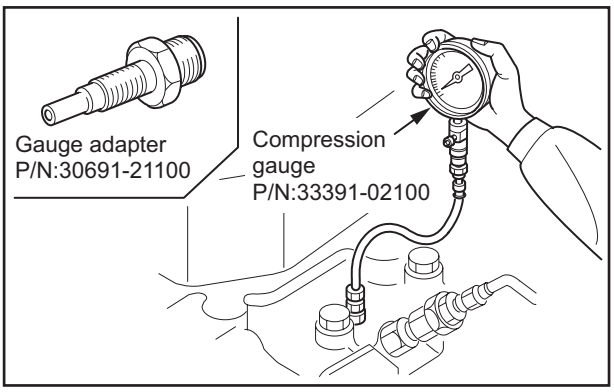
(3) Crank the engine with the starter, then read the compression gauge indication while the engine is running at the specified speed.

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

Item	Standard	Limit
Compression pressure	2.94 MPa {30 kgf/cm²} [427 psi]	2.55 MPa {26 kgf/cm²} [370 psi]

Note: (a) Measure the compression pressure with the engine running at 150 to 200 min^{-1}.

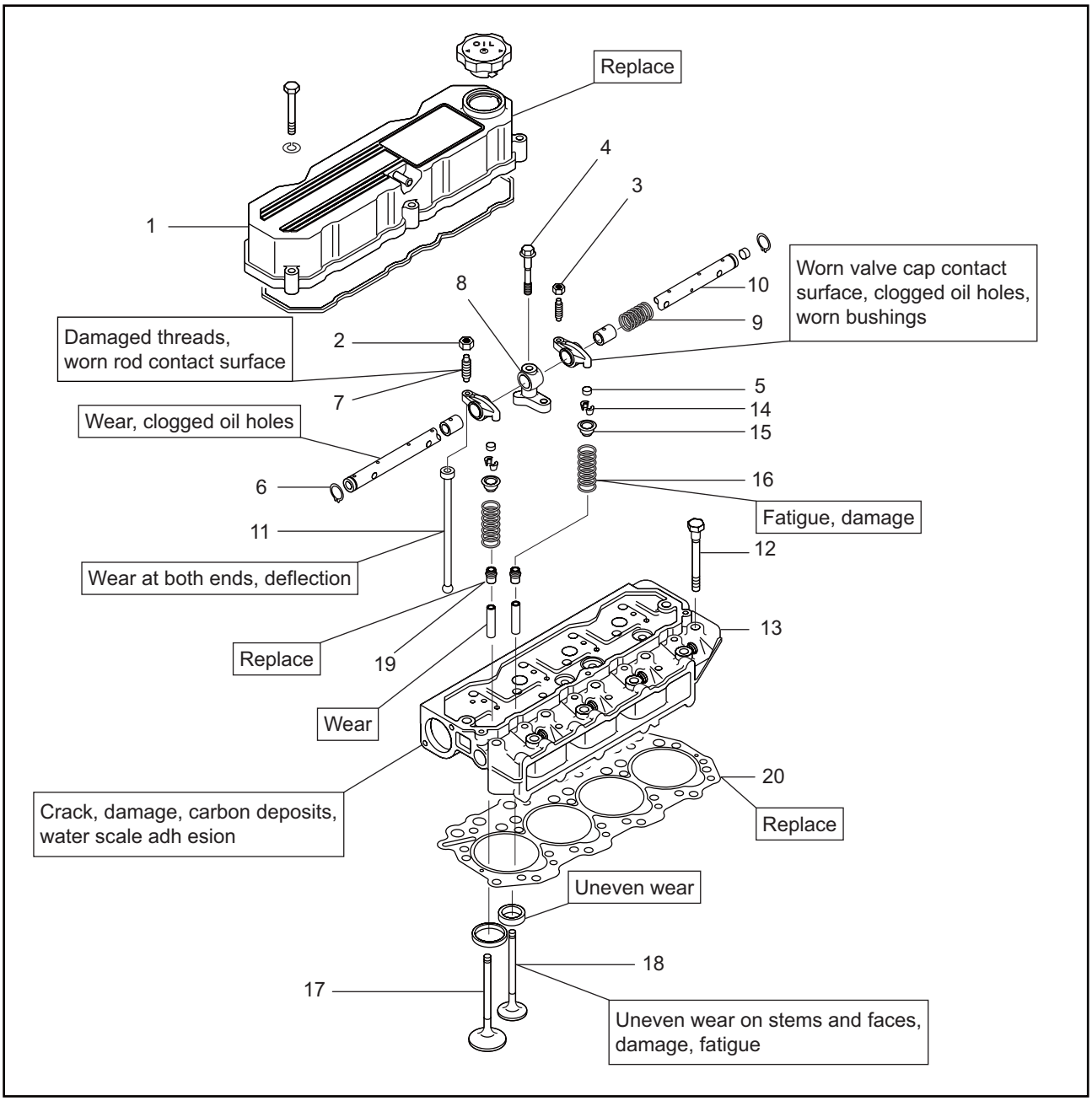
(b) Measure the compression pressure with the oil and coolant temperature at 20 to 30°C [68 to 86°F].



Testing compression pressure

DISASSEMBLY OF BASIC ENGINE

1. Disassembling and inspecting cylinder head and valve mechanism



Disassembling and inspecting cylinder head and valve mechanism

Disassembling sequence

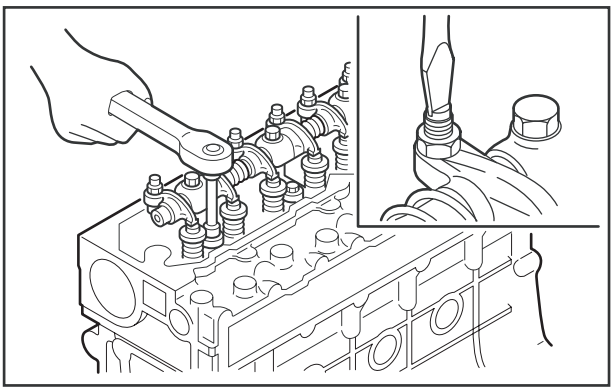
1 Rocker cover
2 Adjusting screw
3 Bolt (short)
4 Bolt (long)
5 Valve cap
6 Snap ring
7 Rocker arm
8 Rocket shaft bracket
9 Rocket shaft spring
10 Rocket shaft
11 Push rod
12 Cylinder head bolt
13 Cylinder head
14 Valve cotter
15 Valve retainer
16 Valve spring
17 Inlet valve
18 Exhaust valve
19 Valve stem seal
20 Cylinder head gasket

1.1 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.

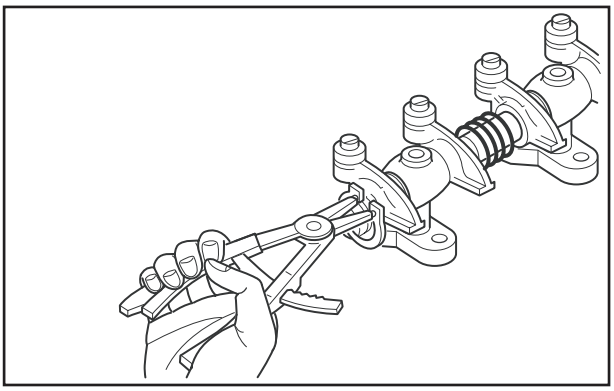


Removing rocker shaft assembly

1.2 Disassembling rocker shaft assembly

Disassemble the rocker shaft assembly.

Note: Be sure to arrange the parts in order during disassembly. Keep the original combination of rocker arm and shaft assembly, and when reassembling, make sure to install them in their original positions to restore the same clearance between the rocker shaft and arms.
Do not remove the rocker bushing unless it is defective or its inside diameter exceeds the limit.



Disassembling rocker shaft assembly

1.3 Removing cylinder head assembly

CAUTION

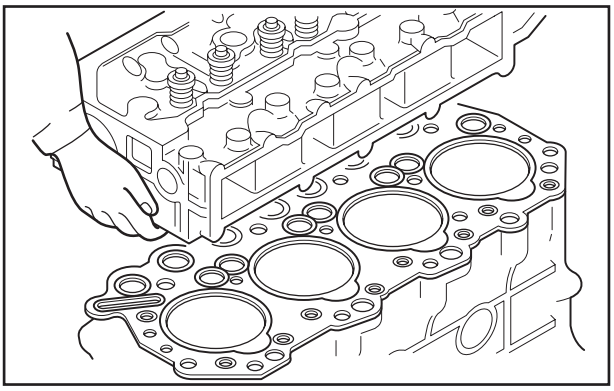
When removing the cylinder head gasket, be careful not to damage the cylinder head or crankcase surface by tools such as a screwdriver.

(1) Remove the cylinder head bolt.
(2) Remove the cylinder head assembly by lifting it up.

Note: If the cylinder head assembly cannot be removed due to crimping of the cylinder head gasket, tap the thick area on the side of the cylinder head using a plastic hammer to give a shock.

(3) Remove the gasket from the cylinder head.

Note: If there is a cylinder head problem, check the bolts for tightness with a torque wrench before removing the cylinder head bolts.

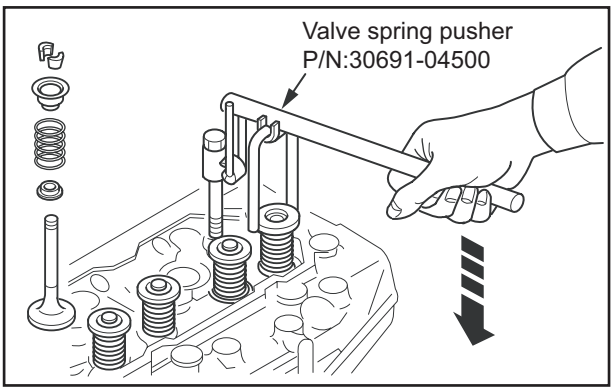


Removing cylinder head assembly

1.4 Removing valve and valve spring

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

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

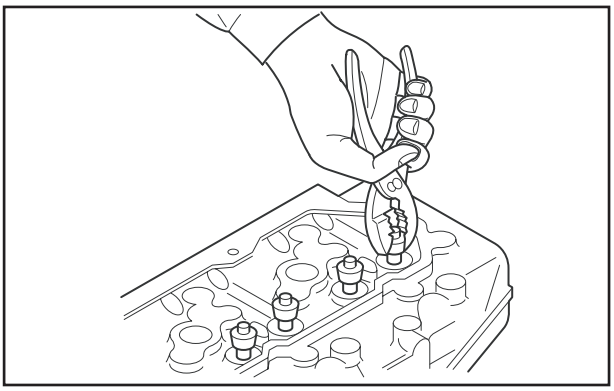


Removing valve and valve spring

1.5 Removing valve stem seal

Grab the stem seal with pliers and remove.

Note: Be sure to replace the stem seal with the new one when reassembling the valve and valve spring.

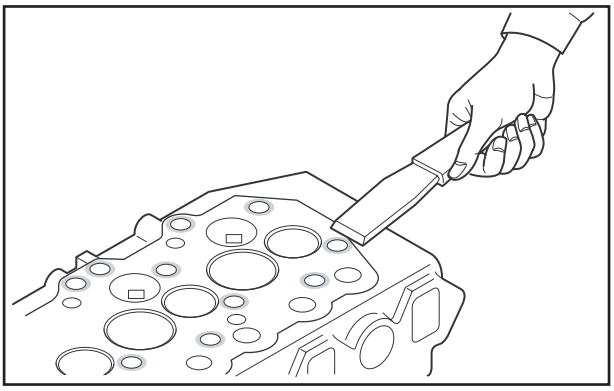


Removing valve stem seal

1.6 Cleaning cylinder head bottom surface

Taking care not to damage the cylinder head bottom surface, remove residue of old gasket.

Note: First, roughly scrape off residue of old gasket using a scraper. Then, grind off the remaining residue using an engine-oil immersed oil stone.



Cleaning cylinder head bottom surface

1.7 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.

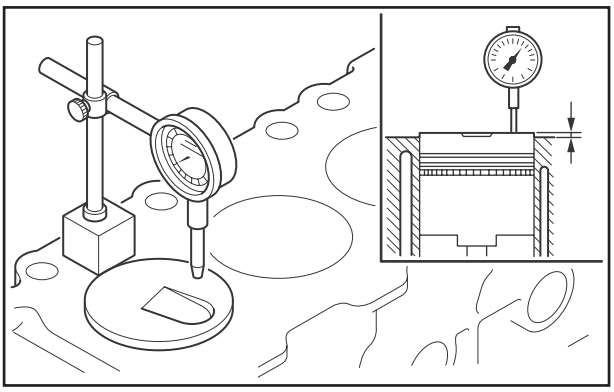
Measure the protrusion of each piston following the instructions below. If the measured value exceeds the limit, inspect and repair each bearings.

(1) Search the top dead center of the piston by using dial guage.

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

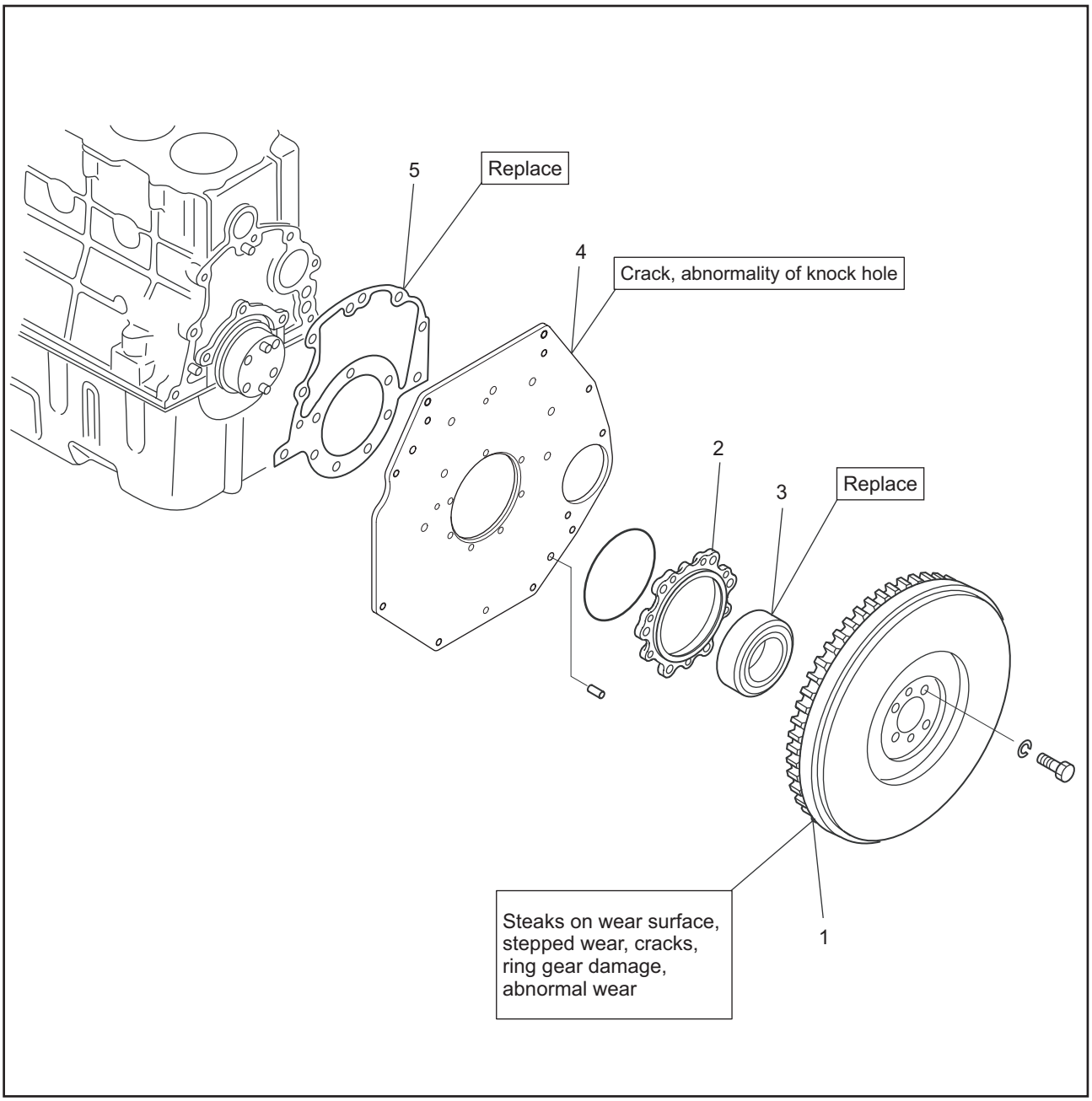
(3) Measure the protrusion at three points on the piston head, and calculate the mean value. Subtract the mean value from the thickness of the gasket compressed by tightening the cylinder head, and the clearance between the piston top and cylinder head will be determined.

Item	Standard
Piston protrusion	0.13 to 0.60 mm [0.0051 to 0.0236 in.]
Compressed thickness of cylinder head gasket	1.27 to 1.37 mm [0.0500 to 0.0539 in.]



Measuring piston protrusion

2. Disassembling and inspecting flywheel



Disassembling and inspecting flywheel

Disassembling sequence

1 Flywheel
2 Oil seal case
3 Oil seal
4 Rear plate
5 Gasket

2.1 Removing flywheel

⚠ CAUTION

(a) Be careful not to cut yourself with the ring gear when pulling out the flywheel.
Be careful not to drop or hit the flywheel when removing.

(b) The personnel who holds the pulley must pay due attention to safety.
Also, personnel must stay in close contact with each other during work.

(1) One personnel must firmly hold the pulley with a wrench to prevent the flywheel from turning.

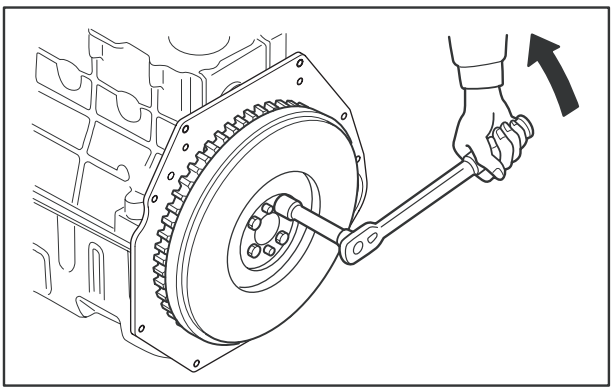
(2) Remove one bolt from the flywheel.

(3) Screw a guide bolt into the threaded hole of the bolt that has been removed.

(4) Remove remaining bolts from the flywheel.

(5) Hold the flywheel firmly with both hands, and by moving it back and forth, pull it out straight.

Note: The ring gear is shrink fitted to the flywheel. Do not remove the ring gear unless it is defective.



Removing flywheel

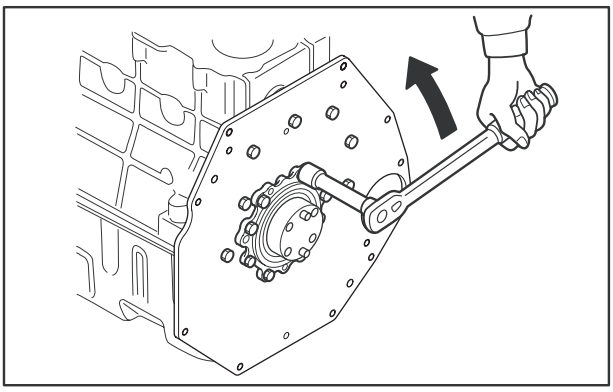
2.2 Removing oil seal case

CAUTION

Be very careful not to damage the oil seal.

(1) Remove bolts from the oil seal case.

(2) Pry out the oil seal case from the cylinder block using a screwdriver.



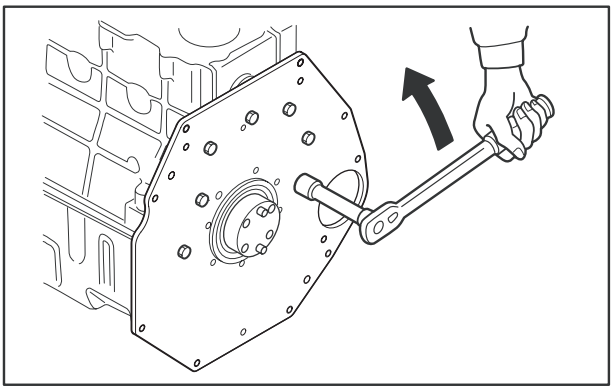
Removing oil seal case

2.3 Removing rear plate

CAUTION

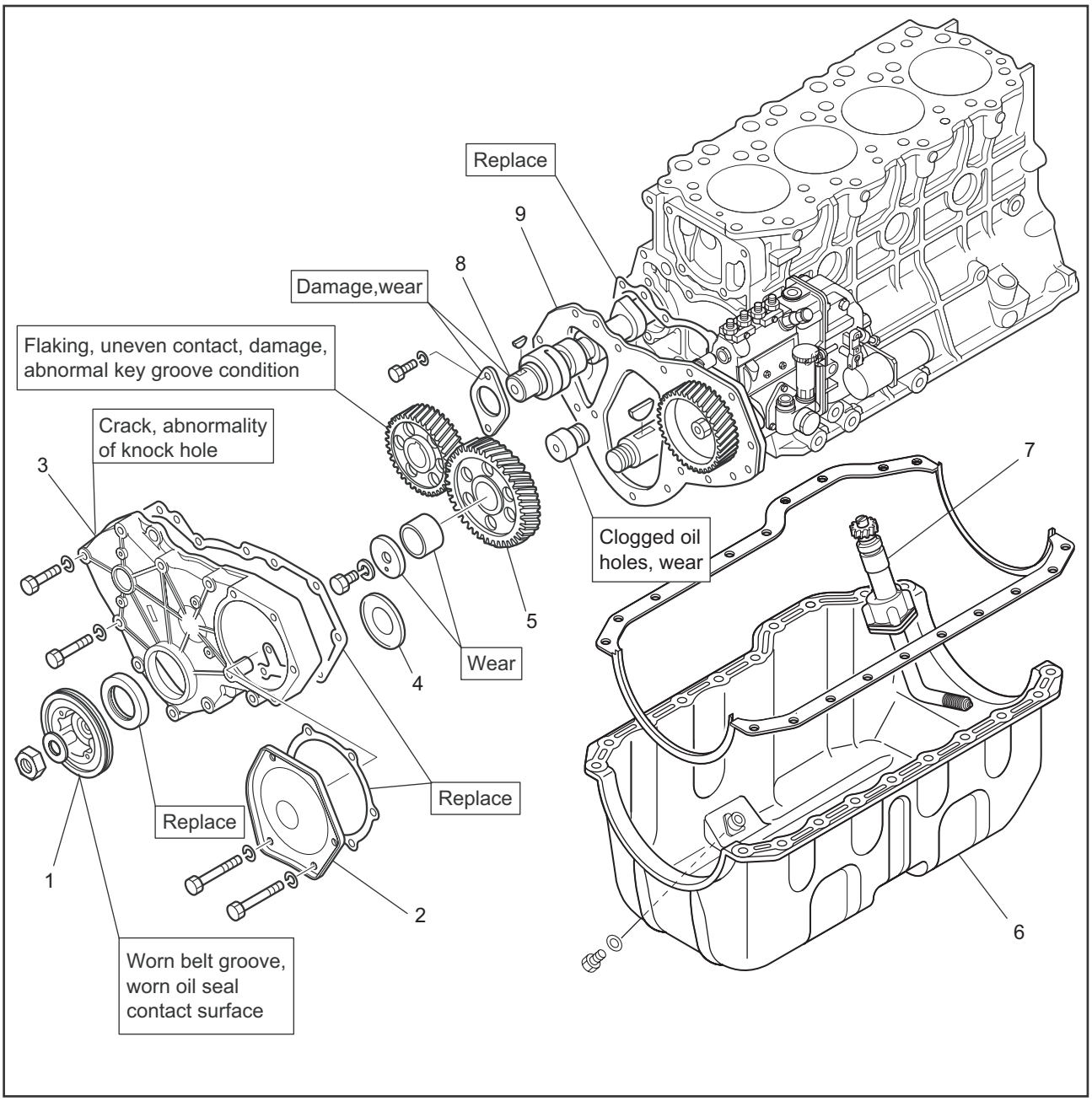
Be very careful not to damage the oil seal.

Remove the rear plate mounting bolts, and remove the rear plate.



Removing rear plate

3. Disassembling and inspecting timing gear, camshaft and oil pan



Disassembling and inspecting timing gear, camshaft and oil pan

Disassembling sequence

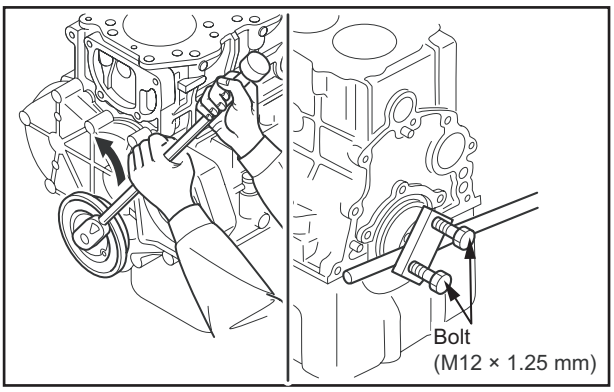
1 Crankshaft pulley
2 Cover
3 Timing gear case
4 Baffle plate
5 Idler gear
6 Oil pan
7 Oil pump
8 Camshaft
9 Front plate

3.1 Removing crankshaft pulley

⚠ CAUTION

The bar that stops the the crankshaft from turning may come off. Pay due attention to safety.

(1) Screw two guide bolts into the threaded holes at the rear end of the crankshaft. Stick a bar across the guide bolts to prevent the crankshaft from turning.
(2) Remove the crankshaft pulley.
(3) Take out the woodruff key of the crankshaft.



Removing crankshaft pulley

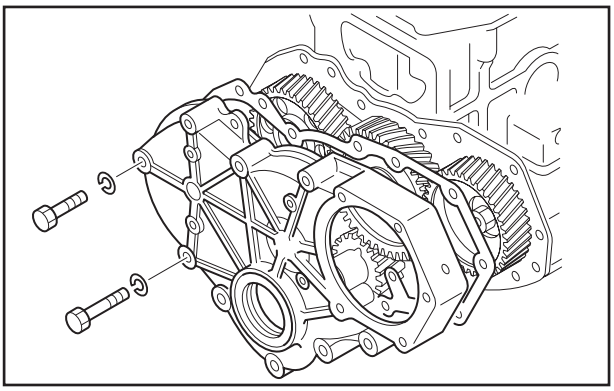
3.2 Removing timing gear case

CAUTION

The front plate is bolted to the crankcase from inside the gear case. Do not attempt to remove the front plate together with the gear case by tapping.

(1) Remove bolts from the timing gear case.
(2) Remove the timing gear case.

Note: Bolts have different lengths. Pay attention to the positions of bolts to ensure correct reassembling.

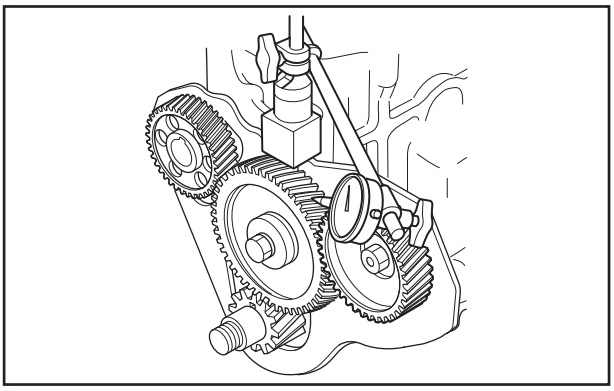


Removing timing gear case

3.3 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
Timing gear backlash	Between crankshaft gear and idler gear	0.03 to 0.16 mm [0.0012 to 0.0063 in.]	0.25 mm [0.0098 in.]
	Between idler gear and valve camshaft gear	0.04 to 0.17 mm [0.0016 to 0.0067 in.]	
	Between idler gear and pump camshaft gear	0.03 to 0.18 mm [0.0012 to 0.0071 in.]	



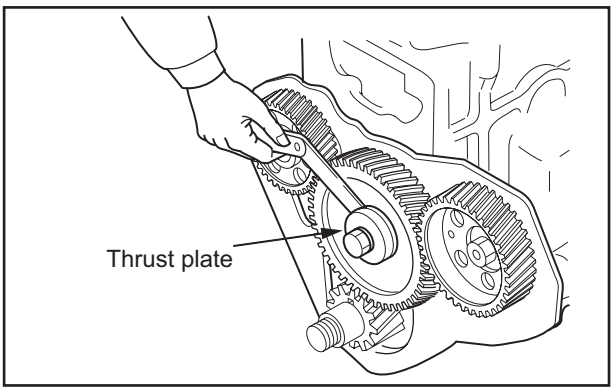
Measuring idler gear backlash

3.4 Measuring idler gear end play

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

If the measured value exceeds the limit, replace the idler gear with the new gear.

Item	Standard	Limit
End play	0.05 to 0.20 mm [0.0020 to 0.0079 in.]	0.35 mm [0.0138 in.]

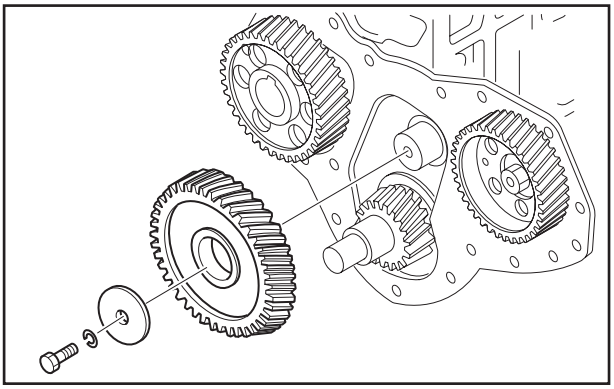


Measuring idler gear end play

3.5 Removing idler gear

(1) Remove the thrust plate bolt.

(2) Remove the idler gear while turning the gear.

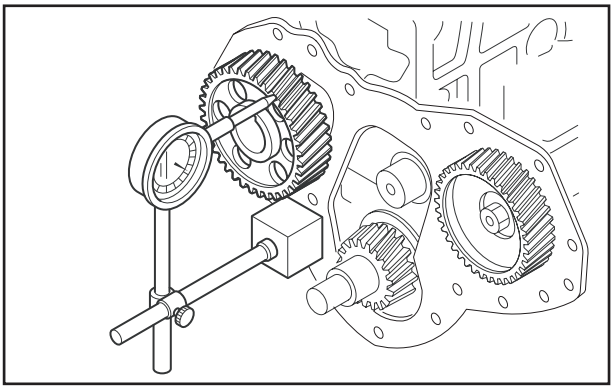


Removing idler gear

3.6 Measuring camshaft end play

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

Item	Standard	Limit
Camshaft end play	0.10 to 0.25 mm [0.0039 to 0.0098 in.]	0.30 mm [0.0118 in.]



Measuring camshaft end play

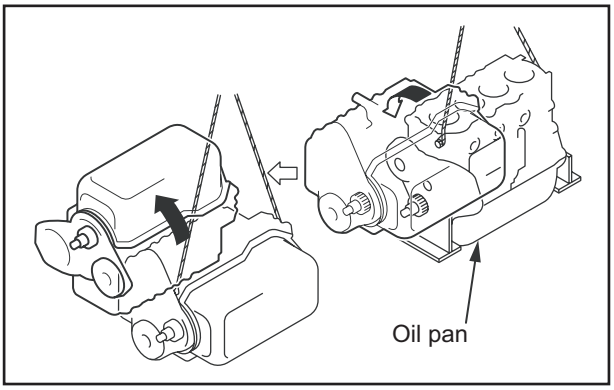
3.7 Inverting crankcase

⚠ CAUTION

Do not place the engine directly on the ground. It causes cracking the oil pan.

(1) Attach the wire rope to the crankcase. Using a crane, hoist the crankcase and lay it with its side faced downwards.

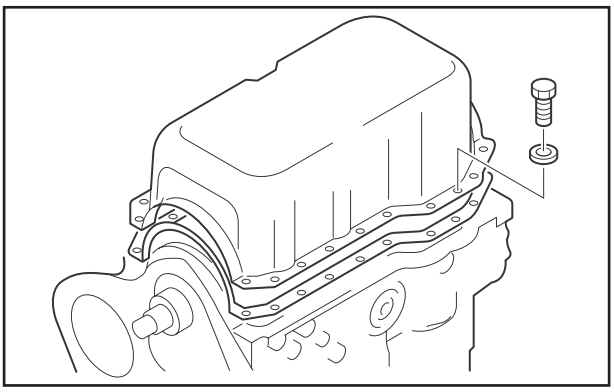
(2) After that, hoist the crankcase again and invert it.



Inverting crankcase

3.8 Removing oil pan and oil pan gasket

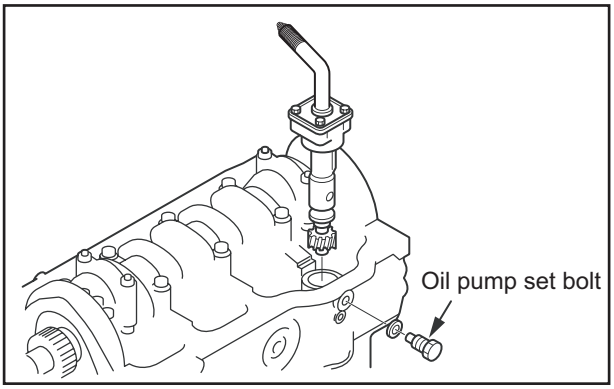
(1) Remove the bolts from the oil pan, and remove the oil pan from crankcase.
(2) Remove the oil pan gasket from crankcase.



Removing oil pan and oil pan gasket

3.9 Removing oil pump

Remove the oil pump set bolts, and pull out the oil pump from crankcase.



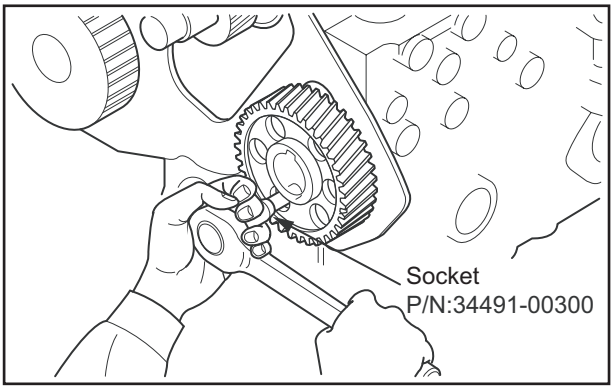
Removing oil pump

3.10 Removing camshaft

CAUTION

Be careful not to damage the cams of camshaft and the bushings.

(1) Rotate the camshaft to see the thrust plate bolt through the camshaft gear hole.
(2) By using the socket, remove the thrust plate bolt.
(3) Remove the camshaft from the crankcase.
(4) Remove the tappet.

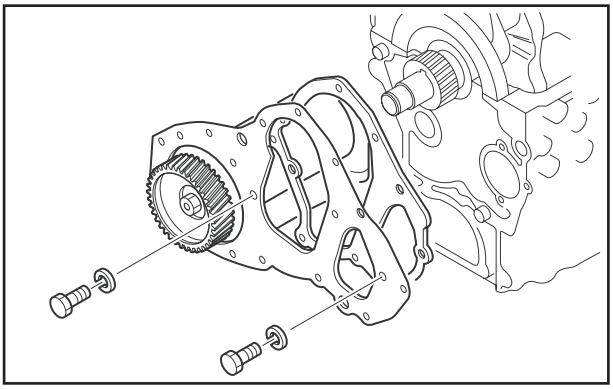


Removing camshaft

3.11 Removing front plate

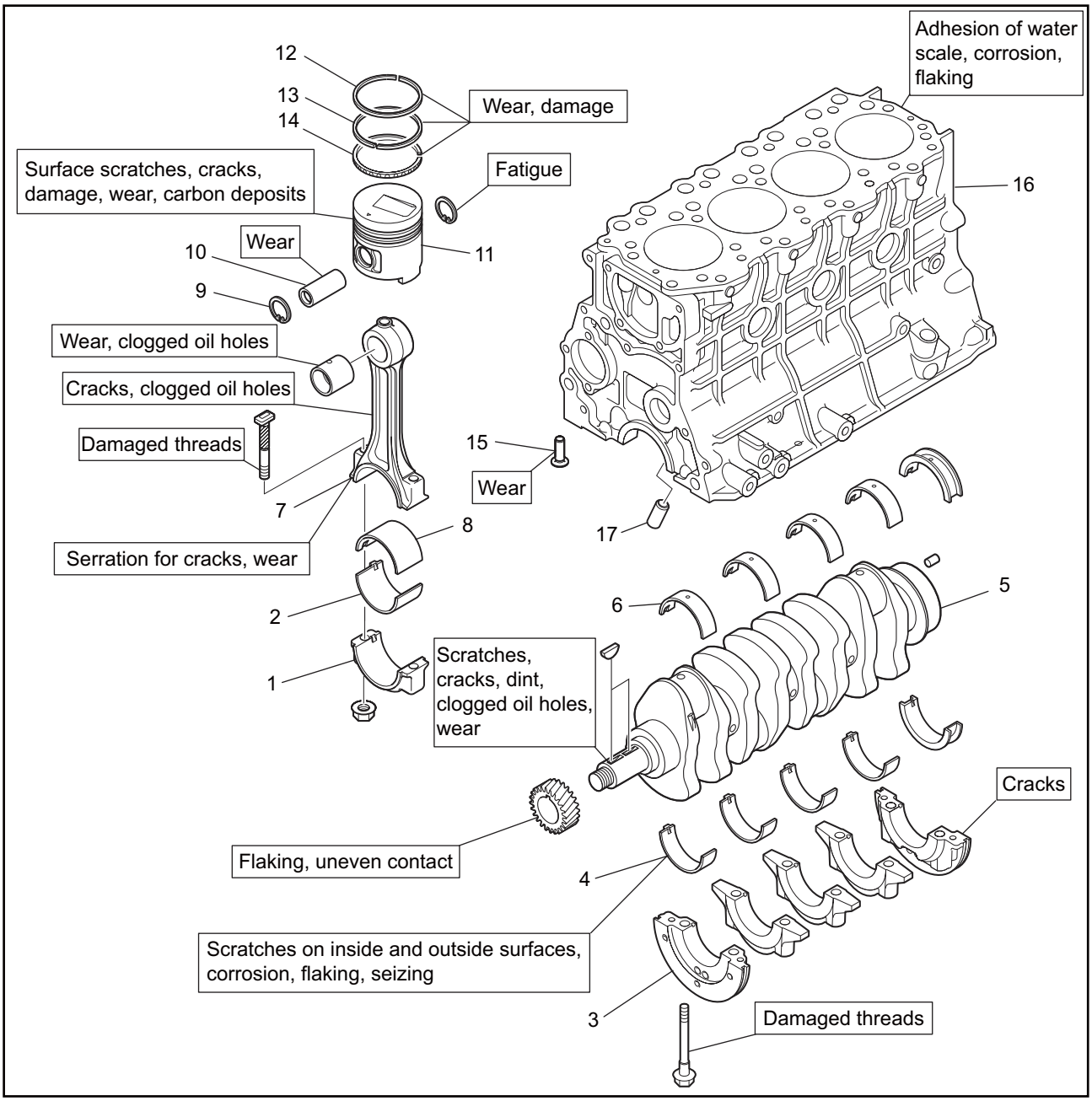
(1) Remove the front plate bolts.
(2) Remove the front plate from the crankcase.

Note: If it is difficult to remove the front plate, lightly tap it with a plastic hammer.



Removing front plate

4. Disassembling and inspecting piston, connecting rod, crankshaft and crankcase



Disassembling and inspecting piston, connecting rod, crankshaft and crankcase

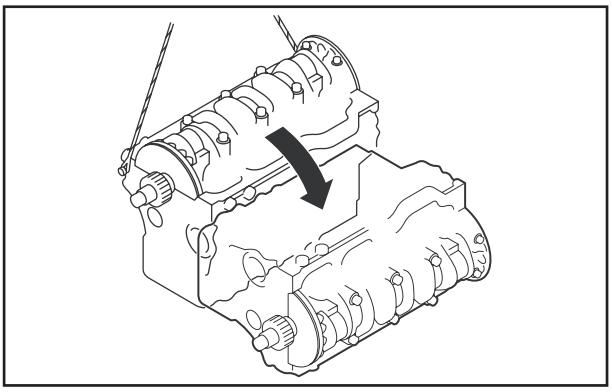
Disassembling sequence

1	Connecting rod cap	7	Connecting rod	13	No.2 compression ring
2	Connecting rod bearing (lower)	8	Connecting rod bearing (upper)	14	Oil ring
3	Main bearing cap	9	Snap ring	15	Tappet
4	Main bearing cap (lower)	10	Piston pin	16	Crankcase
5	Crankshaft	11	Piston	17	Check valve
6	Main bearing (upper)	12	No.1 compression ring		

Note: When replacing the crankcase, carefully remove parts (relief valve, etc.) mounted on the non-reusable crankcase so that they can be reused.

4.1 Laying crankcase on its side

Attach the wire rope to the crankcase. By using a crane, hoist the crankcase and lay it with its side faced downwards.



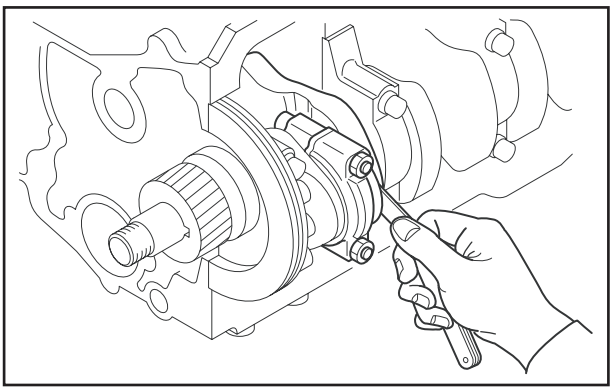
Layin crankcase on its side

4.2 Measuring connecting rod end play

(1) Measure the clearance (end play) between the connecting rod big-end and crankshaft by using the thickness gauge.

(2) If it exceeds the limit, replace the connecting rod with new one.

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



Measuring connecting rod end play

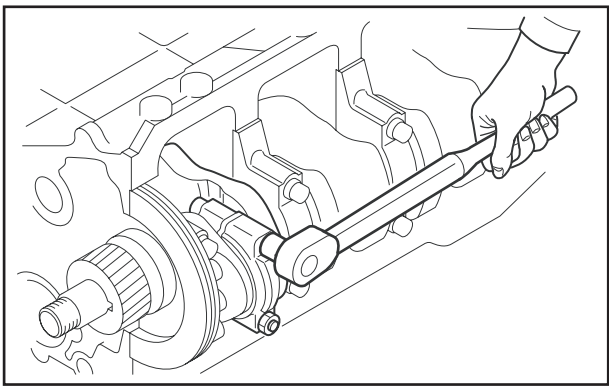
4.3 Removing connecting rod cap

(1) Mark the cylinder number on the connecting rod and connecting rod cap.

(2) Remove the connecting rod cap.

(3) Be sure to make the disassembled lower connecting rod bearing easy to recognize its cylinder number, and upper or lower.

Note: Be careful not to damage the bearings. Be sure to arrange the disassembled bearings in the order for correct assembly.



Removing connecting rod cap

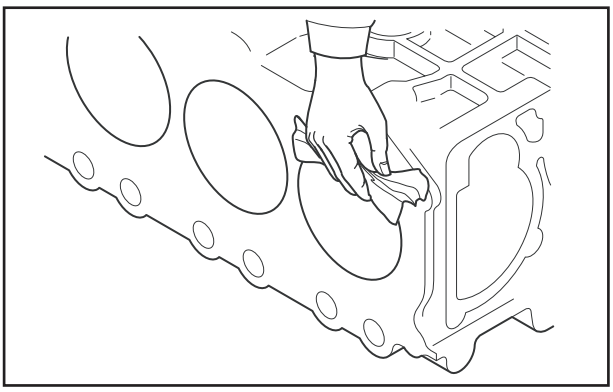
4.4 Removing carbon deposits from the upper part of cylinder

CAUTION

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

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

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

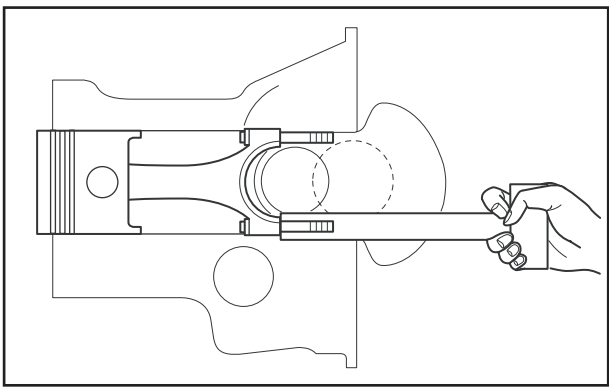


Removing carbon deposits
from the upper part of cylinder

4.5 Pulling out piston

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

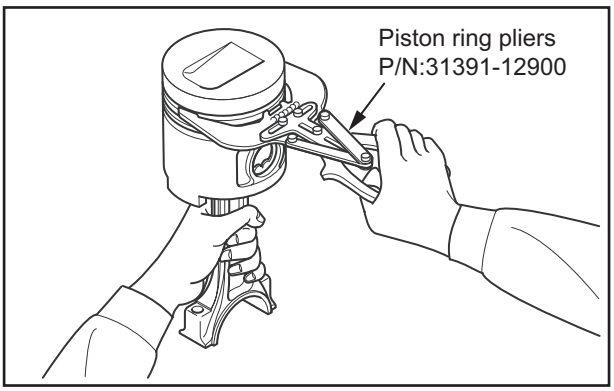
(2) Using a piece of wood such a hammer handle, push the mating surface of the connecting rod cap, and pull the piston and connecting rod upward from the cylinder.



Pulling out piston

4.6 Removing piston ring

Remove the piston rings using piston ring pliers.



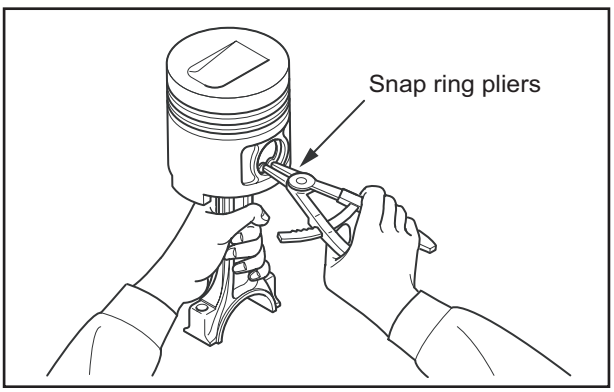
Removing piston ring

4.7 Removing piston pin

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

(2) Remove the piston pin, and separate the piston from the connecting rod.

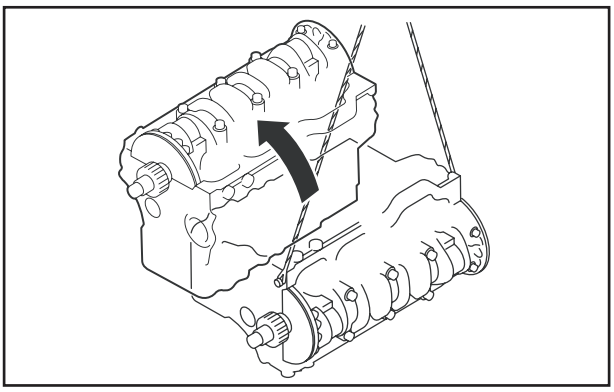
Note: Heat the piston with a piston heater or in hot water if the piston pin is stubborn.



Removing piston pin

4.8 Uprearing crankcase

Uprear the crankcase softly with its upper faced downward.



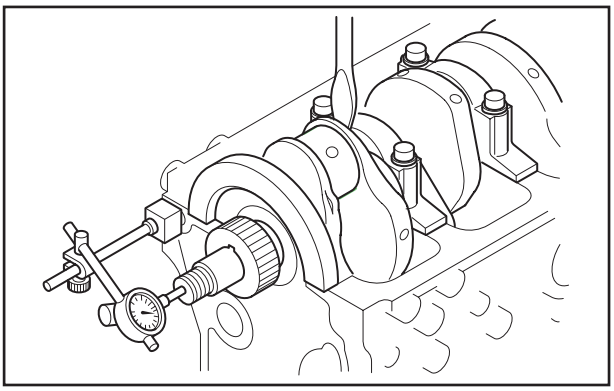
Positioning crankcase

4.9 Measuring crankshaft end play

(1) With attach the dial gauge to top of the crankshaft, measure the end play.

(2) If measured value exceeds the limit, replace the flange bearing with new one.

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



Measuring crankshaft end play

4.10 Removing main bearing cap

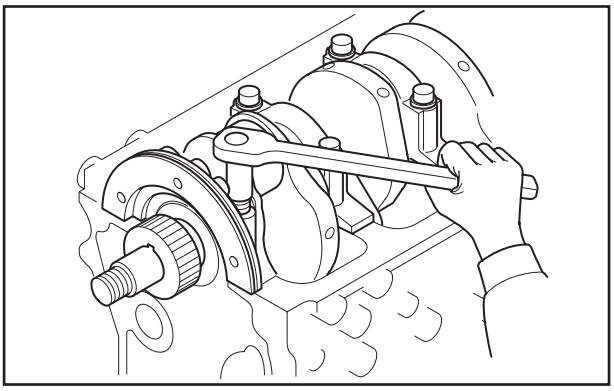
CAUTION

When removing the main bearing cap, be careful to not damage the lower main bearing lower that are attached to the cap. Also be careful not to drop those parts, which may damage the crankshaft.

(1) Unscrew the main bearing cap bolts.

(2) Unscrew the main bearing cap.

Note: Mark the bearings for their cylinder numbers.



Removing main bearing cap

4.11 Removing crankshaft

CAUTION

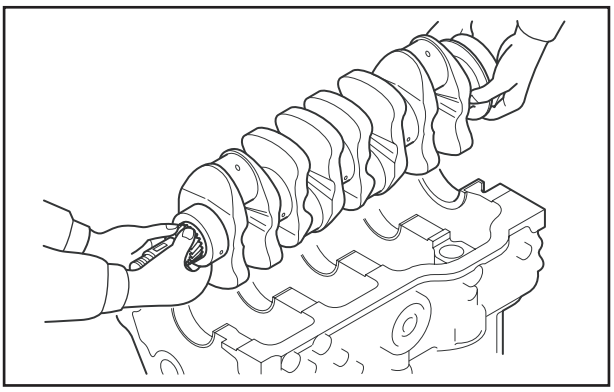
Be careful not to damage bearings when removing the crankshaft.

(1) Slowly lift the crankshaft straight up.

(2) Arrange the bearings in the order of disassembly so that their original positions are restored when reassembling.

Note: (a) When raising the crankshaft, do not allow wire chain to come into contact with the crankshaft. To avoid damage to the crankshaft when raising, use a cloth belt or pad.

(b) Mark the bearings for their cylinder numbers.



Removing crankshaft

INSPECTION AND REPAIR OF BASIC ENGINE

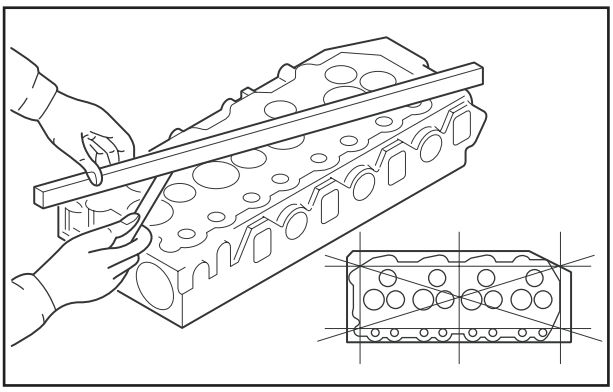
1. Inspecting and repairing cylinder head and valve mechanism

1.1 Measuring distortion of the bottom surface of the cylinder head

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	0.05 mm [0.0020 in.] or less	0.20 mm [0.0079 in.]

Note: Do not grind the surfaces more than 0.2 mm [0.008 in.] in total (cylinder head bottom surface plus crankcase top surface).



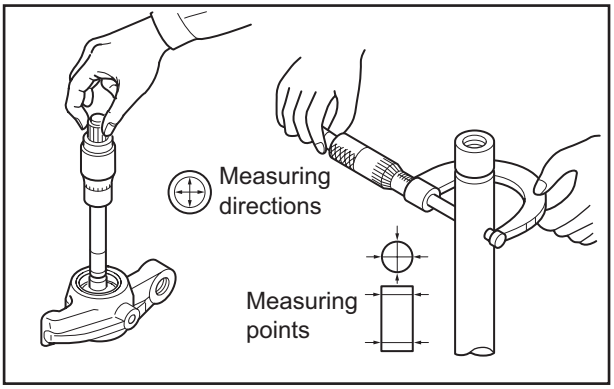
Measuring distortion of the bottom surface of the cylinder head

1.2 Measuring clearance between rocker arm and rocker shaft

Measure the inside diameter of the rocker arm and outside diameter of the rocker shaft.

Replace the rocker arm or rocker shaft if the clearance exceeds the limit.

Item	Nominal	Standard	Limit
Rocker arm inside diameter	ø 19 mm [0.75 in.]	19.01 to 19.03 mm [0.7484 to 0.7492 in.]	-
Rocker shaft diameter	ø 19 mm [0.75 in.]	18.98 to 19.00 mm [0.7472 to 0.7480 in.]	-
Clearance between rocker arm and shaft	-	0.01 to 0.05 mm [0.0004 to 0.0020 in.]	0.07 mm [0.0028 in.]

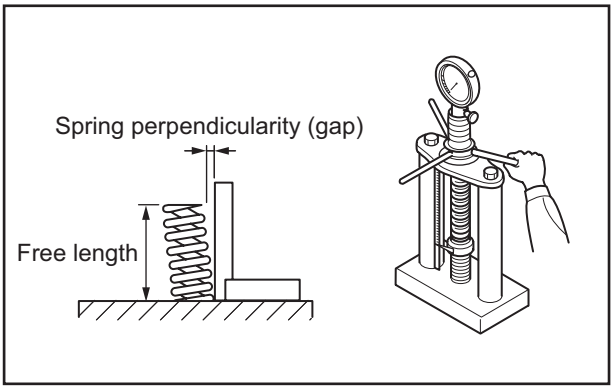


Measuring rocker arm inside diameter and rocker shaft outside diameter

1.3 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	48.85 mm [1.9232 in.]	47.60 mm [1.8740 in.]
Perpendicularity	θ = 1.5° or less Δ (gap) = 1.3 mm [0.051 in.] or less Lf = 48.85 mm [1.9232 in.]	Δ = 1.5 mm [0.059 in.] over entire length
Set length/set force	43 mm [1.69 in.]/ 176 to 196 N {18 to 20 kgf} [130 to 145 lbf]	43 mm [1.69 in.]/ 147 N {15 kgf} [108 lbf]

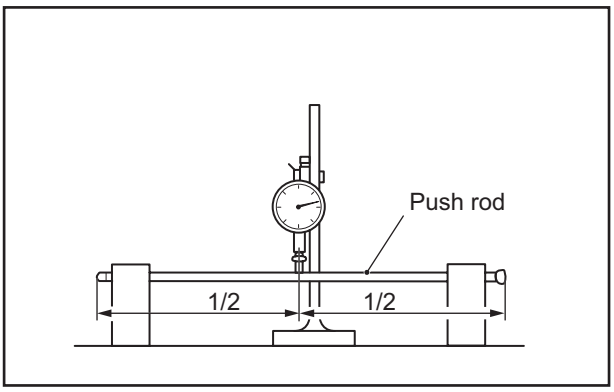


Squareness and free length of spring

1.4 Measuring push rod runout

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

Item	Standard	Remark
Push rod runout	0.3 mm [0.012 in.] or less	Total indicated reading (TIR)



Measuring push rod runout

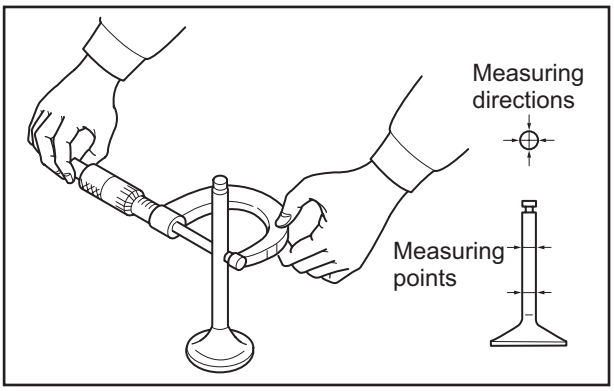
1.5 Measuring valve stem outside diameter and valve guide inside diameter

Remove the carbon deposits from valve and valve guide.

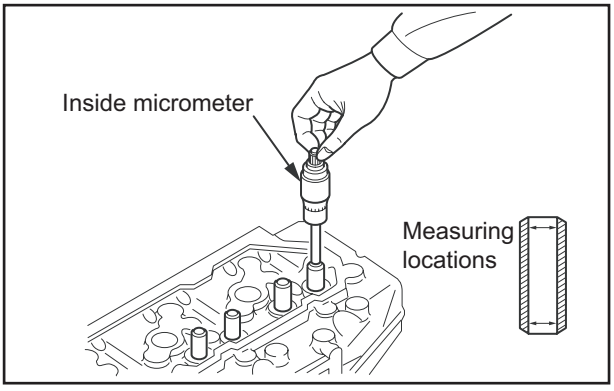
Measure the diameter at the top and bottom ends at right angles to the outer and inner surfaces, since valve stems and valve guides are more likely to wear at both ends.

If the outside diameter is less than the limit, or the clearance exceeds the limit, replace either the valve or the valve guide with a new one.

Item		Nominal	Standard	Limit
Valve stem outside diameter	Inlet	ø 8 mm [0.31 in.]	7.940 to 7.955 mm [0.3126 to 0.3132 in.]	7.900mm [0.3110 in.]
	Exhaust	ø 8 mm [0.31 in.]	7.920 to 7.940 mm [0.3118 to 0.3126 in.]	7.850 mm [0.3091 in.]
Clearance between valve stem and valve guide	Inlet	-	0.045 to 0.075 mm [0.0018 to 0.0030 in.]	0.130 mm [0.0051 in.]
	Exhaust	-	0.060 to 0.095 mm [0.0024 to 0.0037 in.]	0.150 mm [0.0059 in.]
Valve guide mounting dimension		15.5 mm [0.610 in.]	15.1 to 15.6 mm [0.594 to 0.614 in.]	-



Measuring valve stem outside diameter



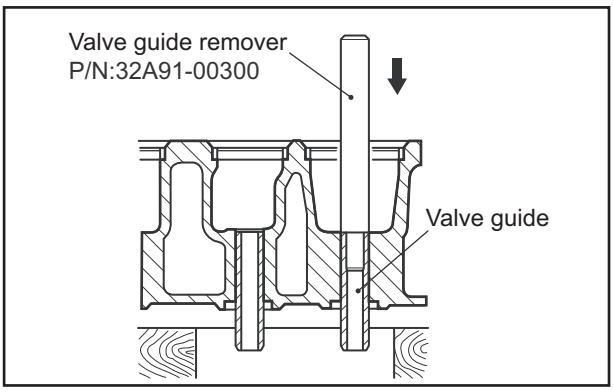
Measuring valve guide inside diameter

1.6 Replacing valve guide

CAUTION

Because valve guides must be inserted to the specified amount, be sure to use a valve guide installer.

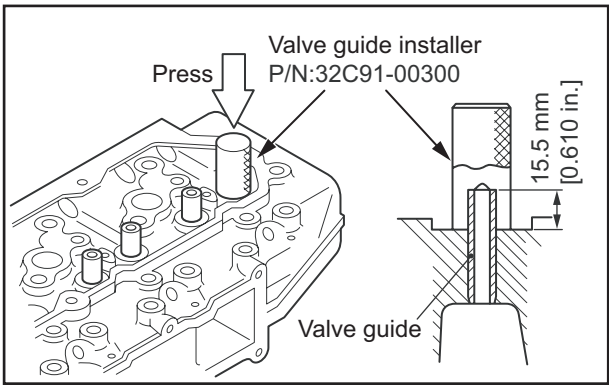
(1) To remove valve guides, use a valve guide remover.



Pulling out valve guide

(2) To press-fit valve guides, use a valve guide installer.

(3) Check contacts between valves and valve seats after replacing valve guides.



Press fitting valve guide

1.7 Inspecting valve face

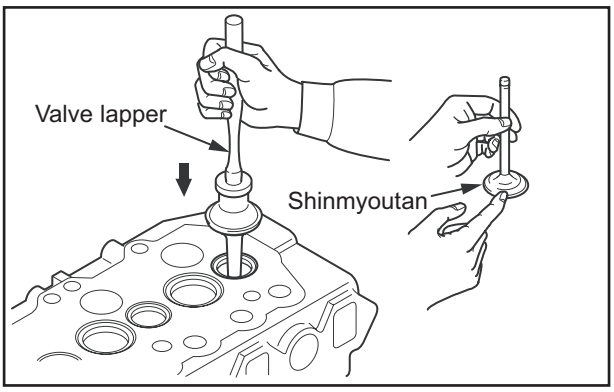
Apply a thin coat of Shinmyoutan or equivalent lead-free coloring paste on the valve face, and strike the valve face against the valve seat using a valve lapper to check for contact condition. If the contact is not even, or any defects are found, or if the limit is exceeded, reface or replace the valve.

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

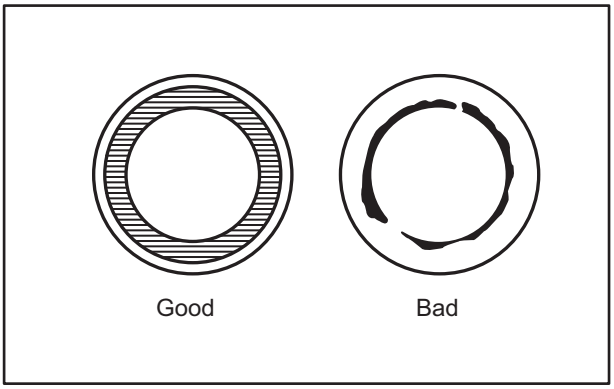
(b) Do not rotate the valve when pressing the valve face coated with Shinmyoutan or equivalent lead-free dye against the valve seat.

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

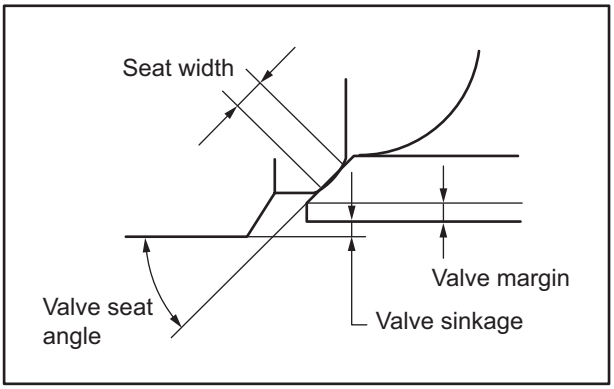
Item		Nominal	Standard	Limit
Valve seat	Valve seat angle	30°	-	-
	Valve sinkage	0.8 mm [0.031 in.]	0.7 to 0.9 mm [0.028 to 0.035 in.]	1.3 mm [0.051 in.]
	Seat width	1.18 mm [0.0465 in.]	1.04 to 1.32 mm [0.0409 to 0.0520 in.]	1.6 mm [0.063 in.]
Valve margin		1.7 mm [0.067 in.]	-	Refacing permissible up to 1.2 mm [0.047 in.]



Checking valve face



Valve-to-valve seat contact

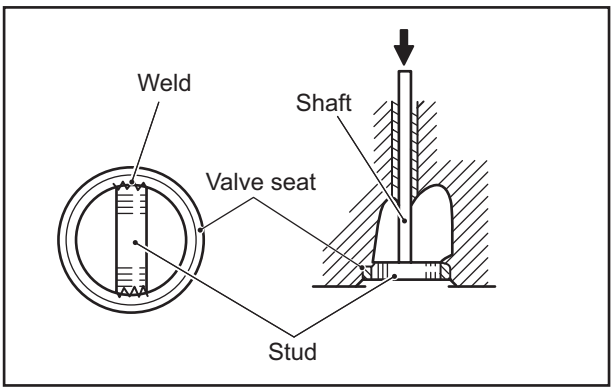


Valve-to-valve seat contact position

1.8 Replacing valve seat

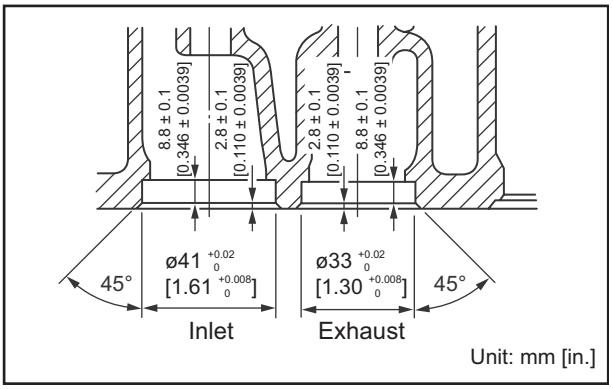
(1) To remove the valve seat, weld a stud to the valve seat as illustrated. Then, insert a rod into the valve guide hole from the top of the cylinder head, and press out the valve seat with the rod.

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



Removing valve seat using valve seat puller

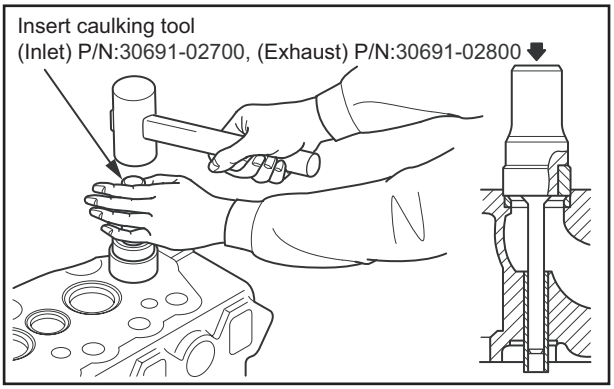
(2) Before inserting a new valve seat, measure the cylinder head bore diameter to make sure the interference meets the specified value.



Valve seat fitting bore

(3) Cool the valve seat for four minutes or more in liquid nitrogen (at approximately -170°C [-274°F]) before fitting it into the cylinder head, while keeping the cylinder head at room temperature. Or heat the cylinder head to 80 to 100°C [176 to 212°F] and cool the valve seat sufficiently in ether or alcohol mixed with dry ice before fitting it into the hot cylinder head.

(4) Fit the cold valve seat into the cylinder head using a insert caulking tool.



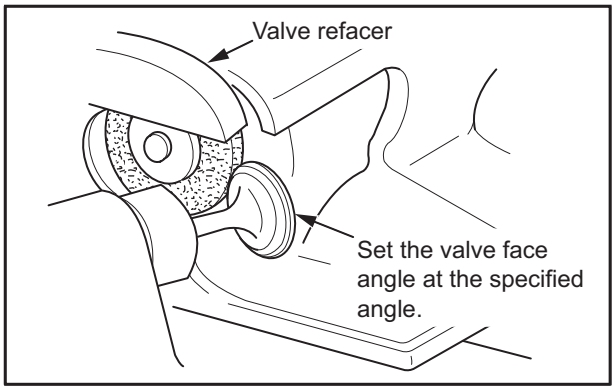
Driving in valve seat

1.9 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

1.10 Refacing valve seat

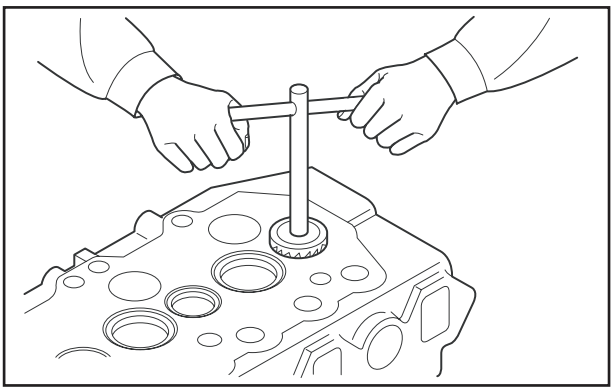
(1) Use the valve seat cutter or valve seat grinder to reface the valve seat. After refacing, sand the valve seat lightly using 400 grit sandpaper, inserting it between the cutter and valve seat.

(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

1.11 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.

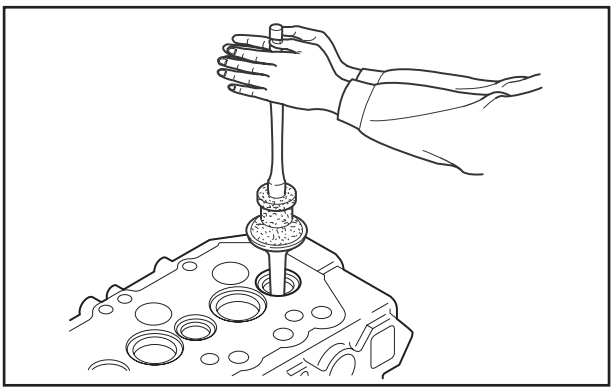
(c) Use medium-grain compound (120 to 150 mesh) for initial lapping, then use fine-grain compound (200 mesh or finer) for finishing.

(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.

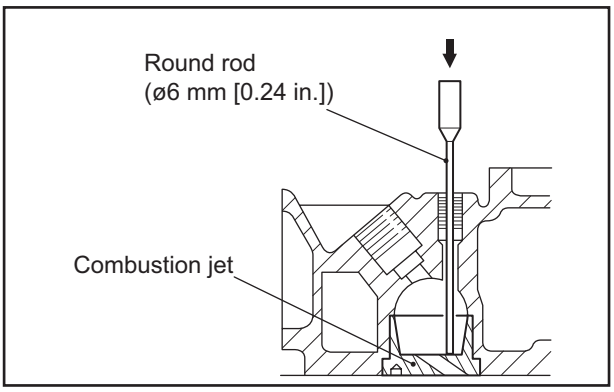


Lapping valve and valve seat

1.12 Removing combustion jet

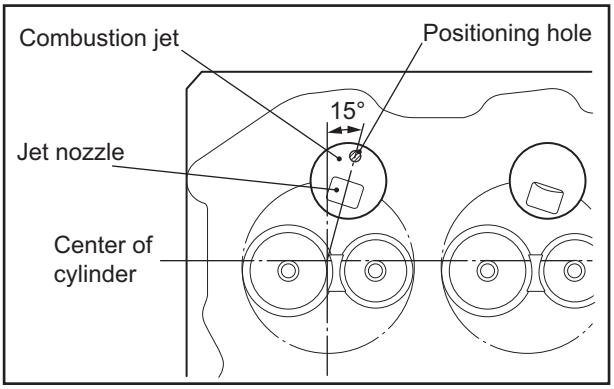
Replace the combustion jet only when it has defect as crack.

(1) Insert a round bar (approx; ø6 mm [0.24 in.]) into glow plug hole, and tap the combustion jet inner face perimeter lightly to pull out the combustion jet.



Removing combustion jet

(2) When installing the combustion jet, align the positioning hole and jet nozzle with the center of cylinder, press fit with tapping by plastic hammer.



Press-fitting combustion jet

2. Inspecting and repairing flywheel

2.1 Inspecting ring gear

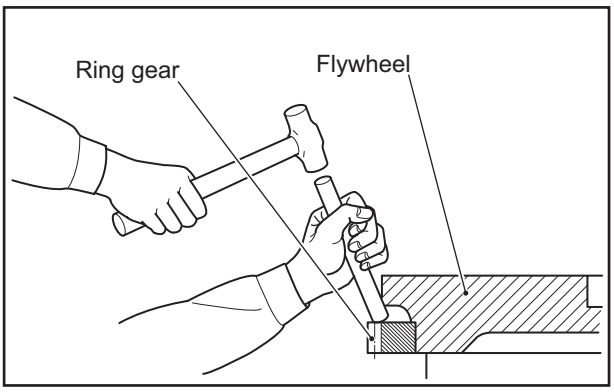
Inspect the ring gear for a missing tooth or worn teeth, and if defects are found, replace the ring gear.

2.2 Replacing ring gear

2.2.1 Removing ring gear

(1) Heat the ring gear evenly using an acetylene torch or other appropriate heat source.

(2) With a rod placed on the periphery of ring gear, tap the rod with a hammer evenly around the ring gear, and remove the ring gear.



Removing ring gear

2.2.2 Installing ring gear

(1) Heat the ring gear evenly up to approx. 150°C [176°F] with an appropriate heater.

(2) Install the ring gear onto the flywheel with the no-gear-chamfering side faced to the flywheel.

Note: Do not heat the ring gear excessively.

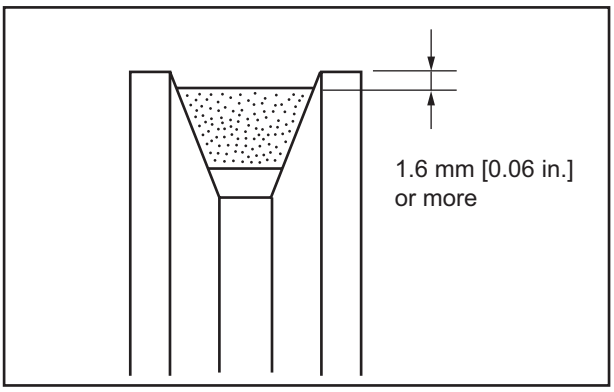
3. Inspecting and repairing timing gear, camshaft and oil pan

3.1 Inspecting V-pulley

Check the V-belt groove of the pulley for wear. Attach a new V-belt around a worn pulley, apply a high tension to the belt, and check whether the top surface of the belt is outside or inside of the pulley groove to determine the degree of pulley groove wear.

When the top surface of V-belt is outside the pulley groove, and the degree of wear is almost the same for every groove (when pulley has two belt grooves or more), the remaining service life of the pulley can be considered sufficient.

If the wear appears excessive, and the belt top surface sinks 1.6 mm or more down from the top edge of groove, the pulley is not reusable. Replace the pulley with a new one.



Inspecting V-belt groove wear

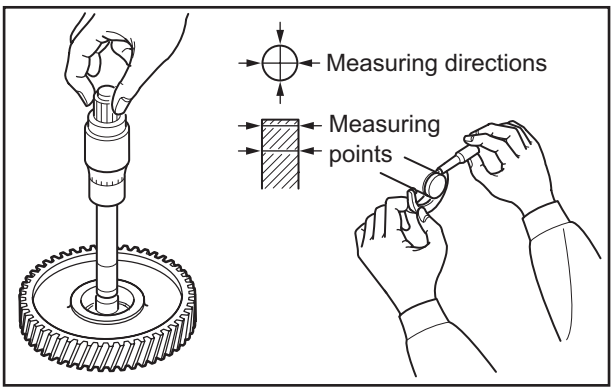
3.2 Inspecting oil seal contact surface

Inspect the oil seal contact surface of the pulley. If the pulley waers due to oil seal, replace the pulley with new one.

3.3 Measuring clearance between idler bushing and idler shaft

Measure the inside diameter of the idler bushing and outside diameter of the idler shaft. Replace the bushing if the clearance exceeds the limit.

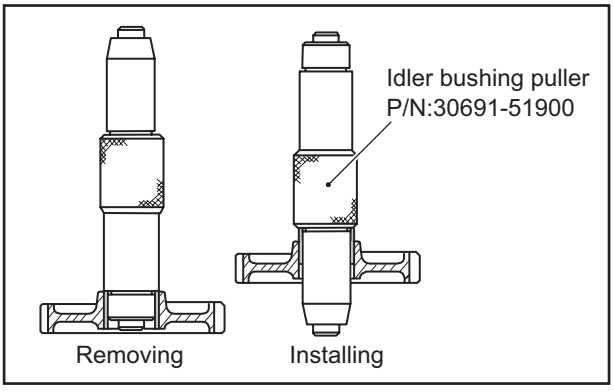
Item	Standard	Limit
Clearance between idler bushing and idler shaft	0.025 to 0.075 mm [0.0010 to 0.0030 in.]	0.100 mm [0.0039 in.]



Measuring idler bushing inside diameter and idler shaft diameter

3.4 Replacing idler bushing

(1) Use the idler bushing puller to replace idler bushing.
(2) To install the bushing, drive it from the boss side so that it is flush with the gear boss face.
(3) After installing the bushing, measure the bushing inside diameter, and if the inside diameter exceeds the standard, ream the bushing.

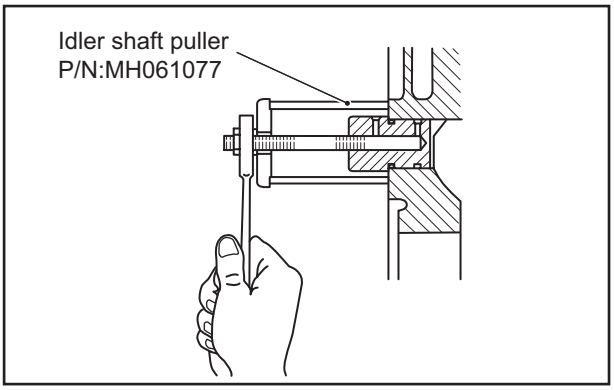


Replacing idler bushing

3.5 Replacing idler shaft

To remove the idler shaft, use the idler shaft puller.

Note: When installing the idler shaft into the crankcase, orient the idler shaft so that its oil hole faces the upper crankcase.

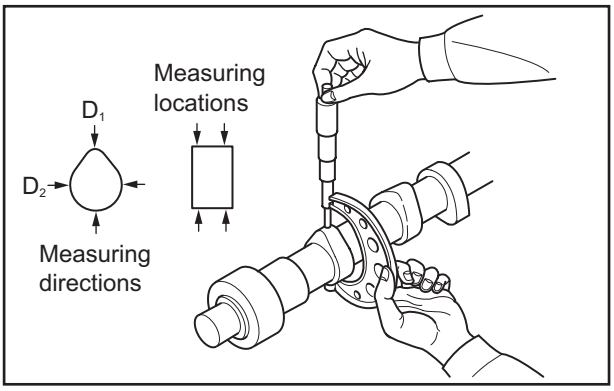


Replacing idler shaft

3.6 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		Nominal	Standard	Limit
Cam lift	Inlet	Major axis 46.916 $^{+0.1}_{-0.3}$ mm [1.8471 $^{+0.004}_{-0.012}$ in.]	Major axis–Minor axis = 6.684 mm [0.2631 in.]	Major axis–Minor axis = 6.184 mm [0.2435 in.]
	Exhaust	Major axis 45.944 $^{+0.1}_{-0.3}$ mm [1.8088 $^{+0.004}_{-0.012}$ in.]	Major axis–Minor axis = 7.344 mm [0.2891 in.]	Major axis–Minor axis = 6.844 mm [0.2694 in.]

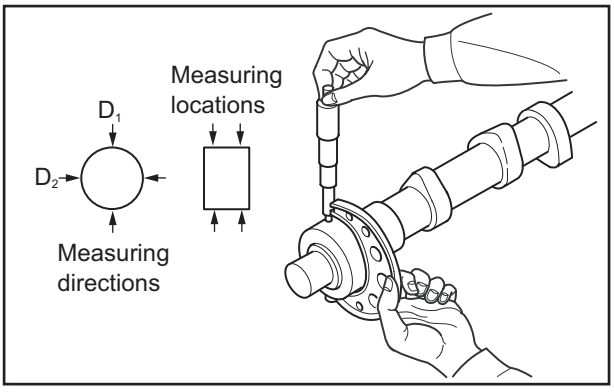


Measuring cam lift

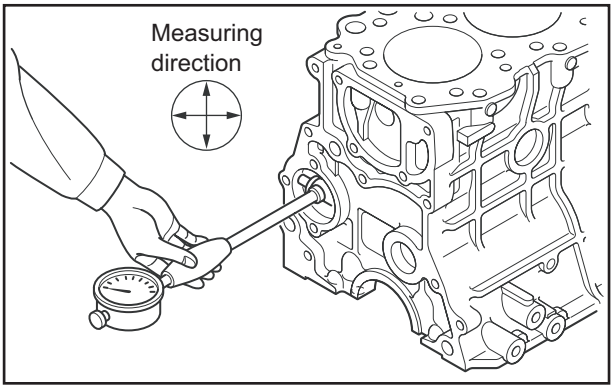
3.7 Measuring camshaft journal diameter and journal bore diameter

Measure the camshaft journal outside diameter and journal bore diameter. If measured values exceeds the limit, replace the camshaft with new one.

Item		Nominal	Standard	Limit
Camshaft journal outside diameter	No.1, 2	ø 54 mm [2.13 in.]	53.94 to 53.96 mm [2.1236 to 2.1244 in.]	53.90 mm [2.1220 in.]
	No.3	ø 53 mm [2.09 in.]	52.94 to 52.96 mm [2.0842 to 2.0850 in.]	52.90 mm [2.0827 in.]
Clearance between camshaft journal outside diameter and camshaft journal inside diameter		-	0.07 to 0.11 mm [0.0028 to 0.0043 in.]	0.15 mm [0.0059 in.]
Camshaft journal inside diameter	No.1, 2	ø 54 mm [2.13 in.]	54.03 to 54.05 mm [2.1272 to 2.1279 in.]	-
	No.3	ø 53 mm [2.09 in.]	53.03 to 53.05 mm [2.0878 to 2.0886 in.]	-



Measuring camshaft journal diameter



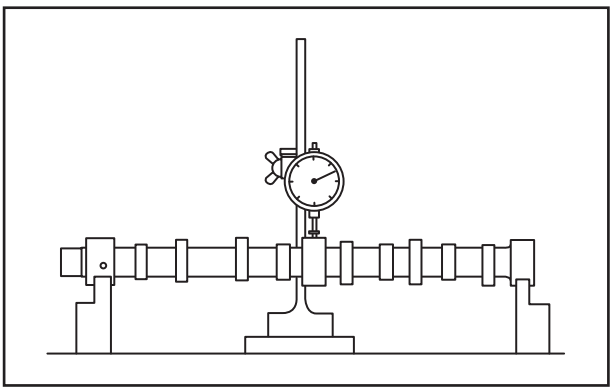
Measuring camshaft buhing inside diameter

3.8 Measuring camshaft runout

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

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

Item	Standard	Limit
Camshaft runout (TIR)	0.04 mm [0.0016 in.] or less	0.10 mm [0.0039 in.]

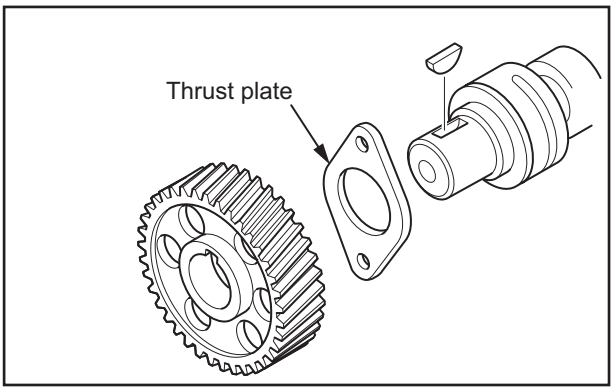


Measuring camshaft runout

3.9 Removing camshaft gear

Remove the camshaft gear by using a press.

Note: Remove the camshaft and thrust plate only when the camshaft gear has defect.



Removing camshaft gear

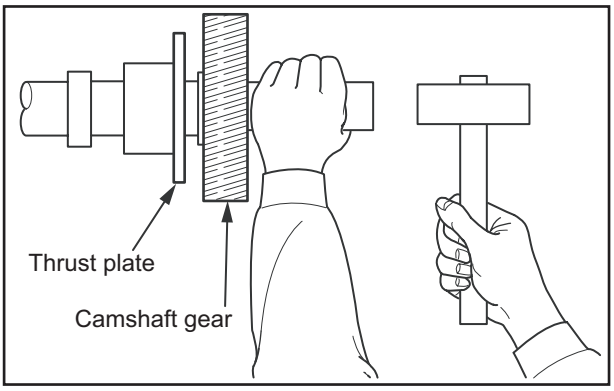
3.10 Installing camshaft gear and thrust plate

(1) Install the key and the thrust plate to the camshaft.

(2) Heat the camshaft to approximately 250°C [482°F] by using gear heater.

(3) Press fit the camshaft gear by tapping.

Note: Do not forget to insert the thrust plate before installing the camshaft gear.



Installing camshaft gear and thrust plate

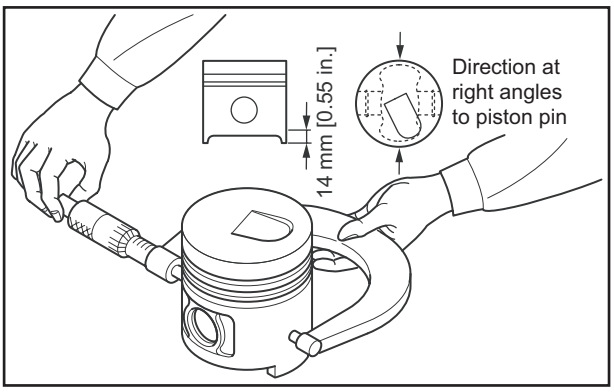
4. Inspecting and repairing piston, connecting rod, crankshaft and crankcase

4.1 Measuring piston outside diameter

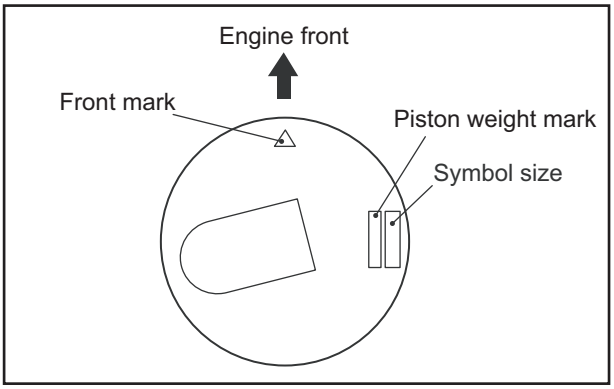
Using a micrometer, measure the piston outside diameter at the skirt perpendicular to the piston pins as shown in the illustration.

Item		Nominal	Standard	Limit
Piston outside diameter	STD	87.970 mm [3.4634 in.]	87.955 to 87.985 mm [3.4628 to 3.4640 in.]	87.770 mm [3.4555 in.]
	0.25 OS	88.220 mm [3.4732 in.]	88.205 to 88.235 mm [3.4726 to 3.4738 in.]	88.020 mm [3.4653 in.]
	0.50 OS	88.470 mm [3.4831 in.]	88.455 to 88.485 mm [3.4825 to 3.4837 in.]	88.270 mm [3.4752 in.]
Weight difference per piston			5g [0.20 oz.] or less	-

The piston weight is stamped on the top of piston head.



Measuring piston outside diameter



Piston weight stamp location

4.2 Measuring piston ring groove

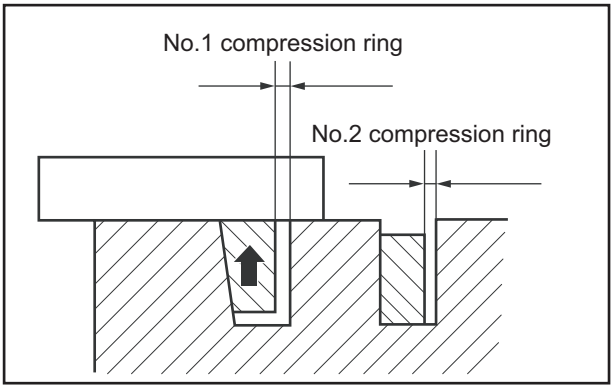
CAUTION

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

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

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

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



Measuring piston ring groove

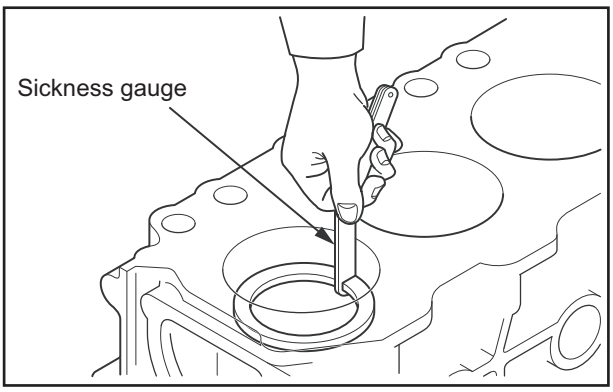
Item		Standard	Limit
Clearance between piston ring and ring groove	No.1 compression ring	0.060 to 0.100 mm [0.0024 to 0.0039 in.]	0.200 mm [0.0079 in.]
	No.2 compression ring	0.045 to 0.080 mm [0.0018 to 0.0031 in.]	0.150 mm [0.0059 in.]
	Oil ring	0.025 to 0.065 mm [0.0010 to 0.0026 in.]	0.150 mm [0.0059 in.]

4.3 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, 2 compression ring	0.25 to 0.40 mm [0.0098 to 0.0157 in.]	1.50 mm [0.0591 in.]
	Oil ring	0.30 to 0.50 mm [0.0118 to 0.0197 in.]	

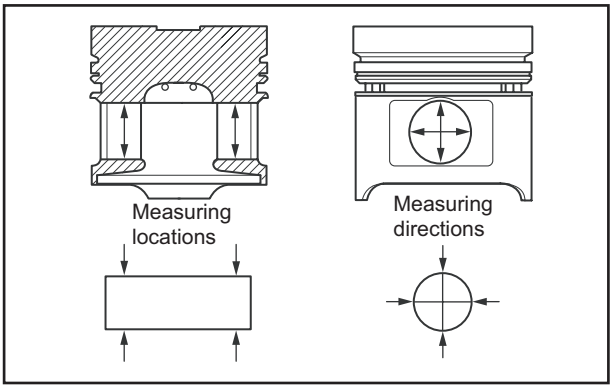


Measuring piston ring end gap

4.4 Measuring piston pin bore diameter and piston pin outside diameter

Measure the piston pin bore diameter and piston pin outside diameter. Replace if the limit is exceeded.

Item	Nominal	Standard	Limit
Piston pin inside diameter	ø 28 mm [1.10 in.]	28.000 to 28.010 mm [1.1024 to 1.1028 in.]	-
Piston pin outside diameter	ø 28 mm [1.10 in.]	27.994 to 28.000 mm [1.1021 to 1.1024 in.]	-
Clearance between piston pin bore and piston pin	-	0.000 to 0.016 mm [0.000 to 0.0006 in.]	0.050 mm [0.0020 in.]

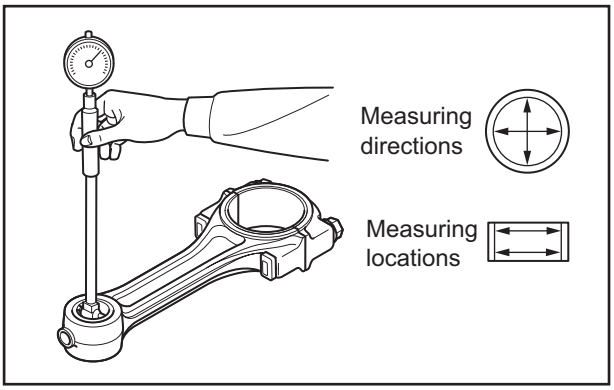


Measuring piston pin bore diameter and piston pin outside diameter

4.5 Measuring clearance between connecting rod bushing and piston pin

Measure the inside diameter of the connecting rod bushing and the outside diameter of the piston pin. Replace if the limit is exceeded.

Item	Nominal	Standard	Limit
Bushing inside diameter	ø 28 mm [1.10 in.]	28.020 to 28.045 mm [1.1031 to 1.1201 in.]	-
Clearance between bushing and piston pin	-	0.020 to 0.051 mm [0.0008 to 0.0020 in.]	0.080 mm [0.0031 in.]



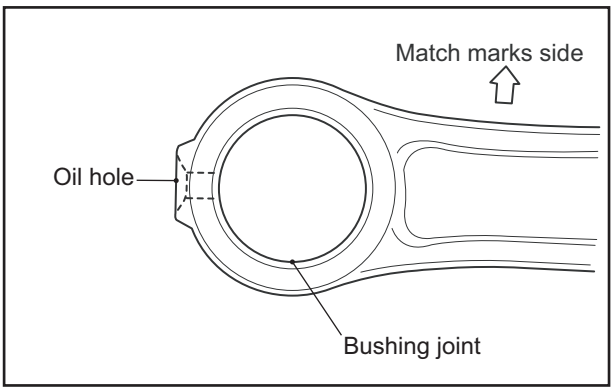
Measuring connecting rod bushing inside diameter

4.6 Replacing connecting rod bushing

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

(1) With the bushing joints oriented as shown in the illustration, align the oil hole of bushing with the oil hole of connecting rod, and press-fit the connecting rod bushing into the connecting rod.

(2) After press-fitting, insert the piston pin, and make sure the smooth movement of the connecting rod and piston without looseness.



Replacing connecting rod bushing

4.7 Inspecting connecting rod bend and twist

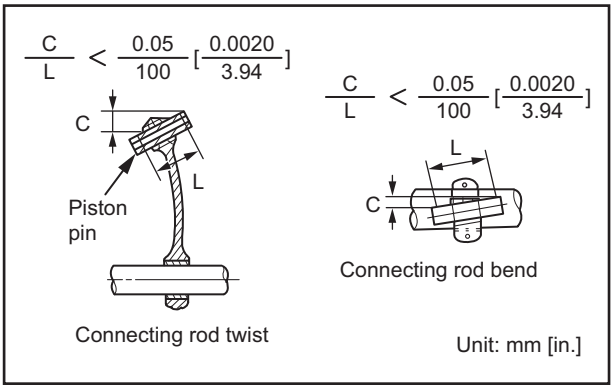
(1) Measure the dimensions of C and L in the illustration to check bend and twist of the connecting rod. Straighten the connecting rod with a press to meet the standard.
If the standard is exceeded after correction, replace the connecting rod with a new one.

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

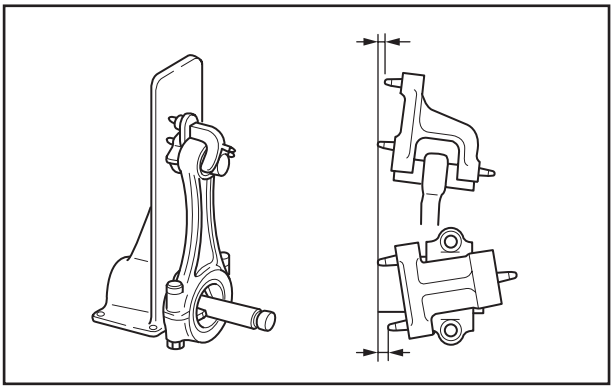
Note: Before checking bend, tighten the connecting rod cap to the specified torque.

(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.

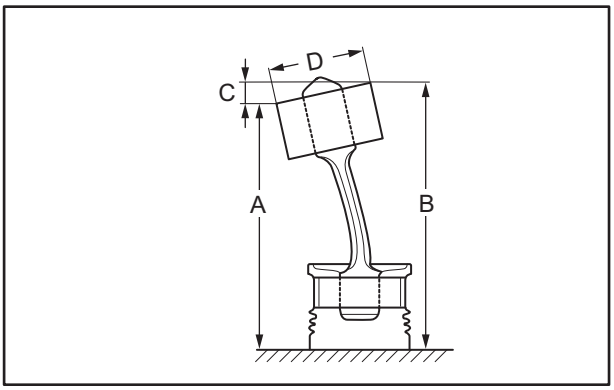
Item	Standard	Limit
Bend and twist of connecting rod	0.05/100 mm [0.0020/3.94 in.] or less	0.15/100 mm [0.0059/3.94 in.]



Inspecting connecting rod bend and twist



Using a connecting rod aligner to measure rod bend and twist

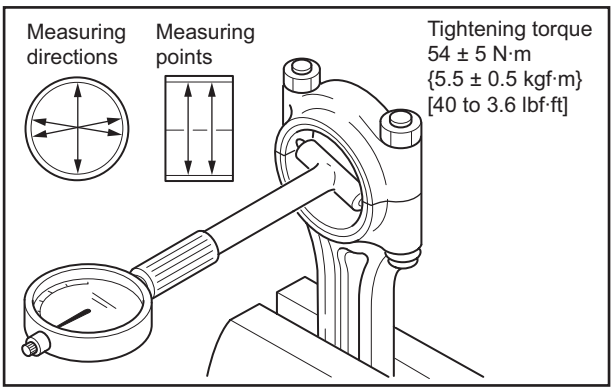


Measuring bend of connecting rod

4.8 Inspecting oil clearance of connecting rod bearing

(1) Install the bearing to the connecting rod big end. After tightening the connecting rod cap with the specified torque, measure the inside diameter of the bearing.

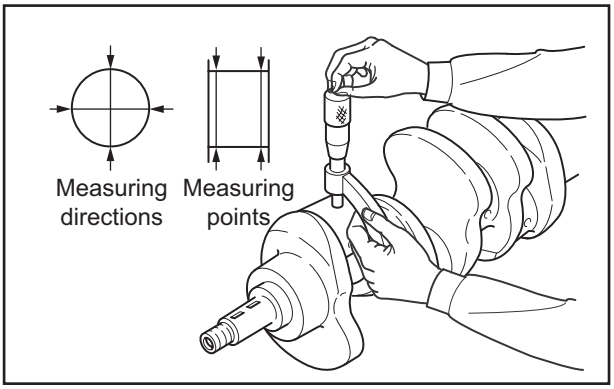
Item	Nominal	Standard	Limit
connecting rod bearing inside diameter	ø 58 mm [2.28 in.]	58.000 to 58.045 mm [2.2835 to 2.2852 in.]	-



Measuring connecting rod bearing inside diameter

(2) Measure the crankpin outside diamter. Calculate the oil clearance of connecting rod bearing by differential between the bearing inside diamter and the crankshaft pin outside diamter.

Item	Nominal	Standard	Limit
Pin outside diameter (S.T.D)	ø 58 mm [2.2835 in.]	57.950 to 57.970 mm [2.2815 to 2.2823 in.]	-
Oil clearance	-	0.030 to 0.095 mm [0.0012 to 0.0037 in.]	0.200 mm [0.0079 in.]

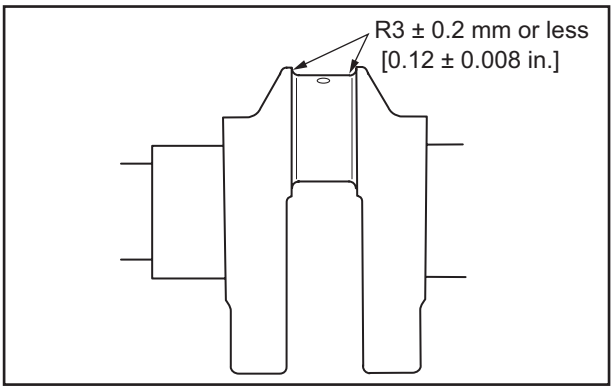


Measuring crankpin diameter

(3) If the oil clearance exceed the limit, install the new bearing and calculate the oil clearance again.

(4) Even so it exceeds the limit, use undersize bearings. (0.25, 0.50, 0.75 U.S) If an undersize bearing is used, grind the crankpin to the specified undersize refer to the following chart.

Item	Undersize	Finished size
Crankpin undersize	0.25 mm [0.0098 in.]	ø 57.75 $^{-0.030}_{-0.050}$ mm [2.2736 $^{-0.0012}_{-0.0020}$ in.]
	0.50 mm [0.0197 in.]	ø 57.50 $^{-0.030}_{-0.050}$ mm [2.2638 $^{0.0012}_{-0.0020}$ in.]
	0.75 mm [0.0295 in.]	ø 57.25 $^{-0.030}_{-0.050}$ mm [2.2539 $^{-0.0012}_{-0.0020}$ in.]



Width of crankshaft thrust bearing surface

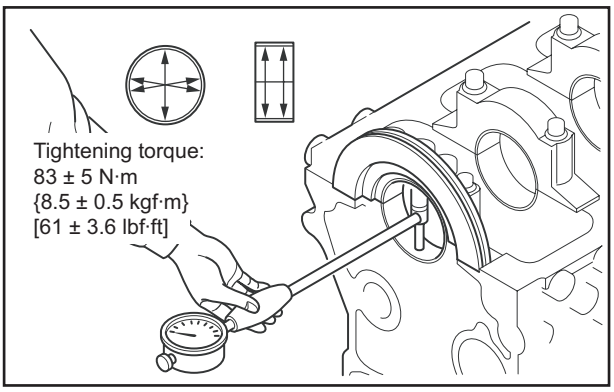
⚠ CAUTION

(a) When grinding the crankshaft pin, be sure to grind the all pin to same size.

(b) Finish the fillet R to R3±0.2 mm [R0.1181±0.0079 in.] or less.

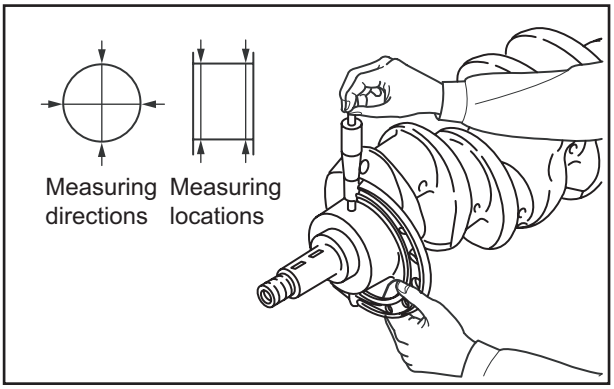
4.9 Inspecting oil clearance of main bearing

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



Measuring main bearing inside diameter

(2) Measure the crankshaft journal outside diameter. Calculate the oil clearance of the main bearing by the differential between the bearing inside diameter and the journal outside diamter.



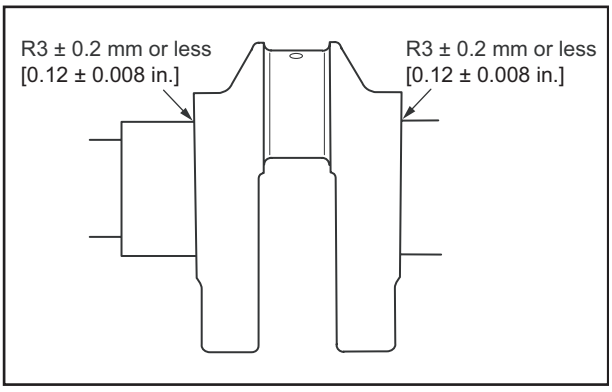
Measuring crank journal outside diameter

Item	Nominal	Standard	Limit
Journal outside diameter (S.T.D)	ø 65 mm [2.56 in.]	64.965 to 64.985 mm [2.5577 to 2.5585 in.]	-
Oil clearance	-	0.035 to 0.085 mm [0.0014 to 0.0033 in.]	0.200 mm [0.0079 in.]

(3) If the oil clearance exceed the limit, install the new bearing and calculate the oil clearance again.

(4) Even so it exceeds the limit, use undersize bearings. (0.25, 0.50, 0.75 U.S) If an undersize bearing is used, grind the crankpin to the specified undersize refer to the following chart.

Item	Undersize	Finished size
Crankpin undersize	0.25 mm [0.0098 in.]	ø 64.75 $^{-0.015}_{-0.035}$ mm [2.5492 $^{-0.0006}_{-0.0014}$ in.]
	0.50 mm [0.0197 in.]	ø 64.50 $^{-0.015}_{-0.035}$ mm [2.5394 $^{-0.0006}_{-0.0014}$ in.]
	0.75 mm [0.0295 in.]	ø 64.25 $^{-0.015}_{-0.035}$ mm [2.5295 $^{-0.0006}_{-0.0014}$ in.]



Width of crankshaft thrust bearing surface

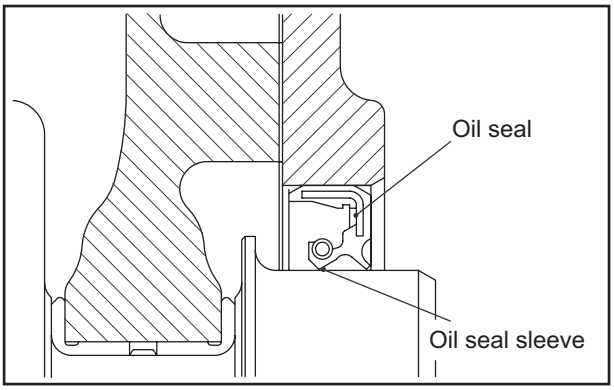
⚠ CAUTION

(a) When grinding the crankshaft journal, be sure to grind the all journals to same size.

(b) Finish the fillet R to R3±0.2 mm [R0.1181±0.0079 in.] or less.

4.10 Inspecting oil seal contact surface

Inspect the oil seal contact surface located on the crankshaft rear part. If the crankshaft wears due to the oil seal, replace the oil seal and the oil seal sleeve with new spare parts.



Installing front oil seal (1)

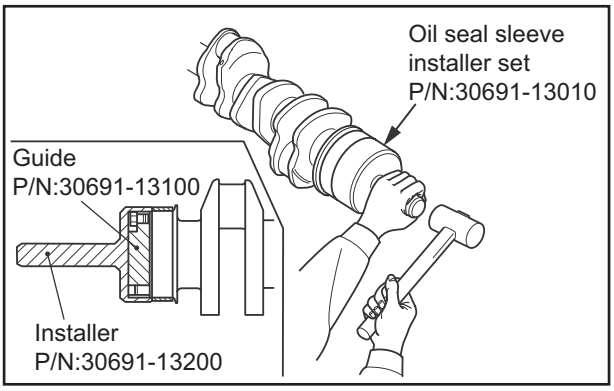
4.10.1 Installing oil seal sleeve

⚠ CAUTION

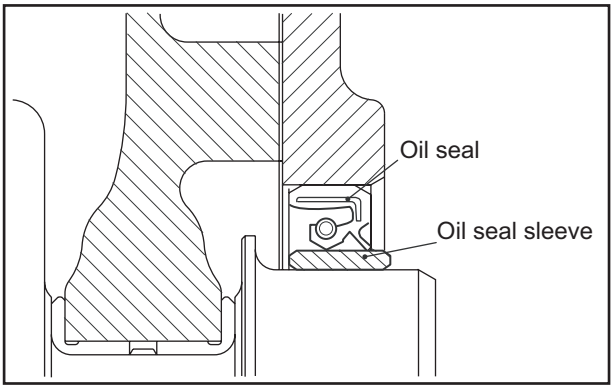
Be careful not to dent or wound the oil seal sleeve circumference.

When installing the oil seal sleeve, apply the oil to the inside of the oil seal sleeve, and drive it into the crankshaft by using oil seal sleeve installer set.

When the engine is operated again and the oil seal sleeve wears, remove the oil seal sleeve by using following method and replace the oil seal assembly (oil seal and oil seal sleeve) with the new spare parts.



Installing oil seal sleeve



Installing front oil seal (2)

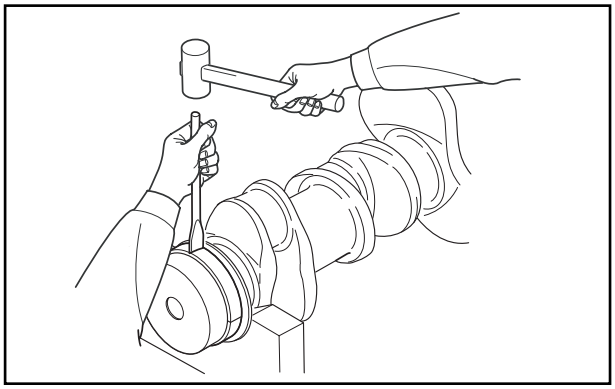
4.10.2 Removing oil seal sleeve

CAUTION

When making a cut in the sleeve, be very careful not to damage the crankshaft with the chisel.

Make a cut at three locations on the periphery of the oil seal sleeve to reduce its tension. To do so, hold a chisel against the sleeve periphery in the radial direction and strike it with a hammer. When the sleeve is loosened, remove the sleeve.

If the sleeve can not be removed by the above procedure, hold the chisel against the sleeve in the axial direction and tap on it lightly to make the sleeve expand. Once the interference between the crankshaft and sleeve is eliminated, the sleeve will be removed easily.



Removing oil seal sleeve

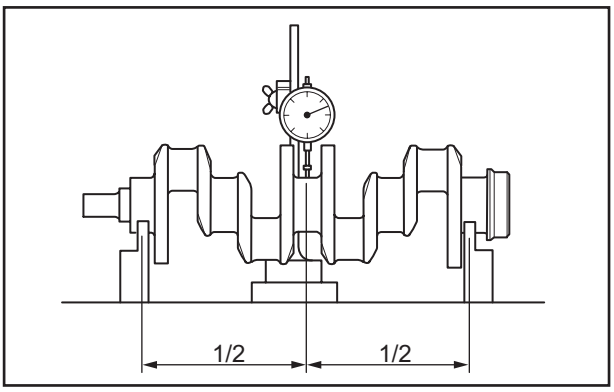
4.11 Measuring crankshaft runout

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	Remark
Crankshaft runout	0.04 mm [0.0016 in.] or less	0.10 mm [0.0039 in.] or less	TIR

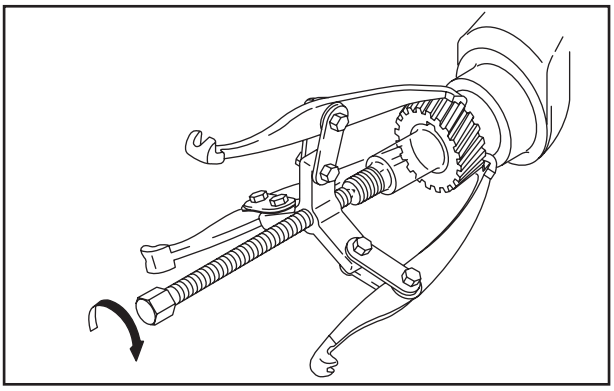


Measuring crankshaft runout

4.12 Removing crankshaft gear

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

Note: Do not strike the gear with a hammer.

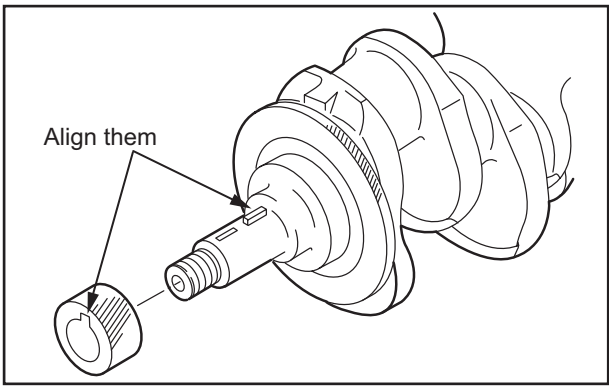


Removing crankshaft gear

4.13 Installing crankshaft gear

(1) Install the key on the crankshaft.

(2) Press-fit the gear fully in alignment with the key.

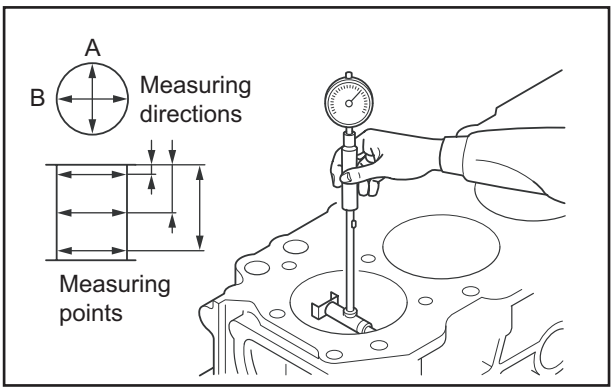


Installing crankshaft gear

4.14 Measuring cylinder inside diameter

Use a cylinder gauge to measure the inside diameter and cylindericity of the cylinder at three locations in the A and B directions as shown in the illustration.

If any one of the cylinders exceeds the repair limit, bore all the cylinders and replace the pistons and piston rings with oversize ones.



Measuring cylinder inside diameter

Piston and piston ring size		Cylinder inside diameter	
Size	Size mark	Standard	Limit
S.T.D	STD	88.000 to 88.035 mm [3.4646 to 3.4659 in.]	Standard +0.2 mm [0.008 in.]
0.25 mm O.S . [0.0098 in.]	25	88.250 to 88.285 mm [3.4744 to 3.4758 in.]	
0.50 mm O.S. [0.0197 in.]	50	88.500 to 88.535 mm [3.4842 to 3.4856 in.]	
Cylindericity of cylinder		0.015 mm [0.0006 in.] or less	-

4.14.1 Reboring cylinder

CAUTION

(a) If the inside diameter of cylinder exceeds the limit, replace the cylinder block.

(b) Bore the cylinders in the cylinder-number sequence to prevent heat-induced distortion.

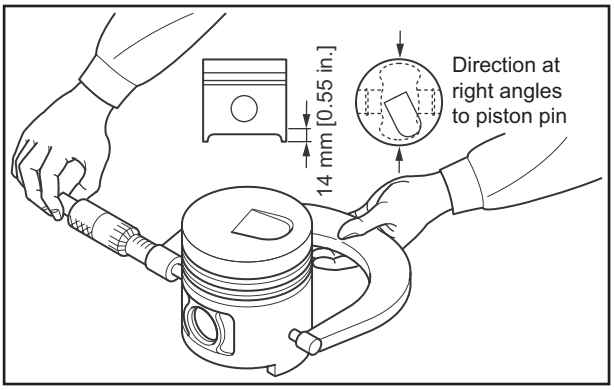
(1) Pistons are available in two sizes (0.25, 0.50 oversizes). Select the piston size for all cylinders based on the largest cylinder bore that has been measured.

(2) Measure the outside diameter of the piston that has been selected.
The measuring position in the outside diameter is shown in the illustration.

(3) Calculate the boring dimensions based on the piston outside diameter that has been measured.
A: Piston outside diameter (mm)
(oversize piston that has been selected)
B: Clearance between piston and cylinder (standard)
0.03 mm [0.0012 in.]
C: Horning allowance 0.04 mm [0.0016 in.] or below
Boring dimension =A+B-C

(4) Bore each cylinder to dimension calculated above.

(5) Horn-finish each cylinder to achieve the final dimension (the piston outside diameter plus the clearance between the oversize piston and the cylinder bore.)



Measuring piston outside diameter

4.15 Measuring crankcase top surface distortion

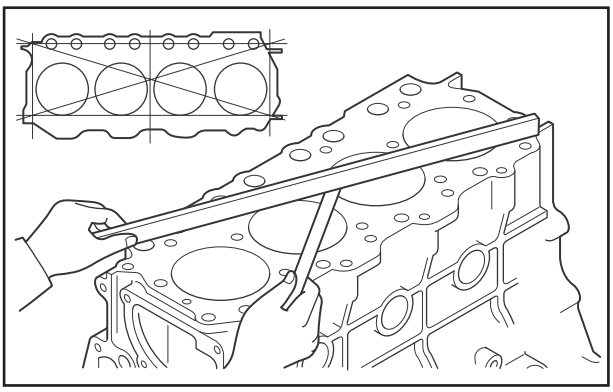
CAUTION

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.



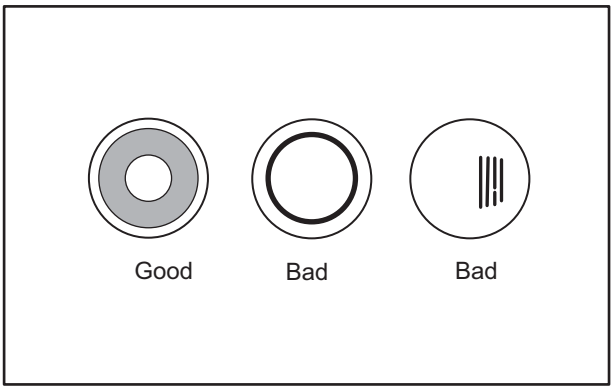
Measuring crankcase top surface distortion

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

Note: Do not grind the surfaces more than 0.2 mm [0.008 in.] in total (cylinder head bottom surface plus crankcase top surface).

4.16 Inspecting tappet

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



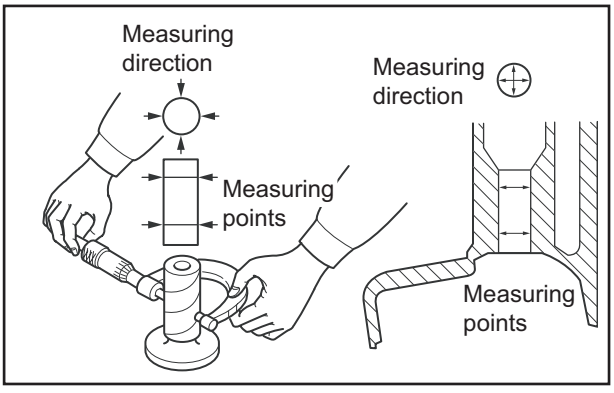
Contact surface of tappet and cam

4.17 Measuring clearance between tappet and tappet guide hole

Measure clearance between the tappet and tappet hole.

Replace the tappet with a new one if the limit is exceeded.

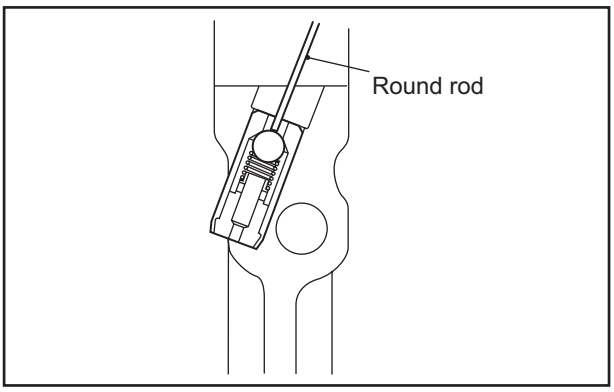
Item	Nominal	Standard	Limit
Tappet hole inside diameter	ø 14 mm [0.55 in.]	14.000 to 14.018 mm [0.5512 to 0.5519 in.]	14.100 mm [0.5551 in.]
Clearance between tappet and tappet hole	-	0.016 to 0.052 mm [0.0006 to 0.0020 in.]	0.080 mm [0.0031 in.]



Measuring tappet outside diameter and crankcase tappet bore inside diameter

4.18 Inspecting piston cooling nozzle

Insert the round bar (ø4 mm [0.1575 in.] or less) to the top of the piston cooling nozzle installed on the crankcase. Inspect that the steal ball operates smoothly. If it does not operated smoothly, replace the piston cooling nozzle with new one.



Inspecting piston cooling nozzle

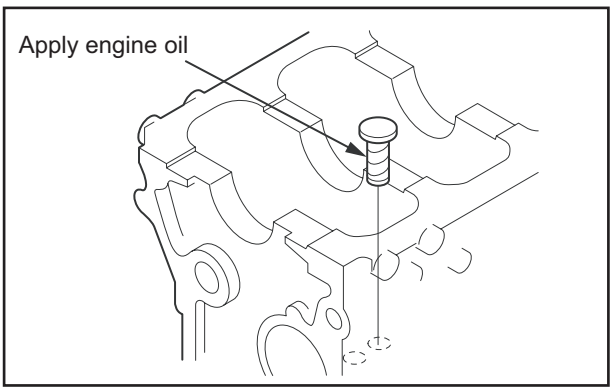
REASSEMBLY OF BASIC ENGINE

1. Reassembling piston, connecting rod, crankshaft and crankcase

1.1 Installing tappet

(1) Apply the engine oil to the tappet, and insert it to the tappet hole on the crankcase.

(2) Make sure that the tappet rotates smoothly.



Installing tappet

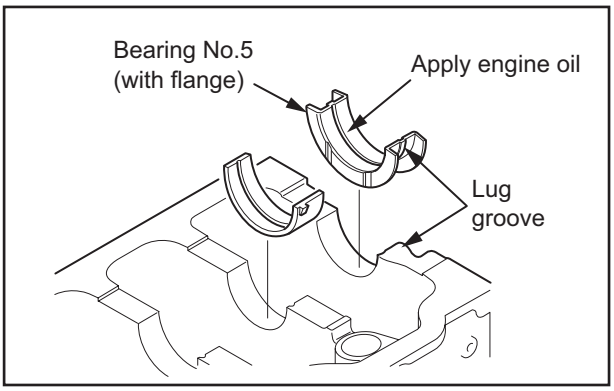
1.2 Installing main bearing

(1) Install the main bearings (upper and lower) with aligning lug groove of the crankcase and main bearing cap.

Note: Install the bearing (upper) with groove to the crankcase, and install the bearing (lower) without groove to the main bearing cap.

(2) Install the flange main bearing to the rearmost crankcase mating surface.

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



Installing main bearing

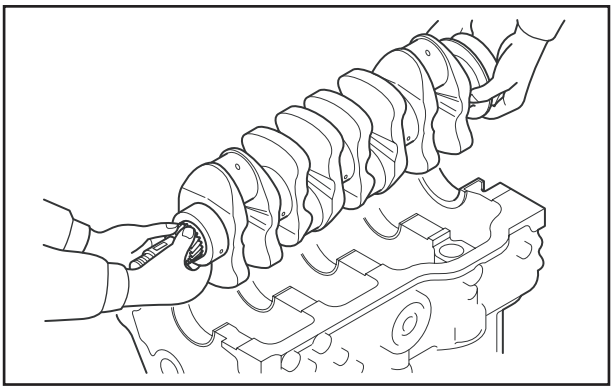
1.3 Installing crankshaft

(1) Wash the crankshaft thoroughly with cleaning oil and dry it completely by compressed air.

Note: When washing the crankshaft, clean the inside of the oil holes completely and make sure that no foreign substances or dirt is present.

(2) Hold the crankshaft horizontally and slowly install it to the crankcase.

(3) Apply a small quantity of engine oil to the crankshaft journals.



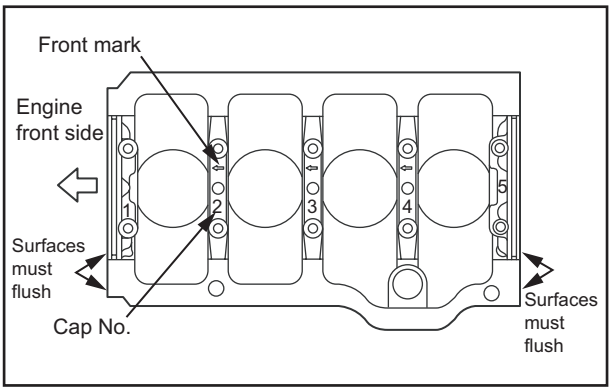
Installing crankshaft

1.4 Installing main bearing cap

CAUTION

The foremost and rearmost caps should be installed so that they are flush with the crankcase surface.

Install the main bearing caps so that their front marks (arrow) and cap numbers are in numerical order from the front of the engine.

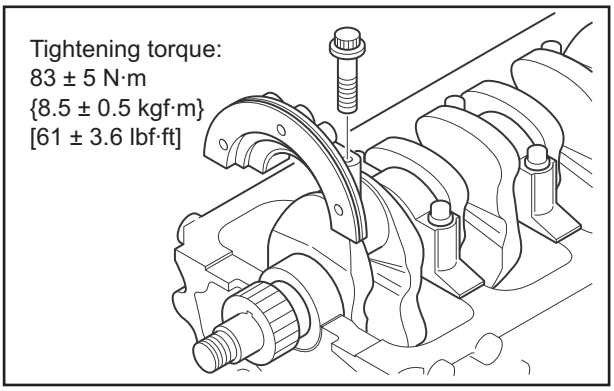


Installing main bearing cap

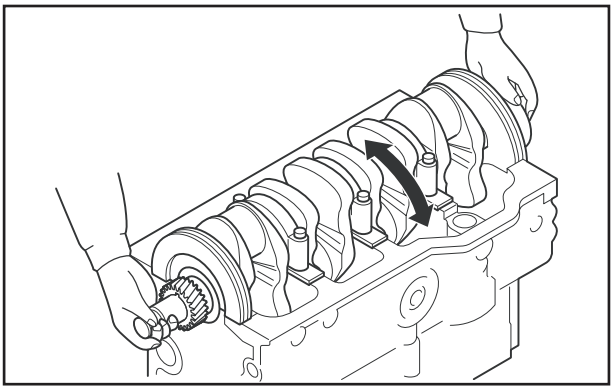
1.5 Installing main bearing cap bolt

(1) Tighten the main bearing cap bolts alternately and progressively to the specified torque.

(2) Make sure that the crankshaft rotates smoothly.



Installing main bearing cap bolt



Inspecting crankshaft for rotation

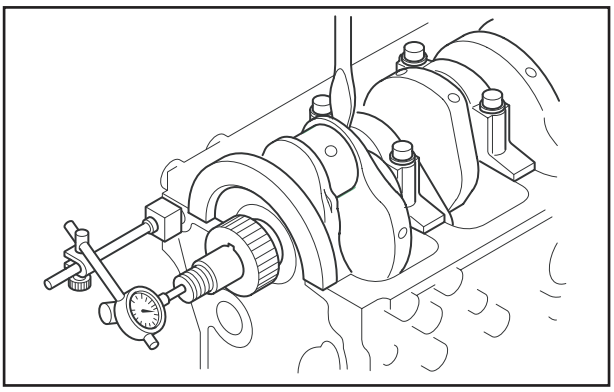
1.6 Measuring crankshaft end play

(1) Measure the crankshaft end play.

(2) If the measured end play is small, loosen the cap bolt and retighten it.

(3) If the measured value exceeds the limit, replace the flange bearing with new one.

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

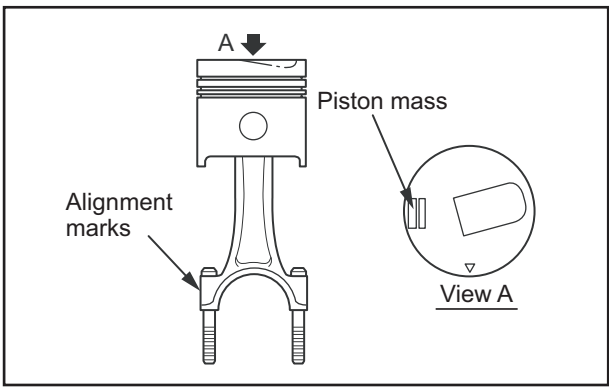


Measuring crankshaft end play

1.7 Reassembling piston and connecting rod

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

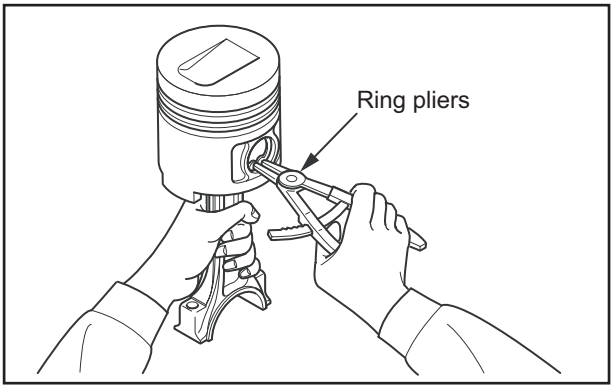
Note: The pistons and piston pins are assembled to each other in clearance fit. However, the piston pins are more easily inserted into the pistons if the pistons are warmed up with a heater or in hot water.



Reassembling piston and connecting rod (1)

(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)

1.8 Installing piston ring

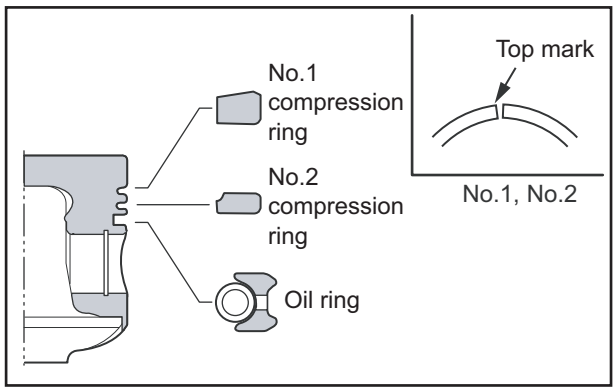
CAUTION

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

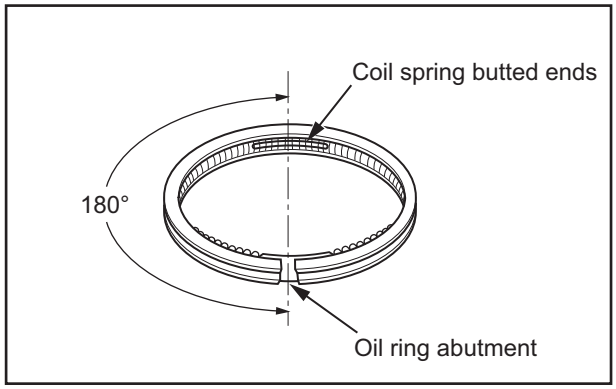
If the rings are installed upside down, it could cause malfunctions such as excessive oil consumption or an engine seizing.

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

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



Piston and piston ring arrangement

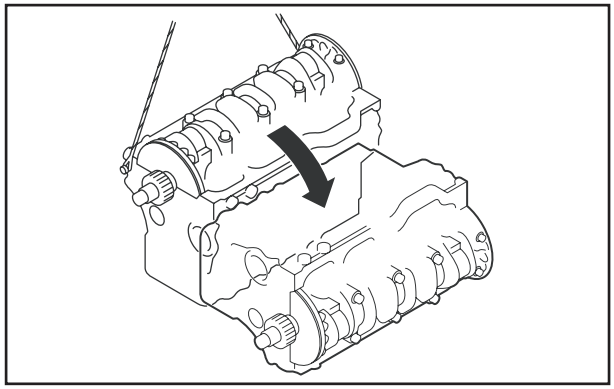


Installing oil ring and coil spring

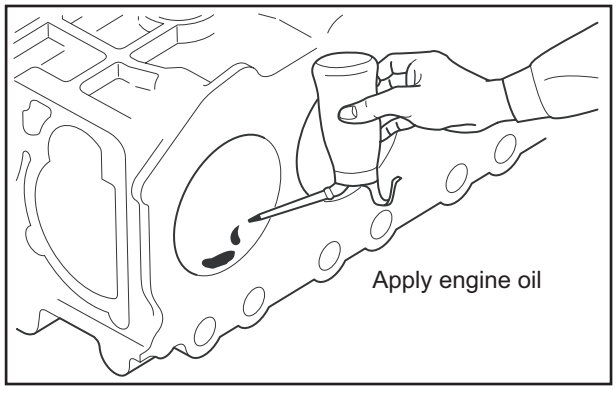
1.9 Preparation for installing pistons

(1) Lay the engine along its side.

(2) Clean the cylinder sleeve inner surface and the crank pin with a cloth, and apply engine oil.



Lay the crankcase on its side



Preparation for installing piston

1.10 Installing connecting rod bolt and connecting rod bearing

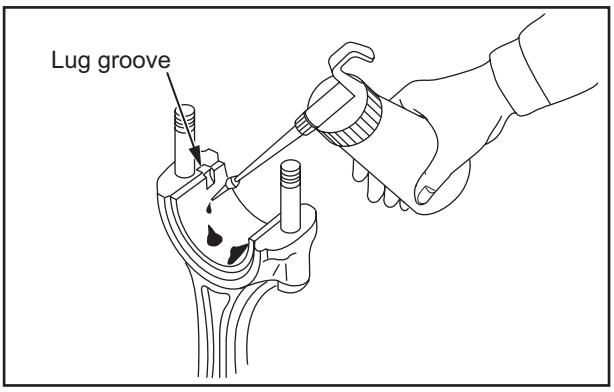
(1) Press fit the connecting rod bolts into the connecting rod.

Note: When press fitting the bolt, make sure that the bolt fully contacts its seating position without any interference with the shoulder of mounting surface.

(2) Install the upper connecting rod bearing with its lug fitted in the lug groove of connecting rod.

(3) Install the lower connecting rod bearing with its lug fitted in the lug groove of connecting rod cap.

(4) Apply engine oil to the inner surface of bearing.



Installing connecting rod bearing

1.11 Installing Pistons

CAUTION

Do not forcefully insert the piston, as it may cause damage to the piston rings and crank pin.

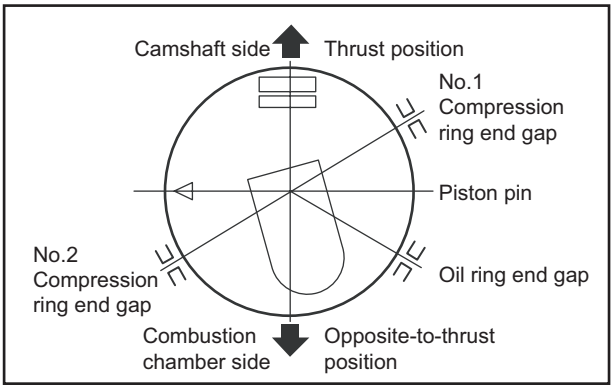
(1) Apply engine oil to the circumference of the piston and piston rings.

(2) Orient the ring end gaps diagonally opposite each other avoiding the piston pin direction and its right angle direction.

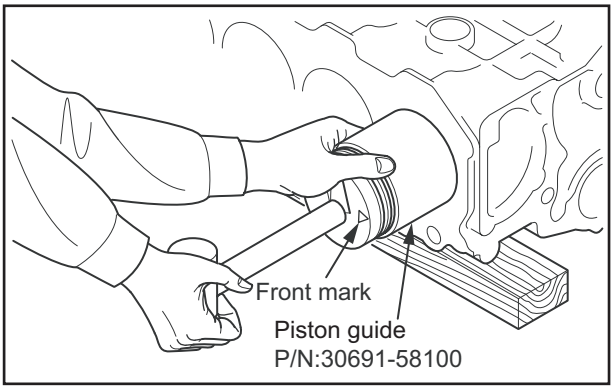
(3) Turn the crankshaft to bring the crank pin of the cylinder to the top dead center.

(4) Using a piston guide, insert the piston from the top face of crankcase into the cylinder sleeve.

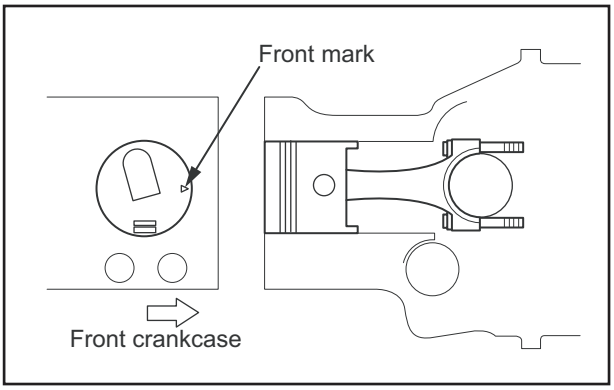
Note: When installing the pistion, be sure to orient the match mark on the connecting rod to the camshaft side.



Installing piston (1)



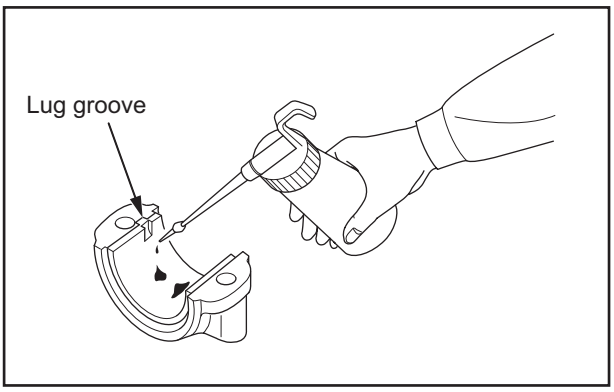
Installing piston (2)



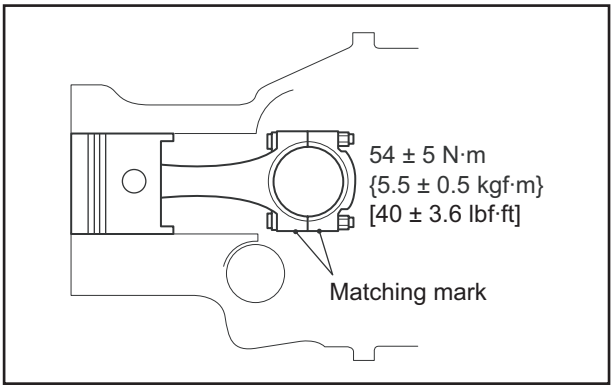
Installing piston (3)

1.12 Installing connecting rod cap

(1) Fit the connecting rod bearing (lower) to the rod cap with the lug aligned with the lug groove, and apply the engine oil inside the bearing.
(2) Install the connecting rod cap to the connecting rod (crankpin) with its match mark facing on the same side as the match mark on the connecting rod.
(3) Tighten the connecting rod cap nuts by using hand.
(4) Tighten the connecting rod cap nuts evenly and progressively to the specified torque.
(5) Inspect end play of the connecting rod. If end play is small, loosen and retighten the cap nuts.



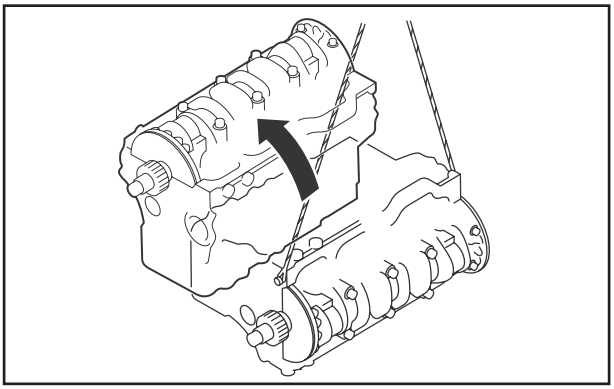
Installing connecting rod cap (1)



Installing connecting rod cap (2)

1.13 Uprearing crankcase

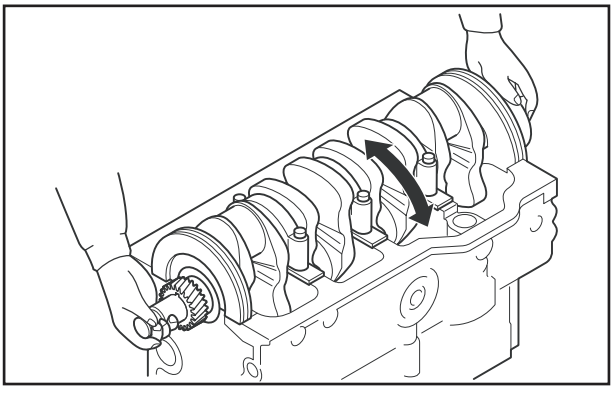
Uprear the crankcase softly with its upper faced downward.



Uprearing crankcase

1.14 Inspecting crankshaft for rotation

Inspect that the crankshaft rotates smoothly.

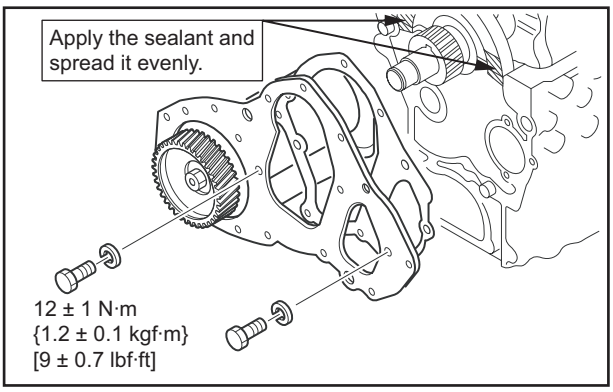


Inspecting crankshaft for rotation

2. Reassembling timing gear, camshaft and oil pan

2.1 Installing front plate

(1) Clean the mounting surface of the gasket.
(2) According to need, apply the sealant to prevent the gasket falling off.
(3) Apply the sealant (TheeBond 1211) to the mating surface of the crankcase and main bearing cap, and spread, the sealant evenly.
(4) With aligning to the dowel pin, install the gasket and the front plate.
(5) Secure the front plate with mounting bolts.



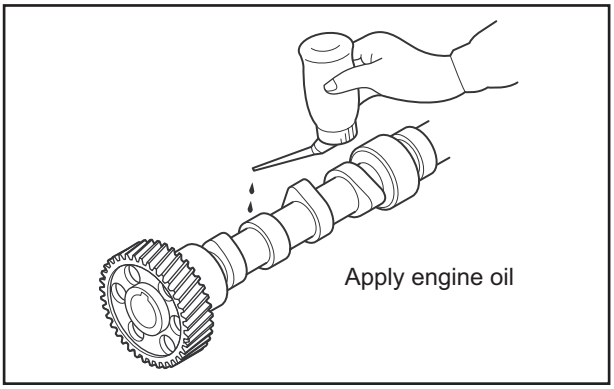
Installing front plate

2.2 Installing camshaft

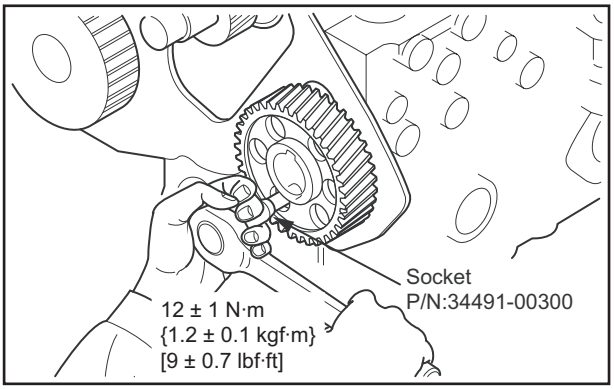
⚠ CAUTION

Be careful not to damage camshaft journals, cams and camshaft holes during insertion.

(1) Apply engine oil to the camshaft journals and cams.
(2) Slowly insert the camshaft assembly.
(3) Tighten the thrust plate bolt to the specified torque.
(4) Make sure that the camshaft rotates lightly. Move the camshaft gear back and forth, and make sure there is end play.



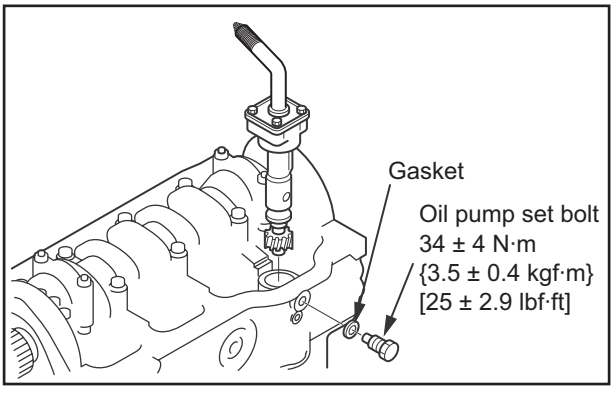
Applying engine oil to camshaft



Installing camshaft

2.3 Installing oil pump

(1) Insert the oil pump to the oil pump hole on the crankcase, then, make sure that the oil pump gear and oil pump drive gear on the camshaft meshes correctly.
(2) From the crankcase side face, tighten the oil pump set bolt with gasket to the specified torque.



Installing oil pump

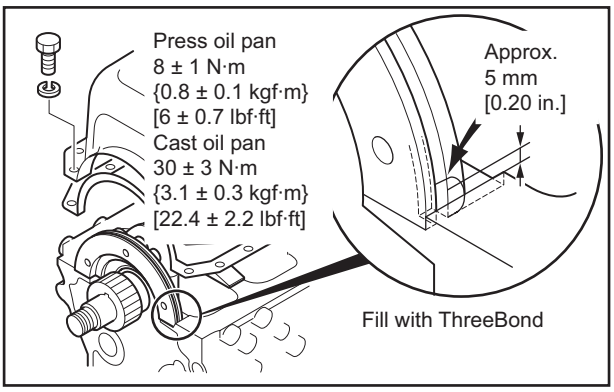
2.4 Installing oil pan

Clean the both side of the oil pan gasket contact surfaces and the contact surfaces of other parts thoroughly.

(1) Apply the sealant (ThreeBond 1212) to the mating surface clearance of the No,1 and 4 main bearings and crankcase.
The filling amount should be approx. 5 mm protruding from the mating surface clearance, and enough to spill out when the oil pan gasket is installed.

(2) Install the oil pan gasket to the crankcase under face, with pushing the gasket circular part into the No,1 and 4 main bearing cap grooves and pushing the gasket protrusion into the mating surface clearance where sealnt is filled.

(3) Install the oil pan, and tighten the bolts to the specified torque.



Installing oil pan

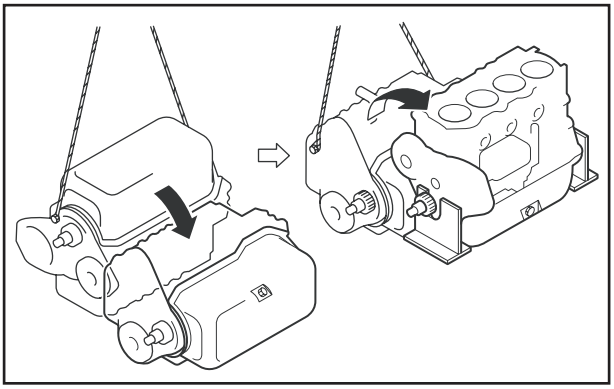
2.5 Inverting crankcase

⚠ CAUTION

Do not place the engine directly on the ground. It causes cracking the oil pan.

(1) Attach the wire rope to the crankcase. Using a crane, hoist the crankcase and lay it with its side faced downwards.

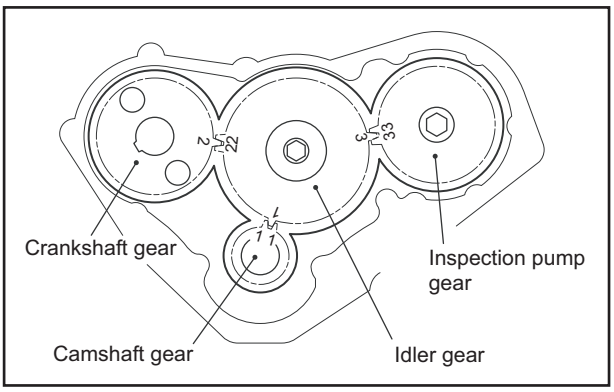
(2) After that, hoist the crankcase again and invert it.



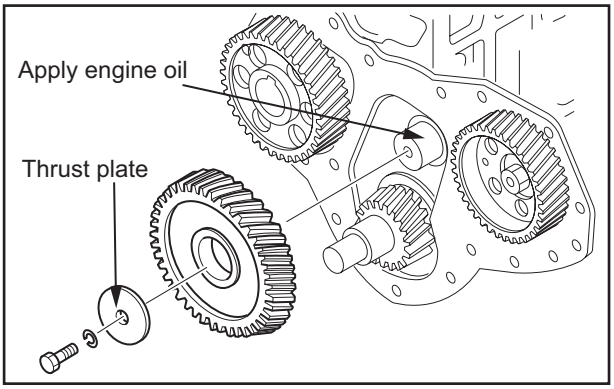
Inverting crankcase

2.6 Installing front idler gear

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



Timing gear train

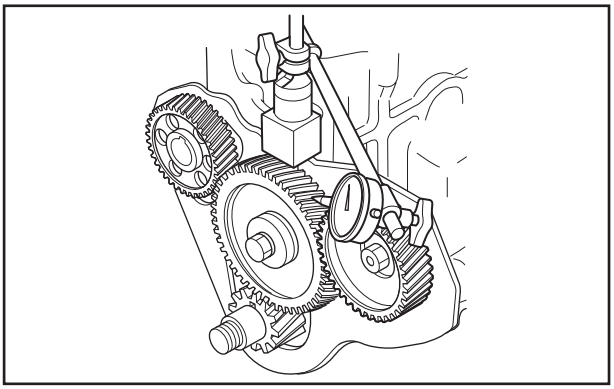


Installing idler gear

2.7 Inspecting and adjusting timing gear after installation

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

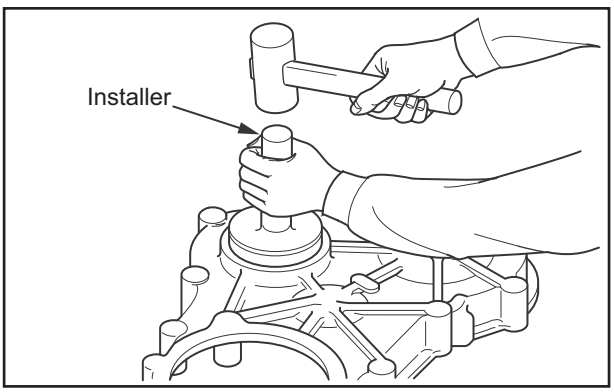
Item		Standard	Limit
Backlash	Crankshaft gear to ider gear	0.03 to 0.16 mm [0.0012 to 0.0063 in.]	0.25 mm [0.0098 in.]
	Ider gear to camshaft gear	0.04 to 0.17 mm [0.0016 to 0.0067 in.]	0.25 mm [0.0098 in.]
	Injection pump gear to ider gear	0.03 to 0.18 mm [0.0012 to 0.0071 in.]	0.25 mm [0.0098 in.]



Measuring timing gear backlash

2.8 Installing oil seal

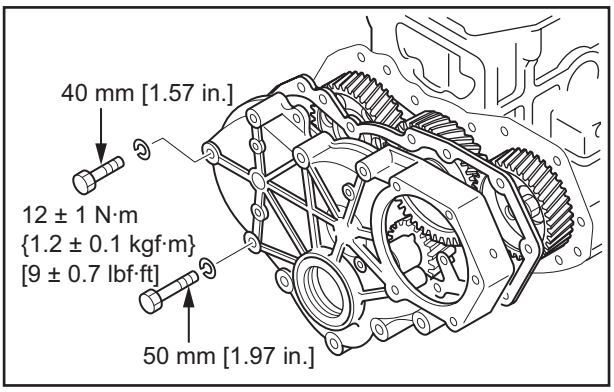
Install oil seal to the timing gear case using installer, and make sure that oil seal is flush with timing gear case.



Installing oil seal

2.9 Installing timing gear case

(1) Install the baffle plate to the crankcase.
(2) Install the gasket and the timing gear case to the crankcase aligning with the dowel pin located on the crankcase front side.
(3) Tighten the bolt to the specified torque.



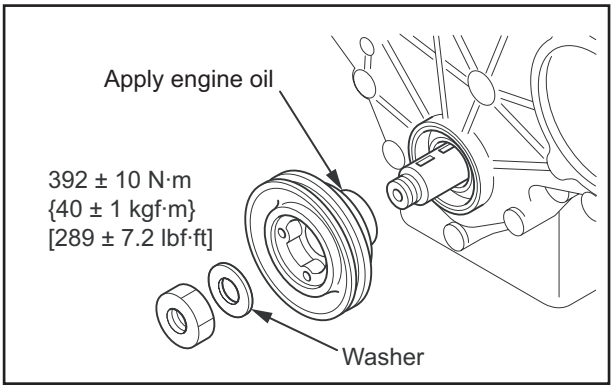
Installing timing gear case

2.10 Installing crankshaft pulley

⚠ CAUTION

The bar could come off. Be very careful.

(1) Apply the engine oil to the oil seal contact surface of the crankshaft pulley.
(2) Drive into the crankshaft pulley aligning with the crankshaft key.
(3) Prevent the crankshaft turning using the threaded hole at the rear end of the crankshaft.
(4) Install the nut with the washer, tighten the nut to the specified torque.



Installing crankshaft pulley

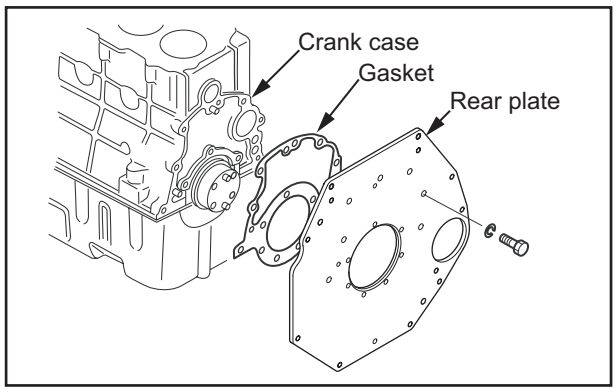
3. Reassembling flywheel

3.1 Installing rear plate

(1) Install a new rear plate gasket.

(2) Install the rear plate aligning with the dowel pins. Tighten the mounting bolt to the specified torque.

Note: Install the starter to the rear plate in advance to facilitate the subsequent reassembly.



Installing rear plate

3.2 Installing oil seal case

CAUTION

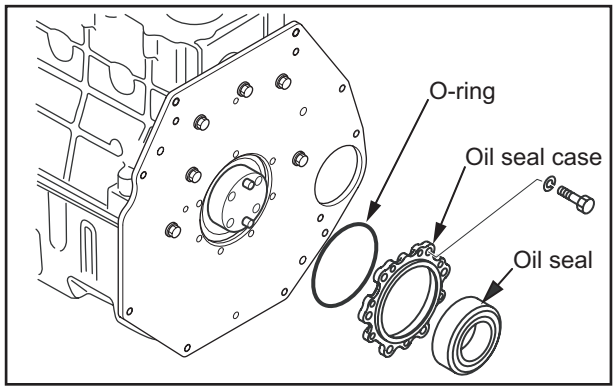
Be very careful not to damage the oil seal

(1) Apply engine oil to the entire circumference of the oil seal.

(2) Install the oil seal into the oil seal case.

(3) Apply engine oil to the engine circumference of the oil seal lip.

(4) Install the O ring into the oil seal case, and install the assembly onto the near plate.



Installing oil seal case

3.3 Installing flywheel

⚠ CAUTION

The person who holds the pulley must be very careful to assure safety by communicating with the person who is installing the flywheel.

(1) One person must firmly hold the pulley with a wrench to prevent the crankshaft from turning.

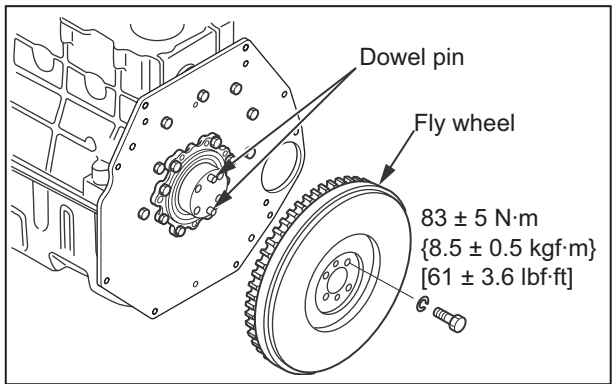
(2) Screw the guide bolt into the rear end of the crankshaft.

(3) Align the bolt hole of flywheel with the guide bolt and install the flywheel to the crankshaft.

(4) Temporarily tighten bolts.

(5) Remove the guide bolt and temporarily tighten the last bolt.

(6) Tighten the flywheel bolts to the specified torque.



Installing flywheel

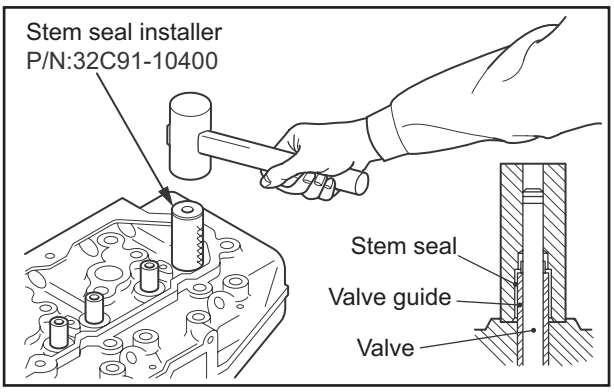
4. Reassembling cylinder head and valve mechanism

4.1 Installing valve stem seal

CAUTION

Do not apply oil or liquid gasket to the inner side of stem seal that comes in contact with the valve guide.

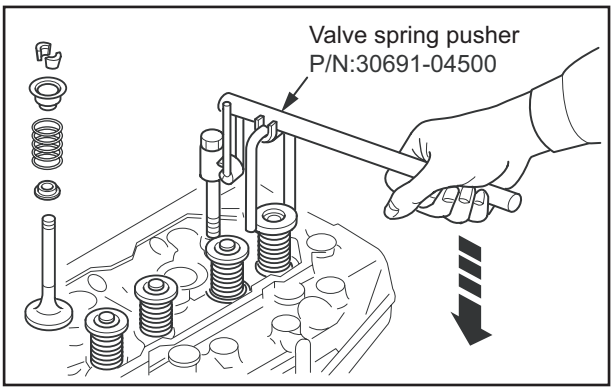
(1) Apply engine oil to the lip of new valve stem seal.
(2) Push the shoulder of the valve stem seal and fit the valve stem steal into the valve guide.
(3) Insert the valve stem seal into the valve guide using the valve stem seal installer.



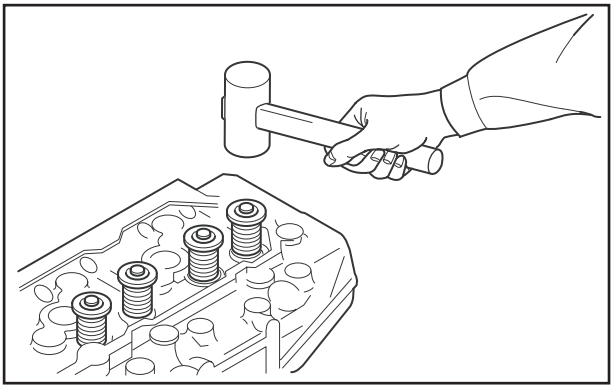
Installing valve stem seal

4.2 Installing valve and valve spring

(1) Install the valve spring and retainer on the valve guide. Install the valve cotter using a valve spring pusher.
(2) Tap the top of valve stem lightly several times with a soft hammer to make sure that the valve spring and valve cotter are properly installed and seated firmly.



Installing valve and valve spring



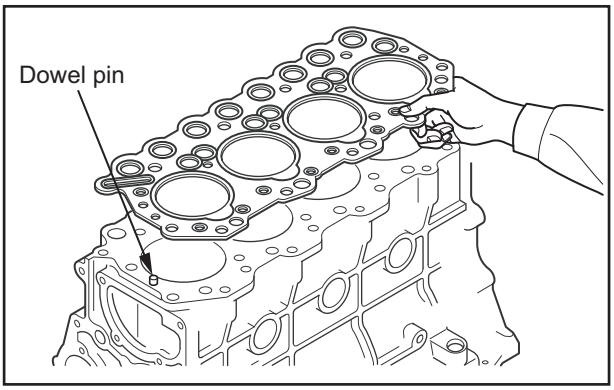
Inspecting valve cotter

4.3 Installing cylinder head gasket

CAUTION

Do not use liquid 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.

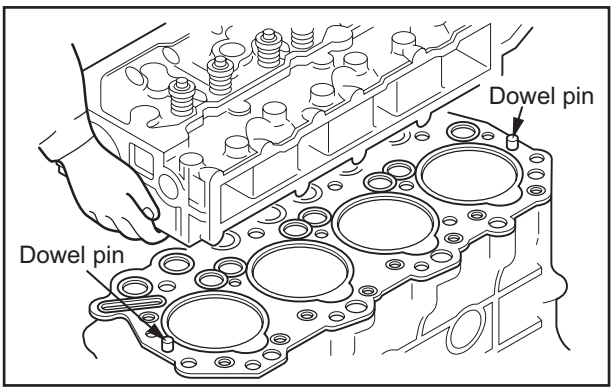


Installing cylinder head gasket

4.4 Installing cylinder head assembly

Install the cylinder head on the crankcase by aligning it with the dowel pins.

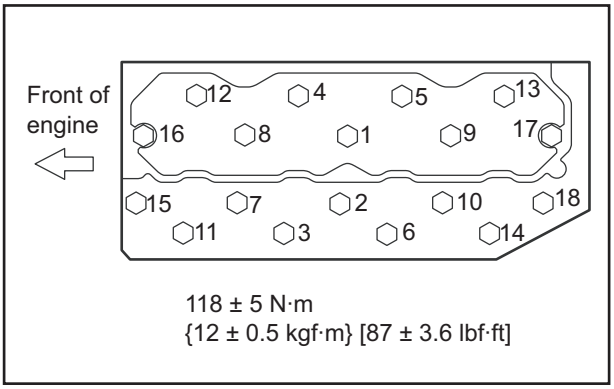
Note: Be careful not to displace the cylinder gasket when installing.



Installing cylinder head

4.5 Tightening cylinder head bolts

In the numerical order as shown in the illustration, tighten cylinder head bolts progressively to the specified torque.



Tightening order of cylinder head bolt

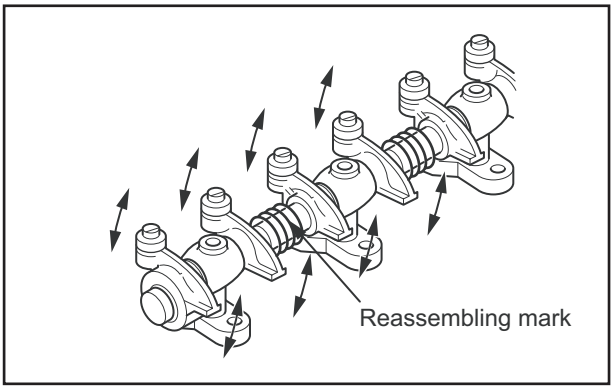
4.6 Reassembling rocker shaft assembly

(1) Apply engine oil to the rocker shaft.

(2) When reassembling, install the rocker shaft assembly in the same position as it was.

Note: If the rocker shaft assembly is not installed as it was, the clearance becomes different, and it may result in a defect such as wear increase.

(3) After reassembling, make sure the rocker arm and oil pipe move freely.



Reassembling rocker shaft assembly

4.7 Inserting push rod

(1) Insert each push rod into its hole in the cylinder head.

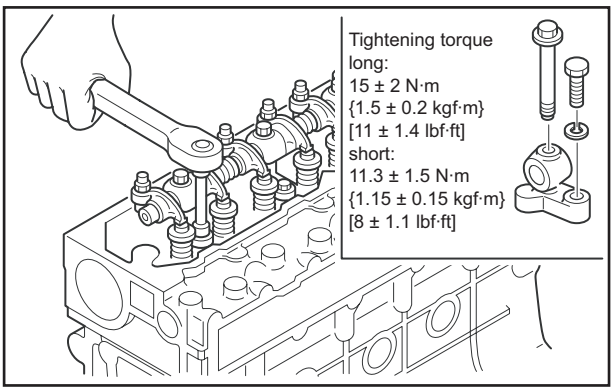
(2) Make sure that the ball end of each push rod is placed correctly on the tappet cup.

4.8 Installing rocker shaft assembly

(1) Install the valve caps to the valve heads.

(2) Tighten the long bolts of the rocker bracket to the specified torque.

(3) Tighten the short bolts of the rocker bracket.

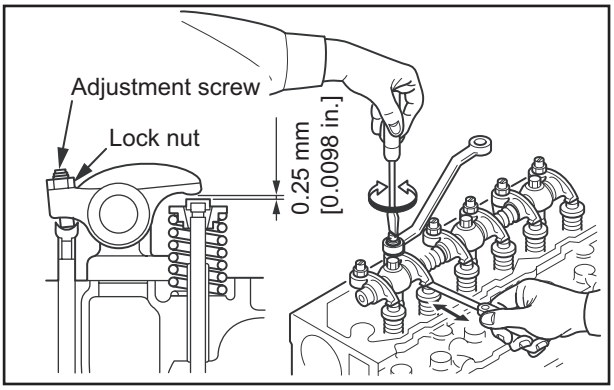


Installing rocker shaft assembly

4.9 Adjusting valve clearance

Adjust the valve clearance.

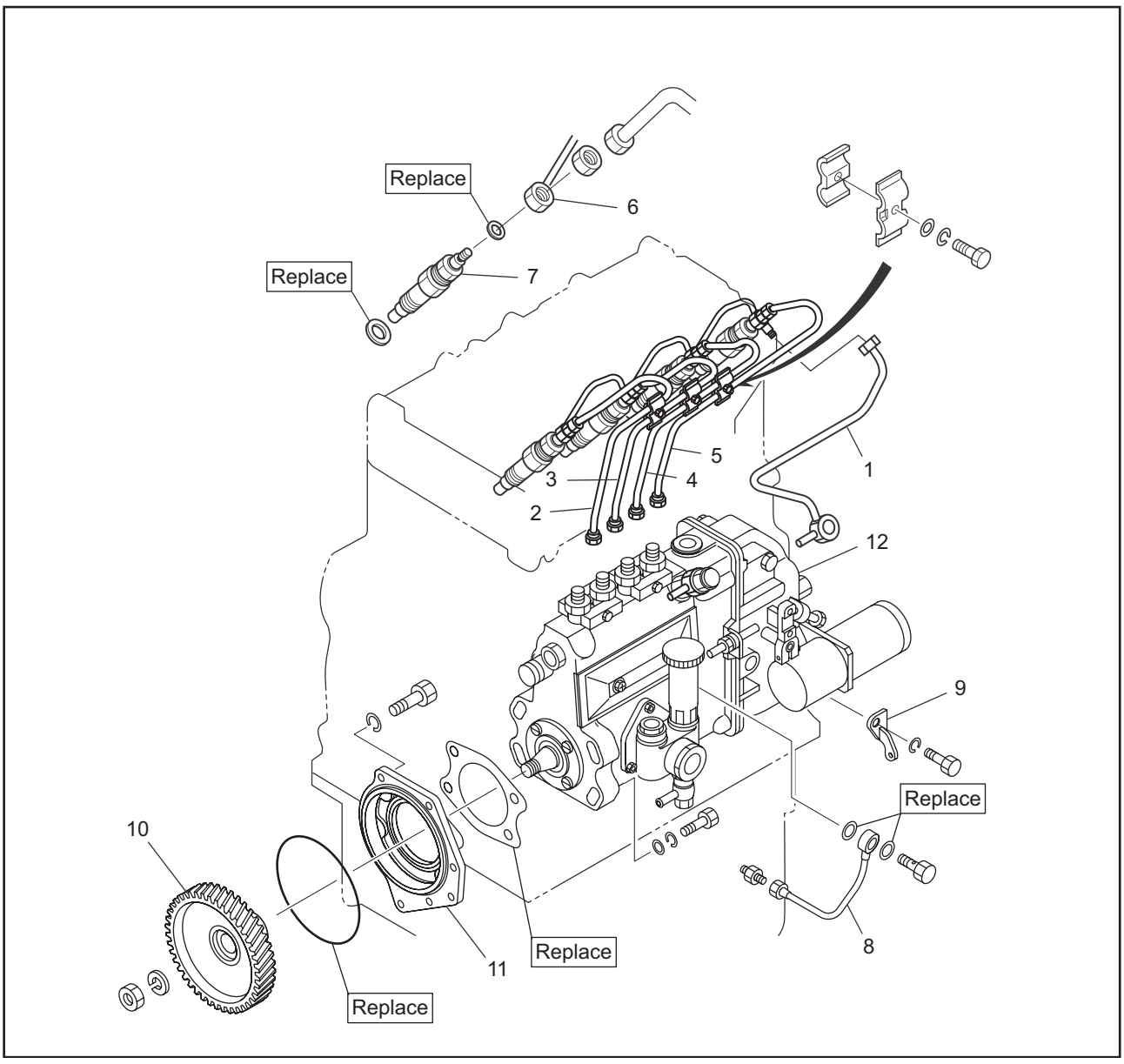
For adjusting procedures, refer to "Adjustment and Operation."



Adjusting valve clearance

FUEL SYSTEM

1. Removing fuel system



Removing fuel system

Removing sequence

1 Fuel return pipe
2 No.1 fuel injection pipe
3 No.2 fuel injection pipe
4 No.3 fuel injection pipe
5 No.4 fuel injection pipe
6 Fuel leak-off pipe
7 Fuel injection nozzle
8 Oil pipe
9 Pump bracket
10 Injection pump gear
11 Injection pump flange
12 Fuel injection pump

CAUTION

To prevent the fuel system from the contaminants, cover the openings such as injection pump openings nozzle openings, injection pipes.

1.1 Removing fuel injection pump

(1) Check the match mark location of the fuel injection pump flange and fuel injection pump installation flange.

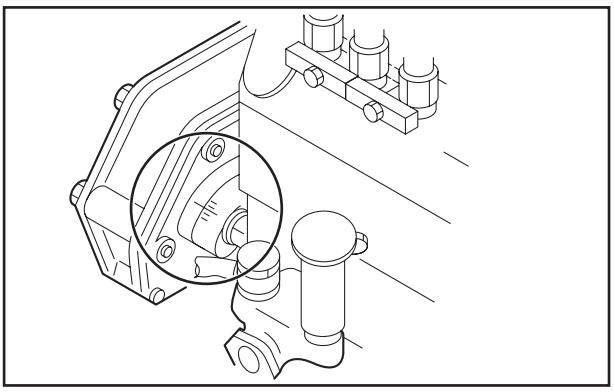
(2) Remove the engine front cover.

(3) Put the match mark on the fuel injection pump gear and the idler gear.

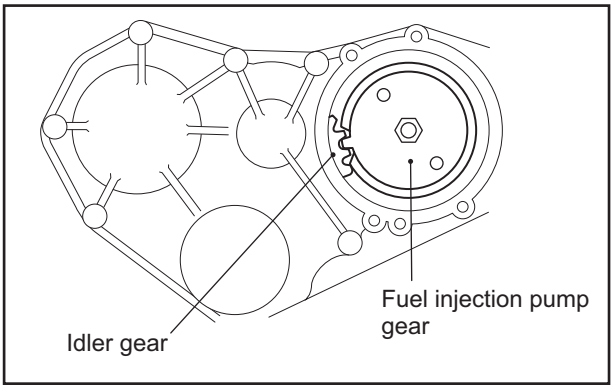
(4) Remove the fuel injection pump flange bolt and remove the fuel injection pump from the front plate together with the flange.

Note: (a) Do not operate the engine without the fuel injection pump.

(b) When removing the fuel injection pump gear, loosen the fuel injection pump gear nut with the pump is installed on the engine.



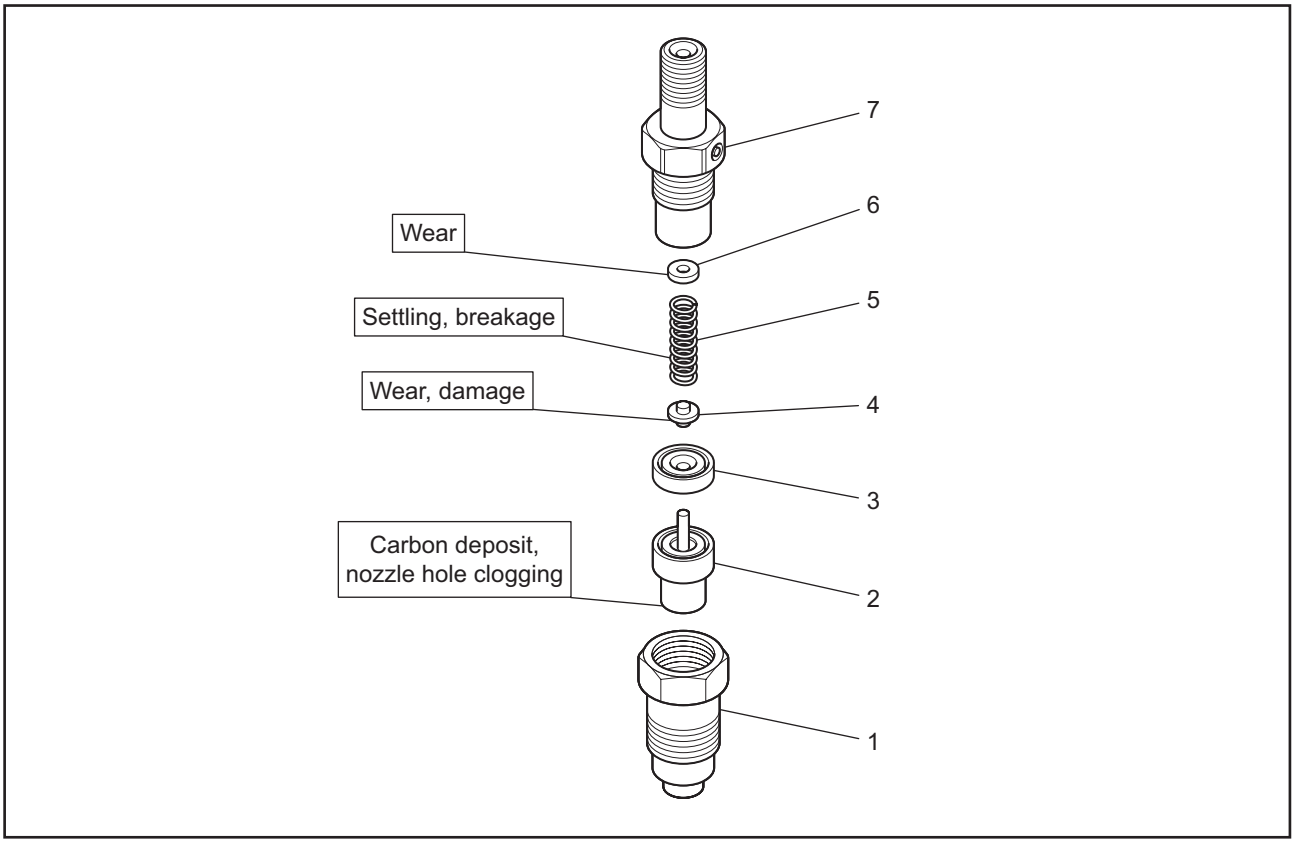
Removing fuel injection pump (1)



Removing fuel injection pump (2)

2. Disassembling, inspecting and reassembling fuel system

2.1 Disassembling and inspecting fuel injection nozzle



Disassembling and inspecting fuel injection nozzle

Disassembling sequence

1 Nozzle retaining nut
2 Nozzle tip assembly
3 Piece
4 Pin
5 Spring
6 Water
7 Nozzle holder

2.1.1 Inspecting and adjusting fuel injection valve opening pressure

⚠ CAUTION

Never touch the spray hole during injection

(1) Mount the nozzle on the nozzle tester.

(2) Pump the tester handle at a rate of approximately one cycle per second while observing the pressure at which injection starts. If the pressure is not in the standard range, make an adjustment by changing shim.

(3) To adjust the valve opening pressure, remove the retaining nut, and change the shim. The thicker the shim, the more it increases the pressure

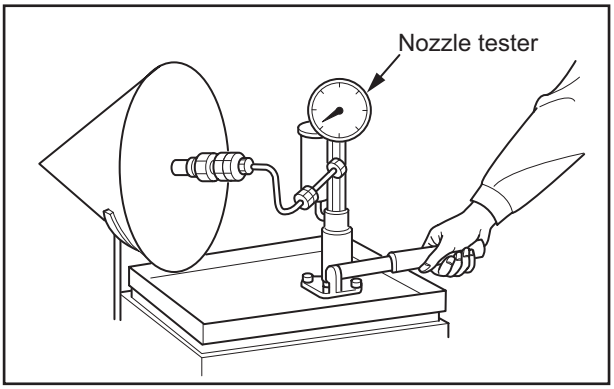
(4) After adjusting the pressure, tighten the retaining nut to the specified torque.

(5) Check the injection valve opening pressure once again to make sure the pressure is within the standard range.

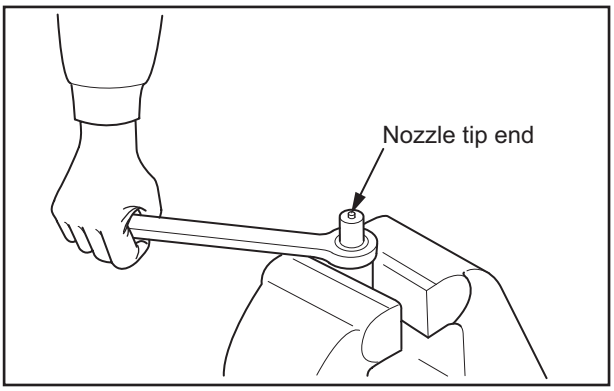
Item	Nominal	Standard
Valve opening pressure	13.73 MPa {140 kgf/cm²} [1991 psi]	13.93 to 14.71 MPa {142 to 150 kgf/cm²} [2020 to 2133 psi]

Note: (a) Standard is a value of new parts.

(b) A chauge in thickness of the shim by 0.1 mm [0.004 in]results in a chauge in the fuel injection pressure by 1.0 Mpa {10kgf/cm² } [142 psi]. There are ten kinds of shim from 1.25 to 1.70 mm [0.0492 to 0.0669 in].



Inspecting valve opening pressure



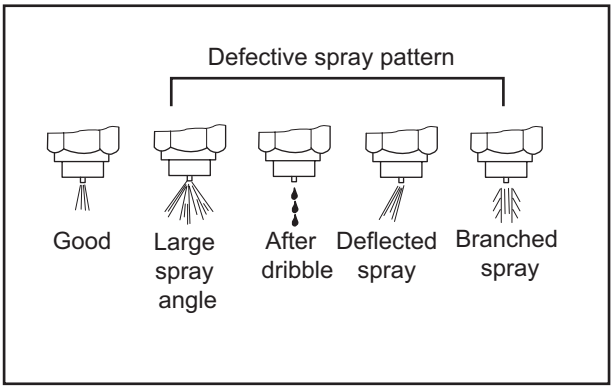
Replacing fuel injection nozzle tip

2.1.2 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.



Inspecting fuel spray pattern of fuel injection nozzle

2.1.3 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.

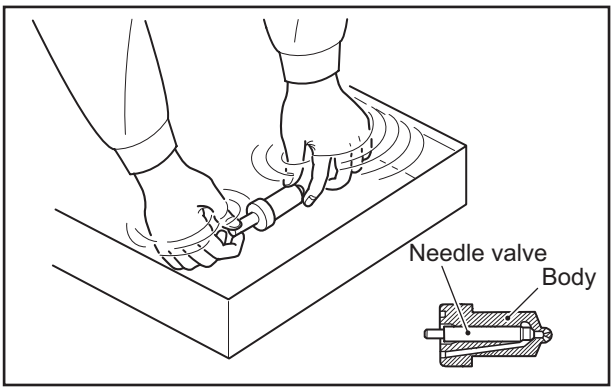
(2) Clean the nozzle tip in clean wash oil. After cleaning, assemble the needle valve and body in clean diesel fuel.

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.

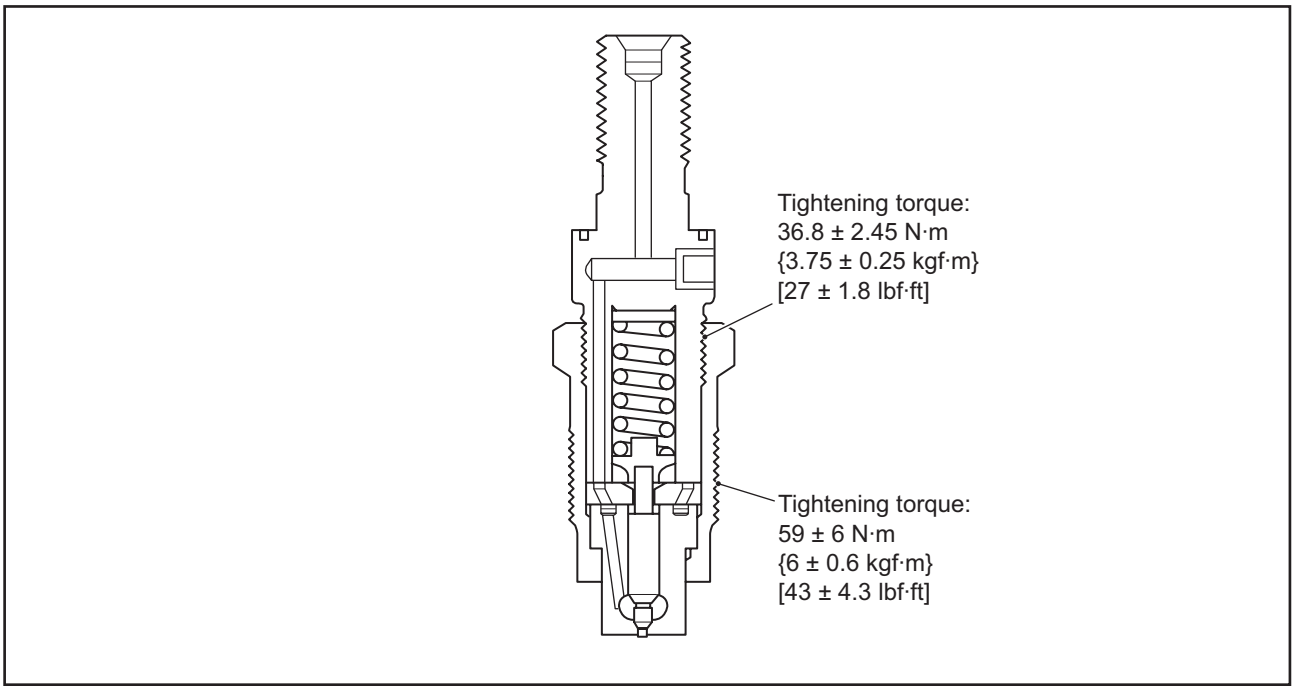
(4) If the spray pattern is still faulty after cleaning and adjusting, replace the nozzle tip.

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.



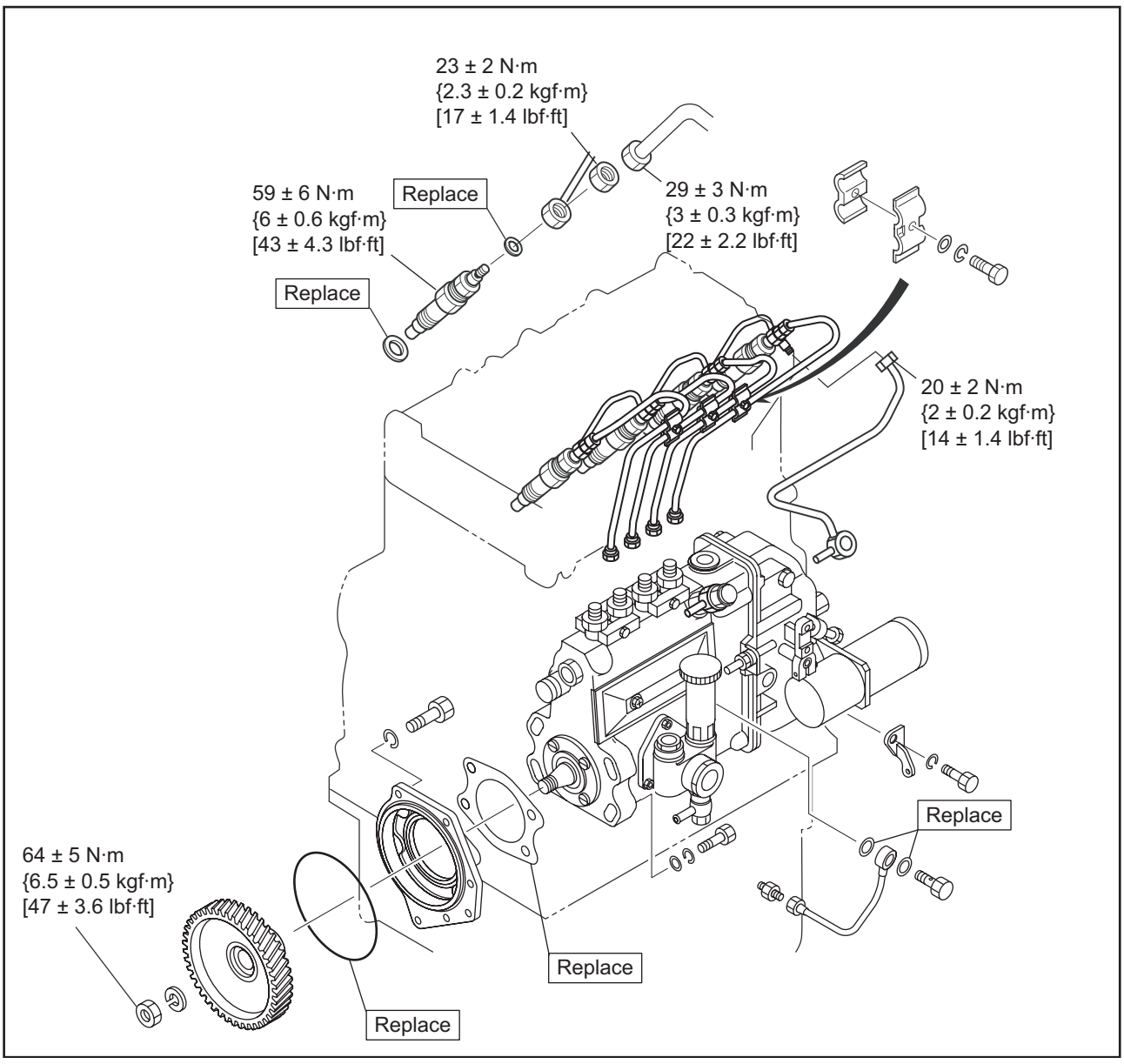
Cleaning fuel injection nozzle tip

2.1.4 Reassembling fuel injection nozzle



Reassembling fuel injection nozzle

3. Installing fuel system

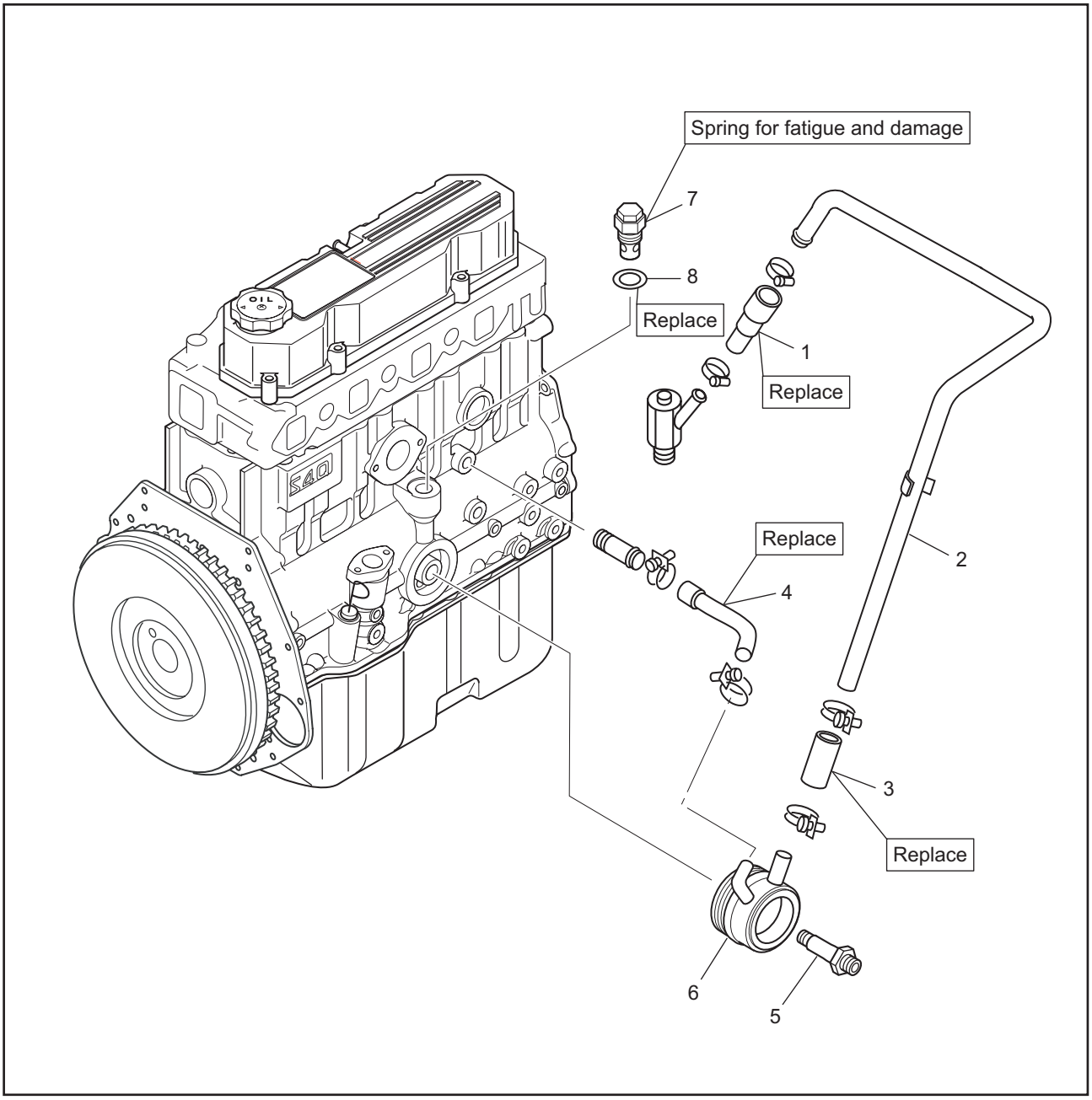


Installing fuel system

LUBRICATION SYSTEM

1. Removing lubrication system

1.1 Removing and inspecting oil cooler and relief valve

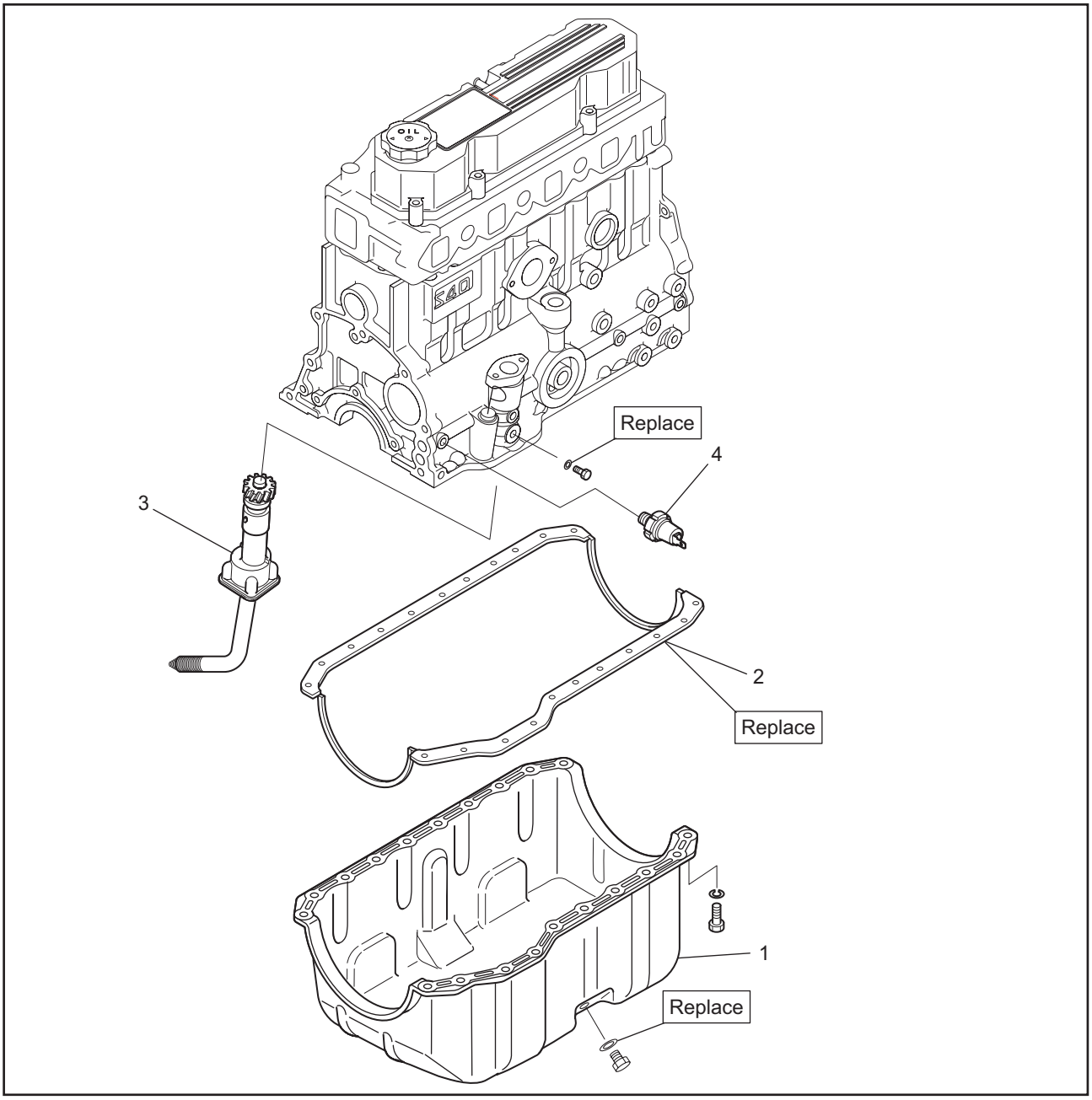


Removing and inspecting oil cooler and relief valve

Removing sequence

1 Rubber hose
2 Oil cooler pipe
3 Rubber hose
4 Rubber hose
5 Connector
6 Oil cooler
7 Relief valve
8 Gasket

1.2 Removing and inspecting oil pan, oil pump, oil pressure switch



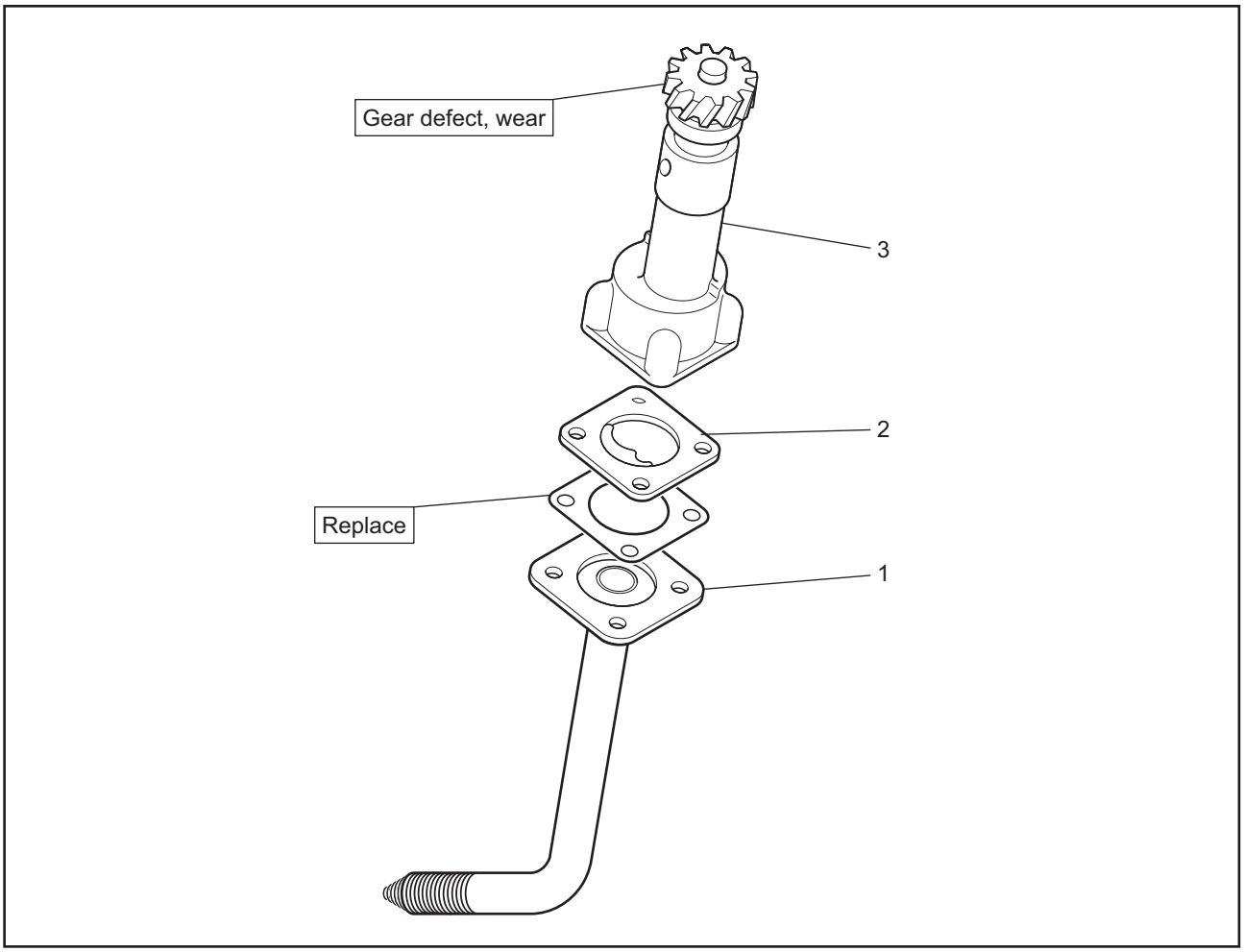
Removing and inspecting oil pan, oil pump, oil pressure switch

Removing sequence

1 Oil pan
2 Oil pan gasket
3 Oil pump
4 Oil pressure switch

2. Disassembling, inspecting and reassembling lubrication system

2.1 Disassembling and inspecting oil pump



Disassembling and inspecting oil pump

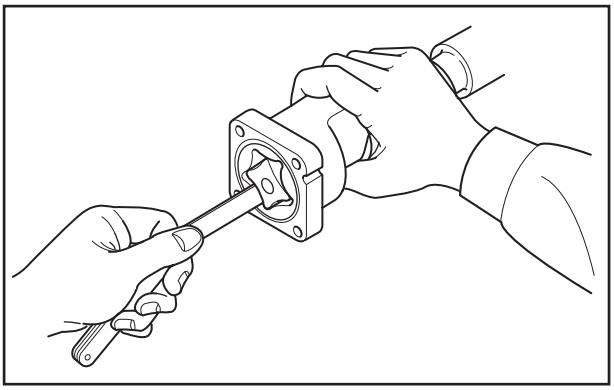
Disassembling sequence

1 Oil strainer
2 Oil pump cover
3 Oil pump

2.2 Measuring clearance between outer rotor and inner rotor

Measure the clearance between the outer rotor and the inner rotor. If measured value exceeds the limit, replace the oil pump with new one.

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

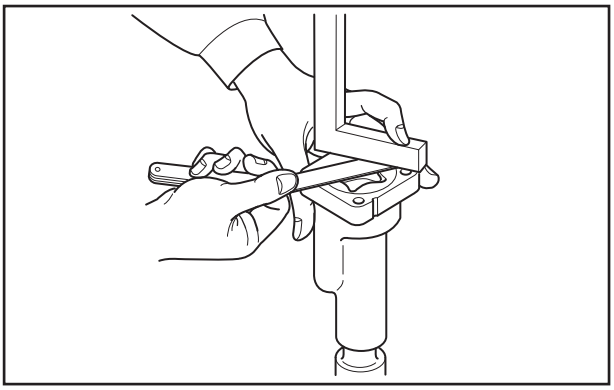


Measuring clearance between outer rotor and inner rotor

2.3 Measuring end play of rotor and pump case

Measure the end play of the rotor and the pump case. If measured value exceeds the limit, replace the oil pump with new one.

Item	Standard	Limit
End play of rotor and pump case	0.04 to 0.09 mm [0.0016 to 0.0035 in.]	0.15 mm [0.0059 in.]

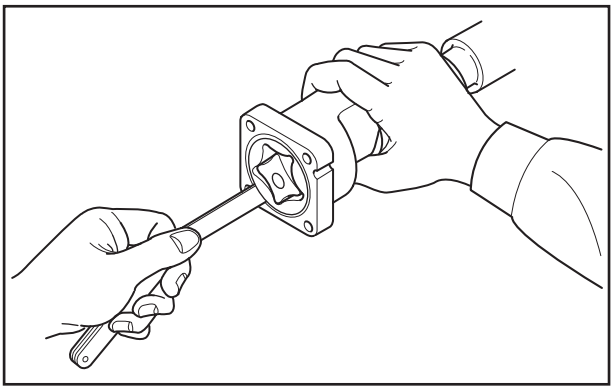


Measuring end play of rotor and pump case

2.4 Measuring clearance between outor rotor and pump case

Measure the clearance between the outer rotor and the pump case. If measured value exceeds the limit, replace the oil pump with new one.

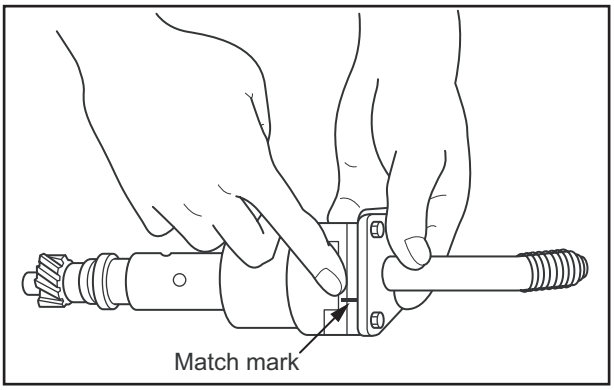
Item	Standard	Limit
Clearance between outer rotor and pump case	0.20 to 0.28 mm [0.0079 to 0.0110 in.]	0.50 mm [0.0197 in.]



Measuring clearance between outer rotor and pump case

2.5 Reassembling oil pump

(1) Install the pump case cover to the pump case with aligning the match marks (indentations). If the match marks are not aligned, the oil pump will not suck up oil.
(2) Install the oil strainer, and tighten the bolt.

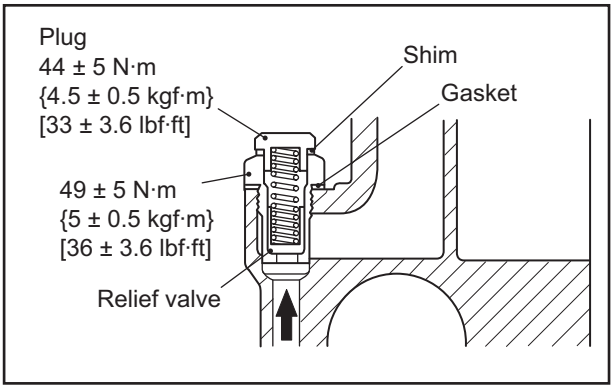


Match mark of pump case and pump case cover

2.6 Inspecting relief valve

(1) Check the relief valve and its valve seat for contact condition. Check the spring for fatigue and damage. If it is faulty, replace the relief valve with new one.
(2) Measure the valve opening pressure (oil pressure when the engine is running at rated speed) of the relief valve. If the measured value is out of the standard, remove the plug and make an adjustment by increasing and decreasing the shim thickness.
Engine oil pressure take-out port
Next to the oil filter Rp 1/8 thread (PS 1/8)

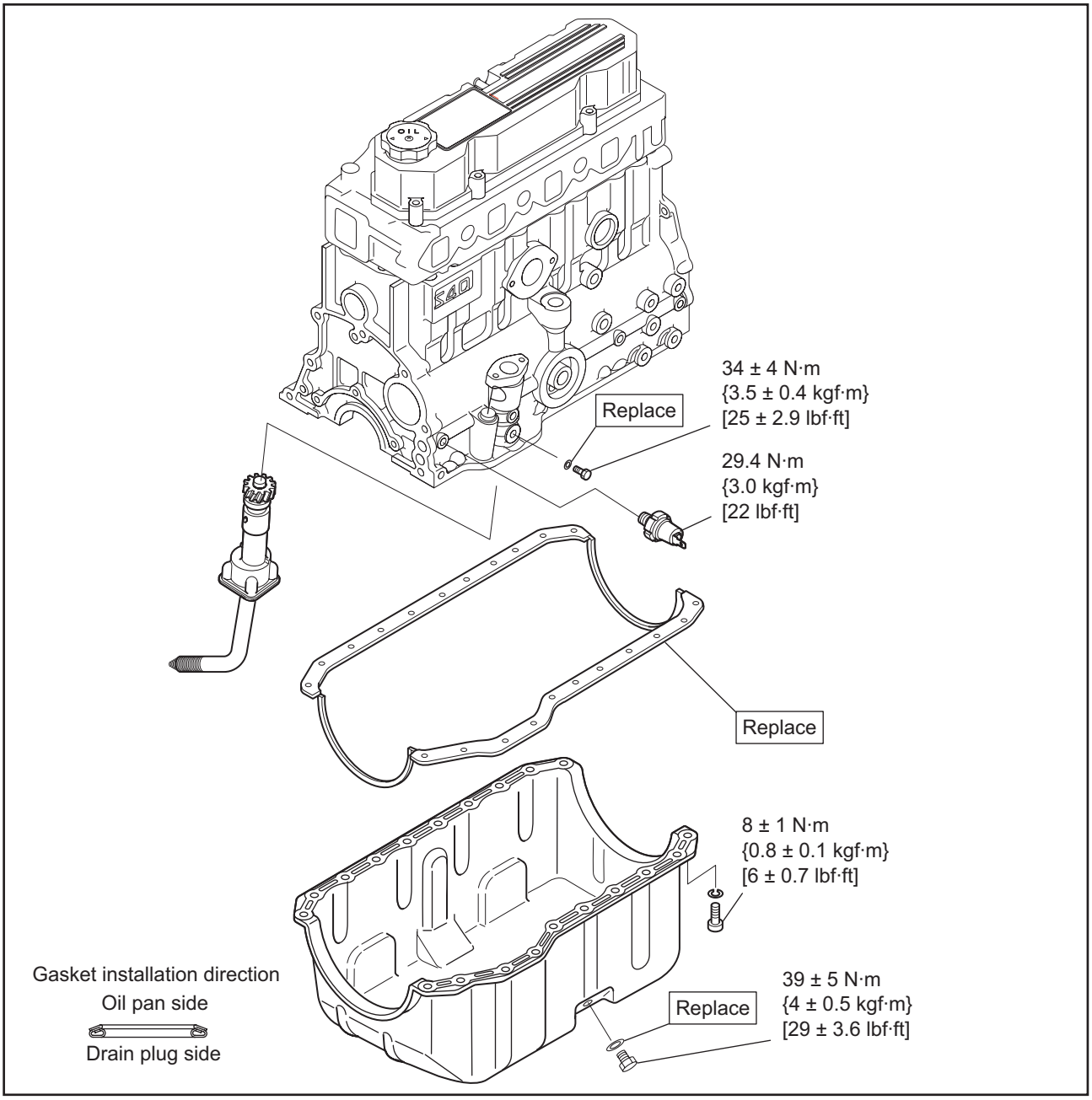
Item	Standard
Relief valve opening pressure	0.3 to 0.4 MPa {3 to 4 kgf/cm²} [42.67 to 56.89 psi]



Installing relief valve

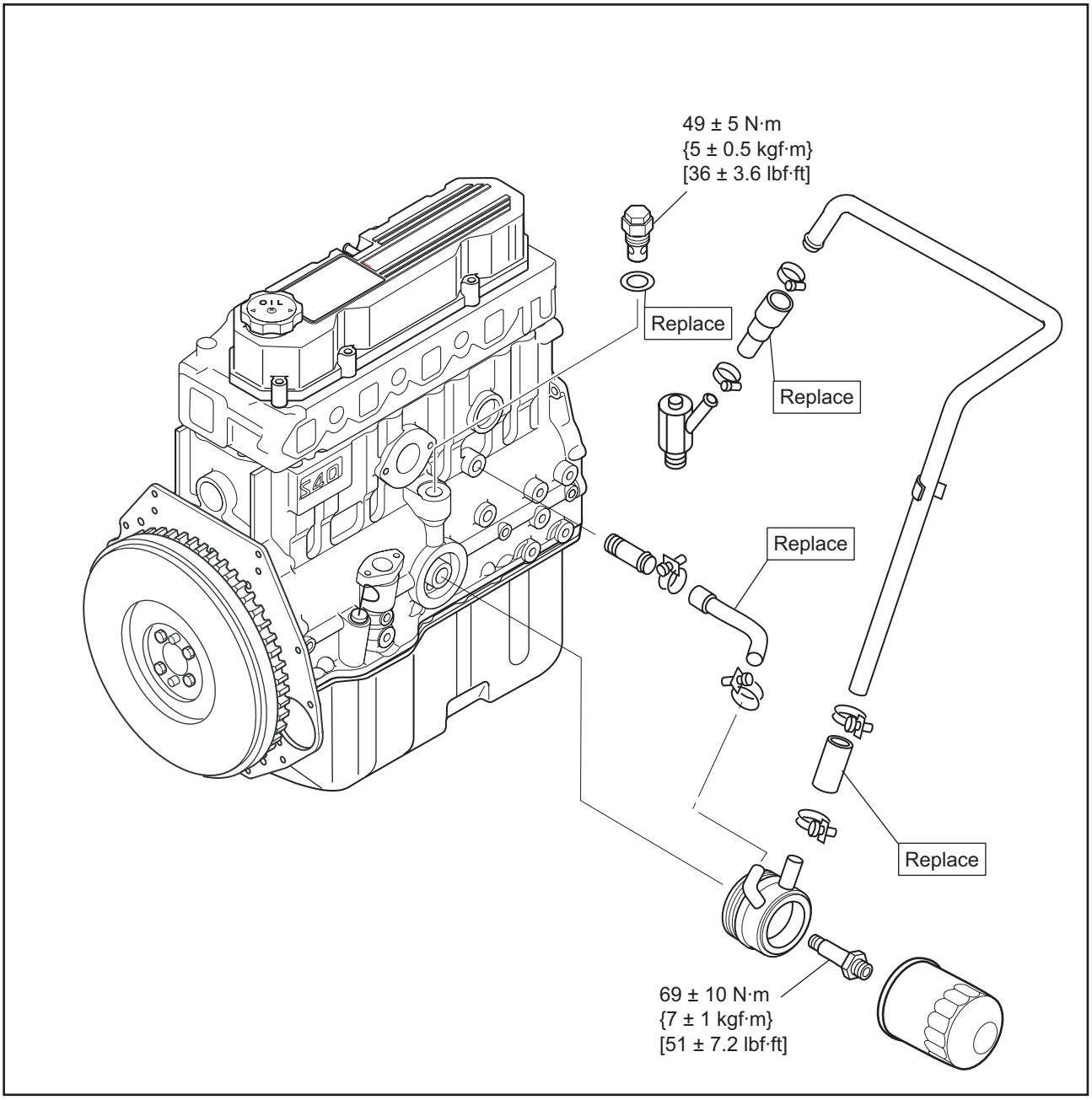
3. Installing lubrication system

3.1 Installing oil pan, oil pump and oil pressure switch



Installing oil pan, oil pump and oil pressure switch

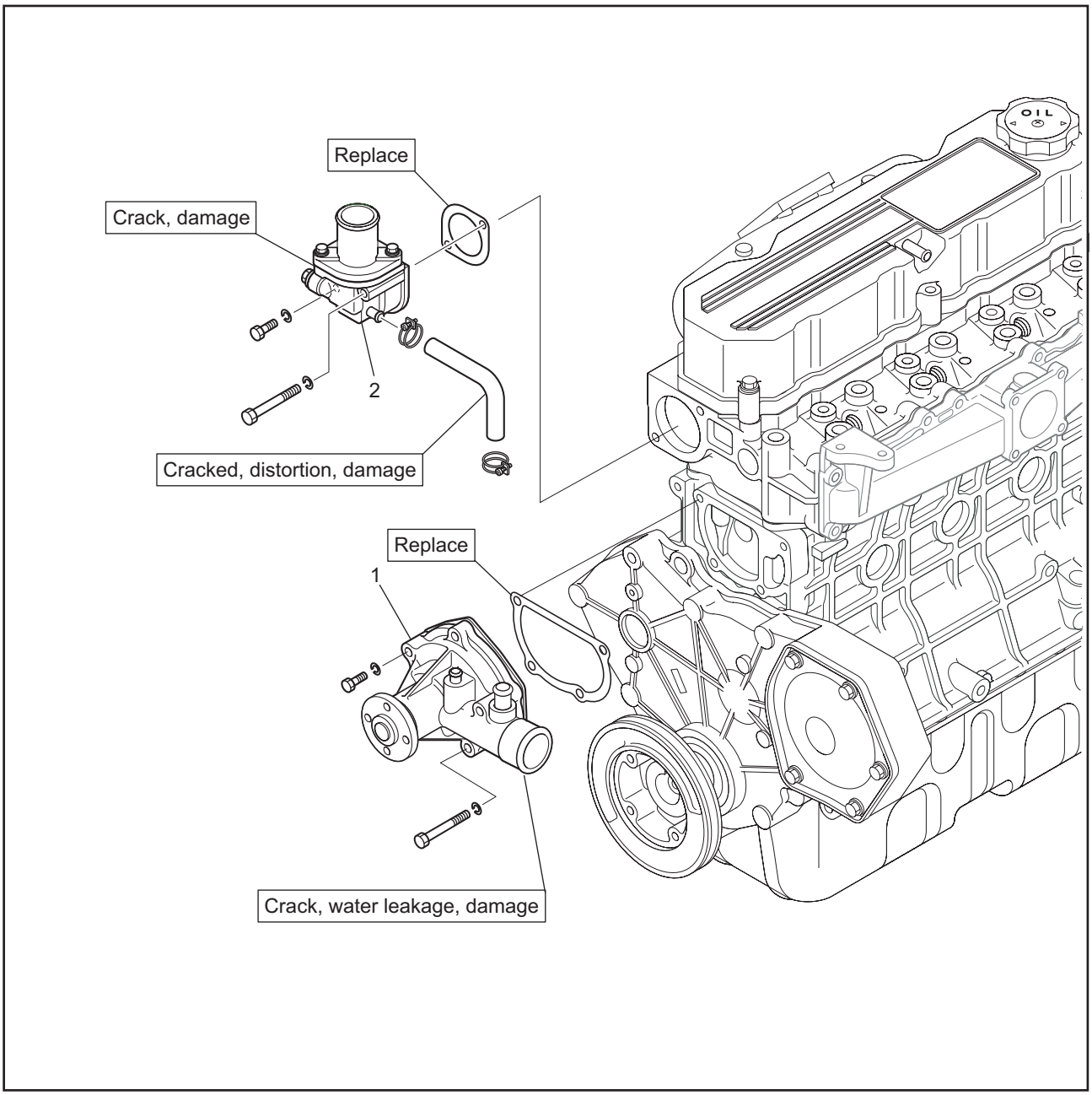
3.2 Installing oil cooler and relief valve



Installing oil cooler and relief valve

COOLING SYSTEM

1. Removing cooling system



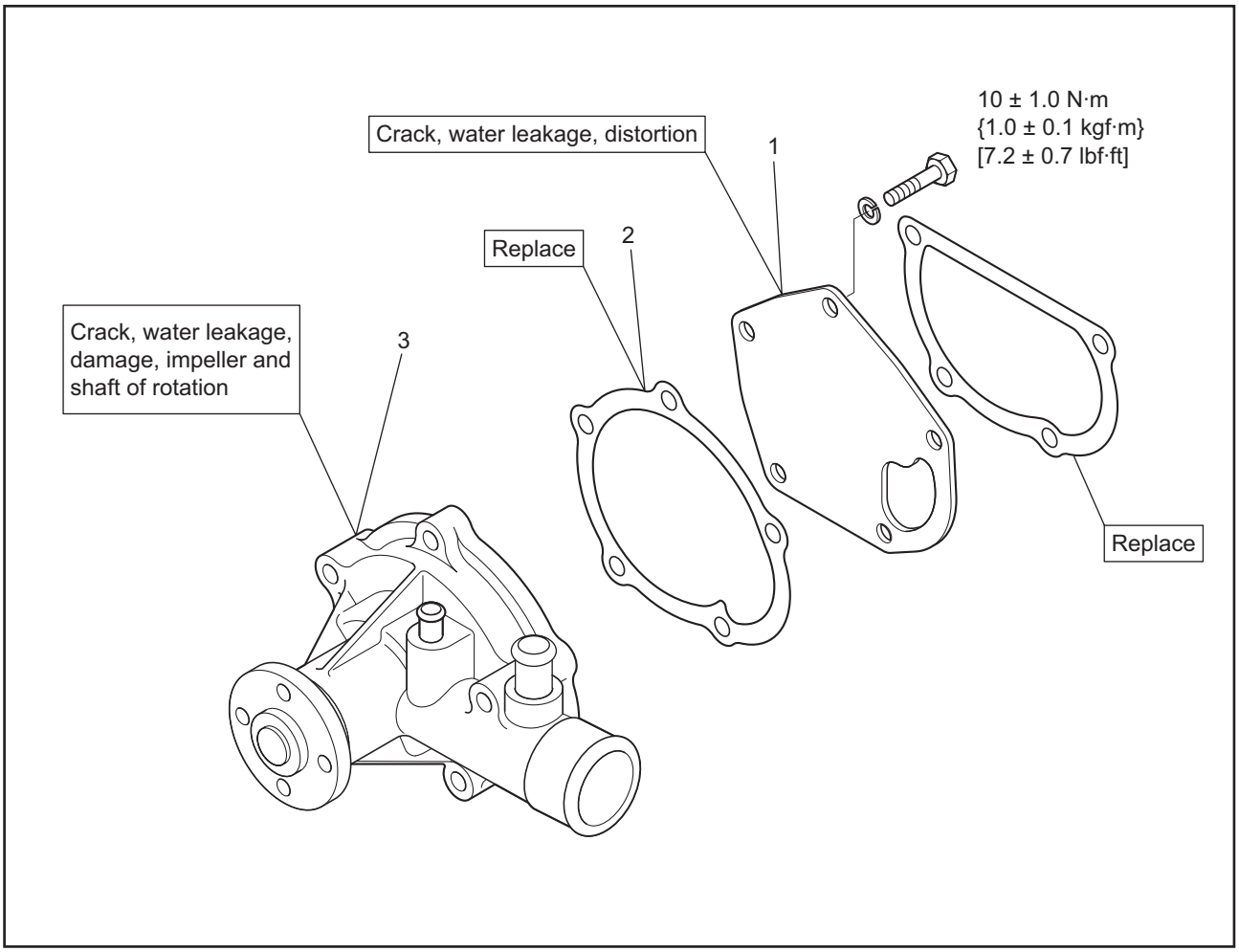
Removing cooling system

Removing sequence

1 Water pump assembly
2 Thermostat

2. Disassembling, inspecting and reassembling cooling system

2.1 Disassembling, inspecting and reassembling water pump



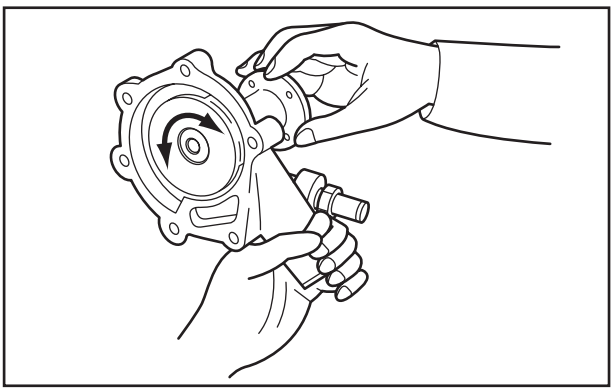
Disassembling, inspecting and reassembling water pump

Disassembling sequence

1 Water pump cover 2 Gasket 3 Water pump

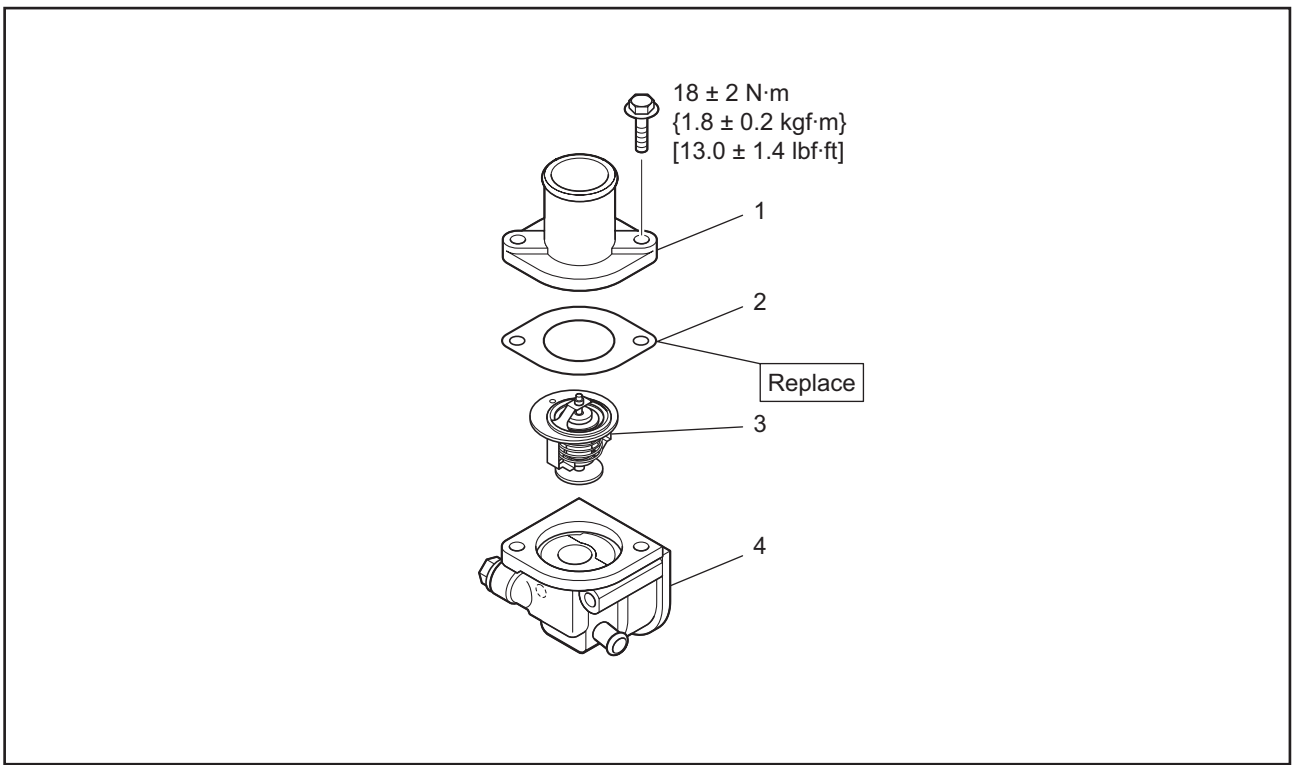
2.1.1 Inspecting water pump for smooth rotation

Check to make sure that the impeller and shaft of water pump rotate smoothly without noise and irregularities. If faulty, replace the water pump assembly.



Inspecting water pump rotation condition

2.2 Disassembling, inspecting and reassembling thermostat



Disassembling, inspecting and reassembling thermostat

Disassembling sequence

1 Thermostat cover
2 Gasket
3 Thermostat
4 Thermostat case

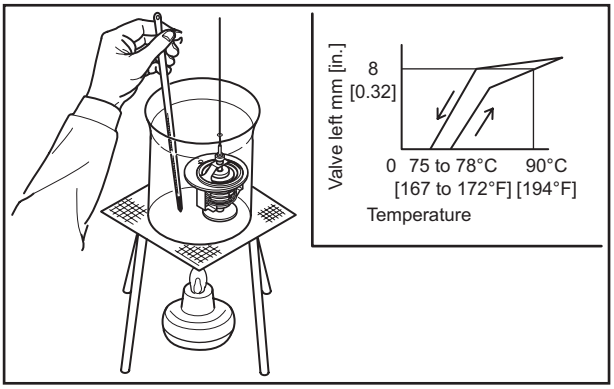
2.2.1 Inspecting thermostat

⚠ 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.

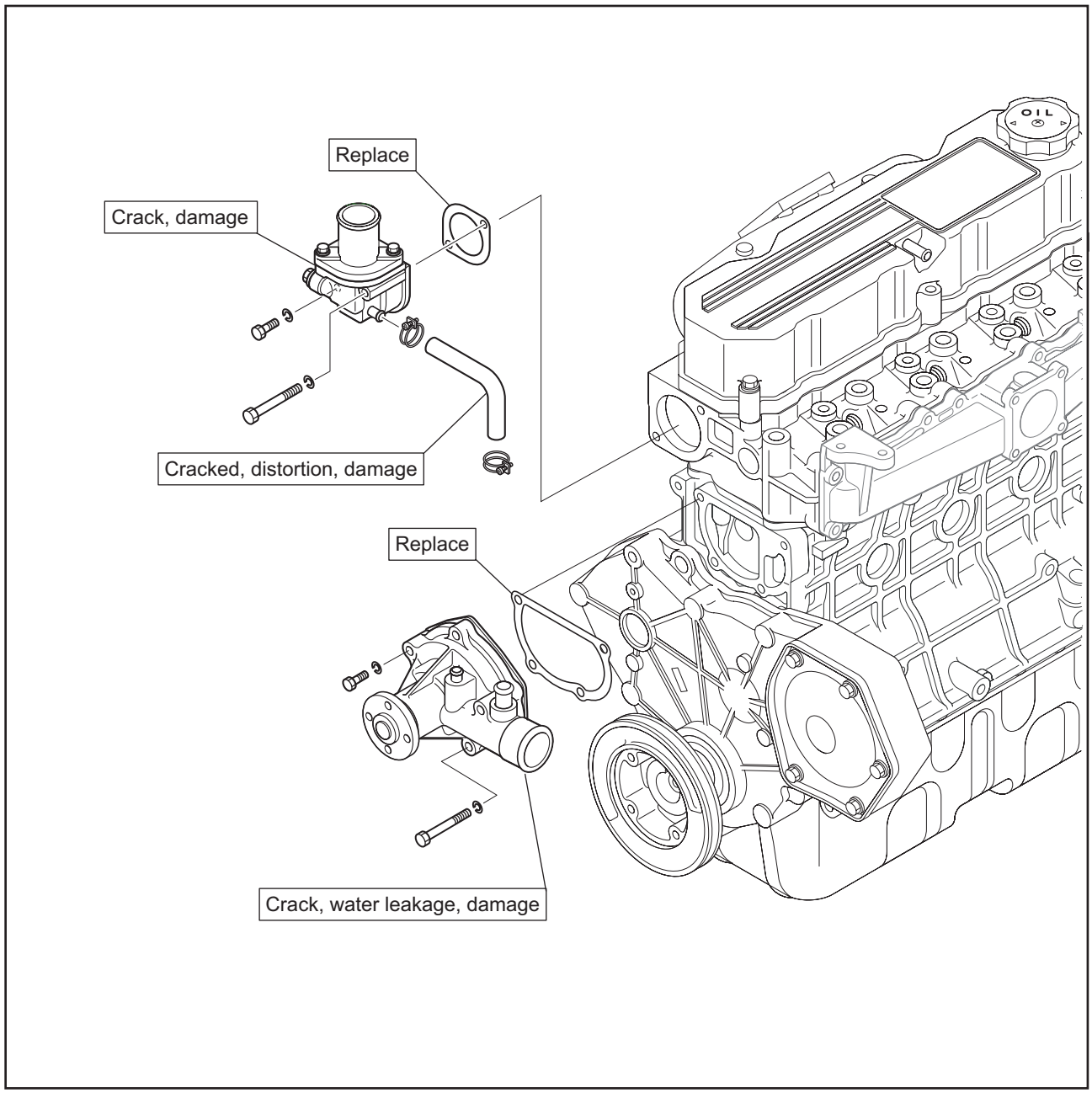
Note: (a) Stir the water in the container with a stick to ensure uniform temperature distribution.
(b) Before installing the thermostat, be sure to check the valve opening temperature stamped on the thermostat valve side face.



Inspecting thermostat

Item	Standard
Temperature at which valve starts opening	75 to 78°C [167 to 172°F]
Temperature at which valve lift becomes 8 mm [0.31 in.] or more.	90°C [194°F]

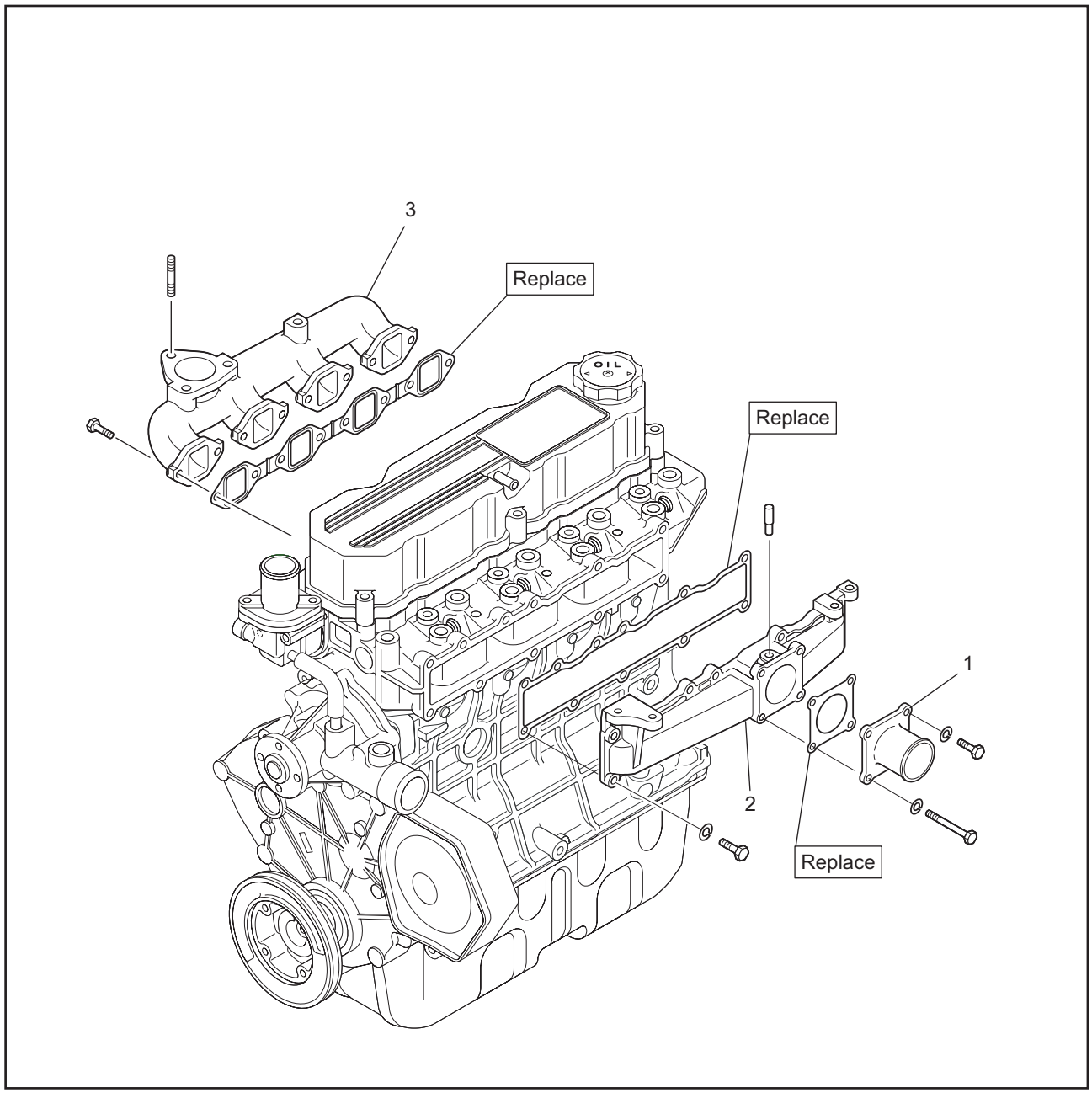
3. Installing cooling system



Installing cooling system

INLET AND EXHAUST SYSTEMS

1. Removing inlet and exhaust system



Removing inlet and exhaust sysytem

Removing sequence

1 Air inlet pipe
2 Inlet manifold
3 Exhaust manifold

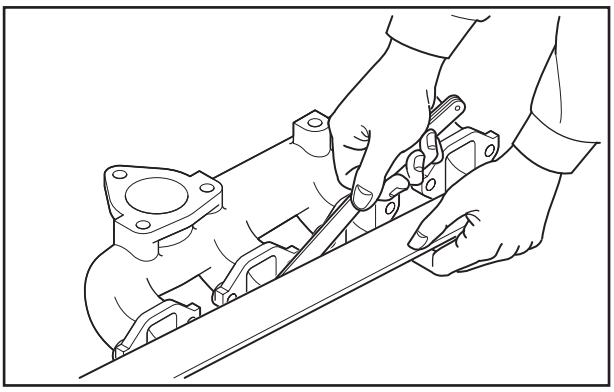
2. Inspecting inlet and exhaust system

2.1 Measuring exhaust manifold distortion

(1) Check the flange for crack.

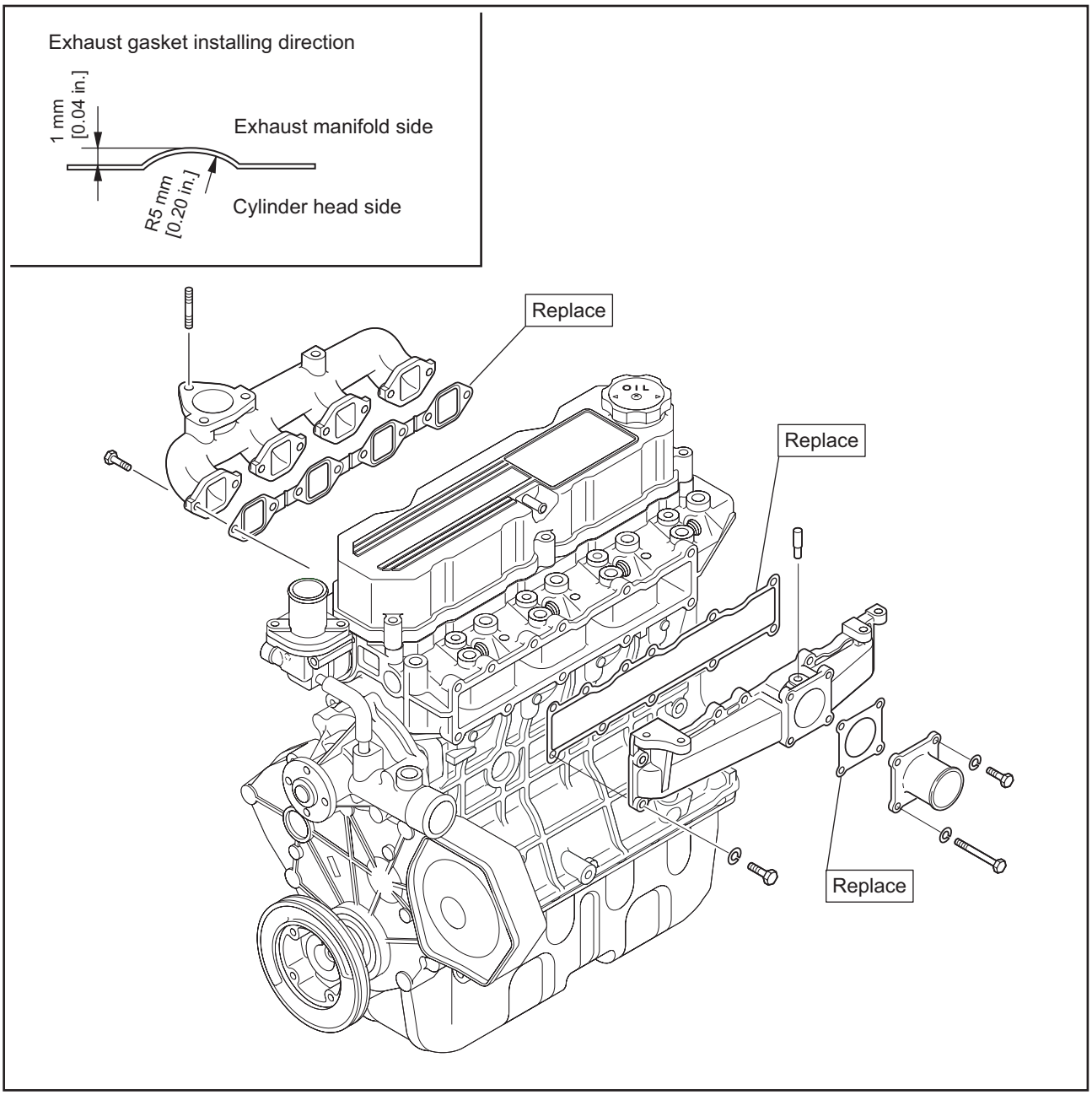
(2) Check the flange suface for distortion. If the distortion exceeds the standard, retouch the surface.

Item	Standard
Exhaust manifold distortion	Less than 0.15 mm [0.0059 in.]



Measuring exhaust manifold distortion

3. Installing inlet and exhaust system

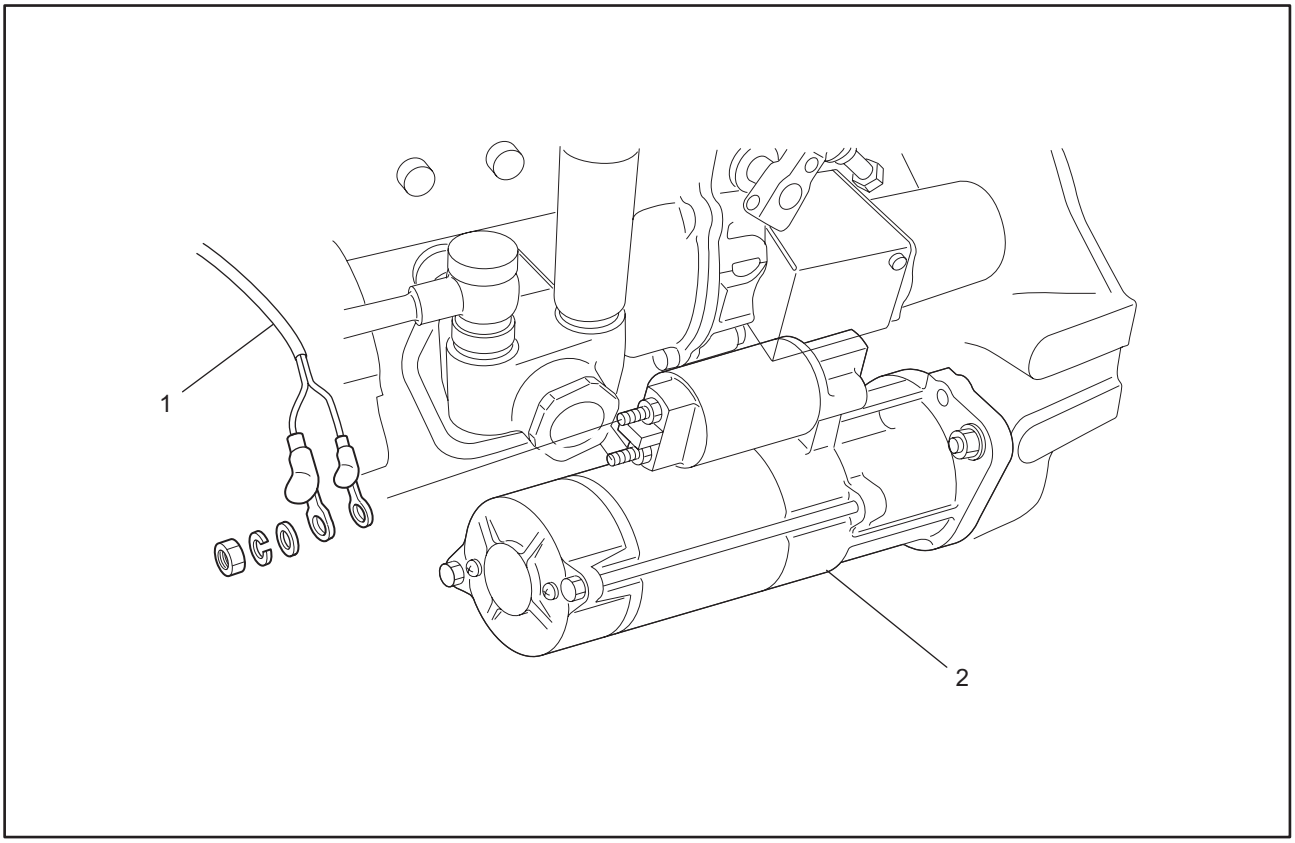


Installing inlet and exhaust system

ELECTRICAL SYSTEM

1. Removing electrical system

1.1 Removing starter



Removing starter

Removing sequence

1 Harness
2 Starter

1.2 Inspection before removing alternator

1.2.1 Inspecting alternator operation

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

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

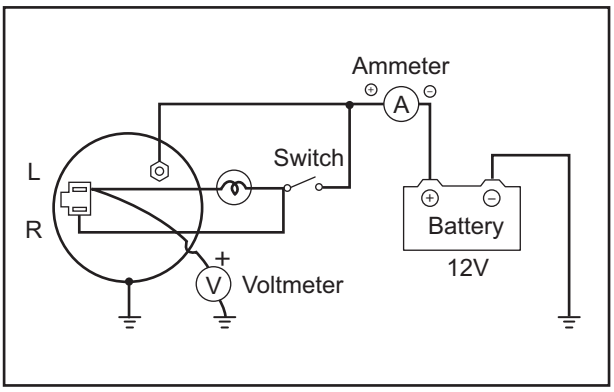
1.2.2 Handling precaution

Improper handling could cause damage or failure to the alternator.

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

1.2.3 Inspecting regulated voltage

(1) Disconnect the battery (+) terminal, and connect an ammeter.
(2) Connect a volt meter to terminal L ground line.
(3) Make sure that the volt meter indicates 0 when the starter switch is OFF position.
Make sure that the volt meter indicates much lower voltage than battery voltage when the starter switch is ON position.
(4) Disconnect the terminal of ammeter, and start the engine.
(5) Measure the adjusting voltage with volt meter.

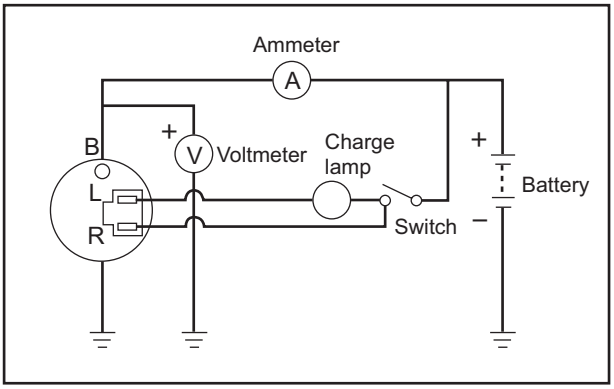


Wiring method of vehicle

Item	Spec	Standard	Condition
Regulated voltage (at 20°C [68°F])	12 V - 50 A	14.4 to 15.0 V	5000 min^{-1}, 5A or lower, 20°C [68°F]

1.2.4 Inspecting output

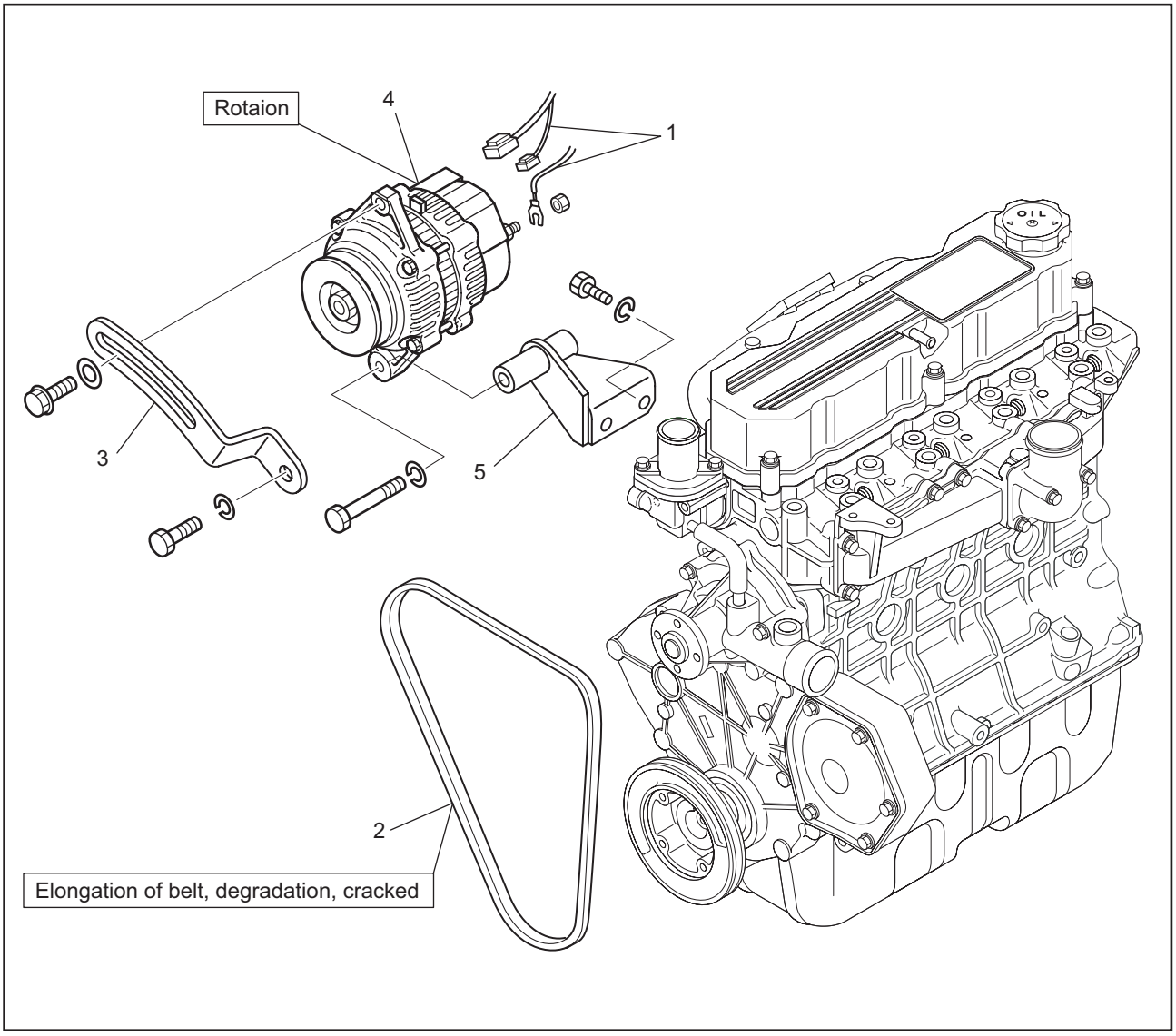
(1) Disconnect the battery ground cable.
(2) Connect B terminal of the alternator to the ammeter, then connect the voltmeter between B terminal and ground.
(3) Connect the battery ground cable.
(4) Start the engine.
(5) Immediately apply all loads such as lamps.
(6) Increase the engine speed and measure the maximum output current at the specified alternator rotation speed with the voltmeter indicated the specified value.
(7) If the measured value meets the standard, the output is normal.



Inspecting regulated voltage

Item	Spec	Standard	
		Terminal voltage/current	Alternator rotation speed
Output characteristics (when hot)	12V - 50A	13.5V / 33A or higher	2500 min^{-1}
		13.5V / 47A or higher	5000 min^{-1}

1.3 Removing alternator

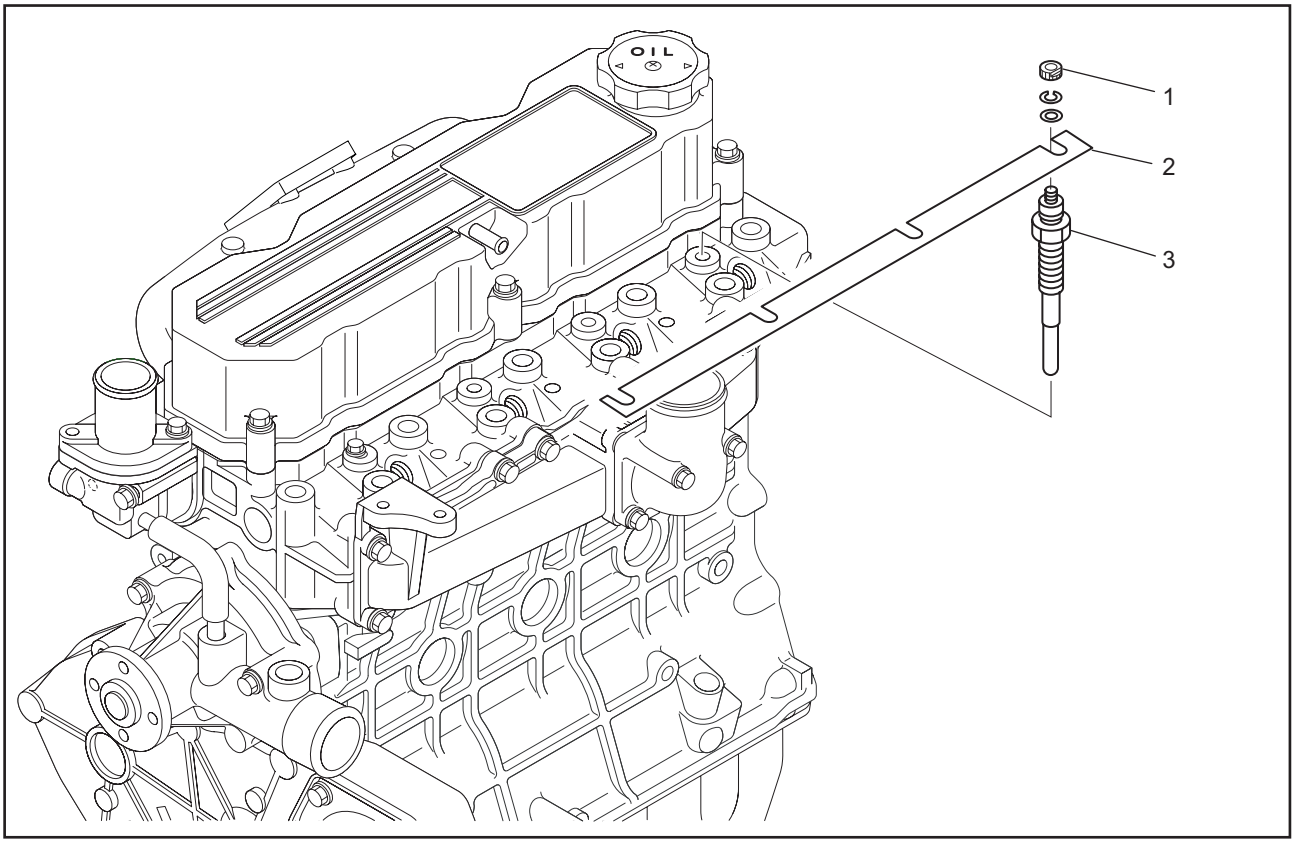


Removing alternator

Removal sequence

1 Harness
2 V-belt
3 Adjusting plate
4 Alternator
5 Alternator bracket

1.4 Removing glow plug



Removing glow plug

Removing sequence

1 Nut
2 Connection plate
3 Glow plug

2. Disassembling, inspecting and reassembling electrical system

2.1 Inspection before disassembling starter

2.1.1 Inspecting magnetic switch

Perform the inspection as described below. If faulty, replace the magnetic switch with a new one.

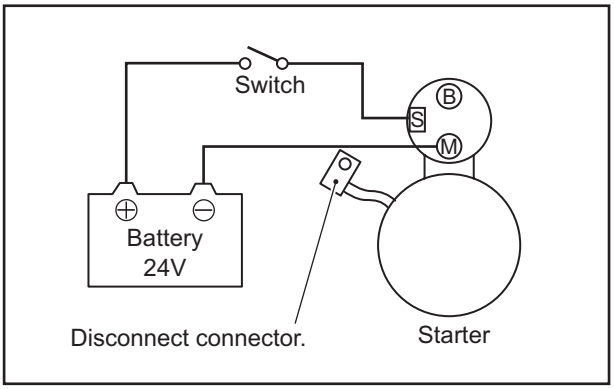
CAUTION

Do not apply current continuously for longer than 10 seconds.

(1) Disconnect the connector of M terminal.

(2) Pull-in test

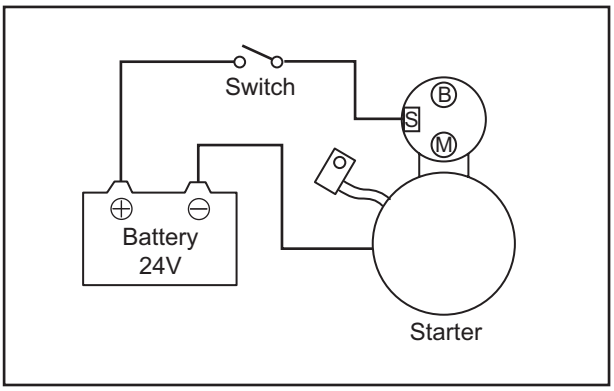
Connect the starter to the circuit as shown in the illustration. The magnetic switch is normal if the pinion springs out when the switch is turned ON.



Pull-in test

(3) Holding test

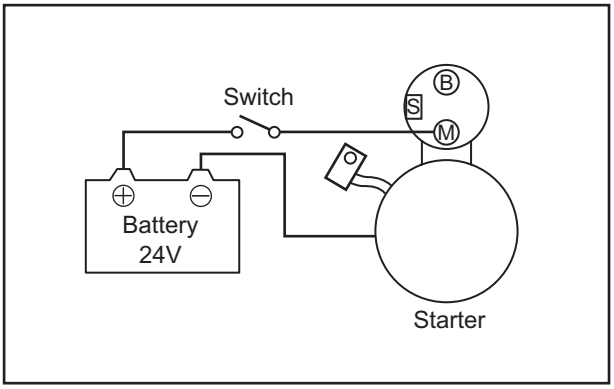
Connect the starter to the circuit as shown in the illustration. Pull out the pinion fully by hand. The magnetic switch is normal if the pinion does not return when it is released.



Holding test

(4) Return test

Connect the starter to the circuit as shown in the illustration. Pull out the pinion fully by hand. The magnetic switch is normal if the pinion returns immediately when it is released.



Return test

2.1.2 No load test

CAUTION

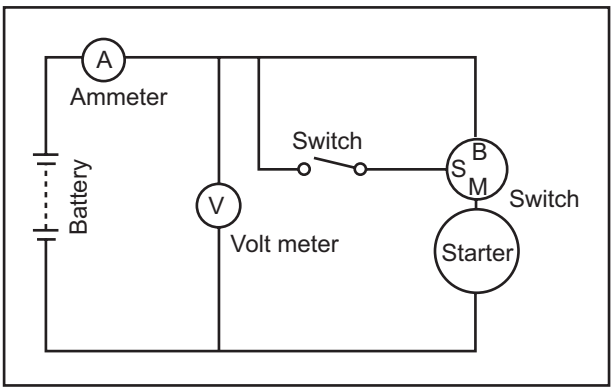
Use as thick a wire as possible and firmly tighten each terminal.

When detecting the rotation at the tip of the pinion, be careful, as the pinion pops out during operation.

(1) Connect the starter to the circuit as shown in the illustration.

(2) In normal condition, the pinion pops out when the switch is turned ON, and the starter rotates at or more the specified rotation speed.

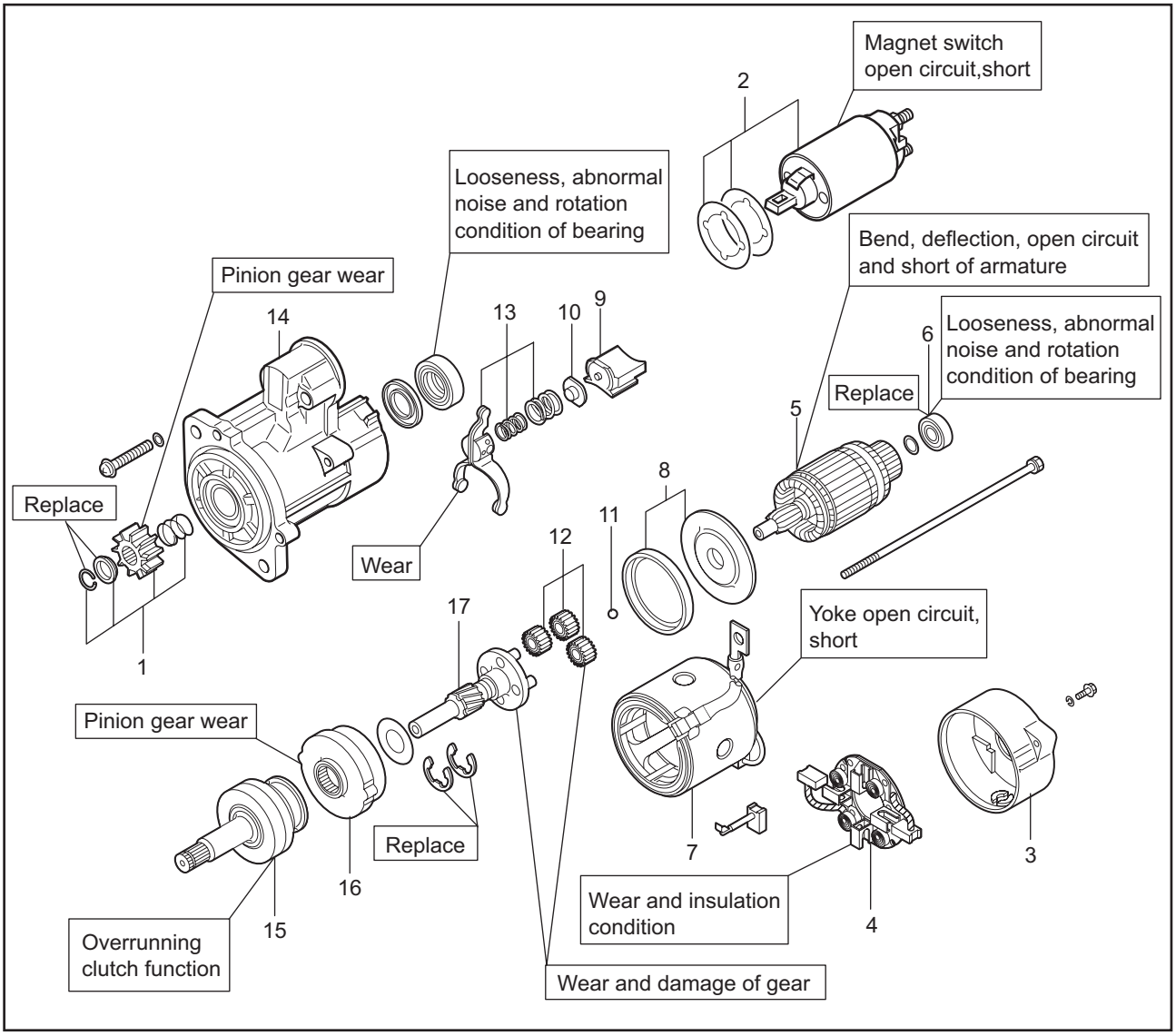
If the terminal voltage, current or rotation speed does not meet the standard, disassemble, inspect and repair the starter.



Test at no load

Item		Standard
No-load characteristics	Terminal voltage	11 V
	Current	130 A or less
	Rotation speed	3600 min^{-1} or more

2.2 Disassembling and inspecting starter



Disassembling and inspecting starter

Disassembling sequence

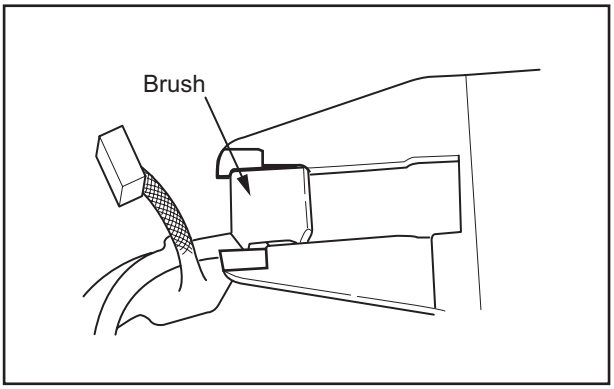
1 Pinion set
2 Magnet switch
3 Rear bracket
4 Brush holder
5 Armature
6 Bearing
7 Yoke
8 Packing
9 Packing
10 Plate
11 Ball
12 Planetary gear
13 Lever
14 Front bracket
15 Overrunning clutch
16 Internal gear
17 Gear shaft

2.3 Inspecting and repairing starter

2.3.1 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	17.5 mm [0.689 in.]	11 mm [0.43 in.]

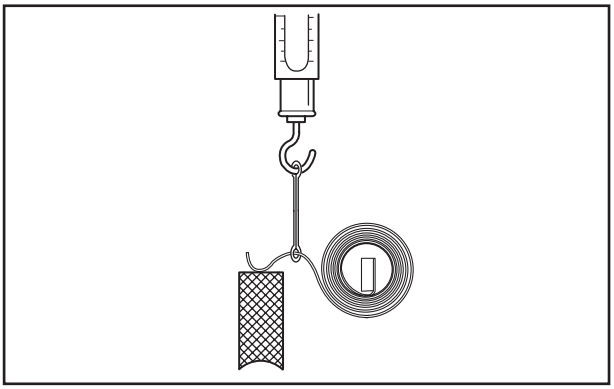


Inspecting brushes for wear

2.3.2 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.

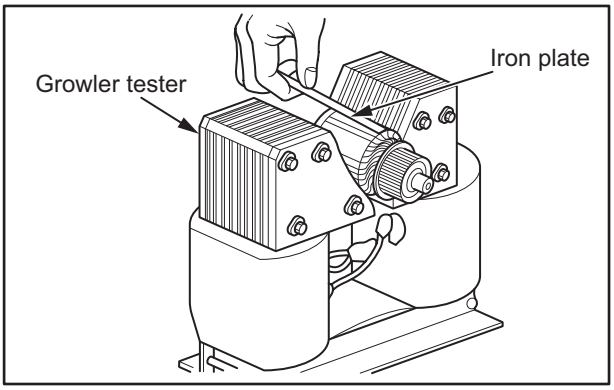
Item	Standard	Limit
Brush spring load	26.7 to 36.1 N {2.7 to 3.7 kgf} [20 to 27 lbf]	14.7 N {1.5 kgf} [11 lbf]



Measuring brush spring load

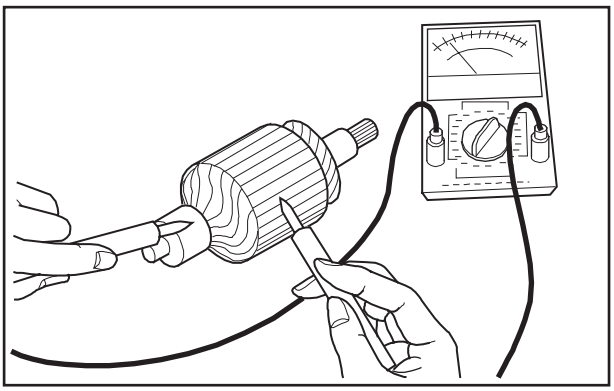
2.3.3 Inspecting armature coil

(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

(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.

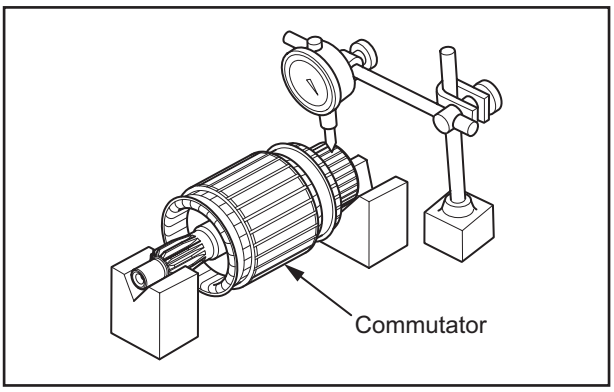


Inspecting insulation between commutator and shaft

2.3.4 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.



Measuring commutator radial runout

2.3.5 Measuring commutator outside diameter

Measure the commutator outside diameter.

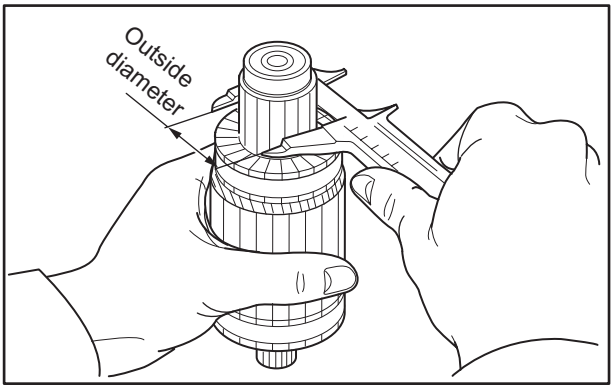
If the measured value is less than the limit, replace the armature with a new one.

2.3.6 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	Standard	Limit
Commutator outside diameter	32 mm [1.26 in.]	31.4 mm [1.236 in.]

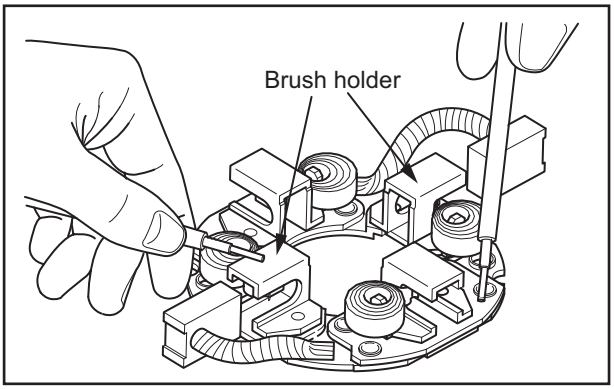


Measuring commutator outside diameter

2.3.7 Inspecting brush holder for insulation

Check that there is no continuity between each brush holder and the brush holder base. If continuity is observed, replace the whole brush holder assembly.

Check the brush holders for looseness.



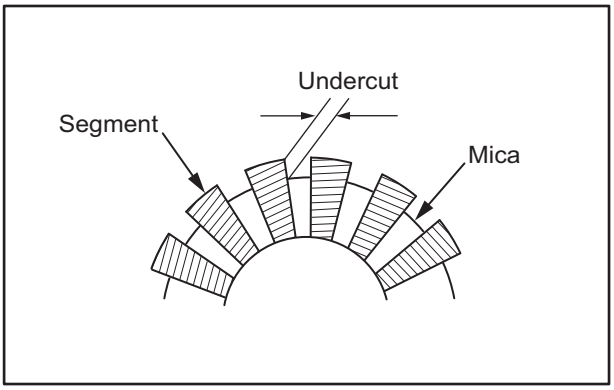
Inspecting brush holder insulation

2.3.8 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	0.5 mm [0.020 in.]	0.2 mm [0.008 in.]



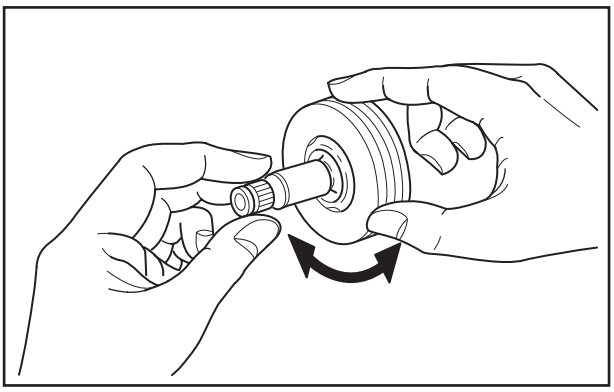
Measuring commutator mica depth

2.3.9 Inspecting overrunning clutch

CAUTION

Do not clean the overrunning clutch in wash oil.

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



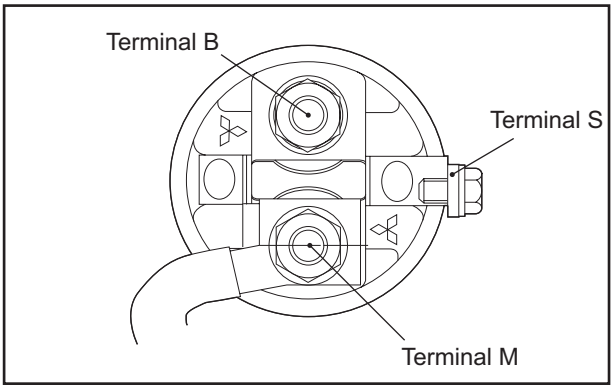
Inspecting overrunning clutch

2.3.10 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.

2.3.11 Inspecting insulation of magnetic switch (between M terminal and B terminal)

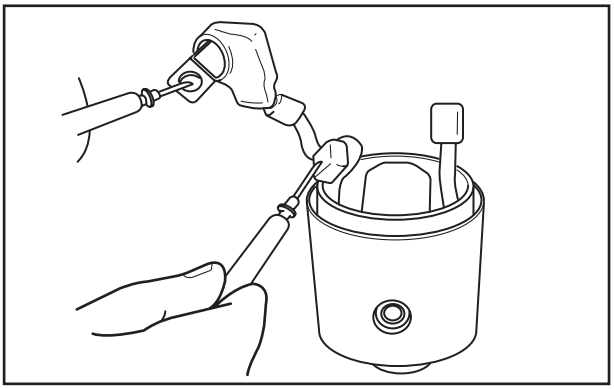
Check that there is no continuity between M terminal and B terminal. If continuity is observed, replace the magnetic switch with a new one.



Inspecting magnet switch

2.3.12 Inspecting continuity of yoke assembly

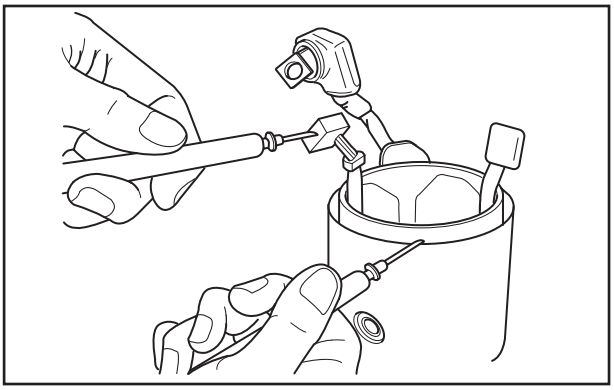
Check that there is continuity between M terminal of field coil and the lead wire for the brush. If no continuity is observed, replace the yoke assembly with a new one.



Inspecting continuity of yoke assembly

2.3.13 Inspecting insulation between yoke body and brush

Check that there is no continuity between yoke body and brush. If continuity is observed, replace the yoke assembly with a new one.



Inspecting insulation between yoke body and brush

2.4 Reassembling starter

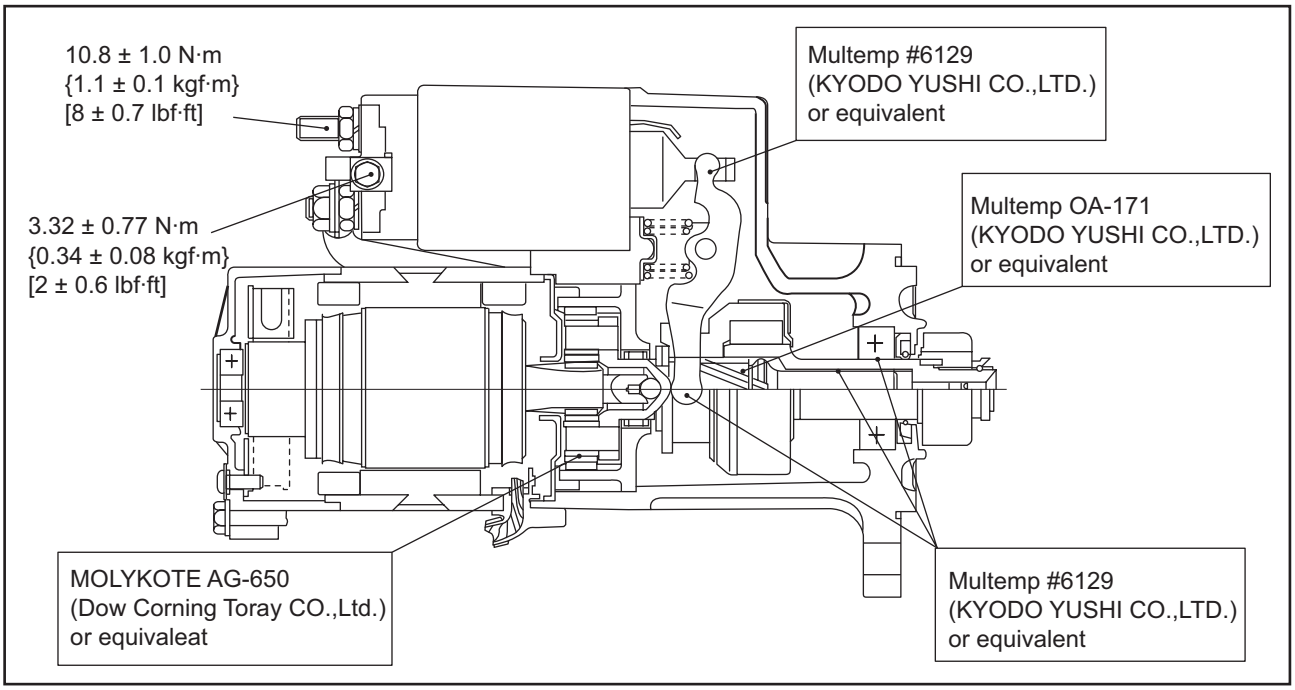
2.4.1 Applying grease

CAUTION

To avoid mixing of different greases, remove old grease before applying new grease.

Make sure that the starter mounting surface, brushes, commutator and other electric current conducting components are free from grease.

When overhauling the starter, apply grease to the following sliding surfaces, gears and bearings.



Reassembling starter

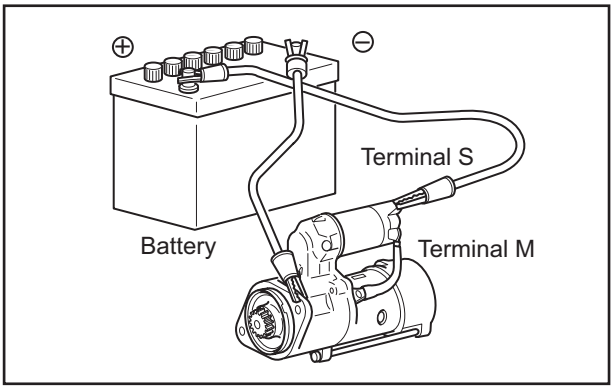
2.5 Inspecting and adjusting after reassembling

2.5.1 Inspecting pinion clearance

CAUTION

Do not apply current continuously for longer than 10 seconds.

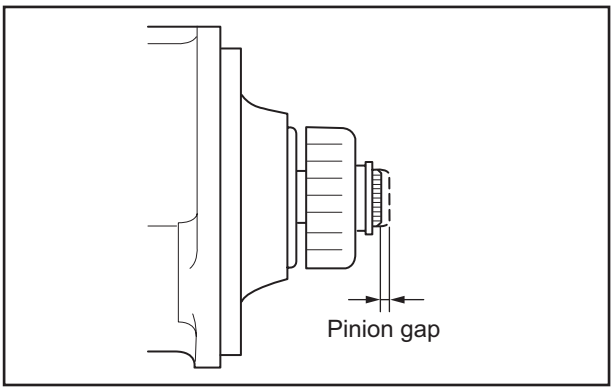
(1) Since connecting the wires of the reassembled starter as shown in the diagram causes the pinion to extends and rotate slowly, disconnect the connector from terminal M to stop the rotation.



Ajusting pinion gap (1)

(2) Lightly push the tip of the extended pinion shaft with a finger, and measure the distance of the shaft movement to obtain the pinion gap measurement.
Adjust the pinion gap by varying the number of packings installed at the magnetic switch section so that it conforms to the standard value. When the number of packings is increased, the pinion gap decreases.
If proper adjustment cannot be achieved by varying the number of packings, replace the lever.

Item	Standard
Pinion gap	0.5 to 2.0 mm [0.020 to 0.079 in.]



Ajusting pinion gap (2)

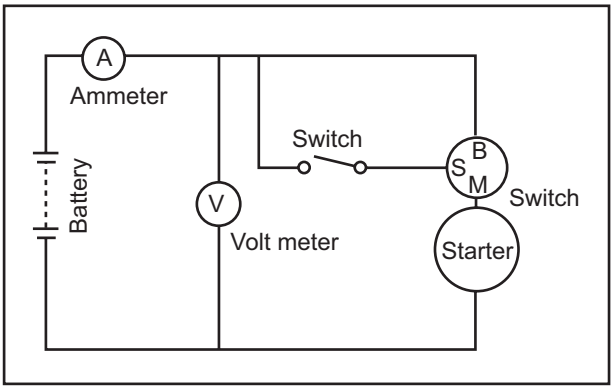
2.5.2 No load test

CAUTION

Use as thick a wire as possible and firmly tighten each terminal.
When detecting the rotation at the tip of the pinion, be careful, as the pinion pops out during operation.

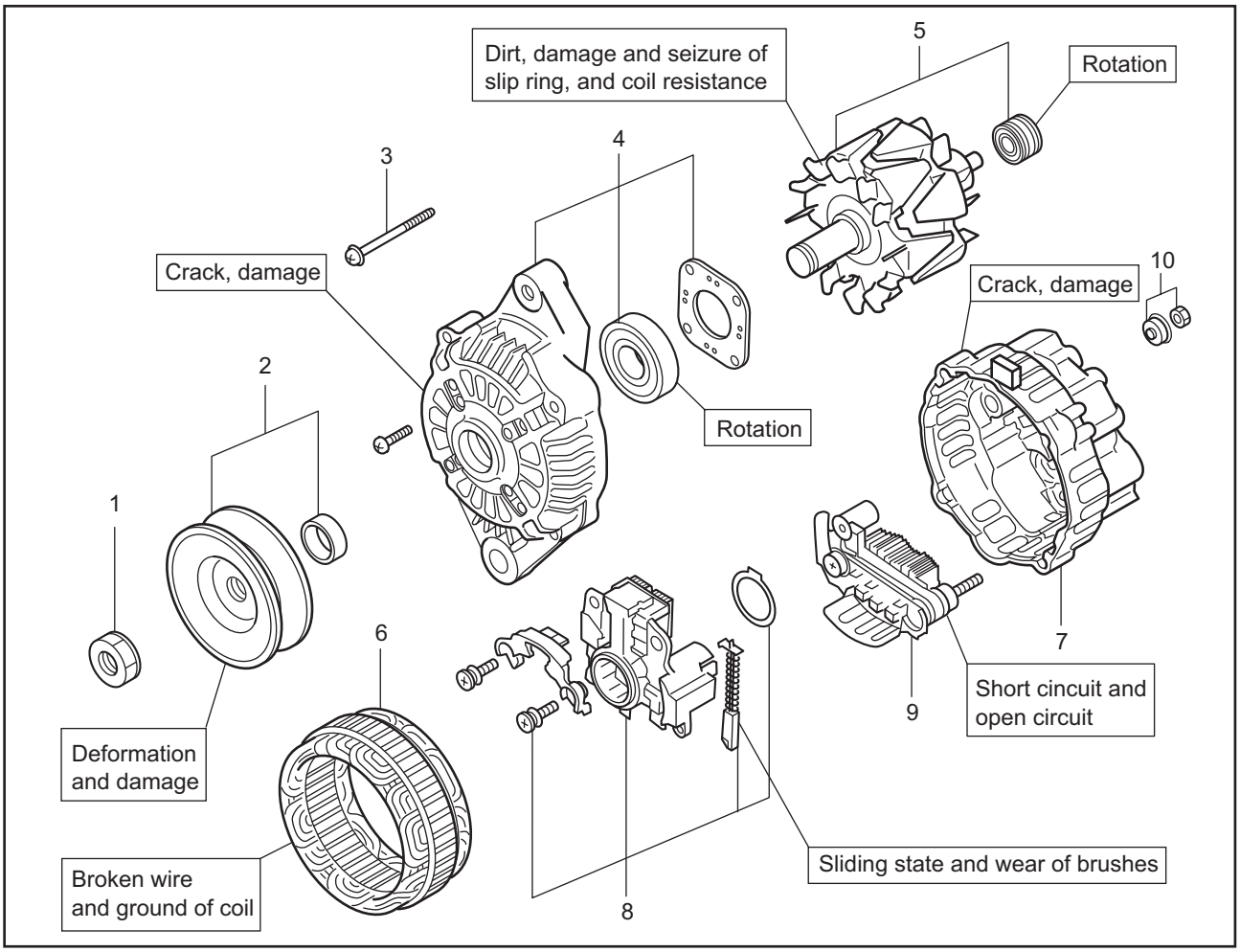
(1) Connect the starter to the circuit as shown in the illustration.

(2) In normal condition, the pinion pops out when the switch is turned ON, and the starter rotates at or more the specified rotation speed.
If the terminal voltage, current or rotation speed does not meet the standard, disassemble, inspect and repair the starter.



Test at no load

2.6 Disassembling, inspecting and reassembling alternator



Disassembling, inspecting and reassembling alternator

Disassembling sequence

1 Nut
2 Pulley, spacer
3 Through bolt
4 Front bracket, bearing
5 Rotor, bearing
6 Stator
7 Rear bracket
8 Regulator
9 Rectifier
10 Nut set

2.6.1 Separating front bracket from stator

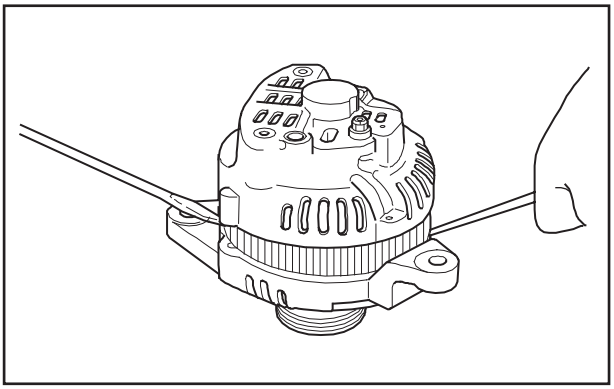
CAUTION

Do not disassemble the alternator unless the repair is necessary.

Do not insert the screwdrivers too deep, as it can damage the stator.

(1) Remove the through bolts.

(2) With two flat-head screwdrivers inserted between the front bracket and stator, pry them apart.



Separating front bracket from stator

2.6.2 Removing pulley

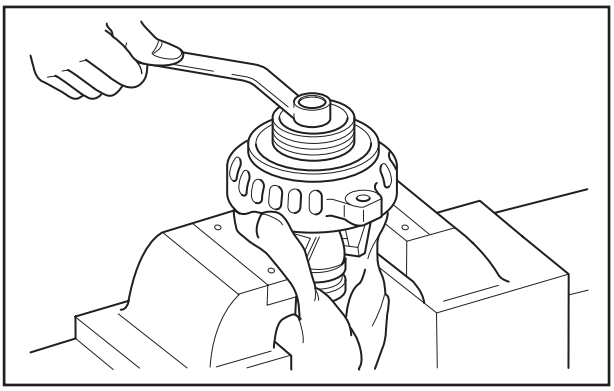
CAUTION

When setting the rotor in a vise, be sure to hold the base of the rotor claw. Do not hold the rotor claw, as it causes damage to the claw.

(1) Apply a cloth to the rotor and set it in a vise.

(2) Remove the pulley nut and then pull out the pulley and spacer.

(3) Remove the rotor from the front bracket.



Removing pulley

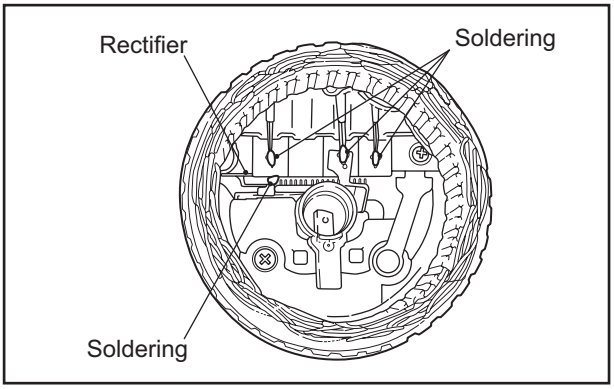
2.6.3 Removing stator

CAUTION

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

(1) Cut off the joint of the stator and remove the stator from the rectifier.

(2) Unscrew the rectifier mounting screws, and dismount the rectifier.

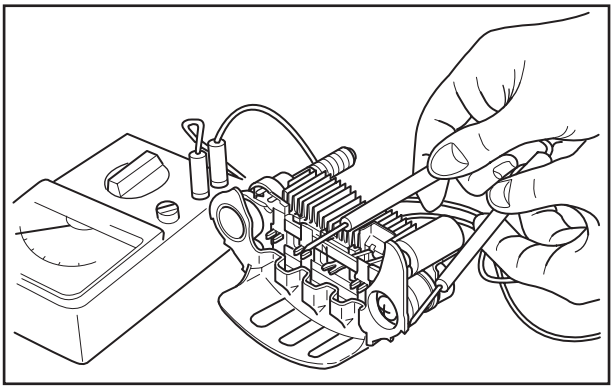


Removing stator

2.6.4 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.

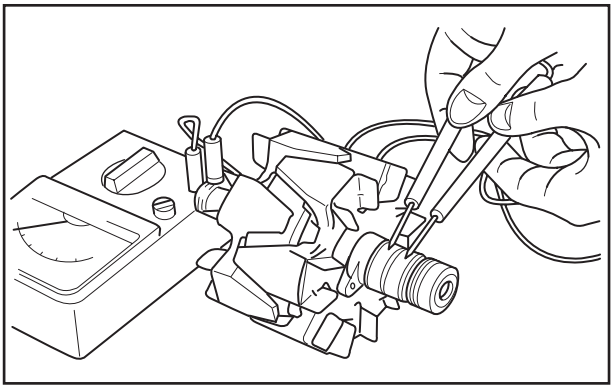
Note: Use a wide measuring range as much as possible. The current flow during test is significantly lower than the current that normally flows in the rectifier, by which the accurate resistance may not be measured using a tester, and this tendency is noticeable if the measuring range is small.



Inspecting rectifier

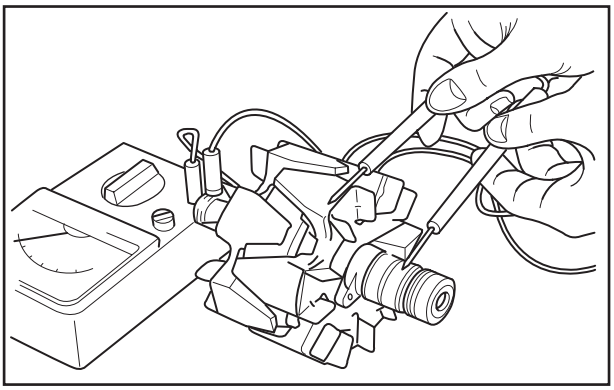
2.6.5 Inspecting rotor

(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 grounding

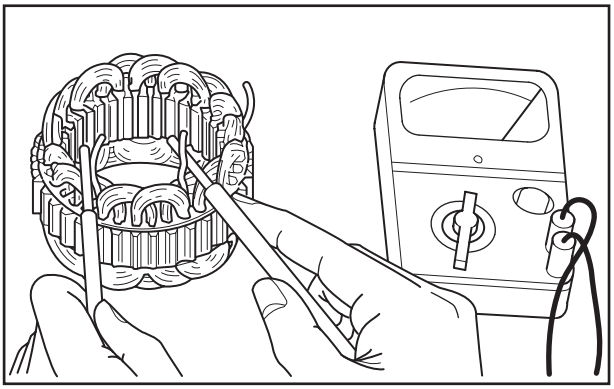
2.6.6 Inspecting stator

(1) Checking continuity between lead wires

Check that there is continuity between a pair of lead wires.

Also check that there is no continuity between a pair of lead wires and other pair of lead wires.

If defective, replace the stator.

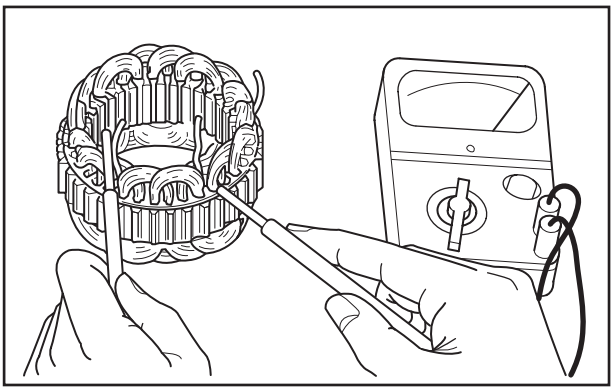


Checking for continuity between leads

(2) Checking insulation between lead wire and core

Check that there is no continuity between each lead wire and the stator core. If continuity is observed, replace the stator.

Note: The core cannot be replaced as a single item.

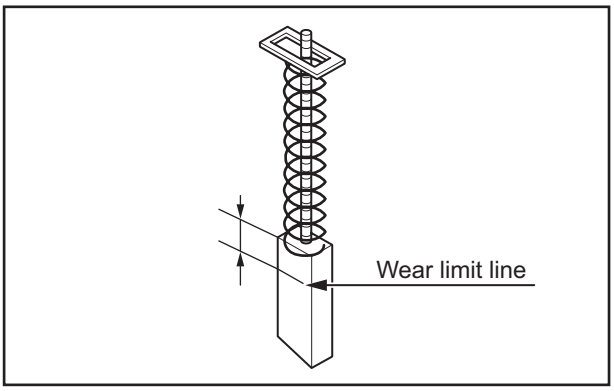


Checking for grounding between the leads and the core

2.6.7 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.

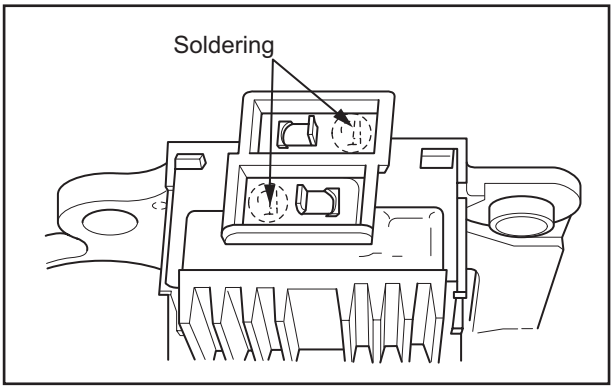
Item	Standard	Limit
Brush length	18.5 mm [0.728 in.]	5.0 mm [0.197 in.]



Inspecting brushes

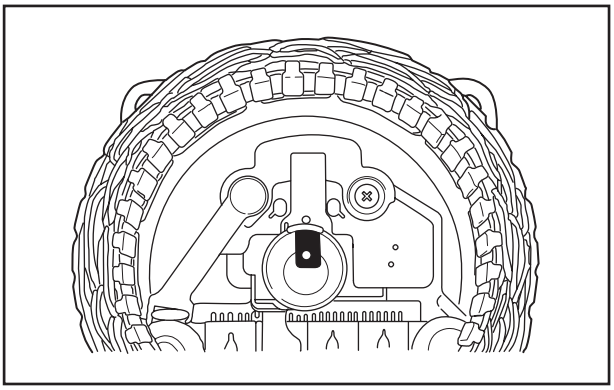
2.6.8 Replacing brushes

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



Replacing brushes

(2) To install a new brush, push the brush into the brush holder as shown in the illustration, and then solder the lead to the brush.



Installing brushes

2.6.9 Reassembling alternator

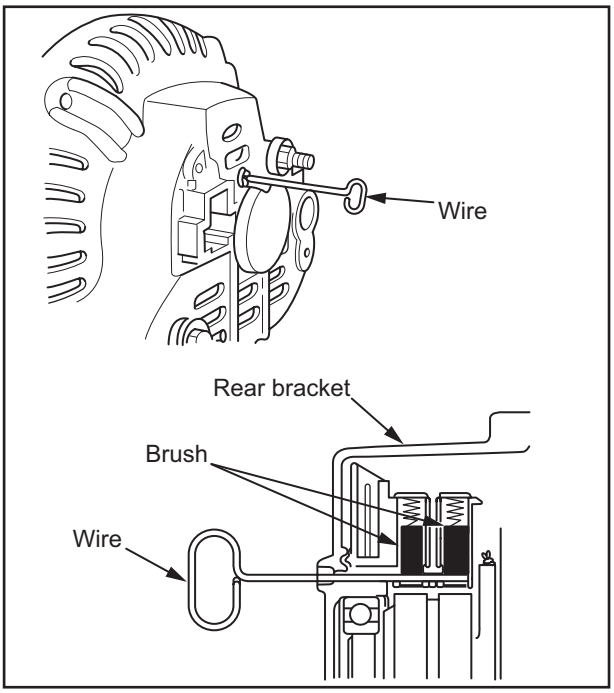
Assemble the alternator in reverse order of disassembly. Key assembly steps follow.

(1) Locate the eccentric groove on the periphery of the rear bearing. Insert the rotation retaining snap ring so that the highest protruded section of the ring is positioned at the deepest section of the groove.

(2) When replacing the rear bearing, press-fit the rear bearing so that the groove on the periphery of the bearing faces the snap ring side.

(3) When press-fitting the rear bearing into the rear bracket, heat the rear bracket to 50 to 60°C [122 to 140°F] first.

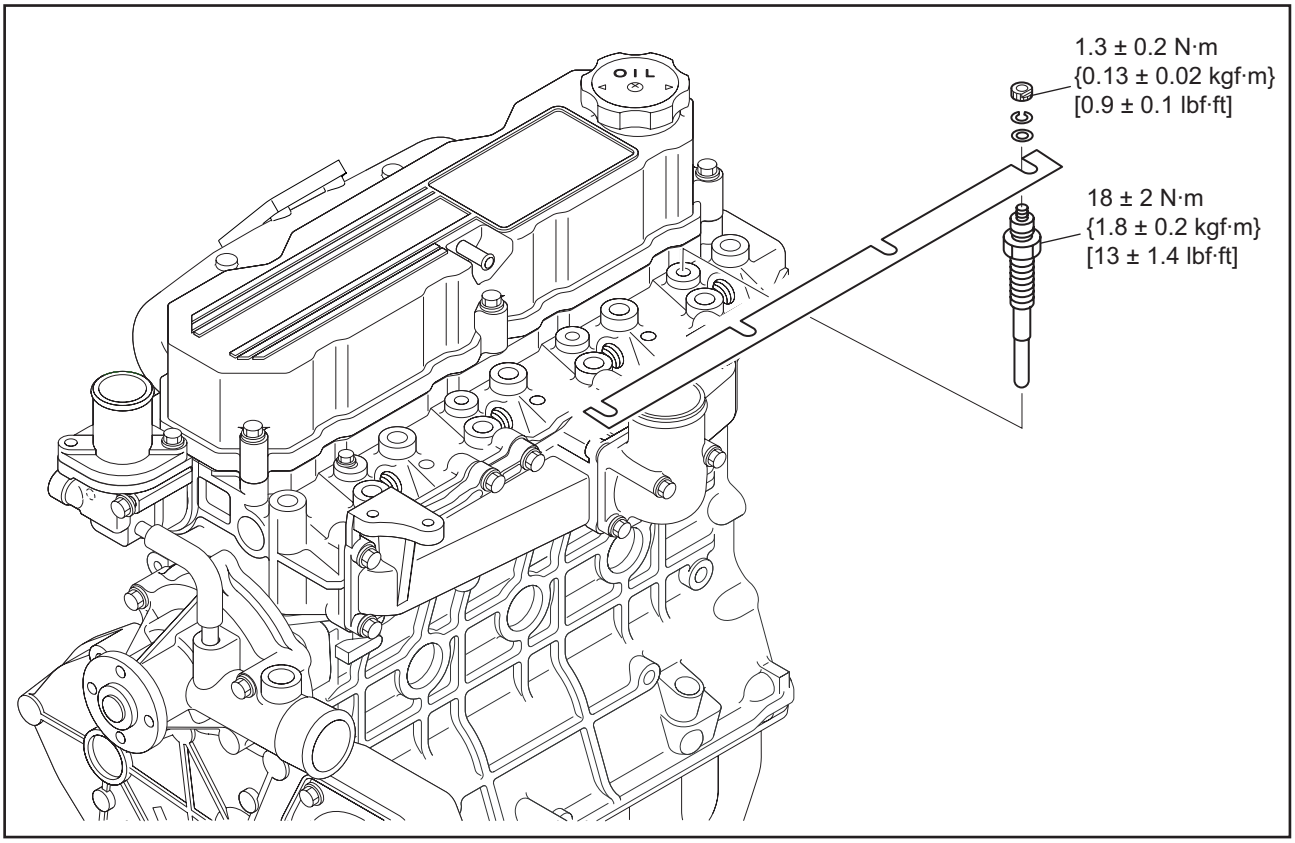
(4) Before installing the rotor to the rear bracket, lift the brushes by inserting a wire through a small hole in the rear bracket, them remove the wire after completing the reassembly.



Reassembling alternator

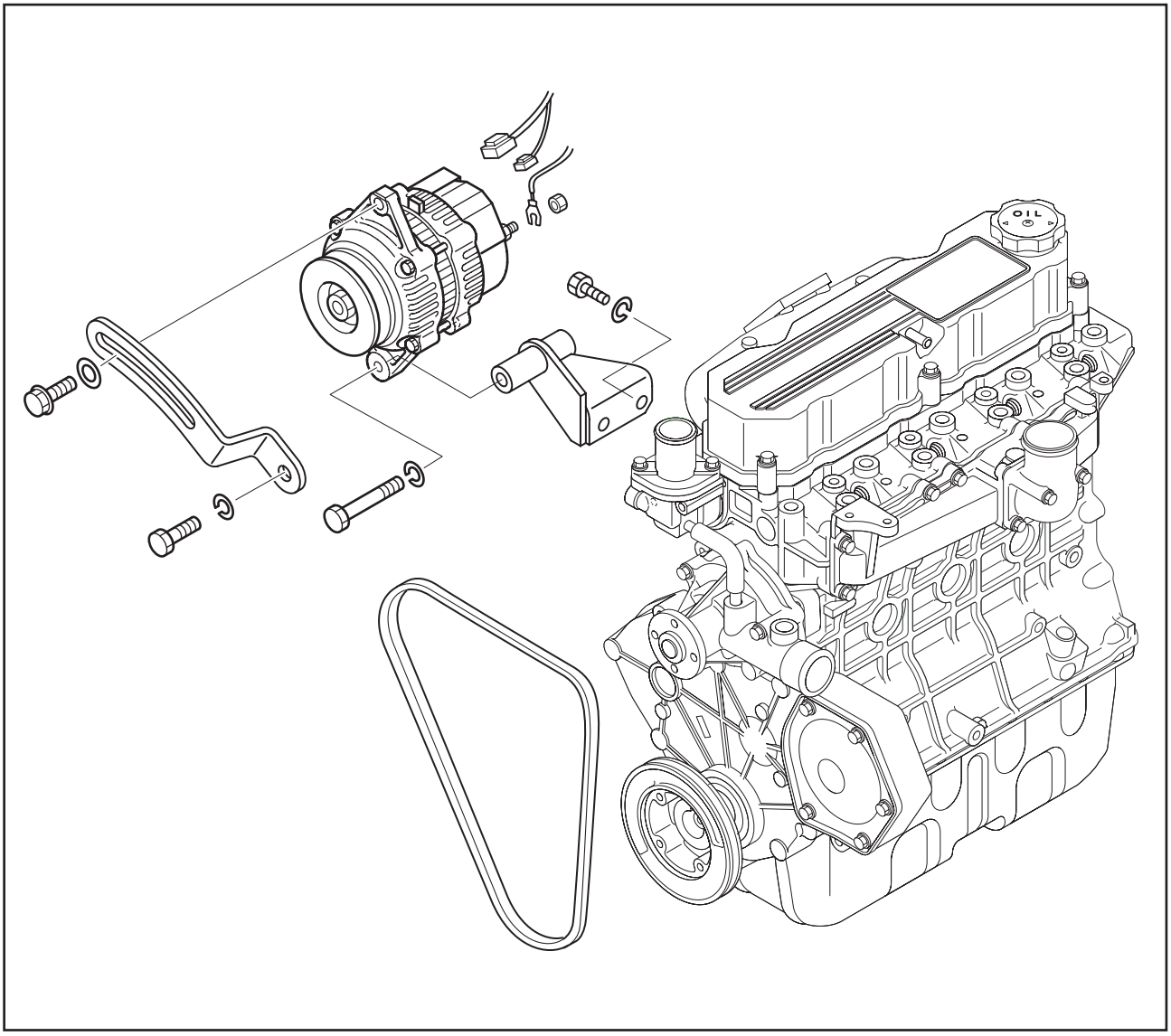
3. Installing electrical system

3.1 Installing glow plug



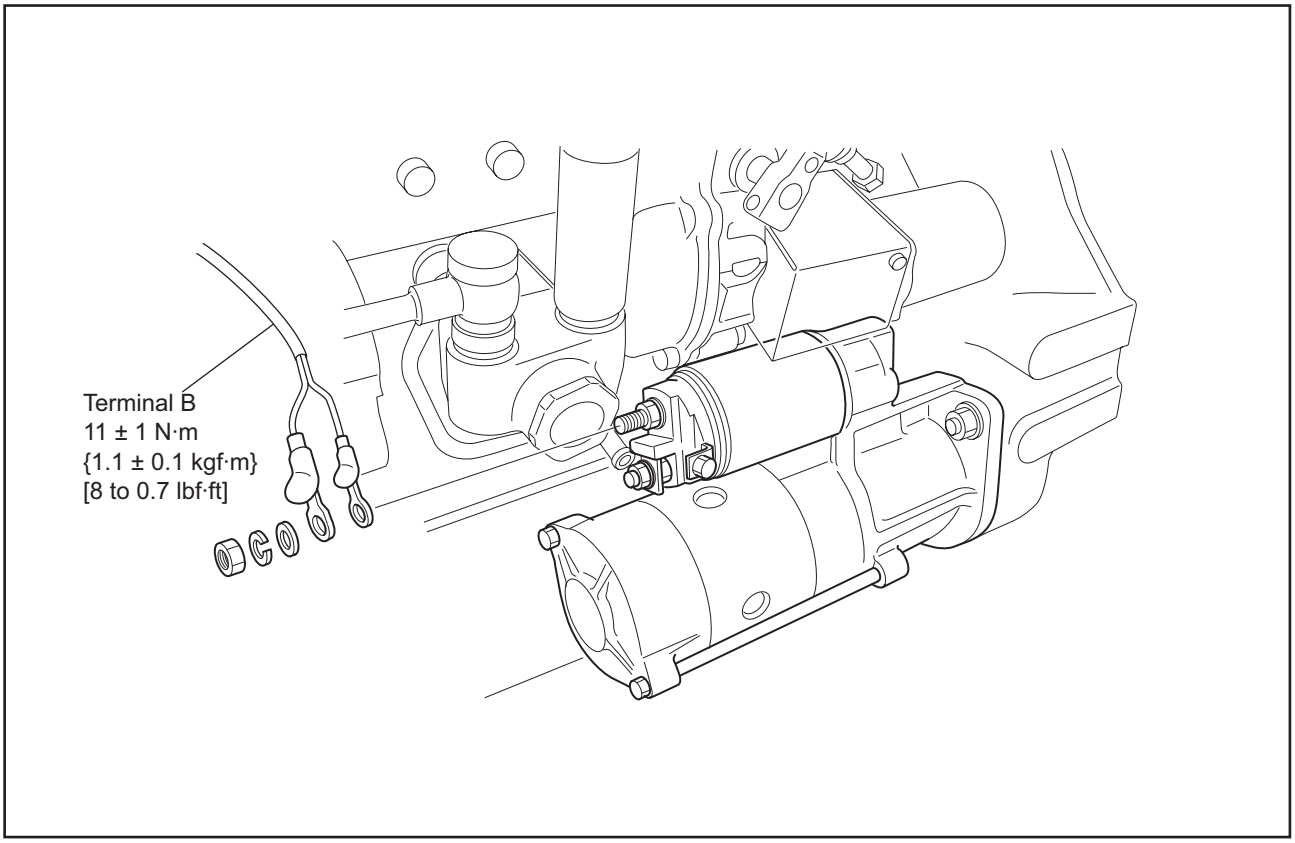
Installing glow plug

3.2 Installing alternator



Installing alternator

3.3 Installing starter



Installing starter

ADJUSTMENT AND OPERATION

1. Adjusting engine

1.1 Inspecting and adjusting valve clearance

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

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

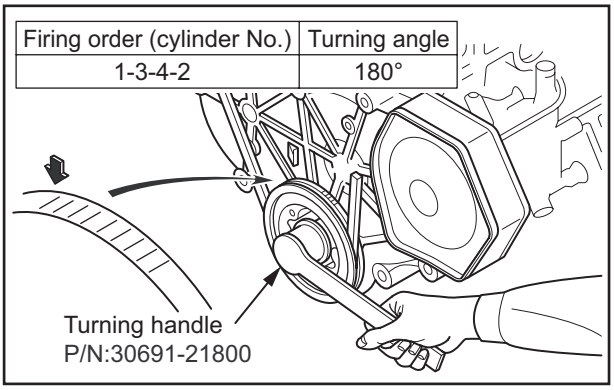
1.1.1 Inspecting valve clearance

(1) Inspect the valve clearance for all cylinders in the firing order by turning the crankshaft to the specified degrees in the normal direction (clockwise when viewed from engine front side) to bring each piston to the top dead center on the compression stroke.

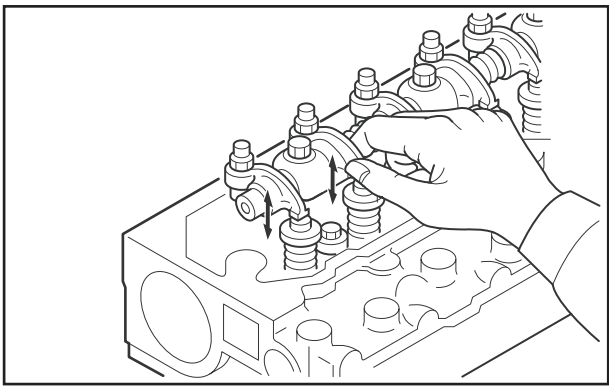
Note: To turn the crankshaft, fit a turning handle on the crankshaft pulley nut.

(2) When the No. 1 piston is at the top dead center on the compression stroke, the "0" graduation mark on the periphery of the crankshaft pulley is aligned with the pointer on the timing gear case, and neither the inlet valve nor the exhaust valve is not lifted off its seat by the push rod.

(3) Insert a thickness gauge between the rocker arm and valve cap to inspect the clearance.



Turning engine

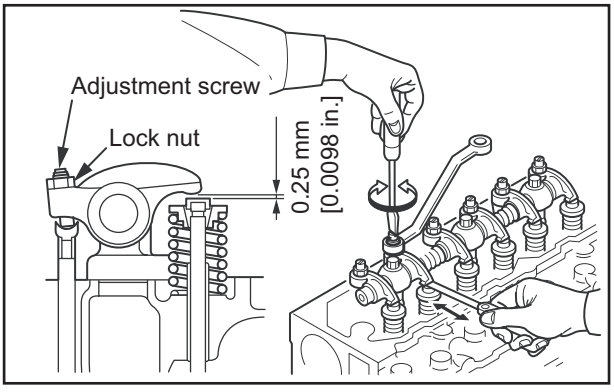


Inspecting and top dead center of No.1 cylinder on compression stroke

1.1.2 Adjusting valve clearances

(1) Insert the feeler gauge of the specified thickness between the rocker arm and bridge cap, then adjust the clearance by turning the screw in either direction so that the gauge is gripped softly between the rocker arm and bridge cap.

(2) After adjusting the clearance, tighten the lock nut firmly, and inspect the clearance again.



Adjusting valve clearance

1.2 Inspecting and adjusting fuel injection timing

1.2.1 Inspecting fuel injection timing

(1) In advance, bring the piston of No.1 cylinder to compession top dead center. Remove the delivery valve holder, delivery valve, spring and stopper from the No.1 cylinder of the fuel injection pump, and reinstall the delivery valve holder only.

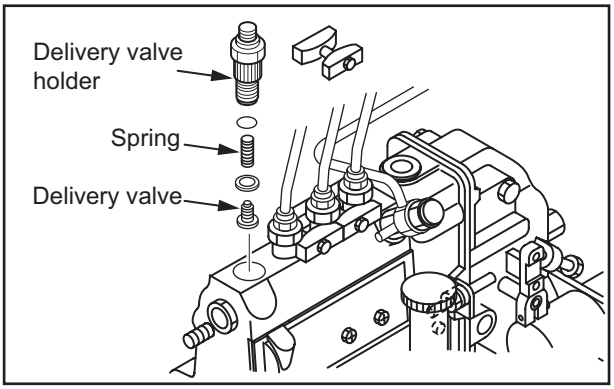
(2) Install a spare injection pipe to the No.1 plunger of the fuel injection pump. Face the other end of the injection pipe to downward so that the fuel flow-out condition can be seen clearly.

(3) Rotate the crankshaft to 60 degree before compression top dead center of No.1 cylinder.

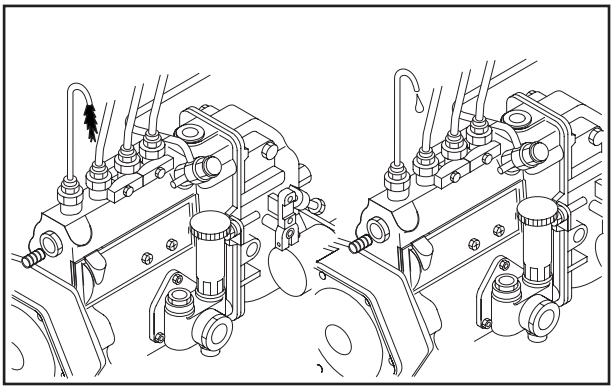
(4) Feed the injection pump using the priming pump. With flowing the fuel out from the injection pipe, rotate the crankshaft gradually in the normal direction.

(5) When the fuel flow is getting fewer, rotate the crankshaft more slowly. When the fuel flow stop completely, stop rotating the crankshaft.

(6) Make sure the pointer indicates the fuel injection timing of the graduation mark on the crankshaft pulley.



Inspecting fuel injection timing (1)

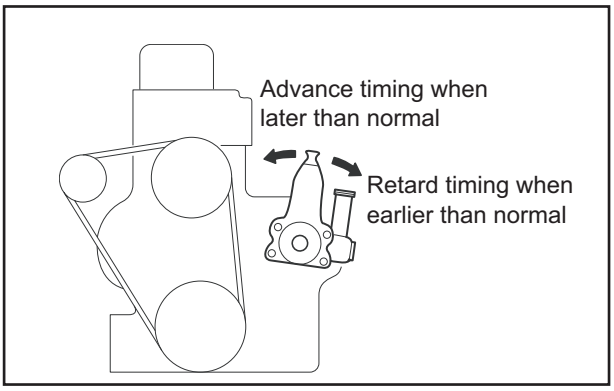


Inspecting fuel injection timing (2)

1.2.2 Adjusting fuel injection timing

To advance the fuel injection timing, turn the fuel injection pump toward the crankcase.

To retard the fuel injection timing, turn the fuel injection pump away from the crankcase.



Adjusting fuel injection timing

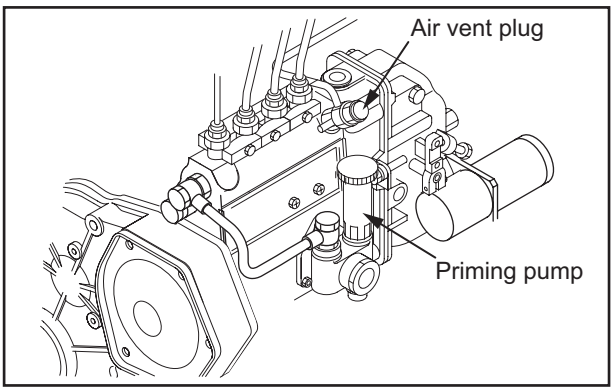
1.3 Bleeding fuel injection pump

(1) Loosen the air vent plugs for the fuel injection pumps. (approx. 1.5 turns)

Note: Do not loose the air vent plug excessively to prevent the spring inside the air vent plug popping out.

(2) Move up and down the priming pump cap. When the fuel wiout bobble flows out from the air vent plug, push the priming pump cap and turn it right to rock.

(3) Tighten th e air vent plug of fuel injection pump.

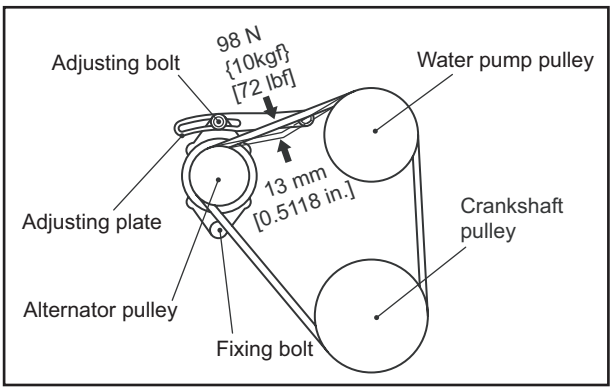


Bleeding fuel injection pump

1.4 Inspecting V-belt

(1) Inspect the belt visually for separation or damage.
If any defect is found, replace the belt with a new one.

(2) Inspect belt tension (deflection).
When it is strongly pressed down on with the thumb at the center of its span, it is normal that the amount of deflection is 13 mm,
If the amount of deflection is not within the standard, adjust the belt tension.



Inspecting and adjusting V-belt tension

1.5 Inspecting and adjusting low idle speed and high idle speed

CAUTION

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

(b) Be sure to seal all the external stoppers in the same manner as they were sealed at the factory if adjustments have been made on the governor. Whether the seals are intact or not has important effect on the validity of claims under warranty. Be sure to seal all of the specified locations.

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

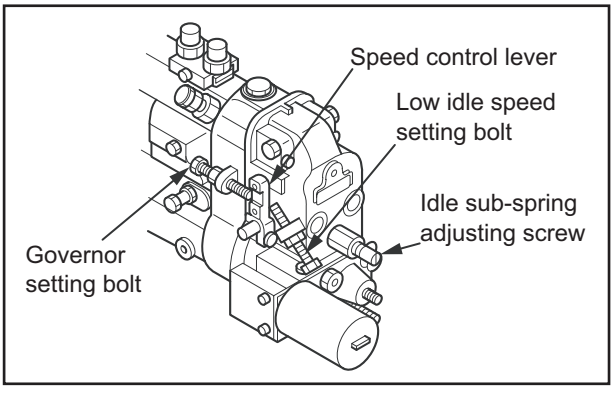
Note: Prior to inspecting and adjusting the governor, be sure to warm up the engine long enough to raise the coolant and oil temperatures to 70°C [158°F] or higher.

1.5.1 Starting engine

(1) Pull the speed control lever to the high-speed side, and operate the starter switch.

(2) The engine fires at a speed of about 150 min^{-1}, and after that its speed will increase. Use the speed control lever to maintain the engine speed at 800 to 1000 min^{-1}.

(3) When the engine speed has stabilized, return the speed control lever to the low idle speed position.



Starting engine

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

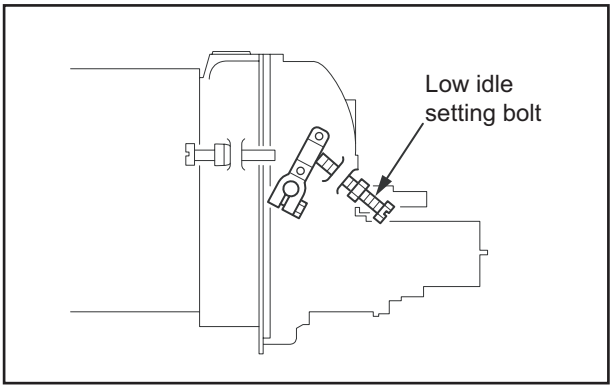
CAUTION

If there is a speed range that torsional vibration may occur, avoid the speed range. If the idle sub-spring is turned clockwise too much, the engine may overrun during no-load, high-speed operations. Be careful about this when adjusting the engine speed.

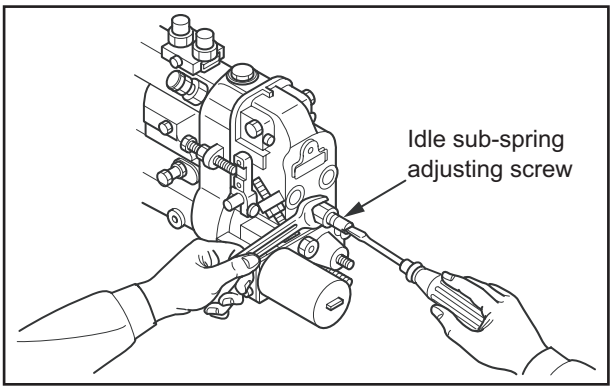
(1) To let the engine operate at the minimum no-load speed, place the speed control lever at a fixed position and adjust the low idle speed setting screw.

Note: Turning the low idle speed setting bolt clockwise increases the speed.

(2) If the engine speed does not stabilize, turn the idle sub-spring adjusting screw clockwise so that the idle sub-spring can lightly contact with the tension lever, then the engine speed will be stable.



Setting low idle speed



Adjusting engine speed stability

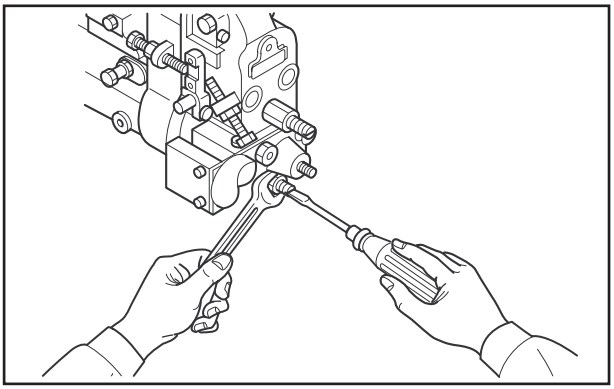
1.5.3 Setting rack (setting maximum output)

(1) Hold the speed control lever at the specified engine output and speed position. In this condition, check if the engine output and speed are stable.

(2) While maintaining the engine in the stabilized condition, adjust the full-load stopper bolt. Tighten or loosen the full-load stopper bolt to find the position where the rated output is attained.

(3) When the rated output position is approximately determined, tighten the full-load stopper bolt, and then turn it counterclockwise by degrees. At the position where the engine speed is about to drop below the rated speed, stop turning the full-load stopper bolt, and lock it securely with the lock nut. Make sure that the speed control lever is in a high-speed side position.

(4) Turning the full-load stopper bolt clockwise increases the fuel injection (engine output increase), and turning it counterclockwise decreases the fuel injection (engine output decrease).

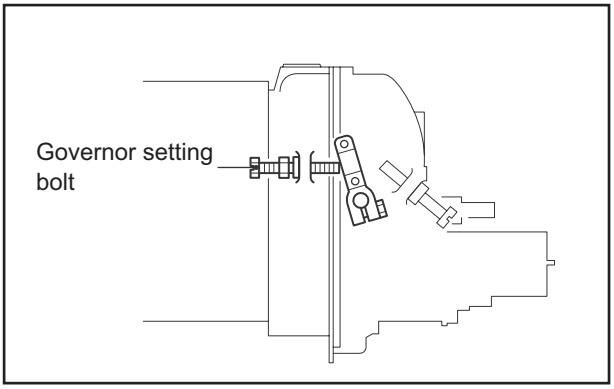


Setting rack

1.5.4 Setting governor (setting maximum speed)

(1) While increasing the engine load to a full-load level, hold the speed control lever in the specified maximum speed position.

(2) Keeping the lever in the specified maximum speed position, turn and set the governor setting bolt (maximum speed setting bolt) to the specified speed.



Setting governor

1.5.5 Measuring speed variation rate

(1) Measuring speed variation rate with load removed

Operate the speed control lever, and set the engine to the rated output and rated speed condition. Under this condition, instantaneously remove the load to bring the engine into the no-load condition. Do this without disturbing the speed control lever position. The engine speed will quickly rise but then will lower and stabilize. Record the momentary maximum speed (N_2), stabilized speed (N_3), and the time needed for the engine to stabilize its speed from the moment the load is removed(t_1).

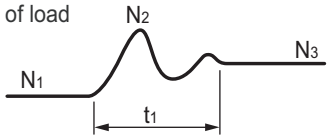
(2) Measuring speed variation with load applied

While operating the engine in a no-load condition, instantaneously apply a specified load to the engine. Record the momentary maximum speed (N_5), stabilized speed (N_6), and time needed for the engine to stabilize its speed from the moment the load is applied(t_2).

(3) Calculating speed variation rate

Calculate the speed variation rate from the results of above measurements. If the speed variation rate deviates the specified limits, make an adjustment by changing the governor notch setting.

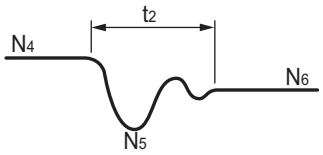
At removal of load



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

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

At application of load



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

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

Measuring speed variation

1.5.6 Adjusting speed variation rate (changing governor notch setting)

CAUTION

The adjusting screw may be loosened by a maximum of 20 governor notches (or 5 turns) from the fully tightened position. Any attempt of a further loosening is strictly prohibited.

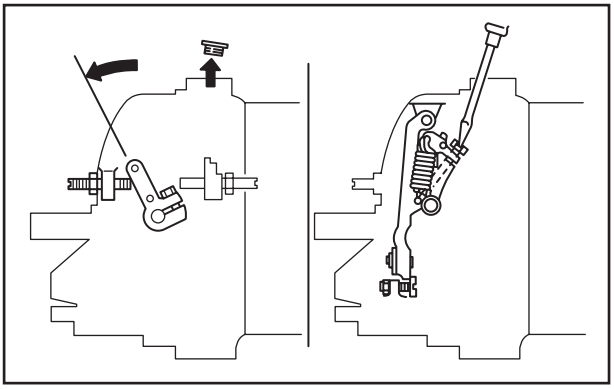
(1) Adjust the speed variation rate by turning the adjusting screw of the swivel lever.

(2) Remove the plug at the top of the governor, and set the speed control lever to the low idle speed position. The swivel lever will turn up, showing the head of the adjusting screw. Use a flat-head screwdriver to turn the adjusting screw.

(3) The speed variation rate decreases as the adjusting screw is tightened and increases as the screw is loosened. A quarter of a turn of the adjusting screw equals to one governor notch and changes the engine speed by three to five revolutions per miute.

(4) Turning the adjusting screw changes the tension of the governor spring and hence the maximum speed. Readjust the governor setting bolt.

(5) The maximum speed increases as the adjusting screw is tightened and decreases as the screw is loosened.



Adjusting speed variation

1.5.7 Sealing

Seal each setting bolt.

2. Break-in operation

After the engine is overhauled, couple the engine to the dynamometer, and run the engine for break-in operation and inspection.

2.1 Starting up

(1) Before starting the engine, check the levels of coolant, engine oil and fuel.
Bleed air from the fuel and cooling systems.

(2) Stop the fuel supply, and crank the engine with the starter for about 10 seconds to lubricate the engine.

(3) Move the control lever slightly in the fuel increase direction (but not to the "full injection" position), and then turn the starter switch key to the [START] position to start the engine.

(4) After the engine is started, adjust the control lever to let the engine operate at a minimum no-load speed (low idle speed).

(5) Turn the starter switch key to the [OFF] position and make sure that the engine is stopped.

2.2 Inspecting engine condition after starting up

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

(1) The oil pressure must be within the specified value.

(2) The coolant temperature must be within the specified value.

(3) The engine must be free from any leakages such as oil, coolant and fuel. Pay special attention to oil leakage from the fitting face of turbocharger lube oil pipe.

(4) Check for an abnormal noise.

Note: Knocking noise will disappear as the coolant temperature rises.

(5) Check for the color of smoke and odors.

2.3 Break-in operation time

The relationship between the load in break-in operation and the operation time is as shown below.

Break-in operation time

	Engine speed (min^{-1})		Load	Duration (min)
1	Low rotation speed	600 to 900	No-load	5
2	Medium rotation speed	1000 to 1200	No-load	5
3	High rotation speed	1400 to rated speed	No-load	10
4	Rated speed		25 %	10
5			50 %	10
6			75 %	30
7			100 %	20

Note: The table above is provided solely for reference purpose. Run the engine at appropriate speed and load for the break-in operation of your engine. Be sure to perform break-in operation after overhaul or installation.

2.4 Inspection and adjustment after break-in operation

(1) Valve clearance adjustment

(2) Ignition timing inspection

(3) Exterior bolt and nut tightness check

3. Performance test (JIS standard)

The following describes the procedures specified in "Earth moving machinery - Engines - Part 1: Test code of net power (JIS D0006-1)" and "Earth moving machinery - Engines - Part 2: Standard format of specifications and testing methods of diesel engines (JIS D0006-2)."
Other test items may be required in some applications. All test results should be evaluated comprehensively in order to determine the engine performance.

3.1 Engine equipment condition

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

3.2 Test items and purposes

3.2.1 Operation load test

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

3.2.2 Continuous load test

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

3.2.3 Low idle test

Conduct this test to confirm that the engine can operate stably at the specified low idle speed.

3.3 Other inspections

Check for gas, coolant and oil leaks; abnormal odors; and hunting. Make adjustment as needed.

3.4 Engine output adjustment

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

3.4.1 Standard atmospheric conditions:

Base temperature: 298 K (25°C) [77°F]
Total pressure: 100 kPa (750 mmHg)
Dry pressure: 99 kPa (743 mmHg)

3.4.2 Calculation of corrected power

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

If the applicable range of the correction formula is exceeded, indicate the corrected values and record the test conditions on the test record.

Colculation output = Correction factor (α_c) × Measured brake power

・Atmospheric conditions during test

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

Dry atmospheric pressure(P_d):80kPa(600mmHg)≦P_d≦110kPa(825mmHg)

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

・Range of correction equation use

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

0.9≦ α_c≦1.1.

Calculation of correction factor(f_a)

・Natural aspiration engine and engine with mechanically driven air charger

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

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

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

・Turbocharged engine with air-to-liquid cooler

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

Calculation of engine factor(f_m)

$f_m=0.036q_c-1.14$

q_c:Corrected fuel supply volume

$$q_c=\frac{q}{r}$$

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

z=120000(4-cycle engine)

r:Ratio between pressure at turbocharger or air cooler outlet and atmospheric pressure (r=1 for natural aspiration engine)

・Applicable range of engine factor(f_m)

37.2≦q_c≦65mg/(l-cycle)

・q_c≦37.2mg/(l-cycle) : f_m=0.2(constant)

・65mg/(l-cycle)≦q_c : f_m=1.2(constant)

ENGINE INSPECTION RECORD SHEET

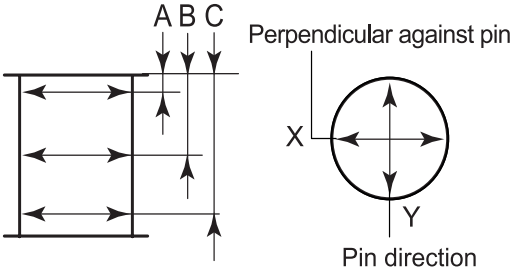
1. Measurement of Cylinder Bore Diameter
2. Measurement of Clearance between Valve Stem and Valve Guide, and Valve Stem Diameter
3. Measurement of Valve Sinkage, Seat Width and Valve Margin
4. Measurement of Distortion of Cylinder Head Bottom Surfaces
5. Measurement of Oil Clearance of Connecting Rod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

ENGINE INSPECTION RECORD SHEET

S4Q,S4Q2

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

Measuring positions



Standards

	Nominal value	Standard	Limit
Cylinder bore diameter	ϕ 88 [3.46]	88.000 to 88.035 [3.4646 to 3.4659]	Standard +0.2 [+00.008]

Measured values

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

Remarks		Approved by	Examined by	Measured by

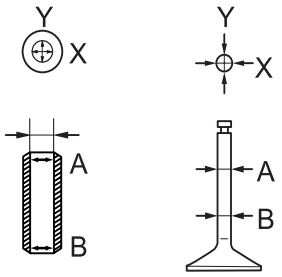
No.2

ENGINE INSPECTION RECORD SHEET

S4Q,S4Q2

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

Measuring positions



Standards

		Nominal value	Standard	Limit
Valve guide bore diameter	Inlet	ϕ 8 [0.31]	8.020 to 8.035 [0.3157 to 0.3163]	–
	Exhaust	ϕ 8 [0.31]	8.020 to 8.035 [0.3157 to 0.3163]	–
Valve stem diameter	Inlet	ϕ 8 [0.31]	7.940 to 7.955 [0.3126 to 0.3132]	7.900 [0.3110]
	Exhaust	ϕ 8 [0.31]	7.920 to 7.940 [0.3118 to 0.3126]	7.850 [0.3091]
Clearance between valve stem and valve guide	Inlet	–	0.045 to 0.075 [0.0018 to 0.0030]	0.130 [0.0051]
	Exhaust	–	0.060 to 0.095 [0.0024 to 0.0037]	0.150 [0.0059]

Measured values

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

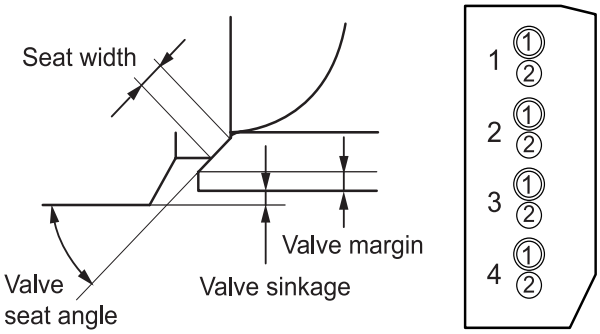
Remarks		Approved by	Examined by	Measured by

ENGINE INSPECTION RECORD SHEET

S4Q,S4Q2

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

Measuring positions



Standards

		Nominal value	Standard	Limit
Valve seat	Valve seat angle	30°		
	Seat width	1.18 [0.0465]	1.04 to 1.32 [0.0409 to 0.0520]	1.6 [0.063]
	Valve sinkage	0.8 [0.031]	0.7 to 0.9 [0.028 to 0.035]	1.3 [0.051]
Valve margin		1.7 [0.067]		Refacing permissible up to 1.2 [0.047]

Measured values

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

Remarks		Approved by	Examined by	Measured by

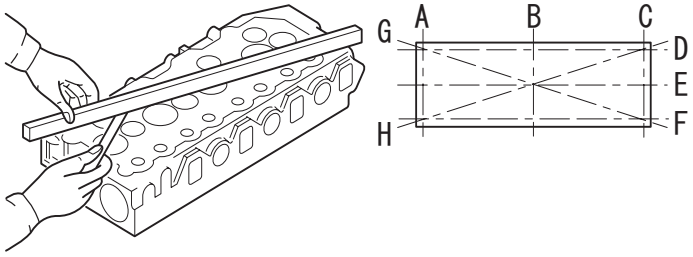
No.4

ENGINE INSPECTION RECORD SHEET

S4Q,S4Q2

Customer		Model		Date	
		Engine Serial No.			
Inspection Item	Measurement of Distortion of Cylinder Head Bottom Surface			Unit	mm [in.]

Measuring positions



Standards

	Standard	Limit
Distortion of cylinder head bottom surface	0.05 [0.0020] or less	0.20 [0.0079]

Measured values

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

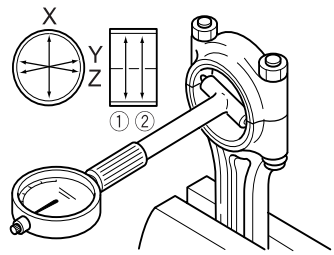
Remarks		Approved by	Examined by	Measured by

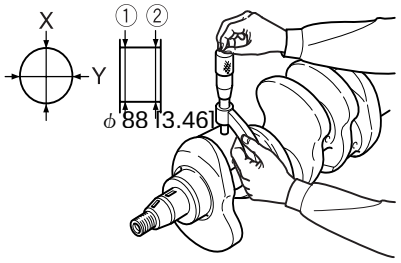
ENGINE INSPECTION RECORD SHEET

S4Q,S4Q2

Customer		Model		Date	
		Engine Serial No.			
Inspection Item	Measurement of Oil Clearance of Connecting Rod Bearing			Unit	mm [in.]

Measuring positions





Standards

	Nominal value	Standard	Limit
Connecting rod bearing inside diameter	ϕ 58 [2.28]	58.000 to 58.045 [2.2835 to 2.2852]	–
Crankshaft pin outside diameter	ϕ 58 [2.28]	57.950 to 57.970 [2.2815 to 2.2823]	–
Connecting rod bearing oil clearance	–	0.030 to 0.095 [0.0012 to 0.0037]	0.20 [0.0079]

Measured values

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

Remarks		Approved by	Examined by	Measured by

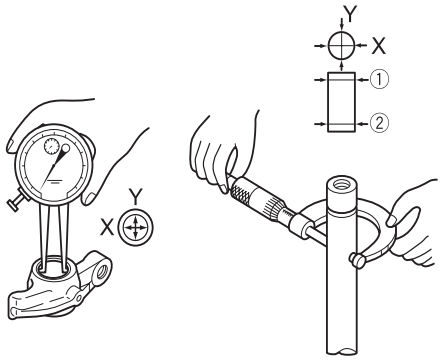
No.6

ENGINE INSPECTION RECORD SHEET

S4Q,S4Q2

Customer		Model		Date	
		Engine Serial No.			
Inspection Item	Measurement of Rocker Arm Inside Diameter and Shaft Diameter			Unit	mm [in.]

Measuring positions



Standards

	Nominal value	Standard	Limit
Rocker arm (bushing) inside diameter	ϕ 19 [0.75]	19.01 to 19.03 [0.7484 to 0.7492]	–
Rocker shaft outside diameter	ϕ 19 [0.75]	18.98 to 19.00 [0.7472 to 0.7480]	–
Clearance between rocker arm (bushing) and shaft	–	0.01 to 0.05 [0.0004 to 0.0020]	0.07 [0.0028]

Measured values

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

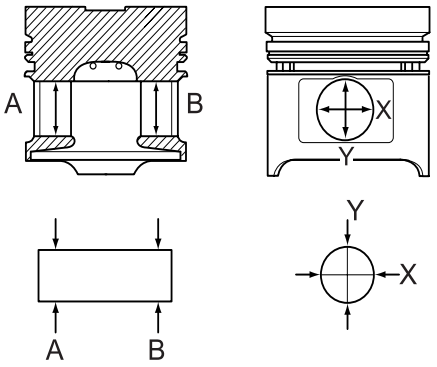
Remarks		Approved by	Examined by	Measured by

ENGINE INSPECTION RECORD SHEET

S4Q,S4Q2

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

Measuring positions



Standards

	Nominal value	Standard	Limit
Piston pin bore diameter	ϕ 28 [1.10]	28.000 to 28.010 [1.1024 to 1.1028]	–
Piston pin diameter	ϕ 28 [1.10]	27.994 to 28.000 [1.1021 to 1.1024]	–
Clearance between piston pin bore and piston pin	–	0.000 to 0.016 [0.0000 to 0.0006]	0.050 [0.0020]

Measured values

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

Remarks		Approved by	Examined by	Measured by

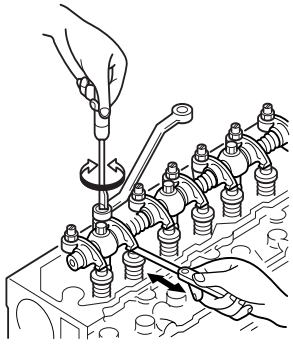
No.8

ENGINE INSPECTION RECORD SHEET

S4Q,S4Q2

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

Measuring positions



Standards

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

Measured values

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

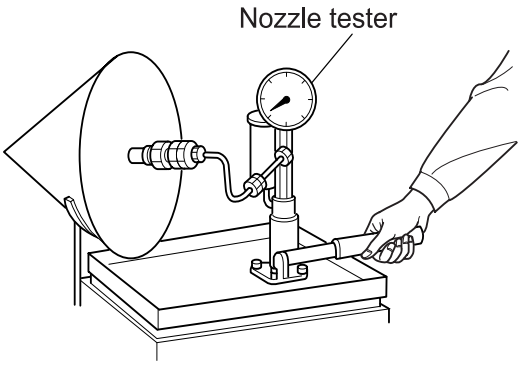
Remarks		Approved by	Examined by	Measured by

ENGINE INSPECTION RECORD SHEET

S4Q,S4Q2

Customer		Model		Date	
		Engine Serial No.			
Inspection Item	Measurement of Injection Pressure of Fuel Injection Nozzle			Unit	MPa {kgf/cm^2} [psi]

Measuring positions



Standards

	Nominal value	Standard
Injection pressure	13.73 {140} [1991]	13.93 to 14.71 {142 to 150} [2020 to 2133] (New parts value)

Measured values

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

Remarks		Approved by	Examined by	Measured by

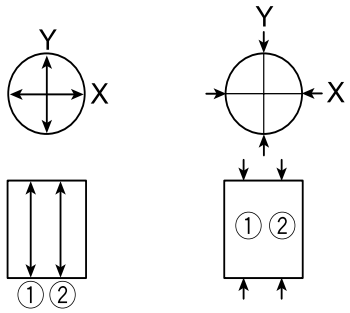
No.10

ENGINE INSPECTION RECORD SHEET

S4Q,S4Q2

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

Measuring positions



Standards

		Nominal value	Standard	Limit
Camshaft journal diameter	No. 1, 2	ϕ54 [2.13]	53.94 to 53.96 [2.1236 to 2.1244]	53.90 [2.1220]
	No. 3	ϕ53 [2.09]	52.94 to 52.96 [2.0842 to 2.0850]	52.90 [2.0827]
Clearance between camshaft journal diameter and camshaft bore diameter of crankcase		–	0.07 to 0.11 [0.0028 to 0.0043]	0.15 [0.0059]
Camshaft bore diameter	No. 1, 2	ϕ54 [2.13]	54.030 to 54.050 [2.1272 to 2.1279]	–
	No. 3	ϕ53 [2.09]	53.030 to 53.050 [2.0878 to 2.0886]	–

Measured values

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

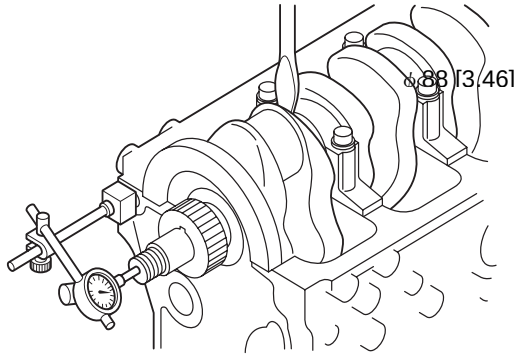
Remarks		Approved by	Examined by	Measured by

ENGINE INSPECTION RECORD SHEET

S4Q,S4Q2

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

Measuring positions



Standards

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

Measured values

During disassembly	During reassembly

Remarks		Approved by	Examined by	Measured by