July 2016

SERVICE MANUAL

S4S

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MITSUBISHI DIESEL ENGINES

S4S

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MITSUBISHI HEAVY INDUSTRIES
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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.

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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.

Avoid accessing crankcase until engine cools

Do not attempt to open the side cover of the crankcase before the engine cools down. Wait at least 10 minutes after stopping the engine.

Opening the cover when the engine is hot allows fresh air to flow into the crankcase, which can cause oil mist to ignite and explode.

Care about fuel, oil and exhaust gas leakage

If any fuel, oil or exhaust gas leakage is found, immediately take corrective measures to stop it.

Such leakages, if left uncorrected, can cause fuel or engine oil to reach hot engine surfaces or hot exhaust gas to contact flammable materials, possibly leading to personal injury and/or damage to equipment.

Use explosion-proof lighting apparatus

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

Prevent electrical wires from short-circuiting

Avoid inspecting or servicing the electrical system with the ground cable connected to the battery. Otherwise, a fire could result from short-circuiting. Be sure to disconnect the battery cable from the negative (-) terminal before beginning with the work procedure.

Short-circuits, possibly resulting in fire, may be caused by a loose terminal or damaged cable/wire. Inspect the terminals, cables and wires, and repair or replace the faulty parts before beginning with the service procedure.

Keep fire extinguishers and first-aid kit handy

Keep fire extinguishers handy, and become familiar with their usage.

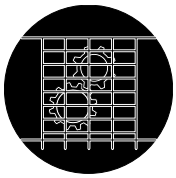
Keep a first-aid kit at the designated place where it is easily accessible by anyone at any time.

Establish response procedures to follow in the event of fire or accident. Provide an emergency evacuation route, contact points, and means of communication in case of emergency.

⚠ WARNING

Stay clear of all rotating and moving parts

Install protective covers on rotating parts



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

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

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

Never remove protective covers.

Ensure safety of neighboring people before starting engine

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

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

Stay clear of moving parts during engine running

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

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

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

Lockout and tagout

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

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

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

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.

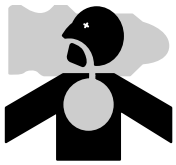
Add coolant only after the coolant temperature dropped

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

⚠ WARNING

Be careful of exhaust fume poisoning

Operate engine in well-ventilated area



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

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

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

⚠ WARNING

Protect ears from noises

Wear ear plugs

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

⚠ WARNING

Be careful of falling down

Lift engine correctly

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

Do not climb onto the engine

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

Establish firm scaffold during work

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

⚠ CAUTION

Be careful of handling fuel, engine oil and LLC

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

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

Handle LLC (long life coolant) carefully

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

Proper disposal of waste oil and coolant (LLC)

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

⚠ CAUTION

Service battery

Handle the battery correctly

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

⚠ CAUTION

When abnormality occurs

Stop overheated engine after cooling run

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

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

Avoid immediate restart after abnormal stop

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

Avoid continuous engine operation with too low oil pressure

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

Stop the engine immediately if the fan belt breaks

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

⚠ CAUTION

Other cautions

Modification of engine prohibited

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

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

Never break the seals

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

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

Pre-operational check and periodic inspection/maintenance

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

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

Break-in operation

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

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

Warming-up operation

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

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

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

Avoid engine operations in a overload condition

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

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

Cooling operation before stopping engine

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

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

During cooling operation, check the engine for abnormalities.

Protection of engine against water entry

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

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

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

Maintenance of air cleaner or pre-cleaner

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

- Do not conduct maintenance of the air cleaner/pre-cleaner while the engine is operating. Engine operation without the air cleaner/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.

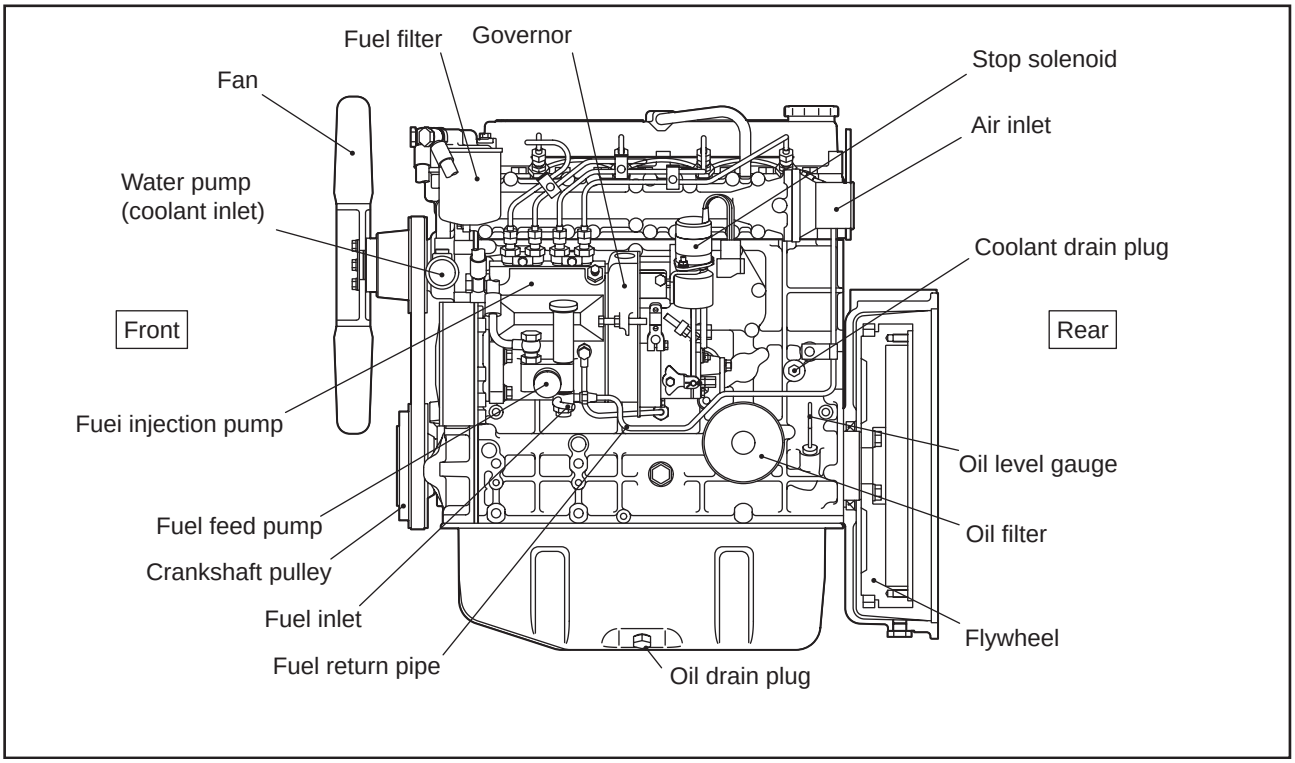
Warning labels

GENERAL CONTENTS

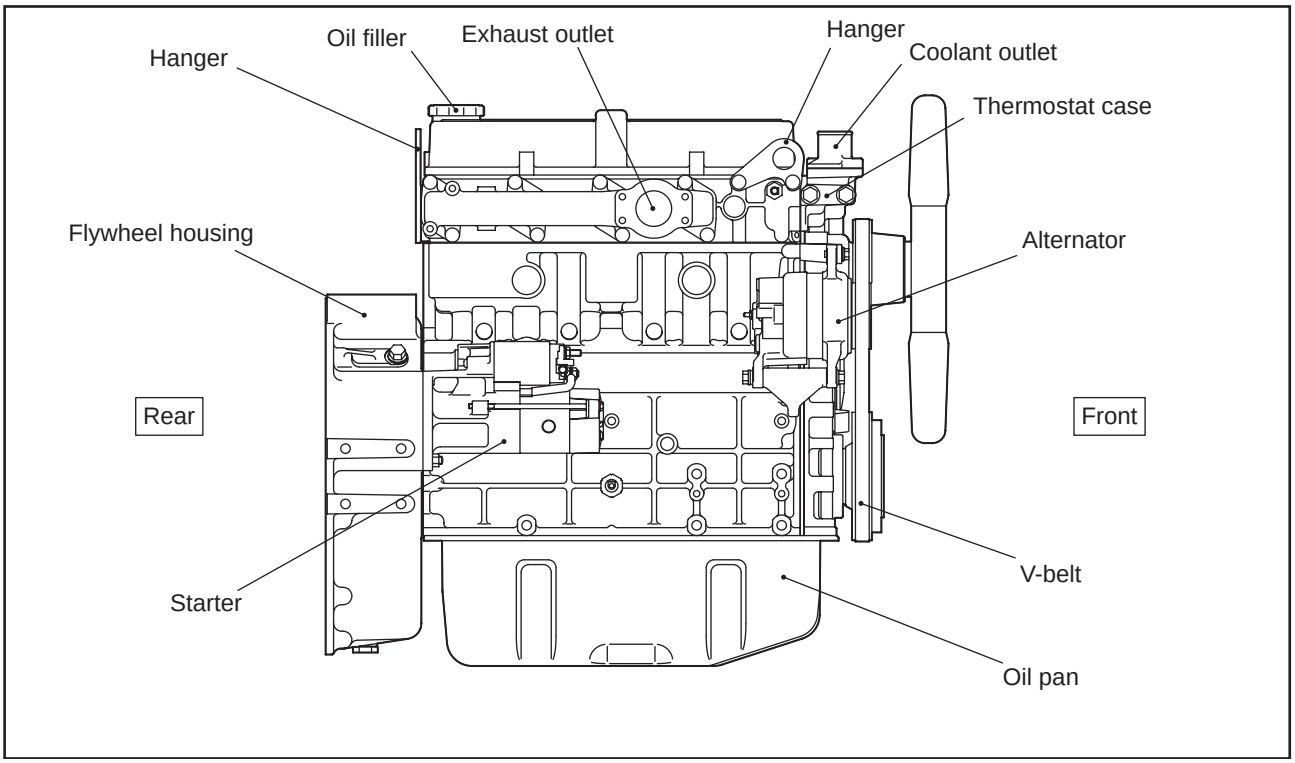
GENERAL

1. External view (in-line fuel injection pump and distributor-type fuel injection pump)

1.1 S4S in-line fuel injection pump specification

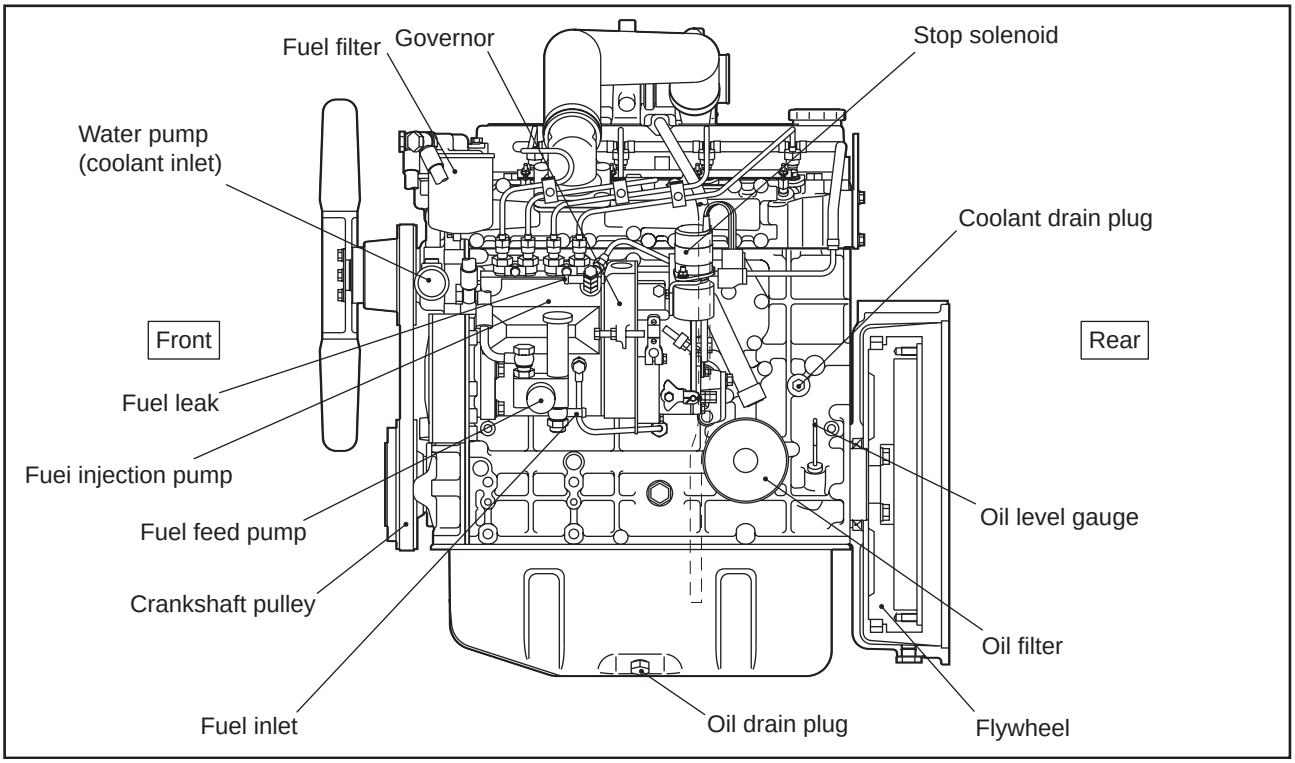


Engine left view

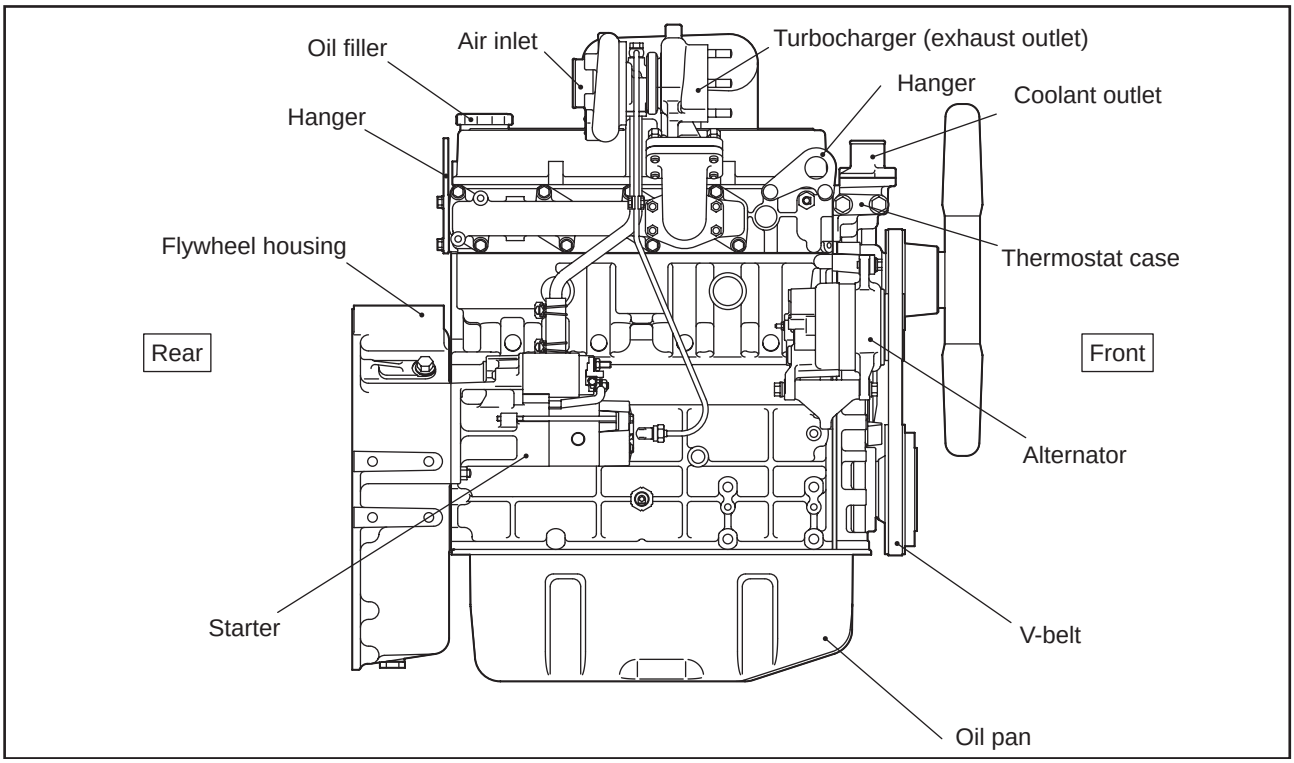


Engine right view

1.2 S4S-DT in-line fuel injection pump specification

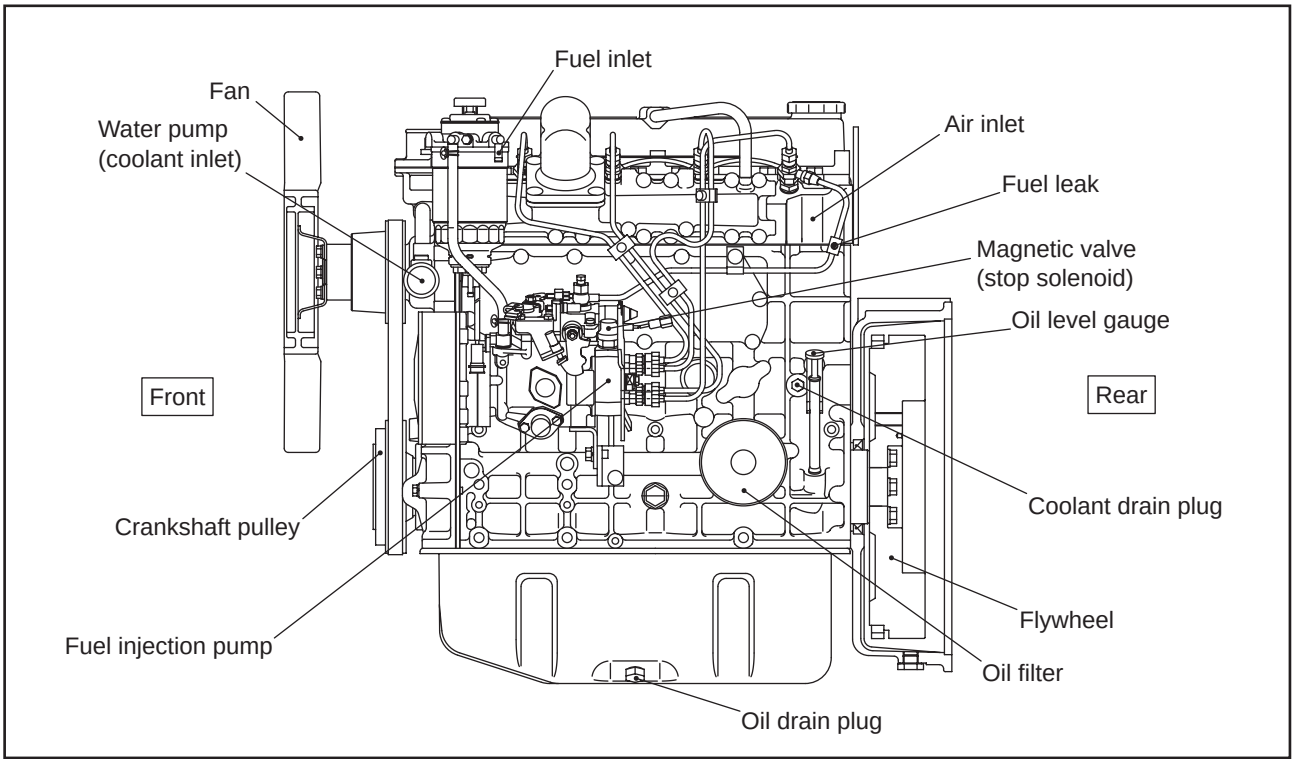


Engine left view

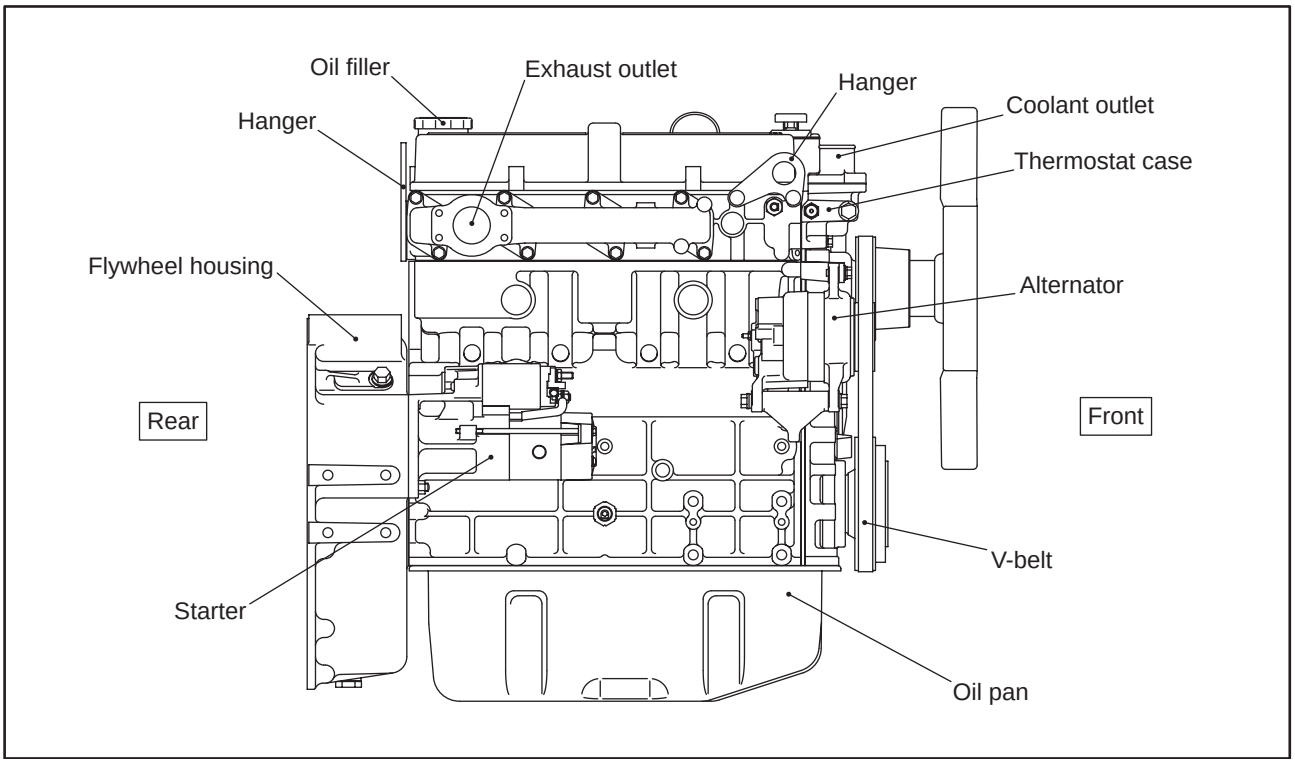


Engine right view

1.3 S4S distributor-type fuel injection pump specification

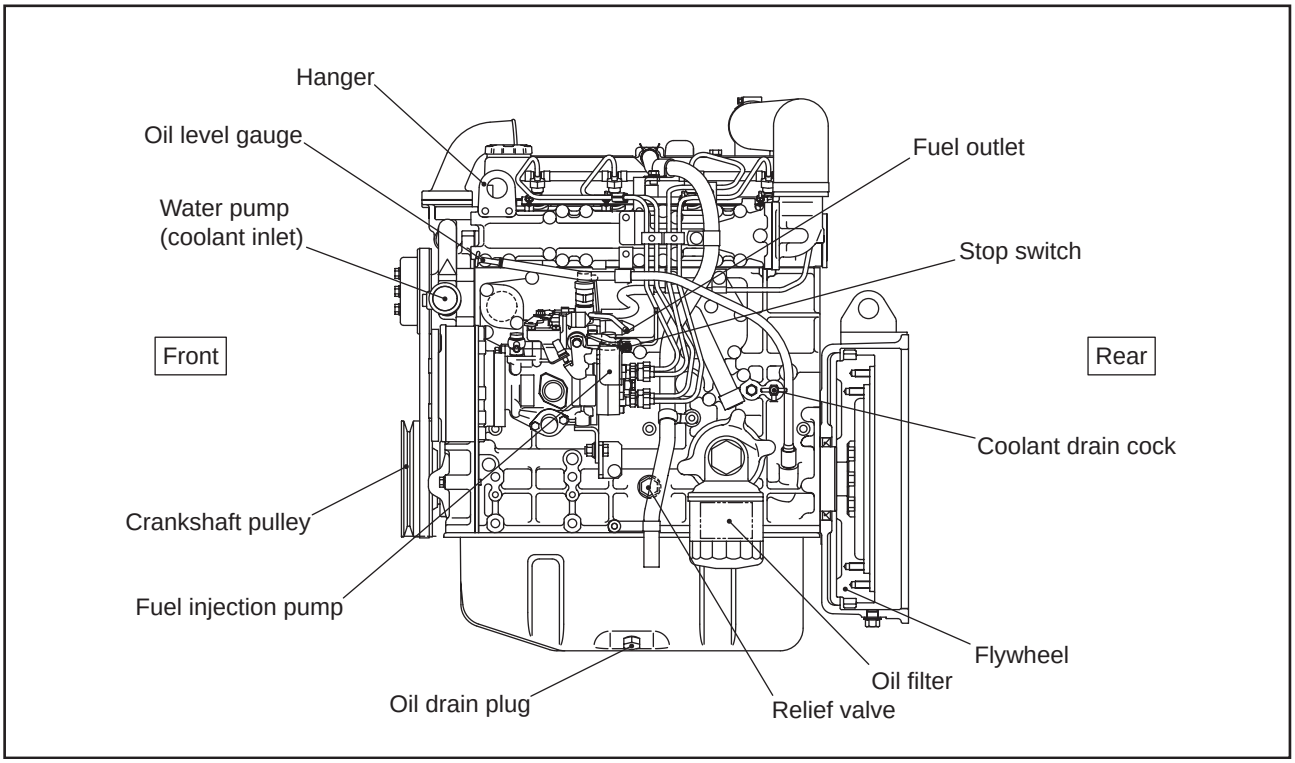


Engine left view

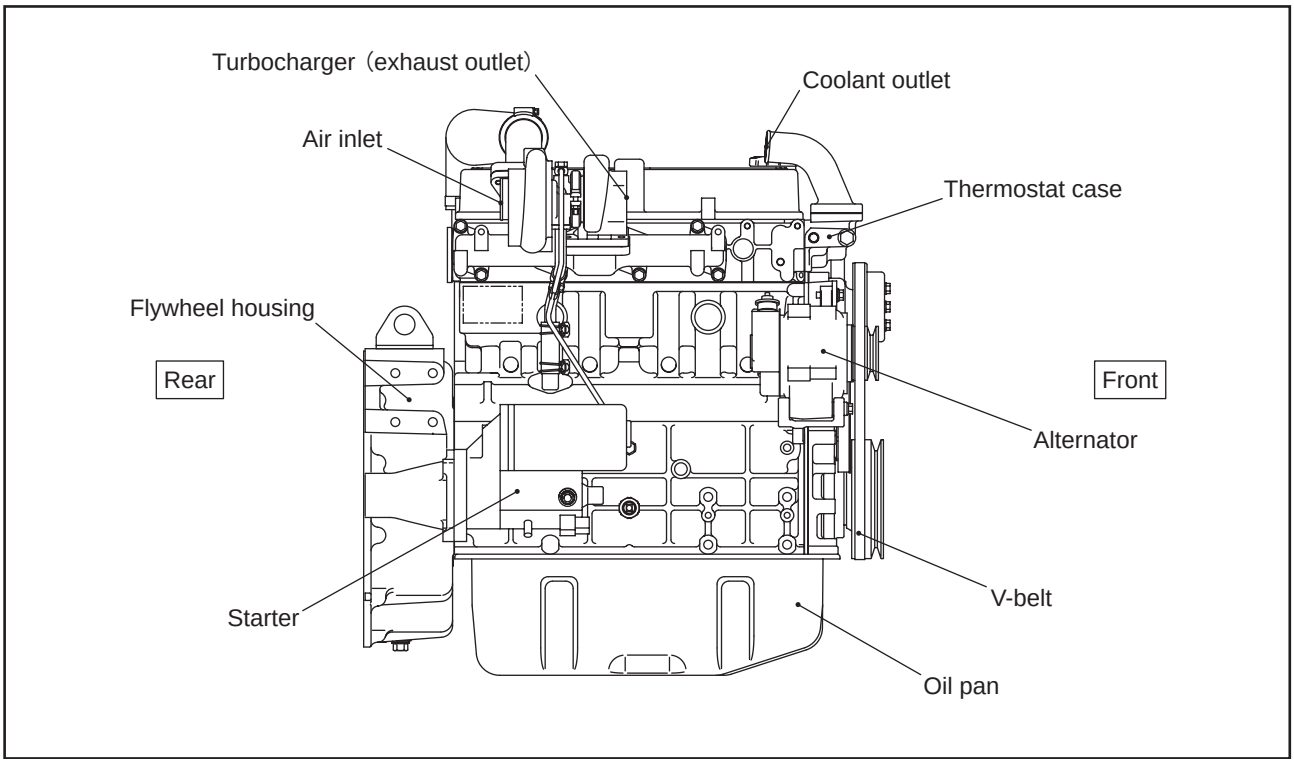


Engine right view

1.4 S4S-DT distributor-type fuel injection pump specification



Engine left view

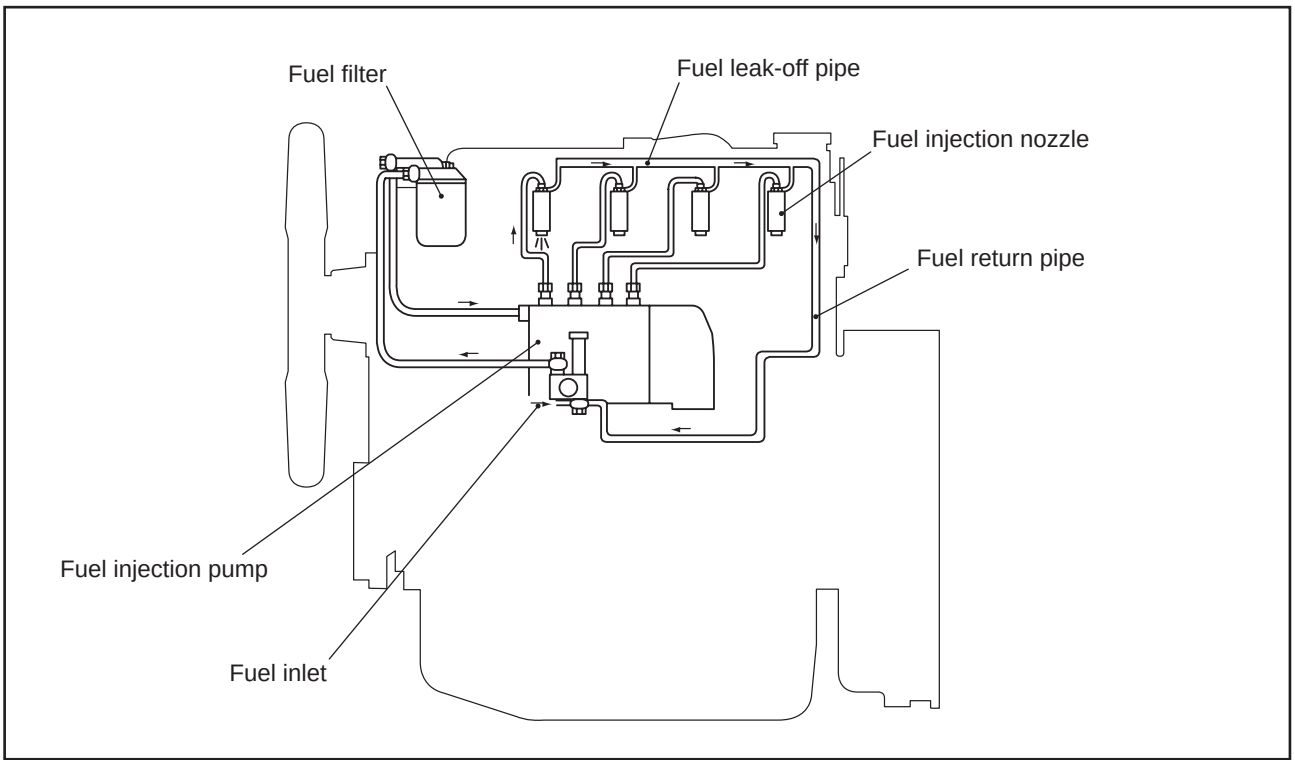


Engine right view

2. System flow diagrams

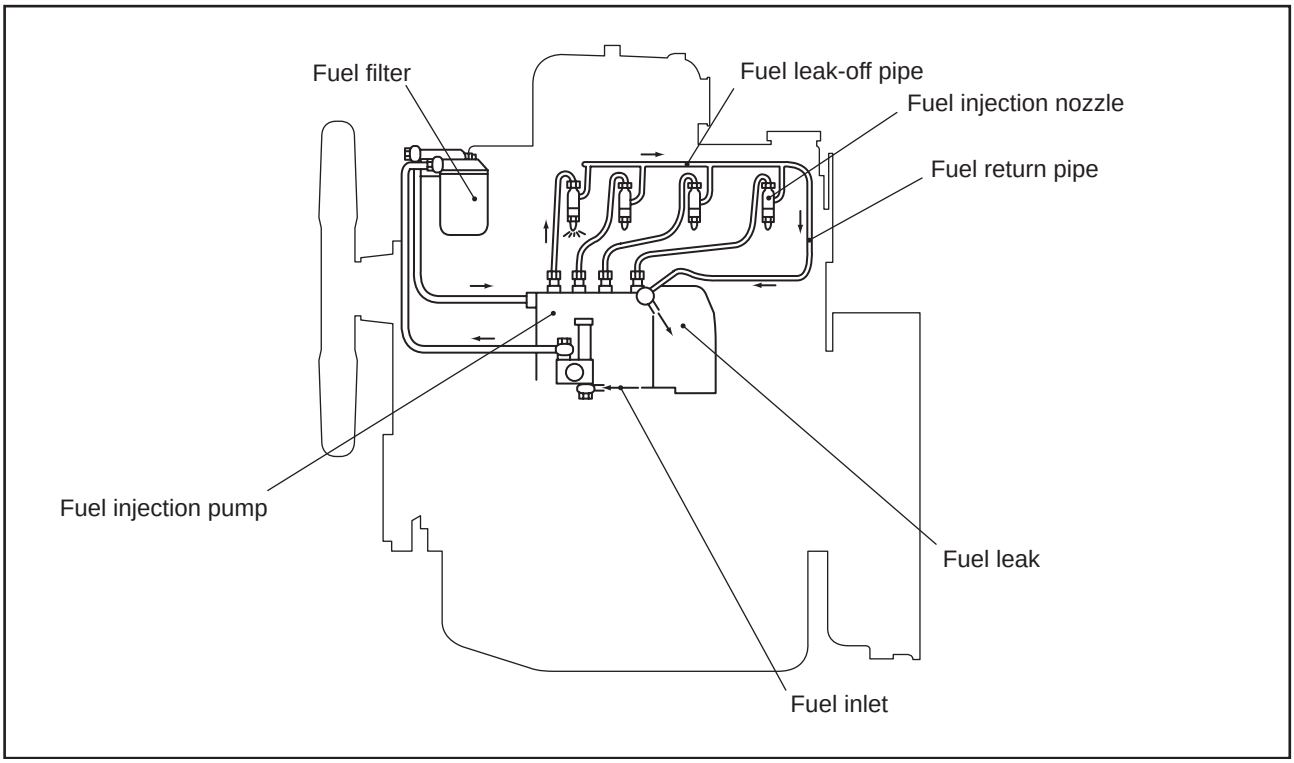
2.1 Fuel system - flow diagram

2.1.1 S4S in-line fuel injection pump (swirl chamber) specification



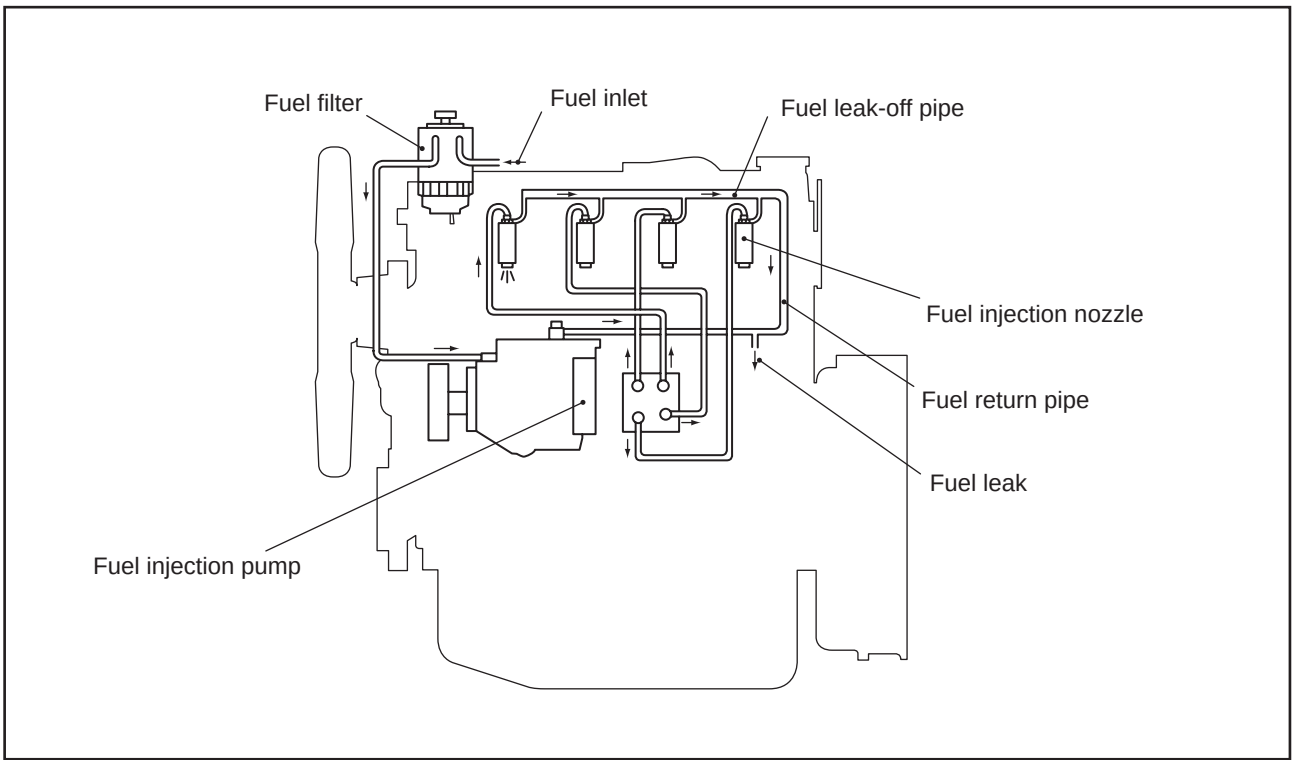
Fuel system - flow diagram

2.1.2 S4S-DT in-line fuel injection pump (direct injection) specification



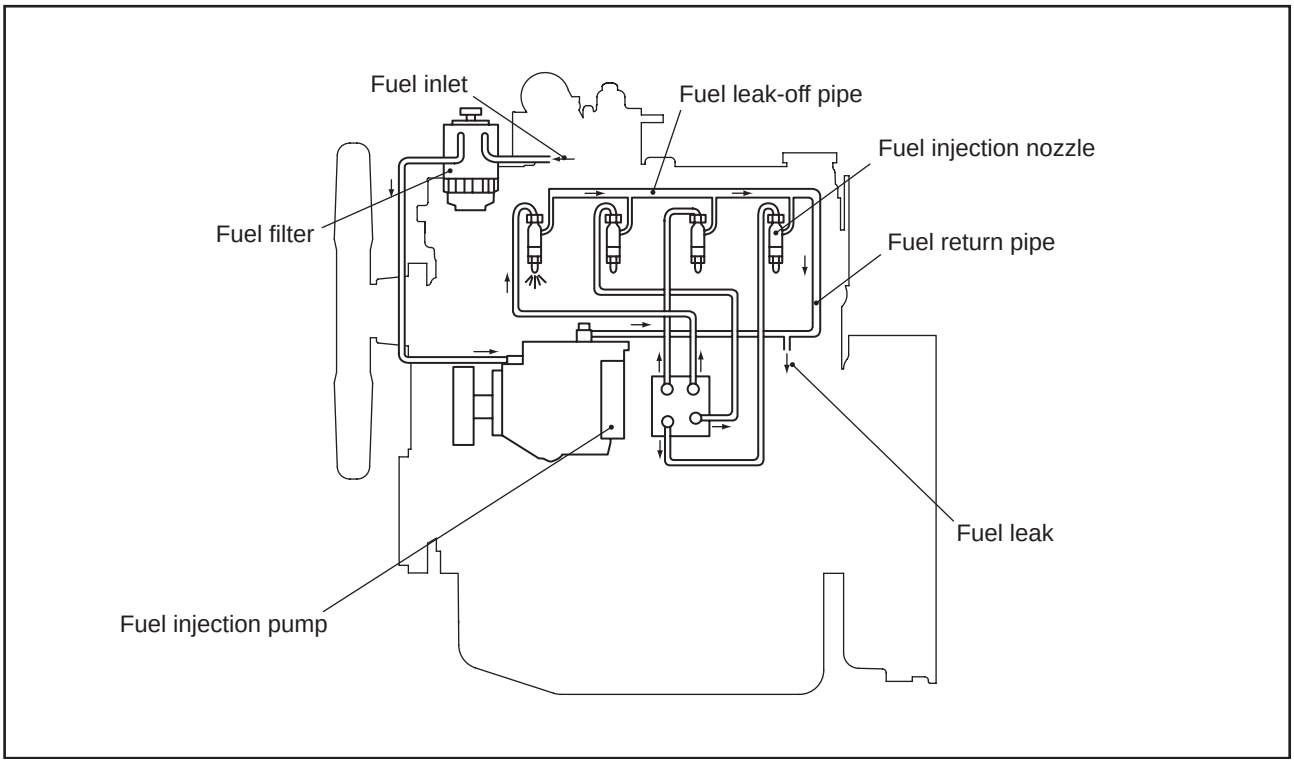
Fuel system - flow diagram

2.1.3 S4S distributor-type fuel injection pump (swirl chamber) specification



Fuel system - flow diagram

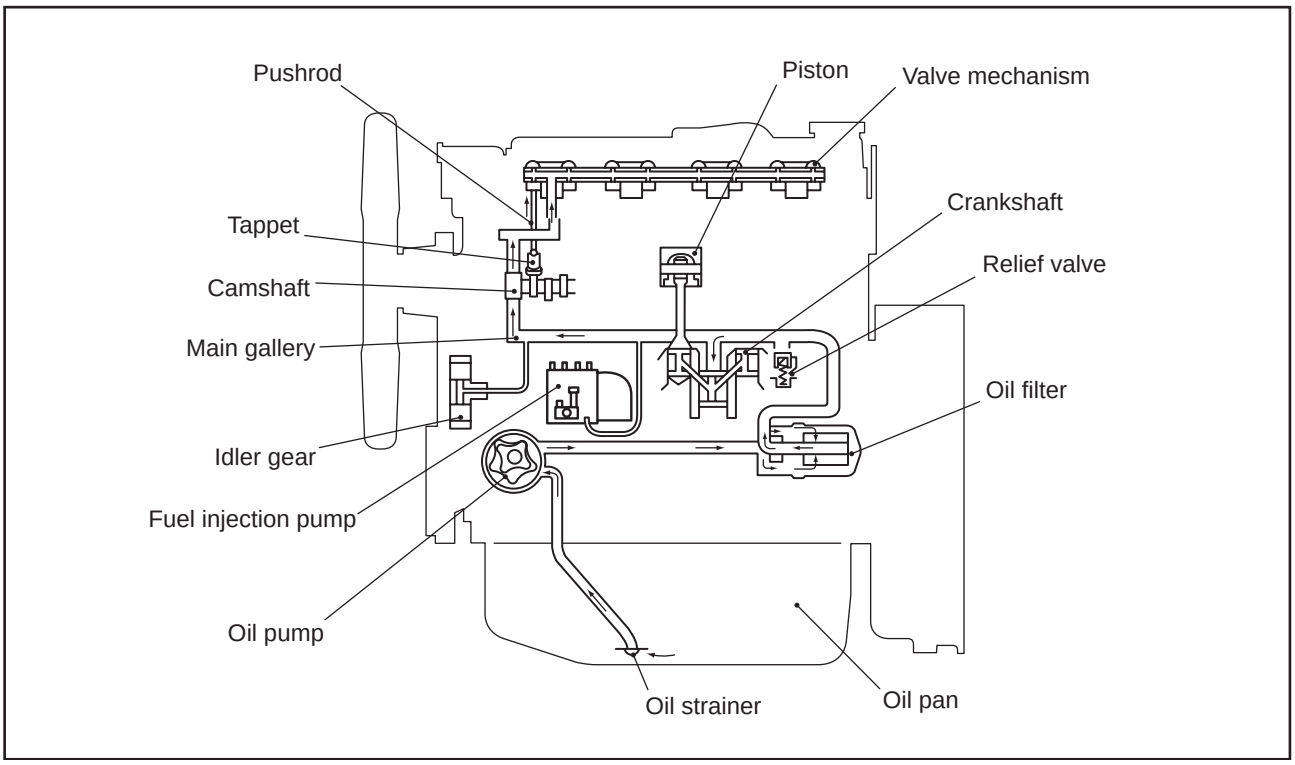
2.1.4 S4S-DT distributor-type fuel injection pump (direct injection) specification



Fuel system - flow diagram

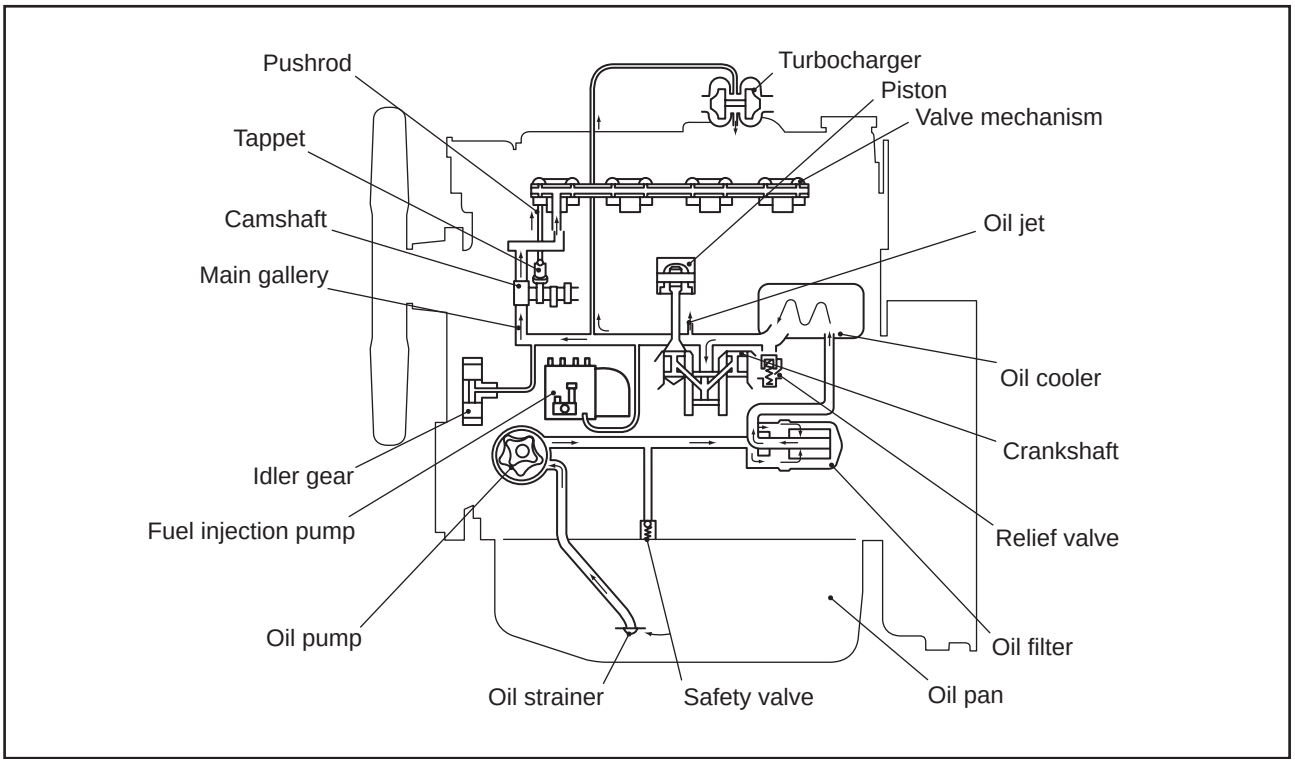
2.2 Lubrication system - flow diagram

2.2.1 S4S in-line fuel injection pump specification



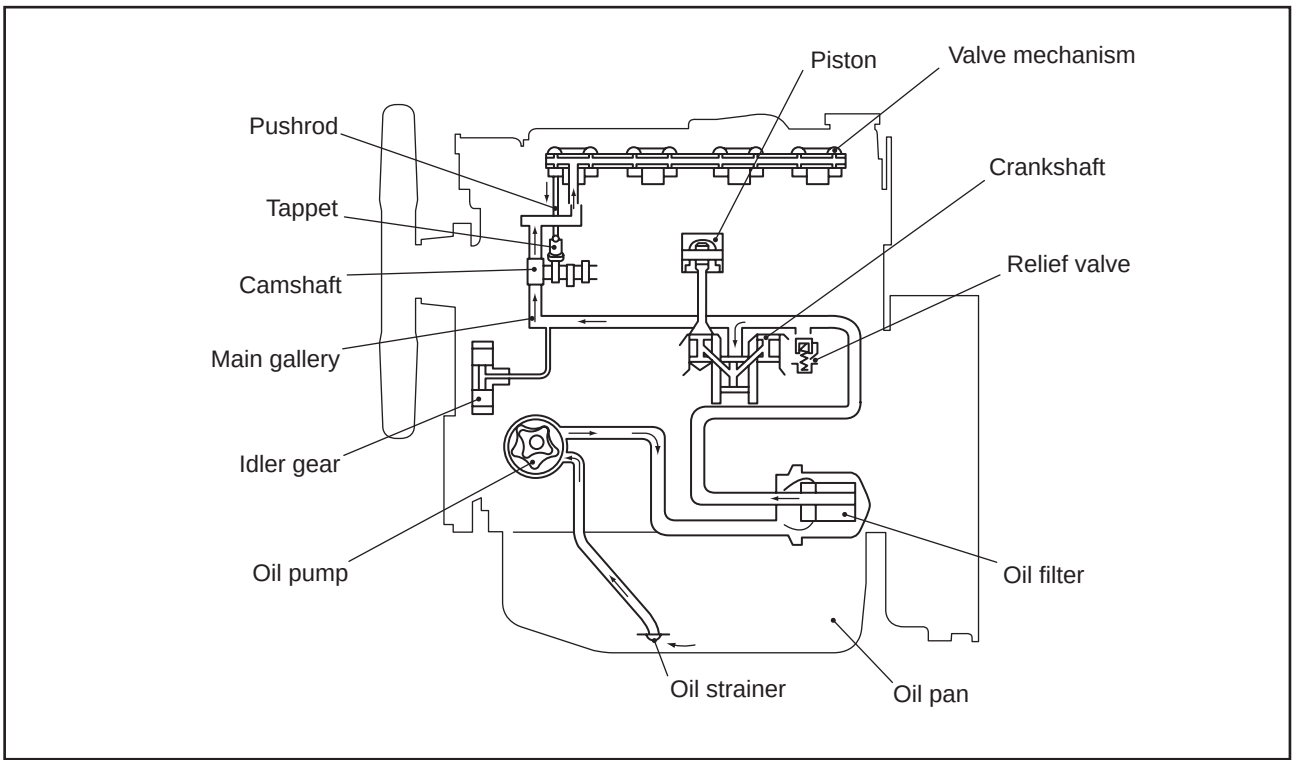
Lubrication system - flow diagram

2.2.2 S4S-DT in-line fuel injection pump specification



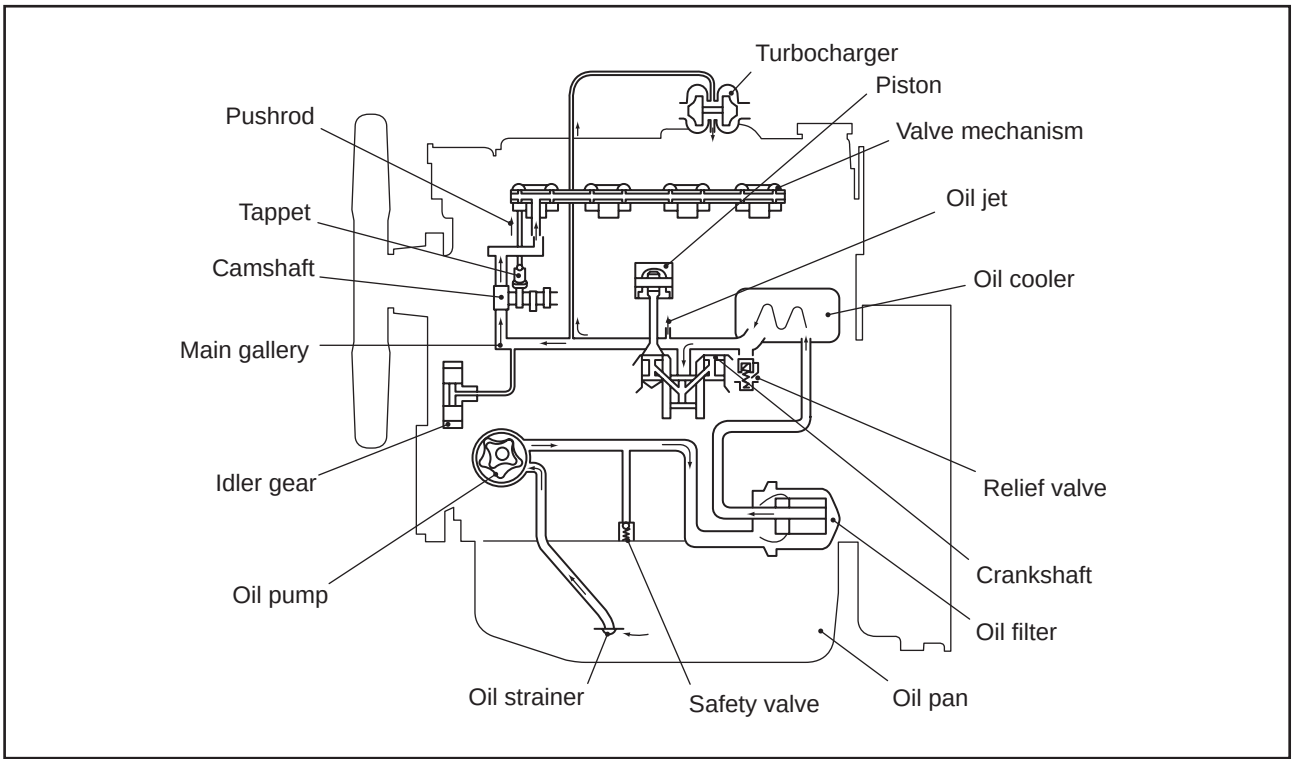
Lubrication system - flow diagram

2.2.3 S4S distributor-type fuel injection pump specification



Lubrication system - flow diagram

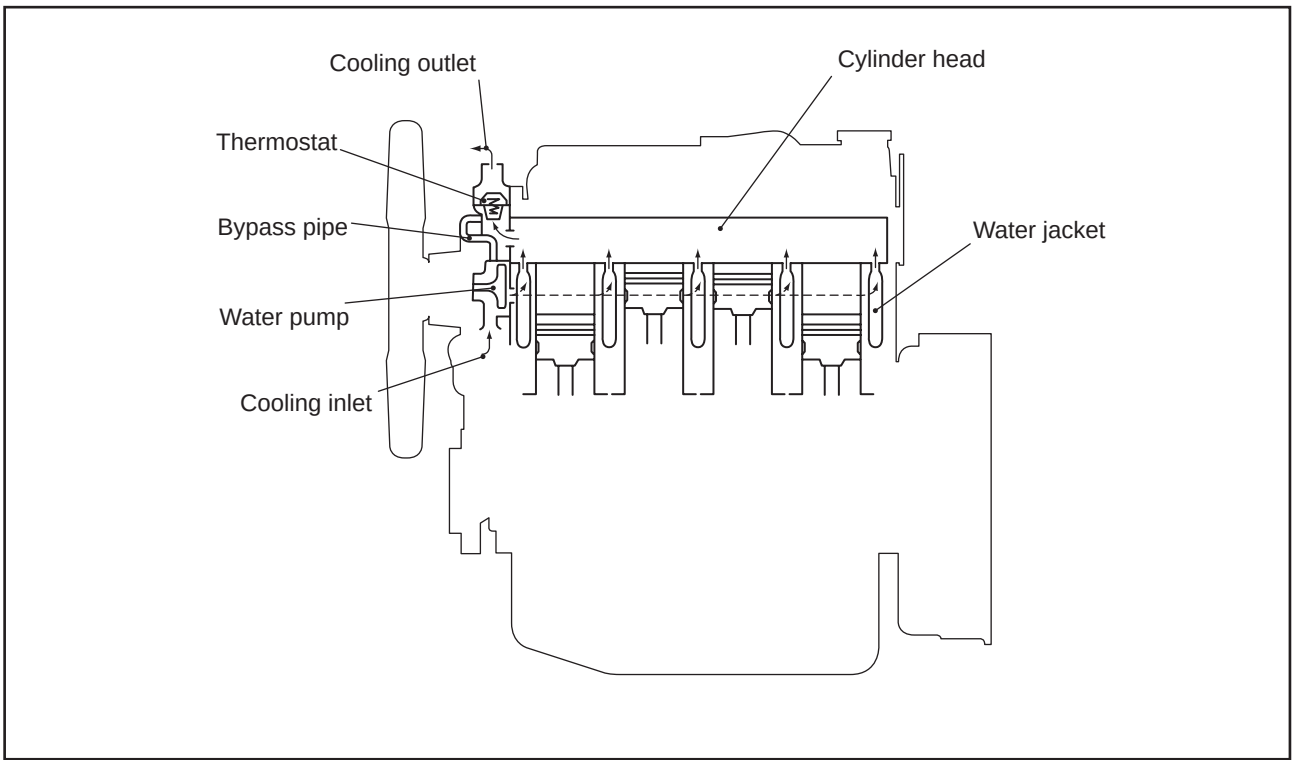
2.2.4 S4S-DT distributor-type fuel injection pump specification



Lubrication system - flow diagram

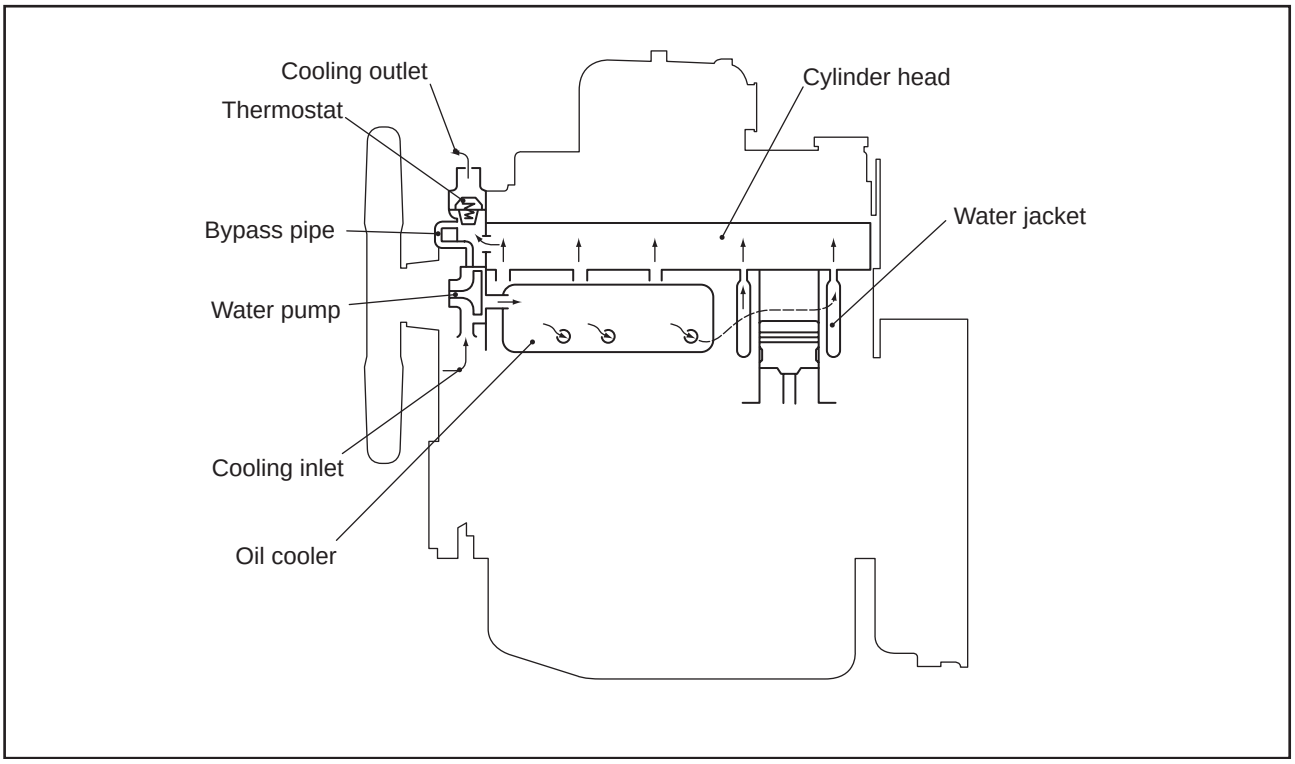
2.3 Cooling system - flow diagram

2.3.1 S4S



Cooling system - flow diagram

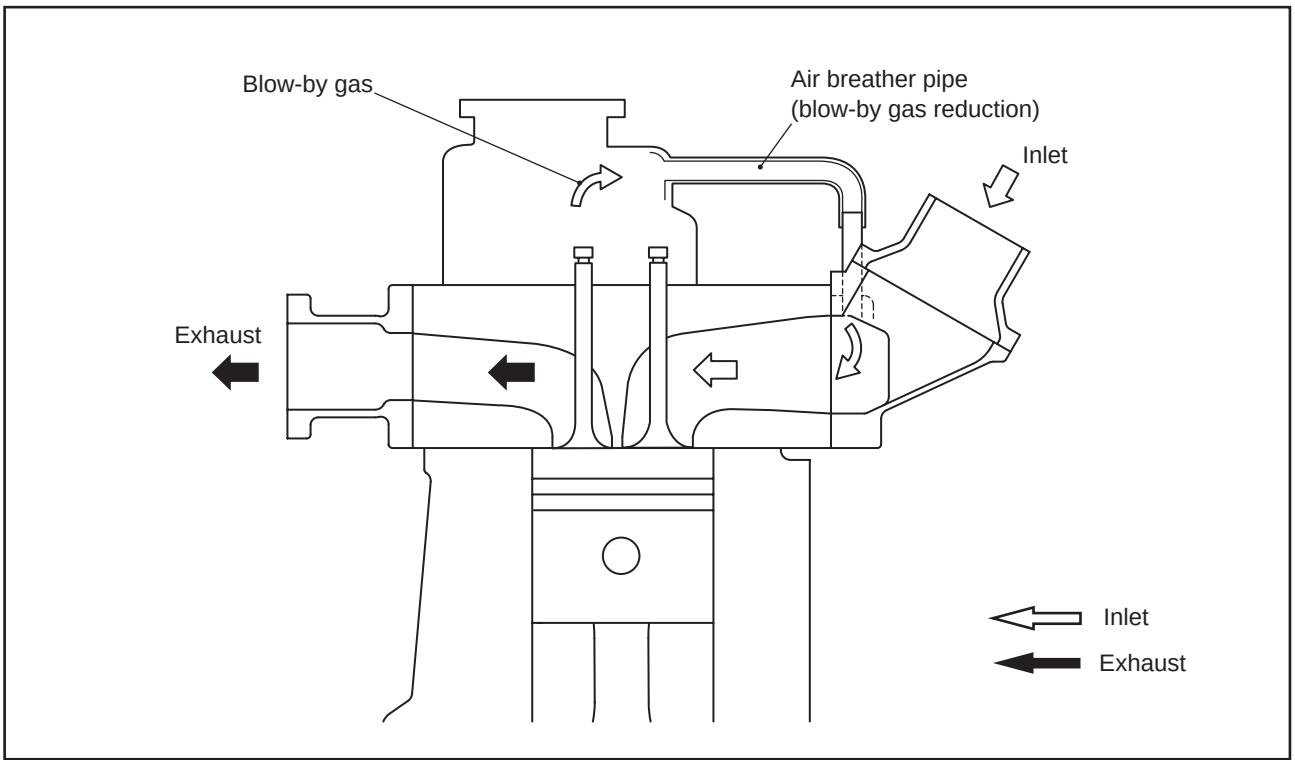
2.3.2 S4S-DT



Cooling system - flow diagram

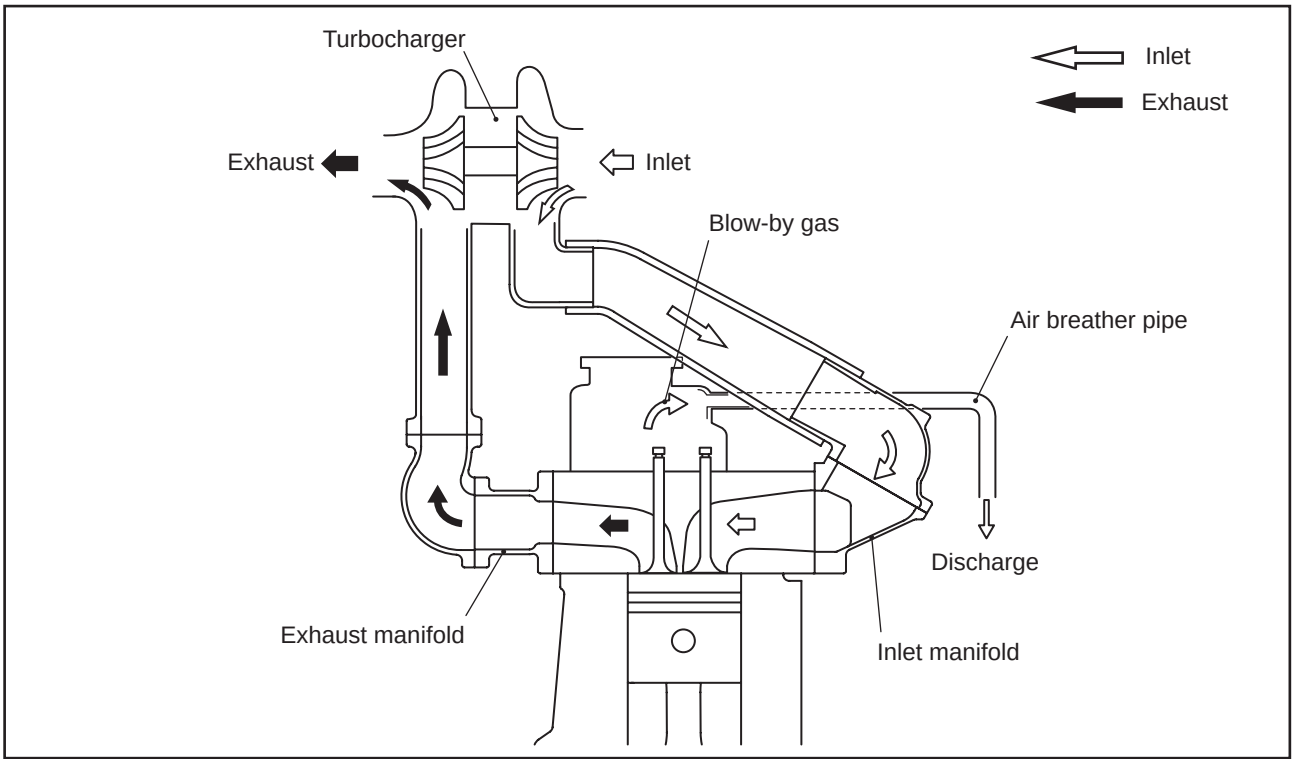
2.4 Inlet and exhaust system - flow diagram

2.4.1 Non-turbocharged engine



Inlet and exhaust system - flow diagram

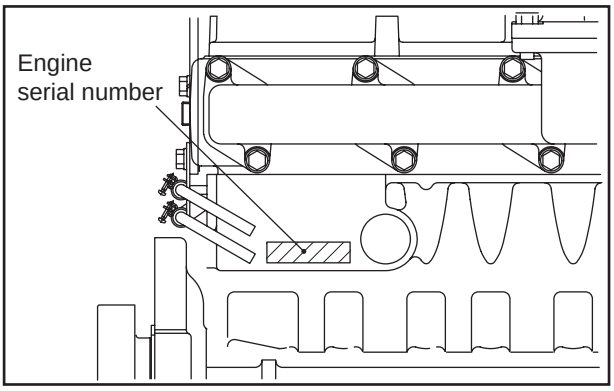
2.4.2 Turbocharged engine



Inlet and exhaust system - flow diagram

3. Engine serial number location

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



Stamp location of engine serial number

4. Main specifications

4.1 S4S in-line fuel injection pump specification (varies depending on the specification)

Table 1-1 Main specifications S4S in-line fuel injection pump specification (1 / 3)

Engine model				S4S	S4S-DT
Main specification	Type			Water cooled, 4 cycle diesel engine	
	No. of cylinders - arrangement			4 cylinder in-line	
	Combustion system			Swirl chamber	Direct injection
	Valve mechanism			Overhead	
	Cylinder bore × stroke			94 × 120 mm [3.70 × 4.72 in.]	
	Displacement			3.331 L [203 cu. in.]	
	Compression ratio			22.0 : 1	19.5 : 1
	Fuel			ASTM diesel fuel oil No.2-D (JIS K2204 gas oil specification No.2 or 3)	
	Firing order			1 - 3 - 4 - 2	
	Direction of rotation			Counterclockwise when viewed from flywheel side	
	Dimensions (with fan)	Length		780 mm [30.71 in.]	780 mm [30.71 in.]
		Width		593 mm [23.35 in.]	593 mm [23.35 in.]
		Height		710 mm [27.95 in.]	821 mm [32.32 in.]
	Dry weight			245 kg [540 lb]	255 kg [562 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°	BTDC 18°
			Close	ABDC 50°	ABDC 54°
		Exhaust valve	Open	BBDC 74°	BBDC 66°
			Close	ATDC 30°	ATDC 22°
	Starting system			Starter	
	Starting aid system			Glow plug	
Fuel system	Fuel injection pump	Type		In-line (A type)	In-line (AD type)
		Plunger diameter		ø 7 mm [0.28 in.]	ø 10.5 mm [0.39 in.]
	Fuel feed pump	Type		Piston type	
	Governor	Speed control system		Centrifugal type	
		Feature		RSV type	
	Fuel injection nozzle	Nozzle type		Throttle type	Hole type
		Number of spray holes		1	6
		Spray hole diameter		ø 1.0 mm [0.039 in.]	ø 0.16 mm [0.0063 in.]
		Spray angle		0°	148°
		Valve opening pressure		11.77 MPa {120 kgf/cm²} [1706.80 psi]	17.7 MPa {180 kgf/cm²} [2567 psi]
	Fuel filter	Type		Cartridge type paper element	

Table 1-1 Main specifications S4S in-line fuel injection pump specification (2 / 3)

Engine model			S4S	S4S-DT
Lubrication system	Lubricating method		Forced circulation type (pressure feed by oil pump)	
	Engine oil	Standard	Class CF or CH-4, SAE30 equivalent (API service classification)	
		Engine oil capacity	Engine total: approx. 10 L [2.64 U.S.gal.] (approx. 9 L [2.38 U.S.gal.] (high level) in oil pan), oil filter: 1 L [0.26 U.S.gal.]	
	Oil pump	Type	Trochoid	
		Speed ratio to crankshaft	0.74	
		Discharge capacity	28.6 L [7.56 U.S.gal.]/min (at pump rotation of 2230 min^{-1}, 0.3 MPa {3 kgf/cm^2} [42.67 psi])	
	Relief valve	Type	Piston valve type	
		Valve opening pressure	0.35 ± 0.05 MPa {3.6 ± 0.5 kgf/cm^2} [49.78 ± 7.11 psi]	
	Safety valve	Opening pressure	-	1.1 MPa {11 kgf/cm^2} [157 psi]
	Oil cooler	Type	-	Water-cooled, multi-plate
	Oil filter	Type	Cartridge type paper element	
Cooling system	Cooling method		Water-cooled, forced circulation	
	Coolant capacity (engine water jacket)		5.5 L [1.45 U.S.gal.]	
	Water pump	Type	Volute type centrifugal pump	
		Speed ratio to crankshaft	1.3 (varies depending on the specification)	
		Discharge capacity	160 L [42.27 U.S.gal.]/min (at pump rotation of 3600 min^{-1}, 0.75 MPa {7.5 kgf/cm^2} [106.67 psi])	
	Cooling fan	Type	Push type (PP fan, varies depending on the specification)	
		Diameter	ø 440 mm [17.32 in.] (varies depending on the specification)	
	Thermostat	Type	Wax type	
		Valve opening temperature	76.5 ± 1.5°C [169.7 ± 2.7°F] (90°C [194.0°F] when fully opened)	
Inlet and exhaust system	Turbocharger	Model number	-	TD04L4 (varies depending on the specification)

Table 1-1 Main specifications S4S in-line fuel injection pump specification (3 / 3)

Engine model				S4S	S4S-DT
Electrical system	Voltage - polarity			12V - negative (-) ground	
	Starter	Pinion meshing type		Pinion shift	
		Output		12V - 2.2kW (varies depending on the specification)	
		Ring gear and pinion ratio		10/122 (varies depending on the specification)	
	Alternator	Type		3-phase alternating current, with rectifier	
		Output		12V - 50A (12V - 75A, option)	
		Speed in use		1000 to 18000 min^{-1}	
		Rated generating speed		5000 min^{-1}	
		Permissible speed		22000 min^{-1}	
		Speed ratio to crankshaft		2.0 (varies depending on the specification)	
	Glow plug	Type		Sheathed	
		Rated voltage - current		10.5V - 9.7A (30-second duration)	11V - 5.5A (30-second duration)
	Magnetic valve (Stop solenoid, option)	ETR type (RUN-ON)	Rated voltage	12V	
			Rated thermometer	20°C [68°F]	
			Rated absorption current	55A	
			Rated hold current	1.1A	

4.2 S4S distributor-type fuel injection pump specification (varies depending on the specification)

Table 1-2 Main specifications S4S distributor-type fuel injection pump specification (1 / 3)

Engine model				S4S	S4S-DT
Main specification	Type			Water cooled, 4 cycle diesel engine	
	No. of cylinders - arrangement			4 cylinder in-line	
	Combustion system			Swirl chamber	Direct injection
	Valve mechanism			Overhead	
	Cylinder bore × stroke			94 × 120 mm [3.70 × 4.72 in.]	
	Displacement			3.331 L [203 cu. in.]	
	Compression ratio			22.0 : 1	20.5 : 1 (varies depending on the specification)
	Fuel			ASTM diesel fuel oil No.2-D (JIS K2204 gas oil specification No.2 or 3)	
	Firing order			1 - 3 - 4 - 2	
	Direction of rotation			Counterclockwise when viewed from flywheel side	
	Dimensions (with fan)	Length		811 mm [31.93 in.]	Varies depending on the specification
		Width		558 mm [21.97 in.]	
		Height		716 mm [28.19 in.]	
	Dry weight			245 kg [540 lb]	250 kg [551 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°	BTDC 18°
			Close	ABDC 50°	ABDC 54°
		Exhaust valve	Open	BBDC 74°	BBDC 66°
			Close	ATDC 30°	ATDC 22°
	Internal EGR valve timing	Inlet valve	Open	-	BBDC 10° (varies depending on the specification)
			Close	-	ABDC 90° (varies depending on the specification)
	Starting system			Starter	
	Starting aid system			Glow plug	
Fuel system	Fuel injection pump	Type		Distribution (VE type)	
		Plunger diameter		ø 11 mm [0.43 in.]	ø 12 mm [0.47 in.]
	Fuel feed pump	Type		Vane type	
	Governor	Speed control system		Centrifugal type	
		Feature		All speed	
	Fuel injection nozzle	Nozzle type		Throttle type	Hole type
		Number of spray holes		1	6 (varies depending on the specification)
		Spray hole diameter		ø 1.0 mm [0.039 in.]	ø 0.16 mm [0.0063 in.] (varies depending on the specification)
		Spray angle		0°	145° (varies depending on the specification)
		Valve opening pressure		11.77 MPa {120 kgf/cm²} [1706.80 psi]	17.7 MPa {180 kgf/cm²} [2560.19 psi]
	Fuel filter	Type		Cartridge type paper element	

Table 1-2 Main specifications S4S distributor-type fuel injection pump specification (2 / 3)

Engine model			S4S	S4S-DT
Lubrication system	Lubricating method		Forced circulation type (pressure feed by oil pump)	
	Engine oil	Standard	Class CF or CH-4, SAE30 equivalent (API service classification)	
		Engine oil capacity	Engine total: approx. 10 L [2.64 U.S.gal.] (approx. 9 L [2.38 U.S.gal.] (high level) in oil pan), oil filter: 1 L [0.26 U.S.gal.]	
	Oil pump	Type	Trochoid	
		Speed ratio to crankshaft	0.74	0.74
		Discharge capacity	28.6 L [7.56 U.S.gal.]/min (at pump rotation of 2230 min^{-1}, 0.3 MPa {3 kgf/cm^2} [42.67 psi])	38.7 L [10.22 U.S.gal.]/min (at pump rotation of 2230 min^{-1}, 0.3 MPa {3 kgf/cm^2} [42.67 psi])
	Relief valve	Type	Piston valve type	
		Valve opening pressure	0.35 ± 0.05 MPa {3.6 ± 0.5 kgf/cm^2} [49.78 ± 7.11 psi]	
	Safety valve	Opening pressure	-	1.1 MPa {11 kgf/cm^2} [157 psi]
	Oil cooler	Type	-	Water-cooled, multi-plate
	Oil filter	Type	Cartridge type paper element	
Cooling system	Cooling method		Water-cooled, forced circulation	
	Coolant capacity (engine water jacket)		5.5 L [1.45 U.S.gal.]	5.5 L [1.45 U.S.gal.]
	Water pump	Type	Volute type centrifugal pump	
		Speed ratio to crankshaft	1.3 (varies depending on the specification)	
		Discharge capacity	160 L [42.27 U.S.gal.]/min (at pump rotation of 3600 min^{-1}, 0.75 MPa {7.5 kgf/cm^2} [106.67 psi])	
	Cooling fan	Type	Push type (PP fan)	
		Diameter	ø 440 mm [17.32 in.]	-
	Thermostat	Type	Wax type	
		Valve opening temperature	76.5 ± 1.5°C [169.7 ± 2.7°F] (90°C [194.0°F] when fully opened)	
Inlet and exhaust system	Turbocharger	Model number	-	TD04HL4

Table 1-2 Main specifications S4S distributor-type fuel injection pump specification (3 / 3)

Engine model				S4S	S4S-DT
Electrical system	Voltage - polarity			12V - negative (-) ground	
	Starter	Pinion meshing type		Pinion shift	
		Output		12V - 2.2kW	
		Ring gear and pinion ratio		10/122	
	Alternator	Type		3-phase alternating current, with rectifier	
		Output		12V - 50A (12V - 75A, option)	
		Speed in use		1000 to 18000 min^{-1}	
		Rated generating speed		5000 min^{-1}	
		Permissible speed		22000 min^{-1}	
		Speed ratio to crankshaft		2.0	
	Glow plug	Type		Sheathed	
		Rated voltage - current		10.5V - 9.7A (30-second duration)	11V - 5.5A (30-second duration)
	Magnetic valve (Stop solenoid)	ETR type (RUN-ON)	Rated voltage	12V	
			Power consumption	20W	
			Starting voltage	6.3V or below	
			Return voltage	2.5V or more	
			Coil resistance	8 Ω	

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 (No-load)		Be sure to check specifications (varies depending on the specification)			
Minimum rotation speed (No-load)					
Compression pressure (at 300 min^{-1})	Swirl chamber		3.2 MPa {33 kgf/cm²} [469 psi]	2.8 MPa {29 kgf/cm²} [412 psi]	When oil and water temperatures at 20 to 30°C [68 to 86°F]
	Direct injection		2.9 MPa {30 kgf/cm²} [421 psi]	2.6 MPa {27 kgf/cm²} [377 psi]	
Lubricating oil pressure	Rotated speed at 1500 min^{-1}		0.3 to 0.5 MPa {3 to 5 kgf/cm²} [43 to 71 psi]	0.15 MPa {1.5 kgf/cm²} [21 psi]	Oil temperature at 70 to 90°C [158 to 194°F]
	Idling speed		0.10 MPa {1.0 kgf/cm²} [14 psi] or more	0.05 MPa {0.5 kgf/cm²} [7 psi]	
Valve clearance	Inlet		0.25 [0.0098]		When engine is cold
	Exhaust		0.25 [0.0098]		
Fuel injection timing (before TDC)		Be sure to check specifications. (The timing varies depending on specification)			

1.2 Basic engine

Table 2-2 Maintenance service data table - Basic engine (1 / 4) Unit: mm [in.]

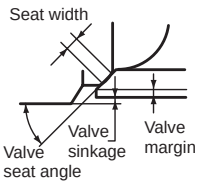
Inspection point			Nominal	Standard	Limit	Remark
Rocker	Rocker bushing inside diameter		ø 19 [0.75]	19.010 to 19.030 [0.7484 to 0.7492]		
	Rocker shaft outside diameter		ø 19 [0.75]	18.980 to 19.000 [0.7472 to 0.7480]		
	Clearance between rocker bushing and shaft			0.010 to 0.050 [0.0004 to 0.0020]	0.070 [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		0.065 to 0.095 [0.0026 to 0.0037]	0.150 [0.0059]	
		Exhaust		0.080 to 0.115 [0.0031 to 0.0045]	0.200 [0.0079]	
	Valve guide mounting dimension		14 [0.55]	13.9 to 14.1 [0.547 to 0.555]		
Valve seat and valve	Valve seat angle		30°			
	Valve sinkage	Inlet	0.4 [0.016]	0.3 to 0.5 [0.012 to 0.020]	1.0 [0.039]	
		Exhaust	0.5 [0.020]	0.4 to 0.6 [0.016 to 0.024]	1.0 [0.039]	
	Seat width		1.4 [0.055]	1.26 to 1.54 [0.0496 to 0.0606]	1.8 [0.071]	
	Valve margin			2.13 [0.0839]	Refacing permissible up to 1.83 [0.0720]	
Valve spring	Free length			48.85 [1.9232]	47.60 [1.8740]	
	Perpendicularity			θ = 1.5°or less Δ = 1.3 [0.051] or less 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]	
Pushrod	Runout			0.6 [0.024] or less	0.6 [0.024] or less	Runout (dial gauge 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		1.2 [0.047]	1.15 to 1.25 [0.0453 to 0.0492]		

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

Inspection point			Nominal	Standard	Limit	Remark
Cylinder	Inside diameter		ø 94 [3.70]	94.000 to 94.035 [3.7008 to 3.7022]	Repair limit: 94.200 [3.7087] Replace limit: 94.700 [3.7283]	Refinish cylinder to 0.25 [0.0098] or 0.50 [0.0197] oversize of nominal valve by honing. Use oversize piston and piston ring.
	Circularity			0.01 [0.0004] or less		
	Cylindricality			0.015 [0.0006] or less		
Piston	Outside diameter (at piston skirt)	STD	ø 94 [3.70]	93.955 to 93.985 [3.6990 to 3.7002]	93.770 [3.6917]	
		0.25 [0.0098]/OS		94.205 to 94.235 [3.7089 to 3.7100]	94.020 [3.7016]	
		0.50 [0.0197]/OS		94.455 to 94.485 [3.7187 to 3.7199]	94.270 [3.7114]	
	Protrusion from crankcase	Swirl chamber		-0.25 to 0.15 [-0.0098 to 0.0059]		Bearing clearance check.
		Direct injection		0.05 to 0.45 [0.0020 to 0.0177]		
	Weight difference in one engine			5 g [0.2 oz.] or less		
Piston ring	Clearance between piston ring groove	No.1 compression ring		0.07 to 0.11 [0.0028 to 0.0043]	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	2.0 [0.079]	0.045 to 0.085 [0.0018 to 0.0033]	0.150 [0.0059]	
		Oil ring	4.0 [0.157]	0.020 to 0.060 [0.0008 to 0.0024]	0.150 [0.0059]	
	Closed gap of ring	No.1 compression ring		0.30 to 0.50 [0.0118 to 0.0197]	1.50 [0.0591]	
		No.2 compression ring		0.50 to 0.70 [0.0197 to 0.0276]	1.50 [0.0591]	
		Oil ring		0.30 to 0.50 [0.0118 to 0.0197]	1.50 [0.0591]	
Piston pin	Outside diameter		ø 30 [1.18]	29.994 to 30.000 [1.1809 to 1.1811]		
	Clearance between piston pin			0.000 to 0.016 [0.0000 to 0.0006]	0.050 [0.0020]	
	Clearance between connecting rod bushing			0.020 to 0.091 [0.0008 to 0.0036]	0.120 [0.0047]	
Connecting rod	Bushing inside diameter		ø 30 [1.18]	30.020 to 30.045 [1.1819 to 1.1829]		
	Bend and twist			0.05/100 [0.0020/3.94] or less	0.15/100 [0.0059/3.94]	
	Clearance between crankpin and connecting rod bearing (oil clearance)			0.03 to 0.09 [0.0012 to 0.0035]	0.20 [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.
	End play			0.15 to 0.35 [0.0059 to 0.0138]	0.50 [0.0197]	Replace connecting rod.
	Weight difference of connecting rod assembly in one engine			10 g [0.35 oz.] or less		

Table 2-2 Maintenance service data table - Basic engine (3 / 4) Unit: mm [in.]

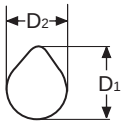
Inspection point				Nominal	Standard	Limit	Remark
Flywheel	Flatness				0.15 [0.0059] or less	0.50 [0.0197]	
	Runout				0.15 [0.0059] or less	0.50 [0.0197]	
Camshaft	Runout				0.04 [0.0016] or less	0.10 [0.0039]	Repair or replace.
	Cam lift	Swirl chamber	Inlet	6.684 [0.2631]	6.384 to 6.784 [0.2513 to 0.2671]	6.184 [0.2435]	
			Exhaust	6.720 [0.2646]	6.420 to 6.820 [0.2528 to 0.2685]	6.220 [0.2449]	
		Direct injection	Inlet	6.682 [0.2631]	6.382 to 6.782 [0.2513 to 0.2670]	6.182 [0.2434]	
			Exhaust	6.722 [0.2646]	6.422 to 6.822 [0.2528 to 0.2686]	6.222 [0.2450]	
	Journal outside diameter		No.1, 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]	
	Clearance between camshaft journal and camshaft bushing				0.040 to 0.090 [0.0016 to 0.0035]	0.15 [0.0059]	Replace bushing if limit is exceeded. Reaming if necessary.
	End play				0.10 to 0.25 [0.0039 to 0.0098]	0.30 [0.0118]	Replace thrust plate.
Idler	Clearance between bushing and shaft				0.009 to 0.050 [0.0004 to 0.0020]	0.100 [0.0039]	
	Idler gear end play				0.05 to 0.20 [0.0020 to 0.0079]	0.35 [0.0138]	Replace thrust plate.
	Interference between shaft and crankcase hole			ø 35 [1.38]	0.035T to 0.076T [0.0014 to 0.0030]		
Timing gear backlash					0.05 to 0.15 [0.0020 to 0.0059]	0.25 [0.0098]	Replace gear.

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

Inspection point		Nominal	Standard	Limit	Remark
Crankshaft	Crank journal outside diameter	ø 78 [3.07]	77.955 to 77.970 [3.0691 to 3.0697]	77.850 [3.0650] (Repair) 77.100 [3.0354] (Replace)	
	Crankpin outside diameter	ø 58 [2.28]	57.955 to 57.970 [2.2817 to 2.2823]	57.800 [2.2756]	
	Distance between centers of journal and crankpin	60 [2.36]	59.96 to 60.04 [2.3606 to 2.3638]		
	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 and journal	R3 [0.12]	2.8 to 3.2 [0.110 to 0.126]		
	Runout (TIR)		0.04 [0.0016] or less	0.10 [0.0039]	TIR
	End play	31 [1.22]	0.100 to 0.264 [0.0039 to 0.0104]	0.300 [0.0118]	Replace thrust plates before limit is reached. If limit is exceeded, use one of following oversize thrust plates; +0.15 [+0.0059], +0.30 [+0.0118]
Main bearing	Clearance between main bearing and crankshaft journal		0.050 to 0.110 [0.0020 to 0.0043]	0.200 [0.0079] crank journal outside diameter (ø 78 [3.0709]) -0.9 [-0.0354]	Replace bearings before limit is reached. Regrind crank journal and use next undersize bearings if limit is exceeded; -0.25 [-0.0098], -0.50 [-0.0197], -0.75 [-0.0295]
Crankcase	Flatness of top surface		0.05 [0.0020] or less	0.20 [0.0079]	Reface minimum thickness.
	Tappet guide hole inside diameter		14.000 to 14.018 [0.5512 to 0.5519]	14.100 [0.5551]	
	Clearance between tappet and tappet guide hole		0.016 to 0.052 [0.0006 to 0.0020]	0.08 [0.0031]	If the diameter is the limit or more, replace tappet.

1.3 Fuel system

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

Inspection point				Nominal	Standard	Limit	Remark
Fuel injection nozzle	Valve opening pressure	Swirl chamber		11.77 MPa {120 kgf/cm²} [1707 psi]	11.77 to 12.75 MPa {120 to 130 kgf/cm²} [1707 to 1849 psi]		Make shim adjustment. Pressure varies by 1 MPa {10 kgf/cm²} [144 psi] per 0.1 [0.004] thickness of shim.
		Direct injection		17.70 MPa {180 kgf/cm²}	18.14 to 19.12 MPa {185 to 195 kgf/cm²}		
	Spray cone angle	Swirl chamber		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.
		Direct injection	Distributor-type	145°			
			In-line type	148°			
	Nozzle valve seat oil sealing			Seat shall hold a test pressure lower than valve opening pressure by 2 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	Clearance between outer rotor and case		0.20 to 0.30 [0.0079 to 0.0118]	0.50 [0.0197]	Replace pump assembly.
	Main shaft outside diameter (between case)	ø 16 [0.63]	15.985 to 16.000 [0.6293 to 0.6299]		
	Main shaft outside diameter (between oil pump bushing)	ø 14 [0.55]	13.957 to 13.975 [0.5495 to 0.5502]		
	Clearance between main shaft and pump case		0.032 to 0.074 [0.0013 to 0.0029]	0.150 [0.0059]	Replace pump case or replace pump assembly.
	Clearance between main shaft and oil pump bushing		0.025 to 0.111 [0.0010 to 0.0044]	0.200 [0.0079]	Replace oil pump bushing or replace pump assembly.
	Clearance between inner rotor and outer rotor		0.13 to 0.15 [0.0051 to 0.0059]	0.20 [0.0079]	Replace outer rotor and shaft assembly.
	Rotor and case end play		0.04 to 0.09 [0.0016 to 0.0035]	0.15 [0.0059]	Replace pump assembly.
Relief valve	Valve opening pressure	0.35 MPa {3.6 kgf/cm²} [51.20 psi]	0.35 ± 0.05 MPa {3.5 ± 0.5 kgf/cm²} [49.78 ± 7.11 psi]		
Safety valve	Valve opening pressure		1.1 MPa {11 kgf/cm²} [157 psi]		

1.5 Cooling system

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

Inspection point		Nominal	Standard	Limit	Remark
Thermostat	Temperature at which valve starts opening		76.5 ± 1.5°C [170 ± 2.7°F]		
	Temperature at which valve lift is 9 [0.35], minimum		90°C [194°F]		

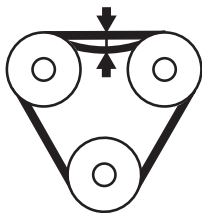
1.6 Inlet and exhaust system

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

Inspection point	Nominal	Standard	Limit	Remark
Distortion of exhaust manifold		0.2 [0.008] or less		Repair by grinding or replace.

1.7 Electrical system

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

Inspection point					Nominal	Standard	Limit	Remark
Starter		Commutator	Outside diameter			32	31.4	Replace
			Runout			0.05 or less	0.1	Repair or replace
			Undercut depth			0.4 to 0.6	0.2	Repair
		Brush length				18	11	Replace
		Tension of brush springs				26 to 35 N {2.7 to 3.6 kgf}	15 N {1.5 kgf}	Replace
		Pinion gap				0.5 to 2.0		Adjust by packing
		Nonload characteristics	Voltage			11V	23V	Inspect
			Armature current			130A or below		
			Rotational speed			3800 min^{-1}		
Alternator	12V - 50A	Output characteristics (when hot)	Rotational speed (min^{-1})	1500 or less				Inspect
				2500 or less		33A or more		
				5000 or less		47A or more		
		IC regulator controlled voltage				14.7 ± 0.3V		at 20°C [68°F]
		Brush length				18.5	5.0	Replace
	12V - 75A	Output characteristics (when hot)	Rotational speed (min^{-1})	1500 or less		24A or more		Inspect
				2500 or less		54A or more		
				5000 or less		73A or more		
		IC regulator controlled voltage				14.7 ± 0.3V		at 20°C [68°F]
		Brush length				18.5	5.0	Replace
Magnetic valve (resistance of stop solenoid ETR type (RUN-ON))					12V	8 to 10.7 Ω		Replace
V-belt			Deflection			10 to 12		When center of belt pressed at approx.98N {10kgf} [22 lbf] 

2. Tightening torque table

2.1 Major bolt tightening torque

2.1.1 Basic engine

Table 2-8 Tightening torque table - Basic engine

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Cylinder head	12 × 1.75	118 ± 5	12 ± 0.5	87 ± 3.6	
Cylinder head plug	16 × 1.5	44.1 ± 5	4.5 ± 0.5	33 ± 3.6	
Rocker cover	8 × 1.25	11.5 ± 1.5	1.17 ± 0.15	8.5 ± 1.1	
Rocker shaft bracket (long)	8 × 1.25	17.5 ± 2.5	1.78 ± 0.2	12.9 ± 1.8	
Main bearing cap	14 × 2.0	103 ± 5	10.5 ± 0.5	76 ± 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	11.3 ± 1.5	1.15 ± 0.15	8.3 ± 1.1	
Front plate	8 × 1.25	11.3 ± 1.5	1.15 ± 0.15	8.3 ± 1.1	
Timing gear case cover	8 × 1.25	18.1 ± 1.5	1.85 ± 0.15	13.4 ± 1.1	
Crankshaft pulley	30 × 1.5	490 ± 10	50 ± 1	361 ± 7.3	
Idler thrust plate	10 × 1.25	34 ± 5	3.5 ± 0.5	25 ± 3.6	
Rocker adjusting nut	8 × 1.25	20 ± 2	2 ± 0.2	15 ± 1.4	

2.1.2 Fuel system

Table 2-9 Tightening torque table - Fuel system

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Fuel injection nozzle (Swirl chamber)	20 × 1.5	58.9 ± 5.9	6 ± 0.6	43 ± 4.3	
Fuel injection nozzle glands (Direct injection)	8 × 1.25	22 ± 1	2.2 ± 0.1	16 ± 0.7	
Fuel injection pump gear nut (In-line type, VE swirl chamber)	12 × 1.75	63.7 ± 5	6.5 ± 0.5	47 ± 3.6	
Fuel injection pump gear nut (In-line type, VE direct injection)	14 × 1.5	91 ± 7	9 ± 0.7	67 ± 5	
Fuel leak off pipe mounting nut	12 × 1.5	22.6 ± 2	2.3 ± 0.2	16.7 ± 1.4	
Fuel injection pump delivery valve holders	-	37 ± 2.5	3.8 ± 0.2	27 ± 1.8	

2.1.3 Lubrication system

Table 2-10 Tightening torque table - Lubrication system

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Oil pan	8 × 1.25	11.3 ± 1.5	1.15 ± 0.15	8.3 ± 1.1	
Oil pan drain plug	14 × 1.5	39 ± 5	4 ± 0.5	29 ± 3.7	
	20 × 1.5	78 ± 5	8 ± 0.5	57 ± 3.7	
Oil pump gear	10 × 1.25	33 ± 5	3.4 ± 0.5	24 ± 3.7	
Oil relief valve	22 × 1.5	49 ± 4.9	5 ± 0.5	36 ± 3.7	
Safety valve	18 × 2.0	69 ± 5	7 ± 0.5	50 ± 3.7	
Fuel injection pump oil supply pipe (In-line type)	12 × 1.0	19.5 ± 3.5	2 ± 0.36	14 ± 2.6	

2.1.4 Cooling system

Table 2-11 Tightening torque table - Cooling system

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Thermostat case	8 × 1.25	18.1 ± 1.5	1.85 ± 0.15	13.4 ± 1.1	
Water drain plug	1/4-18NPTF	39.2 ± 3.9	4 ± 0.4	28.9 ± 2.8	
Water pump mounting bolt	8 × 1.25 (Tightening with water pump case cover)	9.8 ± 1	1 ± 0.1	7.2 ± 0.7	
	8 × 1.25	18.6 ± 2.9	1.9 ± 0.3	13.7 ± 2.1	
Water pump plug	R3/8	32.4 ± 2	3.3 ± 0.2	23.9 ± 1.4	

2.1.5 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 (bolt only)	8 × 1.25	30.4 ± 2.9	3.1 ± 0.3	22.4 ± 2.1	
Exhaust manifold (with spacer)	8 × 1.25	18.5 ± 3.5	1.9 ± 0.3	13.6 ± 2.5	
Turbocharger oil supply eyebolt	10 × 1.25	16.2 ± 2.4	1.6 ± 0.2	11.9 ± 1.7	
Turbocharger air hose plate clamp	-	4 ± 1	0.4 ± 0.1	3 ± 0.7	

2.1.6 Electrical system

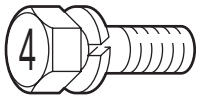
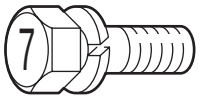
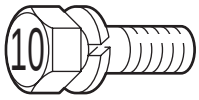
Table 2-13 Tightening torque table - Electrical system

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Starter terminal B	8 × 1.25	$9.8\ ^{+2}_{0}$	$1\ ^{+0.2}_{0}$	$7\ ^{+1.5}_{0}$	
Glow plug (Engine body, swirl chamber)	10 × 1.25	17.2 ± 2.5	1.75 ± 0.25	12.7 ± 1.8	
Glow plug (Engine body, direct injection)	12 × 1.25	25 ± 5	2.5 ± 0.5	18 ± 3.6	
Glow plug (terminal)	4 × 0.7	1.3 ± 0.3	0.13 ± 0.03	0.96 ± 0.22	

2.2 Standard bolt and nut tightening torque

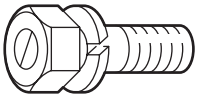
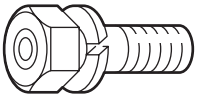
2.2.1 Metric automobile screw thread

Table 2-14 Metric automobile screw thread

Threads Dia × Pitch (mm)	Width across flats (mm) [in.]	Strength classification								
		4T			7T			10.9		
										
		N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft
M6 × 1.0	10 [0.39]	3.9	0.4	2.9	8.8	0.9	6.5	12.7	1.3	9.4
M8 × 1.25	12 [0.47]	11.8	1.2	8.7	18	1.9	13	30	3.1	22
M10 × 1.25	14 [0.55]	21.1	2.15	16	35	3.6	26	60	6.1	44
M12 × 1.25	17 [0.67]	35.3	3.6	26	64	6.5	47	108	11.0	80

2.2.2 Metric course screw thread

Table 2-15 Metric course screw thread

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
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

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

2.3 Standard stud tightening torque

Table 2-16 Standard stud tightening torque

Threads Dia × Pitch (mm)	For driving in aluminum materials			For driving in ferrous materials		
	N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft
M8 × 1.25	5.4 ± 0.5	0.55 ± 0.05	4.0 ± 0.4	13.7 ± 1.0	1.4 ± 0.1	10.1 ± 0.7
M10 × 1.25	12.7 ± 1.0	1.3 ± 0.1	9.4 ± 0.7	23.5 ± 2.0	2.4 ± 0.2	17.4 ± 1.4

SERVICE TOOLS

1. Special tool

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

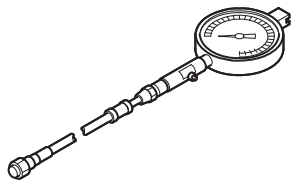
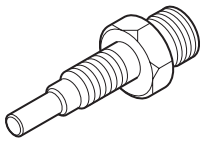
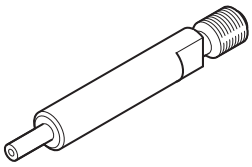
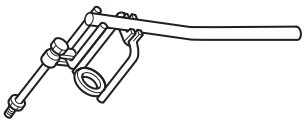
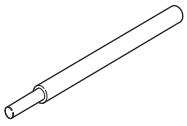
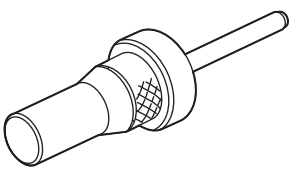
Tool name	Part No.	Shape	Use
Compression gauge	33391-02100		Engine compression pressure measuring 0 to 7 MPa {0 to 71.4 kgf/cm²} [0 to 1015.54 psi]
Gauge adapter (swirl chamber)	30691-21100		Engine compression pressure measuring
Gauge adapter (direct injection)	32A91-01100		Engine compression pressure measuring
Socket	58309-73100		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: 36791-00200 Exhaust: 34491-03020		Valve seat installation

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

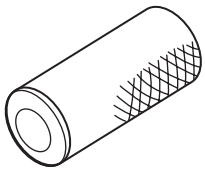
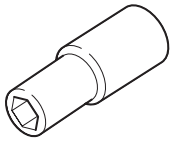
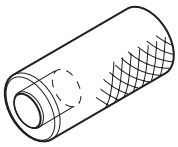
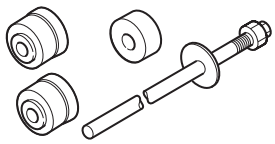
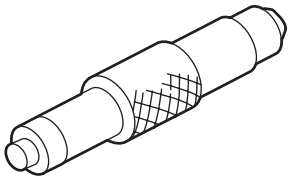
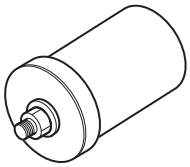
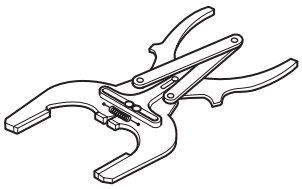
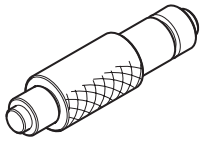
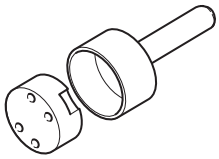
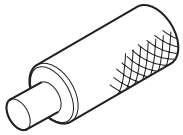
Tool name	Part No.	Shape	Use
Stem seal installer	32A91-10200		Stem seal installation
Socket	34491-00300		Camshaft, thrust plate and rocker bracket installation
Valve guide installer	32A91-00100		Valve guide installation
Camshaft bushing installer set	30691-00010		Camshaft bushing removal/installation
Idler bushing installer	30091-07300		Idler bushing removal/installation
Idler shaft puller	MH061077		Idler shaft removal
Piston ring pliers	31391-12900		Piston ring removal/installation

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

Tool name	Part No.	Shape	Use
Connecting rod bushing puller	32A91-00500		Connecting rod bushing removal/installation
Oil seal sleeve installer guide set	30691-13010		Oil seal sleeve installation of crankshaft rear side
Piston installer	34491-00200		Piston installation
Oil pump bushing installer	32A91-00400		Oil pump bushing 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

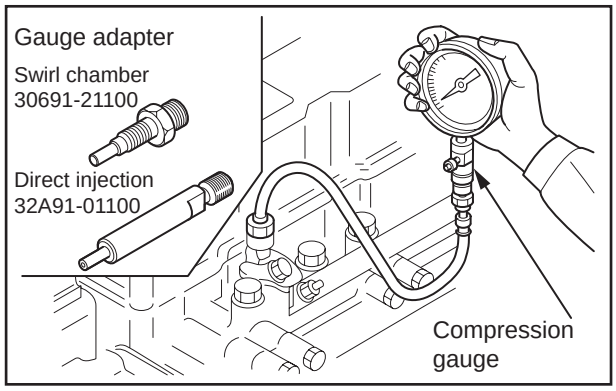
(a) Be sure to measure the compression pressure for all the cylinders. It is not a good practice to measure the compression pressure for only one cylinder, and presume the compression for the remaining cylinder.
(b) Also be sure to check engine speed when measuring the compression pressure, as compression pressure varies with engine speed.
(c) Measuring the compression pressure at regular intervals is important to obtain correct data.
(d) The compression pressure will be slightly higher in a new or overhauled engine due to new piston rings, valve seats, etc. Pressure will drop gradually by the wear of these parts.
(e) When measuring the compression pressure for cylinders one by one, do not remove other fuel injection nozzles, except for the one being measured, from their positions.
(f) Turn off the solenoid valve to stop fuel injection.

(For swirl chamber type)

(1) Remove the glow plug from the cylinder head where the compression pressure is to be measured.
(2) Attach the compression gauge adapter to the glow plug mount and connect compression gauge.
(3) Crank the engine with the starter, then read the compression gauge indication while the engine is running at the specified speed.
(4) If the compression pressure is lower than the limit, overhaul the engine.

(For direct injection type)

(1) Remove the injection nozzle from the cylinder head where the compression pressure is to be measured.
(2) Attach the compression gauge adapter to the injection nozzle mount and connect compression gauge.
(3) Crank the engine with the starter, then read the compression gauge indication while the engine is running at the specified speed.
(4) If the compression pressure is lower than the limit, overhaul the engine.

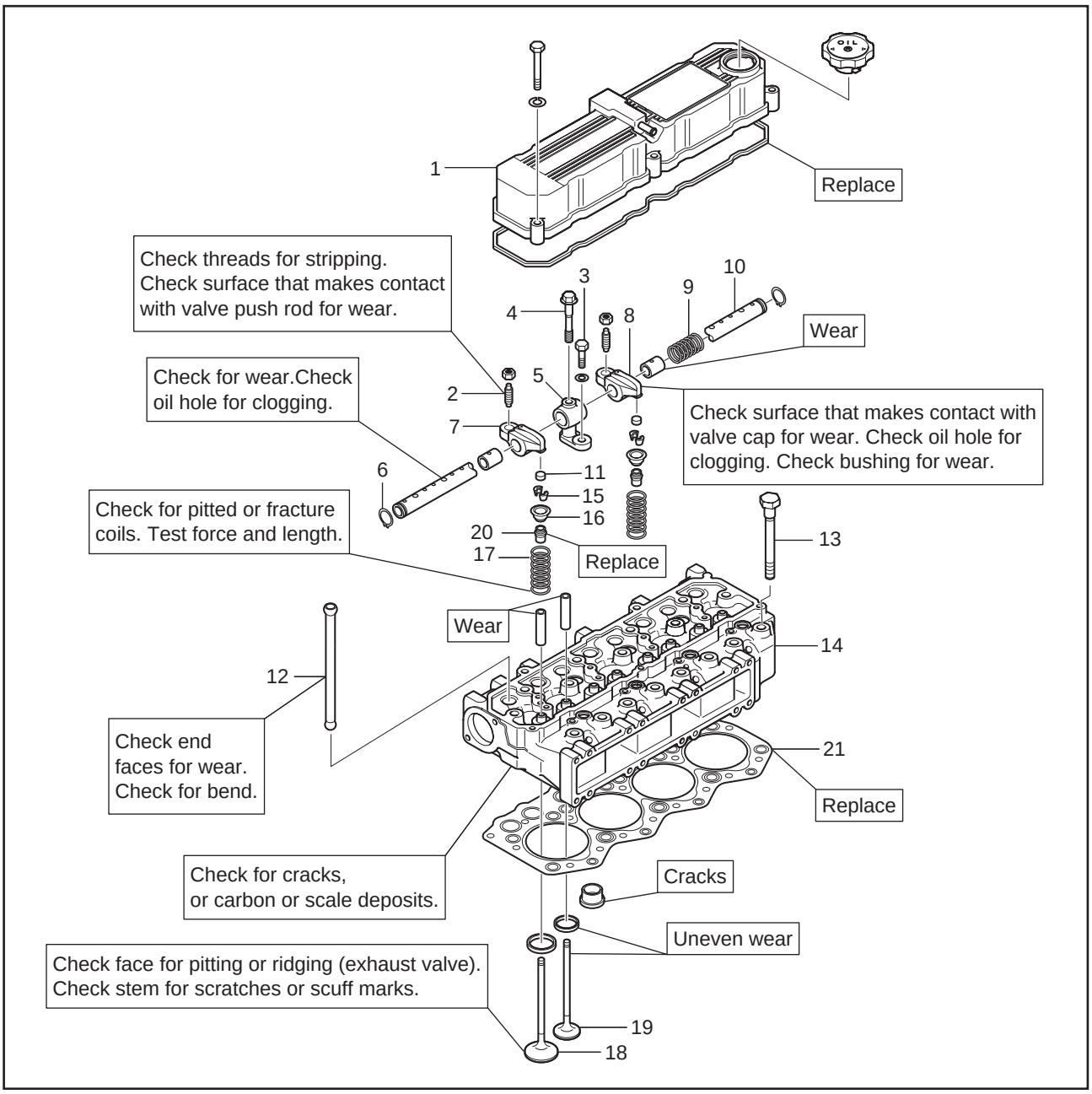


Testing compression pressure

Item		Standard	Limit
Compression pressure	Swirl chamber	3.2 MPa {33 kgf/cm²} [469 psi]	2.8 MPa {29 kgf/cm²} [412 psi]
	Direct injection	2.9 MPa {30 kgf/cm²} [427 psi]	2.6 MPa {27 kgf/cm²} [384 psi]
Engine speed		300 min^{-1}	-
Oil and water temperatures		20 to 30°C [68 to 86°F]	-

DISASSEMBLY OF BASIC ENGINE

1. Disassembling and inspecting cylinder head and valve mechanism



Disassembling and inspecting cylinder head and valve mechanism

Disassembling sequence

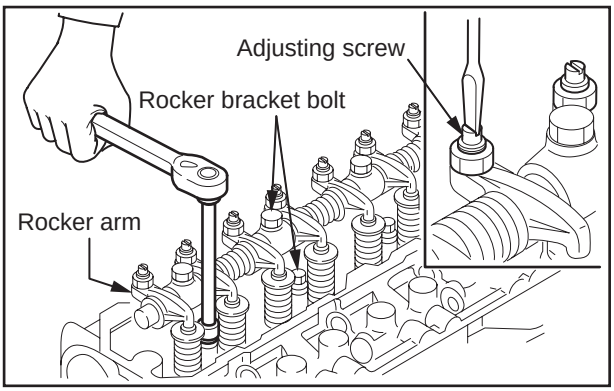
1	Rocker cover	8	Rocker arm (EX)	15	Valve cotter
2	Adjusting screw	9	Rocker shaft spring	16	Valve retainer
3	Bolt (short)	10	Rocker shaft	17	Valve spring
4	Bolt (long)	11	Valve cap	18	Valve (IN)
5	Rocker shaft bracket	12	Push rod	19	Valve (EX)
6	Snap ring	13	Cylinder head bolt	20	Valve stem seal
7	Rocker arm (IN)	14	Cylinder head	21	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 rocker bracket bolts, and remove the rocker shaft assembly from the cylinder head.
(5) Remove push rods.



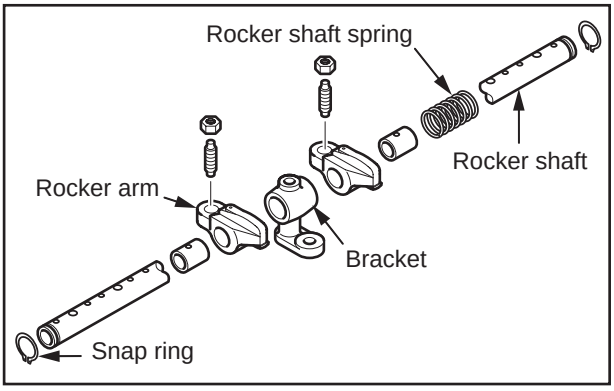
Removing rocker shaft assembly

1.2 Disassembling rocker shaft assembly

Remove the snap ring, disassemble the rocker shaft assembly into the rocker arms, brackets, rocker shaft springs and rocker shaft.

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

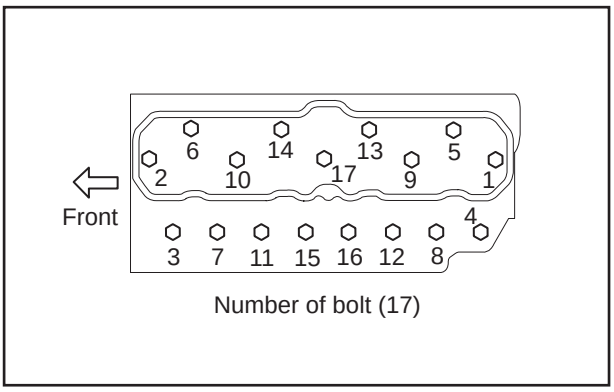
(b) Do not remove the rocker bush when it is not faulty, and its inside diameter is not exceed the limit.



Disassembling rocker shaft assembly

1.3 Removing cylinder head bolt

Loosen cylinder head bolts in the numerical order as shown in the illustration.



Removing cylinder head bolt

1.4 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.

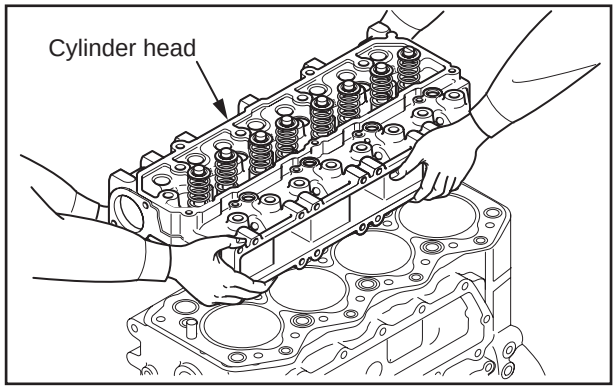
Note: If the cylinder head assembly cannot be removed due to crimping of the cylinder head gasket, tap the thick area on the side of the cylinder head using a plastic hammer to give a shock.

Do not lift up the cylinder head by one person.

Use crane or lift up by two persons.

(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.

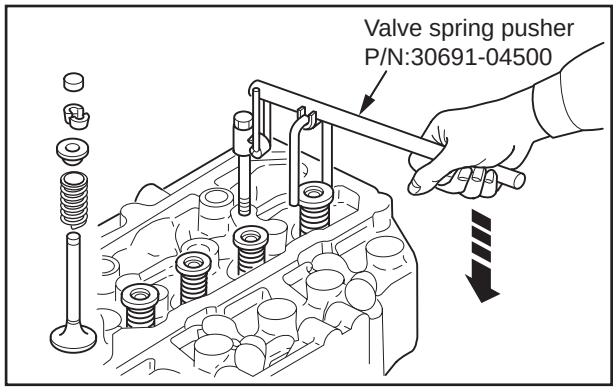


Removing cylinder head assembly

1.5 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 for identifying their original positions. Do not mix valve seats with other valve.

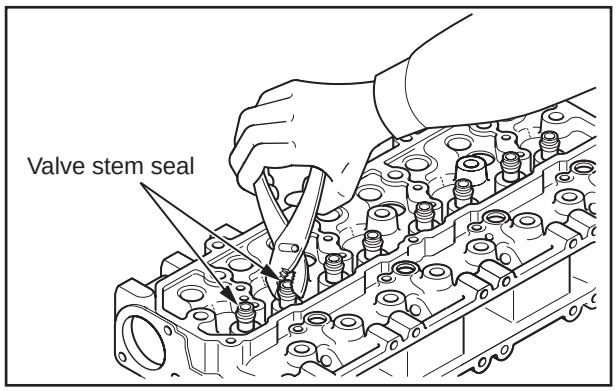


Removing valve and valve spring

1.6 Removing valve stem seal

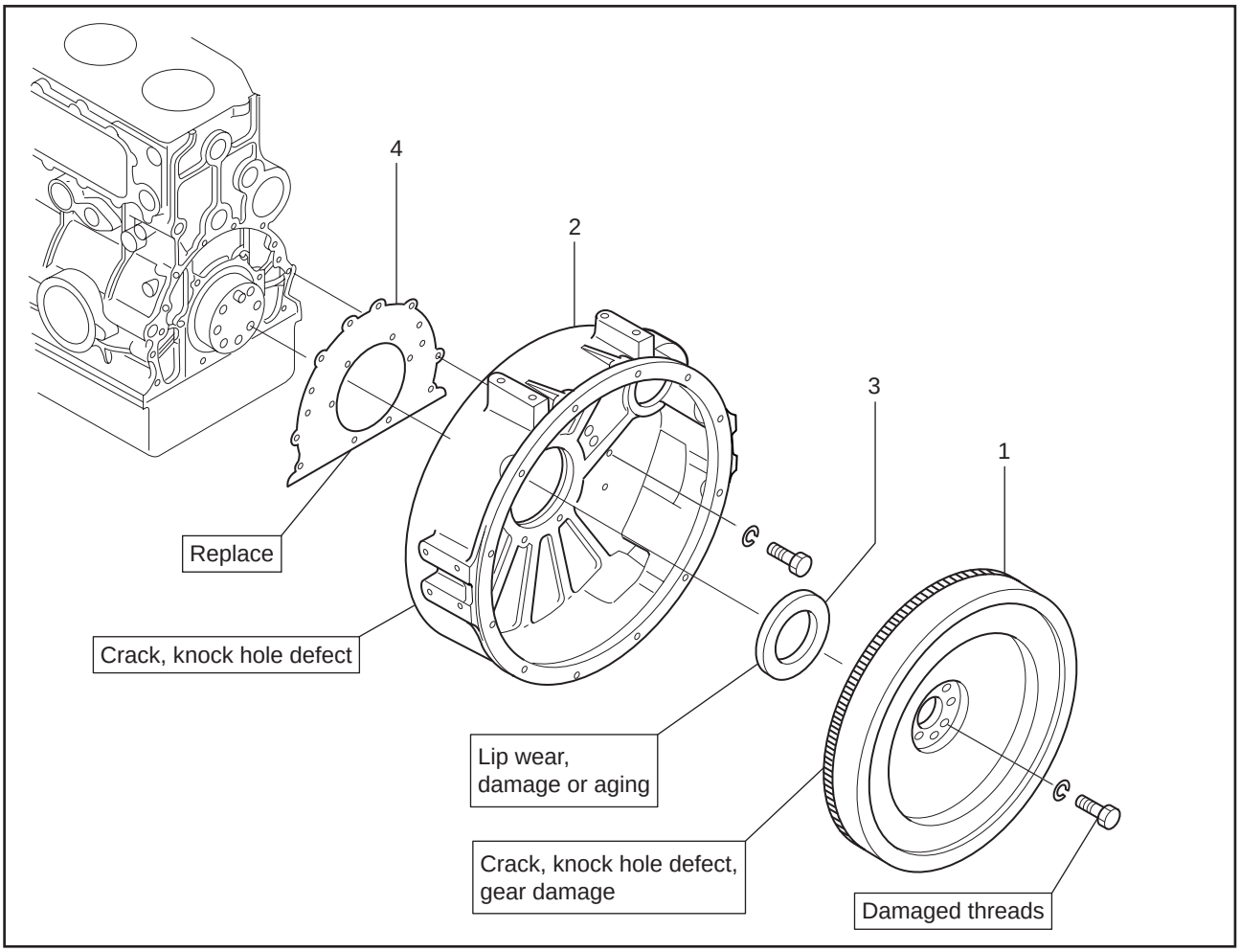
Grab the valve stem seal with pliers and remove.

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



Removing valve stem seal

2. Disassembling and inspecting flywheel



Disassembling and inspecting flywheel

Disassembling sequence

1 Flywheel
2 Flywheel housing
(Remove parts 2 and 3 as a unit)
3 Oil seal
4 Gasket

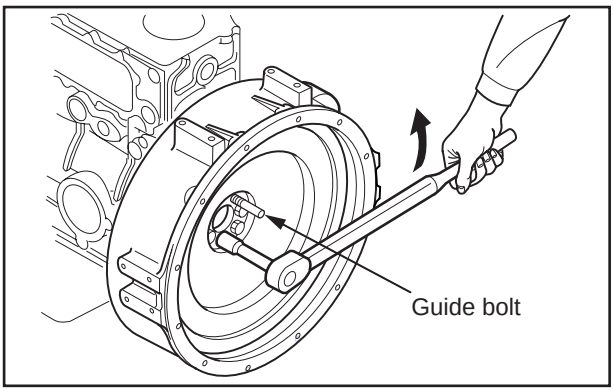
2.1 Removing flywheel

⚠ CAUTION

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.

(1) Remove one bolt from the flywheel.
(2) Screw a guide bolt into the threaded hole of the bolt that has been removed.
(3) Remove remaining bolts from the flywheel.
(4) Remove the lock washer.
(5) Hold the flywheel firmly with both hands, and by moving it back and forth, pull it out straight.



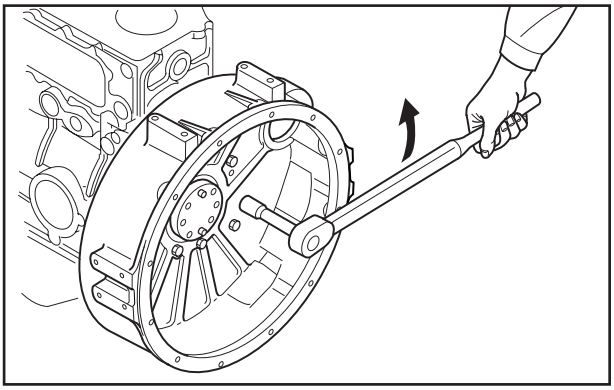
Removing flywheel

2.2 Removing flywheel housing

CAUTION

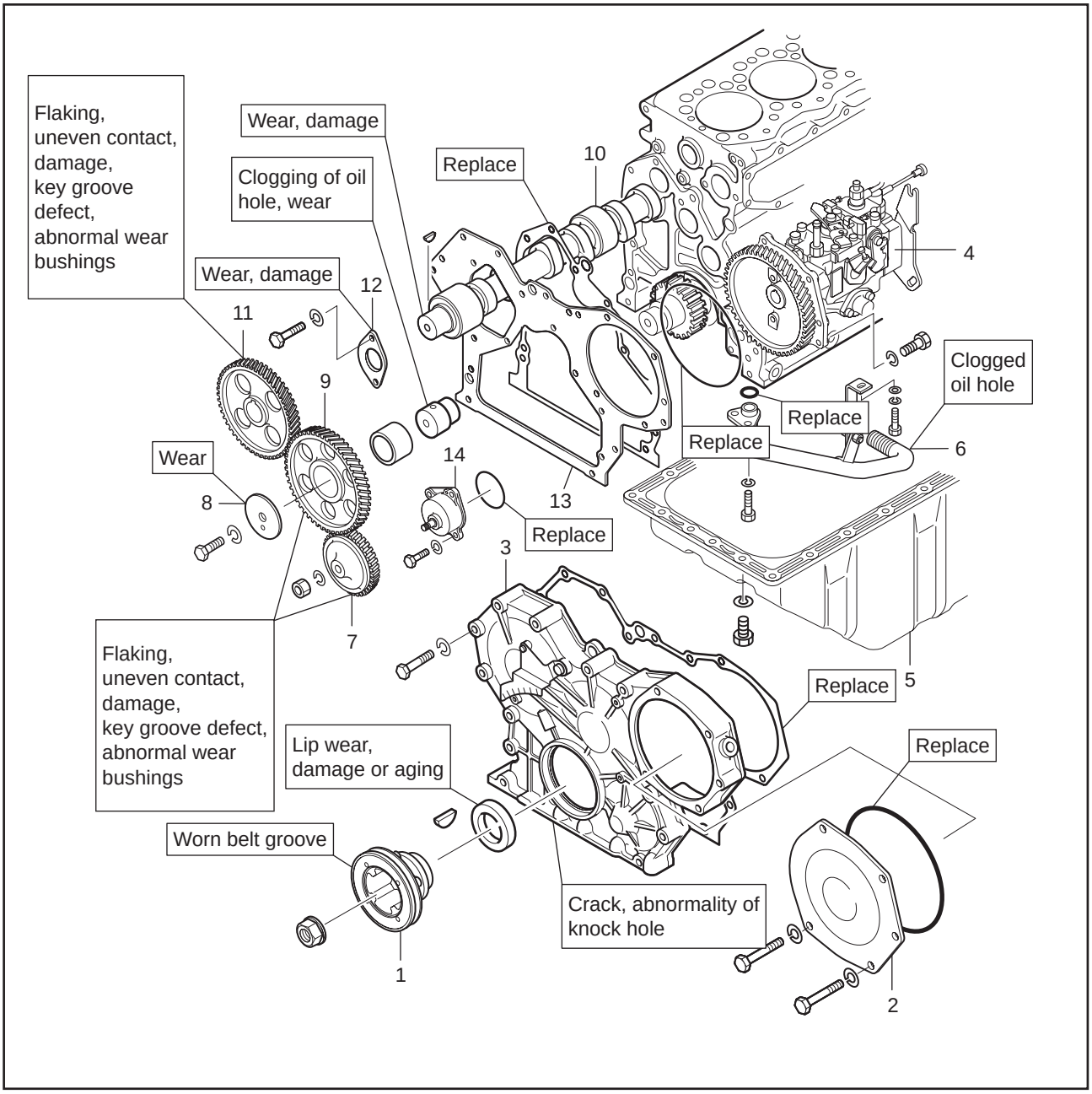
Be careful not to damage the oil seal.

(1) Remove bolts from the flywheel housing.
(2) Screw a guide bolt into the threaded hole of the bolt that has been removed.
(3) Remove the flywheel housing.



Removing flywheel housing

3. Disassembling and inspecting gear case, timing gear and camshaft



Disassembling and inspecting gear case, timing gear and camshaft

Disassembling sequence

1 Crankshaft pulley
2 Cover
3 Timing gear case
4 Fuel injection pump
5 Oil pan
6 Oil strainer
7 Oil pump gear
8 Thrust plate
9 Idler gear
10 Camshaft
11 Camshaft gear
12 Thrust plate
13 Front plate
14 Oil pump

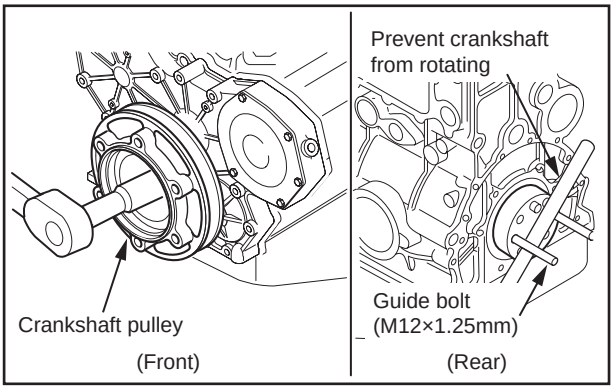
3.1 Removing crankshaft pulley

⚠ CAUTION

The bar that stops 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.

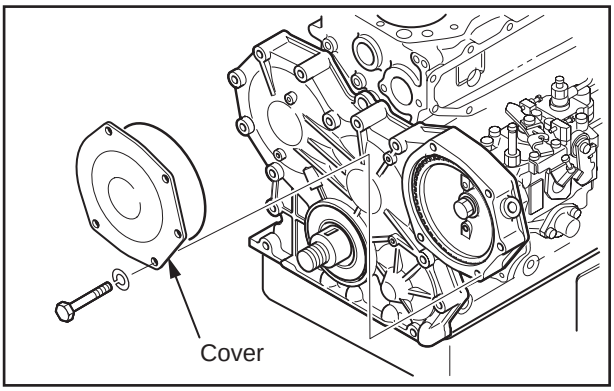
(2) Remove the crankshaft pulley.



Removing crankshaft pulley

3.2 Removing cover

Unscrew the cover mounting bolts, and dismount the cover.



Removing cover

3.3 Removing timing gear case

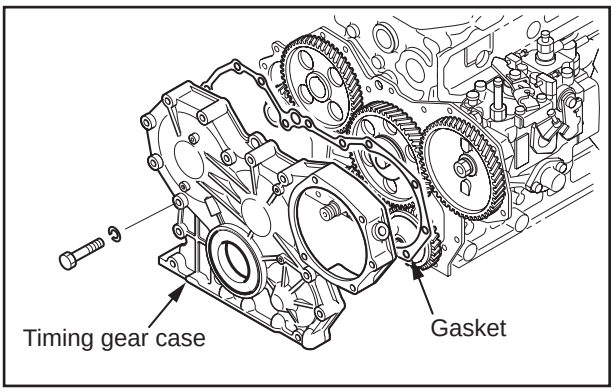
CAUTION

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.



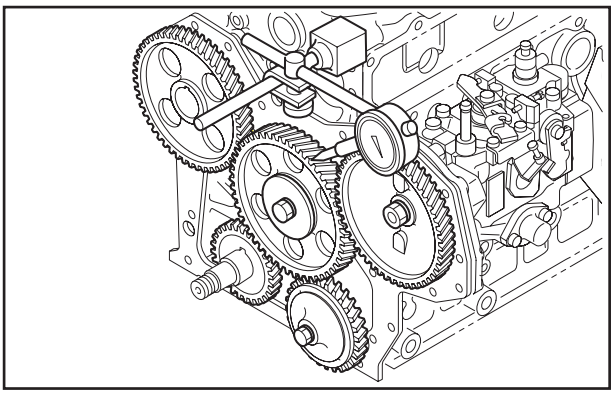
Removing timing gear case

3.4 Measuring timing gear backlash

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

Item	Standard	Limit
Timing gear backlash	0.05 to 0.15 mm [0.0020 to 0.0059 in.]	0.25 mm [0.0098 in.]

Note: With the injection pump gear attached to the pump, install the injection pump gear to the front plate.



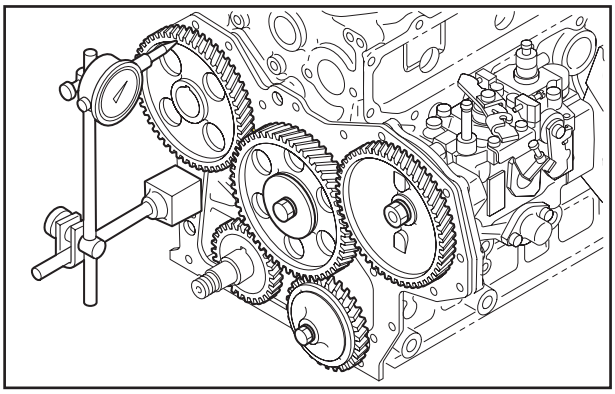
Measuring backlash timing gear

3.5 Measuring idler gear and camshaft gear end play

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

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

Item		Standard	Limit
End play	Idler gear	0.05 to 0.20 mm [0.0020 to 0.0079 in.]	0.35 mm [0.0138 in.]
	Camshaft	0.10 to 0.25 mm [0.0039 to 0.0098 in.]	0.30 mm [0.0118 in.]

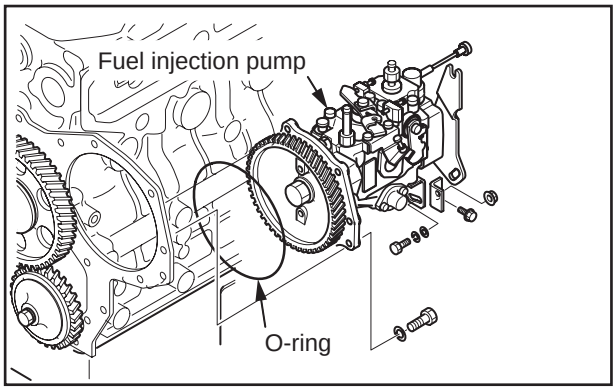


Measuring idler gear and camshaft gear end play

3.6 Removing fuel injection pump

(1) Remove the pump bracket mounting bolts.

(2) Unscrew the mounting bolts of fuel injection pump, and dismount the fuel injection pump.



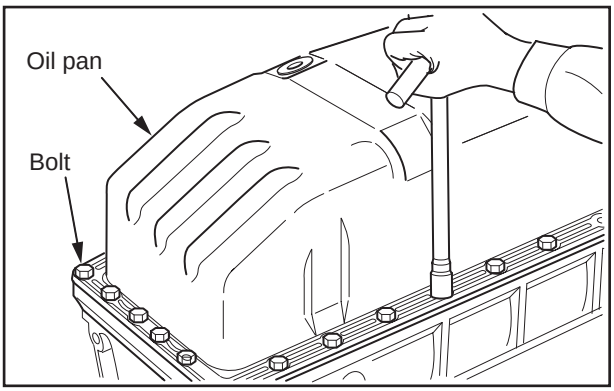
Removing fuel injection pump

3.7 Removing oil pan

CAUTION

Do not insert a chisel or screwdriver between the oil pan and crankcase to remove the oil pan, as it could deform the oil pan flange.

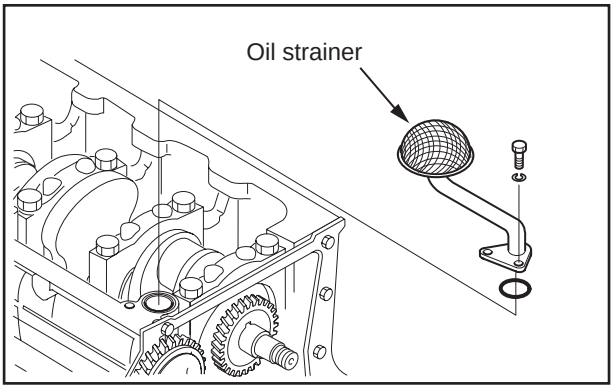
(1) Turn the engine around.
(2) Remove bolts from the oil pan.
(3) To remove oil pan, tap bottom corners of the oil pan with a plastic hammer.



Removing oil pan

3.8 Removing oil strainer

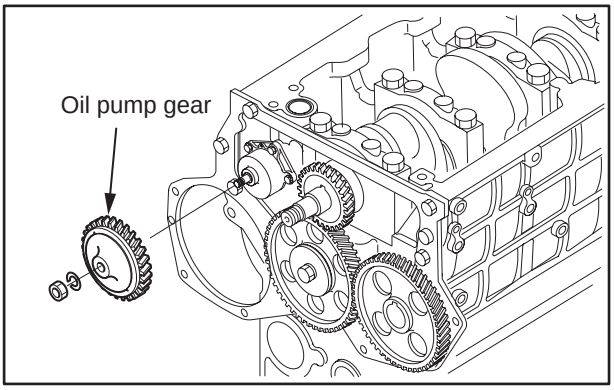
(1) Remove the oil strainer mounting bolts.
(2) Remove the oil strainer from the crankcase.



Removing oil strainer

3.9 Removing oil pump gear

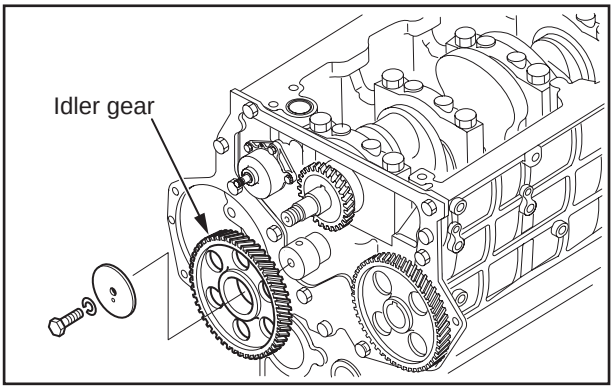
(1) Remove the oil pump gear tightening nuts.
(2) Remove the oil pump gear.



Removing oil pump gear

3.10 Removing idler gear

(1) Remove the thrust plate bolt.
(2) Remove the idler gear while turning the gear.



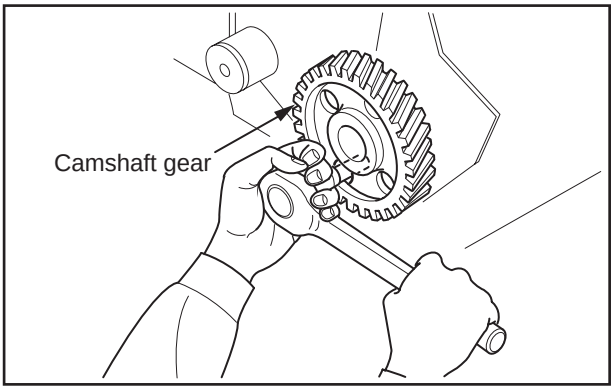
Removing idler gear

3.11 Removing camshaft

CAUTION

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

(1) Reverse the crankcase.
(2) Remove the thrust plate bolt.
(3) Remove the camshaft from the crankcase.
(4) Remove the tappet.

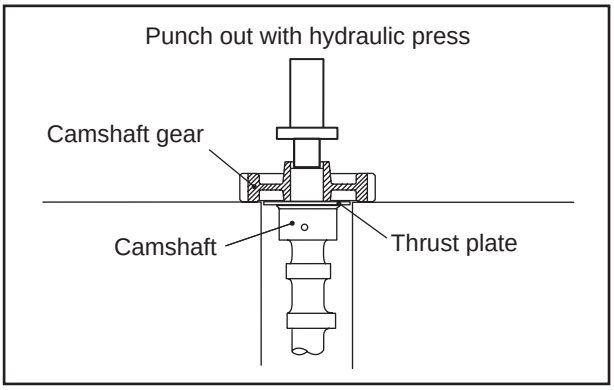


Removing camshaft

3.12 Separating camshaft gear

Using hydraulic press, remove the camshaft gear and thrust plate from the camshaft.

Note: Do not remove the camshaft gear from the camshaft unless the camshaft gear or the thrust plate is defective.



Separating gear from camshaft

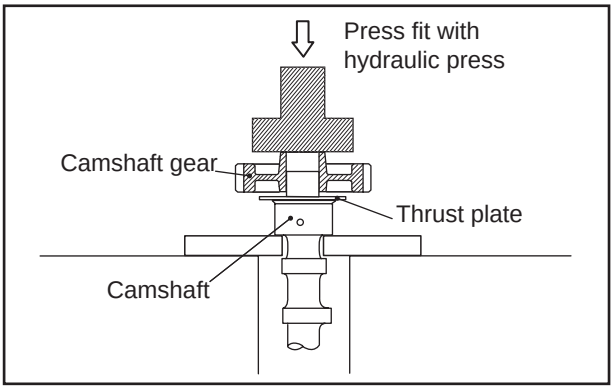
3.13 Installing camshaft gear and thrust plate

(1) Install the woodruff key and the thrust plate on the crankshaft.

Note: Be sure to install the thrust plate before installing the camshaft gear.

(2) Heat the camshaft gear with a gear heater to a temperature of about 150°C [302°F].

(3) Press fit the camshaft gear with press.



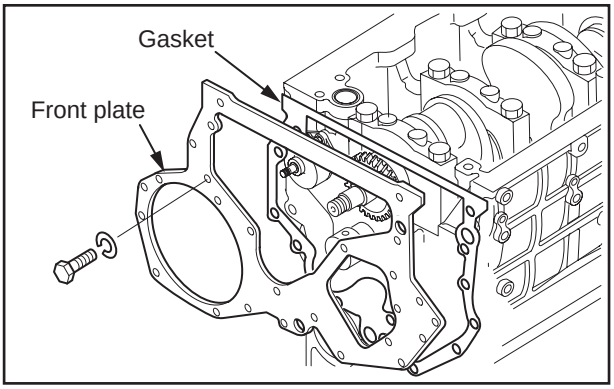
Installing camshaft gear and thrust plate

3.14 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.

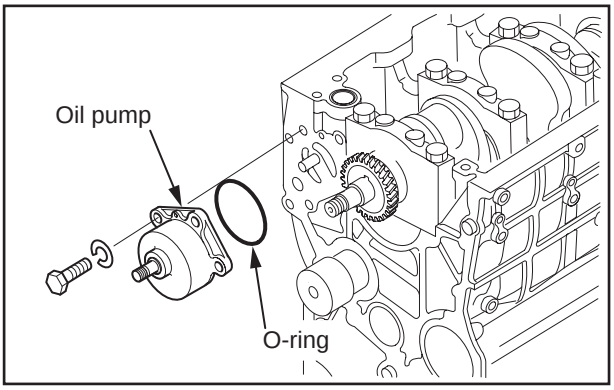


Removing front plate

3.15 Removing oil pump

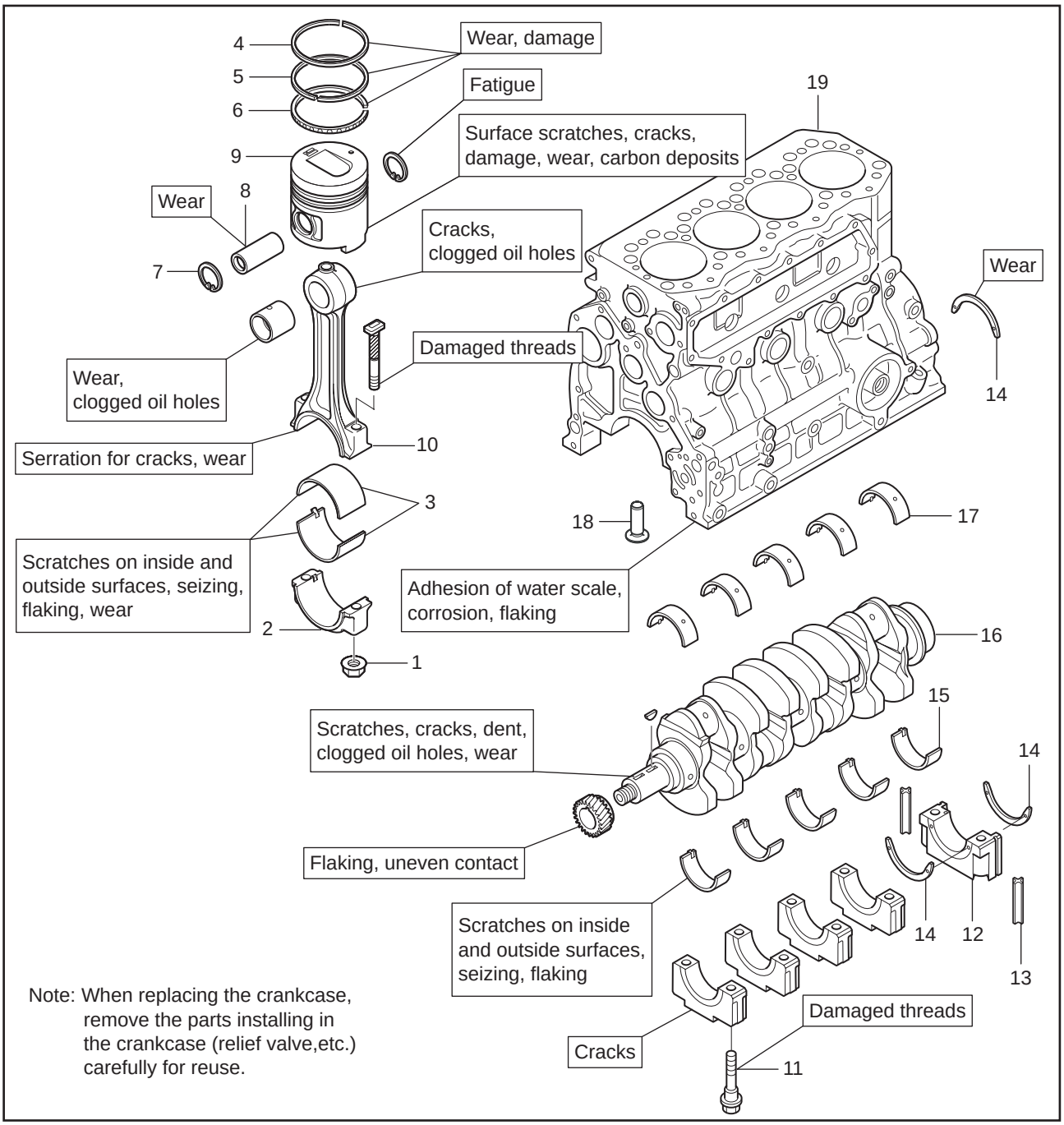
(1) Remove the oil pump mounting bolts.

(2) Remove the oil pump.



Removing oil pump

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



Disassembling and inspecting piston, connecting rod, crankshaft and crankcase

Disassembling sequence

1 Nut
2 Connecting rod cap
3 Connecting rod bearing
4 No.1 compression ring
5 No.2 compression ring
6 Oil ring
7 Snap ring
8 Piston pin
9 Piston
10 Connecting rod
11 Bearing cap bolt
12 Main bearing cap
13 Side seal
14 Thrust plate
15 Main bearing (lower)
16 Crankshaft
17 Main bearing (upper)
18 Tappet
19 Crankcase

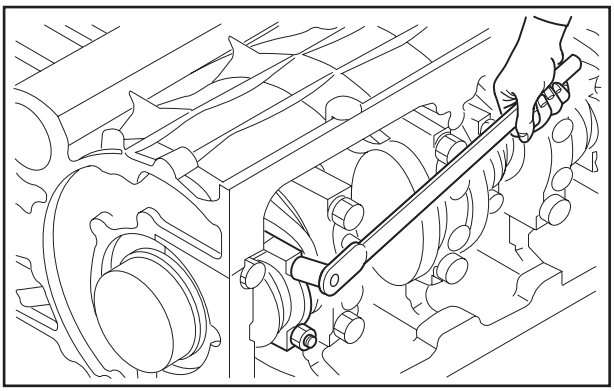
4.1 Removing connecting rod cap

(1) Lay the engine by its side.

(2) Mark the cylinder number on the connecting rod and connecting rod cap so that their combination is not changed when reassembling.

(3) Remove the connecting rod caps.

Note: Mark the cylinder No. and upper/lower on connecting rod bearings to ensure correct reassembling.



Removing connecting rod cap

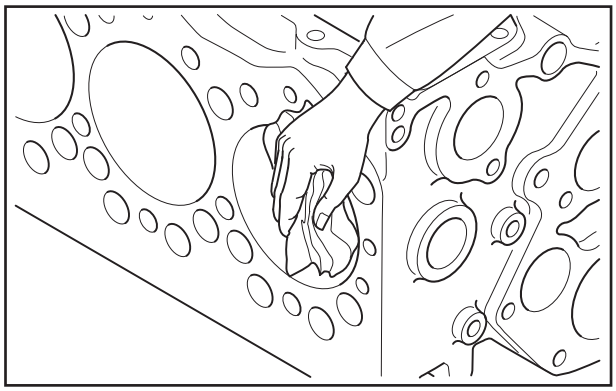
4.2 Removing carbon deposits from the upper part of cylinder

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.

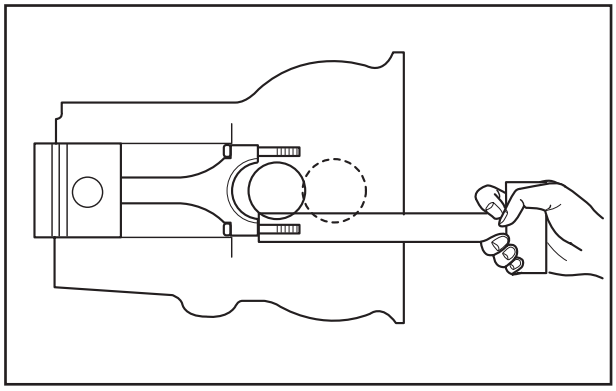


Removing carbon deposits from the upper part of cylinder

4.3 Pulling out piston

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

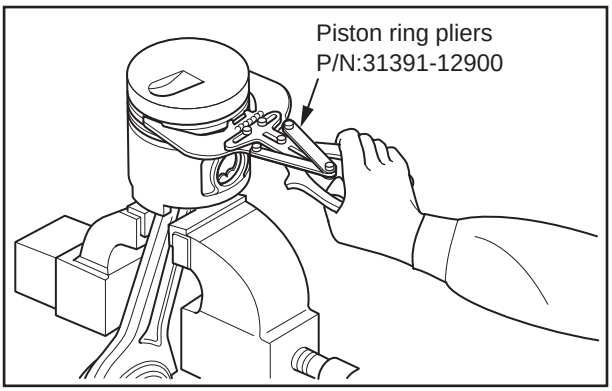
(2) Using a piece of wood such a hammer handle, push the mating surface of the connecting rod cap, and pull the piston and connecting rod upward from the cylinder.



Removing piston

4.4 Removing piston ring

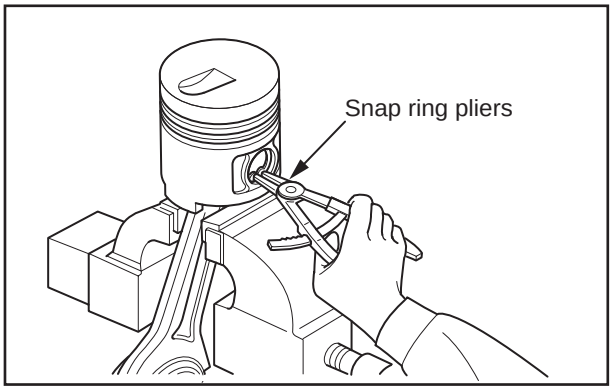
Remove the piston rings using piston ring pliers.



Removing piston ring

4.5 Removing piston pin and piston

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



Removing piston pin

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

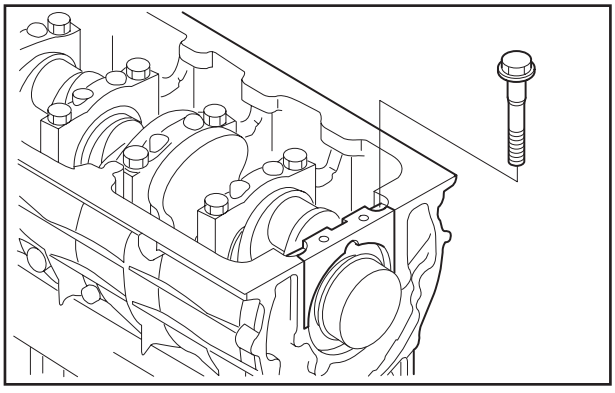
Note: (a) Do not tap the piston pin directly with a mallet.
(b) If the piston is stubborn, heat the piston with a piston heater or in hot water.

4.6 Removing main bearing cap

(1) Unscrew the main bearing cap bolts.

(2) Remove the main bearing cap.

Note: (a) Be careful not to damage the main bearings.
(b) Mark the bearings for their cylinder numbers.



Removing main bearing cap

4.7 Removing crankshaft

CAUTION

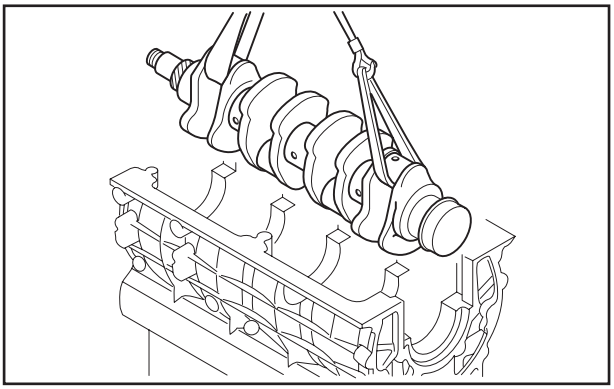
Be careful not to damage bearings when removing the crankshaft.

(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

4.8 Removing tappet

Remove the tappets using a magnetic.

Note: Be sure to arrange the removed tappets for reassembling to the same tappet hole.

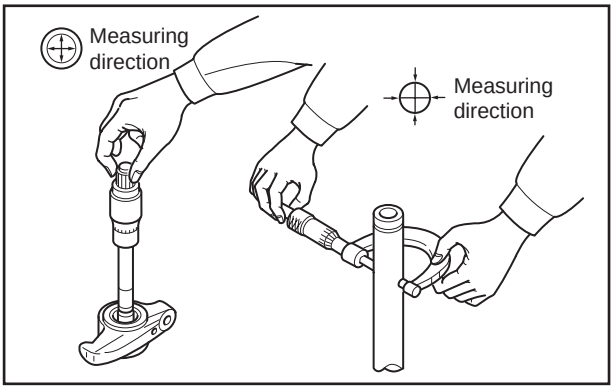
INSPECTION AND REPAIR OF BASIC ENGINE

1. Inspecting and repairing cylinder head and valve mechanism

1.1 Measuring clearance between rocker bushing and rocker shaft

Measure the rocker assembly inside diameter and the rocker shaft diameter. If the clearance exceeds the limit, replace either rocker assembly or rocker shaft with a new one.

Item	Nominal	Standard	Limit
Rocker bushing inside diameter	ø 19 mm [0.75 in.]	19.010 to 19.030 mm [0.7484 to 0.7492 in.]	-
Rocker shaft outside diameter	ø 19 mm [0.75 in.]	18.980 to 19.000 mm [0.7472 to 0.7480 in.]	-
Clearance between rocker bushing and shaft	-	0.010 to 0.050 mm [0.0004 to 0.0020 in.]	0.070 mm [0.0028 in.]

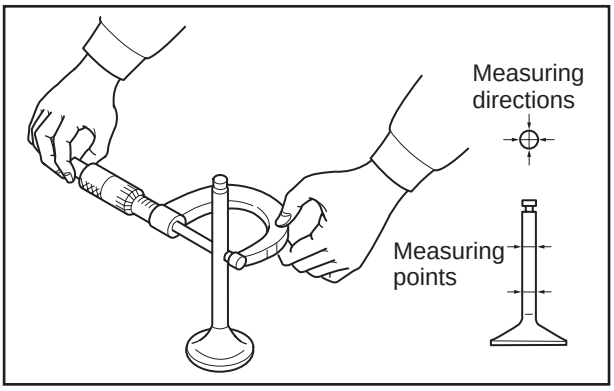


Measuring clearance between rocker bushing and rocker shaft

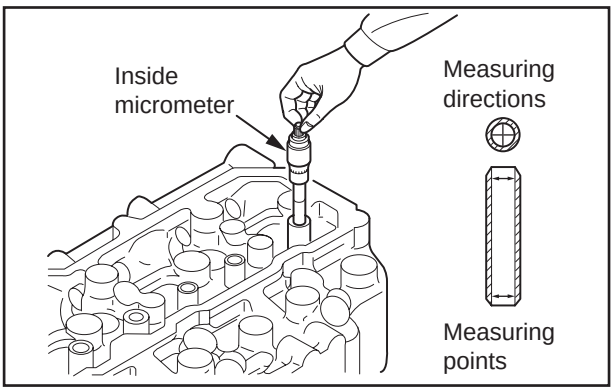
1.2 Measuring valve stem outside diameter and valve guide inside diameter

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.]	7.900 mm [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	-	0.065 to 0.095 mm [0.0026 to 0.0037 in.]	0.150 mm [0.0059 in.]
	Exhaust	-	0.080 to 0.115 mm [0.0031 to 0.0045 in.]	0.200 mm [0.0079 in.]
Valve guide mounting dimension		14 mm [0.55 in.]	13.9 to 14.1 mm [0.547 to 0.555 in.]	-



Measuring valve stem outside diameter



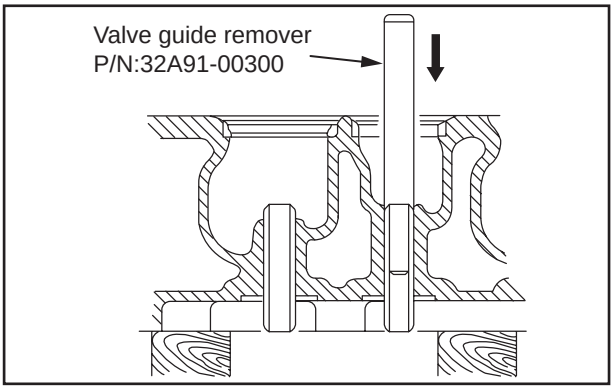
Measuring valve guide inside diameter

1.3 Replacing valve guide

CAUTION

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

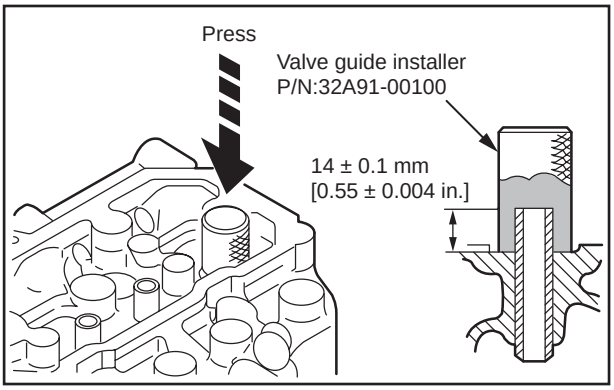
(1) To remove valve guides, use a valve guide remover.



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.



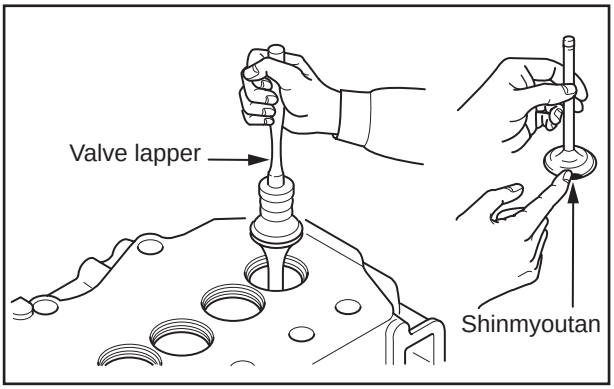
Press fitting valve guide

1.4 Inspecting valve face

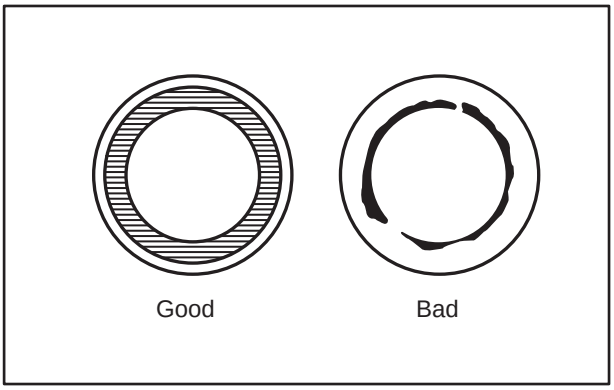
Apply a thin coat of Shinmyoutan or equivalent lead-free coloring paste on the valve face, and strike the valve face against the valve seat using a valve lapper to check for contact condition. If the contact is not even, or any defects are found, or if the limit is exceeded, reface or replace the valve.

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.

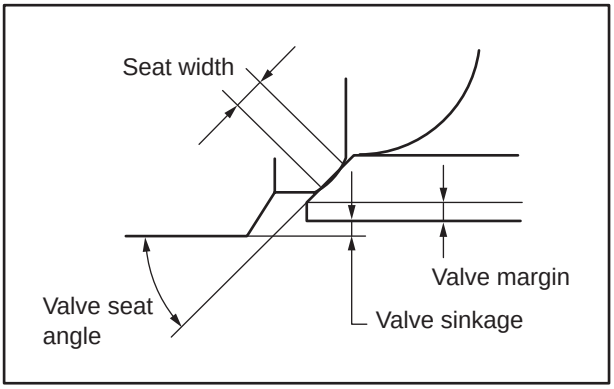
Item			Nominal	Standard	Limit
Valve seat	Valve seat angle		30°	-	-
	Valve sinkage	Inlet	0.4 mm [0.016 in.]	0.3 to 0.5 mm [0.012 to 0.020 in.]	1.0 mm [0.039 in.]
		Exhaust	0.5 mm [0.020 in.]	0.4 to 0.6 mm [0.016 to 0.024 in.]	1.0 mm [0.039 in.]
	Seat width		1.4 mm [0.055 in.]	1.26 to 1.54 mm [0.0496 to 0.0606 in.]	1.8 mm [0.071 in.]
Valve margin			-	2.13 mm [0.0839 in.]	Refacing permissible up to 1.83 mm [0.0720 in.]



Checking valve face



Valve-to-valve seat contact

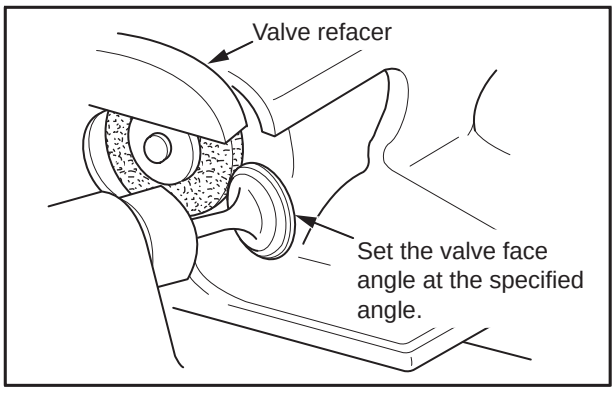


Measuring positions of valve seat and valve

1.5 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

1.6 Refacing valve seat

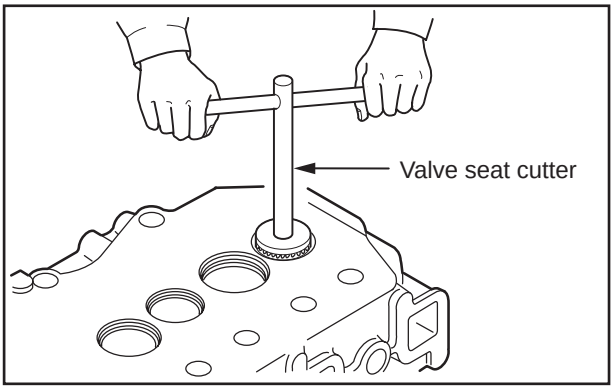
(1) Use the valve seat cutter or valve seat grinder to reface the valve seat. After refacing, sand the valve seat lightly using 400 grit sandpaper, inserting it between the cutter and valve seat.

(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

1.7 Replacing valve seat

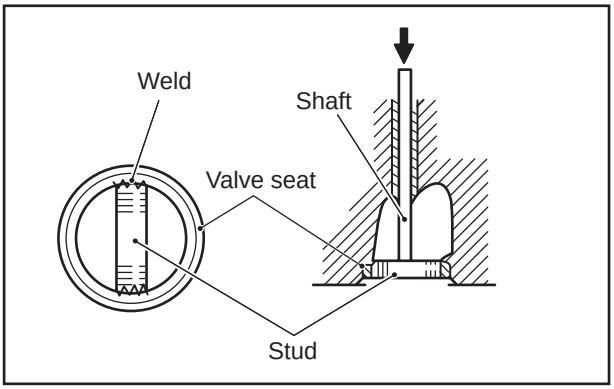
(1) To remove the valve seat, weld a stud to the valve seat as illustrated. Then, insert a rod into the valve guide hole from the top of the cylinder head, and press out the valve seat with the rod.

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

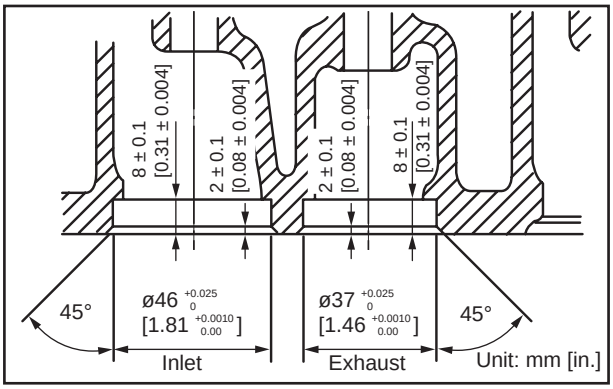
(2) Before inserting a new valve seat, measure the cylinder head bore diameter and valve seat outside diameter to make sure the interference meets the specified value.

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

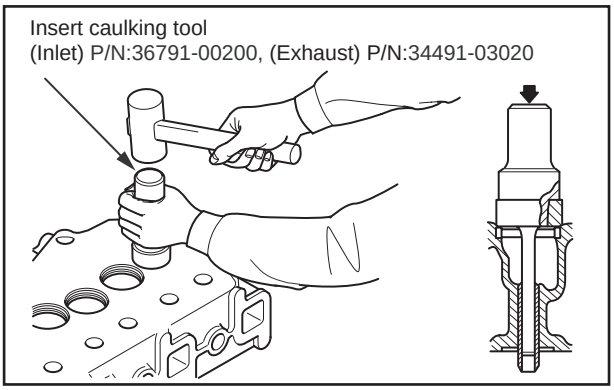
(4) Fit the cold valve seat into the cylinder head using a insert caulking tool.



Replacing valve seat



Valve seat fitting bore



Driving in valve seat

1.8 Lapping valve and valve seat

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

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

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

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

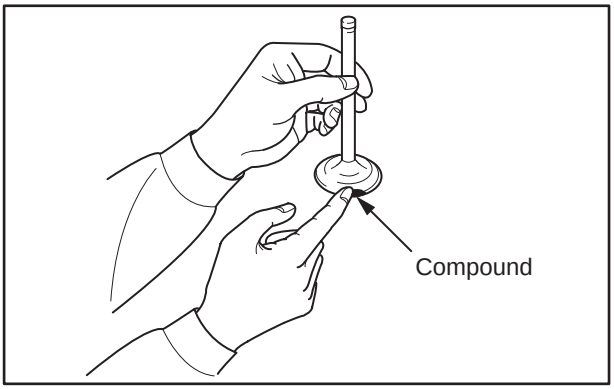
(c) Use medium-grain compound (120 to 150 mesh) for initial lapping, then use fine-grain compound (200 mesh or finer) for finishing.

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

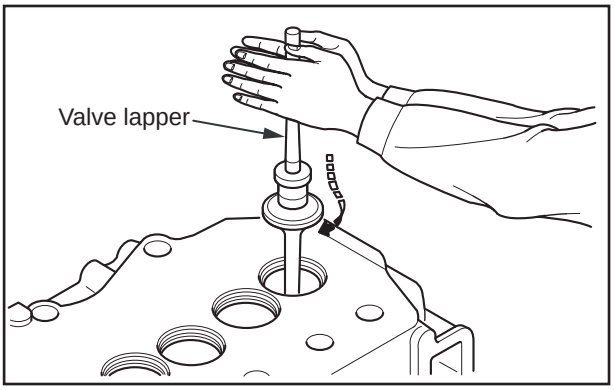
(3) Wash off the compound using diesel fuel.

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

(5) Check valve-to-seat contact.



Coating valve with lapping

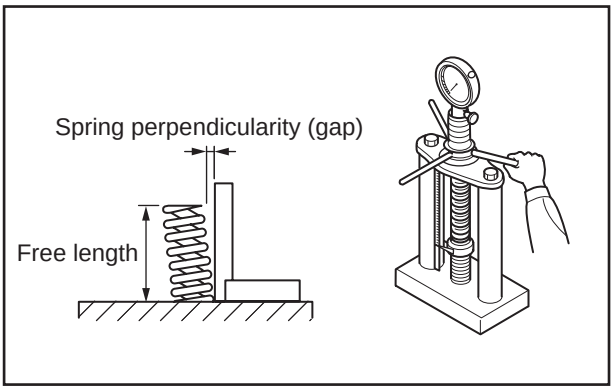


Lapping valve and valve seat

1.9 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 = 1.3 mm [0.051 in.] or less Lf = 48.85 mm [1.9232 in.]	Δ = 1.5 mm [0.059 in.] at the end
Set length/set load	43 mm [1.69 in.]/ 176 to 196 N {18 to 20 kgf} [39 to 44 lbf]	43 mm [1.69 in.]/ 147 N {15 kgf} [33 lbf]



Squareness and free length of spring

1.10 Measuring distortion of the bottom surface of the cylinder head

CAUTION

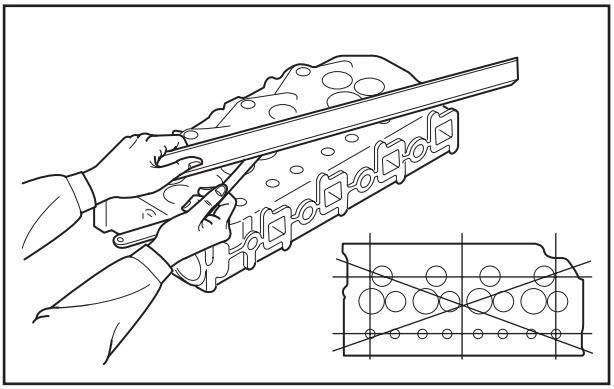
Refacing of cylinder head should be kept to an absolute minimum.

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

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

Item	Standard	Limit
Distortion of bottom face	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).

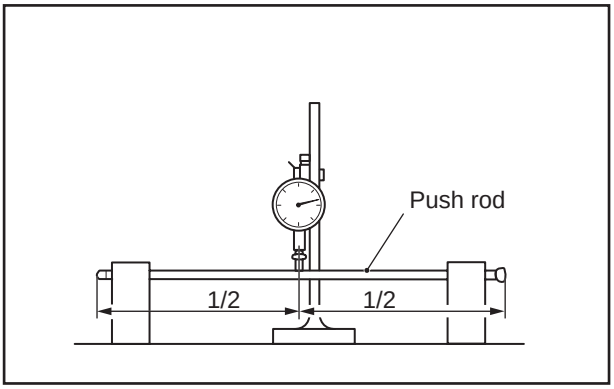


Measuring distortion of the bottom surface of the cylinder head

1.11 Measuring pushrod runout

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

Item	Standard	Limit	Remark
Pushrod runout	0.6 mm [0.024 in.] or less	0.6 mm [0.024 in.]	Total indicated reading (TIR)

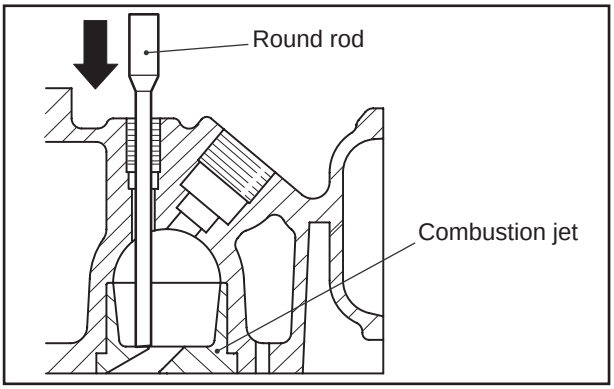


Measuring pushrod runout

1.12 Removing combustion jet

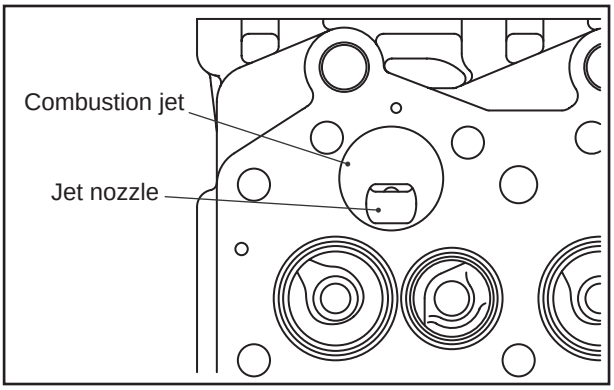
Replace the combustion jet only when it has defect as crack.

(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

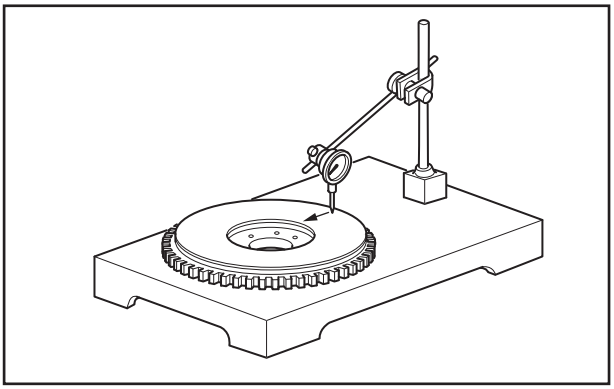
2. Inspecting and repairing flywheel

2.1 Measuring flatness of flywheel

Place the flywheel on a surface plate and move a dial gauge on the friction surface of the flywheel to measure the flatness.

Grind the friction surface of the flywheel if the limit is exceeded.

Item	Standard	Limit
Flywheel flatness	0.15 mm [0.0059 in.] or less	0.50 mm [0.0197 in.]

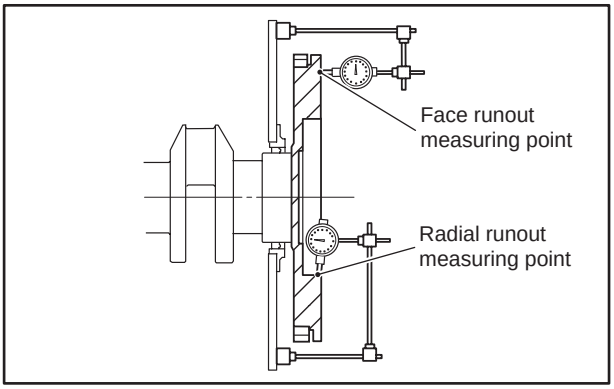


Measuring flatness of flywheel

2.2 Measuring flywheel face and radial runouts

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

Item	Standard	Limit
Flywheel face runout and radial runout	0.15 mm [0.0059 in.] or less	0.50 mm [0.0197 in.]



Measuring flywheel face and radial runout

2.3 Inspecting ring gear

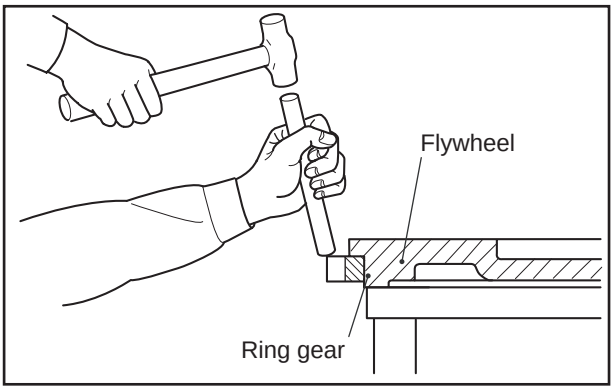
Inspect the ring gear for a missing tooth or worn teeth, and if defects are found, replace the ring gear.

2.4 Replacing ring gear

2.4.1 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

2.4.2 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.

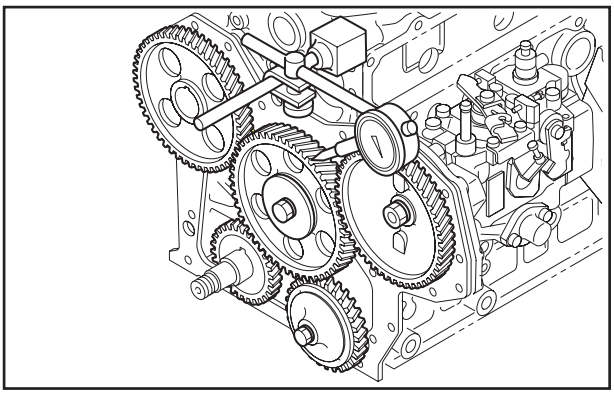
3. Inspecting and repairing timing gear and camshaft

3.1 Measuring timing gear backlash

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

Item	Standard	Limit
Timing gear backlash	0.05 to 0.15 mm [0.0020 to 0.0059 in.]	0.25 mm [0.0098 in.]

Note: With the injection pump gear attached to the pump, install the injection pump gear to the front plate.



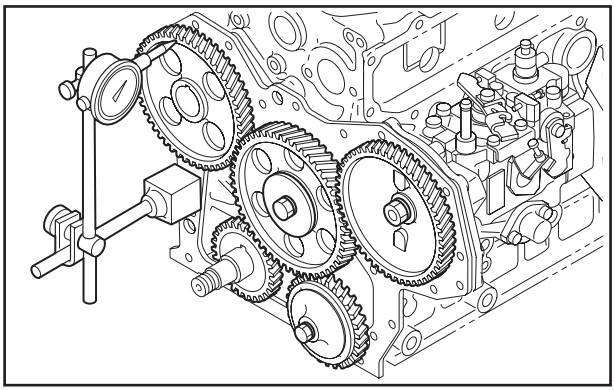
Measuring timing gear backlash

3.2 Measuring idler gear and camshaft gear end play

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

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

Item		Standard	Limit
End play	Idler gear	0.05 to 0.20 mm [0.0020 to 0.0079 in.]	0.35 mm [0.0138 in.]
	Camshaft	0.10 to 0.25 mm [0.0039 to 0.0098 in.]	0.30 mm [0.0118 in.]

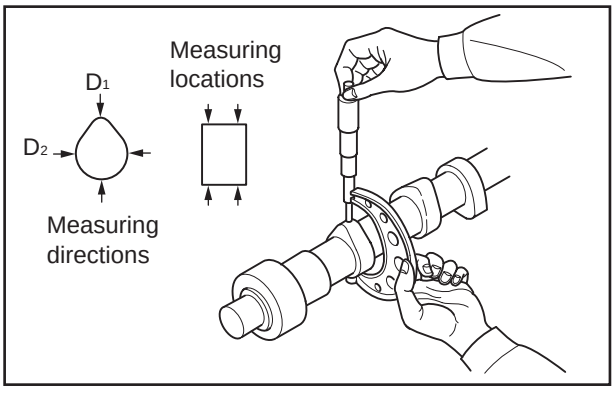


Measuring idler gear and camshaft gear end play

3.3 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	Swirl chamber	Inlet	6.684 mm [0.2631 in.]	6.384 to 6.784 mm [0.2513 to 0.2671 in.]	6.184 mm [0.2435 in.]
		Exhaust	6.720 mm [0.2646 in.]	6.420 to 6.820 mm [0.2528 to 0.2685 in.]	6.220 mm [0.2449 in.]
	Direct injection	Inlet	6.682 mm [0.2631 in.]	6.382 to 6.782 mm [0.2513 to 0.2670 in.]	6.182 mm [0.2434 in.]
		Exhaust	6.722 mm [0.2646 in.]	6.422 to 6.822 mm [0.2528 to 0.2686 in.]	6.222 mm [0.2450 in.]



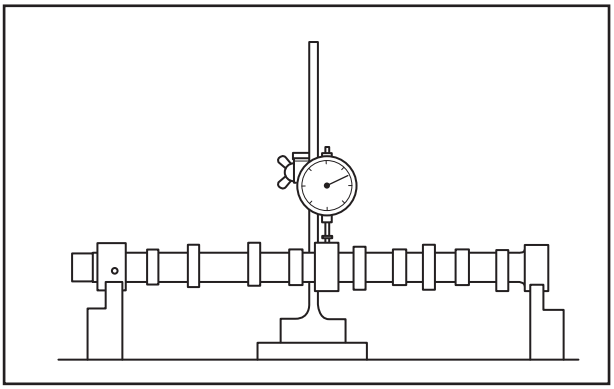
Measuring cam lift

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

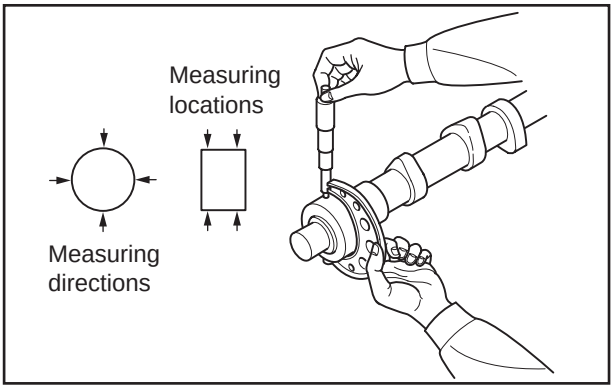


Measuring camshaft runout

3.5 Measuring camshaft journal outside diameter

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

Item		Standard	Limit
Camshaft journal outside diameter	No.1, 2	53.94 to 53.96 mm [2.1236 to 2.1244 in.]	53.90 mm [2.1220 in.]
	No.3	52.94 to 52.96 mm [2.0842 to 2.0850 in.]	52.90 mm [2.0827 in.]



Measuring camshaft journal outside diameter

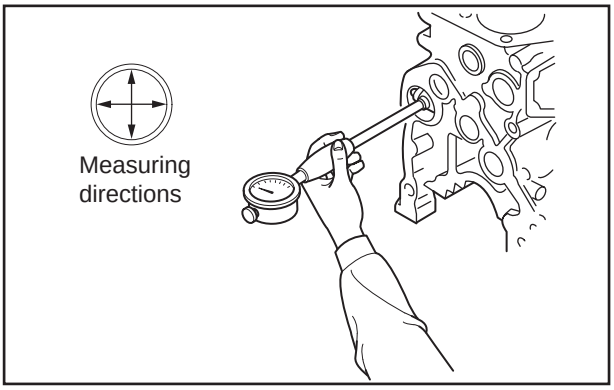
3.6 Measuring camshaft hole (bushing) inside diameter

Measure the inside diameters of camshaft hole (camshaft bushing, if installed) using a cylinder gauge.

If the limit is exceeds, drive in the camshaft bushing.

If the camshaft bushing has already been installed, replace the camshaft bushing with a new one.

Item	Standard	Limit
Clearance between camshaft journal and camshaft hole	0.040 to 0.090 mm [0.0016 to 0.0035 in.]	0.15 mm [0.0059 in.]
Clearance between camshaft journal and camshaft bushing	0.07 to 0.11 mm [0.0028 to 0.0043 in.]	0.15 mm [0.0059 in.]



Measuring camshaft hole (bushing) inside diameter

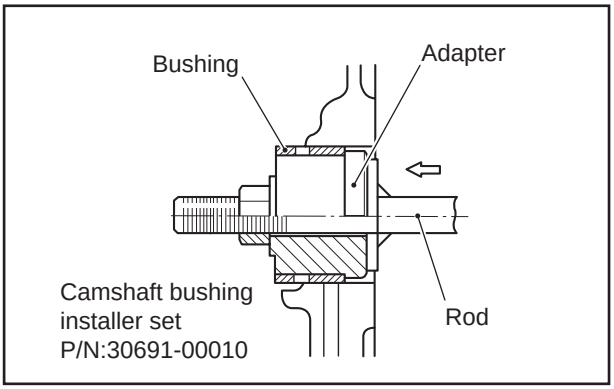
3.7 Replacing camshaft bushing

3.7.1 Removing camshaft bushing

Note: If the camshaft bushing is not installed, bore the camshaft hole to ø57H6($^{+0.019}_{0}$) $\overset{12.5S}{\nabla\nabla}$ and drive in the camshaft bushing when the clearance between camshaft journal and camshaft bushing exceeds the limit.

(1) Install a camshaft bushing installer set to the camshaft bushing.

(2) Remove the camshaft bushing by tapping the end of the rod of camshaft bushing installer set.

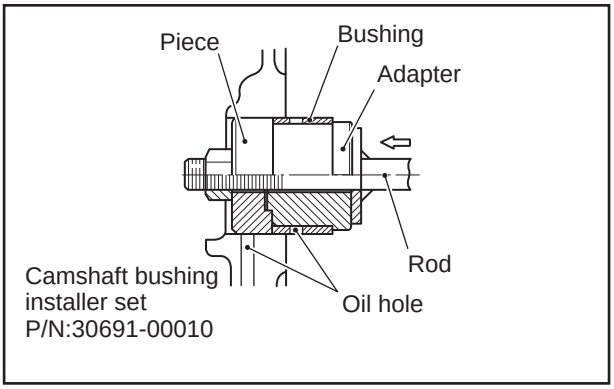


Removing camshaft bushing

3.7.2 Installing camshaft bushing

(1) Install the camshaft bushing to a camshaft bushing installer set.

(2) When driving in a bushing, tap the end of rod of camshaft bushing installer set so that the oil hole in the bushing aligns with the oil hole to the oil gallery.

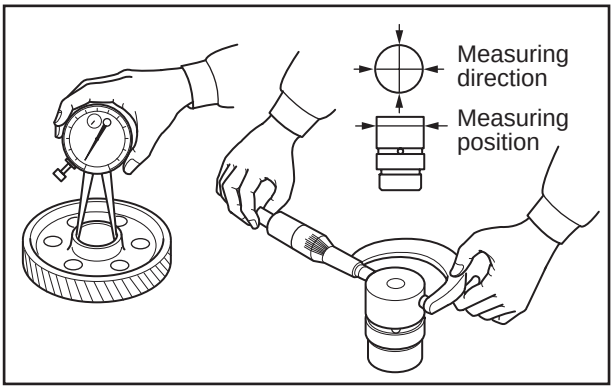


Installing camshaft bushing

3.8 Measuring idler bushing inside diameter and idler shaft outside diameter

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

Item	Standard	Limit
Clearance between idler bushing and idler shaft	0.009 to 0.050 mm [0.0004 to 0.0020 in.]	0.100 mm [0.0039 in.]



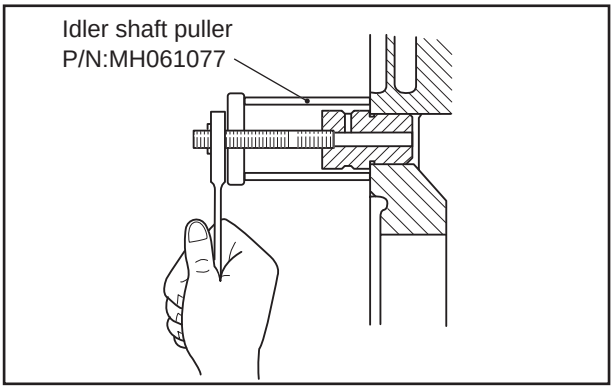
Measuring idler bushing inside diameter and idler shaft outside diameter

3.9 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.

Item	Nominal	Standard
Interference between shaft and crankcase hole	ø 35 mm [1.38 in.]	0.035T to 0.076T mm [0.0014 to 0.0030 in.]



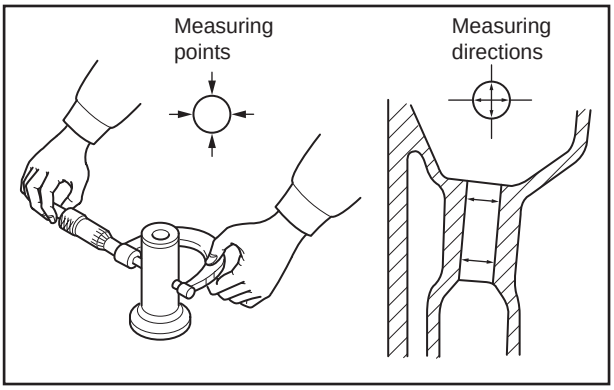
Replacing idler shaft

3.10 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	Standard	Limit
Tappet guide hole inside diameter	14.000 to 14.018 mm [0.5512 to 0.5519 in.]	14.100 mm [0.5551 in.]
Clearance between tappet and tappet guide hole	0.016 to 0.052 mm [0.0006 to 0.0020 in.]	0.08 mm [0.0031 in.]

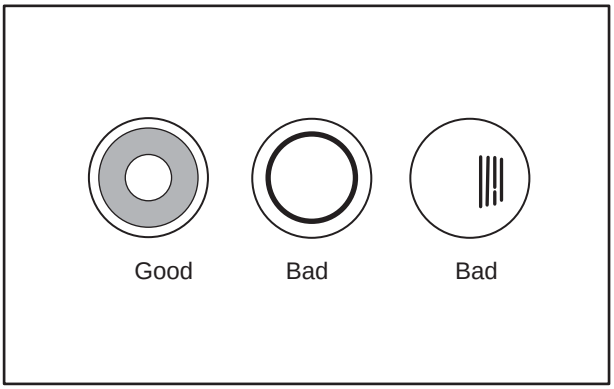


Measuring clearance between tappet and tappet guide hole

3.11 Inspecting tappet

3.11.1 Contact surface of camshaft

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

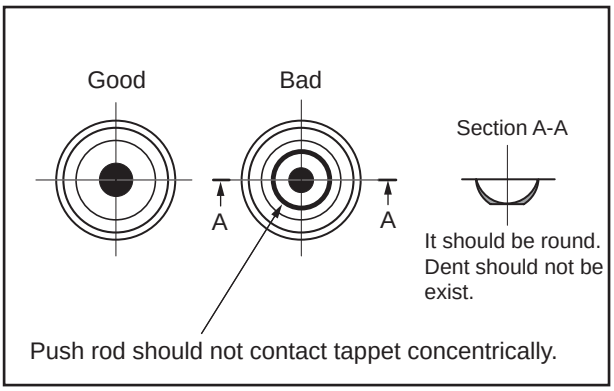


Contact surface of camshaft

3.11.2 Contact surface of pushrod

(1) Apply Shinmyoutan or equivalent lead-free coloring paste on the pushrod, and check the contacts.

(2) Check that the pushrod contacts the tappet concentrically. If it does, replace the tappet and pushrod with new one.



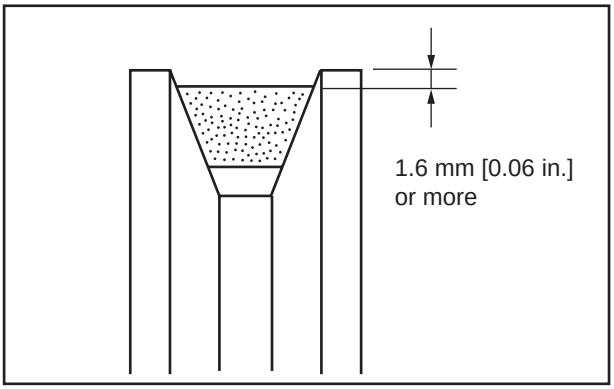
Contact surface of pushrod

3.12 Inspecting V-belt groove wear

Check the V-belt groove of the pulley for wear. Attach a new V-belt around the pulley, apply high tension and measure the sinkage of V-belt.

If the wear appears excessive, and the belt top surface sinks 1.6mm [0.06 in.] or more down from the top edge of groove, replace the pulley with a new one.

If the pulley has two or more grooves for belt, and the difference of the wear amount between grooves is significant, replace the pulley with a new one.



Inspecting V-belt groove wear

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

4.1 Measuring crankcase top surface distortion

CAUTION

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

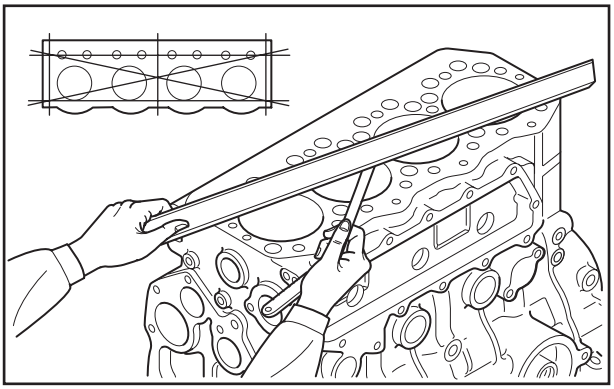
Excessive grinding of the cylinder head may result in defects such as defective combustion and stamping (contact between piston and valve).

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

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

Item	Standard	Limit
Flatness of 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 [0.0079 in.] in total (cylinder head bottom surface plus crankcase top surface).



Measuring crankcase top surface distortion

4.2 Measuring cylinder inside diameter

(1) Measure the inside diameter of the cylinder at three levels, i.e., upper (with much stepped wear), middle, and lower levels, in both directions parallel to and perpendicular to the crankshaft direction.

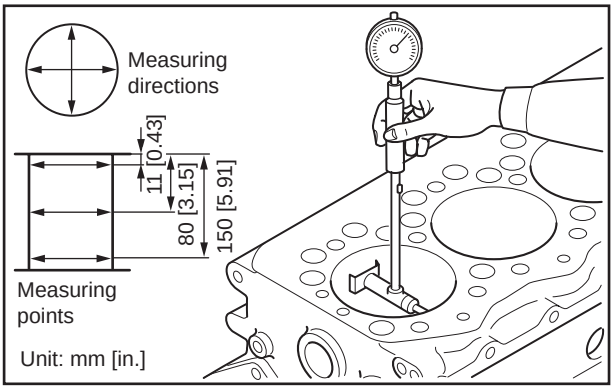
(2) If the measurement is between the repair limit and replacement limit, re-bore the cylinder to +0.25 mm [0.0098 in.] or +0.5 mm [0.0197 in.] oversize. Hone the re-bored cylinder to the accuracy of the standard.

(3) Use an oversize piston and piston rings to fit the re-bored cylinder.

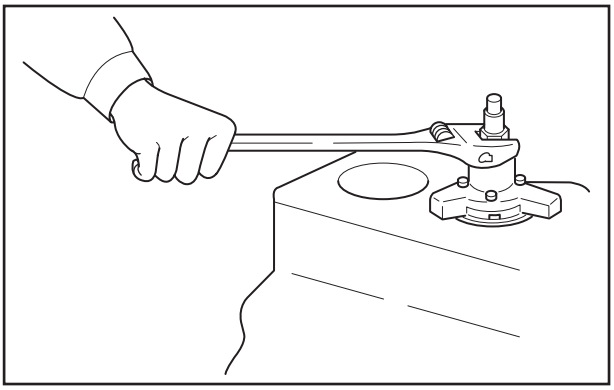
(4) If the cylinder is worn unevenly, select an oversize that ensures complete cylindericity when the cylinder is re-bored to the maximum. All cylinders must be re-bored to the same oversize if one cylinder is re-bored.

(5) If the cylinder has a slight wear and is reused after replacing only the piston rings, remove the steps in worn portion in the upper part of the cylinder using a ridge reamer. Hone it as necessary.

Item	Standard	Limit
Cylinder inside diameter	94.000 to 94.035 mm [3.7008 to 3.7022 in.]	Repair limit: 94.200 mm [3.7087 in.] Replace limit: 94.700 mm [3.7283 in.]
Circularity	0.01 mm [0.0004 in.] or less	-
Cylindricality	0.015 mm [0.0006 in.] or less	-



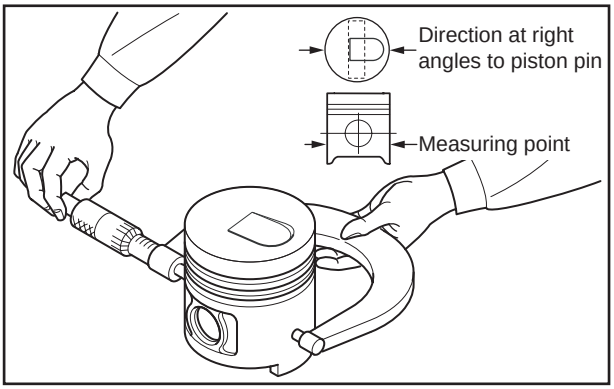
Measuring cylinder sleeve inside diameter



Refacing using a ridge reamer

4.3 Measuring piston outside diameter

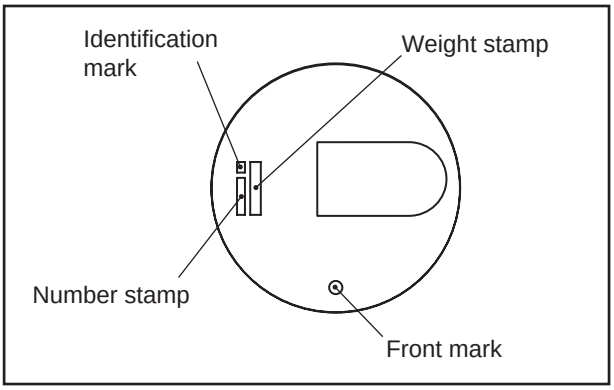
(1) Measure the piston outside diameter of the piston skirt at right angles to the piston pin. If it is less than the limit, replace the piston with a new piston. When replacing piston, be sure to select a piston so that the piston weight difference in one engine is kept within the permissible range.



Measuring piston outside diameter

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

Item		Nominal	Standard	Limit
Piston outside diameter (at piston skirt)	STD	ø 94 mm [3.70 in.]	93.955 to 93.985 mm [3.6990 to 3.7002 in.]	93.770 mm [3.6917 in.]
	0.25 mm [0.0098 in.] /OS		94.205 to 94.235 mm [3.7089 to 3.7100 in.]	94.020 mm [3.7016 in.]
	0.50 mm [0.0197 in.] /OS		94.455 to 94.485 mm [3.7187 to 3.7199 in.]	94.270 mm [3.7114 in.]
Weight difference in one engine			5 g [0.2 oz.] or less	-



Piston weight stamp location

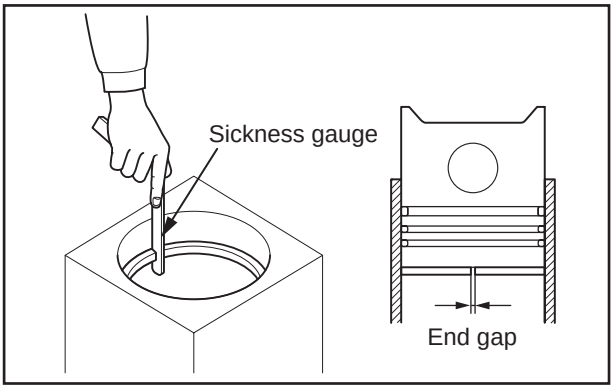
The piston weight is stamped on the top of piston head.

4.4 Measuring piston ring end gap

Place the piston ring in a gauge or a new sleeve to measure the ring end gap. If the limit is exceeded, replace all the rings as a set.

Note: Use a piston to push the piston ring squarely into the gauge or the sleeve.

Item		Standard	Limit
Closed gap of ring	No.1 compression ring	0.30 to 0.50 mm [0.0118 to 0.0197 in.]	1.50 mm [0.0591 in.]
	No.2 compression ring	0.50 to 0.70 mm [0.0197 to 0.0276 in.]	
	Oil ring	0.30 to 0.50 mm [0.0118 to 0.0197 in.]	



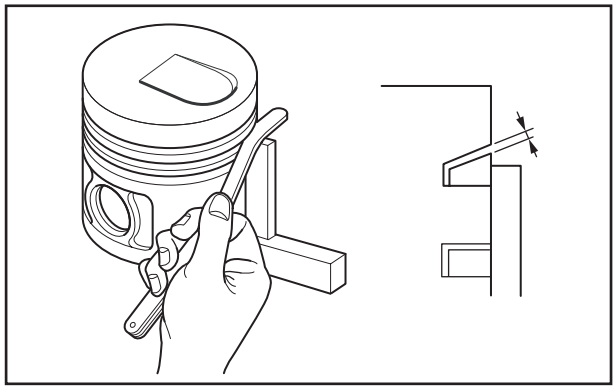
Measuring piston ring end gap

4.5 Measuring clearance between piston ring groove and piston ring

CAUTION

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

(1) Remove deposits such as carbon from each ring groove.
(2) Check each ring groove for wear or damage. If it is worn or damaged, replace the piston with a new one.
(3) Insert the piston ring into the piston ring groove. Apply a straight edge and insert thickness gauges to measure the clearance between ring and ring groove.
If the limit is exceeded, replace the piston ring with a new one.
(4) When the piston ring has been replaced, measure the clearance again, and if the limit is exceeded, then replace the piston with a new one.



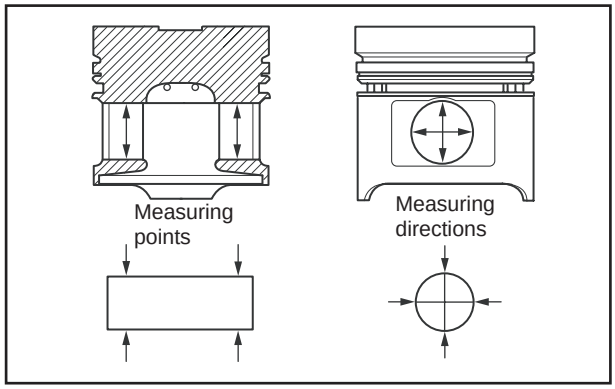
Measuring clearance between piston ring groove and piston ring

Item		Standard	Limit
Clearance between piston ring groove	No.1 compression ring	0.07 to 0.11 mm [0.0028 to 0.0043 in.]	0.200 mm [0.0079 in.]
	No.2 compression ring	0.045 to 0.085 mm [0.0018 to 0.0033 in.]	0.150 mm [0.0059 in.]
	Oil ring	0.020 to 0.060 mm [0.0008 to 0.0024 in.]	0.150 mm [0.0059 in.]

4.6 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 outside diameter	ø 30 mm [1.18 in.]	29.994 to 30.000 mm [1.1809 to 1.1811 in.]	-
Clearance between piston pin	-	0.000 to 0.016 mm [0.0000 to 0.0006 in.]	0.050 mm [0.0020 in.]



Measuring piston pin bore diameter and piston pin outside diameter

4.7 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 does not meet the standard, inspect the clearances between various parts involved.

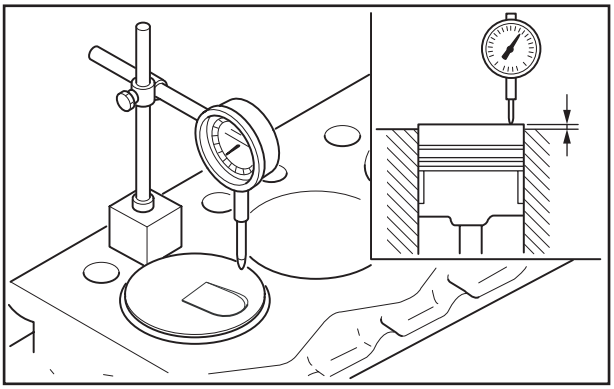
(1) Bring the piston to the top dead center.

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

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

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

Item		Standard
Piston protrusion	Swirl chamber	-0.25 to 0.15 mm [-0.0098 to 0.0059 in.]
	Direct injection	0.05 to 0.45 mm [-0.0020 to 0.0177 in.]
Compressed thickness of cylinder head gasket	Swirl chamber	1.15 to 1.25 mm [0.0453 to 0.0492 in.]
	Direct injection	



Measuring piston protrusion

4.8 Measuring clearance between connecting rod bearing and crankpin

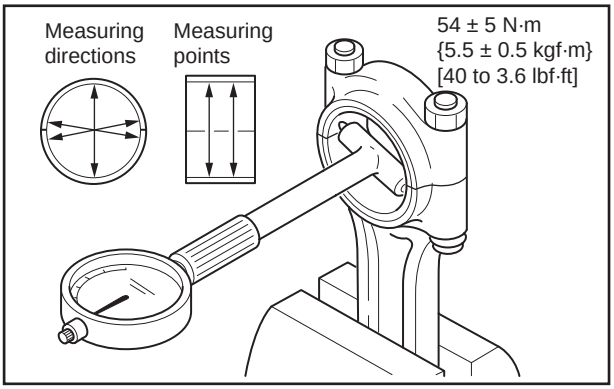
CAUTION

When grinding crankpins, be sure to grind all the pins to the same size.

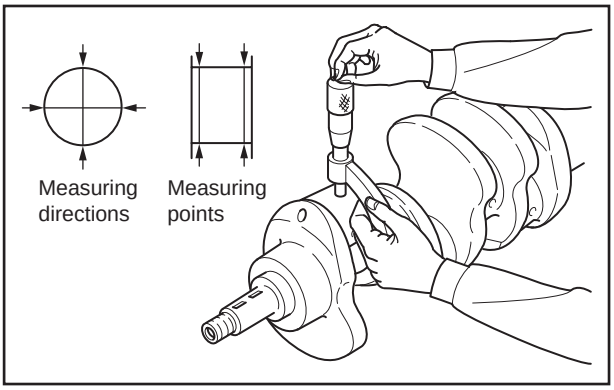
Finish the fillet radius to the specified dimension.

(1) Reassemble the bearing into the big end of the connecting rod.
(2) Tighten the connecting rod cap bolts to the specified torque.
(3) Measure the inside diameter of the connecting rod bearing.
(4) Measure the outside diameter of the crankpin.
(5) Calculate the clearance from the difference between the inside diameter of the connecting rod bearing and outside diameter of the crankpin.
(6) Replace the connecting rod bearing if the clearance exceeds the limit.
(7) Measure the clearance between the connecting rod bearing and the crankpin again. Use the undersize bearing if the limit is exceeded.
(8) If an undersize bearing is used, grind the crankpin to the specified undersize.

Item	Nominal	Standard	Limit
Crankpin outside diameter	ø 58 mm [2.28 in.]	57.955 to 57.970 mm [2.2817 to 2.2823 in.]	57.800 mm [2.2756 in.]
Clearance between crankpin and connecting rod bearing (oil clearance)	-	0.030 to 0.090 mm [0.0012 to 0.0035 in.]	0.200 mm [0.0079 in.]



Measuring connecting rod bearing inside diameter

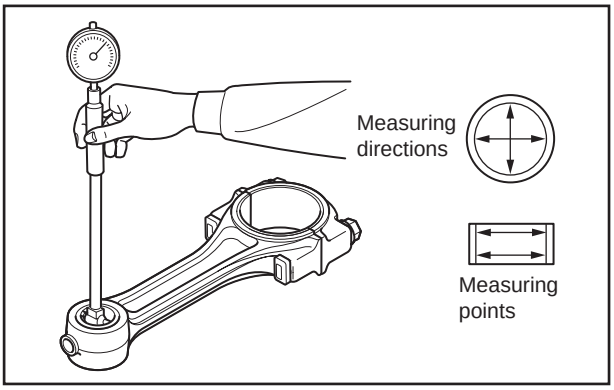


Measuring crankpin diameter

4.9 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 30 mm [1.18 in.]	30.020 to 30.045 mm [1.1819 to 1.1829 in.]	-
Clearance between connecting rod bushing	-	0.020 to 0.091 mm [0.0008 to 0.0036 in.]	0.120 mm [0.0047 in.]



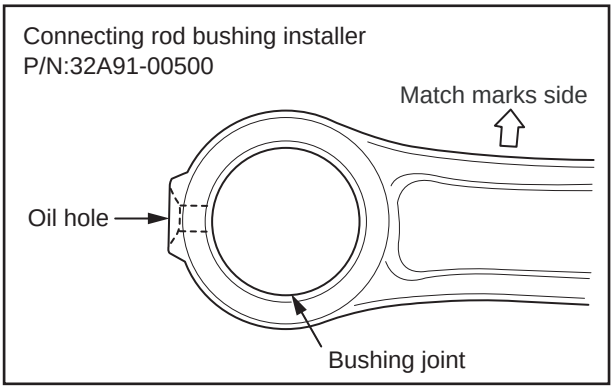
Measuring connecting rod bushing inside diameter

4.10 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

4.11 Inspecting connecting rod bend and twist

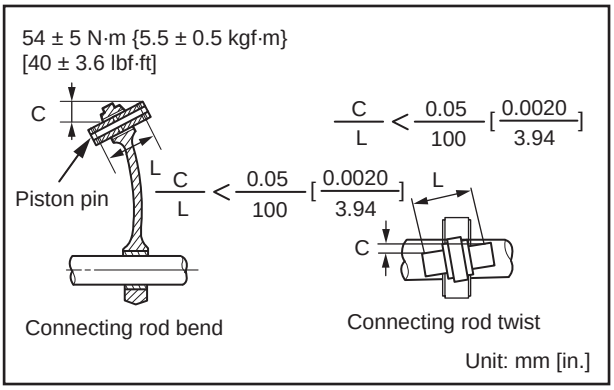
(1) Measure the dimensions of C and L in the illustration to check bend and twist of the connecting rod. Straighten the connecting rod with a press to meet the standard.
If the standard is exceeded after correction, replace the connecting rod with a new one.

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

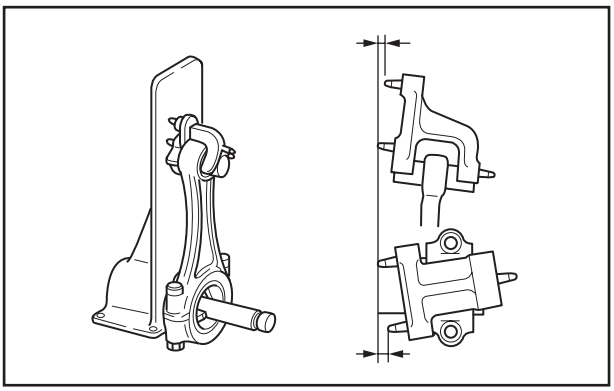
Note: Before checking bend, tighten the connecting rod cap to the specified torque.

(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.

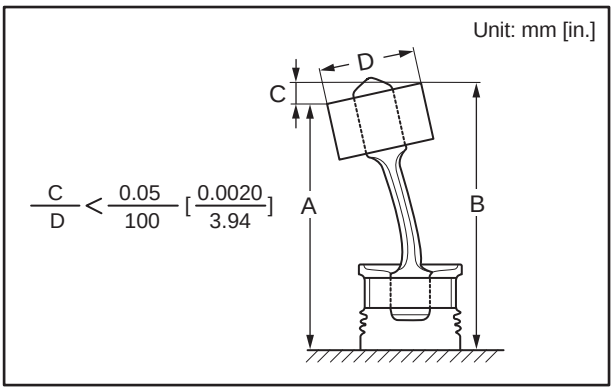
Item	Standard	Limit
Connecting rod bend and twist	0.05/100 mm [0.0020/3.94 in.] or less	0.15/100 mm [0.0059/3.94 in.]



Inspecting connecting rod bend and twist



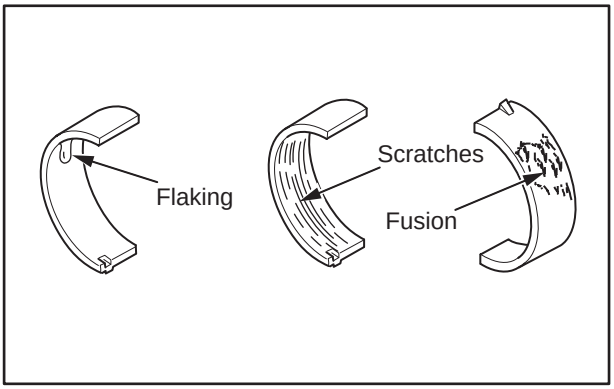
Using a connecting rod aligner to measure rod bend and twist



Measuring with a dial gauge

4.12 Inspecting connecting rod bearing

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

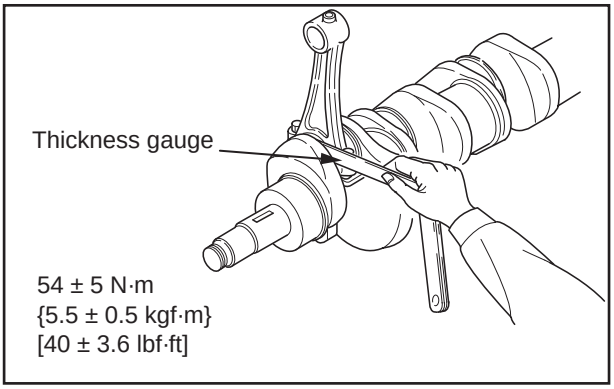


Inspecting connecting rod bearing

4.13 Measuring connecting rod end play

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

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

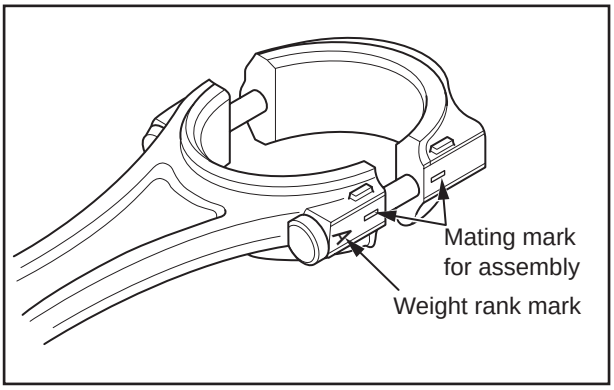


Measuring connecting rod end play

4.14 Weight difference of connecting rod assembly in one engine

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

Item	Tolerance on weight
Weight difference of connecting rod assembly	10 g [0.35 oz.] or less

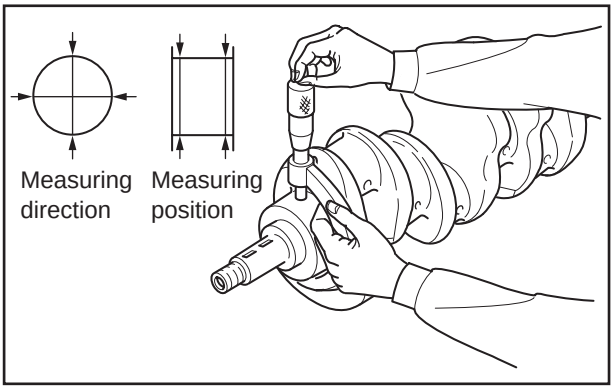


Weight difference in connecting rod assembly

4.15 Measuring crankshaft journal outside diameter

Measure the crankshaft journal diameter using a micrometer. Check the crankshaft journal for roundness, cylindricality and the clearance with the bearing. If the measurement value is below the repair limit, grind the journal to fit the undersize bearing. If the measurement value is below the service limit, replace the crankshaft with a new one.

Item	Nominal	Standard	Limit
Outside diameter	ø 78 mm [3.07 in.]	77.955 to 77.970 mm [3.0691 to 3.0697 in.]	77.850 mm [3.0650 in.] (Repair) 77.100 mm [3.0354 in.] (Replace)
Roundness	-	0.01 mm [0.0004 in.] or less	0.03 mm [0.0012 in.]
Cylindericity	-	0.01 mm [0.0004 in.] or less	0.03 mm [0.0012 in.]
Parallelism	-	Pin maximum defection: 0.01 mm [0.0004 in.] or less	-

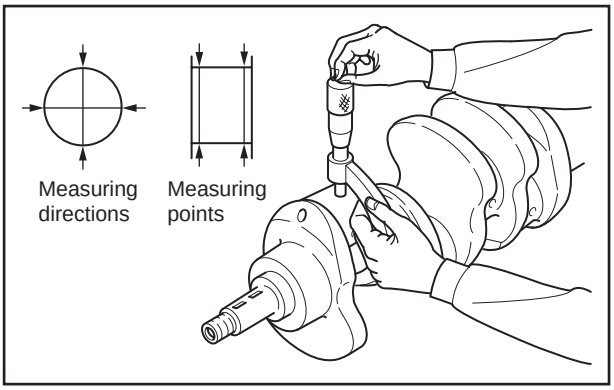


Measuring crankshaft journal outside diameter

4.16 Measuring crankshaft crankpin outside diameter

Measure the crankpin outside diameter using a micrometer. Check the crankpin for roundness, cylindricality, and the clearance with the bearing. If the measurement value is below the limit, grind the journal to fit the undersize bearing. If the measurement value is below the service limit, replace the crankshaft with a new one.

Item	Nominal	Standard	Limit
Outside diameter	ø 58 mm [2.28 in.]	57.955 to 57.970 mm [2.2817 to 2.2823 in.]	57.800 mm [2.2756 in.]
Roundness	-	0.01 mm [0.0004 in.] or less	0.03 mm [0.0012 in.]
Cylindericity	-	0.01 mm [0.0004 in.] or less	0.03 mm [0.0012 in.]
Parallelism	-	Pin maximum defection: 0.01 mm [0.0004 in.] or less	-



Measuring crankpin diameter

4.17 Grinding crankshaft

CAUTION

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

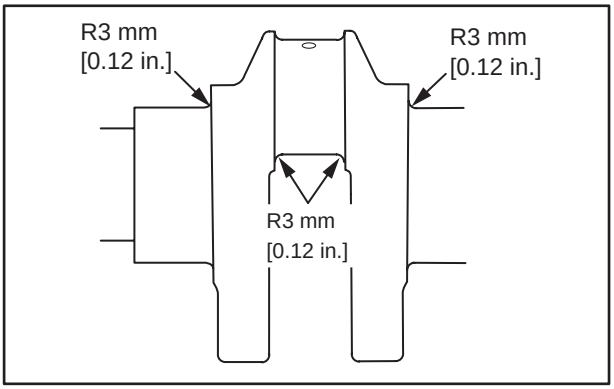
(b) Finish the fillet radius to the specified dimension.

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

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

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

Item	Undersize	Finished size
Crank journal	0.25 mm [0.0098 in.]	77.705 to 77.720 mm [3.0592 to 3.0598 in.]
	0.50 mm [0.0197 in.]	77.455 to 77.470 mm [3.0494 to 3.0500 in.]
	0.75 mm [0.0295 in.]	77.205 to 77.220 mm [3.0396 to 3.0402 in.]
Crankpin	0.25 mm [0.0098 in.]	57.705 to 57.720 mm [2.2718 to 2.2724 in.]
	0.50 mm [0.0197 in.]	57.455 to 57.470 mm [2.2620 to 2.2626 in.]
	0.75 mm [0.0295 in.]	57.205 to 57.220 mm [2.2522 to 2.2528 in.]



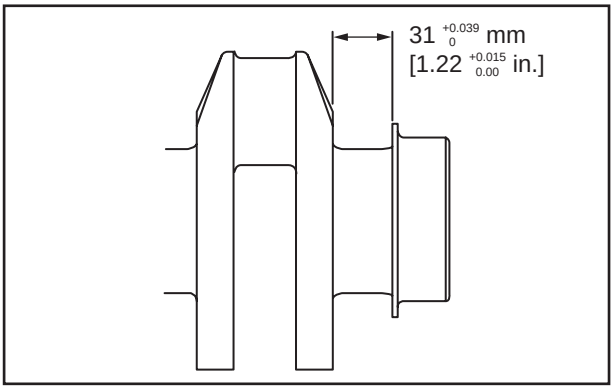
Finished dimension of fillet R

4.18 Measuring crankshaft end play

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

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

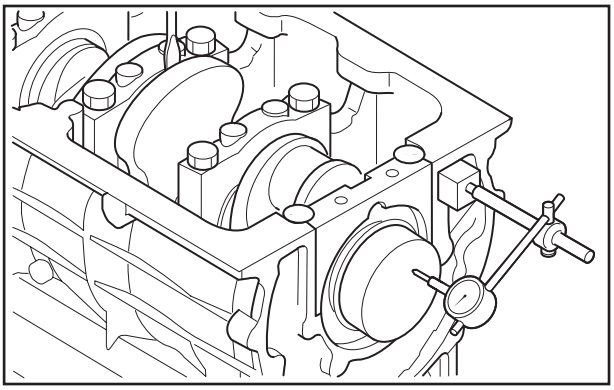
Note: In general, the rear thrust bearing wears faster than the front thrust bearing. Therefore, in most cases, the correction is achieved by replacing the rear thrust plate with a next oversize one.



Width of crankshaft thrust journal

Item	Standard	Limit
Crankshaft end play	0.100 to 0.264 mm [0.0039 to 0.0104 in.]	0.300 mm [0.0118 in.]

Crankshaft thrust size after grinding			
Item	OS, used on one side	OS, used on both sides	Tolerance
+0.15 mm [+0.0059 in.] OS	31.15 mm [1.2264 in.]	31.30 mm [1.2323 in.]	$^{+0.039}_{0}$ mm [$^{+0.0015}_{0.00}$ in.]
+0.30 mm [+0.0118 in.] OS	31.30 mm [1.2323 in.]	31.45 mm [1.2382 in.]	



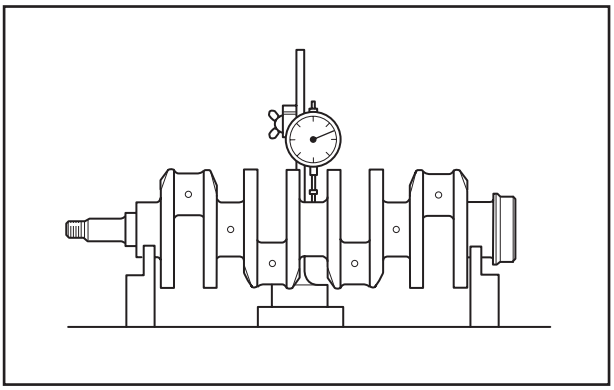
Measuring crankshaft end play

4.19 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.



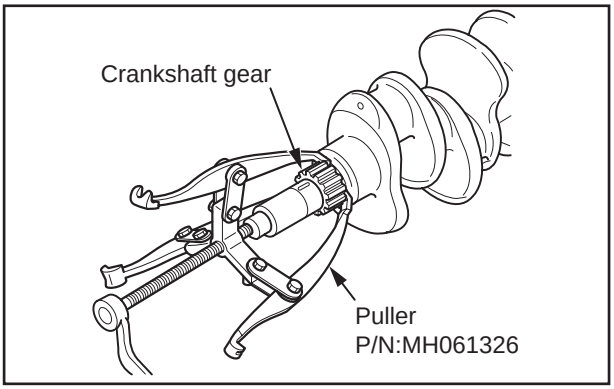
Measuring crankshaft runout

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

4.20 Replacing crankshaft gear

4.20.1 Removing crankshaft gear

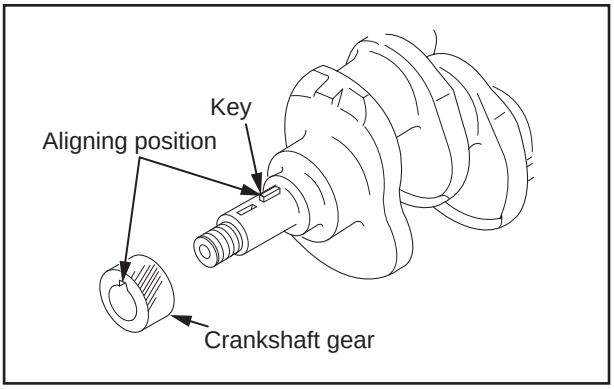
Using a gear puller, remove the gear from the crankshaft.
Note: Do not strike the gear with a hammer.



Removing crankshaft gear

4.20.2 Installing crankshaft gear

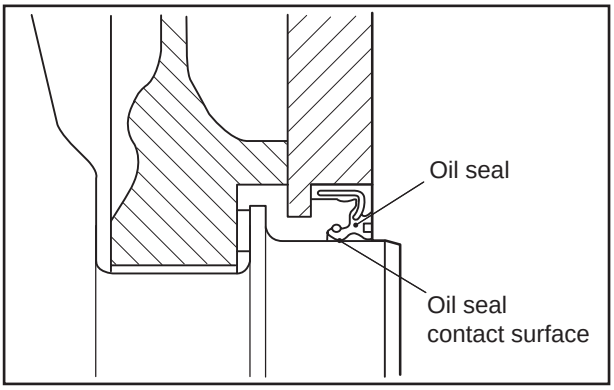
(1) Install the key on the crankshaft.
(2) Press-fit the gear fully in alignment with the key.



Installing crankshaft gear

4.21 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.



Inspecting oil seal contact surface (1)

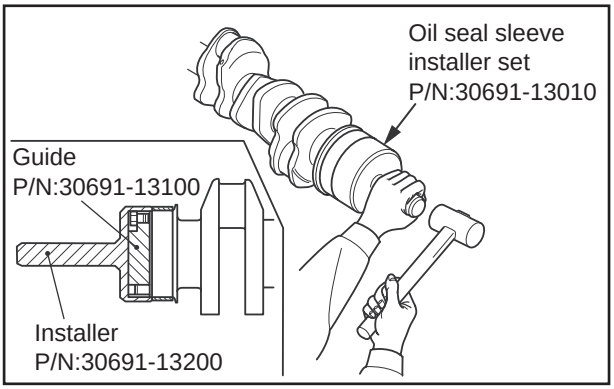
4.22 Installing oil seal sleeve

⚠ CAUTION

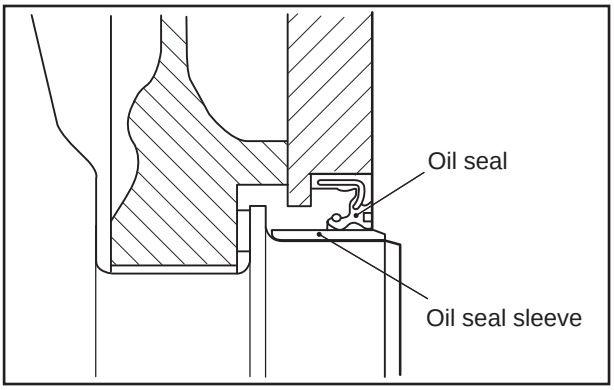
Be careful not to dent or wound the oil seal sleeve circumference.

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



Inspecting oil seal contact surface (2)

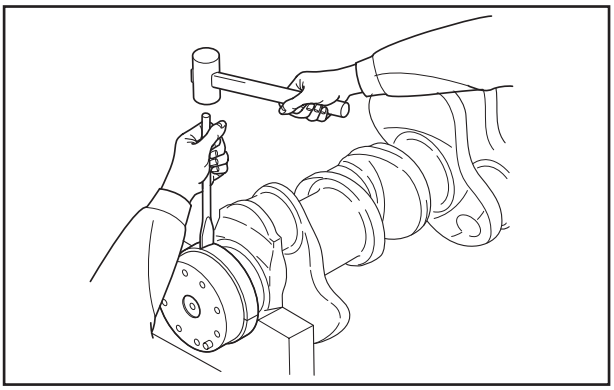
4.23 Removing oil seal sleeve

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.

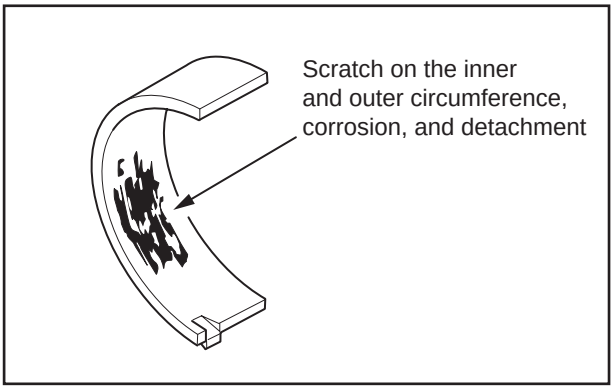
If the sleeve can not be removed by the above procedure, hold the chisel against the sleeve in the axial direction and tap on it lightly to make the sleeve expand. Once the interference between the crankshaft and sleeve is eliminated, the sleeve will be removed easily.



Removing oil seal sleeve

4.24 Inspecting main bearing surface

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

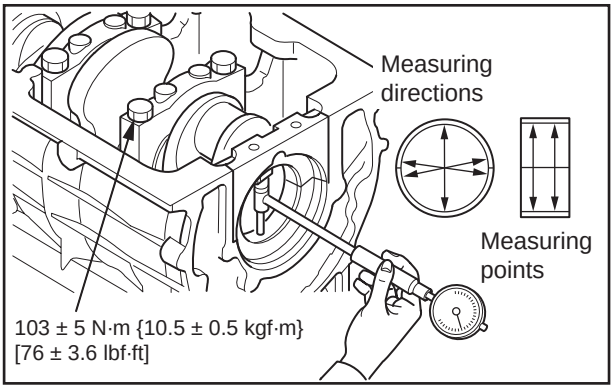


Inspecting main bearing surface

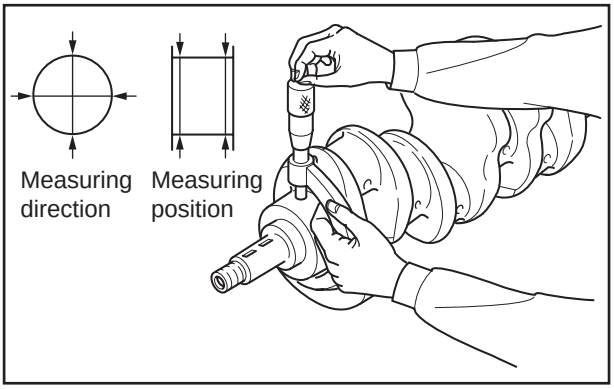
4.25 Measuring clearance between main bearing and crankshaft journal

(1) Reassemble main bearings.
(2) Tighten the main bearing caps to the specified torque.
(3) Measure the inside diameter of the main bearings.
(4) Measure the outside diameter of the crank journal.
(5) Calculate the clearance between the inside diameter of the main bearing and outside diameter of the crank journal.
(6) Replace the main bearing if the clearance exceeds the limit.
(7) Measure the clearance between the main bearing cap and the crank journal again. Use the undersize bearing if the limit is exceeded.
(8) If an undersize bearing is used, grind the crank journal to the specified undersize.

Item	Standard	Limit
Clearance between main bearing and crankshaft journal	0.050 to 0.110 mm [0.0020 to 0.0043 in.]	0.200 mm [0.0079 in.]



Measuring inside diameter of lower hole of main bearing



Measuring crank journal outside diameter

REASSEMBLY OF BASIC ENGINE

1. Reassembling piston, connecting rod, crankshaft and crankcase

1.1 Installing main bearing

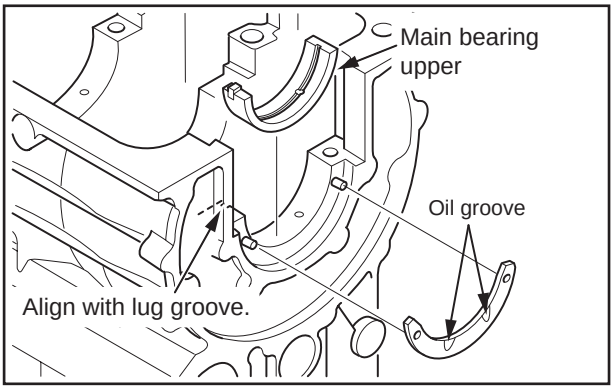
CAUTION

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

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

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

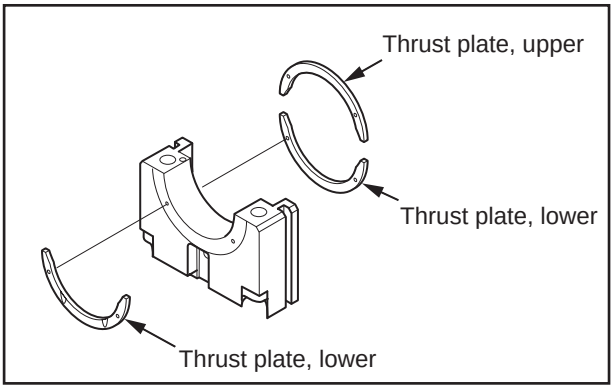
(2) Apply a small amount of engine oil to each bearing.



Installing main bearing upper

1.2 Installing thrust plate

Install the thrust plates to the crankcase outside face of rearmost bearing and to the main bearing cap with their grooves facing outward.



Installing thrust plate

1.3 Installing tappet

Apply engine oil onto the periphery of tappets, insert them into the tappet holes.

1.4 Installing crankshaft

(1) Install the wood ruff key on the crankshaft.

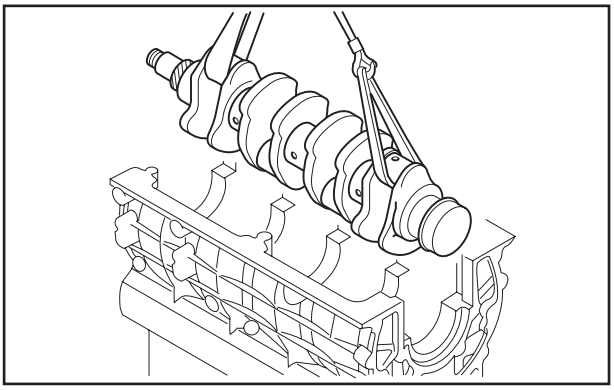
(2) Make sure that the main bearing upper shells that are installed in the crankcase bores have their inner periphery (the surface comes into contact with the journal) lubricated with an even coat of fresh engine oil.

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

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

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

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



Installing crankshaft

1.5 Installing main bearing caps

CAUTION

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

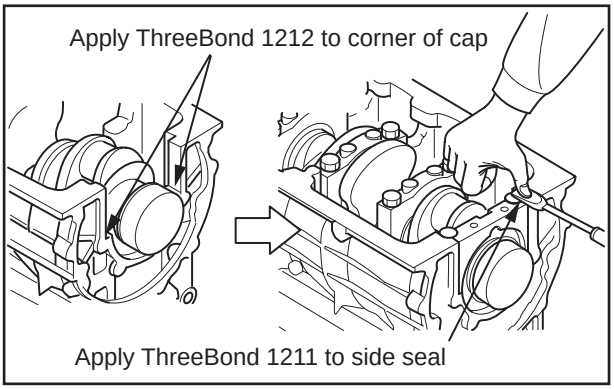
Install the main bearing caps from the front side in the order of the numbers marked on them.

(1) Apply engine oil to lower main bearings and install them to the main bearing caps.

(2) Apply ThreeBond 1212 to the mating surface of the rearmost caps and the crankcase mating faces before installing the main bearing caps.

Note: Do not apply ThreeBond 1212 to any other surface other than the mating surfaces of the rearmost caps and the crankcase mating faces.

(3) Install the main bearing caps and temporarily tighten bolts.



Installing main bearing cap

1.6 Inserting side seal

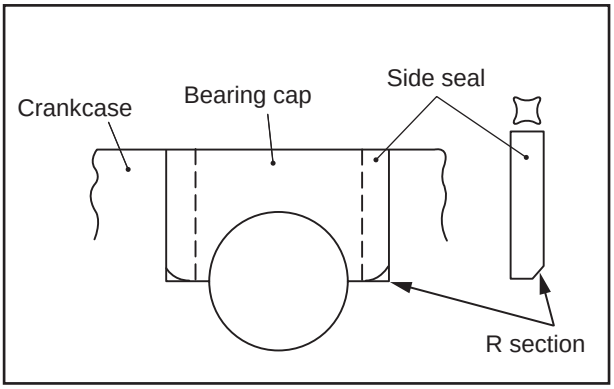
(1) Apply a sealant to the outer periphery of new side seals.

Sealant	ThreeBond 1211

(2) With the round section of the side seals facing outward, press them partway into the front and rear caps using hands.

(3) When the side seals are installed partway into caps, use a tool with flat surface such as to install completely, taking care not to bend them.

Note: Make sure that the rear bearing cap rear face is flushed with the engine rear face.

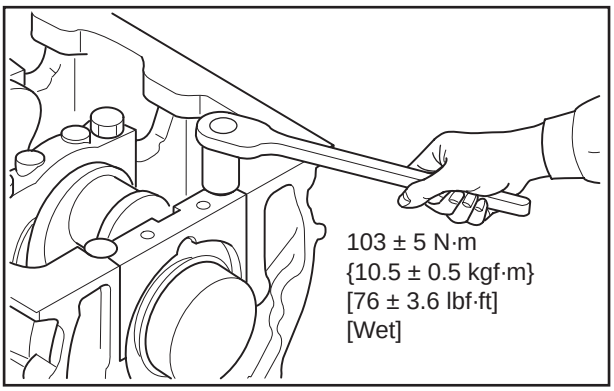


Inserting side seal

1.7 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

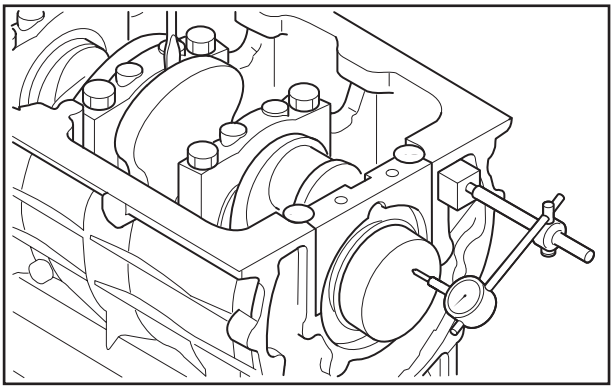
1.8 Measuring crankshaft end play

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

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

Make sure that the crankshaft turns freely.

Item	Standard	Limit
Crankshaft end play	0.100 to 0.264 mm [0.0039 to 0.0104 in.]	0.300 mm [0.0118 in.]

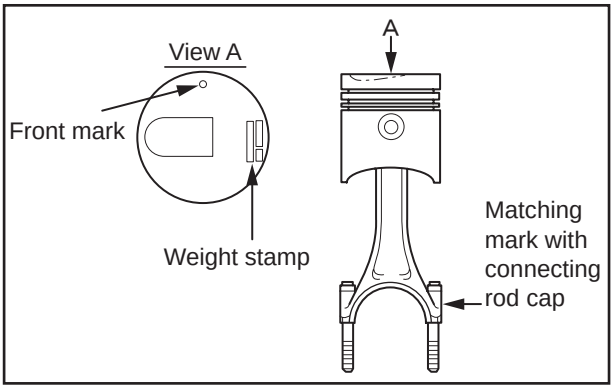


Measuring crankshaft end play

1.9 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.

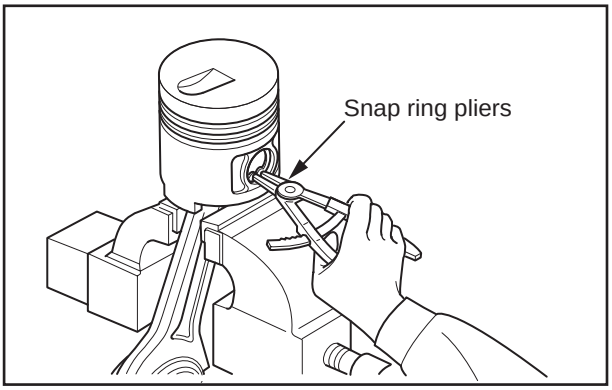
Note: The pistons and piston pins are assembled to each other in clearance fit. However, the piston pins are more easily inserted into the pistons if the pistons are warmed up with a heater or in hot water.



Reassembling piston and connecting rod

(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.



Installing snap ring

1.10 Installing piston ring

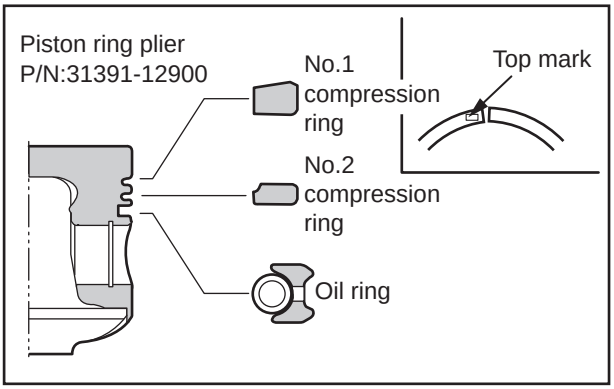
CAUTION

A marking is stamped near the end gap to indicate the top face of piston ring. Install all piston rings with this mark facing upward.

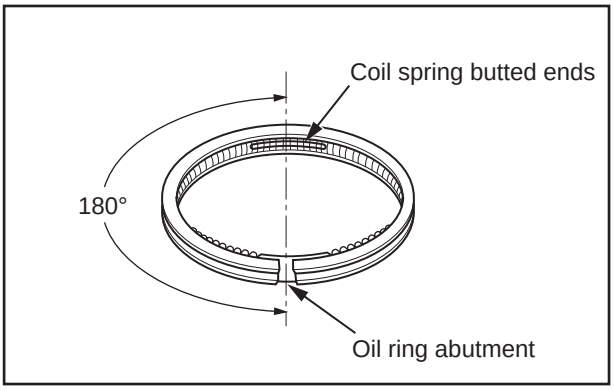
If the rings are installed upside down, it could cause malfunctions such as excessive oil consumption or an engine seizing.

(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/piston ring orientation

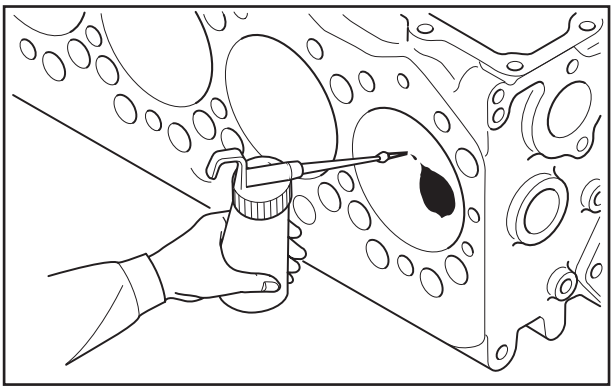


Reassembling oil ring

1.11 Preparation for installing pistons

(1) Lay the engine along its side.

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



Cleaning cylinder inner surface and applying engine oil

1.12 Installing connecting rod bolt and connecting rod bearing

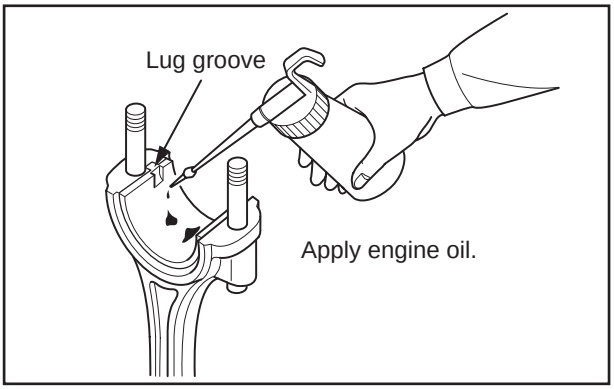
(1) Press fit the connecting rod bolts into the connecting rod.

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.

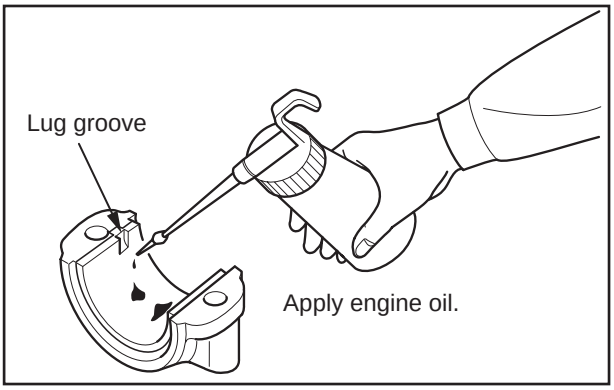
(2) Install the upper connecting rod bearing with its lug fitted in the lug groove of connecting rod.

(3) Install the 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 bolt and bearing upper



Installing connecting rod bearing

1.13 Installing pistons

CAUTION

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

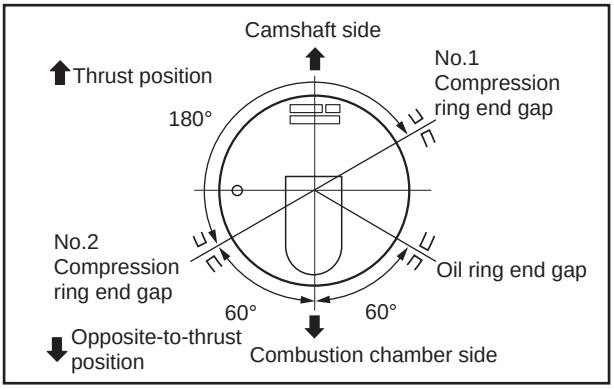
(1) Apply engine oil to the circumference of the piston and piston rings.

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

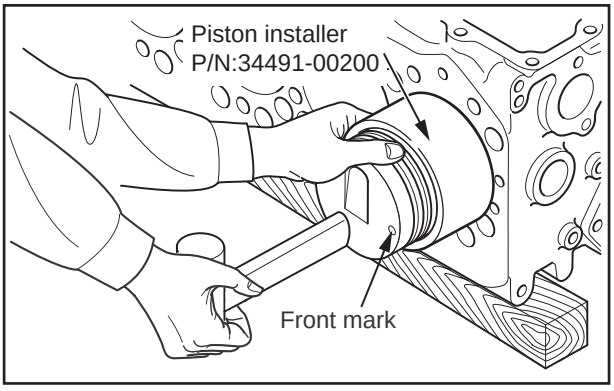
(3) Turn the crankshaft to bring the crank pin of the cylinder to the bottom dead center.

(4) Orient the front mark on the top of piston toward engine front.

(5) Using a piston installer, insert the piston from the top face of crankcase into the cylinder.



Orientation of piston ring end gaps



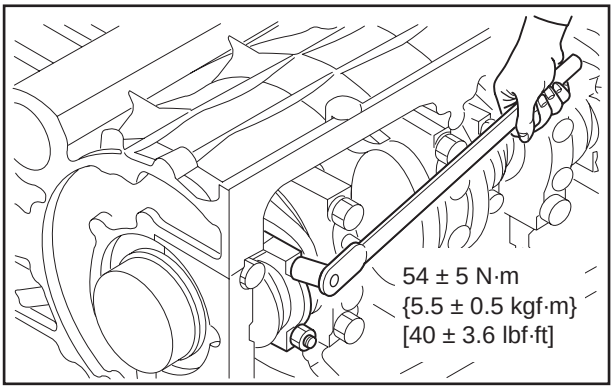
Installing piston

1.14 Installing connecting rod cap

(1) Install the connecting rod cap with its match mark facing on the same side as the match mark on the connecting rod.

(2) Tighten the connecting rod cap nuts evenly and progressively to the specified torque.

(3) Inspect end play of the connecting rod. If end play is small, loosen and retighten the cap nuts.

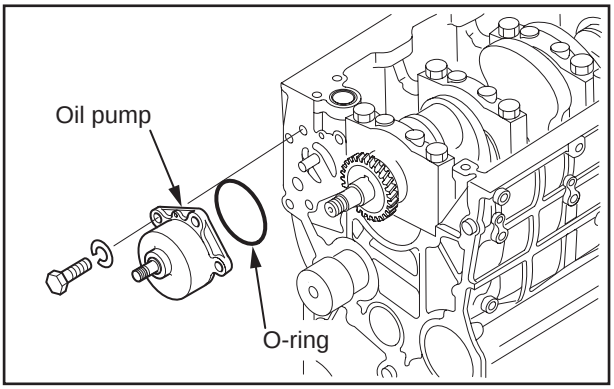


Installing connecting rod cap

2. Reassembling timing gear and camshaft

2.1 Installing oil pump

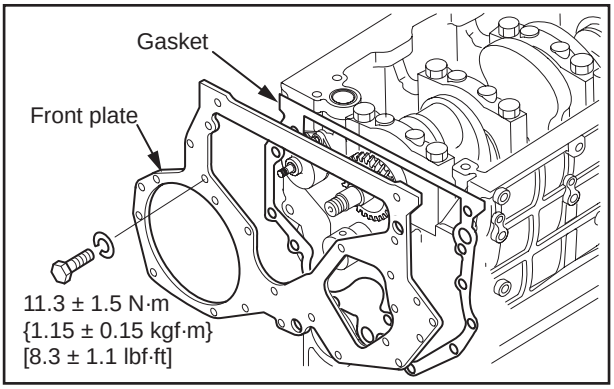
Set a new O-ring to the oil pump case, and install the oil pump to the crankcase.



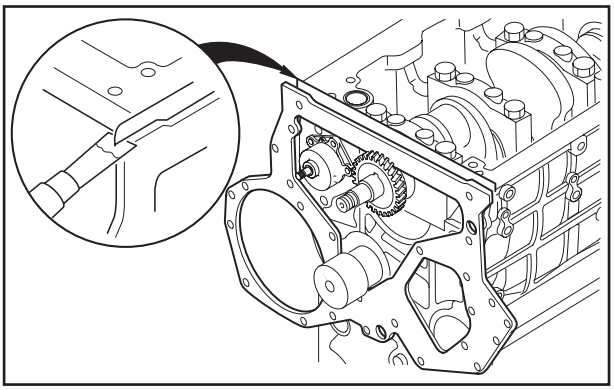
Installing oil pump

2.2 Installing front plate

(1) Clean the mounting surface of the gasket.
(2) Apply sealant to the gasket to prevent it from falling.
(3) With aligning to the dowel pin, install the gasket and the front plate.
(4) Secure the front plate with mounting bolts.
(5) Cut the gasket protruding from crankcase bottom side with cutter.



Installing front plate (1)



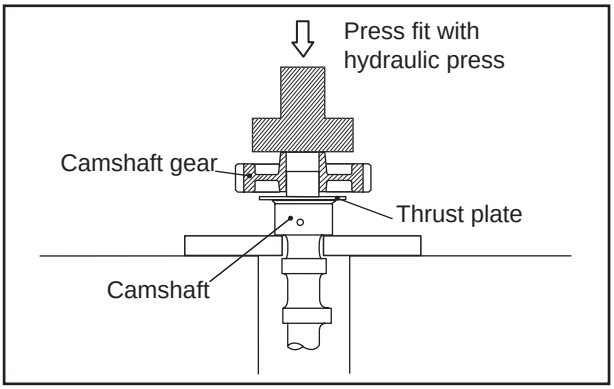
Installing front plate (2)

2.3 Installing camshaft gear and thrust plate

CAUTION

Be careful not to damage the cam of the camshaft and the bushing.

Warm the camshaft gear and insert the thrust plate without fail when installing the gear.



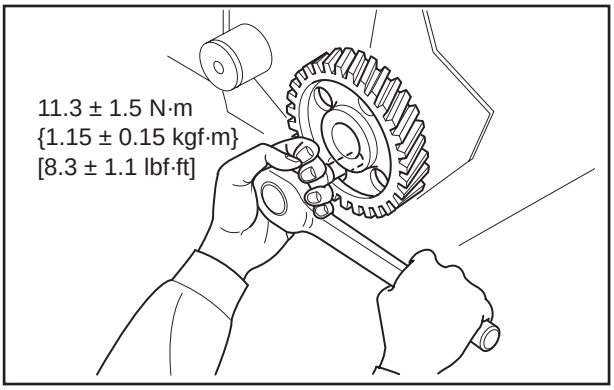
Installing camshaft gear and thrust plate

2.4 Installing camshaft

CAUTION

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

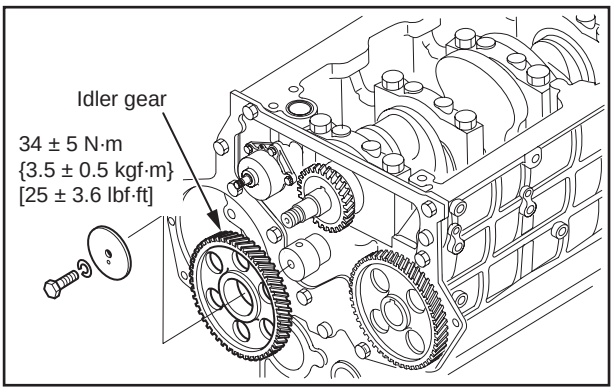
(1) Apply engine oil to the camshaft journals and cams.
(2) Slowly insert the camshaft assembly.
(3) Tighten the thrust plate bolt to the specified torque.
(4) Make sure that the camshaft rotates lightly. Move the camshaft gear back and forth, and make sure there is end play.



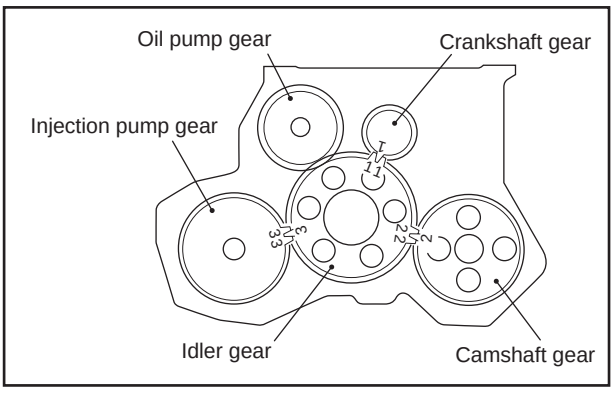
Installing camshaft

2.5 Installing idler gear

(1) Apply engine oil to the idler gear shaft.
(2) Install the idler gear with its match marks aligned with the marks on the crankshaft gear and camshaft gear.
(3) Attach the thrust plate to the idler gear and tighten the mounting bolt to the specified torque.



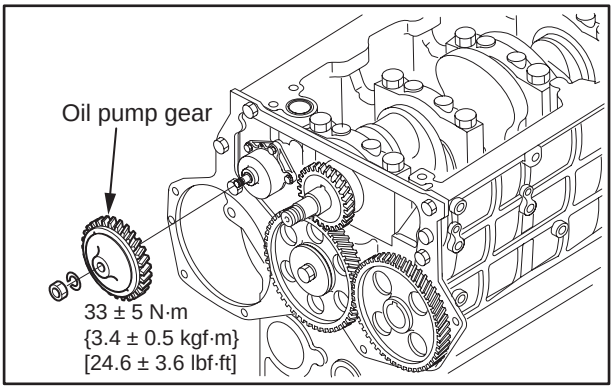
Installing idler gear



Timing gear train

2.6 Installing oil pump gear

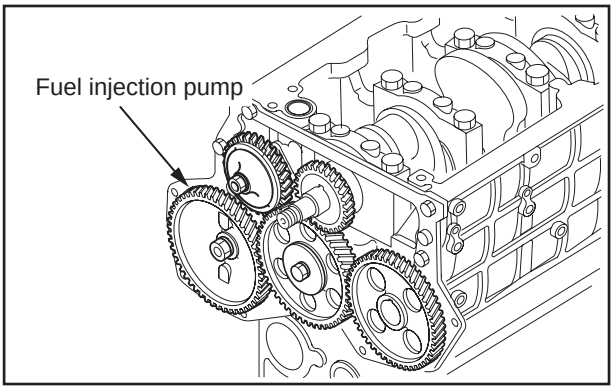
(1) Install the oil pump gear to the oil pump shaft.
(2) Tighten the jam nut to the specified torque.



Installing oil pump gear

2.7 Installing fuel injection pump

(1) Install the fuel pump gear with its match marks aligned with the marks on the fuel injection pump and idler gear.
(2) Tighten the fuel injection pump mounting bolts evenly.



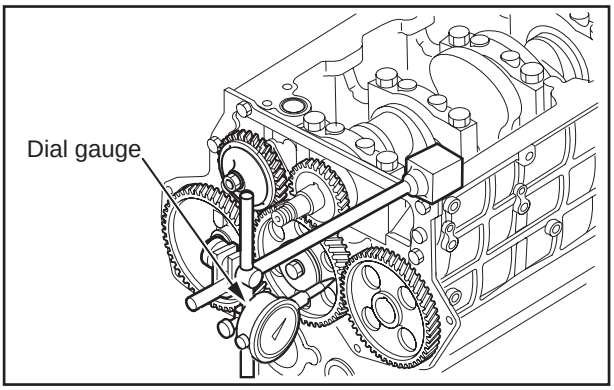
Installing fuel injection pump

2.8 Inspecting and adjusting timing gear after installation

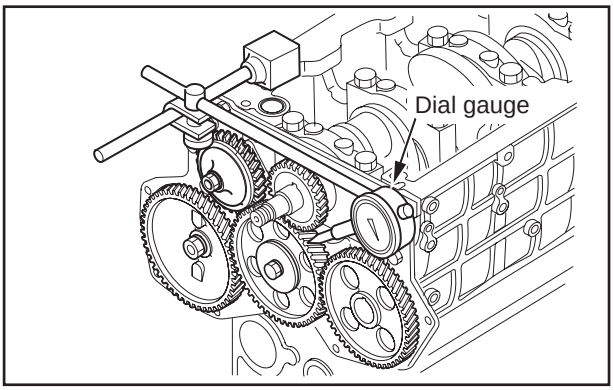
Be sure to inspect and adjust the timing gear when the timing gear has been reassembled.

2.8.1 Inspecting backlash and end play

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



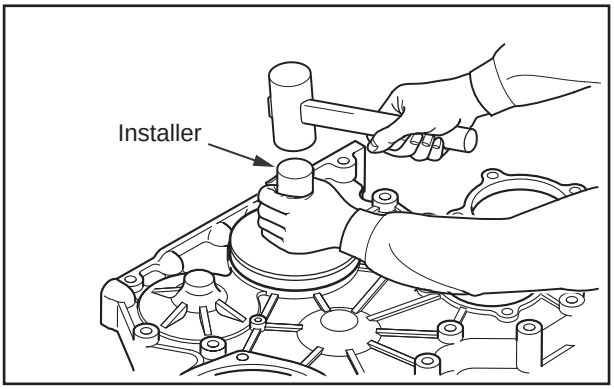
Measuring idler gear end play



Measuring timing gear backlash

2.9 Installing front oil seal

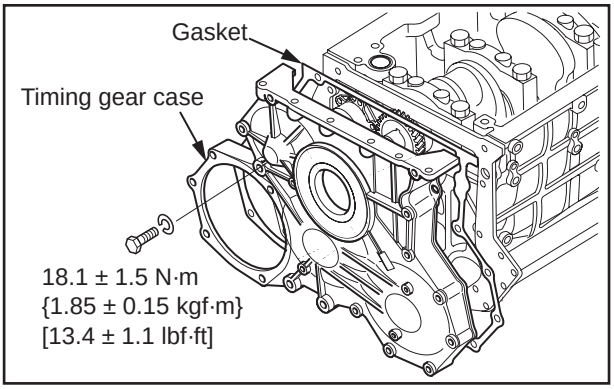
Using an installer, install new oil seal in the timing gear case. Make sure the oil seal is flush with the gear case.



Installing front oil seal

2.10 Installing timing gear case

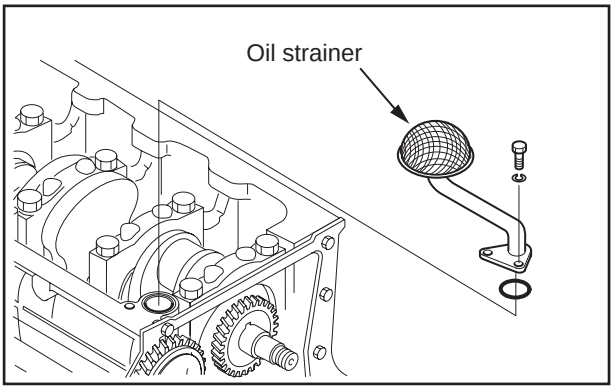
(1) Aligning with the dowel pins, install the gasket to the crankcase.
(2) Apply engine oil to the oil seal lip.
(3) Install the timing gear case and tighten the bolts.
(4) Cut the gasket protruding from crankcase bottom side with cutter.



Installing timing gear case

2.11 Installing oil strainer

Set a new O-ring to the oil strainer, and install the oil strainer to the crankcase.



Installing oil strainer

2.12 Installing oil pan

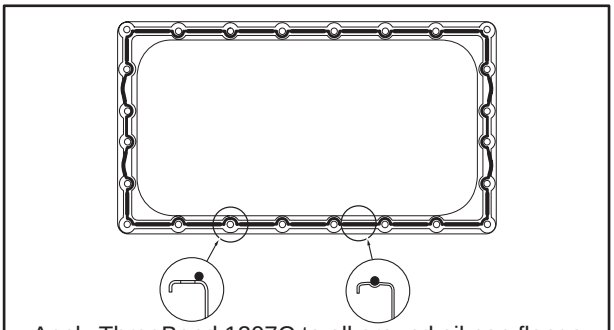
(1) Clean the mount surfaces of the crankcase, timing gear case, and oil pan.

(2) Squeeze ThreeBond 1207C (32A91-05100: liquid gasket) in a 4 mm [0.16 in.] diameter bead all around the oil pan flange periphery, and spread it.

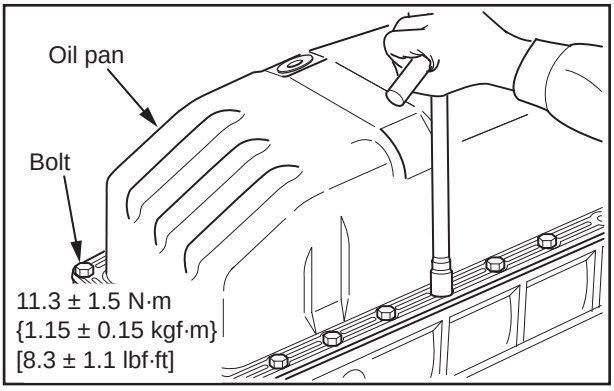
(3) Install the oil pan to the crankcase within five minutes of applying the liquid gasket.

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

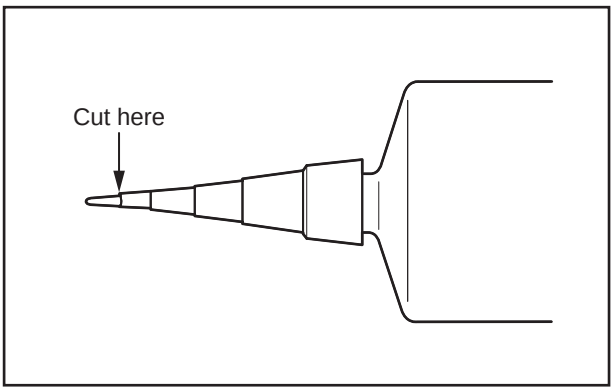
Note: Cut the nozzle tip of the liquid gasket tube at the position shown on the right when squeezing the liquid gasket in a 4 mm [0.16 in.] diameter bead.



Liquid gasket application position



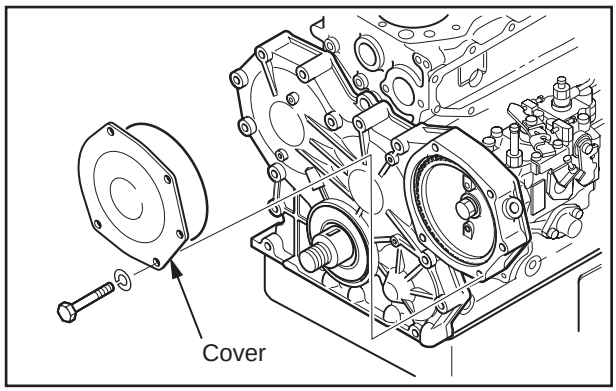
Installing oil pan (1)



Installing oil pan (2)

2.13 Installing cover

Tighten the cover mounting bolts evenly.



Installing cover

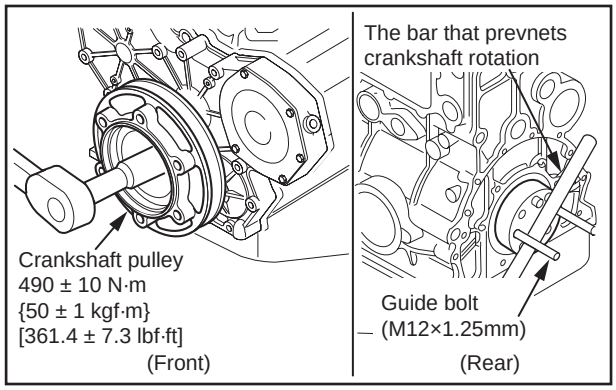
2.14 Installing crankshaft pulley

⚠ CAUTION

The bar could come off. Be very careful.

(1) Screw two guide bolts into the threaded holes at the rear end of the crankshaft. Place a bar across the two guide bolts so that the crankshaft does not turn.

(2) Install the crankshaft pulley and tighten the nuts to the specified torque.



Installing crankshaft pulley

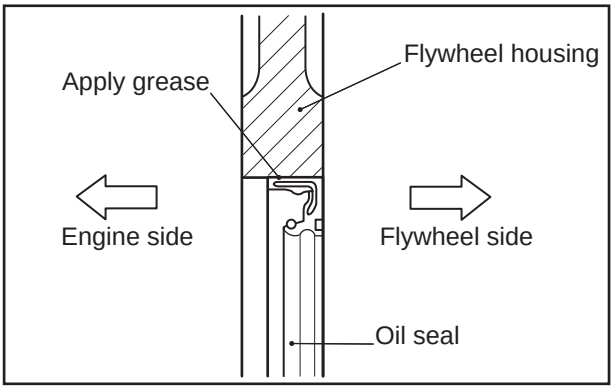
3. Reassembling flywheel

3.1 Installing oil seal

Apply a small quantity of grease to the new oil seal, and install the oil seal to the rear plate.

Be careful of the oil seal installation direction.

Note: Use an oil seal with a sleeve if the oil seal contacting surface of the crankshaft is worn.



Installing oil seal

3.2 Installing flywheel housing

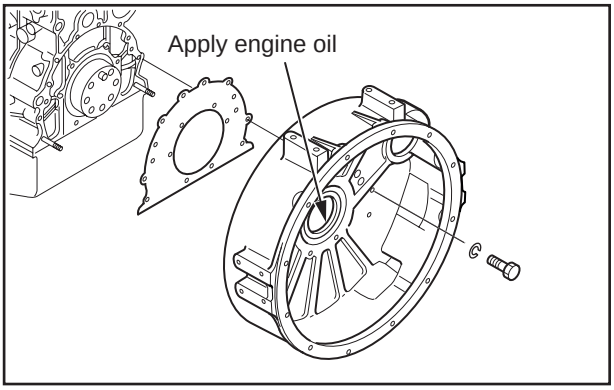
(1) Clean the mounting surface of the gasket.

(2) Apply sealant to the gasket with using guide bolt to prevent it from falling off.

(3) Install the gasket.

(4) Install the flywheel housing, aligning its dowel pin holes and dowel pins, and tighten the bolts.

Note: When the dowel pins are worn or when the flywheel housing is replaced, replace the dowel pins with new ones.



Installing flywheel housing

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.

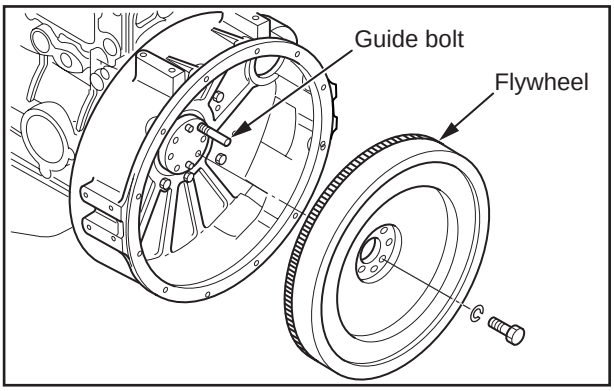
(2) Screw the guide bolt into the rear end of the crankshaft.

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

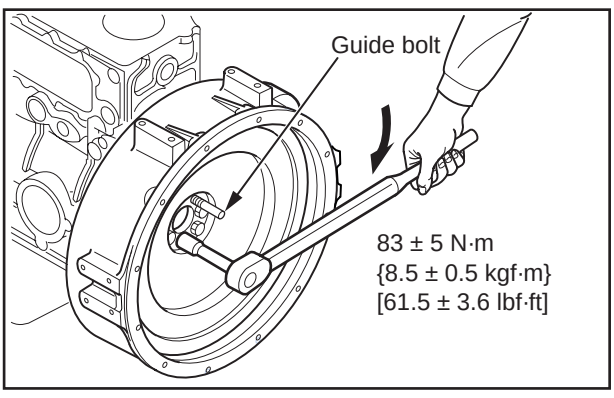
(4) Temporarily tighten bolts.

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

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



Installing flywheel (1)



Installing flywheel (2)

4. Reassembling cylinder head and valve mechanism

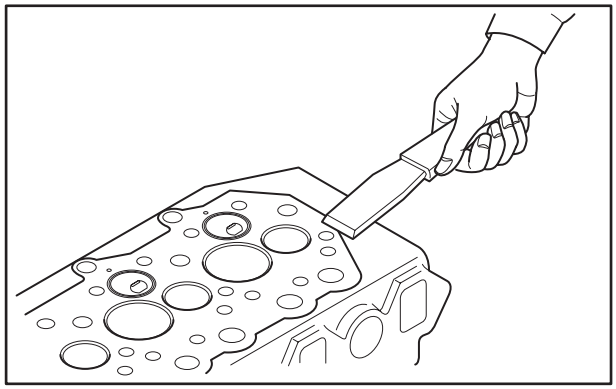
4.1 Cleaning cylinder head bottom surface

CAUTION

Do not use the liquid gasket to the cylinder head.

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

4.2 Installing valve stem seal

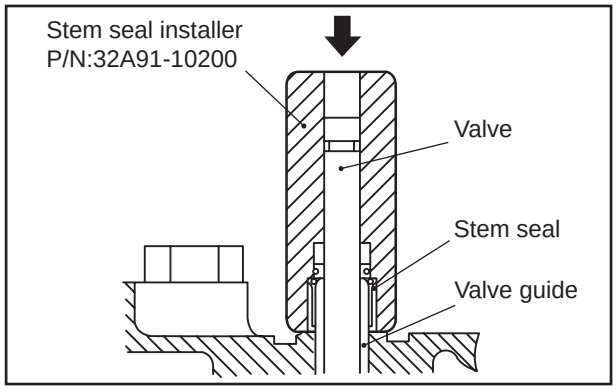
CAUTION

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.

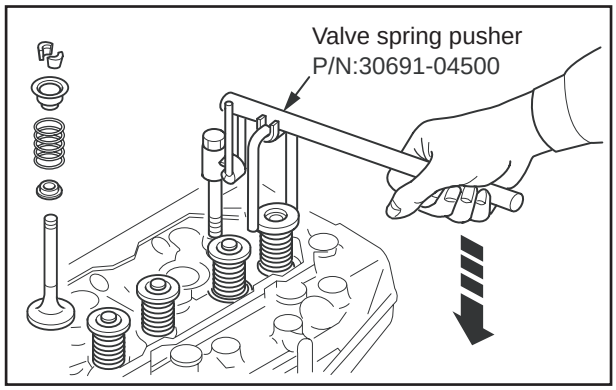


Installing valve stem seal

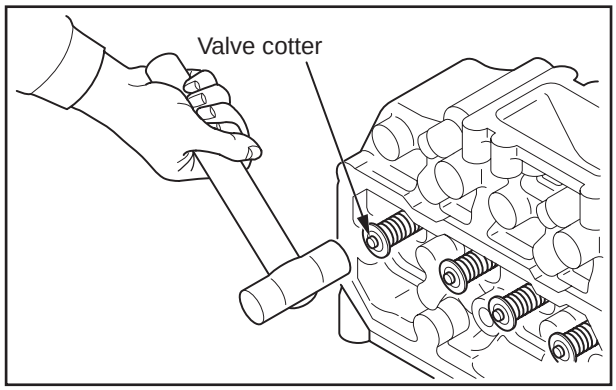
4.3 Installing valve and valve spring

(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

4.4 Installing cylinder head gasket

CAUTION

Do not use the liquid gasket to the cylinder head.

(1) Make sure that there is no dirt or dents on the top surfaces of the crankcase and pistons.

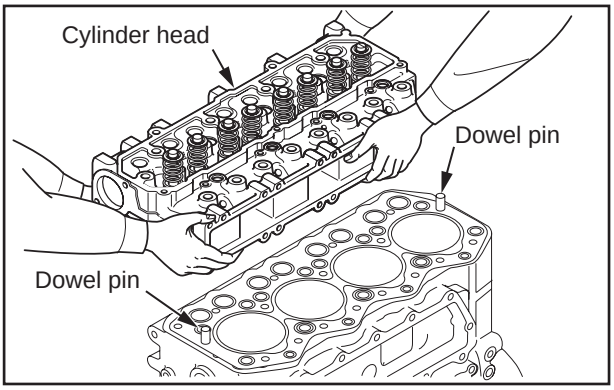
(2) Place new gasket on the crankcase by aligning it with dowel pins on the crankcase.

4.5 Installing cylinder head assembly

Install the cylinder head to fit the dowel pins on the crankcase top surface with guide.

Note: (a) Be careful not to displace the cylinder head gasket when installing.

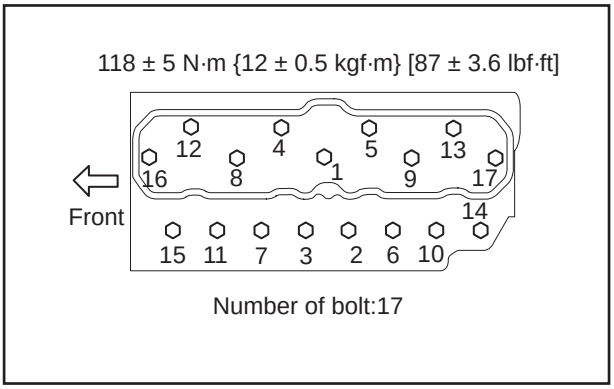
(b) Do not lift up cylinder head by one person. Use crane or lift up by two persons.



Installing cylinder head assembly

4.6 Tightening cylinder head bolts

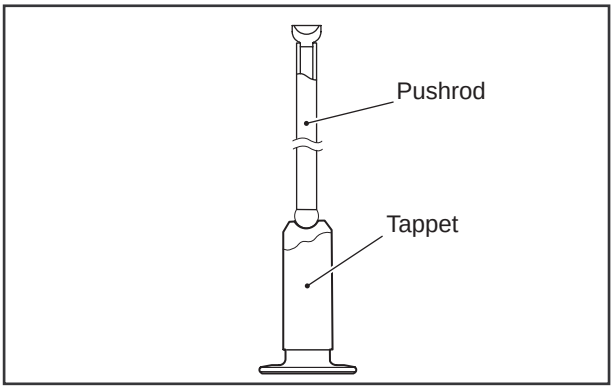
In the numerical order as shown in the illustration, tighten cylinder head bolts progressively to the specified torque.



Tightening order of cylinder head bolt

4.7 Inserting pushrod

(1) Insert each pushrod into its hole in the cylinder head.
(2) Make sure that the ball end of each pushrod is placed correctly on the tappet cup.



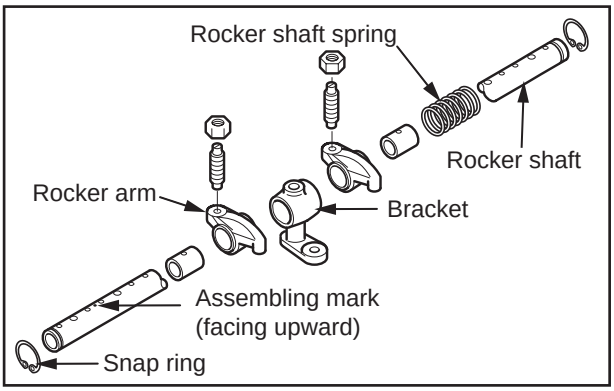
Inserting pushrod

4.8 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.

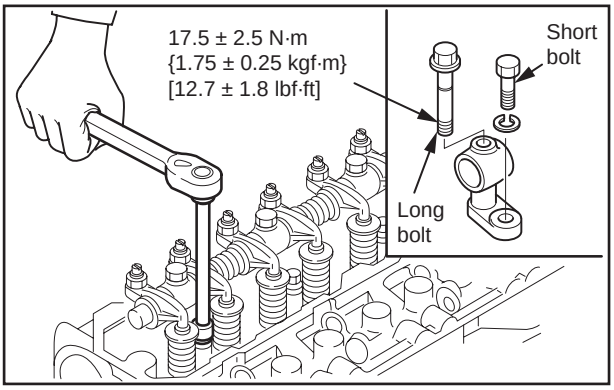
(3) After reassembling, make sure the rocker arm and oil pipe move freely.



Reassembling rocker shaft assembly

4.9 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

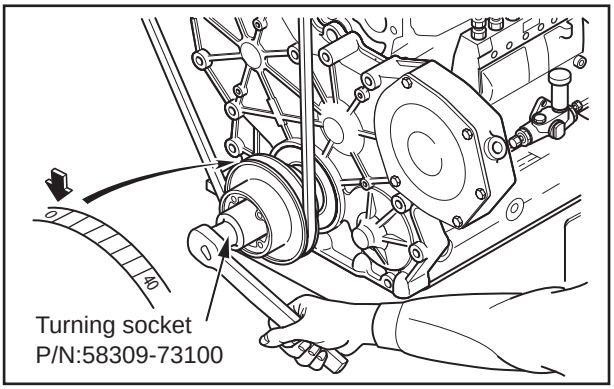
4.10 Determining top dead center of No.1 cylinder compression stroke

(1) Determine the No.1 cylinder top dead center position, and at this position, ensure that the notch mark "0" stamped on the crankshaft pulley is aligned with the pointer.
If the top mark on the circumference of the crankshaft pulley is hard to look, put the mark again.

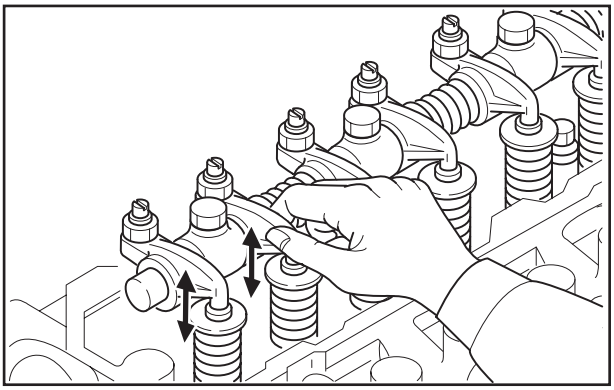
(2) Attach a socket and rachet handle to the nut of crankshaft pulley, and rotate the crankshaft in the normal direction (clockwise when viewed from the front of the engine).

(3) Stop turing the crankshaft when "0" notch mark stamped on the crankshaft pulley is aligned with the pointer.

(4) At this position, move the rocker arms of the inlet and exhaust valves for the No.1 cylinder up and down, and make sure there is clearance, that is, the pushrods are not pushing the inlet and exhaust valves off their seats.



Determining top dead center of No.1 cylinder compression stroke (1)

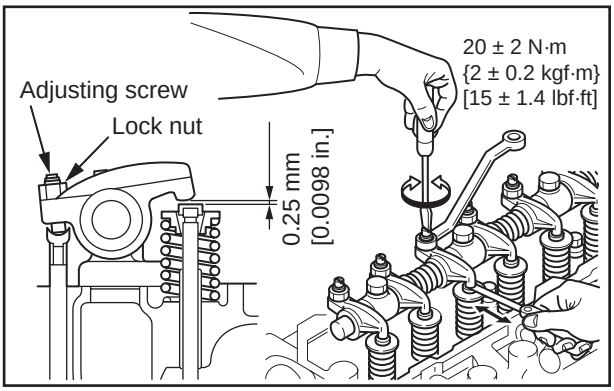


Determining top dead center of No.1 cylinder compression stroke (2)

4.11 Adjusting valve clearance

Adjust the valve clearance.

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

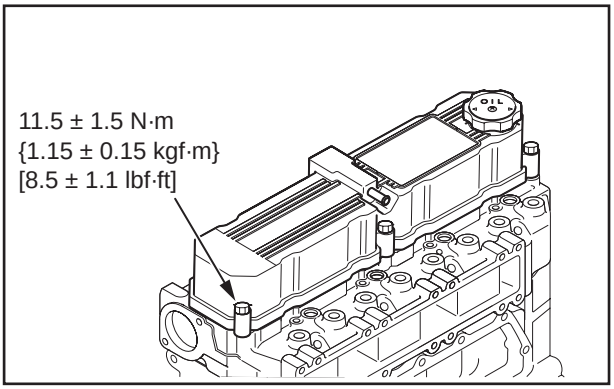


Adjusting valve clearance

4.12 Installing rocker cover

(1) Make sure that the gasket is firmly installed into the rocker cover.

(2) Tighten the rocker cover mounting nuts to the specified torque.



Installing rocker cover

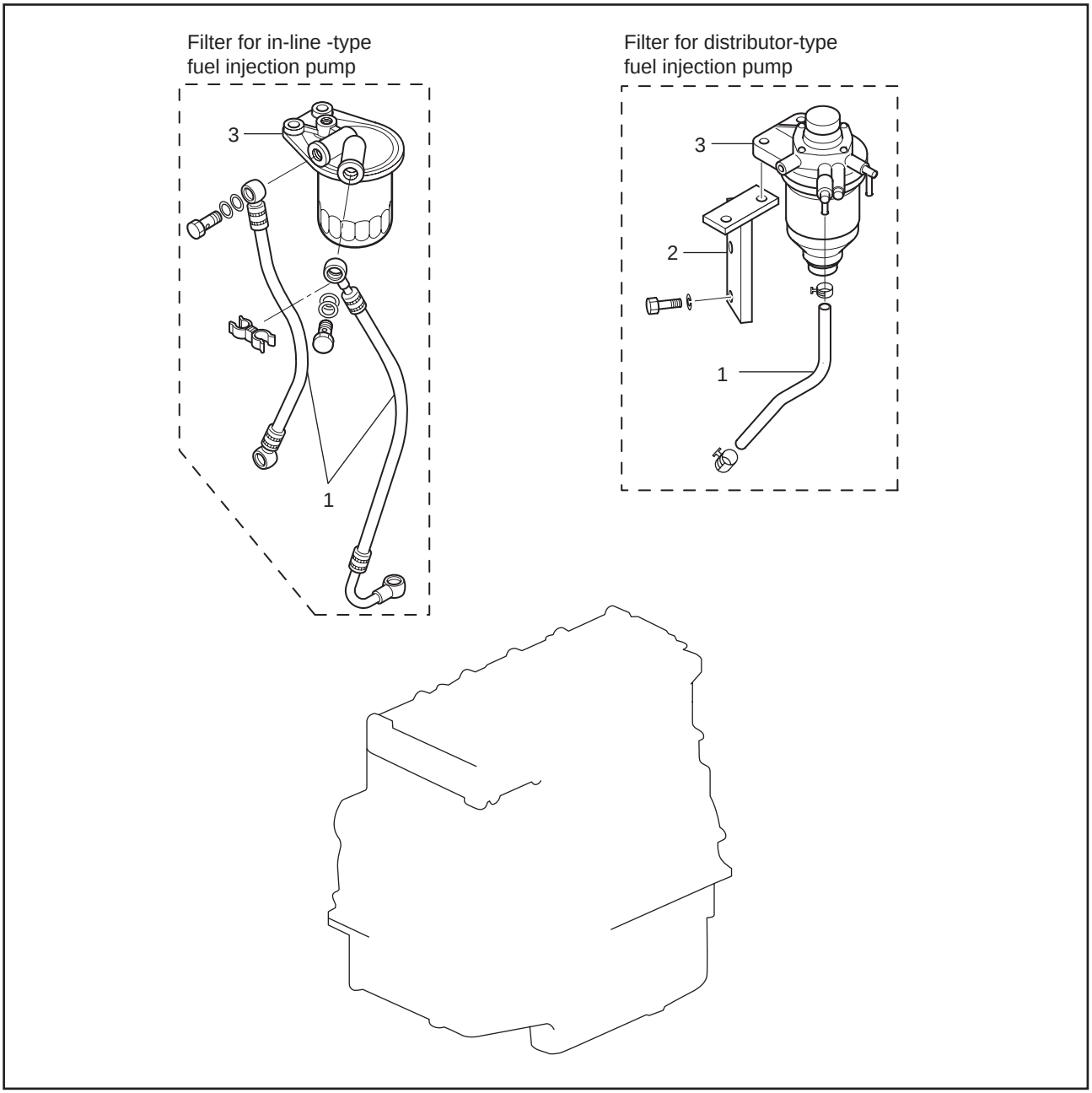
FUEL SYSTEM

1. Removing fuel system

CAUTION

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

1.1 Removing fuel filter and fuel pipe



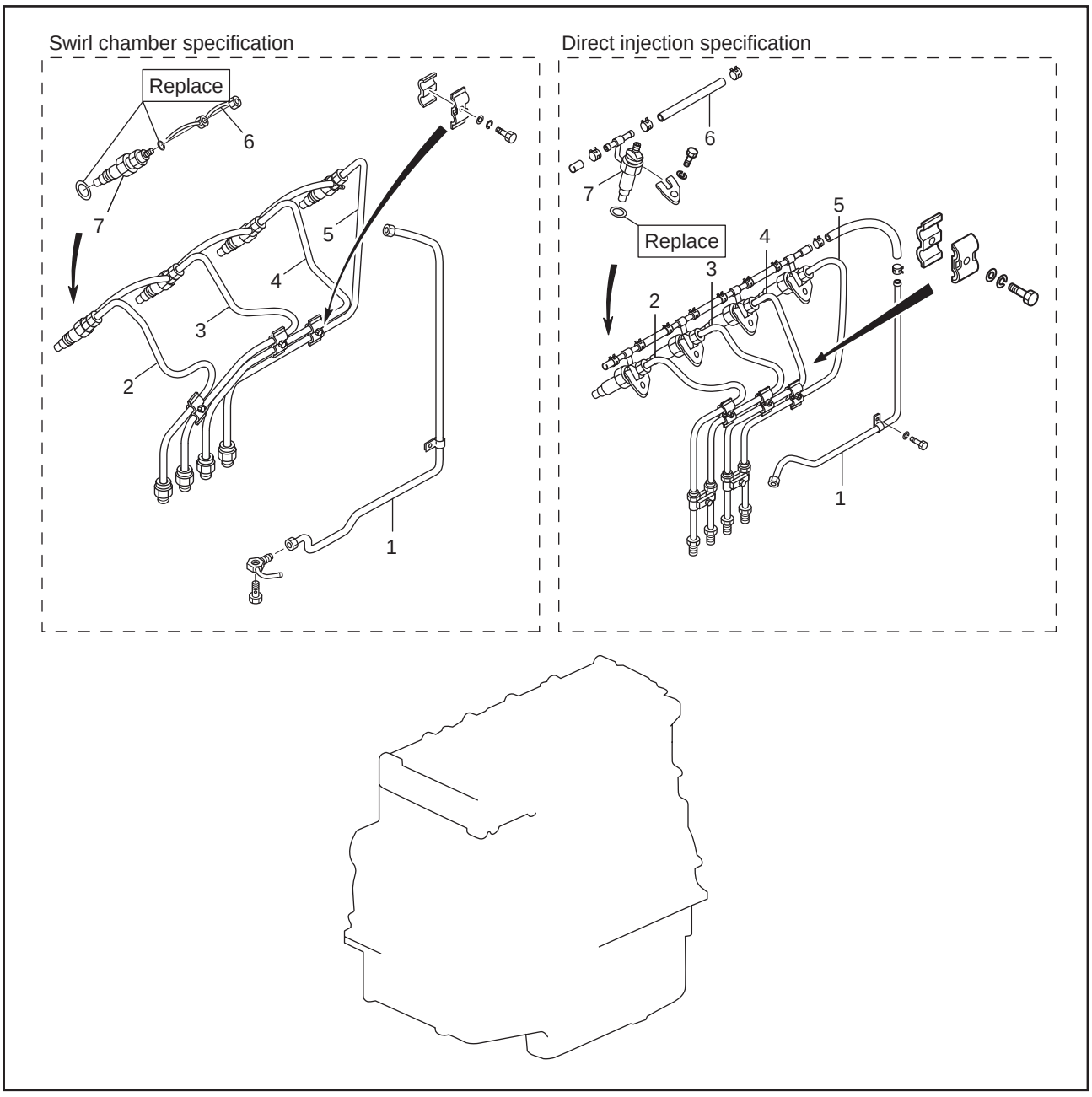
Removing fuel filter and fuel pipe

Removing sequence

1 Fuel hose
2 Fuel filter bracket
3 Fuel filter

1.2 Removing fuel injection pipe, fuel leak-off pipe and fuel injection nozzle

1.2.1 Removing fuel injection pipe, fuel leak-off pipe and fuel injection nozzle (in-line type fuel injection pump)

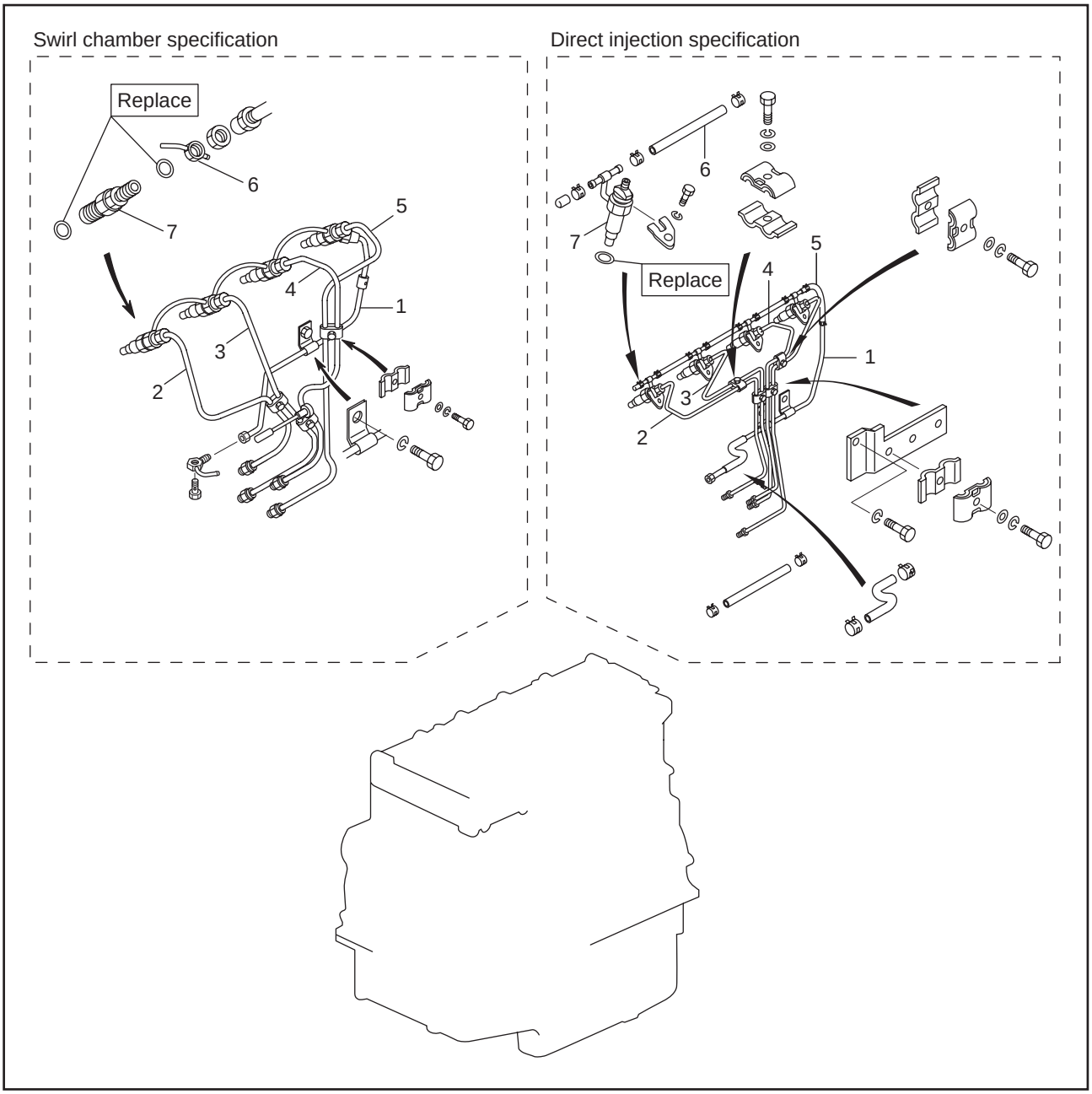


Removing fuel injection pipe, fuel leak-off pipe and fuel injection nozzle
(in-line type fuel injection pump)

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 (swirl chamber specification)
Fuel hose (direct injection specification)
7 Fuel injection nozzle

1.2.2 Removing fuel injection pipe, fuel leak-off pipe and fuel injection nozzle (distributor-type fuel injection pump)

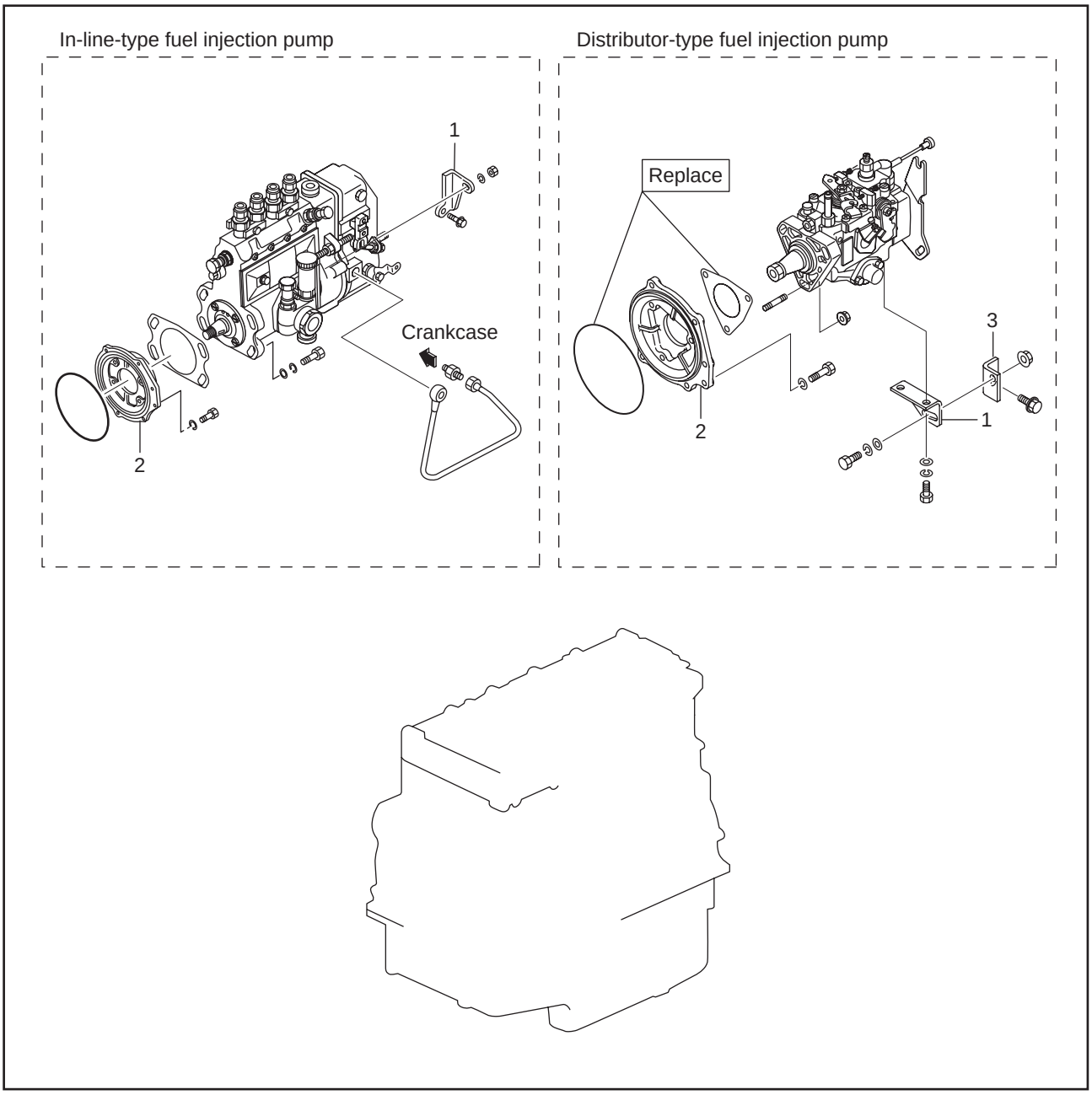


Removing fuel injection pipe, fuel leak-off pipe and fuel injection nozzle
(distributor-type fuel injection pump)

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 (swirl chamber specification)
Fuel hose (direct injection specification)
7 Fuel injection nozzle

1.3 Removing fuel injection pump



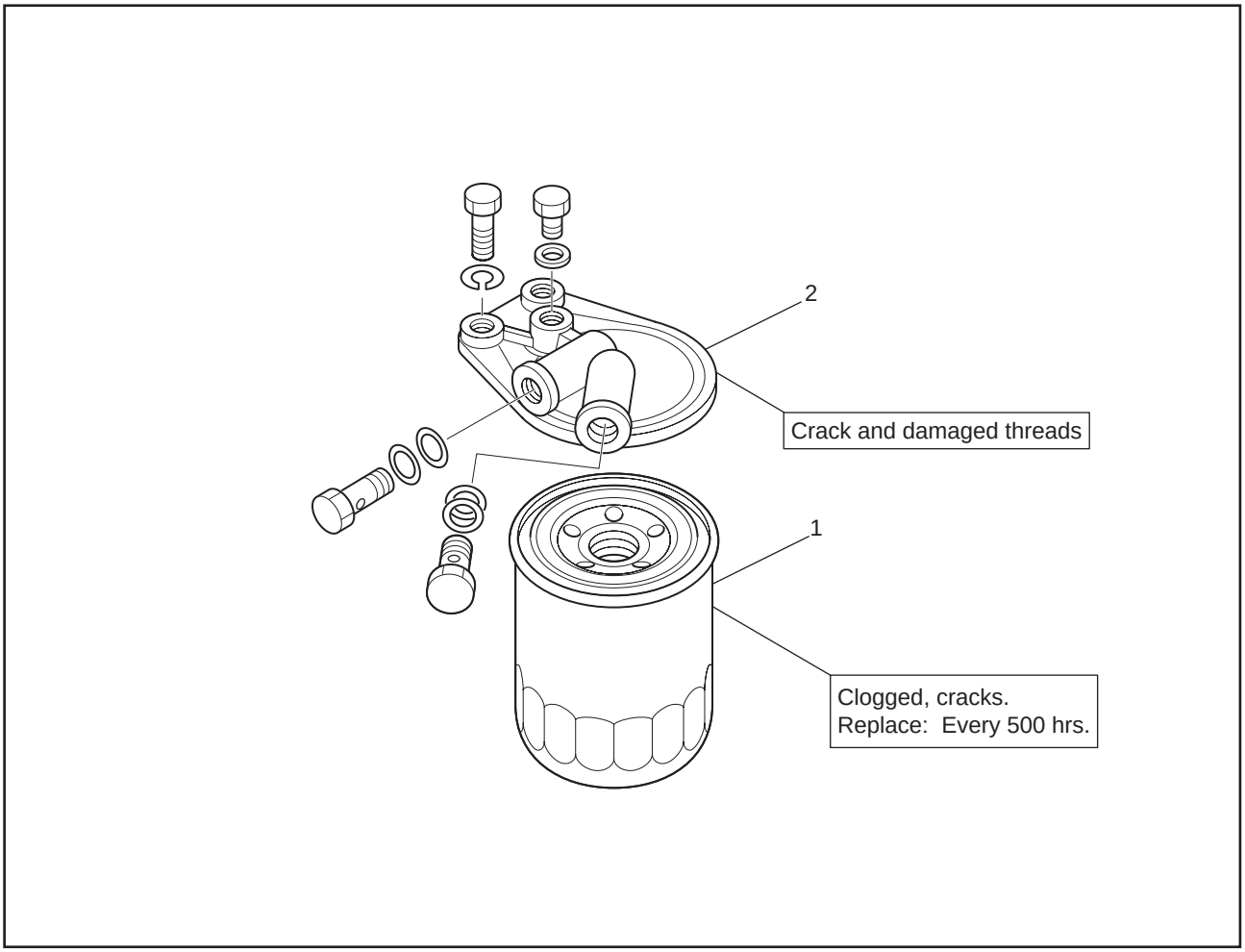
Removing fuel injection pump

Removing sequence

1 Bracket
2 Fuel injection pump flange
3 Bracket

2. Disassembling, inspecting and reassembling fuel system

2.1 Disassembling and inspecting fuel filter (in-line type fuel injection pump)

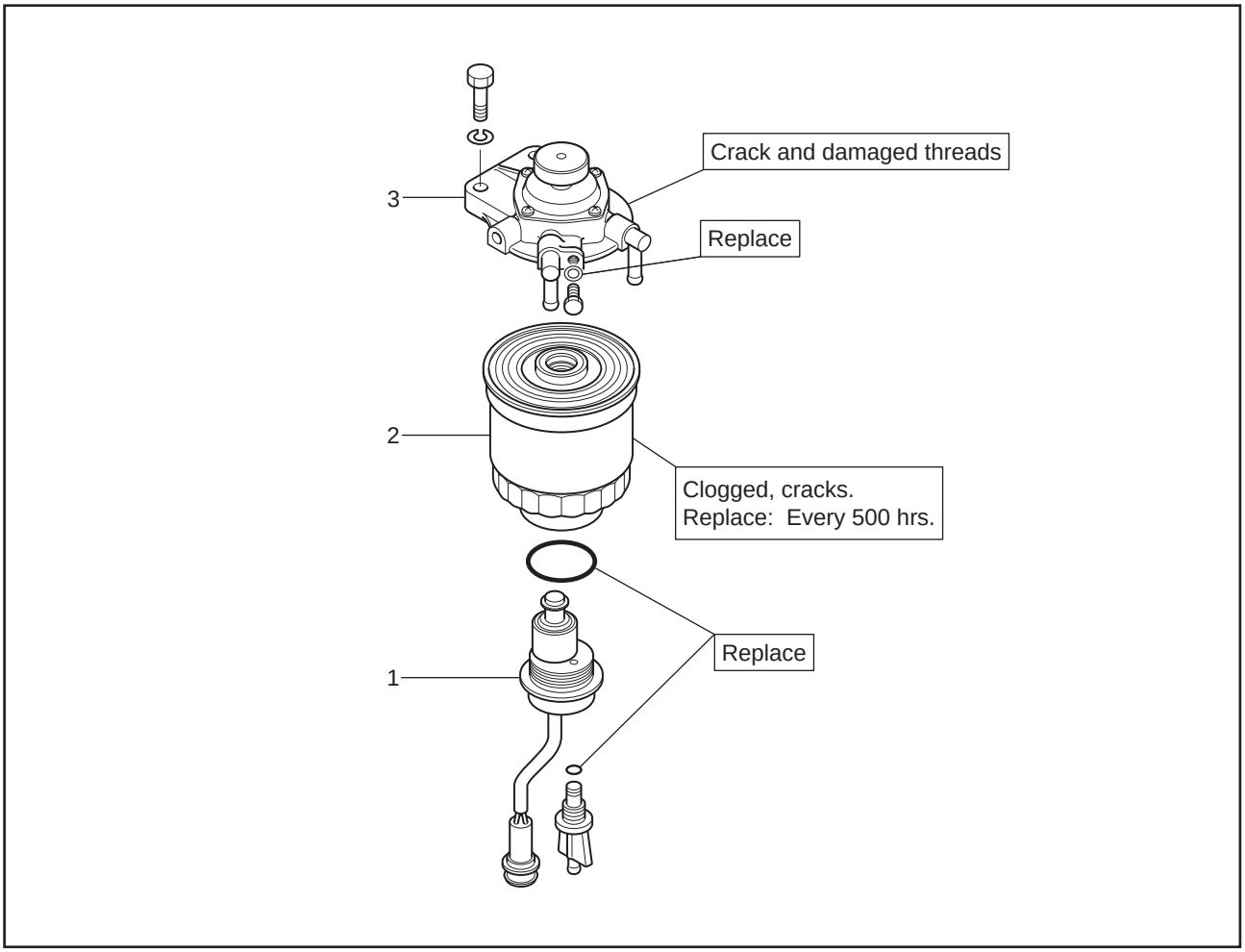


Disassembling and inspecting fuel filter (in-line type fuel injection pump)

Disassembling sequence

1 Filter element
2 Filter bracket

2.2 Disassembling and inspecting fuel filter



Disassembling and inspecting fuel filter

Disassembling sequence

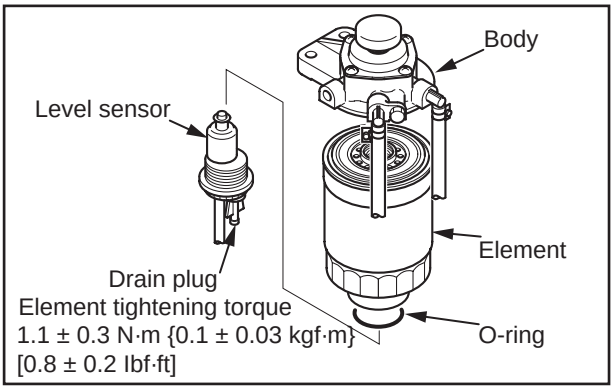
1 Level sensor
2 Filter element
3 Body

2.3 Changing fuel filter

⚠ WARNING

When handling fuel, make sure no open flames are nearby.
Wipe off any spilled fuel. Spilled fuel becomes fire hazard.

(1) Clean the outside of the fuel filter and the area around it.
(2) Disconnect the fuel filter level sensor from its connector.
(3) Place a drip pan under the fuel filter.
(4) Loosen the drain plug and drain fuel from the fuel filter.
(5) Remove the level sensor from the fuel filter.
(6) Remove the fuel filter element.
(7) Wipe off any fuel on the fuel filter element mounting surface of fuel filter body with a cloth.
(8) Have the new fuel filter element ready for installation and make sure that the gasket is properly seated on the groove.



Changing fuel filter

⚠ WARNING

Do not use the filter of which case has dents, as it may be damaged during operation, and cause fuel leakage that becomes fire hazard.

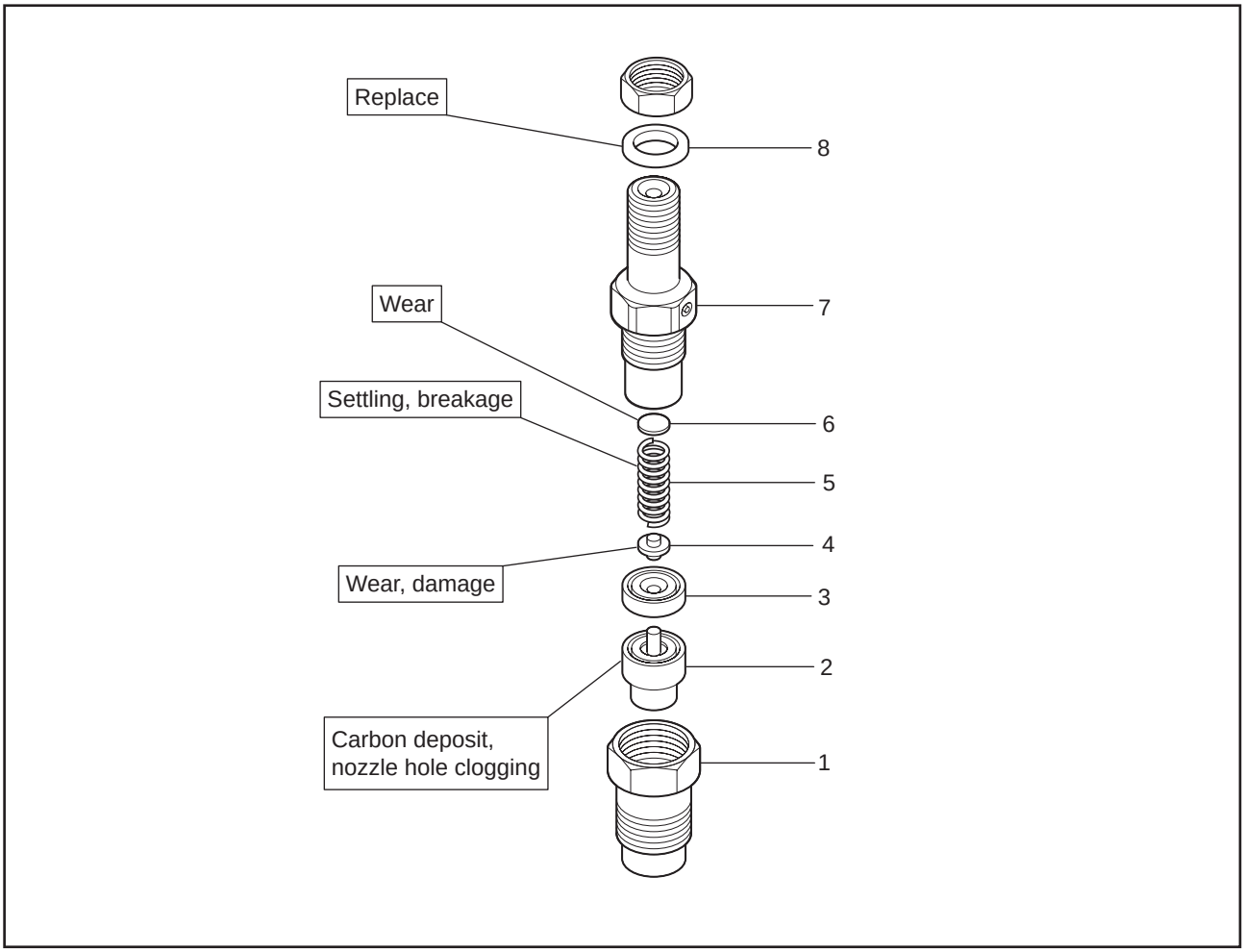
(9) Install the fuel filter element to the filter body.

CAUTION

Be careful not to dent or damage the fuel filter case.

(10) Using new O-ring, install the level sensor to the fuel filter element.
(11) After completion of the fuel filter change, bleed the fuel system.
(12) Start the engine and run at idling speed for a few minutes.
(13) Check the fuel filter element mounting surface for fuel leakages. If leakages are found, loosen the fuel filter and check the gasket for seating or damage. Then retighten the fuel filter.

2.4 Disassembling and inspecting fuel injection nozzle (swirl chamber type)

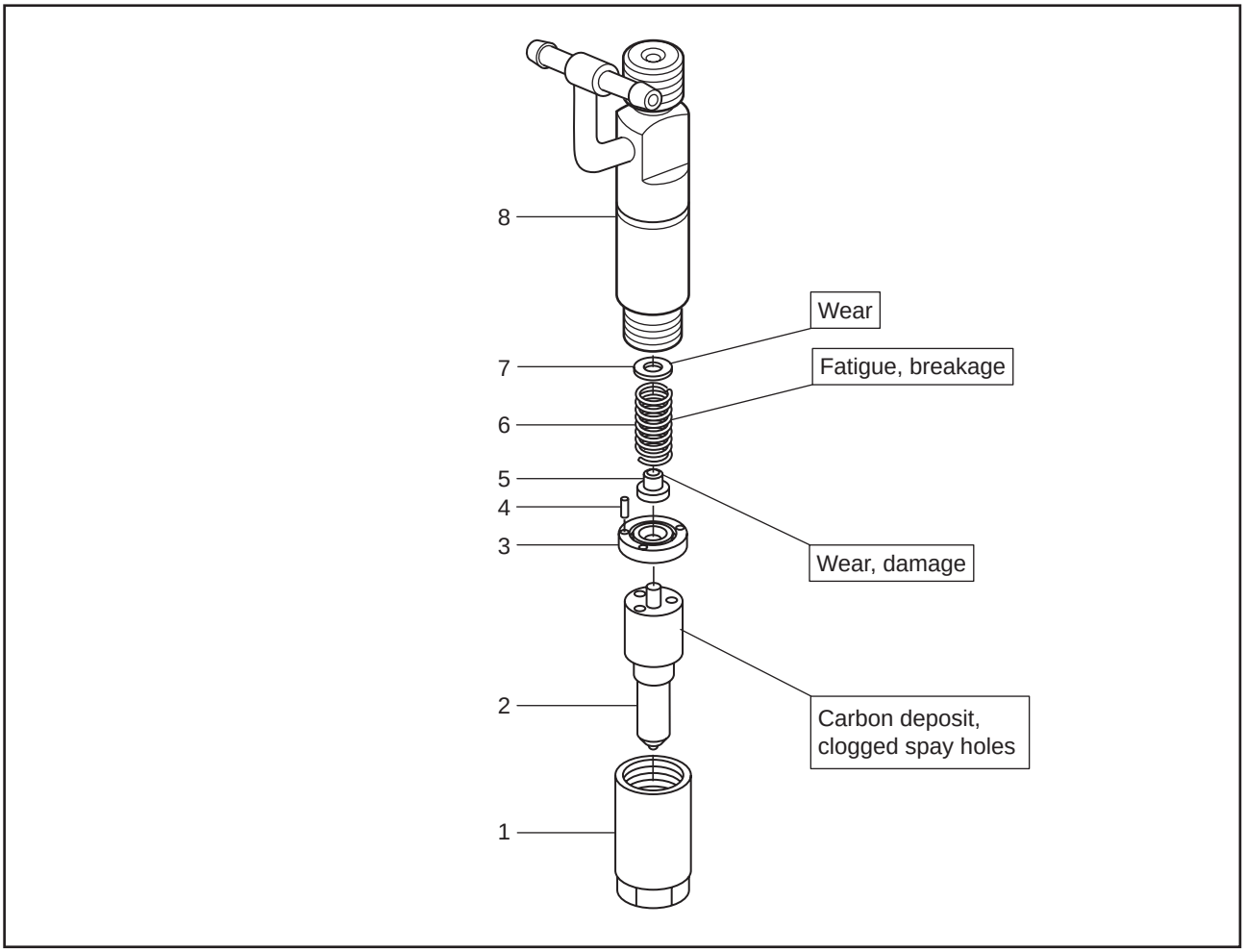


Disassembling and inspecting fuel injection nozzle (swirl chamber type)

Disassembling sequence

1 Nozzle retaining nut
2 Nozzle tip assembly
3 Distance piece
4 Pressure pin
5 Pressure spring
6 Washer
7 Nozzle holder
8 Gasket

2.5 Disassembling and inspecting fuel injection nozzle (direct injection type)



Disassembling and inspecting fuel injection nozzle (direct injection type)

Disassembling sequence

1 Nozzle retaining nut
2 Nozzle tip assembly
3 Tip packing
4 Straight pin
5 Pressure pin
6 Pressure spring
7 Shim
8 Nozzle body

2.6 Inspecting and adjusting fuel injection valve opening pressure

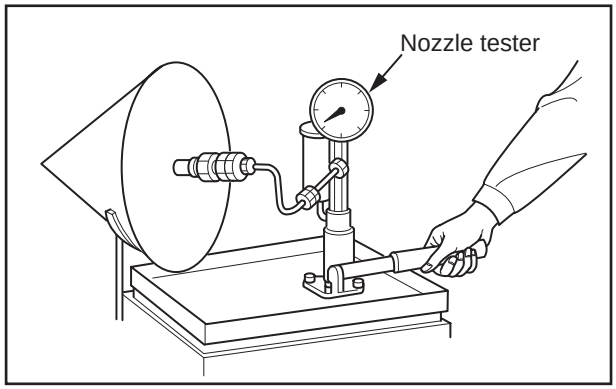
⚠ CAUTION

Never touch the injection nozzle tip during nozzle injection test.

(1) Mount the nozzle on the nozzle tester.
(2) Push down the handle at a speed of once a second and read the pressure when injection starts. Make adjustment if it is outside the standard,
(3) To adjust the injection start pressure, remove the retaining nut, and change the shim. Changing the shim with thicker one increases the pressure, and changing the shim with thinner one decreases 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	Swirl chamber	11.77 MPa {120 kgf/cm²} [1707 psi]	11.77 to 12.75 MPa {120 to 130 kgf/cm²} [1707 to 1849 psi]
	Direct injection	17.70 MPa {180 kgf/cm²} [2560 psi]	18.14 to 19.12 MPa {185 to 195 kgf/cm²} [2631 to 2773 psi]

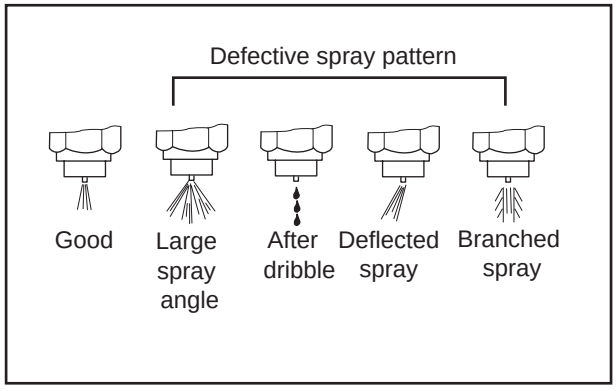
Note: (a) Standard is a value of new parts.
(b) A change in thickness of the shim by 0.1 mm [0.004 in]results in a change in the fuel injection pressure by 1.0 MPa {10kgf/cm² } [142 psi].
There are ten kinds of shim from 1.25 to 1.70 mm [0.0492 to 0.0669 in].



Inspecting fuel injection nozzle with nozzle tester

2.7 Inspecting fuel spray pattern of fuel injection nozzle

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



Inspecting fuel injection nozzle spray condition

2.8 Cleaning and inspecting nozzle tip

(1) Clean the needle valve and body of the nozzle tip in a clean wash oil.

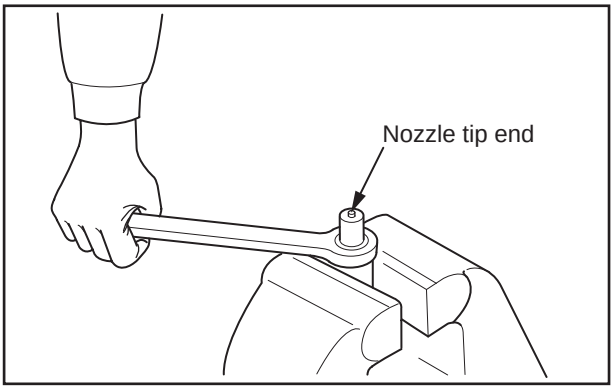
(2) After cleaning, assemble the needle valve and the body in a clean gas oil.

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

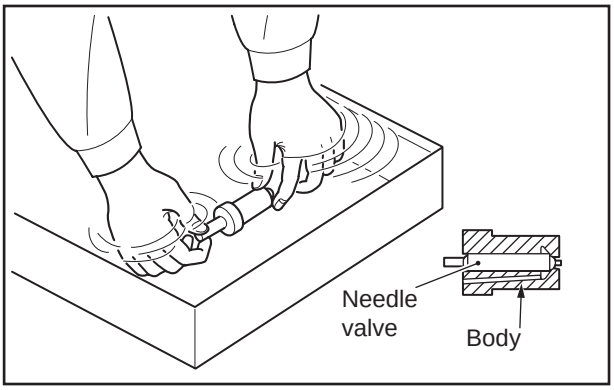
(3) Tighten the nozzle tip tightening retainer nut to the specified torque.

(4) If the spray pattern is still faulty after cleaning and adjusting, change the nozzle tip with a new one.

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

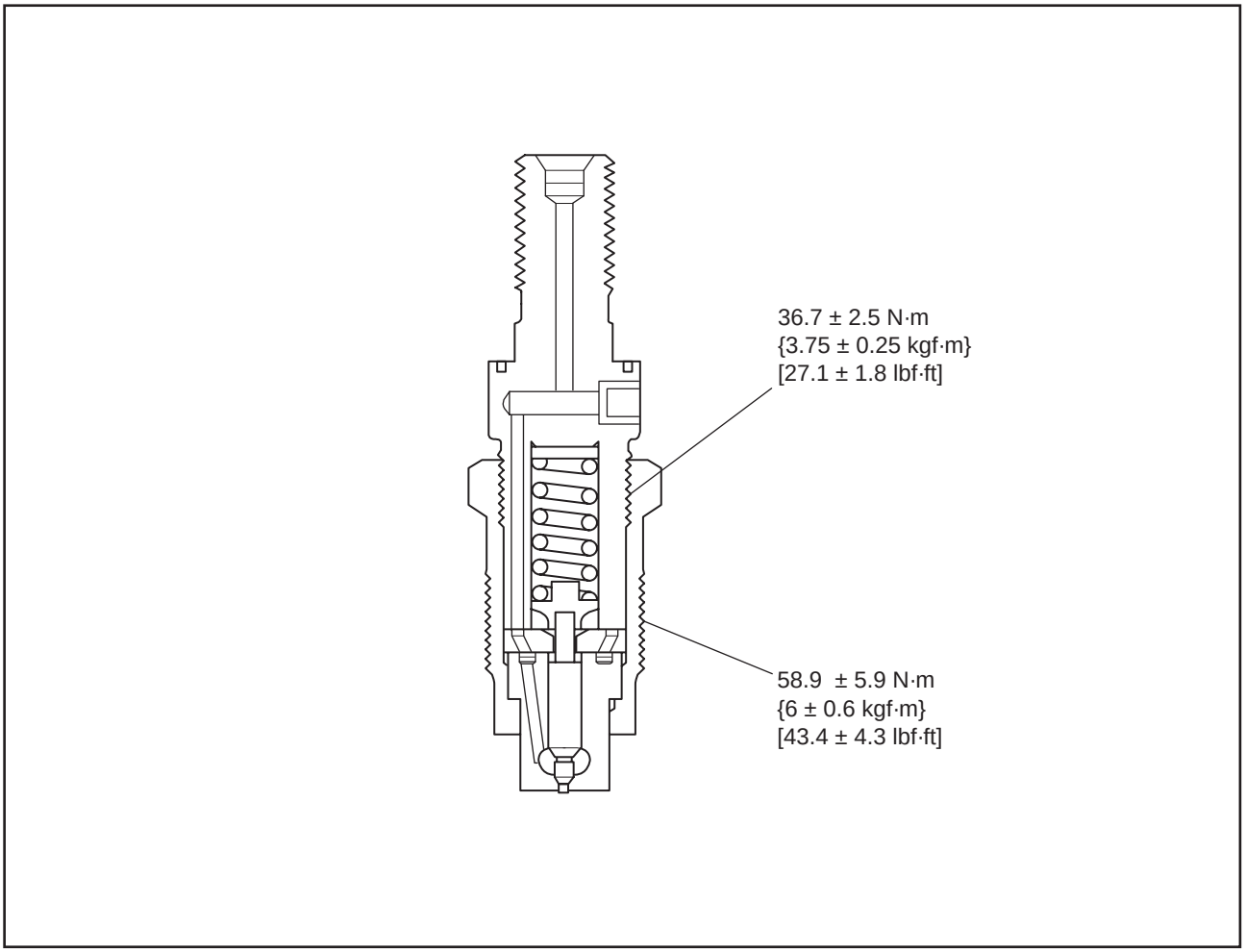


Replacing fuel injection nozzle tip



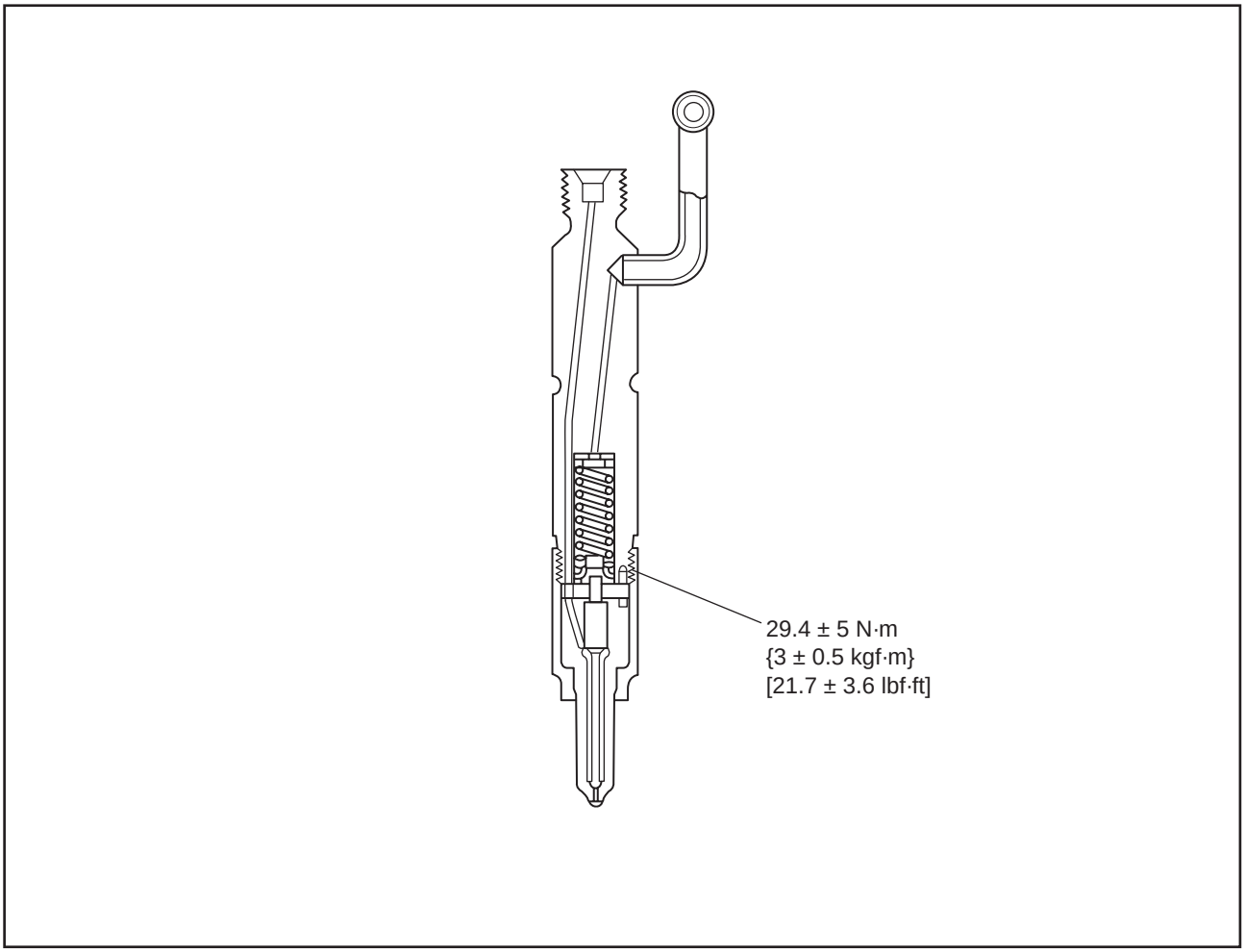
Cleaning nozzle tip assembly

2.9 Reassembling fuel injection nozzle (swirl chamber type)



Reassembling fuel injection nozzle (swirl chamber type)

2.10 Reassembling fuel injection nozzle (direct injection type)



Reassembling fuel injection nozzle (direct injection type)

2.11 Inspecting and cleaning gauze filter of distribute type fuel injection pump (Bosch)

⚠ WARNING

Keep flames away when handling a diesel fuel. Wipe off any spilled fuel thoroughly.
Spilled fuel could cause a fire.

CAUTION

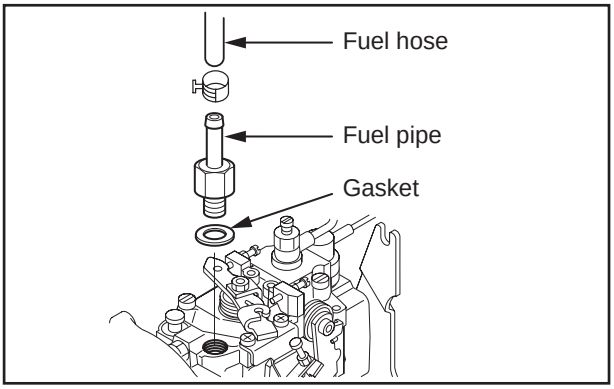
Cover the openings on the fuel injection pump to prevent dust from entering the fuel system.

When output shortage and/or hunting of the engine occured, the gauze filter may be dirty. Clean the gauze filter accordingly.

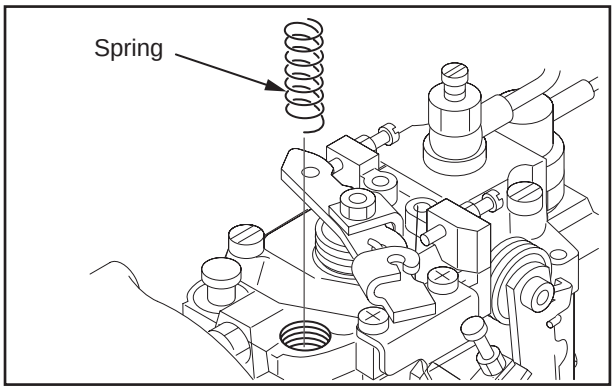
(1) Clean around the injection pump.
(2) Drain the fuel in the injection pump, and remove the fuel hose and fuel pipe.
(3) Remove the spring with a tweezer.
(4) Remove the gauze filter with a tweezer.

Note: When removing the gauze filter, be careful not to damage the metal mesh of the gauze filter.

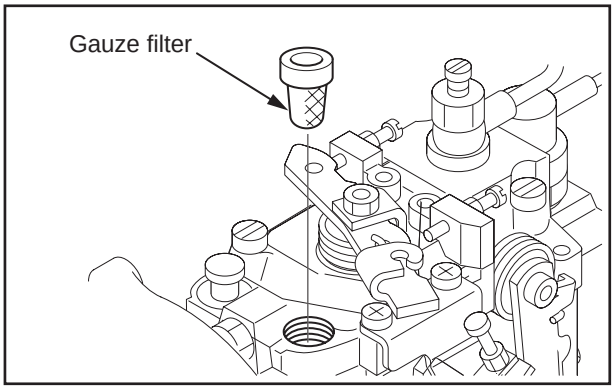
(5) Remove the dirt and dust from the gauze filter cleaning with compressed air or diesel fuel. When damage is found, or when the gauze filter is still dirty after cleaning, replace the gauze filter with a new one.
(6) Install the cleaned gauze filter and new gasket, and in reverse order of disassembly, install the fuel pipe and fuel hose.



Removing fuel hose and fuel pipe



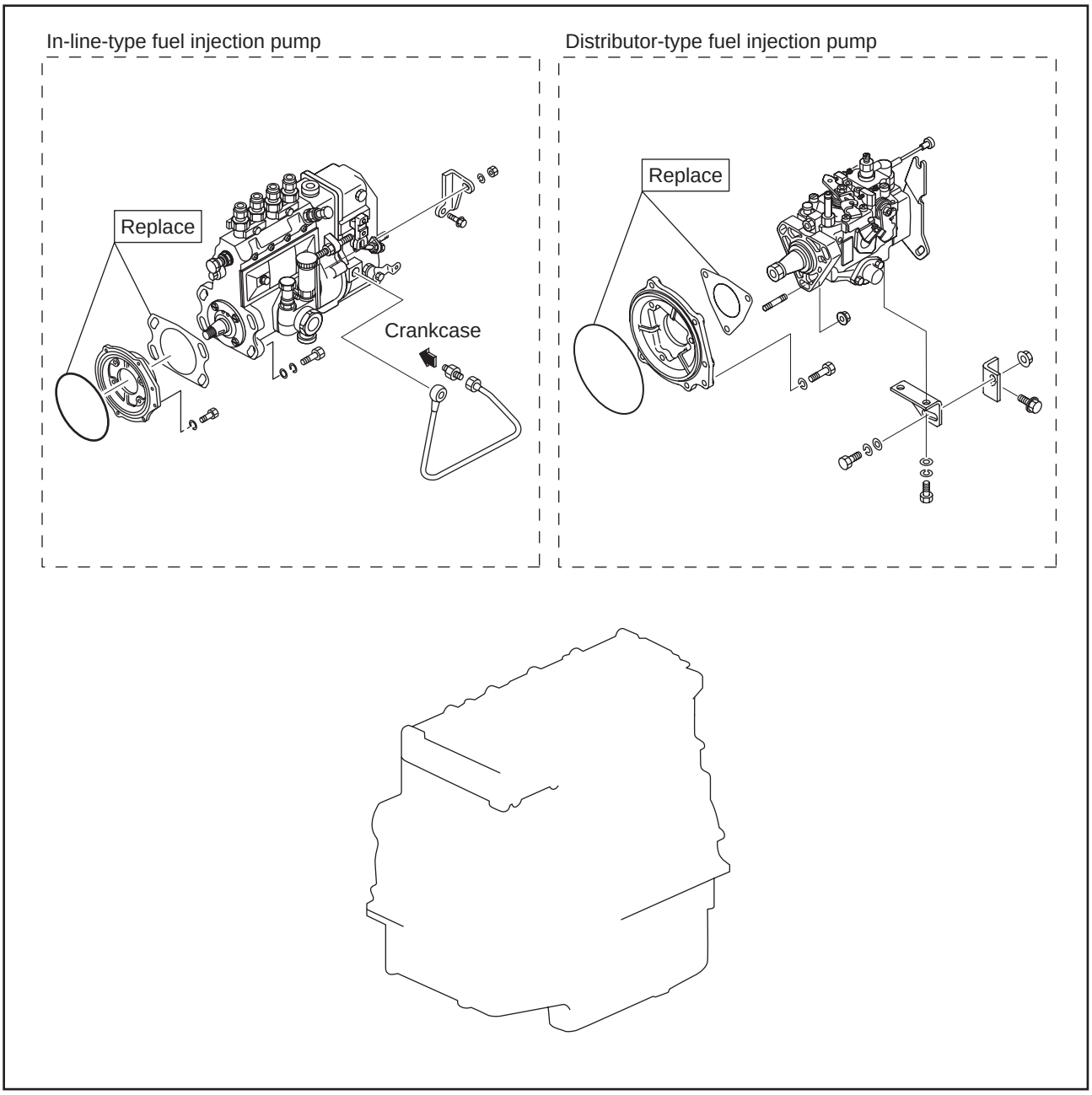
Removing spring



Removing gauze filter

3. Installing fuel system

3.1 Installing fuel injection pump



Installing fuel injection pump

3.2 Checking fuel injection timing (in-line fuel injection pump type)

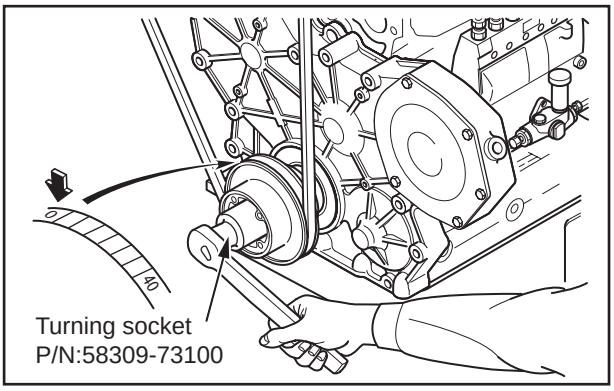
The fuel injection timing varies with the output, speed and other engine specifications. Be sure to check the engine's specification sheet.

3.2.1 Determining top dead center of No.1 cylinder compression stroke

(1) Attach a socket and rachet handle to the nut of crankshaft pulley, and rotate the crankshaft in the normal direction (clockwise when viewed from the front of the engine).

(2) Stop turning the crankshaft when "0" notch mark stamped on crankshaft pulley is aligned with the timing gear pointer.

(3) At this position, move the rocker arms of the inlet and exhaust valves for the No.1 cylinder up and down, and make sure there is clearance, that is, the pushrods are not pushing the inlet and exhaust valves off their seats.



Determining top dead center of No.1 cylinder compression stroke

3.2.2 Checking fuel injection timing

(1) Bring the piston to the top, and check the 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.

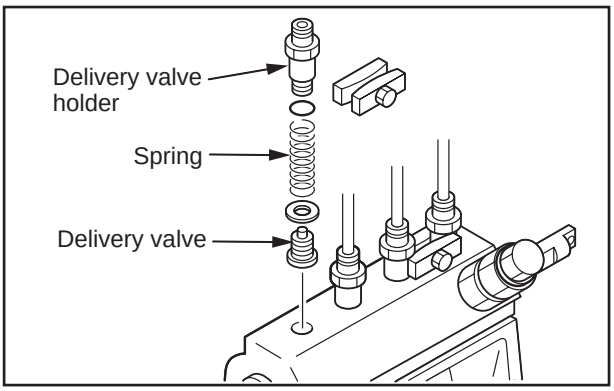
(2) Install a spare injection pipe to the No.1 plunger of the fuel injection pump. Face the other end of the injection pipe to downward so that the fuel flow-out condition can be seen clearly.

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

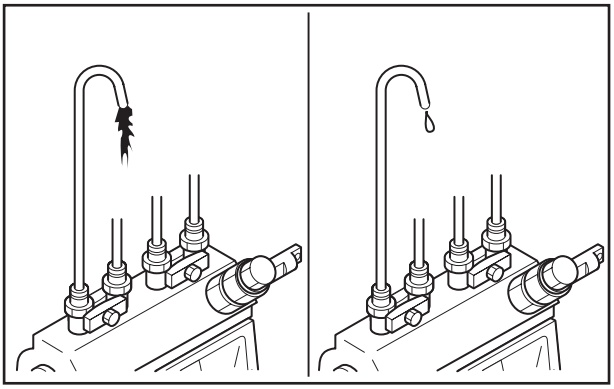
(4) Feed the injection pump using the priming pump. With flowing the fuel out from the injection pipe, rotate the crankshaft gradually in the normal direction.

(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)

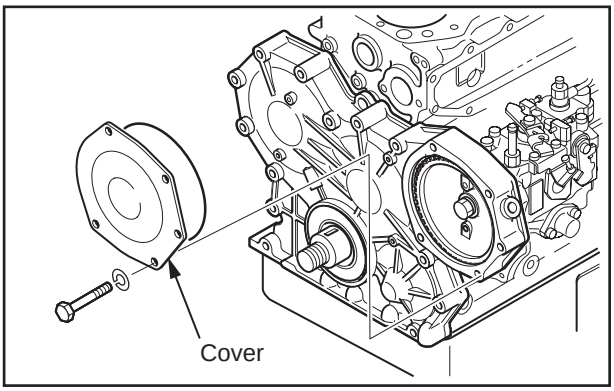
3.3 Inspecting fuel injection timing (distributor-type fuel injection pump)

3.3.1 Inspecting fuel injection timing

When the fuel injection pump is replaced, confirm the fuel injection timing after the replacement.

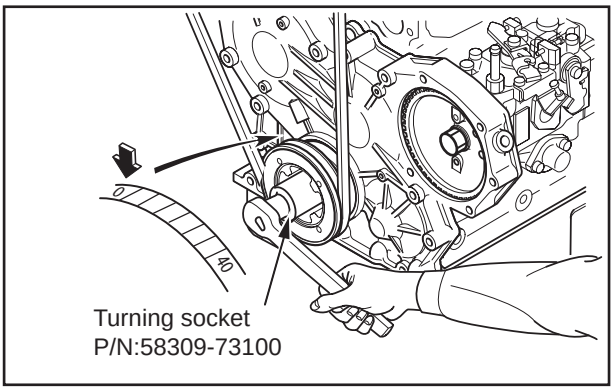
To confirm it, bring No. 1 cylinder piston to the top dead center on compression stroke. Make sure that the marks on the flange plate and the fuel injection pump body are aligned.

(1) Remove the gear case cover.



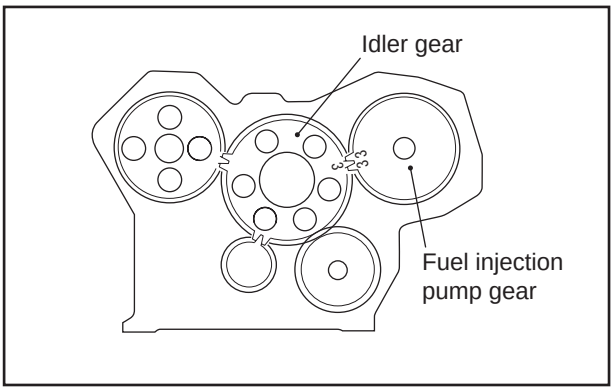
Removing gear case cover

(2) Attach the turning socket to the pulley nut and turn the crankshaft in the normal direction (clockwise as viewed from the front end).



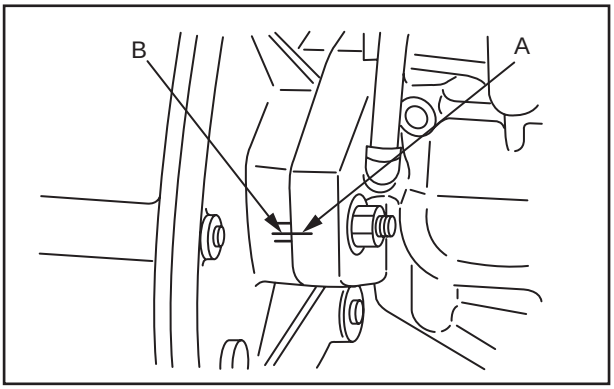
Turning engine

(3) Stop turning the crankshaft when the marks of the fuel injection pump gear and idler gear are aligned.



Match mark of gears

(4) Put a mark B on the flange plate where aligned with the mark A of the fuel injection pump.



Alignment mark of fuel injection pump

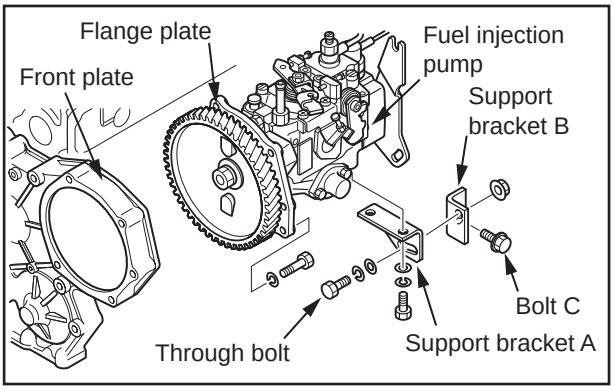
CAUTION

When removing the flange plate from the fuel injection pump assembly, be sure to put a mark on the flange plate before removal to ensure proper reassembly.

(5) Remove the pump bracket retaining bolt C.

(6) Unscrew the flange plate retaining bolt and remove the fuel injection pump from the front plate.

(7) Remove the retaining bolt and support bracket A and B, remove the flange plate from the fuel injection pump.



Removing fuel injection pump

CAUTION

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

(b) Take care that the parts may be partly modified due to improvement, for example.

(c) Work related to the exhaust emission regulations can be conducted only at our designated service factories.
However, do not change the adjustment by cutting and removing the tamper-proofs on the fuel injection pump assembly.

(d) The fuel injection pump must be replaced as an assembly.

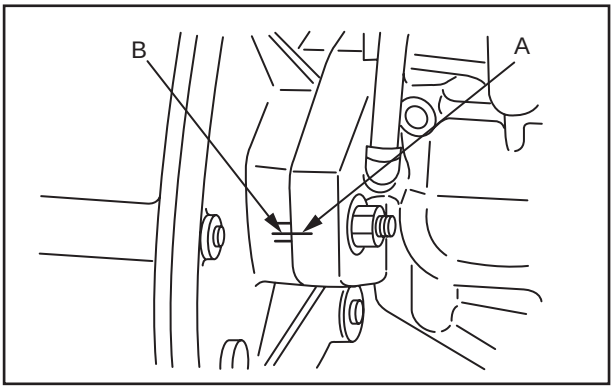
(8) Replace the fuel injection pump with a new one.

(9) Replace the gasket installed between flange plate and the fuel injection pump with a new one.
Install the flange plate and the fuel injection pump gear to the fuel injection pump.

(10) Align the mark A of the fuel injection pump with the mark B which was marked above procedure (4) and tighten the nut. Then install the retaining bolt to the nut.

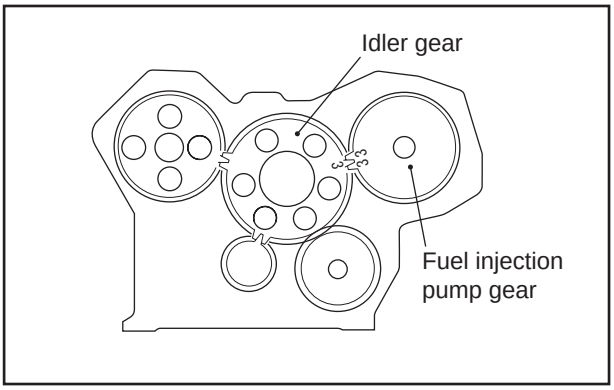
(11) Install the support bracket A onto the fuel injection pump.

(12) Install the support bracket B onto the support bracket A, and temporary tighten with through bolt and nut.



Alignment mark of fuel injection pump

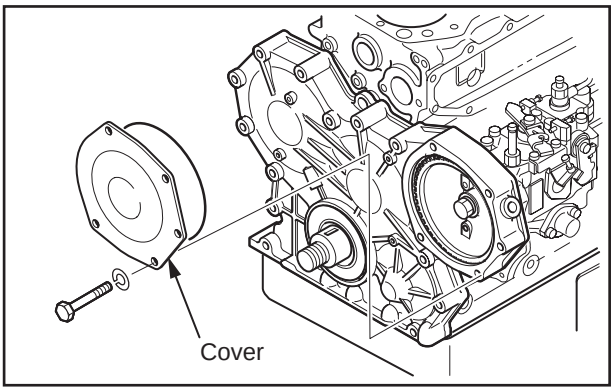
(13) By aligning the timing marks of the fuel injection pump gear and the idler gear, install the fuel injection pump to the front plate.



Match mark of gears

(14) Install the gear case cover.

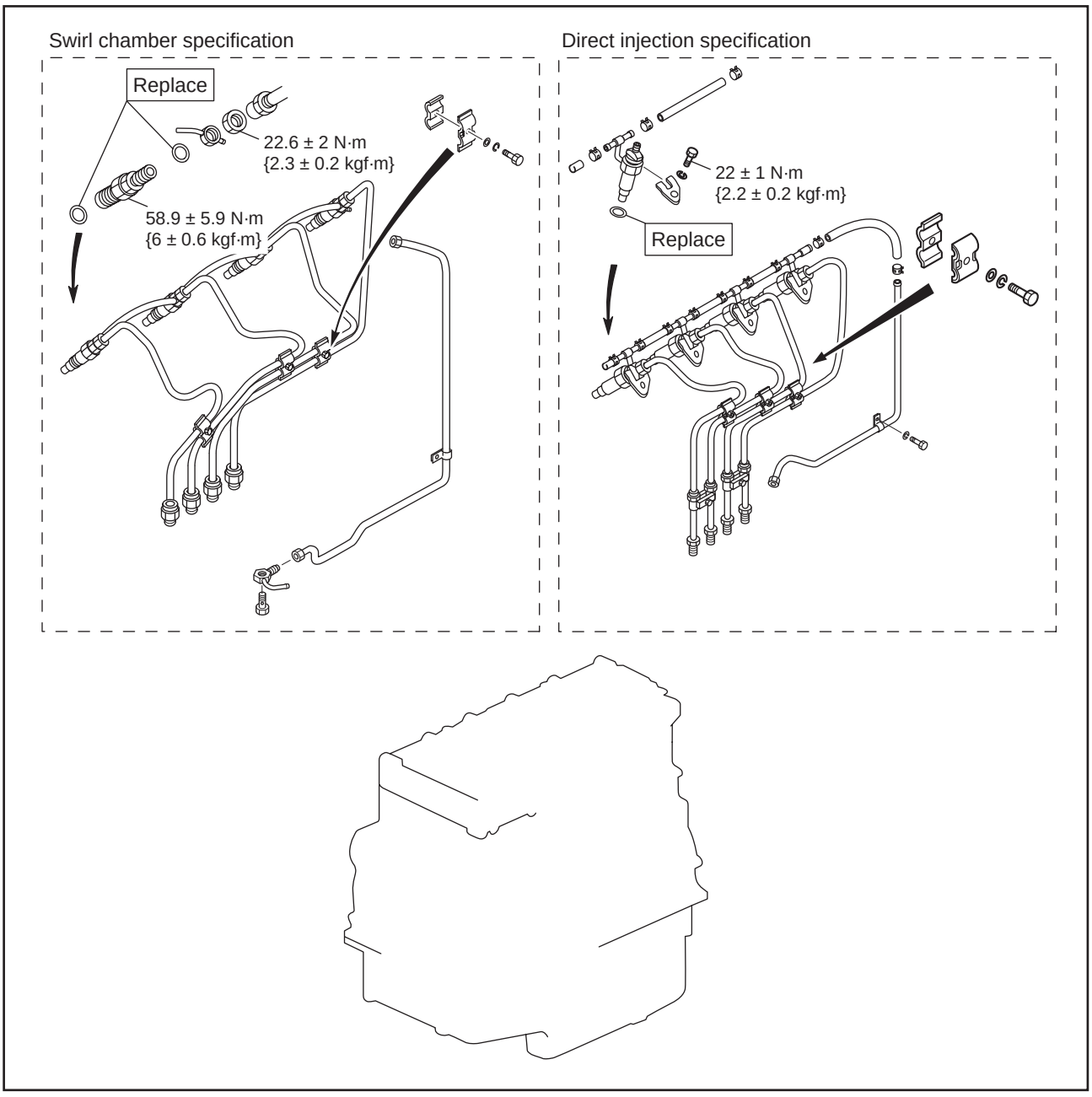
(15) Install the through bolt and nut of the support bracket A, and install the bolt C.



Removing gear case cover

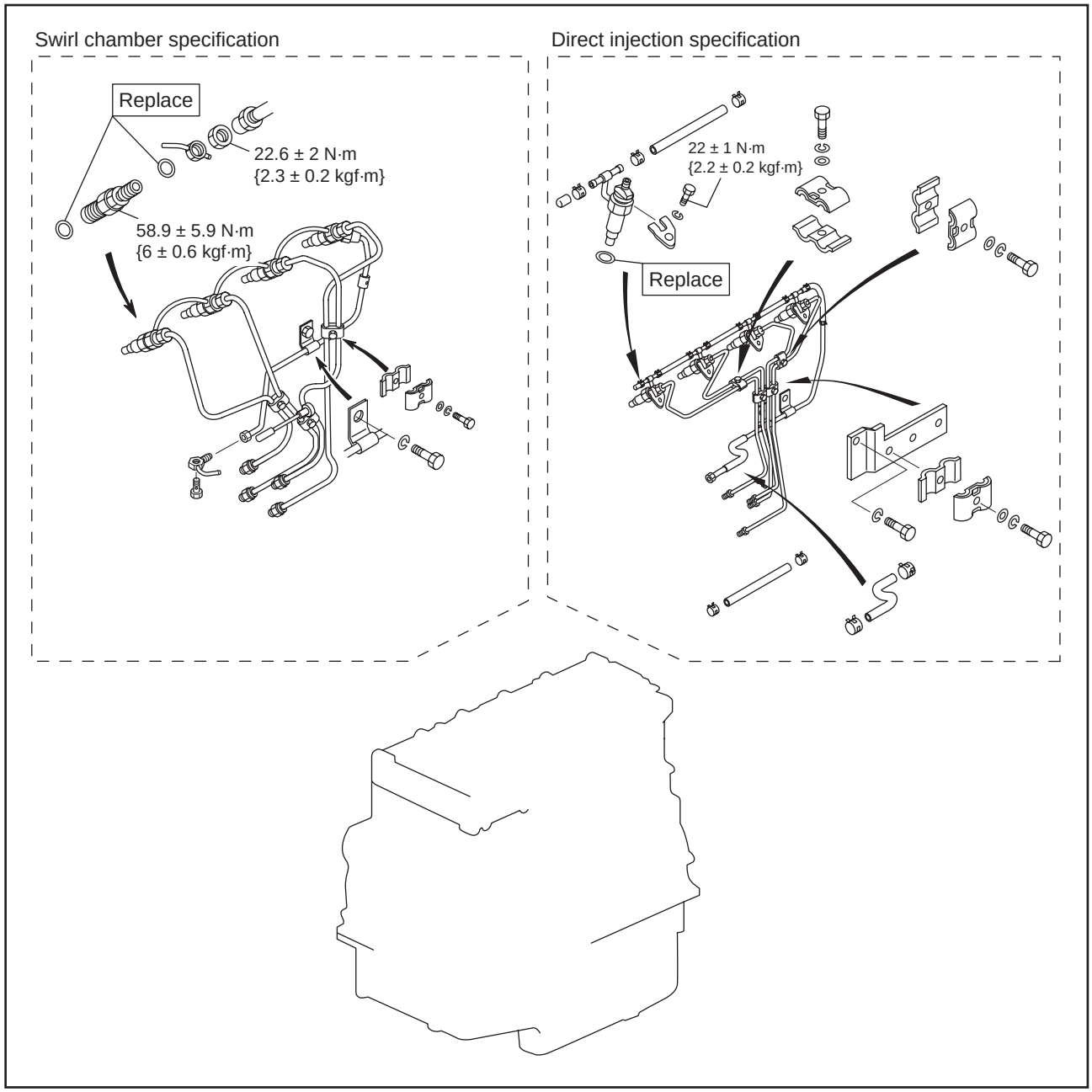
3.4 Installing fuel injection pipe, fuel leak-off pipe and fuel injection nozzle

3.4.1 Installing fuel injection pipe, fuel leak-off pipe and fuel injection nozzle (in-line type fuel injection pump)



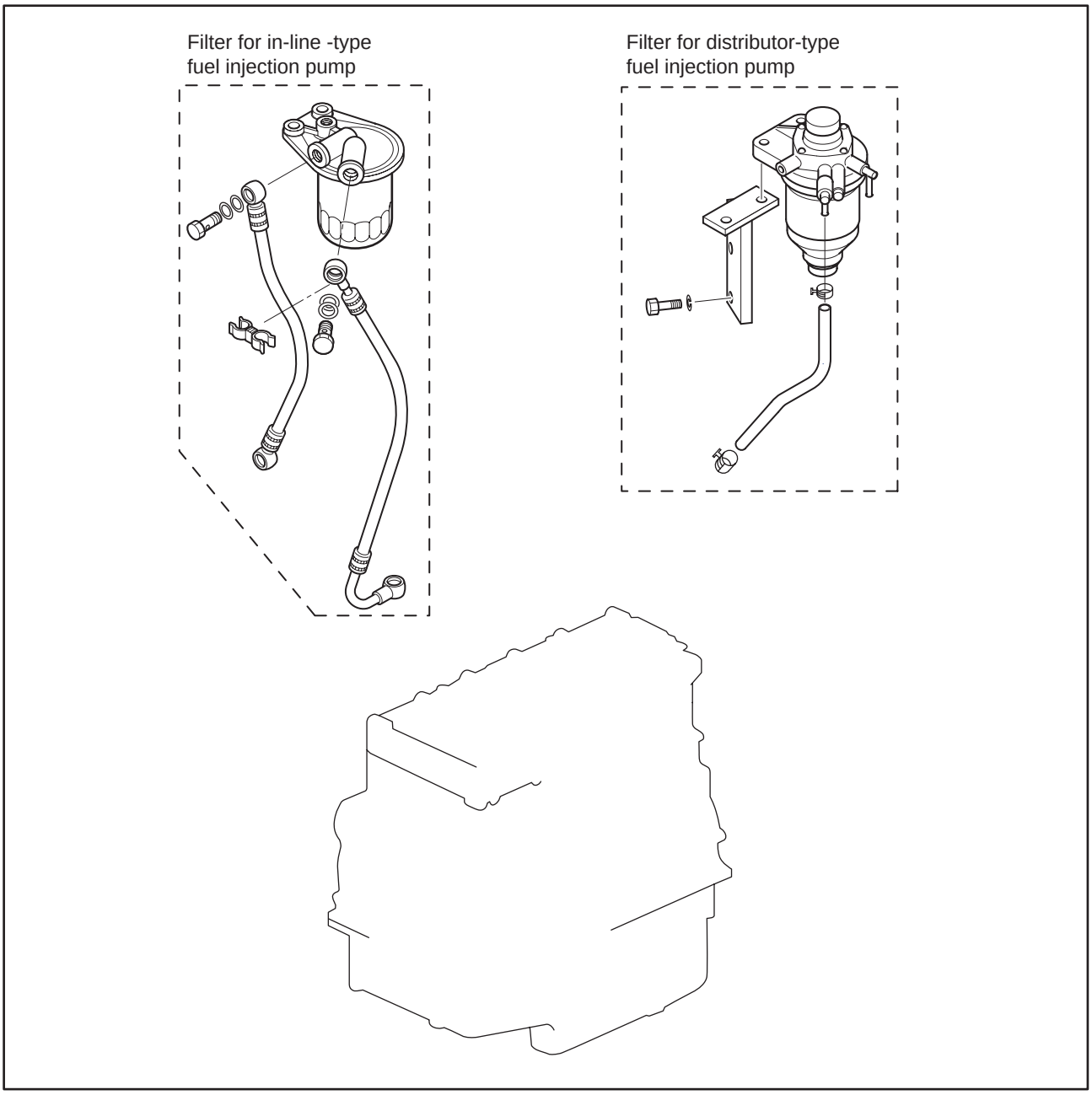
Installing fuel injection pipe, fuel leak-off pipe and fuel injection nozzle
(in-line type fuel injection pump)

3.4.2 Installing fuel injection pipe, fuel leak-off pipe and fuel injection nozzle (distributor-type fuel injection pump)



Installing fuel injection pipe, fuel leak-off pipe and fuel injection nozzle
(distributor-type fuel injection pump)

3.5 Installing fuel filter and fuel pipe

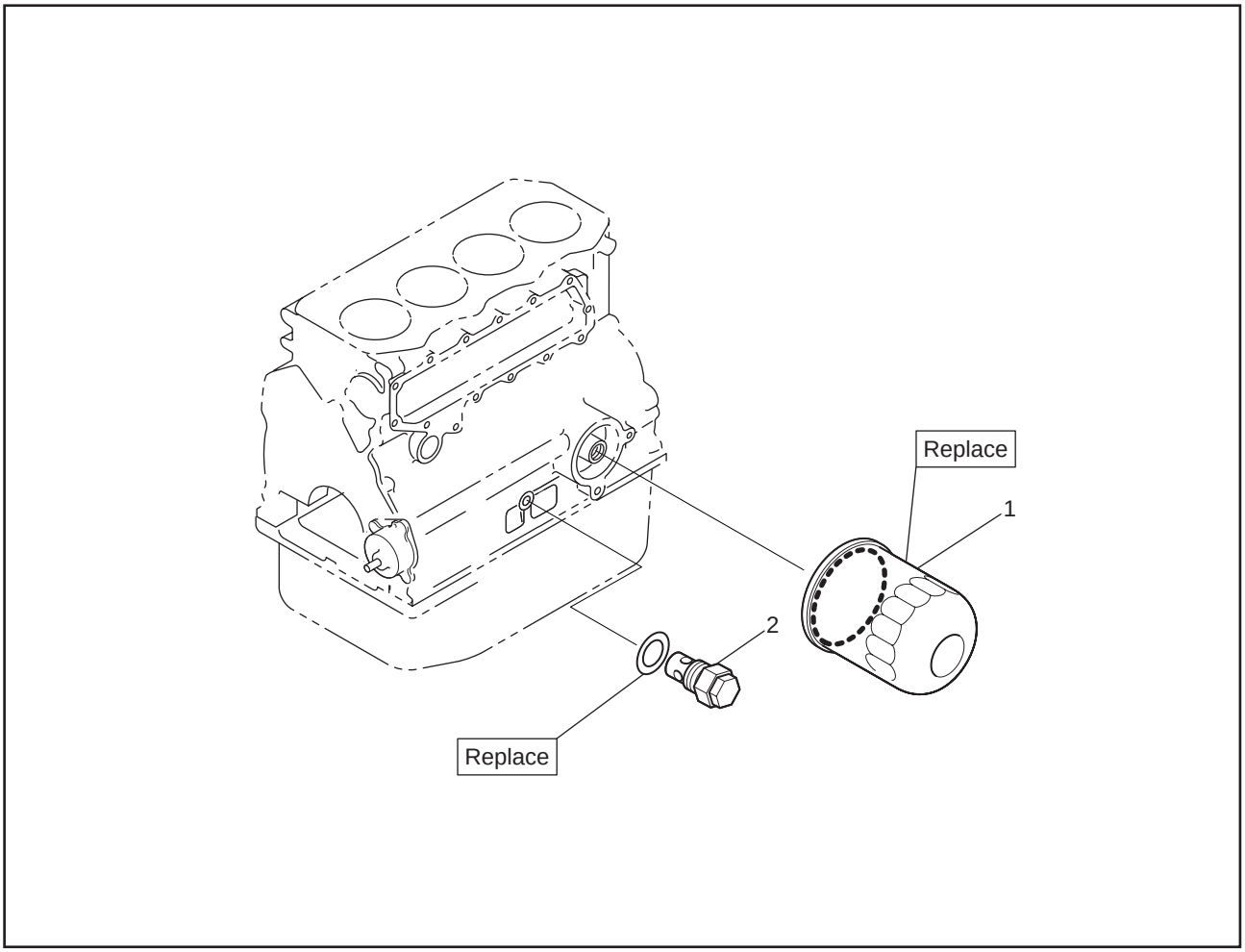


Installing fuel filter and fuel pipe

LUBRICATION SYSTEM

1. Removing lubrication system

1.1 Removing oil filter and relief valve

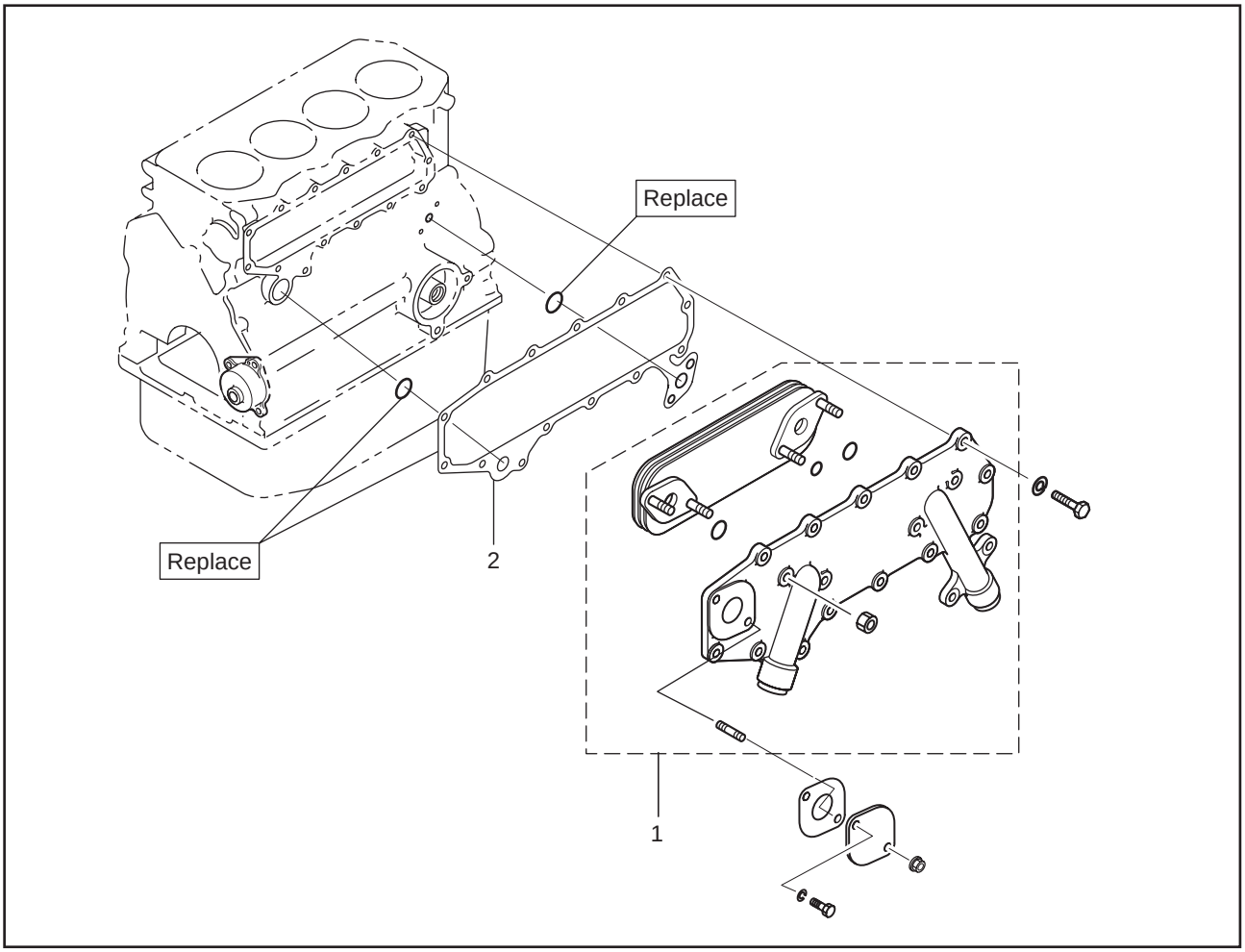


Removing oil filter and relief valve

Removing sequence

1 Oil filter
2 Relief valve

1.2 Removing oil cooler

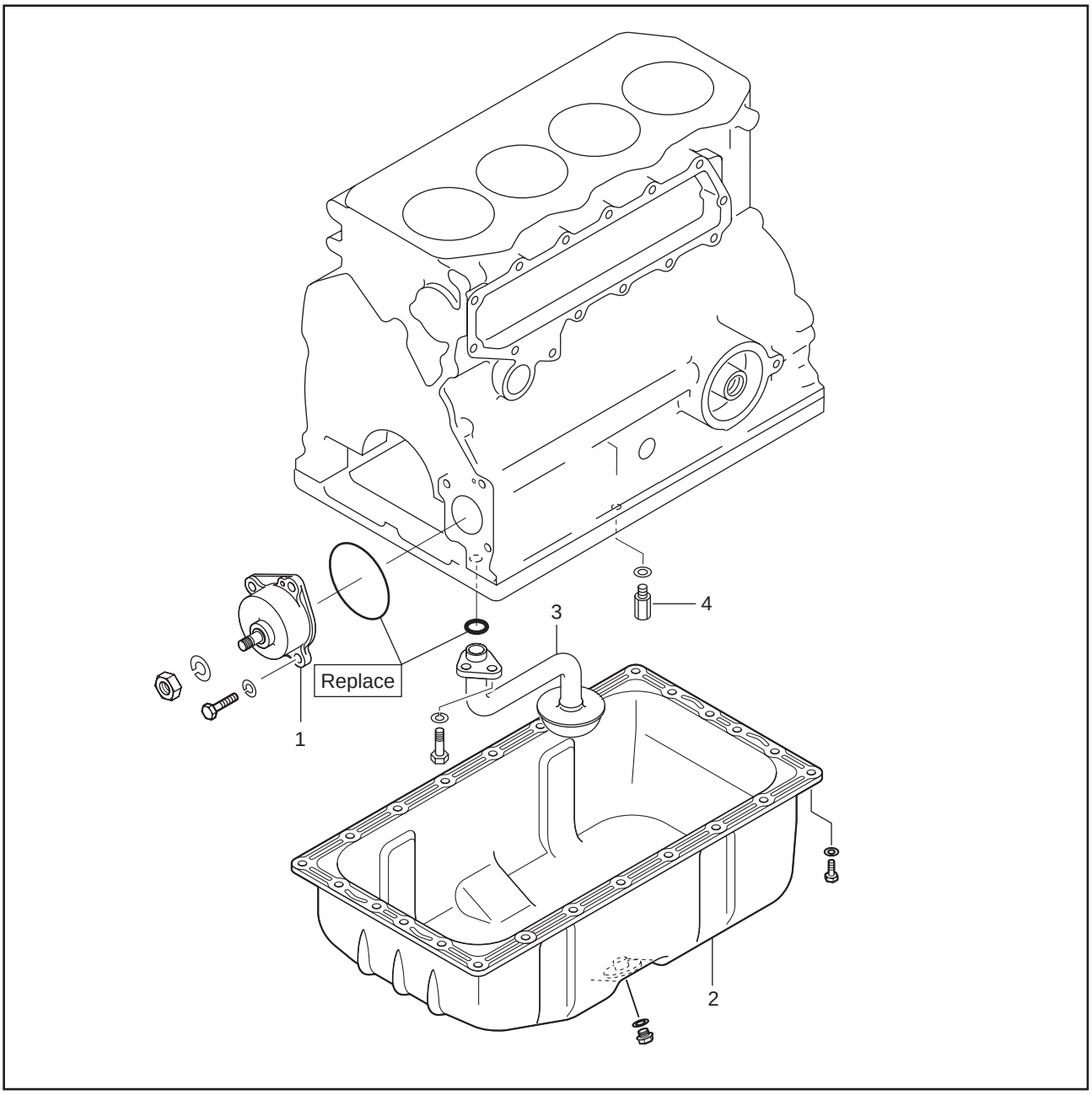


Removing oil cooler

Removing sequence

1 Oil cooler assembly
2 Oil cooler gasket

1.3 Removing oil pump, oil pan and oil strainer



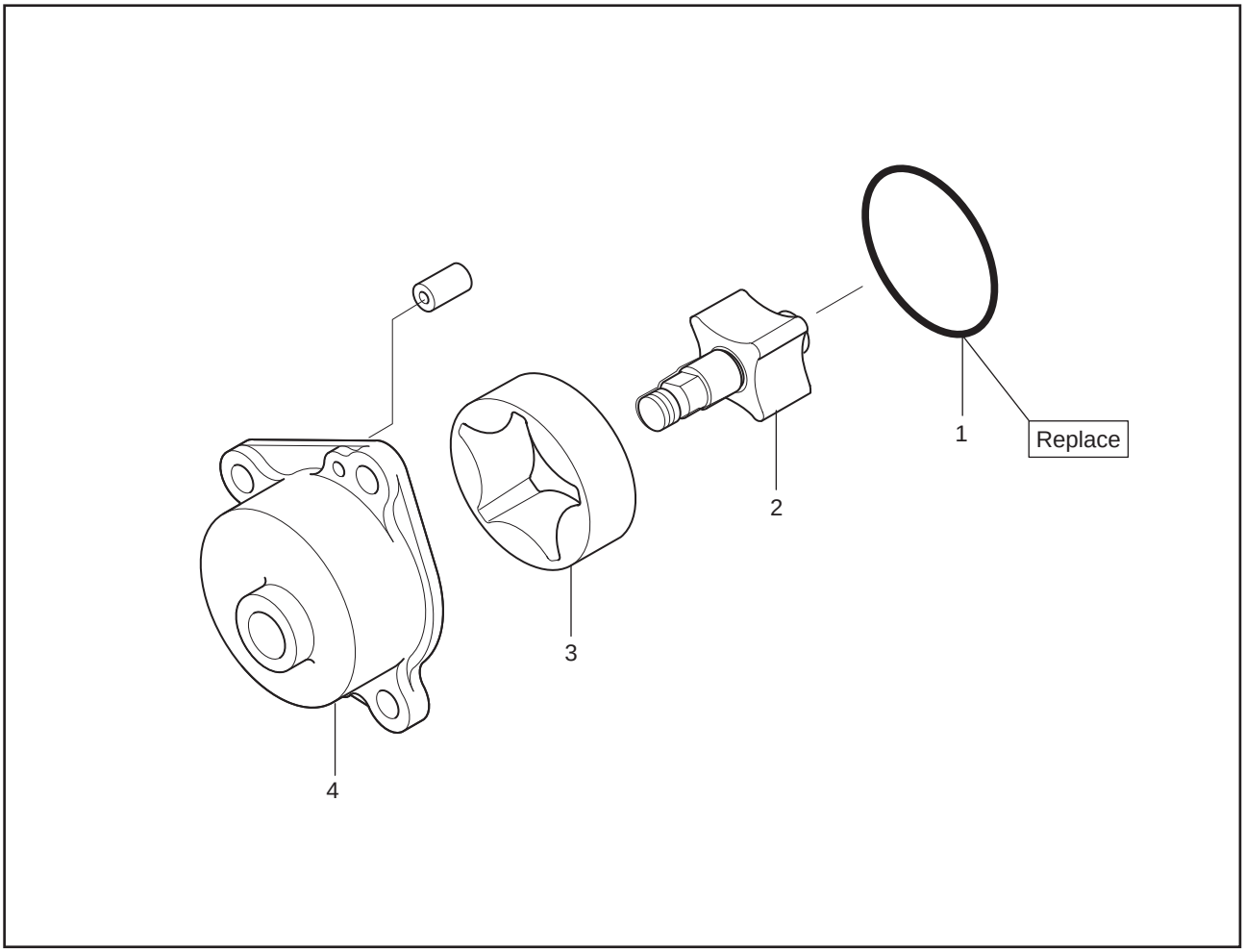
Removing oil pump, oil pan and oil strainer

Removing sequence

1 Oil pump 2 Oil pan 3 Oil strainer 4 Safety valve (for the engine with oil cooler)

2. Disassembling, inspecting and reassembling lubrication system

2.1 Disassembling and inspecting oil pump



Disassembling oil pump

Disassembling sequence

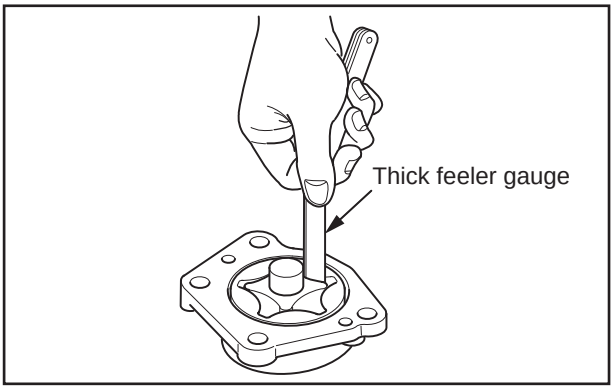
1 O-ring
2 Shaft assembly
3 Outer rotor
4 Pump case

2.2 Inspecting oil pump

2.2.1 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.]

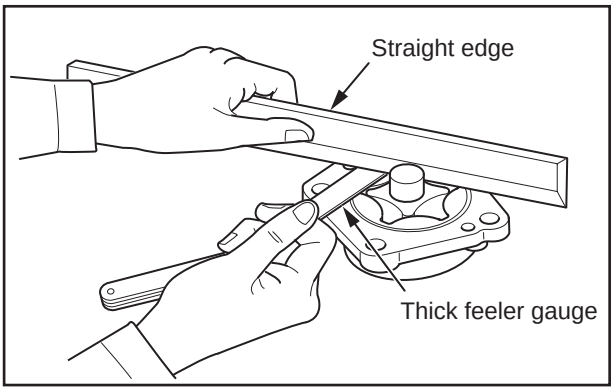


Measuring clearance between outer rotor and inner rotor

2.2.2 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.]

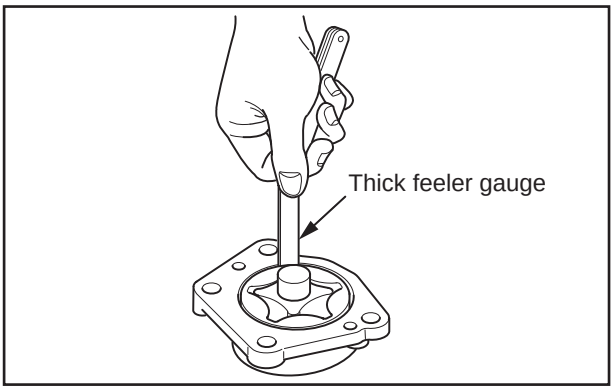


Measuring end play of rotor and pump case

2.2.3 Measuring clearance between outer 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 case	0.20 to 0.30 mm [0.0079 to 0.0118 in.]	0.50 mm [0.0197 in.]

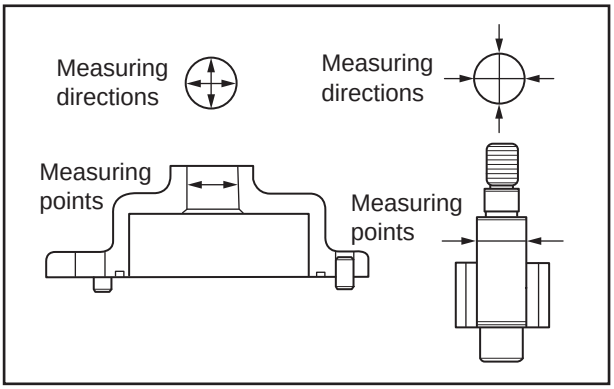


Measuring clearance between outer rotor and pump case

2.2.4 Measuring clearance between main shaft and pump case

Measure the diameter of the shaft and the inside diameter of the bore in the case for the shaft to find the clearance between the two. If the clearance exceeds the limit, replace the oil pump assembly.

Item	Standard	Limit
Main shaft outside diameter (between case)	15.985 to 16.000 mm [0.6293 to 0.6299 in.]	-
Clearance between main shaft and pump case	0.032 to 0.074 mm [0.0013 to 0.0029 in.]	0.150 mm [0.0059 in.]

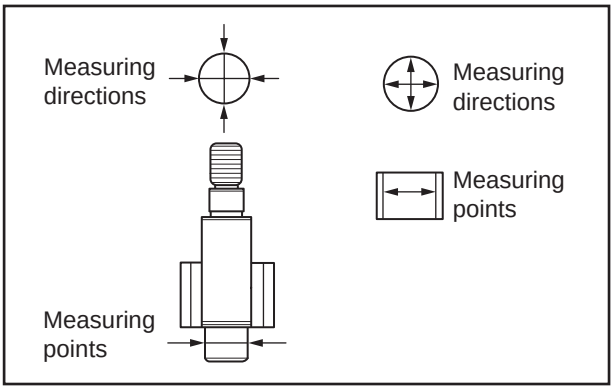


Measuring clearance between main shaft and pump case

2.2.5 Measuring clearance between main shaft and bushing

Measure the diameter of the main shaft and the inside diameter of the oil pump bushing in the crankcase to find the clearance between the two. If the clearance exceeds the limit, replace the bushing or the oil pump assembly.

Item	Standard	Limit
Main shaft outside diameter (between oil pump bushing)	13.957 to 13.975 mm [0.5495 to 0.5502 in.]	-
Clearance between main shaft and oil pump bushing	0.025 to 0.111 mm [0.0010 to 0.0044 in.]	0.200 mm [0.0079 in.]



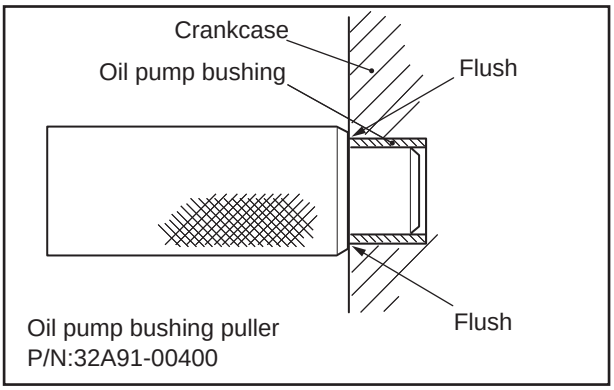
Measuring clearance between main shaft and bushing

2.2.6 Installing oil pump bushing

CAUTION

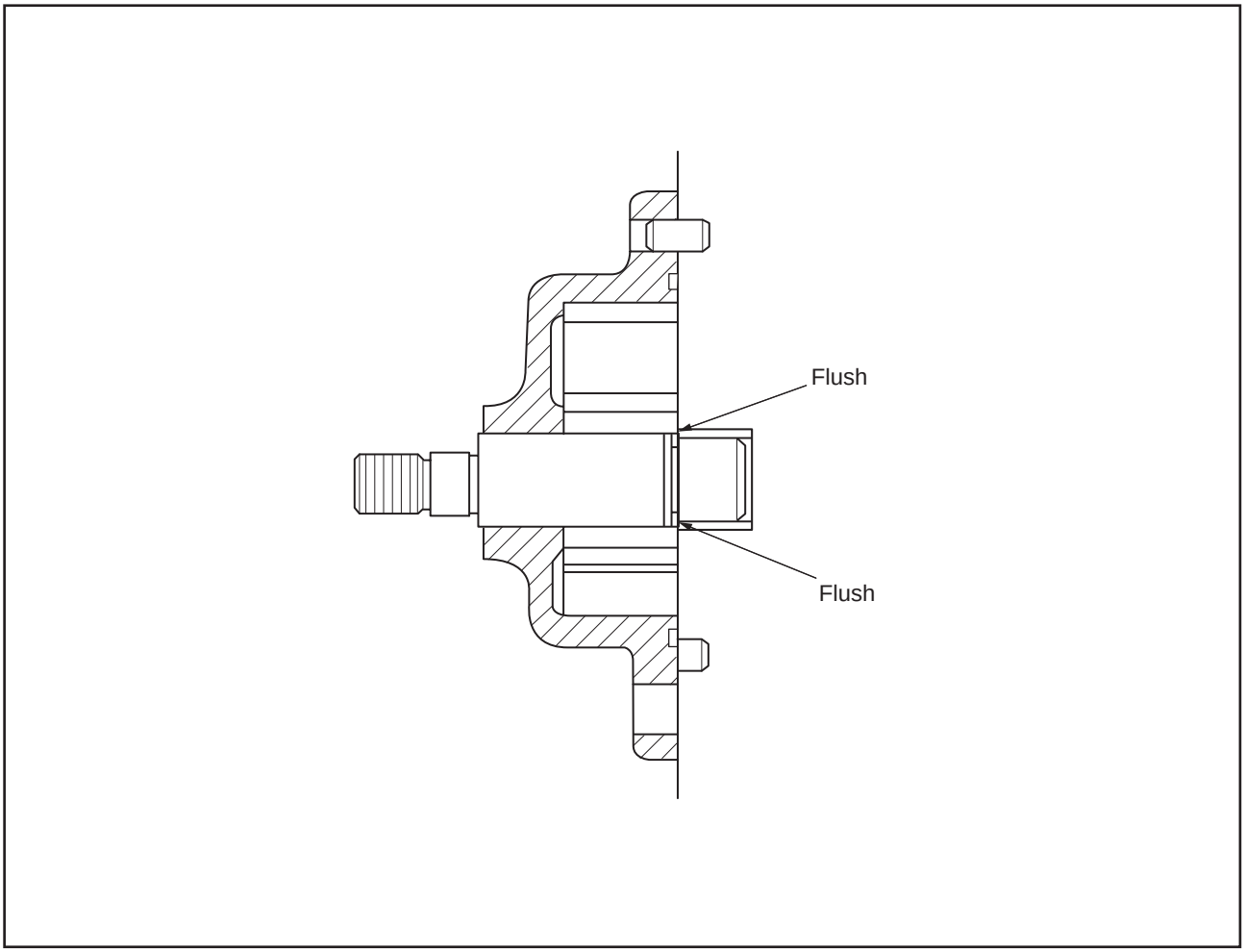
Install the oil pump bushing in the crankcase so that it is even with the front face of the crankcase.

Install the oil pump bushing by using the oil pump bushing installer.



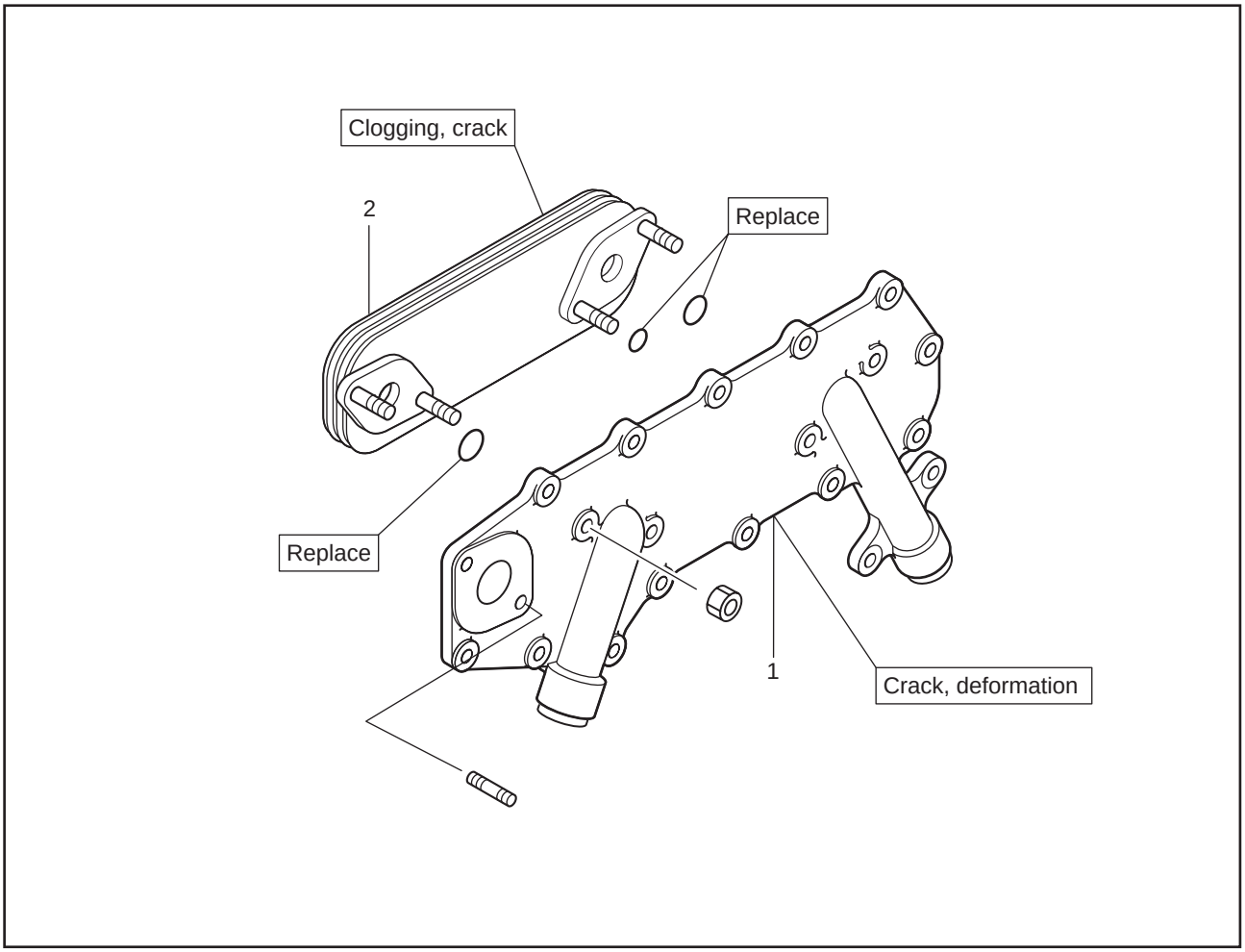
Installing oil pump bushing

2.3 Reassembling oil pump



Reassembling oil pump

2.4 Disassembling and inspecting oil cooler

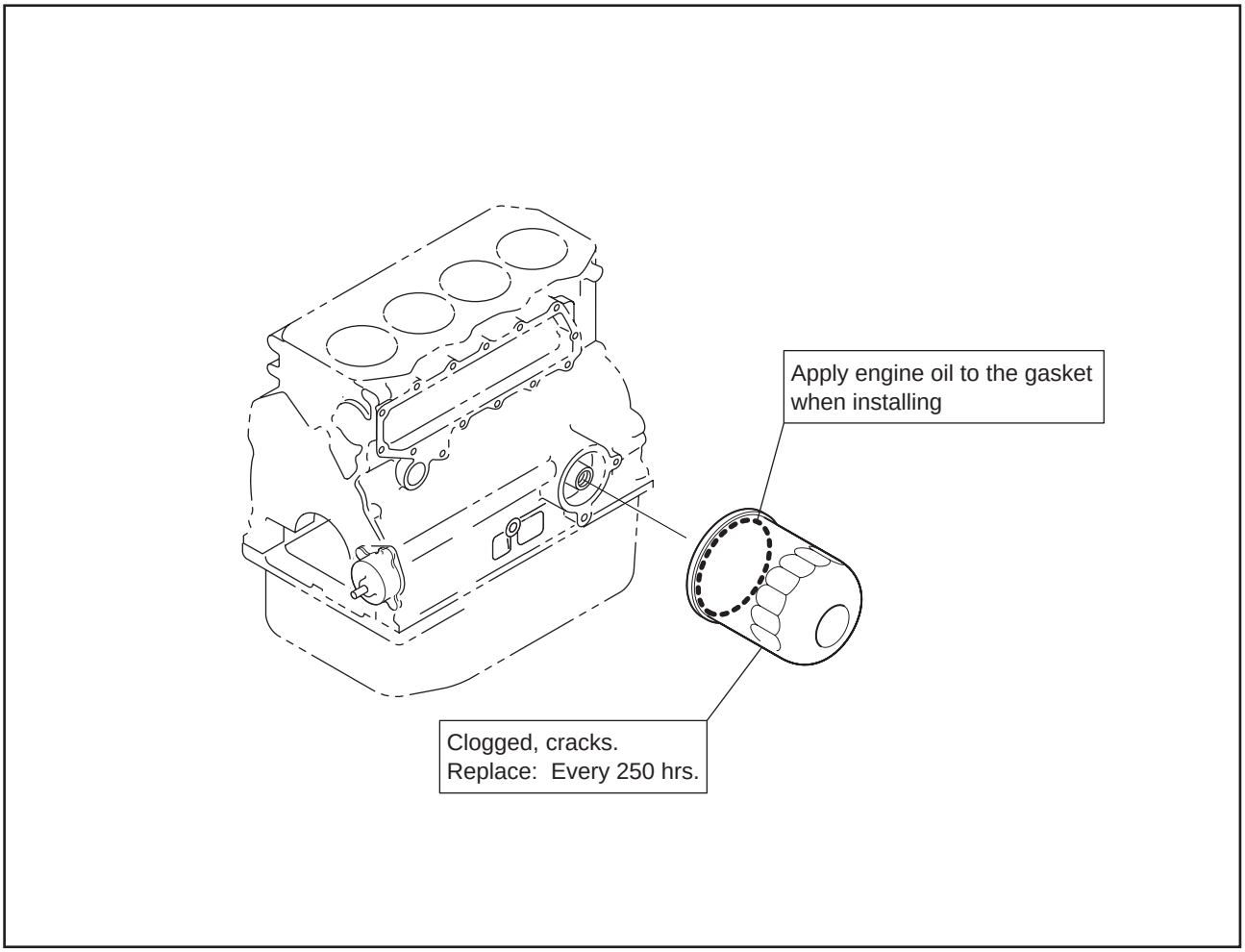


Disassembling and inspecting oil cooler

Disassembling sequence

1 Oil cooler case
2 Oil cooler element

2.5 Inspecting oil filter



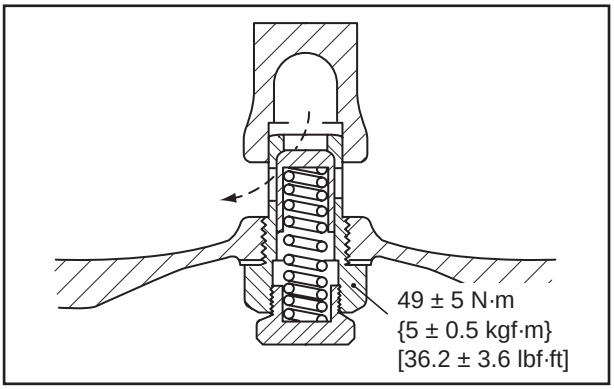
Inspecting oil filter

2.6 Inspecting relief valve

(1) Check the relief valve and its seat for contact. Check the spring for fatigue and damage. If faulty, replace the relief valve with new one.

(2) Measure the relief valve opening pressure. If the pressure does not fall within the standard range, replace the relief valve with new one.

Item	Standard
Relief valve opening pressure	0.35 ± 0.05 MPa {3.5 ± 0.5 kgf/cm²} [49.78 ± 7.11 psi]



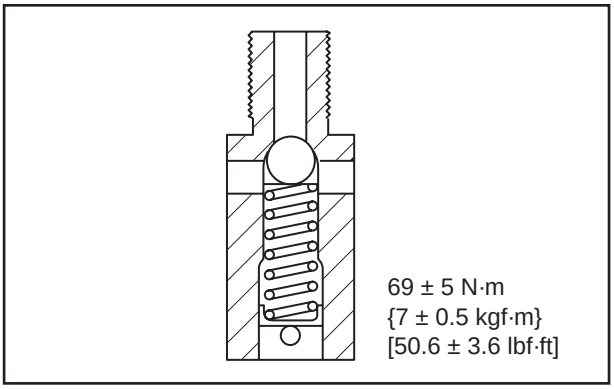
Inspecting relief valve

2.7 Inspecting safety valve (for the engine with oil cooler)

(1) Check the safety valve and its seat for contact. Check the spring for fatigue and damage. If faulty or damaged, replace the part.

(2) Measure the safety valve opening pressure. If the pressure does not fall within the standard range, replace the spring with a new one.

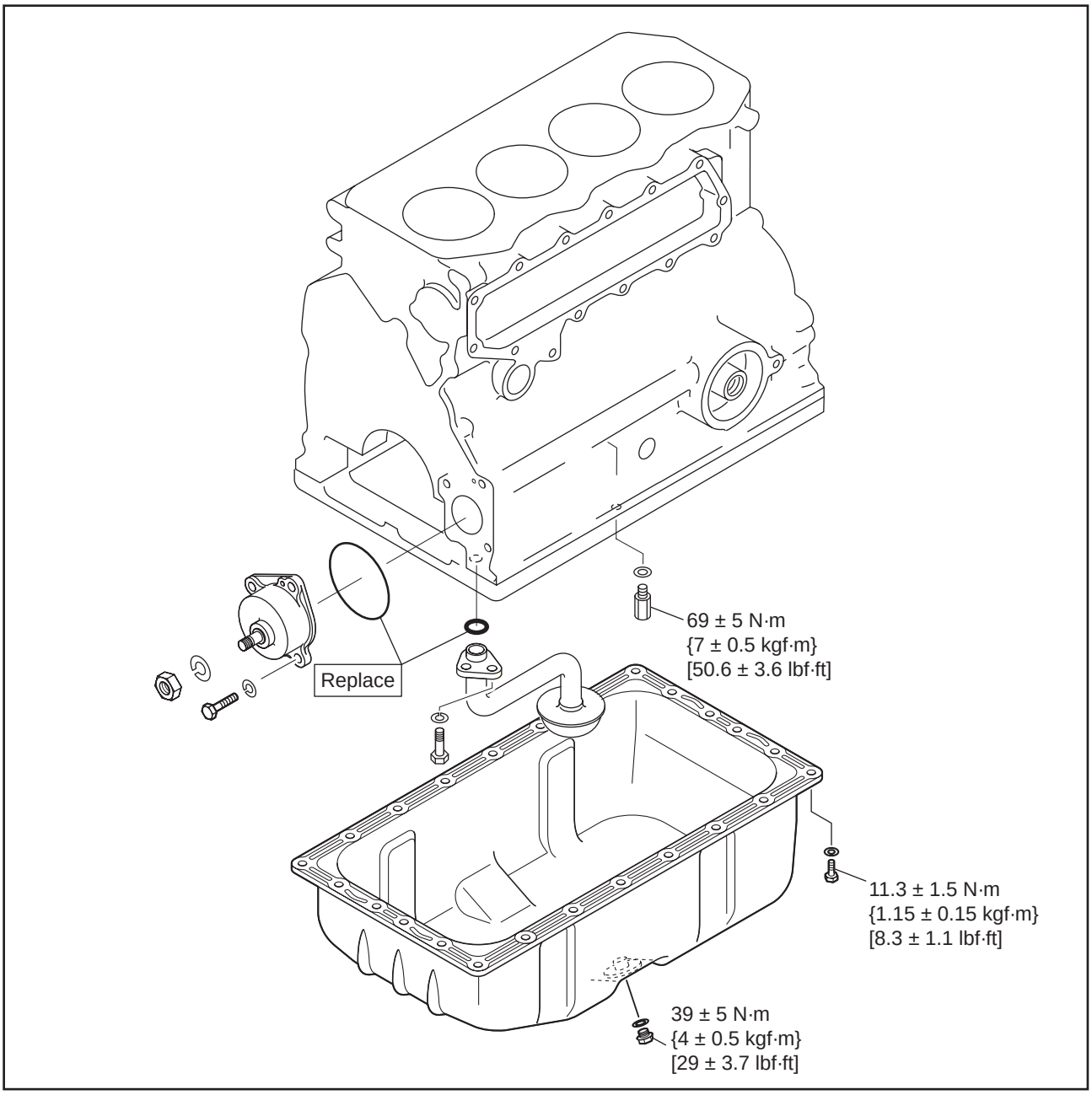
Item	Standard
Safety valve opening pressure	1.1 MPa {11 kgf/cm² } [157 psi]



Inspecting safety valve

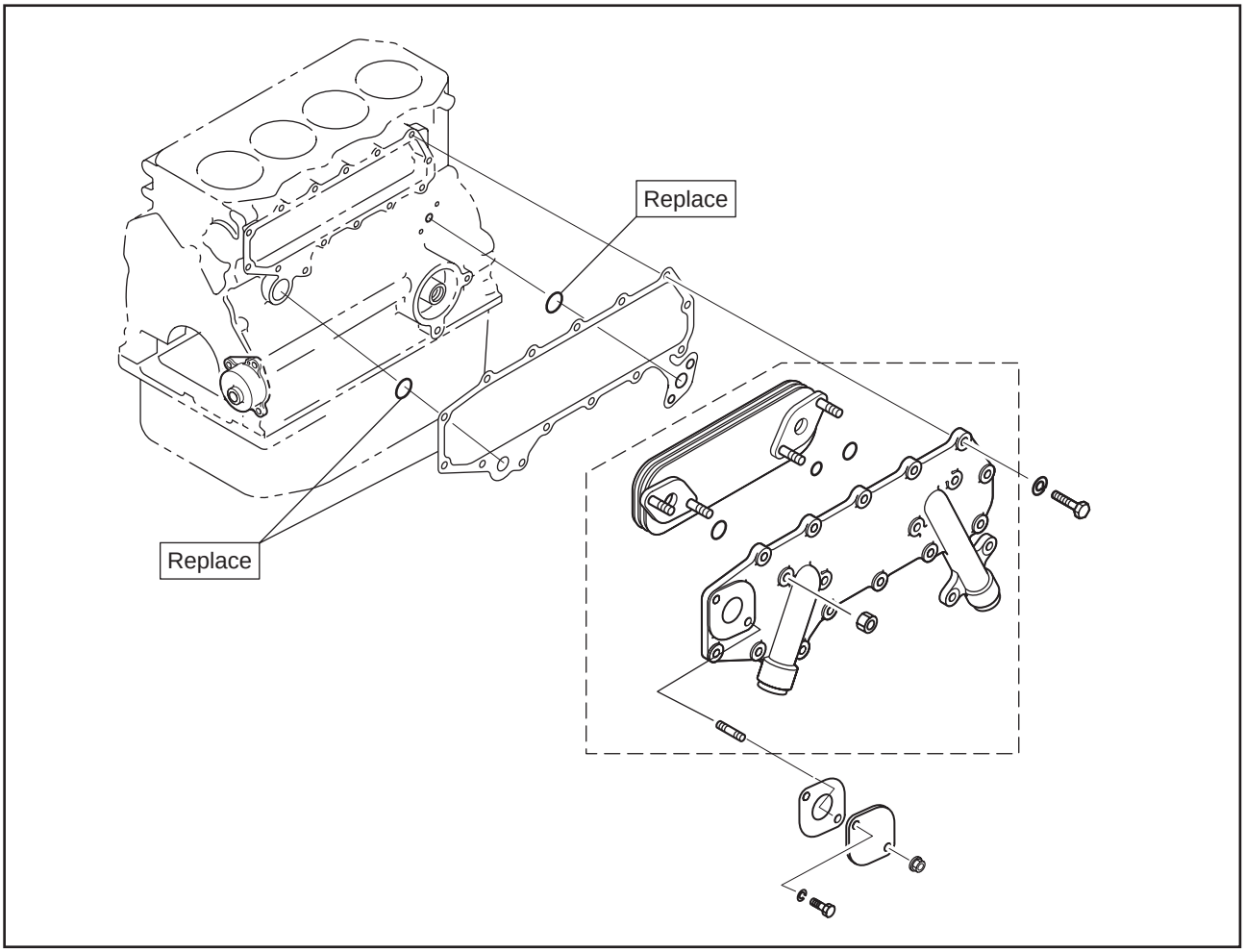
3. Installing lubrication system

3.1 Installing oil pump, oil pan and oil strainer



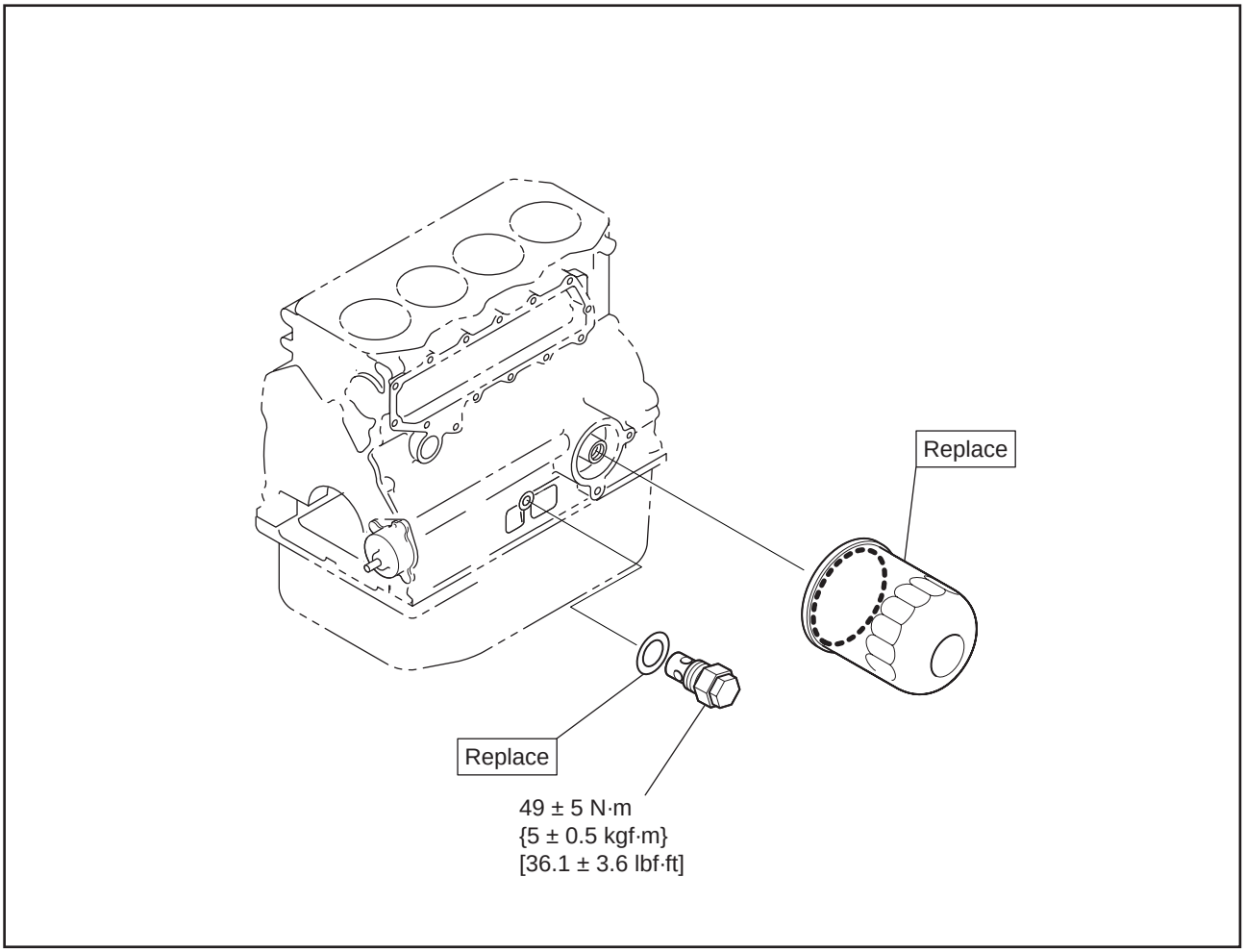
Installing oil pump, oil pan and oil strainer

3.2 Installing oil cooler



Installing oil cooler

3.3 Installing oil filter and relief valve

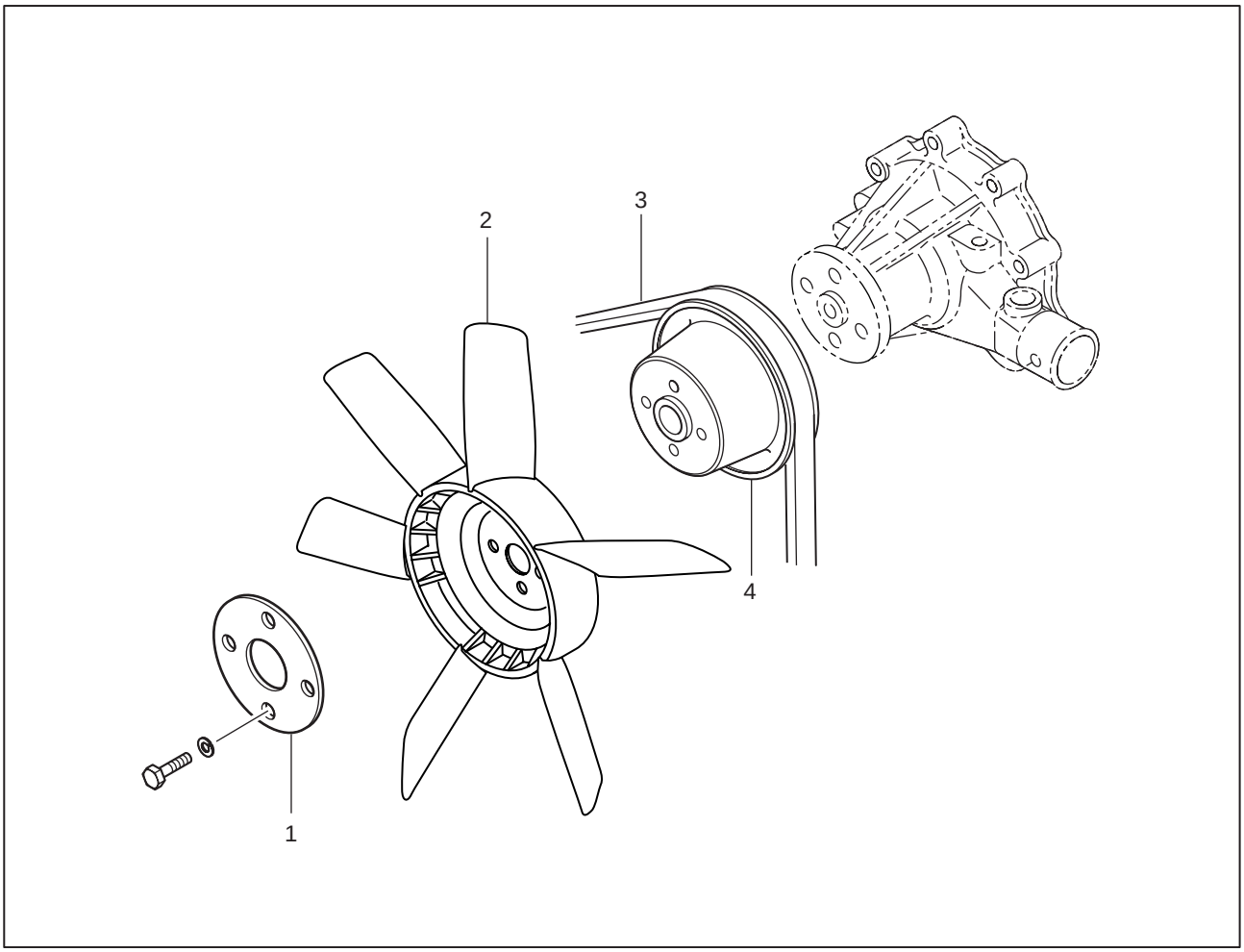


Installing oil filter and relief valve

COOLING SYSTEM

1. Removing cooling system

1.1 Removing cooling fan, fan pulley and V-belt

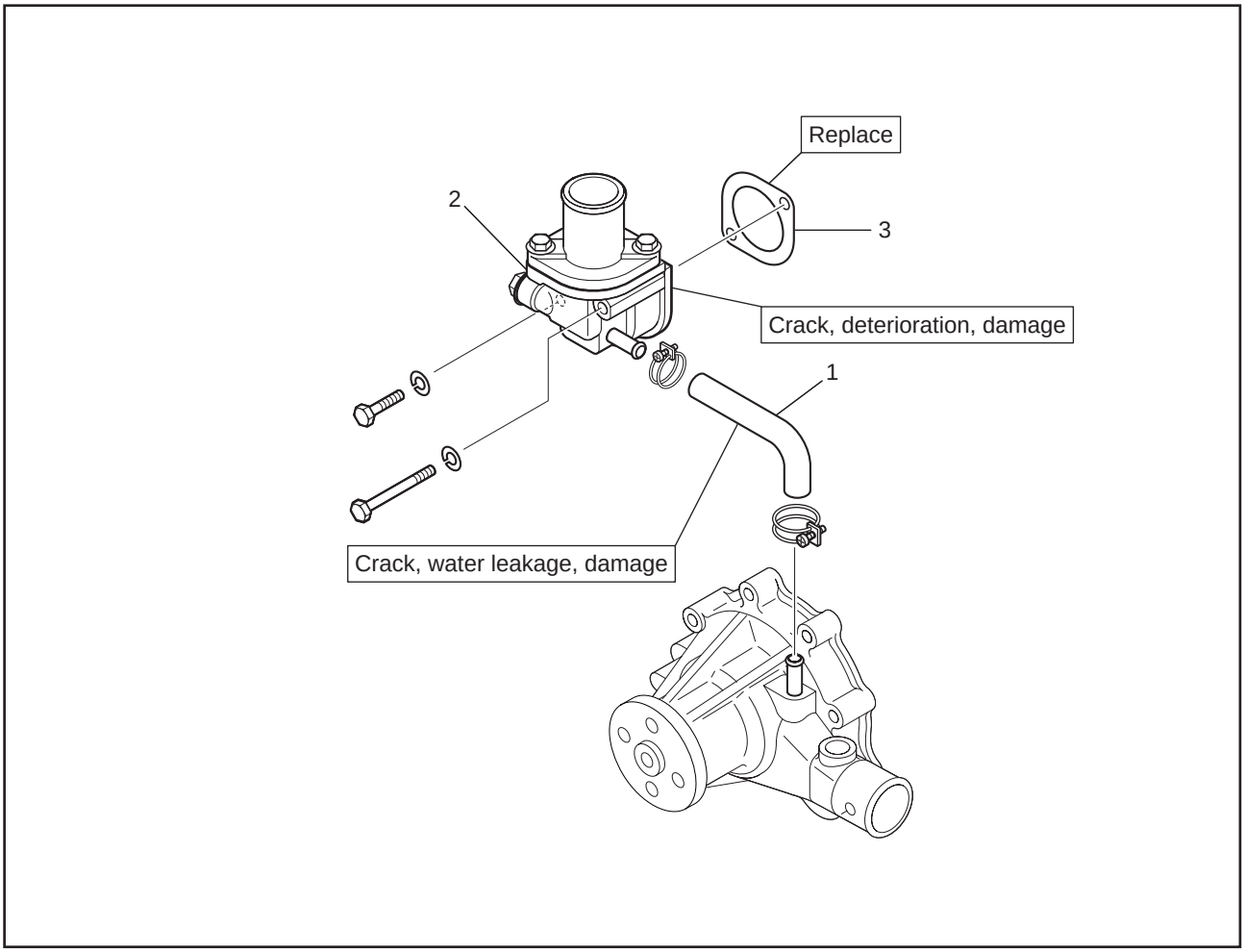


Removing cooling fan, fan pulley and V-belt

Removing sequence

1 Plate
2 Cooling fan
3 V-belt
4 Water pump pulley

1.2 Removing thermostat

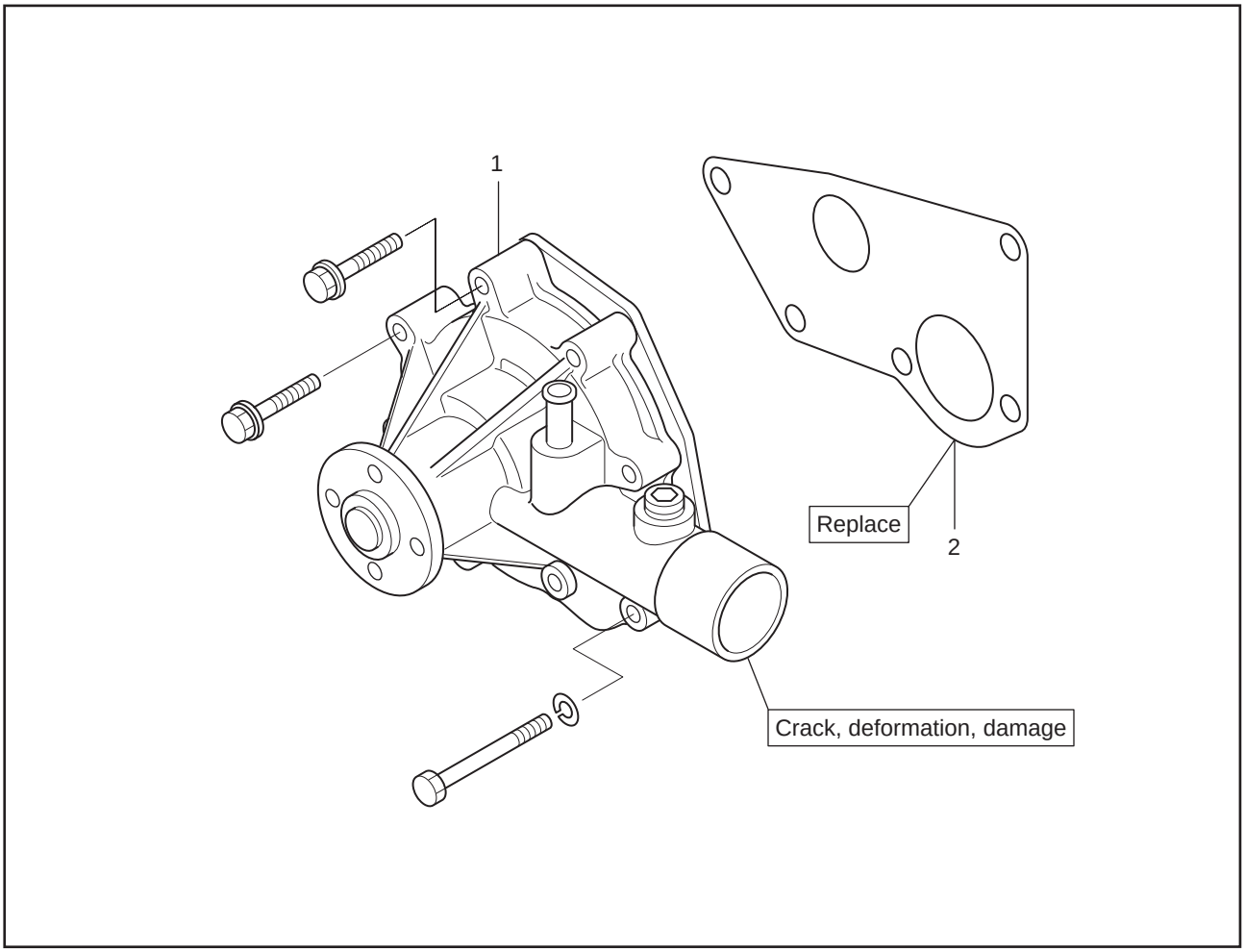


Removing thermostat

Removing sequence

1 Hose
2 Thermostat assembly
3 Gasket

1.3 Removing water pump



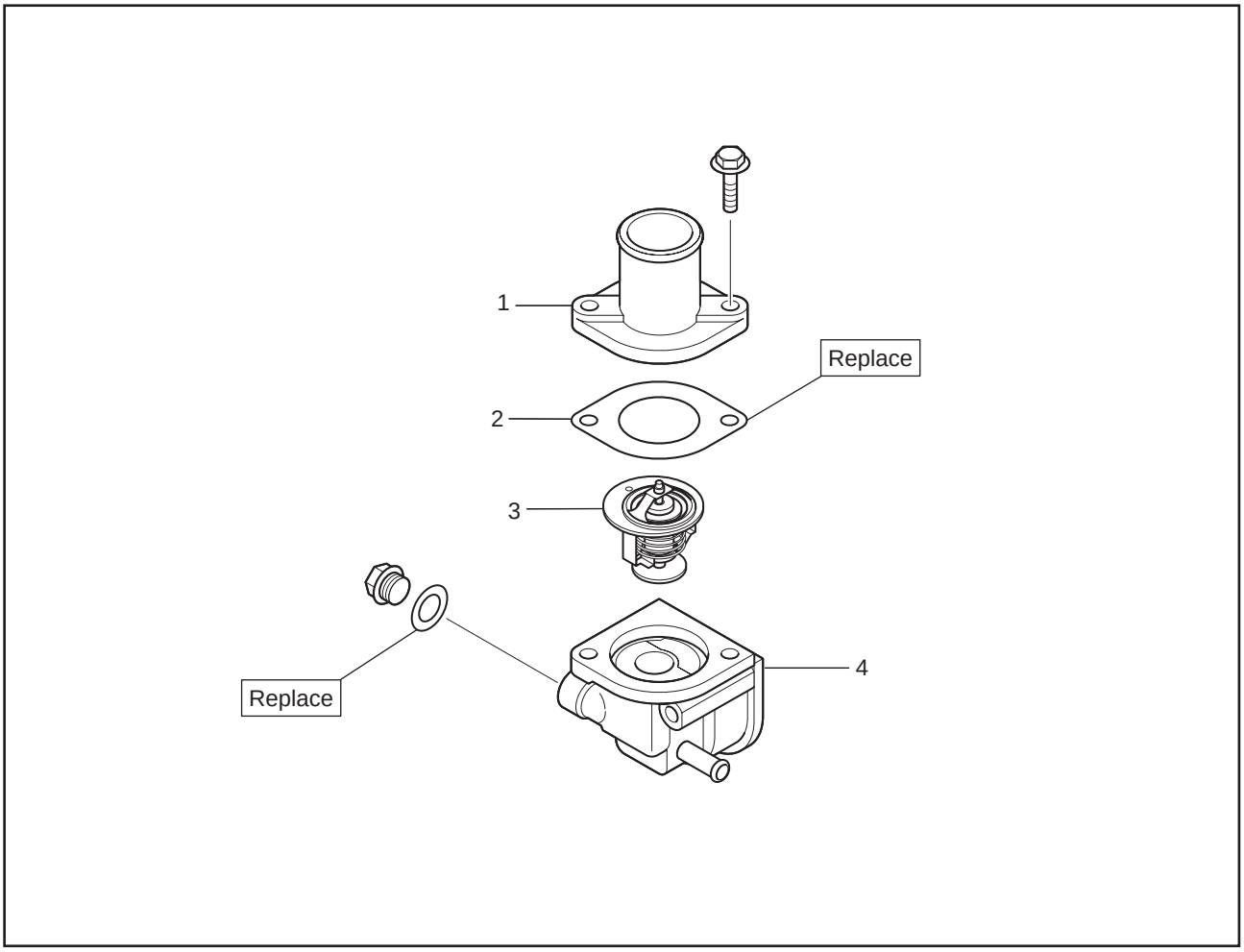
Removing water pump

Removing sequence

1 Water pump assembly
2 Gasket

2. Disassembling, inspecting and reassembling cooling system

2.1 Disassembling and inspecting thermostat



Disassembling thermostat

Disassembling sequence

1 Thermostat cover 2 Gasket 3 Thermostat 4 Thermostat case

2.2 Inspecting thermostat

⚠ CAUTION

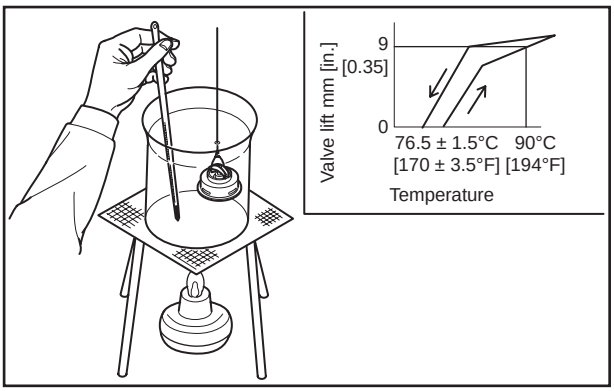
Be careful of burns or a fire when measuring temperature, as it involves a high-temperature and open flame.

To test the thermostat operation, immerse the thermostat in a container filled with water. Heat the water, while measuring the water temperature. Record the temperature at the conditions shown in the table below. If the temperatures are not within the standard range, replace the thermostat.

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

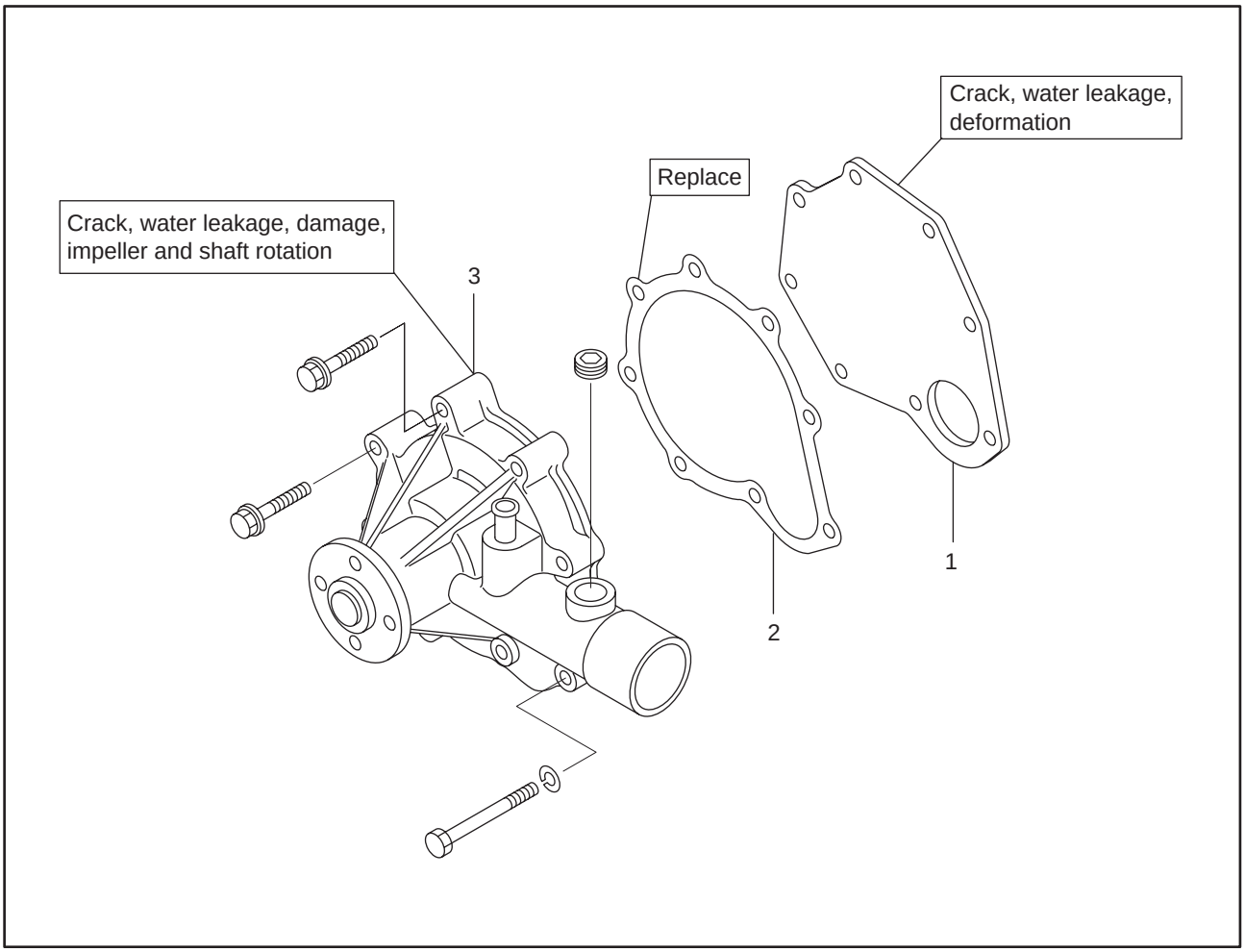
(b) Before installing the thermostat, be sure to check the valve opening temperature stamped on the thermostat valve side face.

Item	Standard
Temperature at which valve starts opening	76.5 ± 1.5°C [170 ± 3.5°F]
Temperature at which valve lift becomes 9 mm [0.35 in.] or more.	90°C [194°F]



Inspecting thermostat

2.3 Disassembling water pump



Disassembling water pump

Disassembling sequence

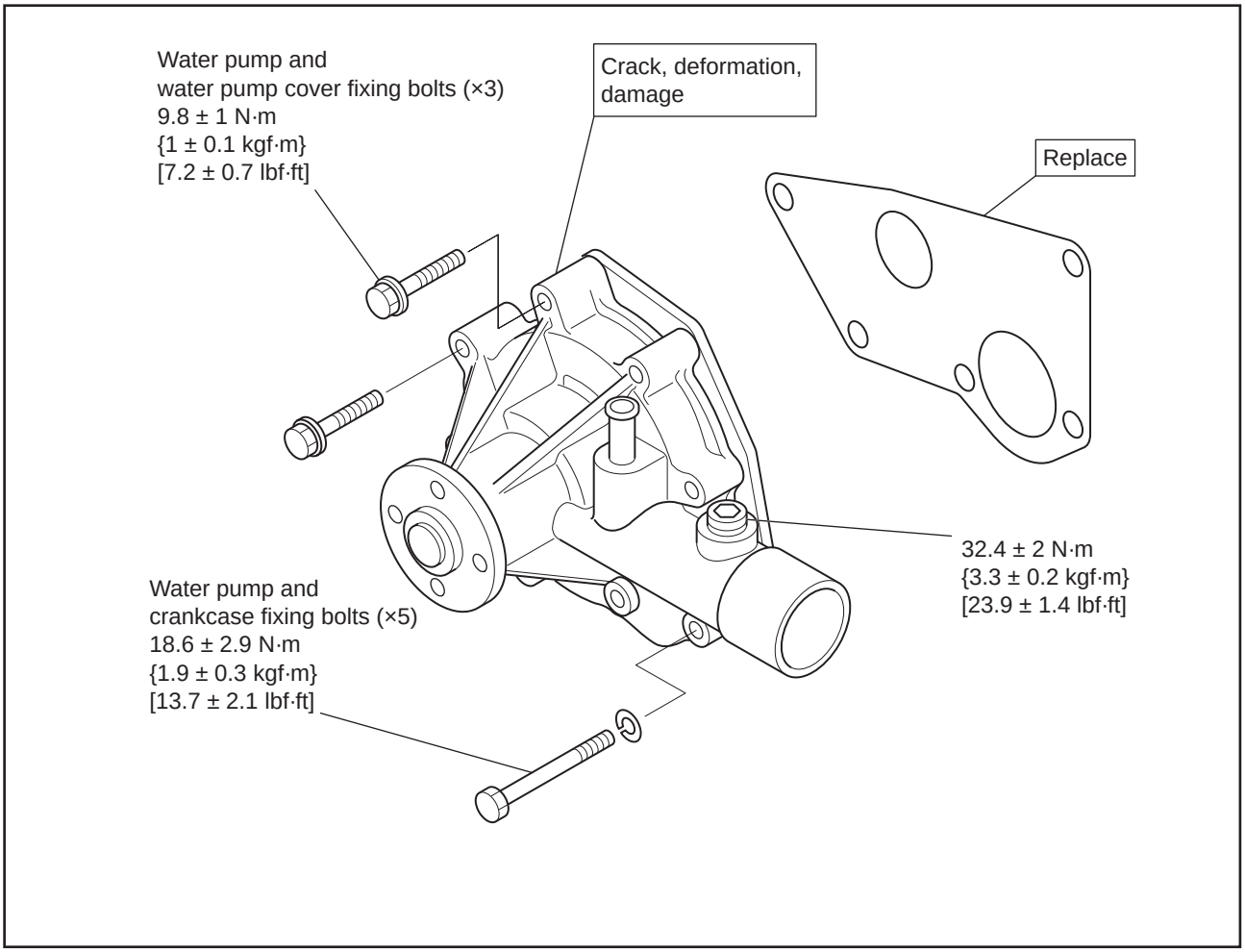
1 Water pump cover
2 Gasket
3 Water pump

2.4 Inspecting water pump

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

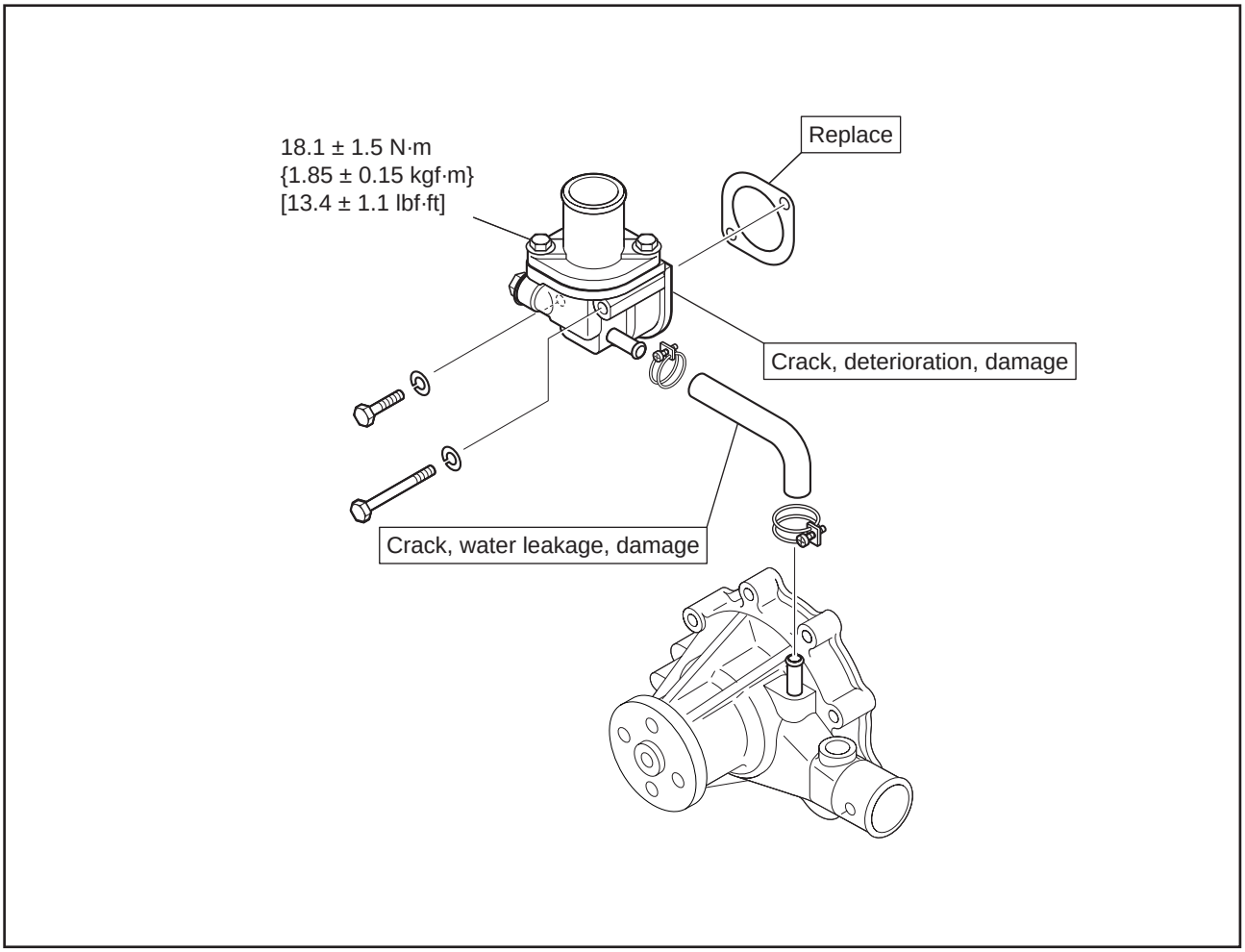
3. Installing cooling system

3.1 Installing water pump



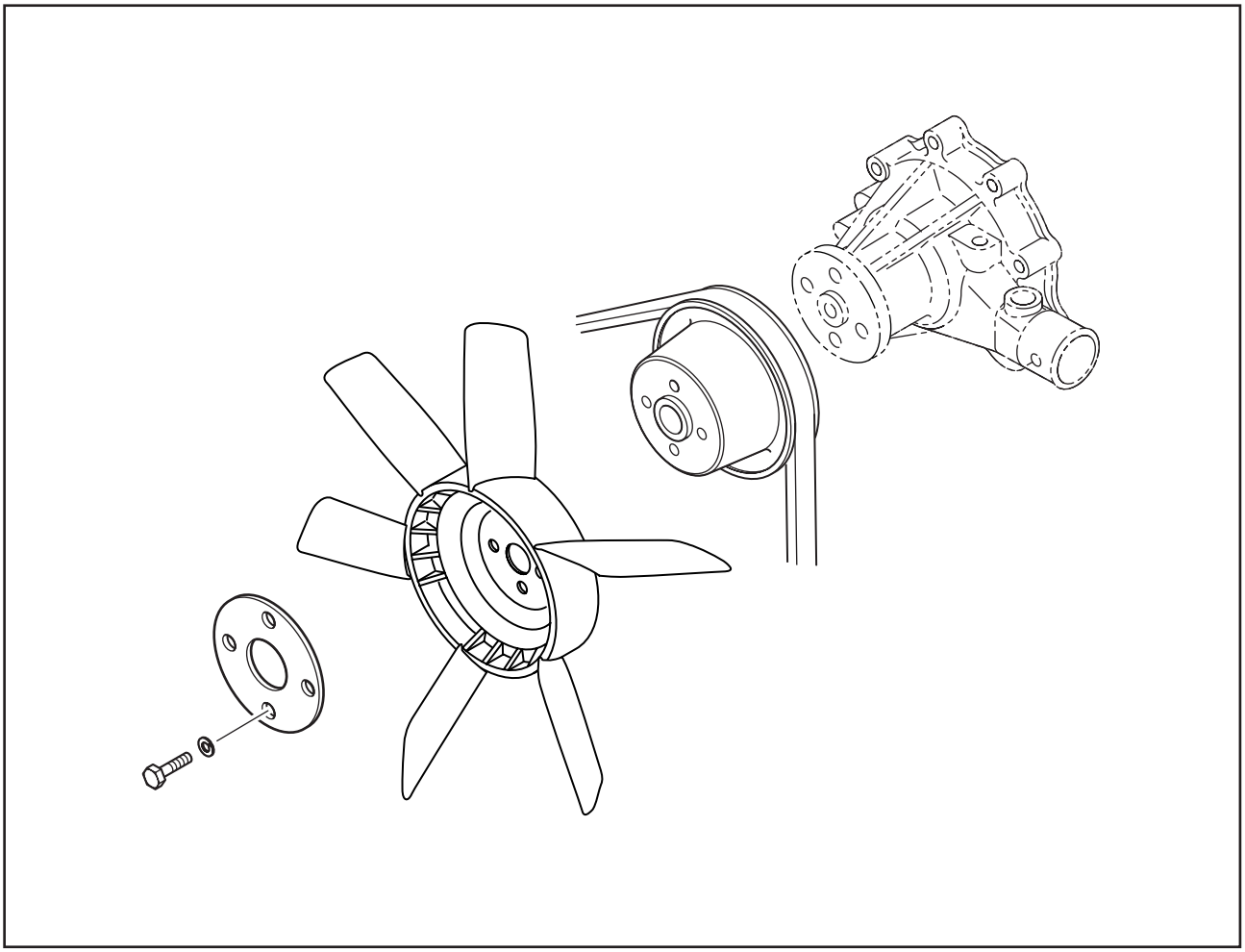
Installing water pump

3.2 Installing thermostat



Installing thermostat

3.3 Installing cooling fan, fan pulley and V-belt



Installing cooling fan, fan pulley and V-belt

CAUTION

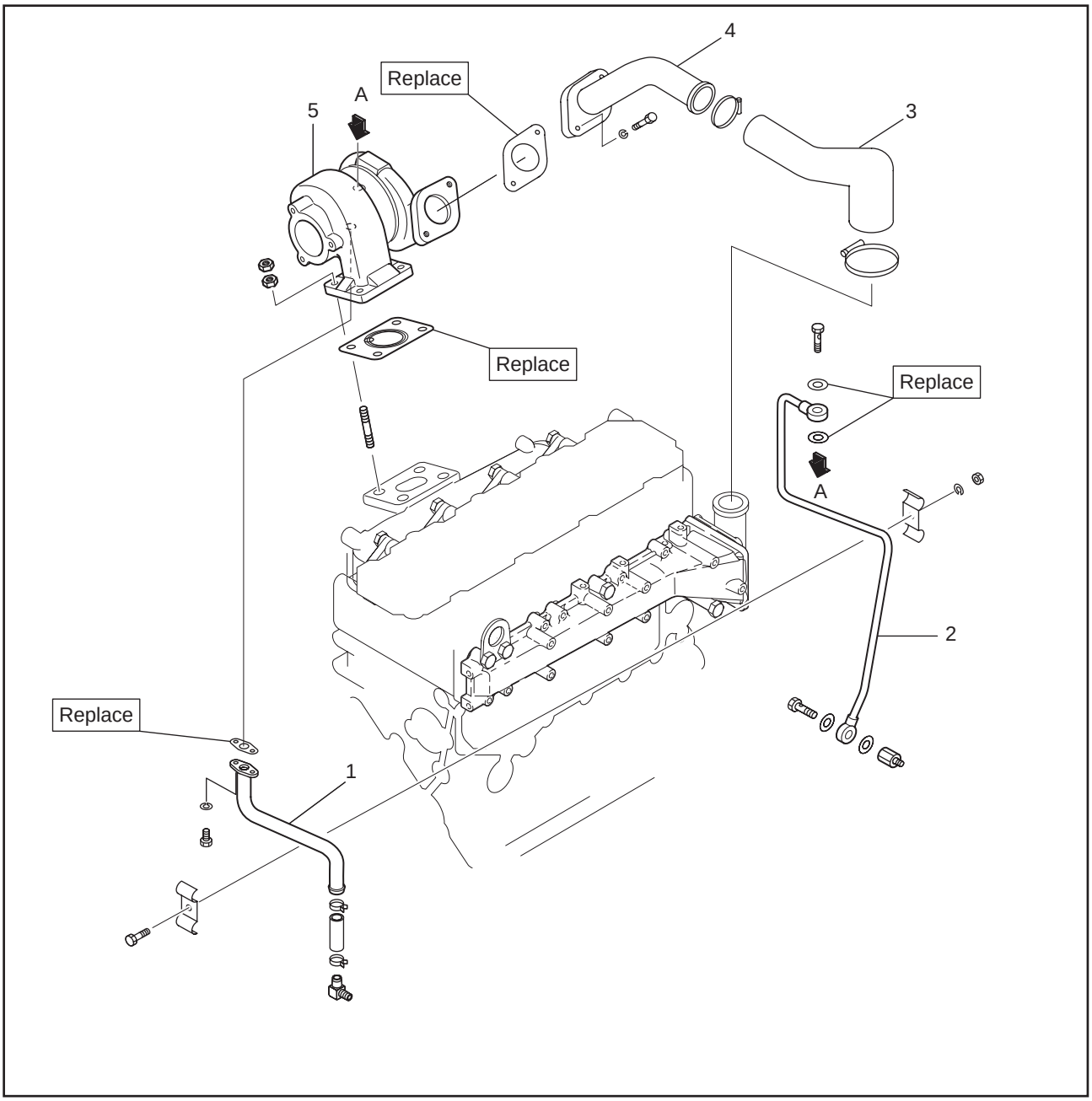
Inspect and adjust the V-belt within 200 hours operation.

Depending on the operating condition, inspecting and adjusting interval may shorten.

INLET AND EXHAUST SYSTEMS

1. Removing turbocharger, inlet and exhaust systems

1.1 Removing turbocharger

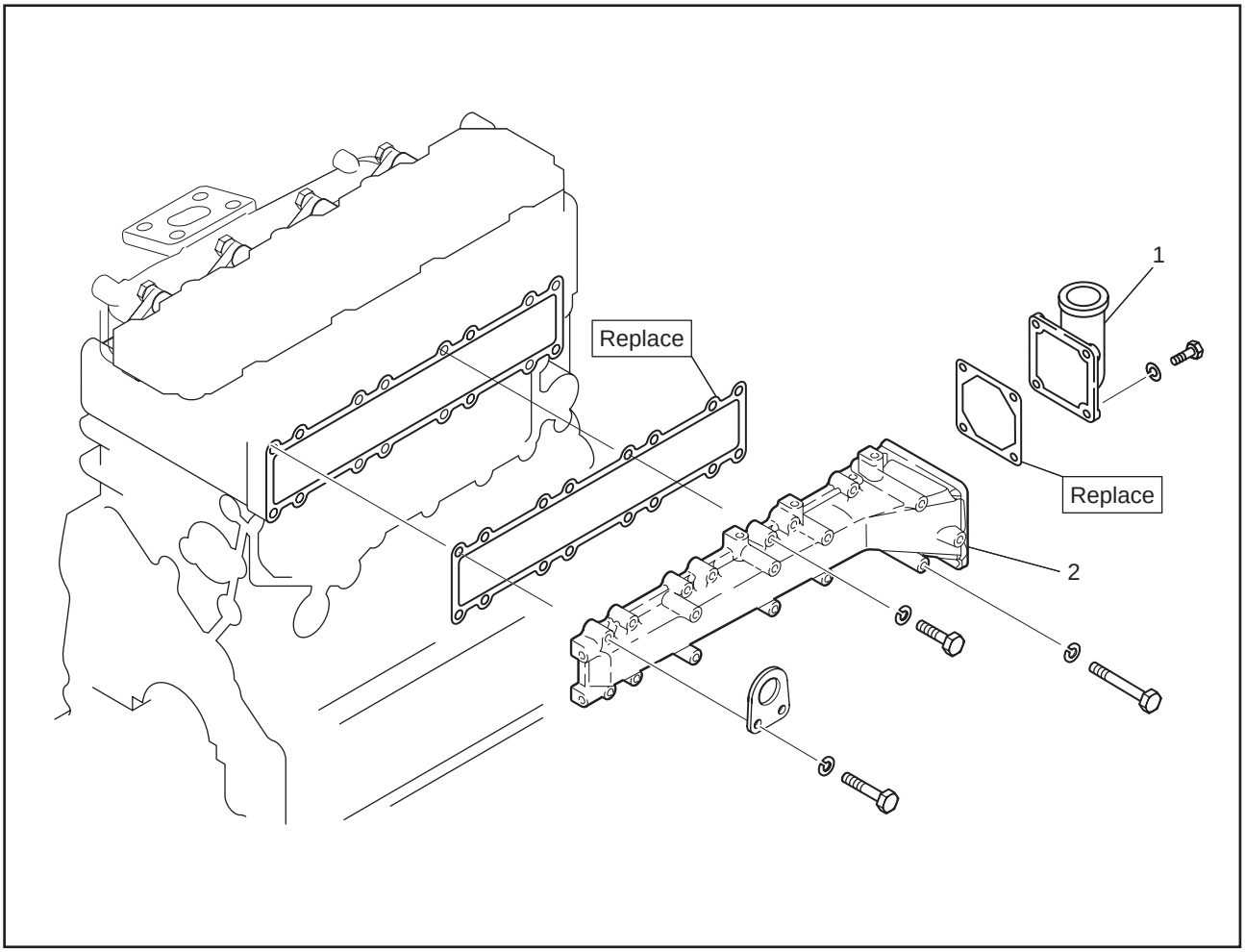


Removing turbocharger

Removing sequence

1 Oil pipe
2 Oil pipe
3 Air hose
4 Air pipe
5 Turbocharger

1.2 Removing inlet manifold

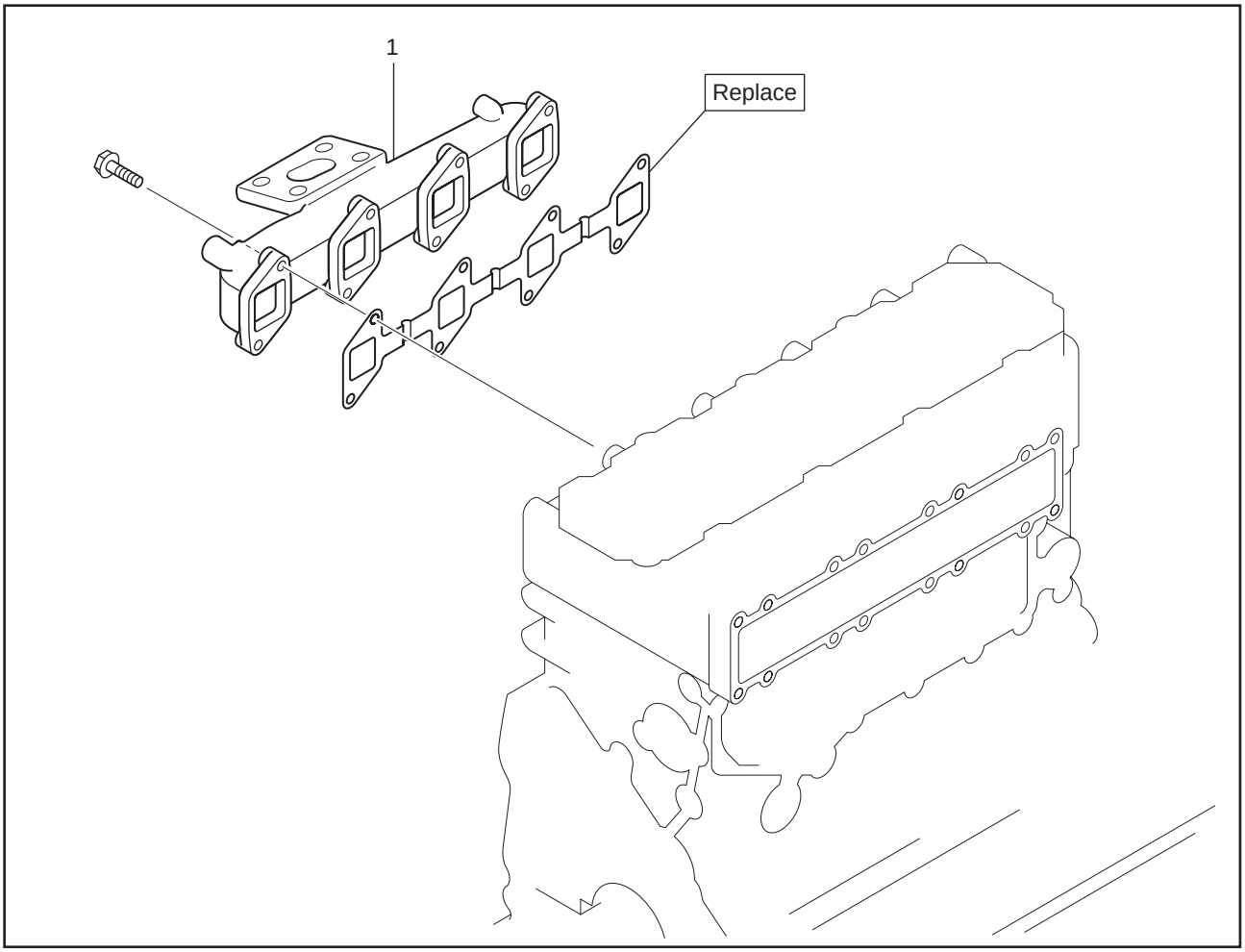


Removing inlet manifold

Removing sequence

1 Air inlet elbow
2 Inlet manifold

1.3 Removing exhaust manifold



Removing exhaust manifold

Removing sequence

1 Exhaust manifold

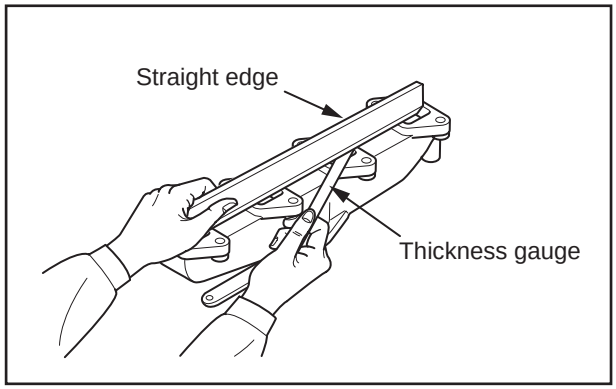
2. Disassembling, inspecting and reassembling inlet and exhaust systems

2.1 Measuring exhaust manifold distortion

(1) Check the flange for crack.

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

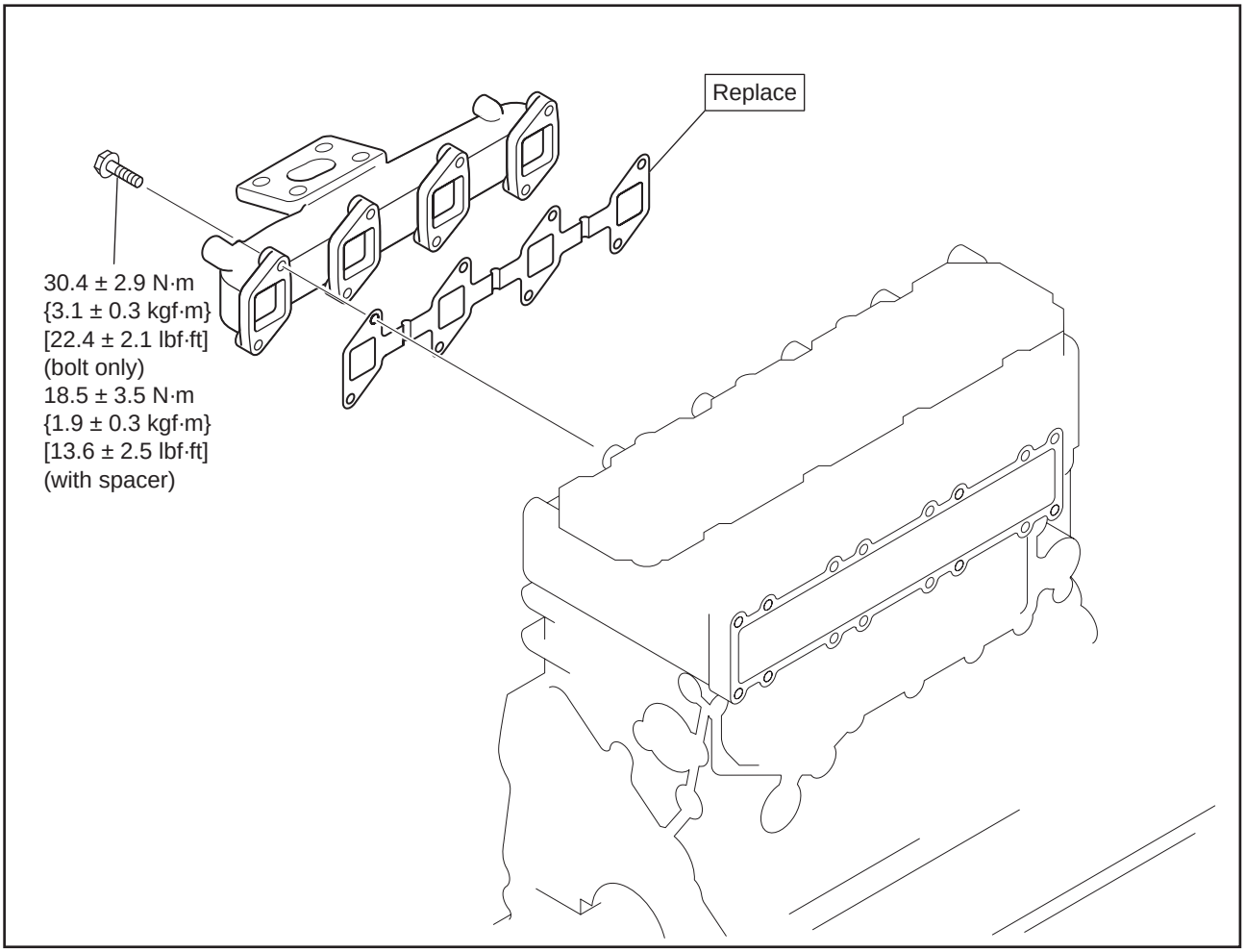
Item	Standard
Exhaust manifold distortion	0.2 mm [0.008 in.] or less



Measuring exhaust manifold distortion

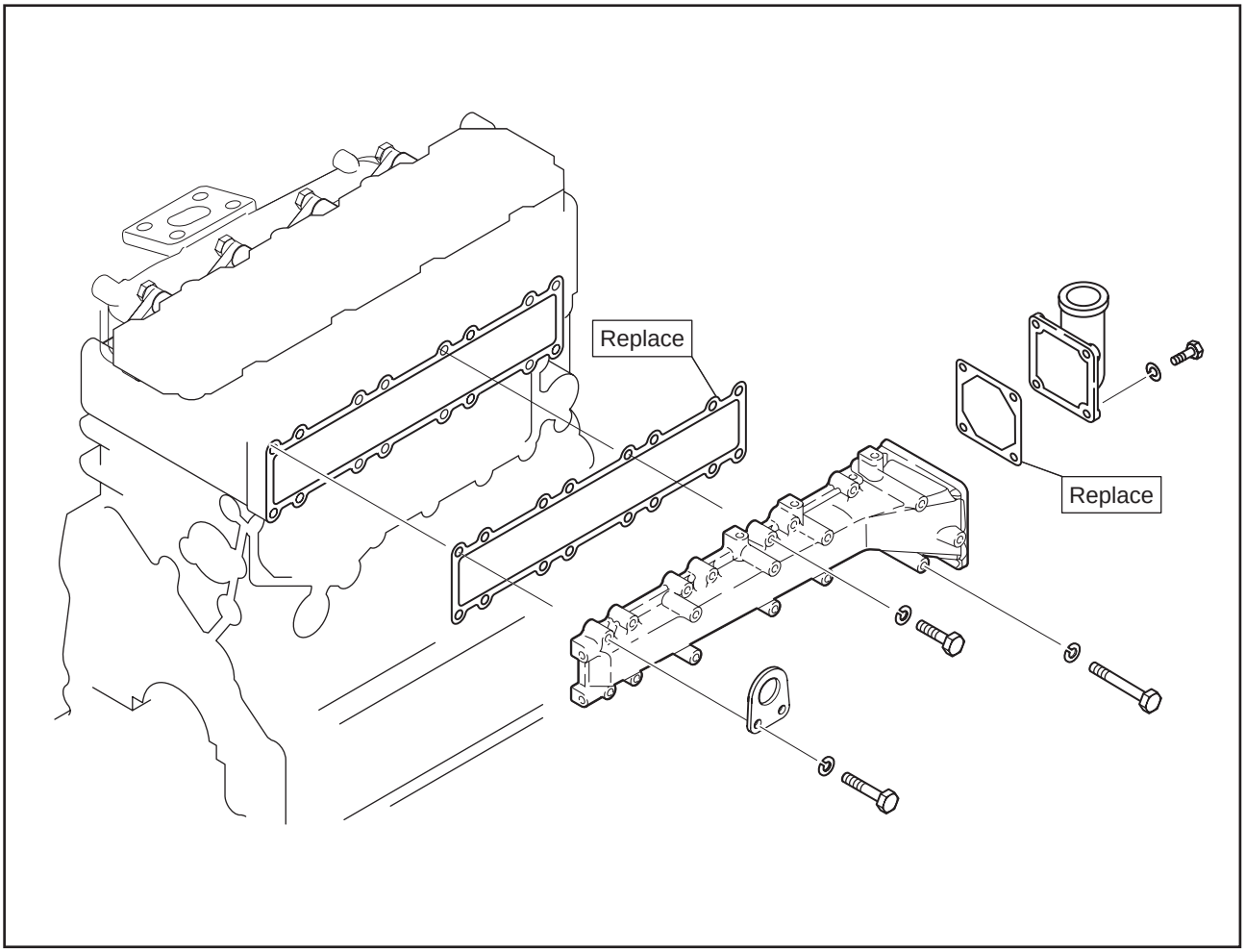
3. Installing turbocharger, inlet and exhaust systems

3.1 Installing exhaust manifold



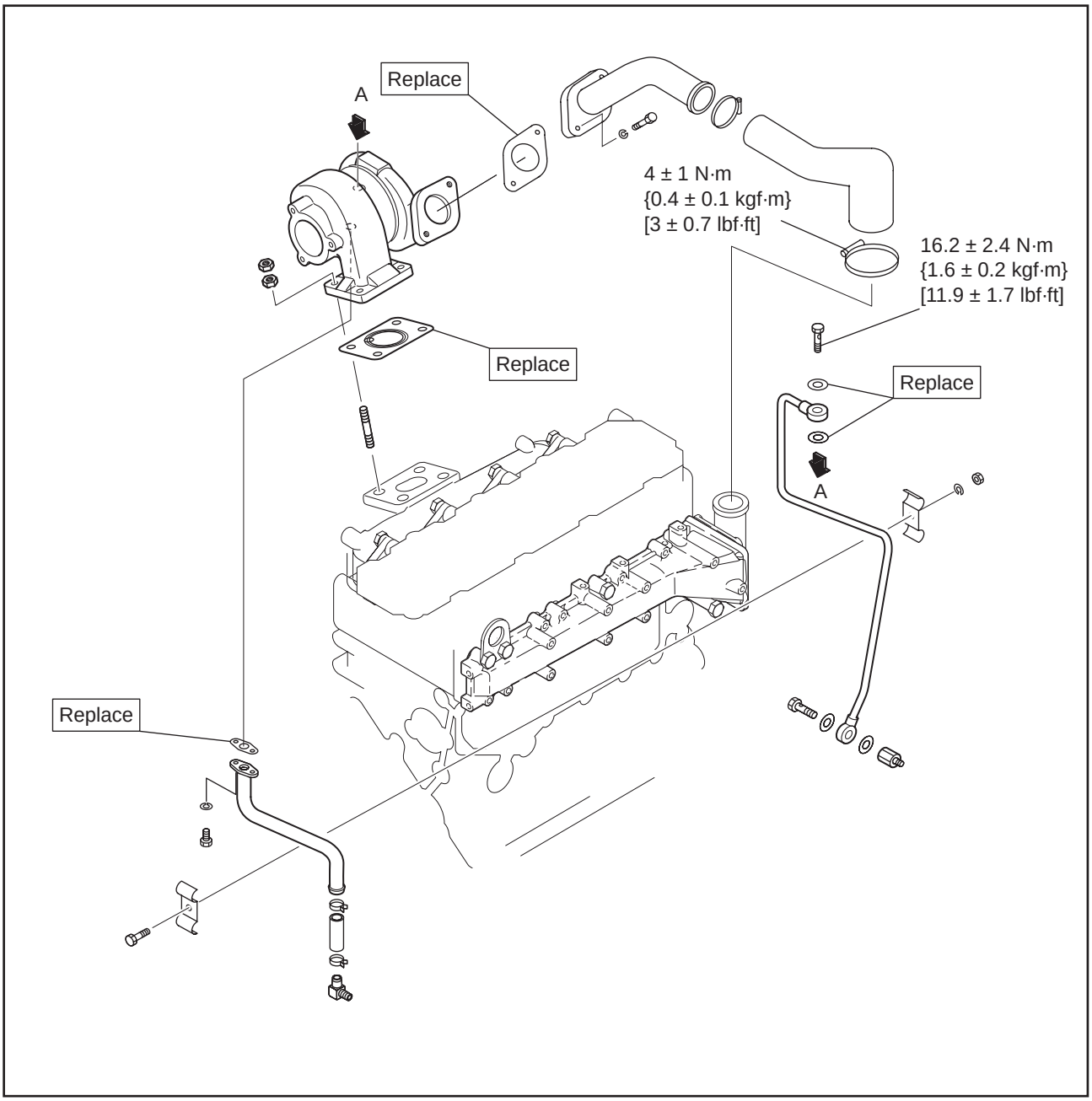
Installing exhaust manifold

3.2 Installing inlet manifold



Installing inlet manifold

3.3 Installing turbocharger

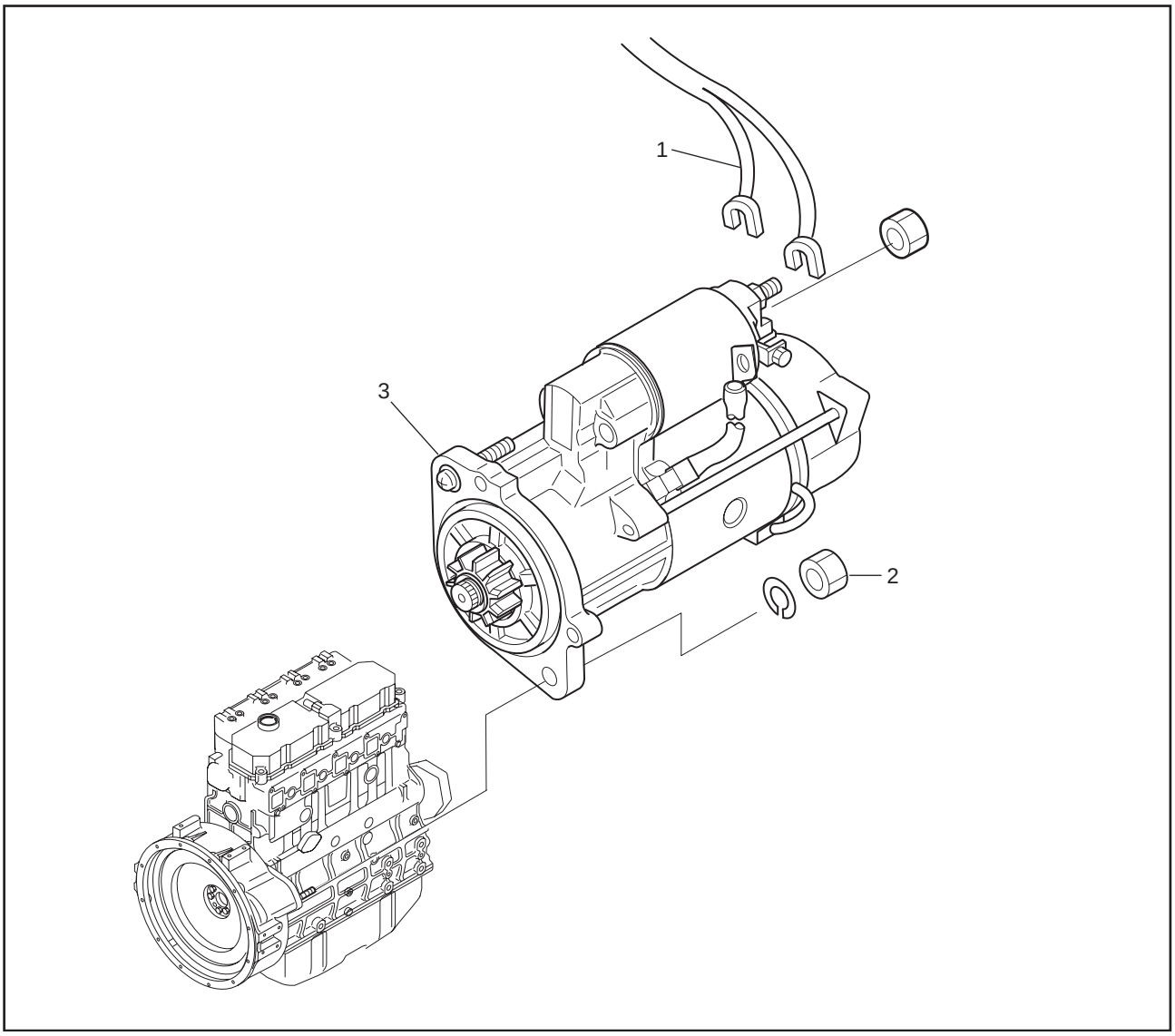


Installing turbocharger

ELECTRICAL SYSTEM

1. Removing electrical system

1.1 Removing starter



Removing starter

Removing sequence

1 Harness
2 Nut
3 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.

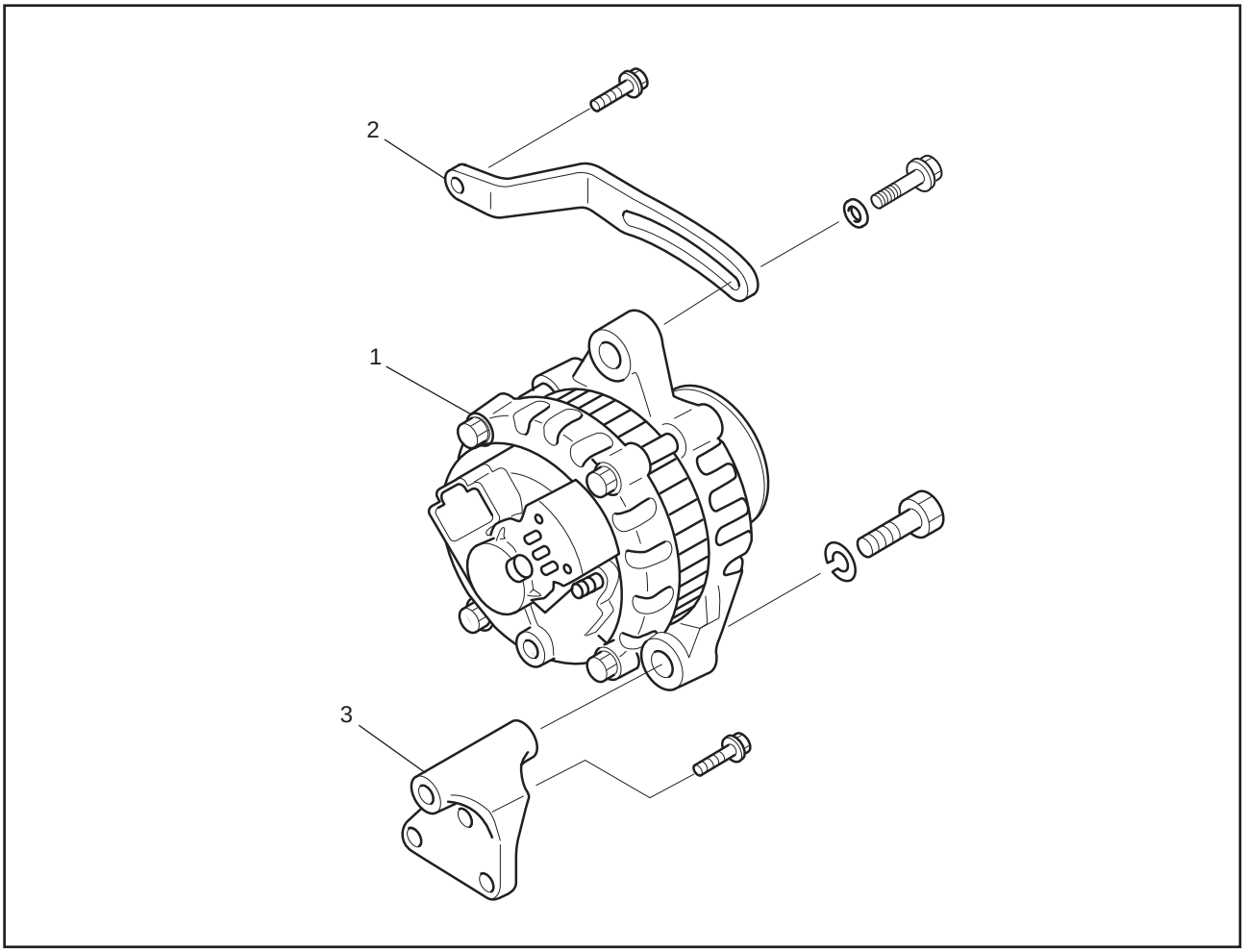
Overcharge	Adjusted value of voltage regulator is high.
	Faulty battery.
Over discharge	Low adjusted value of voltage relay.
	Faulty alternator output.
	Electric power consumption is extremely high.
	Special load is used.
	Faulty wiring.

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.

1.3 Removing alternator (12V-50A)

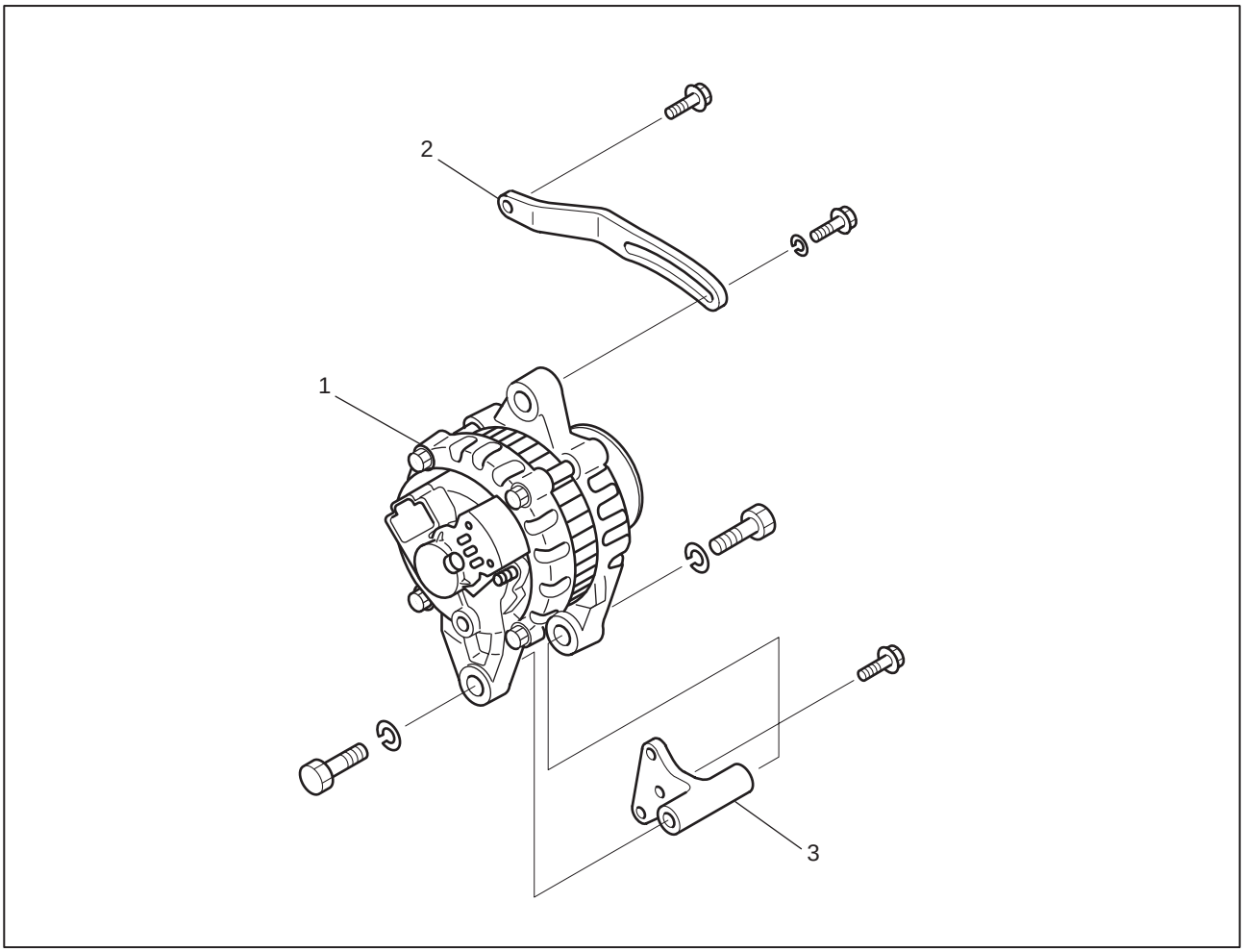


Removing alternator (12V-50A)

Removing sequence

1 Alternator
2 Adjusting plate
3 bracket

1.4 Removing alternator (12V-75A, option)

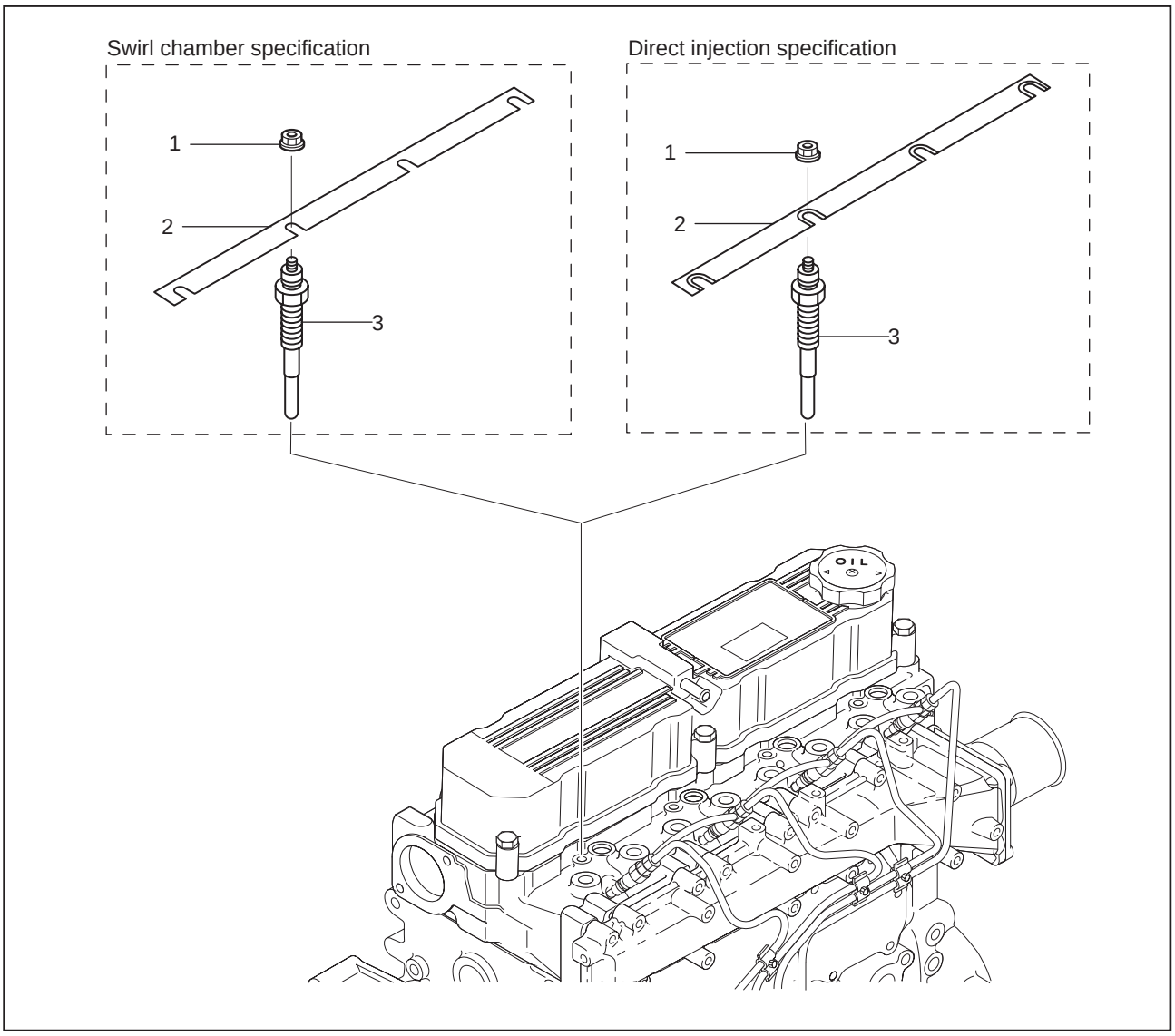


Removing alternator (12V-75A, option)

Removing sequence

1 Alternator
2 Adjusting plate
3 bracket

1.5 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.

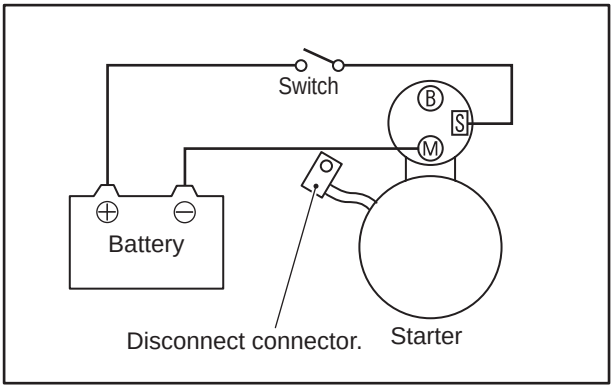
CAUTION

Do not apply current continuously for longer than 10 seconds.

(1) Disconnect the connector of M terminal.

(2) Pull-in test

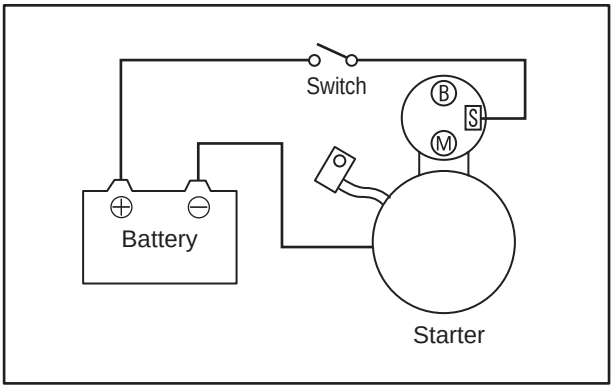
Connect the starter to the circuit as shown in the illustration. The magnetic switch is normal if the pinion springs out when the switch is turned ON.



Pull-in test

(3) Holding test

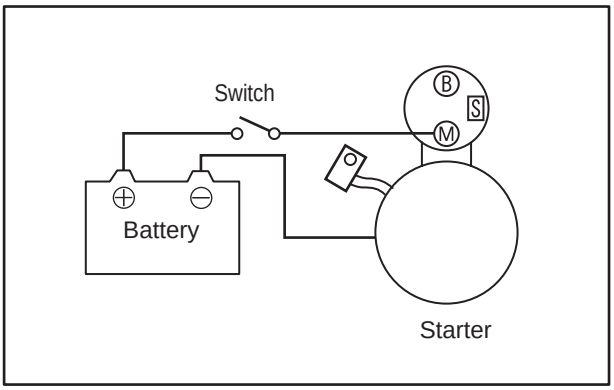
Connect the starter to the circuit as shown in the illustration. Pull out the pinion fully by hand. The magnetic switch is normal if the pinion does not return when it is released.



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

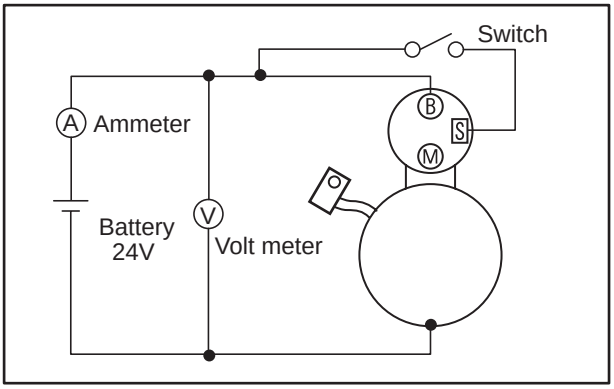
Use as thick a wire as possible and firmly tighten each terminal.

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.

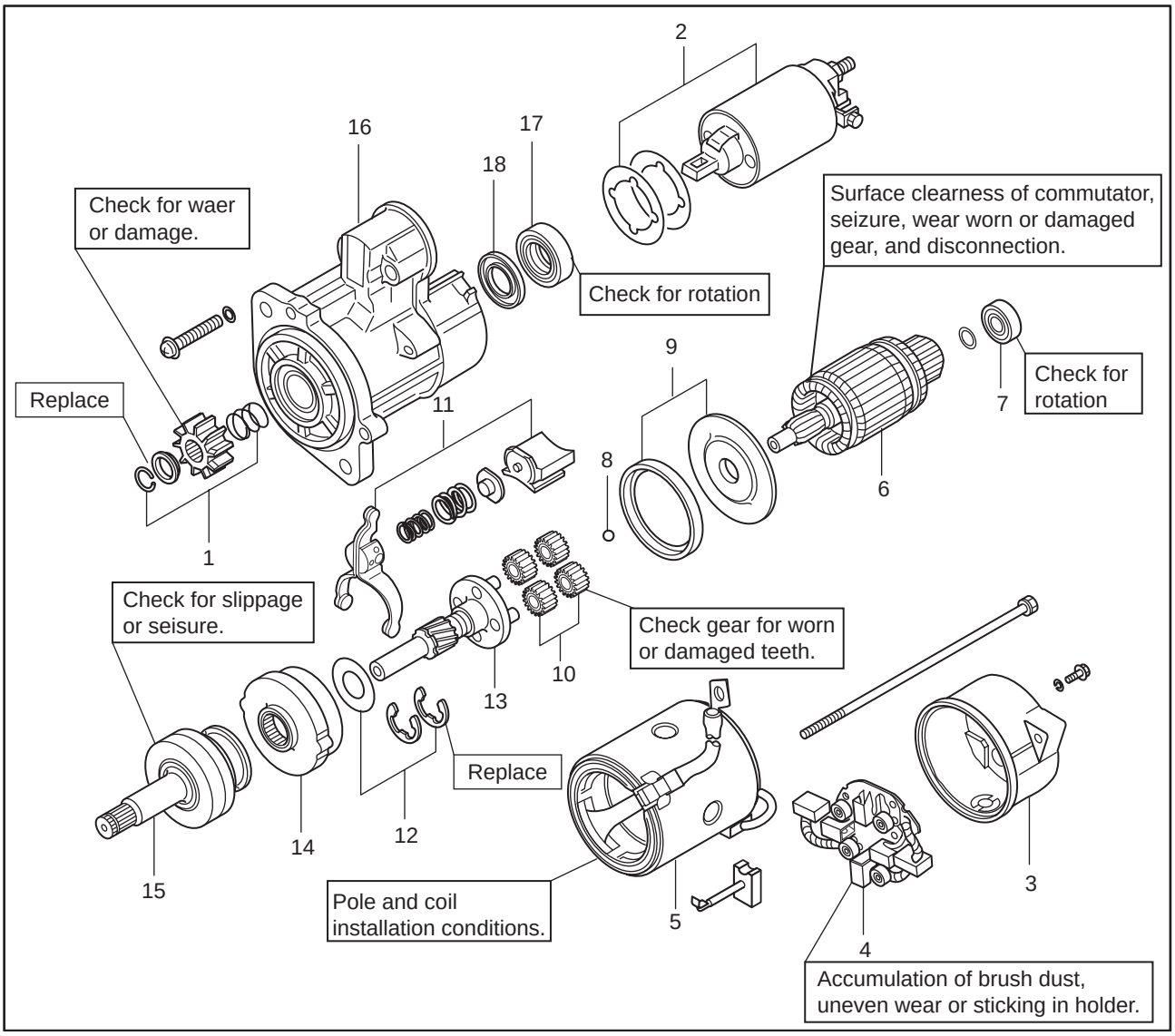
(2) In normal condition, the pinion pops out when the switch is turned ON, and the starter rotates at more than the specified rotation speed.

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



Test at no load

2.2 Disassembling and inspecting starter



Disassembling and inspecting starter

Disassembling sequence

1	Pinion set	7	Bearing	13	Gear shaft
2	Magnetic switch	8	Ball	14	Internal gear
3	Rear bracket	9	Packing set	15	Overrunning clutch
4	Brush holder assembly	10	Gear	16	Front bracket
5	Yoke assembly	11	Lever assembly	17	Bearing
6	Armature	12	Washer set	18	Oil seal

2.2.1 Removing pinion set

CAUTION

The starter generates heat if it is left with current being applied. Remove the pinion within 10 seconds.

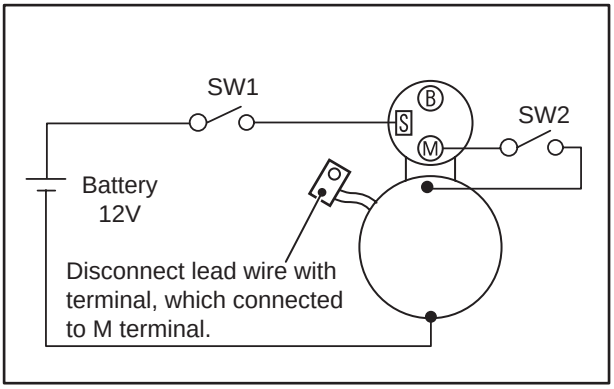
(1) Connect the starter to the circuit as shown in the illustration.

(2) Turn the switches SW1 and SW2 ON to move the pinion out and then turn the SW2 OFF to stop the rotation of the armature and the pinion.

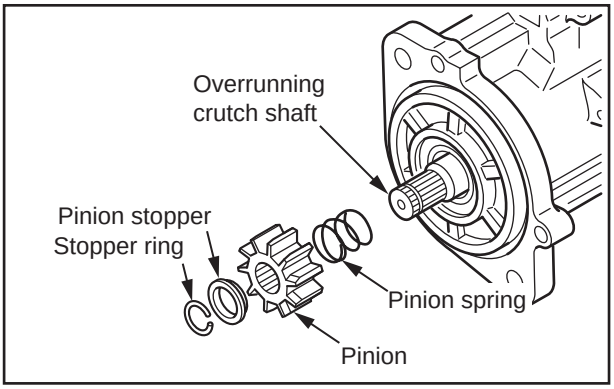
(3) Place an appropriate tube on the pinion stopper.
Tap the tube with a hammer to drop the pinion stopper to the clutch side. This will expose the stopper ring.

(4) Remove the stopper ring with pliers and remove the pinion.

Note: Do not reuse the stopper ring for reassembly.



Connection to move the pinion forward



Removing pinion

2.2.2 Removing magnetic switch

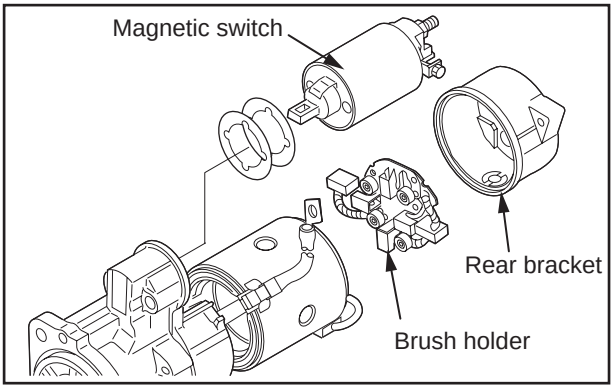
Disconnect the leads, and remove the magnetic switch.

2.2.3 Removing rear bracket

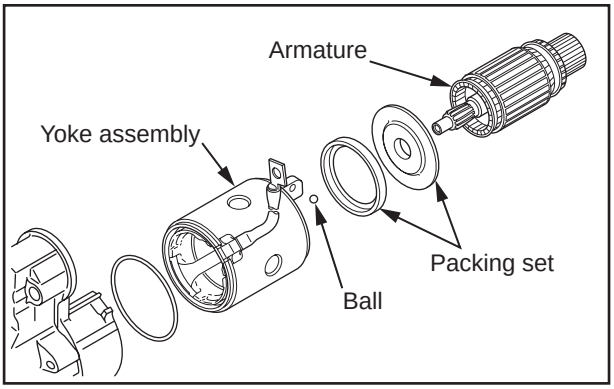
Remove the through bolts and screws of the brush holder, and then remove the rear bracket.

2.2.4 Removing armature and yoke

(1) Remove the armature and the yoke.
(2) Remove the packing from the internal gear.
(3) Remove the packing and plate on the lever support.
(4) Remove the ball from the internal gear.
(5) Remove the planetary gears.



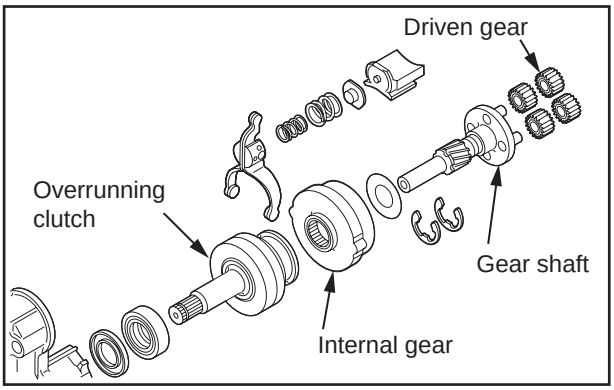
Disassembling starter (1)



Disassembling starter (2)

2.2.5 Removing overrunning clutch

Pull out the internal gear, gear shaft, overrunning clutch and lever as an assembly from the front bracket, and remove the lever.



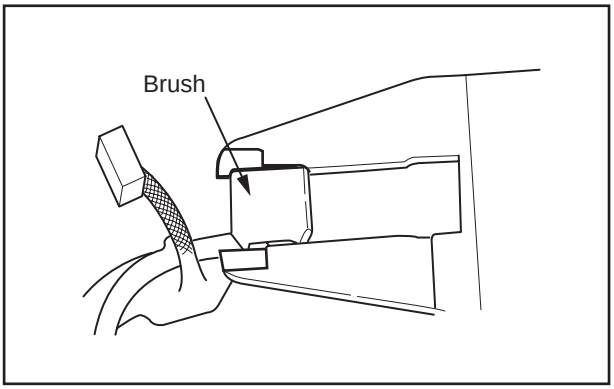
Disassembling starter (3)

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	18 mm [0.71 in.]	11 mm [0.43 in.]

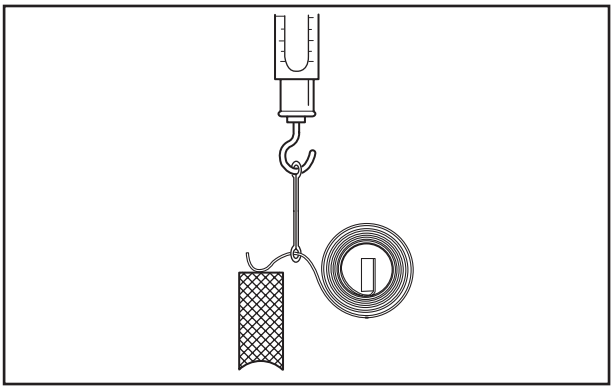


Inspecting brushes for wear

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 to 35 N {2.7 to 3.7 kgf} [5.9 to 8.1 lbf]	15 N {1.5 kgf} [3.3 lbf]

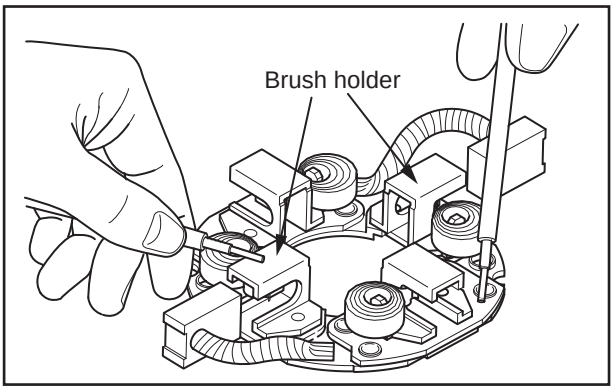


Measuring brush spring load

2.3.3 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.



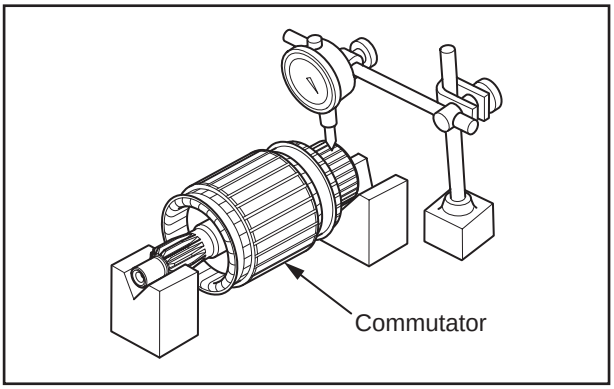
Checking brush holder for grounding

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.

Item	Standard	Limit
Commutator runout	0.05 mm [0.0020 in.] or less	0.10 mm [0.0039 in.]



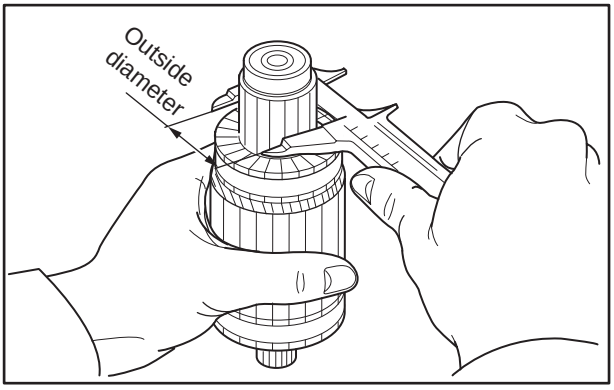
Measuring commutator radial runout

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.

Item	Nominal	Limit
Commutator outside diameter	32 mm [1.26 in.]	31.4 mm [1.236 in.]



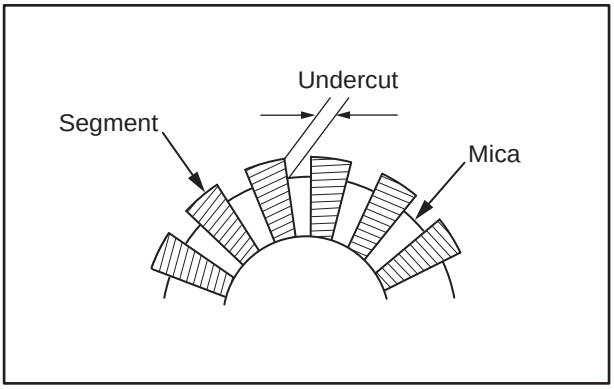
Measuring commutator outside diameter

2.3.6 Measuring undercut depth

Measure the depth of undercutting between the commutator segments.

If the measured value is less than the limit, repair or replace with a new part.

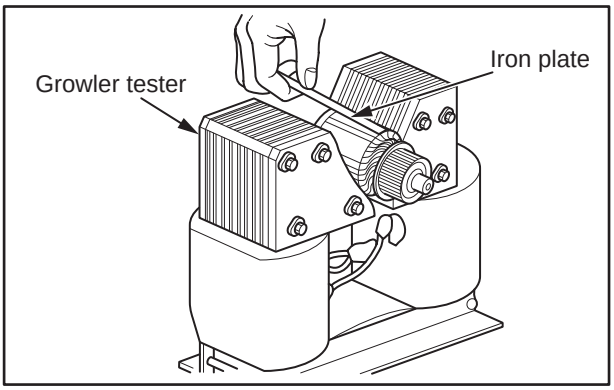
Item	Standard	Limit
Undercut depth	0.4 to 0.6 [0.016 to 0.024 in.]	0.2 mm [0.008 in.]



Measuring commutator undercut depth

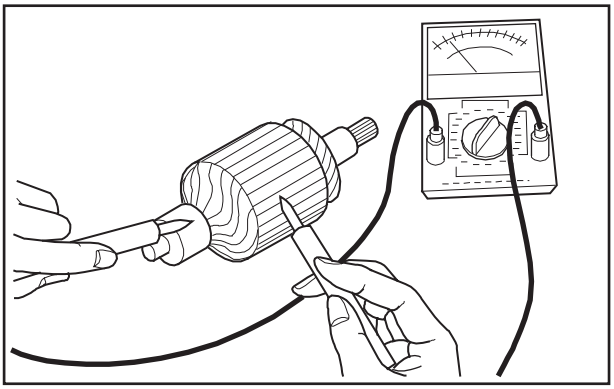
2.3.7 Checking armature coil

(1) Inspect the armature coil using a growler.
Hold a piece of iron plate against the armature core. If the iron plate vibrates, replace the armature with a new one.



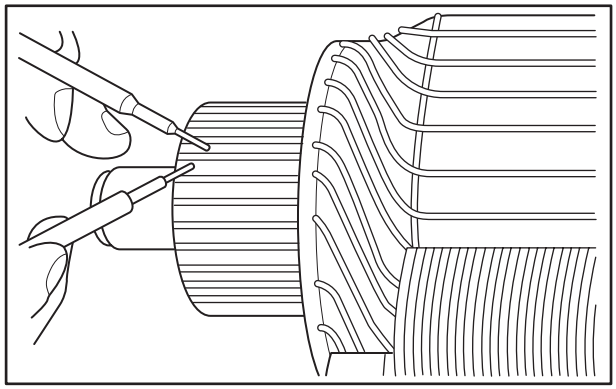
Inspecting armature coil for short circuit

(2) Check that there is no continuity between the commutator and the shaft (core).
If any continuity is observed, replace the armature with a new one.



Inspecting insulation between commutator and shaft

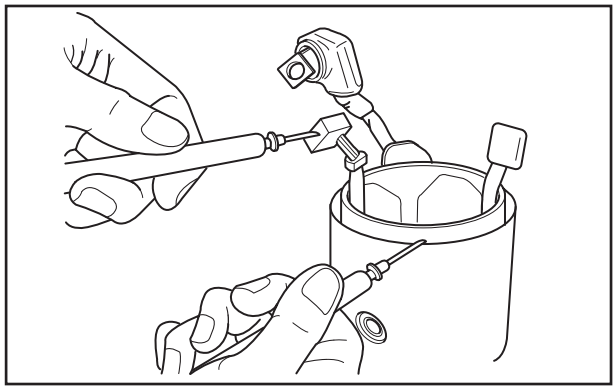
(3) Check that there is continuity between segments in various combinations.
If poor or no continuity is observed, replace the armature with a new one.



Inspecting continuity between segment

2.3.8 Inspecting field coil

(1) Check that there is no continuity between the end of the coil (brush) and the yoke.
(2) Check that there is continuity between the both end of the coil.
(3) Check that the pole piece and the coil is not loosen.
(4) If it is defective, replace the yoke with a new one.



Inspecting field coil

2.3.9 Inspecting rear bracket

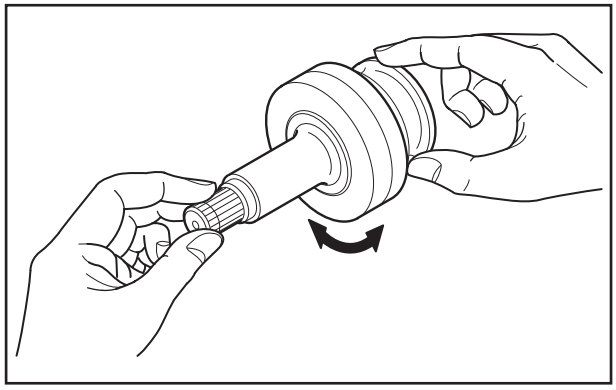
Replace the rear bracket if the bearing is worn.

2.3.10 Inspecting overrunning clutch

CAUTION

Do not clean the overrunning clutch in wash oil.

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



Inspecting overrunning clutch

2.3.11 Inspecting front bracket

The ball bearing should rotate smoothly without abnormal noise. If defective, replace the whole front bracket.

2.3.12 Inspecting gears of starter

Check gears of the starter for wear or damage. If faulty, replace the starter.

2.3.13 Inspecting magnetic switch

Inspect the magnetic switch for following items. Replace the magnetic switch if it is defective.

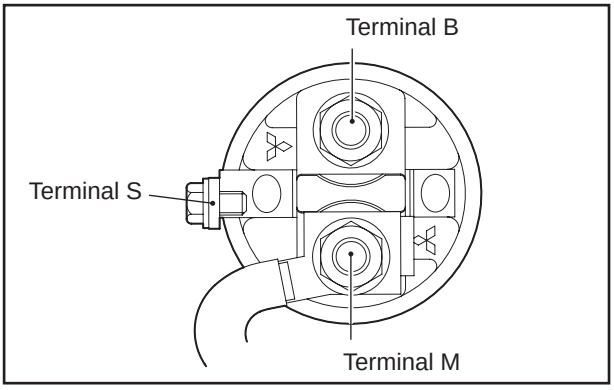
(1) Open circuit of coil

Check the continuity between terminal S and terminal M, also check the continuity between terminal S and ground, If continuity is not exist, the coil is open circuit.

(2) Adhesion of contactor

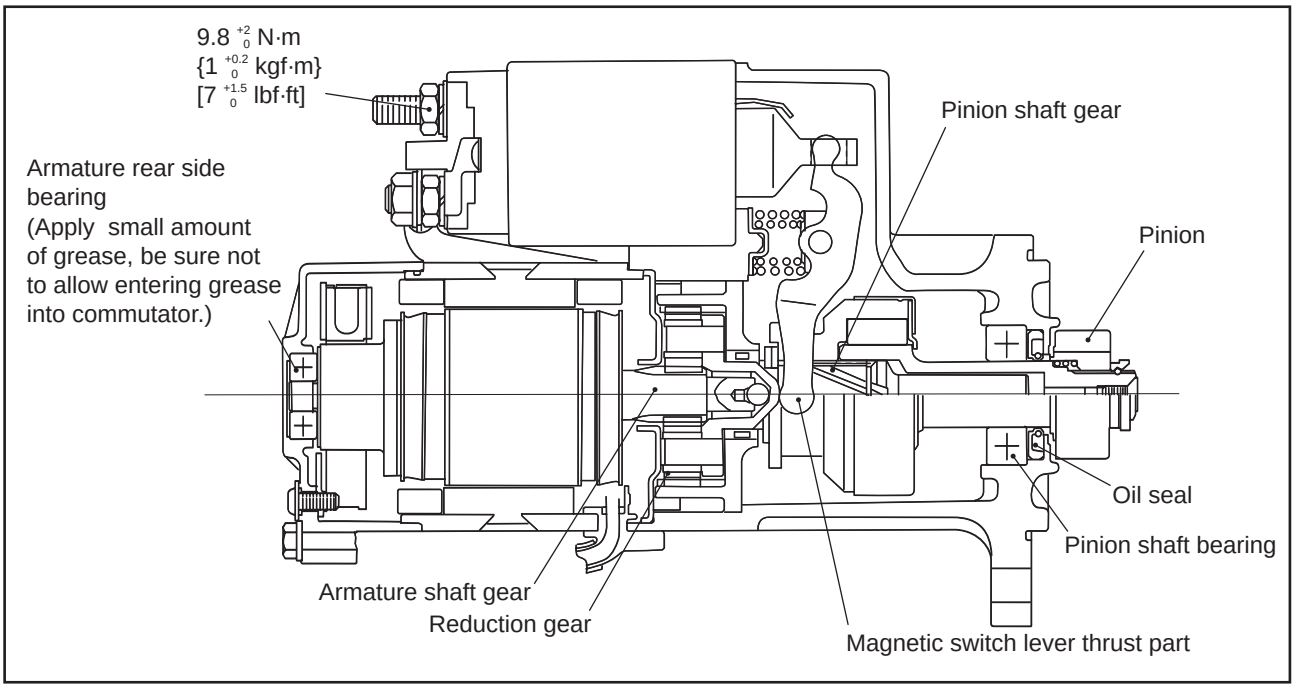
Check that there is no continuity between terminal B and terminal M.

If continuity is exist, the contactor are welded closed.



Inspecting magnetic switch

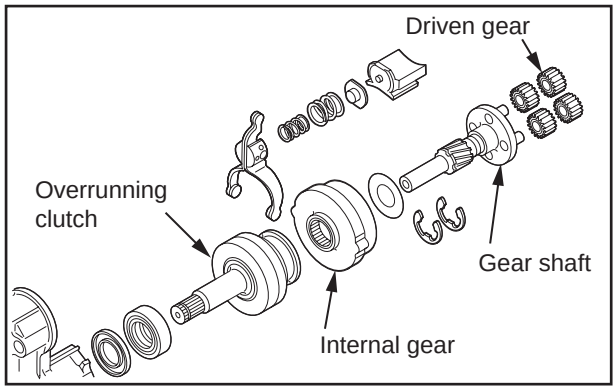
2.4 Reassembling starter



Reassembling starter

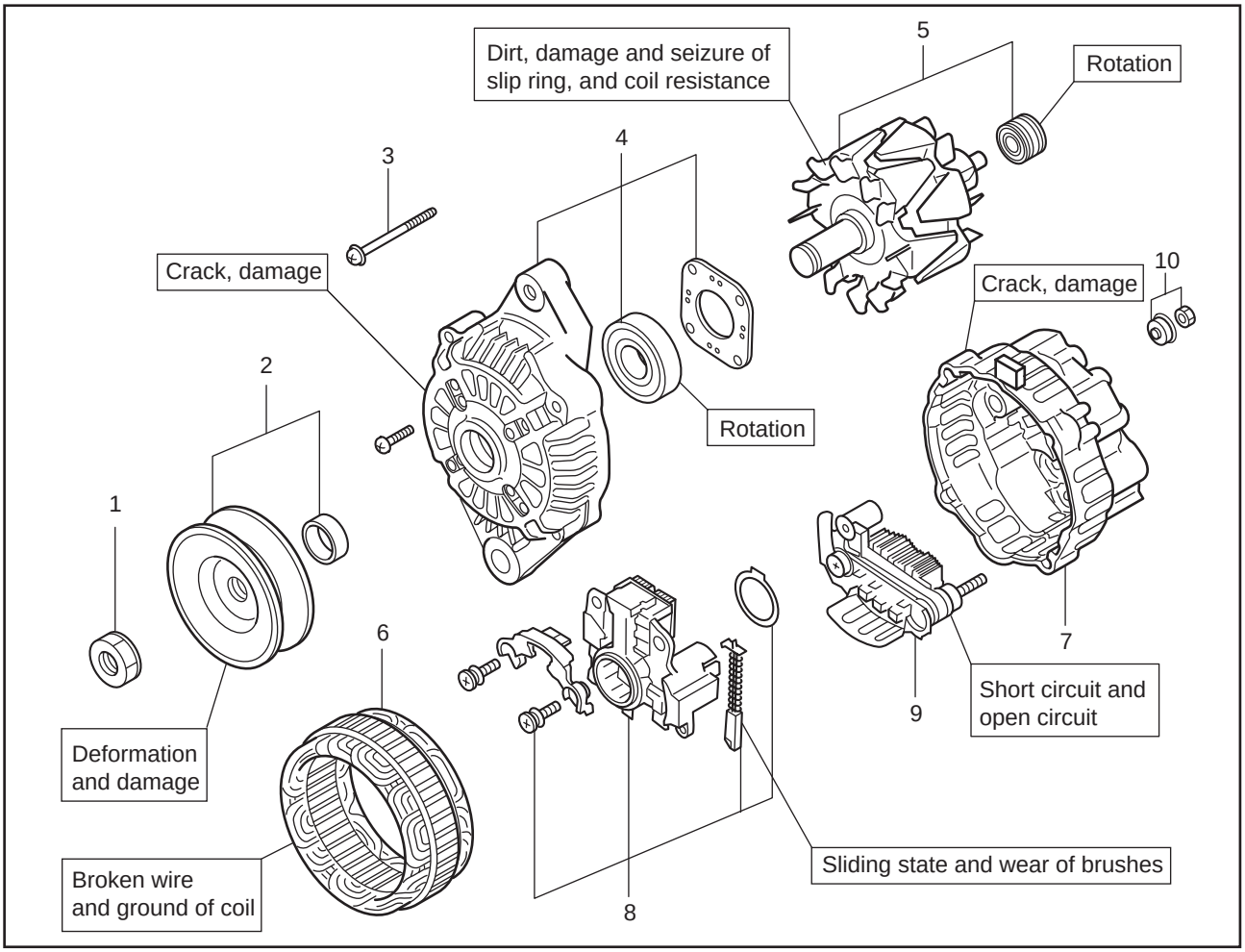
2.4.1 Installing gear shaft

(1) Install the lever to the overrunning clutch.
(2) Fit the internal gear into the gear shaft.
(3) Put the gear shaft into the overrunning clutch.



Installing gear shaft

2.5 Disassembling and inspecting alternator



Disassembling and inspecting alternator

Disassembling sequence

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

2.5.1 Separating front bracket from stator

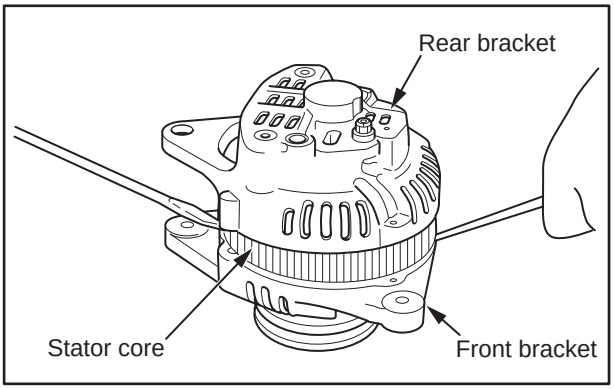
CAUTION

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

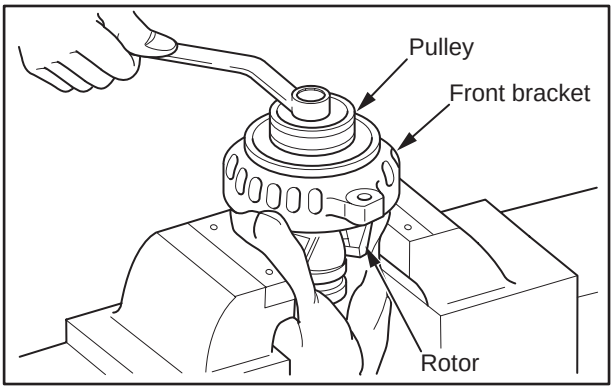
2.5.2 Removing pulley

CAUTION

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

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

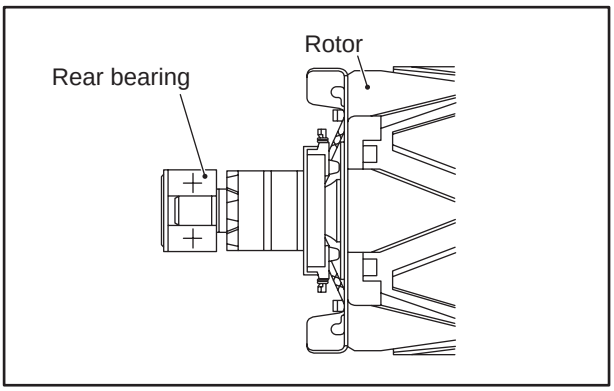
(2) Remove the pulley nut and then pull out the pulley.



Removing pulley

2.5.3 Removing rear bearing

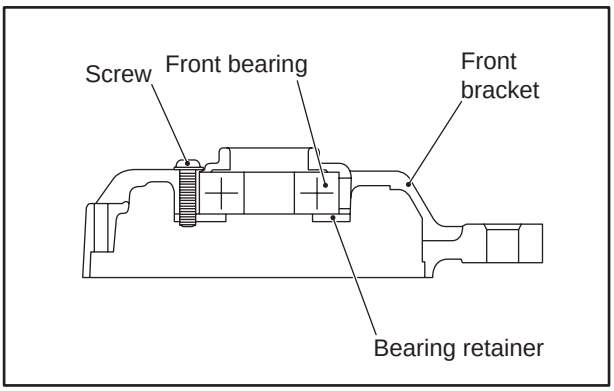
Remove the rear bearing from the rotor using a bearing puller.



Removing rear bearing

2.5.4 Removing front bearing

Remove the screw, and then remove the bearing retainer and front bearing from the front bracket.



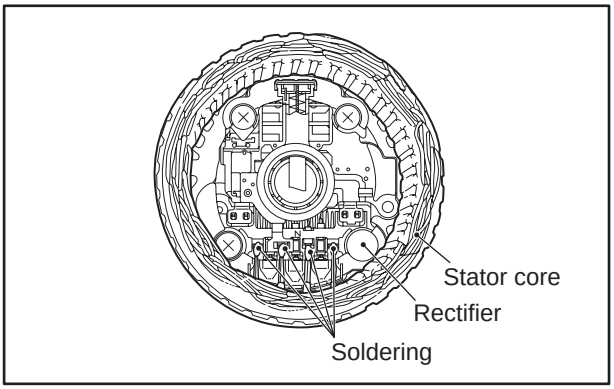
Removing front bearing

2.5.5 Removing stator

CAUTION

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

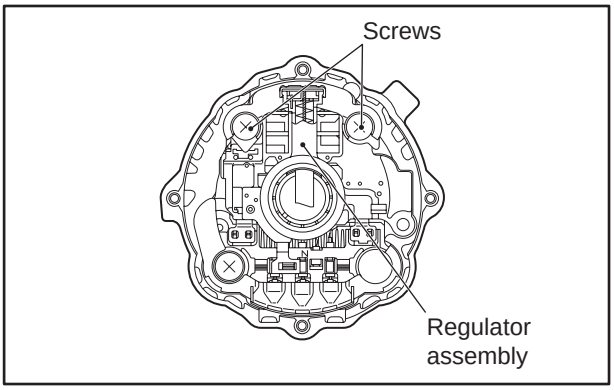
Cut off the joint of the stator and remove the stator from the rectifier.



Removing stator

2.5.6 Removing regulator assembly

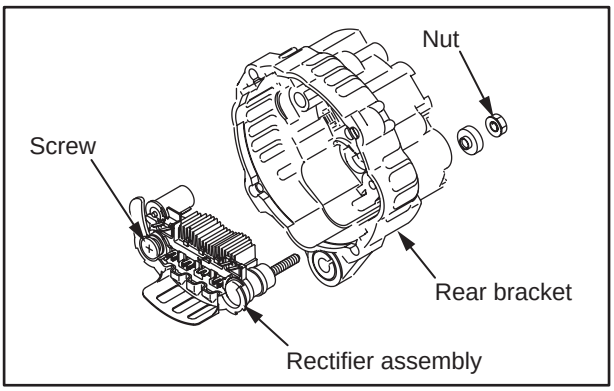
Remove the screws of the regulator assembly and then remove the regulator assembly.



Removing regulator assembly

2.5.7 Removing rectifier assembly

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



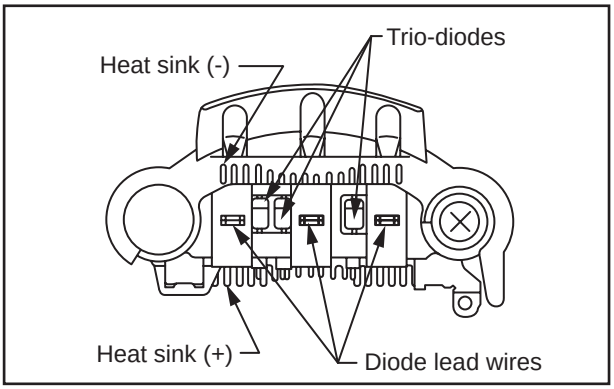
Removing rectifier assembly

2.6 Inspecting and repairing alternator

2.6.1 Inspecting rectifier

Check that diodes in a rectifier function properly. To check, measure both negative (-) and positive (+) resistance alternately twice. If both infinite negative and infinite positive resistances are observed, the diode is open-circuited. If measured value is close to 0 Ω, the diode is short-circuited. In either case, replace the rectifier with a new one.

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



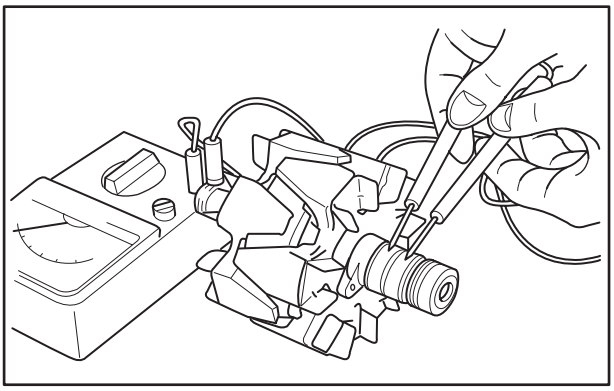
Inspecting rectifier

2.6.2 Inspecting rotor assembly

(1) Measure the resistance between the slip rings (rotor coil).

If measured value is out of standard, replace the rotor assembly with a new one.

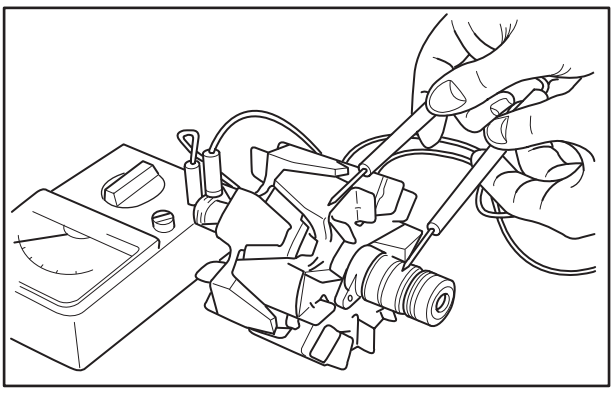
Item	Standard
Resistance between slip rings	9 to 10.4 Ω



Inspecting field coils for continuity

(2) Check that there is continuity between the slip ring and the shaft (or core).

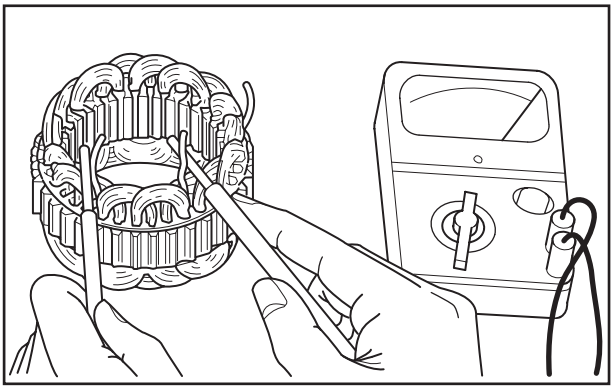
If continuity is observed, replace the rotor assembly with a new one.



Inspecting field coils for grounding

2.6.3 Inspecting stator

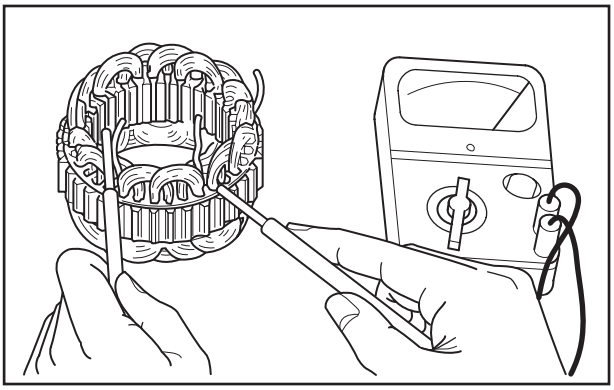
(1) Checking continuity between lead wires.
Check that there is continuity between a pair of lead wires.
Also check that there is no continuity between a pair of lead wires and other pair of lead wires.
If defective, replace the stator.



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.

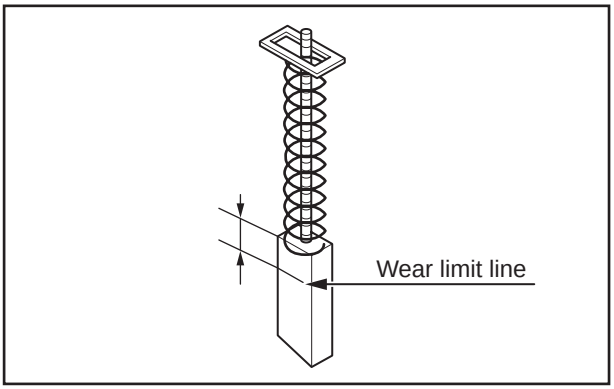


Checking for grounding between the leads and the core

2.6.4 Inspecting brushes for wear

Measure the length of the brushes. If the measured value is less than the limit, replace both the brush holder assembly and the brush assembly with new ones.

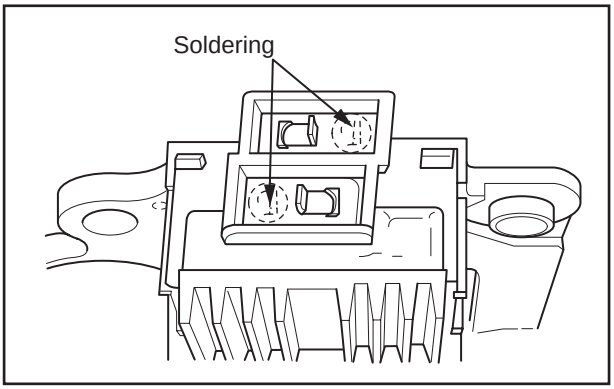
Item	Standard	Limit
Brush length	18.5 mm [0.728 in.]	5.0 mm [0.197 in.]



Inspecting brushes

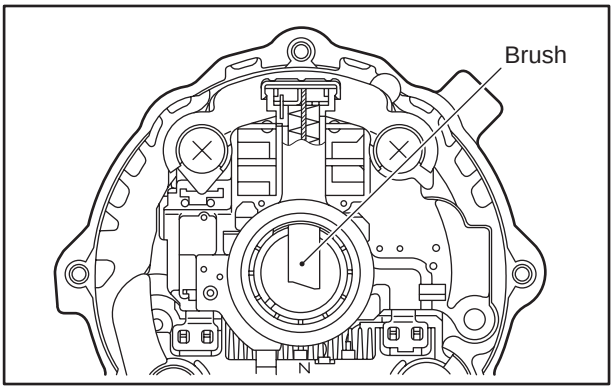
2.6.5 Replacing brushes

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



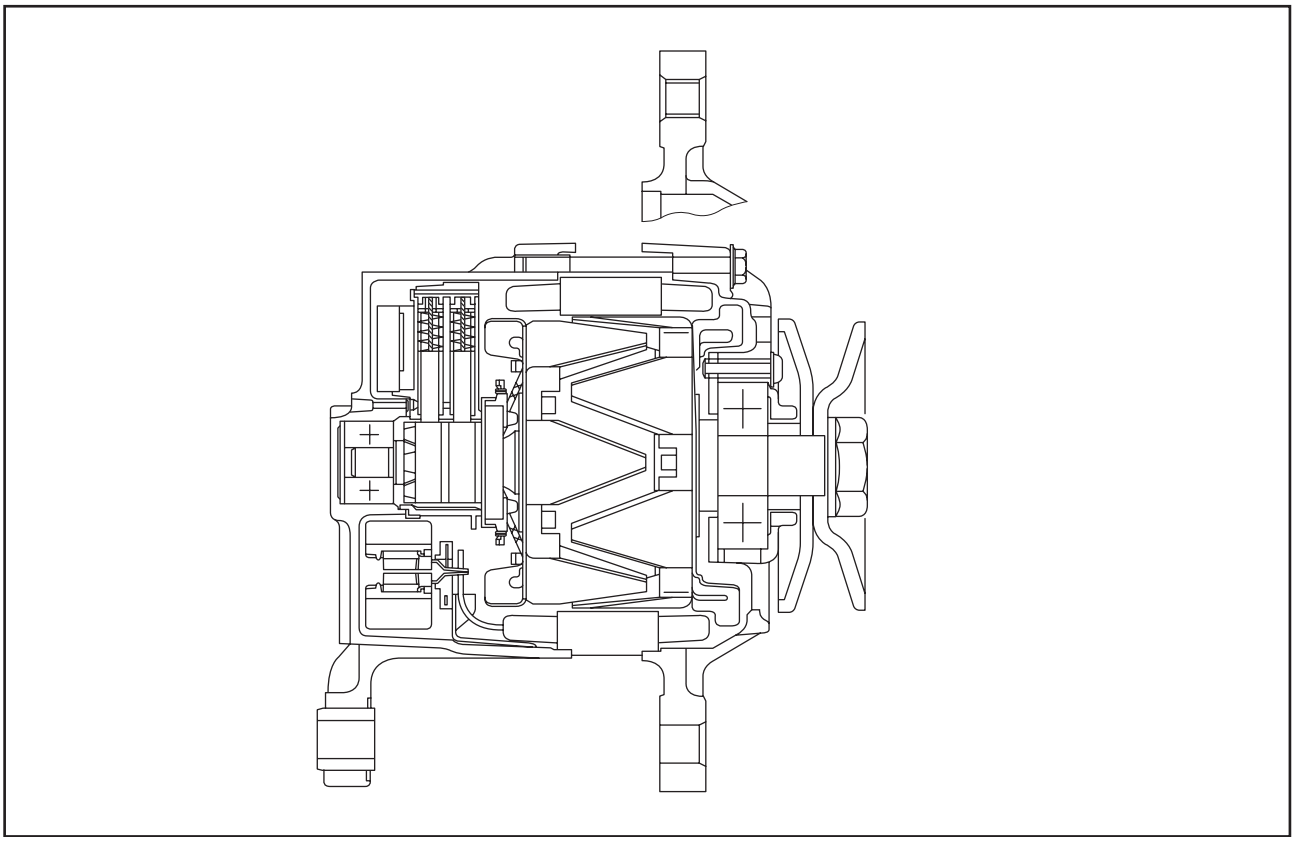
Replacing brushes

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



Installing brushes

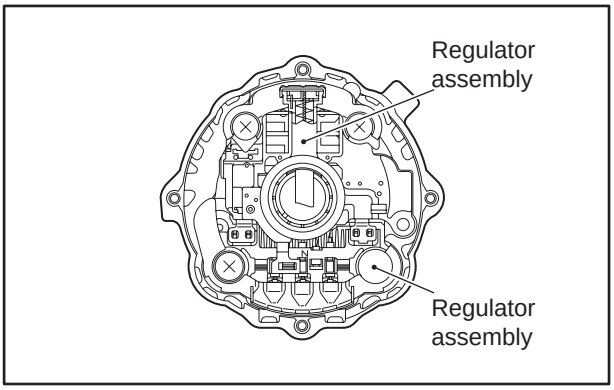
2.7 Reassembling alternator



Reassembling alternator

2.7.1 Installing rectifier assembly and regulator assembly

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



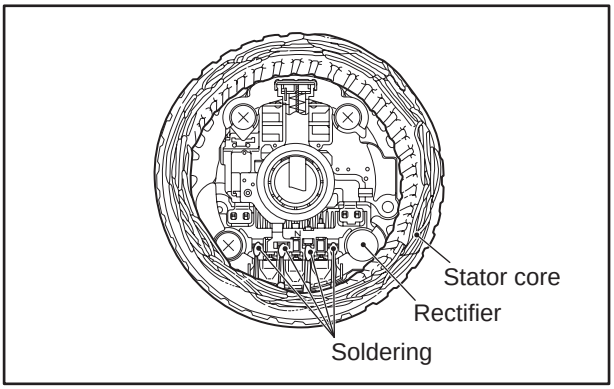
Removing rectifier assembly and regulator assembly

2.7.2 Installing stator

CAUTION

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

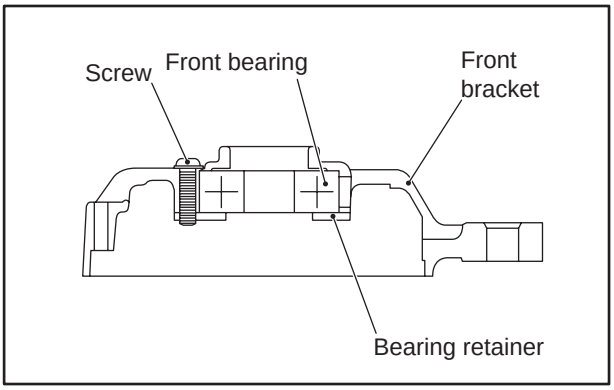
Install the stator and solder the leads of the stator to the rectifier.



Installing stator

2.7.3 Installing front bearing

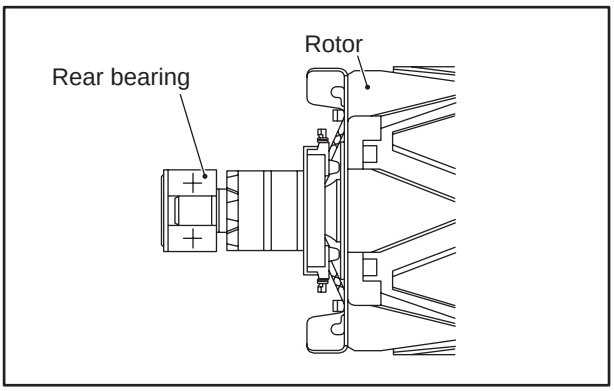
Drive the front bearing into the front bracket and secure the bearing retainer with a screw.



Installing front bearing

2.7.4 Installing rear bearing

Press-fit the rear bearing to the rotor.

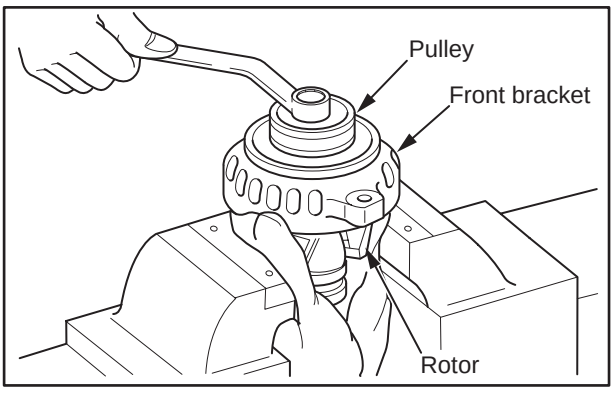


Installing rear bearing

2.7.5 Installing pulley

(1) Insert the rotor into the front bracket.
Apply a cloth to the rotor and set it in a vise.

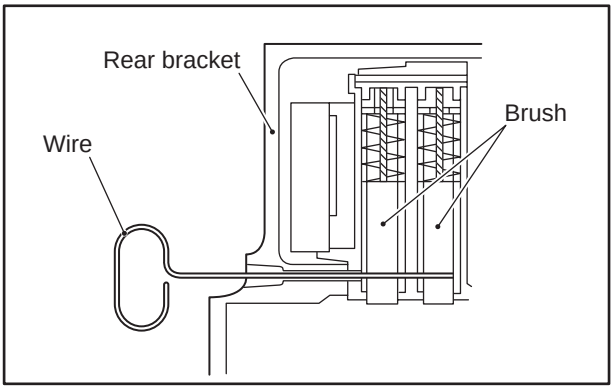
(2) Install the spacer and pulley, and secure the pulley with a nut.



Installing pulley

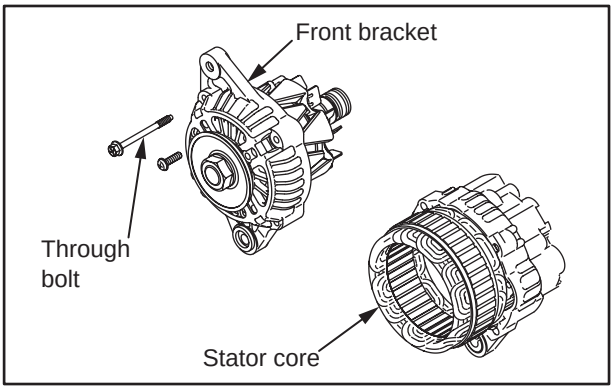
2.7.6 Assembling stator and front bracket

(1) When installing the rotor into the rear bracket, lift the brushes with a piece of wire inserted through the small hole in the bracket. After installation, remove the wire.



Securing brushes

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

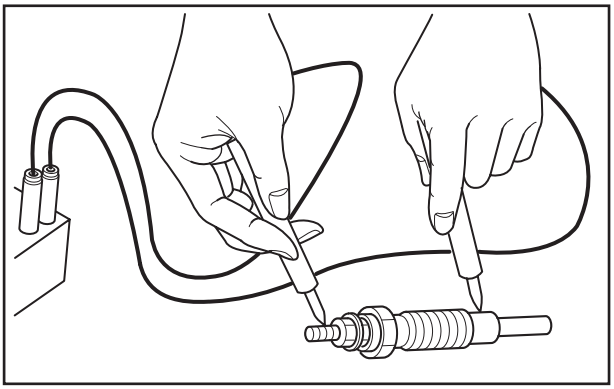


Installing stator and front bracket

2.8 Heating test of glow plug

Connect the wiring to the terminal, and ground the body.
If the glow plug heats red, it is normal.

Item	Rated voltage - Armature current	Temperature
Swirl chamber	10.5 ± 0.1 V - 9.7 ± 1.0 A (When applying for 30 seconds.)	800°C [1472°F] (When applying the rated voltage for 9 ± 2 seconds.)
Direct injection	11.0 V - 5.5 A (When applying for 30 seconds.)	800°C [1472°F] (When applying the rated voltage for $7^{+1.5}_{-1.0}$ seconds.)



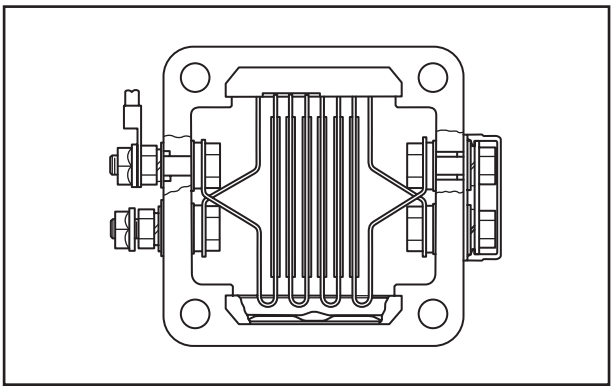
Heating test of glow plug

2.9 Inspecting air heater

Note: Air heater is not installed in all engines. Check the specification of your engine.

(1) Using an ammeter or inspection lamp, check to make sure a current flows to the indicator, heater relay and air heater when the starter switch is turned to the HEAT position. Also make sure the current flow stops when the starter switch is turned to the ON or OFF position.

(2) Make sure the indicator becomes red hot in 34 to 44 seconds after the starter switch is turned to HEAT position. If the indicator becomes red hot too fast or does not heat, check the indicator and air heater for shorting and an open circuit using a tester.



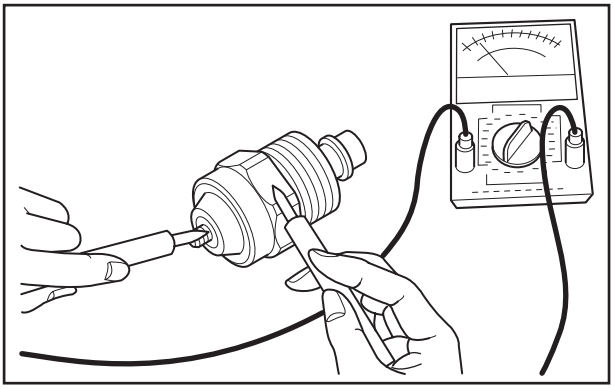
Inspecting air heater

2.10 Inspecting magnetic valve (stop solenoid, distributor-type)

2.10.1 Continuity test of magnetic valve (stop solenoid)

Inspect the continuity between the terminal and body as shown in the illustration. If there is no continuity or if the resistance is lower than the standard value, replace the magnetic valve assembly with new one.

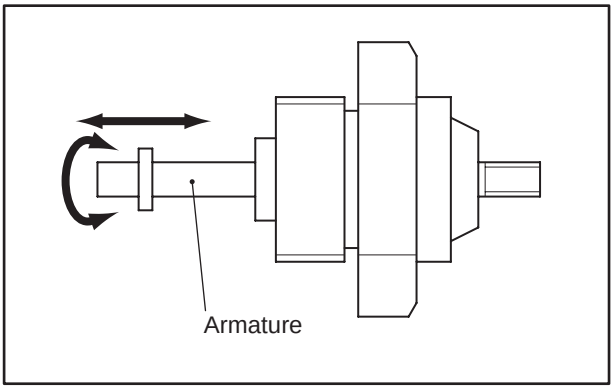
Item	Standard
Resistance value	8 to 9.2 Ω (Ambient temperature: 23 ± 5°C [73.4 ± 9°F])



Continuity test of magnetic valve

2.10.2 Inspecting magnetic valve (stop solenoid) operation

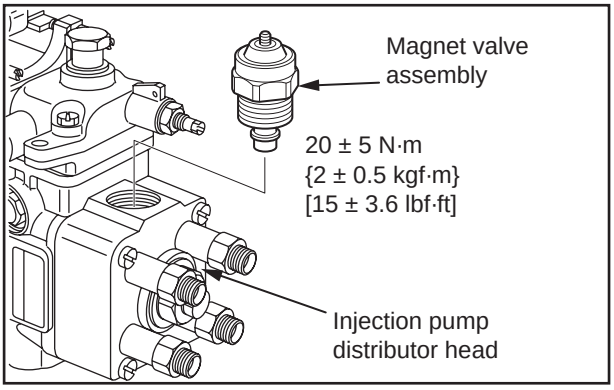
Check visually for rubber strips of the tip of the armature and damages. Also check the armature moves smoothly by rotating with a hand.



Inspecting magnetic valve operation

2.11 Installing magnetic valve (stop solenoid)

Install the magnetic valve assembly to the distributor with the specified torque.



Installing magnetic valve

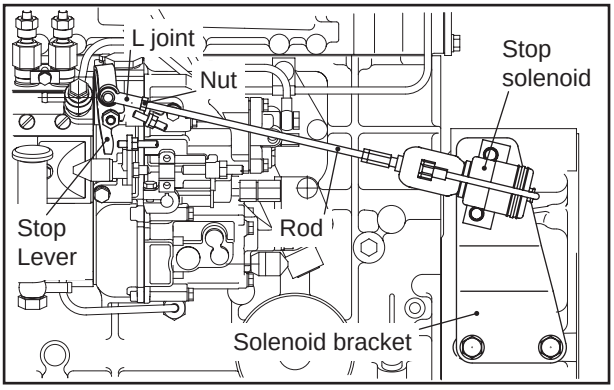
2.12 Installing stop solenoid (RUN-ON type, for in-line pump type)

(1) Install the solenoid bracket to the flywheel housing. Install the stop solenoid to the solenoid bracket.

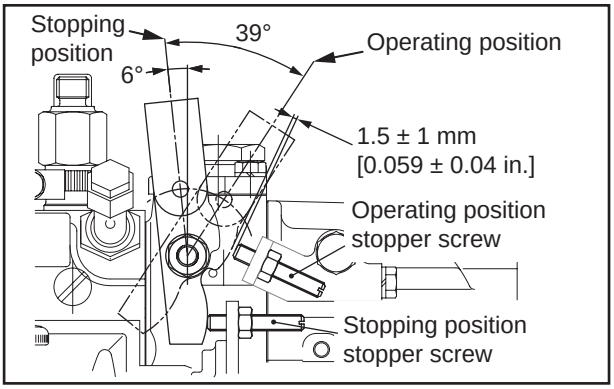
(2) With placing the stop lever of the fuel injection pump on the operating position (fully pulled), install the L joint, the rod and the nut, and connect the stop lever and the stop solenoid.

(3) Energize the stop solenoid and move the stop lever to the operating position. Adjust the length of the rod to make the clearance between the stop lever and the operating position stopper screw to 1.5 ± 1 mm, and secure it by the nut.

(4) After installing the stop solenoid, energize the stop solenoid again to check that the stop solenoid operates normally.



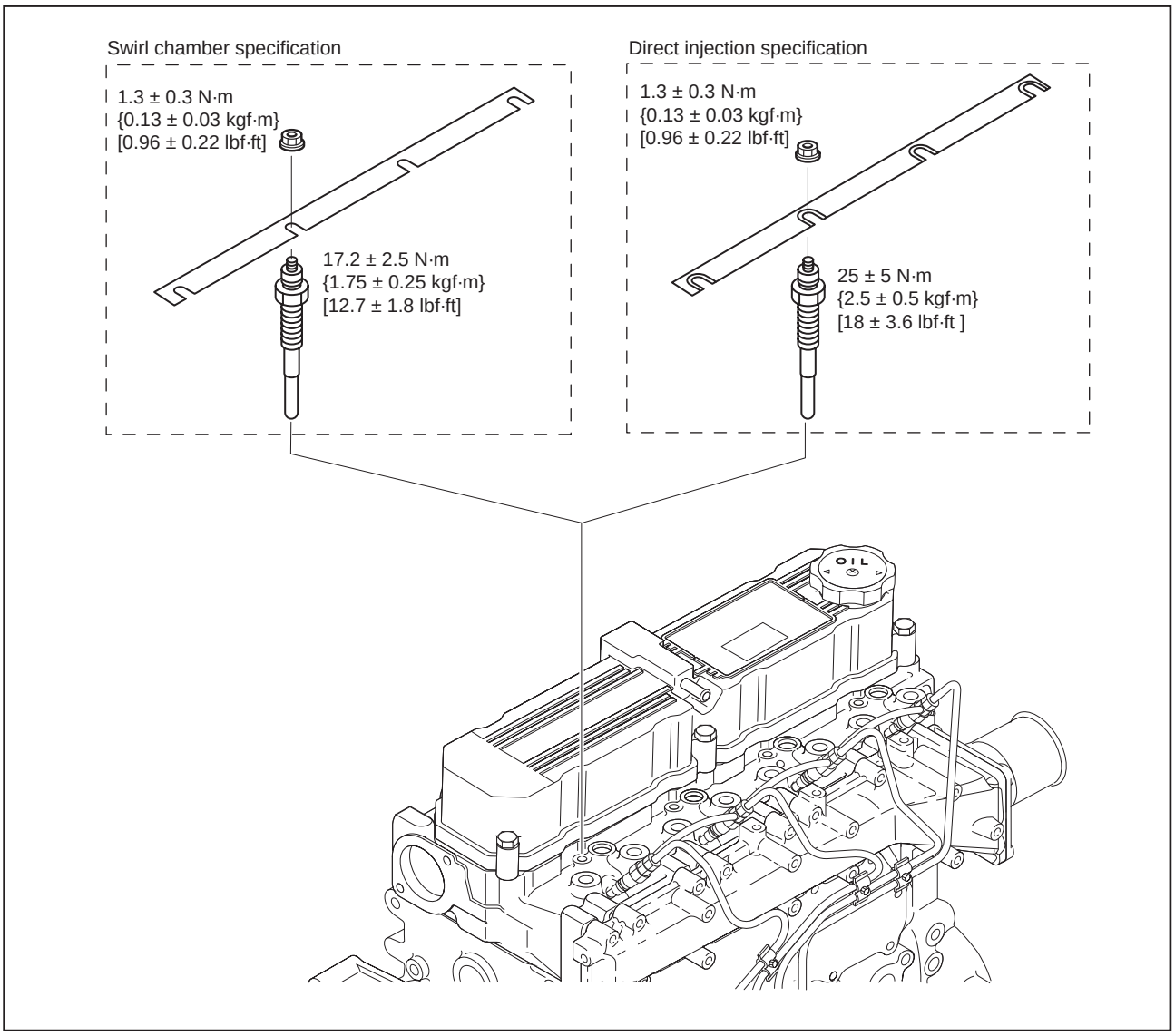
Installing stop solenoid (1)



Installing stop solenoid (2)

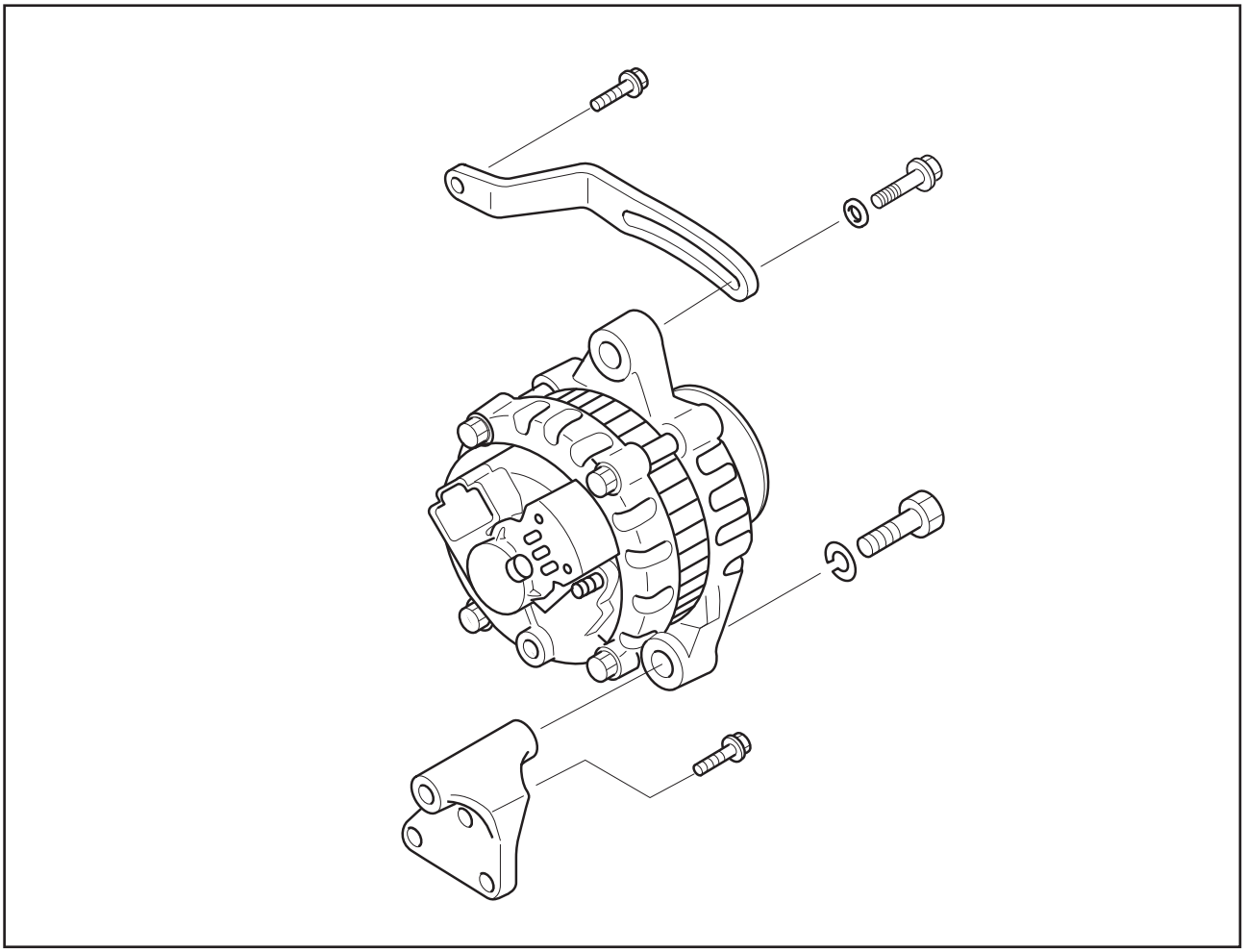
3. Installing electrical system

3.1 Installing glow plug



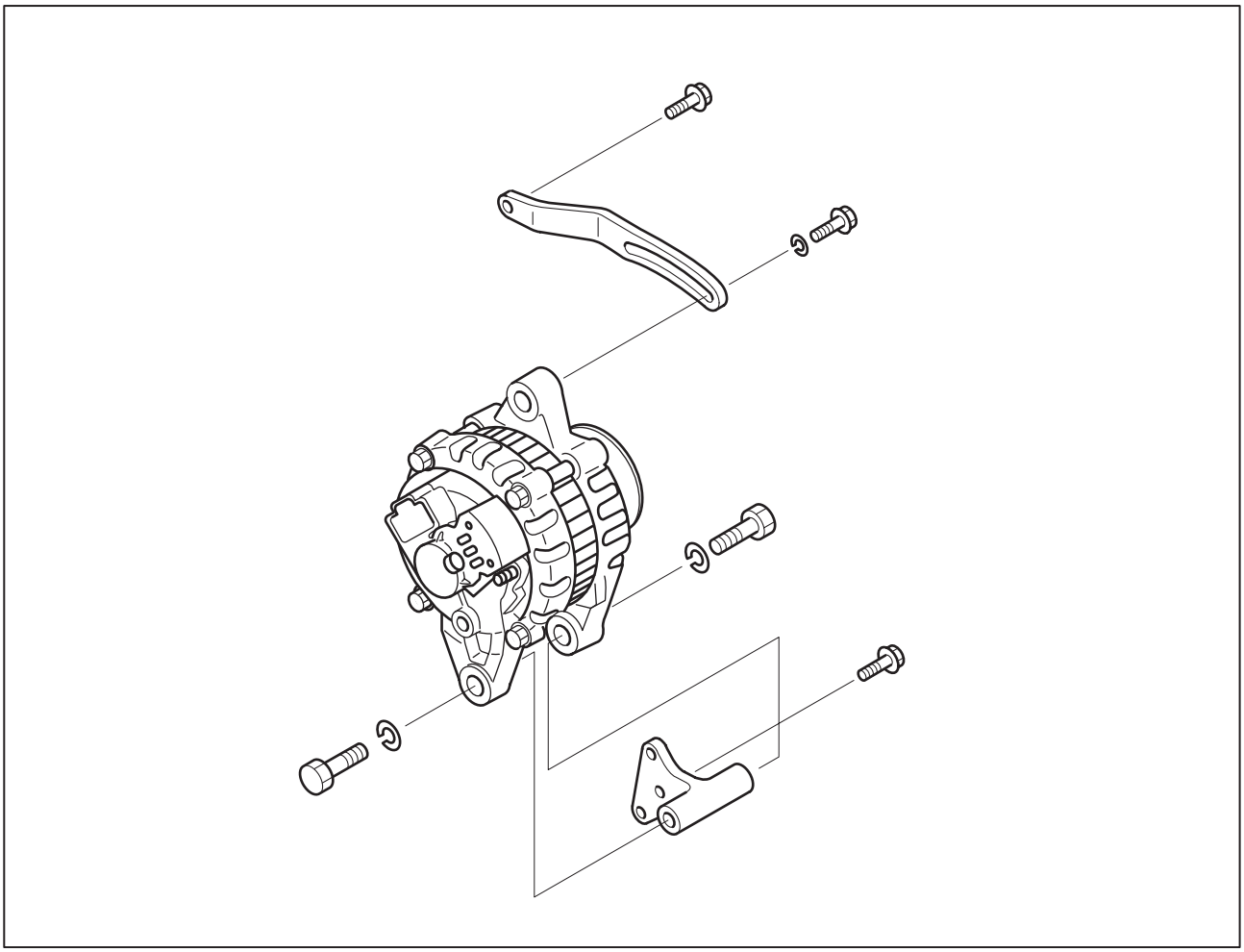
Installing glow plug

3.2 Installing alternator (12V-50A)



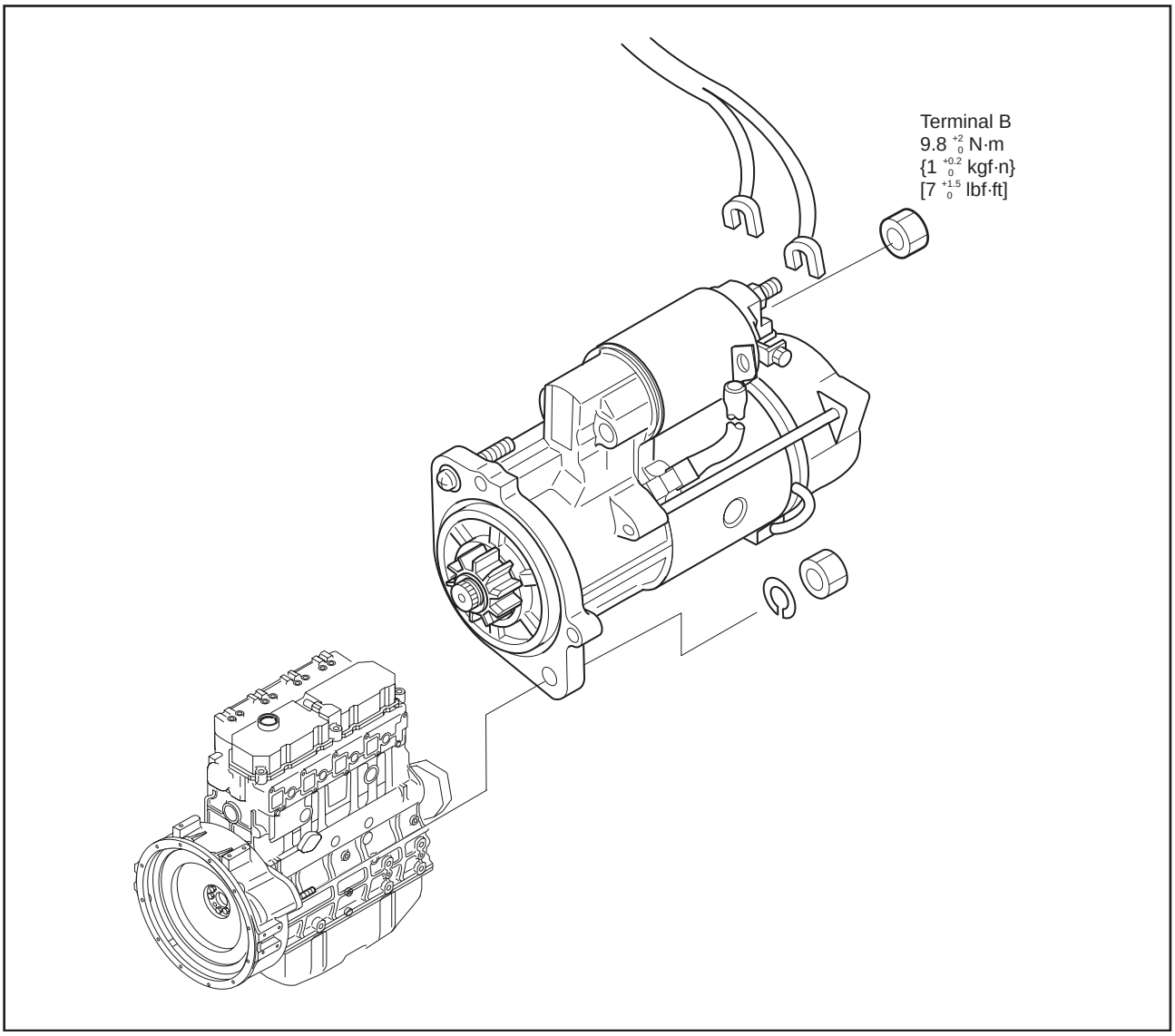
Installing alternator (12V-50A)

3.3 Installing alternator (12V-75A, option)



Installing alternator (12V-75A, option)

3.4 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 socket and ratchet handle on the crankshaft pulley nut.

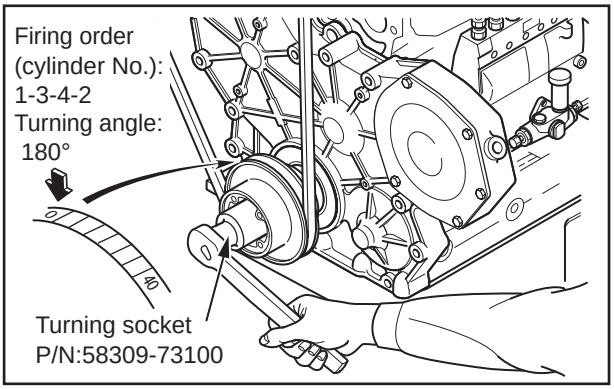
(2) When the No. 1 piston is at the top dead center on the compression stroke, the "0" graduation mark on the periphery of the crankshaft pulley is aligned with the pointer on the timing gear case, and neither the inlet valve nor the exhaust valve is not lifted off its seat by the push rod.

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

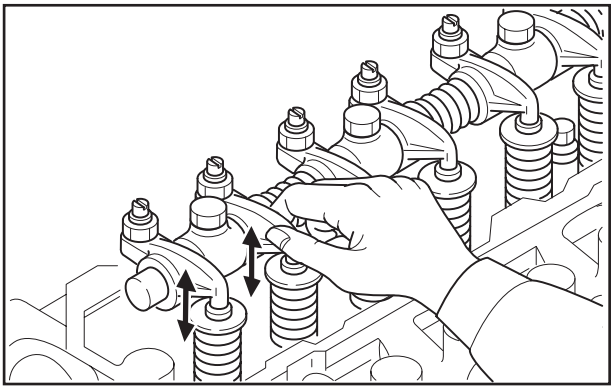
1.1.2 Adjusting valve clearance

(1) Insert the feeler gauge of the specified thickness between the rocker arm and valve 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.

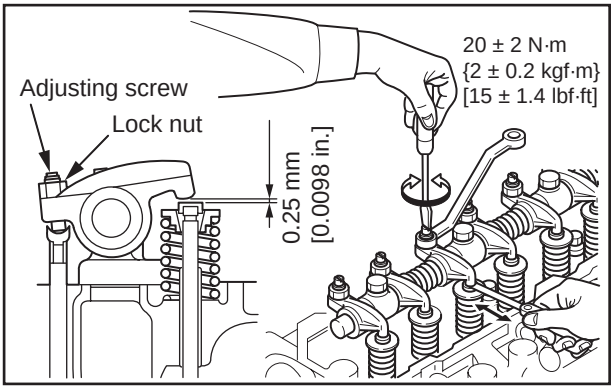
(2) After adjusting the clearance, tighten the lock nut firmly, and inspect the clearance again.



Turning engine



Determining top dead center of No.1 cylinder compression stroke



Adjusting valve clearance

1.2 Draining fuel system

⚠ WARNING

(a) When draining the fuel filter, fuel flows out together with the water. Wipe off spilled fuel thoroughly. Spilled fuel cause a fire.

(b) Tighten the drain plug securely after draining water otherwise fuel may leak, and it will lead to a fire.

When water stayed in the bottom of the fuel filter exceeds the specified level, the water may enter into the fuel system. Bleed the fuel filter of water in the following procedures.

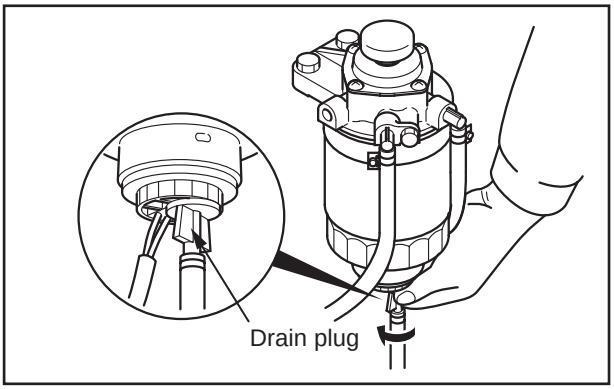
1.2.1 Draining fuel filter

(1) Loosen the drain plug on the bottom of the fuel filter.

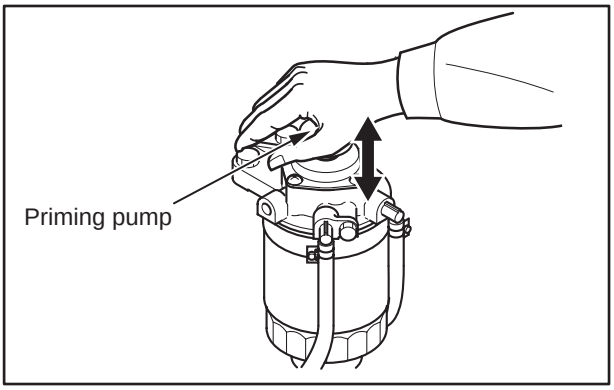
(2) Water is easily drained by pressing the manual feed pump repeatedly (approx. 7 times) to feed the fuel.

(3) Tighten the drain plug securely after draining the water.

(4) Bleed the fuel system of air after bleeding the fuel system of water.



Draining fuel filter (1)



Draining fuel filter (2)

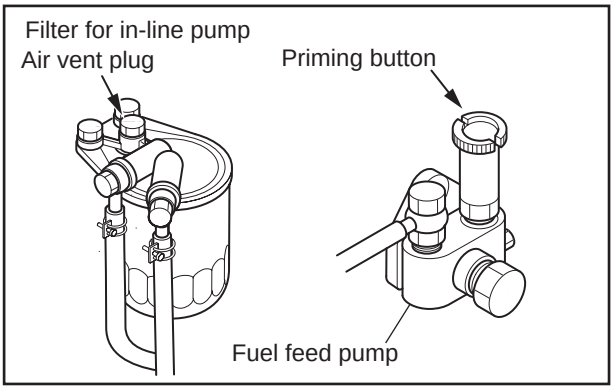
1.3 Bleeding fuel system

⚠ WARNING

Completely wipe off any spilled fuel from the air vent plug with a cloth, and be sure to tighten the air vent plug after air bleeding. Failure to do so could cause a fire.

1.3.1 Bleeding fuel filter (in-line fuel injection pump)

(1) Loosen the air vent plugs of the fuel filters. (approx. 1.5 turns)
(2) Unlock the priming pump cap by turning it counterclockwise, then move the cap up and down repeatedly.
(3) When fuel flowing from the vent holes no longer contains air bubbles, tighten the air vent plugs.

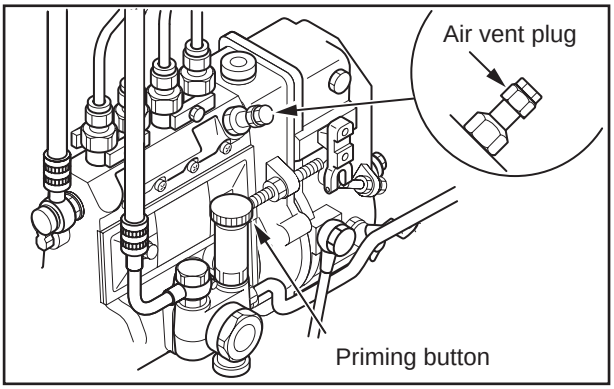


Bleeding fuel filter
(in-line fuel injection pump)

1.3.2 Bleeding fuel injection pump (in-line fuel injection pump)

(1) Loosen the air vent plugs for the injection pumps. (approx. 1.5 turns)
(2) Move the cap up and down repeatedly.
(3) When fuel flowing from the vent holes no longer contains air bubbles, tighten the air vent plugs. Before tightening the last air vent plug, lock the priming pump cap by turning it clockwise while pushing it down.
(4) Follow the same procedure for the fuel injection pumps on both right and left sides.

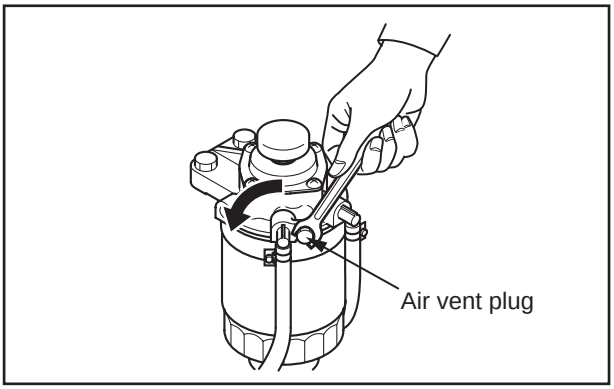
Note: (a) If all the vent plugs are tightened before the priming pump cap is locked, fuel pressure acts on the feed pump, making it impossible to return the cap to the original position.
(b) Wipe off fuel spilled from the vent holes thoroughly with a cloth.



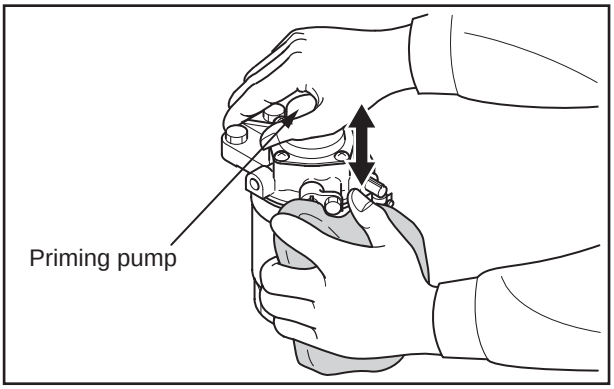
Bleeding fuel injection pump
(in-line fuel injection pump)

1.3.3 Bleeding fuel filter (distributor-type fuel injection pump)

(1) Loosen the air vent plug of the fuel filter with a wrench.
(2) Repeatedly press the priming pump with the cloth applied to the air vent plug.
(3) When fuel with air bubbles no longer comes out, tighten the air vent plug securely.



Bleeding fuel filter
(distributor-type fuel injection pump) (1)



Bleeding fuel filter
(distributor-type fuel injection pump) (2)

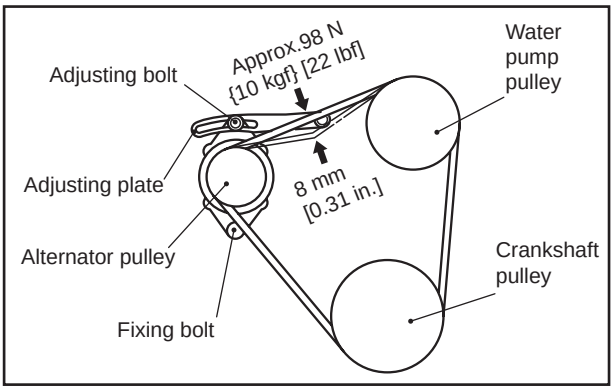
1.4 Inspecting V-belt and adjusting V-belt tension

CAUTION

(a) If defects such as cuts or surface separations are found during inspection, replace the V-belt.
(b) Keep oil and grease away from the V-belt, since they may cause the V-belt to slip and shorten the service life.
(c) Excessive V-belt tension can cause rapid wear of the alternator bearing and shorten the service life of the V-belt. Adjust the belt tension accurately by following the procedures below.

1.5 Inspecting V-belt

(1) Inspect the V-belt visually for separation or damage. If any abnormality is found, replace the V-belt with a new one.
(2) Inspect V-belt tension (deflection).
When pressing the V-belt strongly at the center of its span, the deflection should be 8 mm [0.31 in.].
Force on the V-belt: Approx. 98 N {10 kgf} [22 lbf]
If the deflection of V-belt is not within the standard, adjust the V-belt tension.



Inspecting V-belt

1.6 Adjusting V-belt tension

(1) Loosen all retaining bolts of the alternator and adjusting plate.
(2) Adjust V-belt tension properly with the adjusting bolt.
(3) Tighten all retaining bolts of the alternator and adjusting plate.

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.
Also check the inlet system and exhaust system.

(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	800 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)