



# SERVICE MANUAL

October 2007

 SERVICE MANUAL

**L-SERIES**

L2A, L2C, L2E, L3A, L3C, L3E

**MITSUBISHI  
DIESEL ENGINES**

**L-SERIES**

L2A, L2C, L2E  
L3A, L3C, L3E

October 2007





# 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.



## 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.



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



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



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



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<sup>2</sup>
- 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<sub>2</sub>O (cmAq)
- Rotational speed: 1 min<sup>-1</sup> = 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.

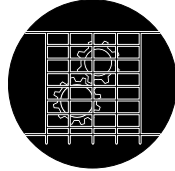


**⚠ WARNING**

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

### Keep engine stopped during servicing

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

### Always restore engine turning tools after use

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

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



**⚠ WARNING****Be careful of burns****Do not touch the engine during or immediately after operation**

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

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

**Slowly and carefully open radiator cap**

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

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

Close the radiator cap tightly without fail.

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

**Add coolant only after the coolant temperature dropped**

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

**Never remove heat shields**

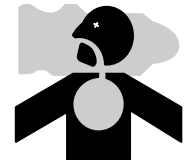
The exhaust system, which becomes extremely hot while the engine is operating, is provided with various heat shields. Do not remove these heat shields. If any of these heat shields have been removed owing to unavoidable circumstances during the work, be sure to restore them after the work is completed.

**⚠ WARNING****Be careful of exhaust fume poisoning****Operate engine in well-ventilated area**

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

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

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

**⚠ WARNING****Protect ears from noises****Wear ear plugs**

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



**⚠ WARNING**

**Be careful of falling down**

**Lift engine correctly**

To lift the engine, always use a correct wire rope capable of withstanding the engine weight.

Attach the wire rope to the lifting hangers provided on the engine using a correct sling.

During lifting process, keep the engine in a well-balanced position by taking the center of gravity of the engine into consideration.

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.



## Other cautions

### Modification of engine prohibited

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

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

### Never break the seals

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

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

### Pre-operational check and periodic inspection/maintenance

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

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

### Break-in operation

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

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

### Warming-up operation

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

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

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

### Avoid engine operations in a overload condition

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

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

### Cooling operation before stopping engine

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

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

During cooling operation, check the engine for abnormalities.

### Protection of engine against water entry

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

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

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

### Maintenance of air cleaner or pre-cleaner

The major cause of abnormal wear on engine parts is dust entering with intake air. Worn parts produce many

problems such as an increase of oil consumption, decrease of output, and starting difficulties. For effective removal of dust from intake air, conduct maintenance of the air cleaner according to the following instructions.

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

### **Observe safety rules at work site**

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

Do not operate the engine if you are feeling ill.

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

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

### **Work clothing and protective gear**

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

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

### **Use of tools optimum for each work**

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

### **Avoidance of prolonged time of starter operation**

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

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

### **Do not turn off battery switch during operation**

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

### **Cautionary instructions for transporting engine**

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

### **Avoid continuous engine operation in a low load condition**

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

### **Ventilation of engine room**

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

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

### **Avoid contact with high-pressured fuel**

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

Fuel in the fuel injection pipes is under high pressure. If high-pressured fuel contacts 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

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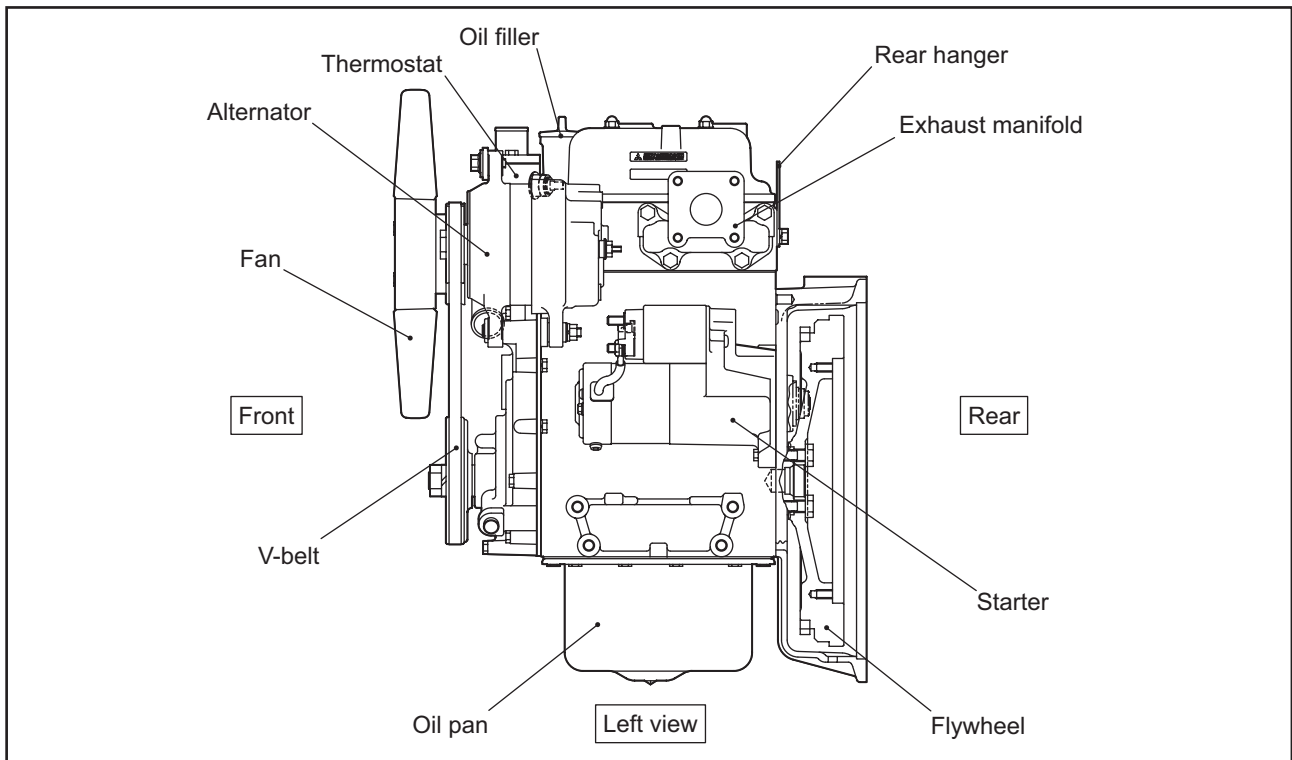


# GENERAL

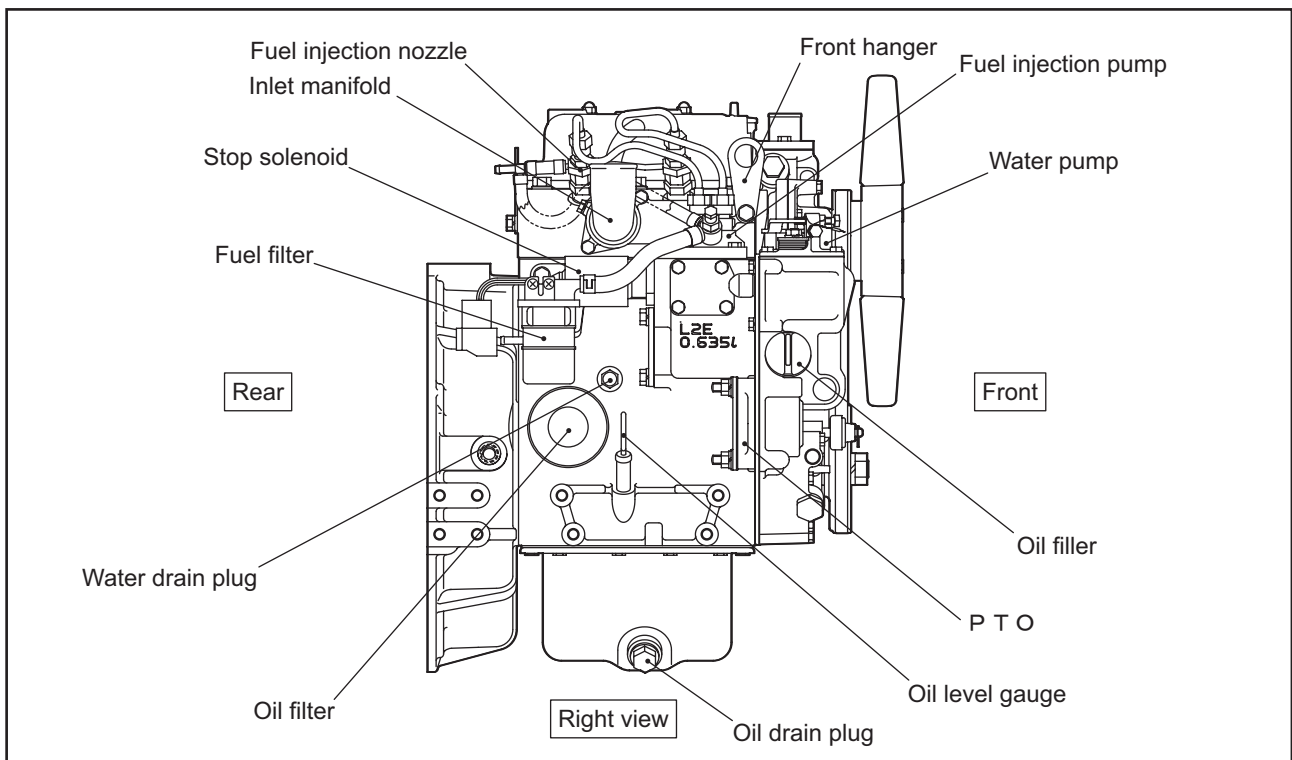
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# 1. External view

## 1.1 External view of L2A, L2C and L2E

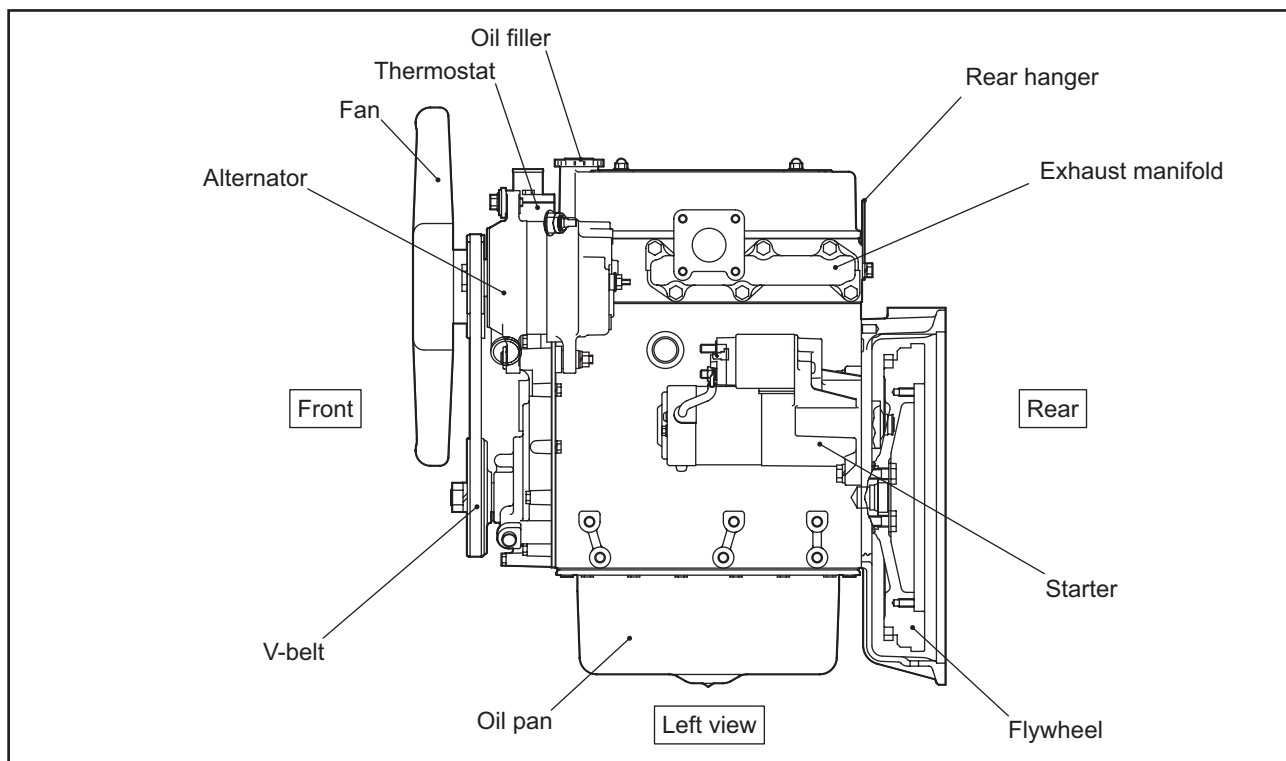


Engine left view

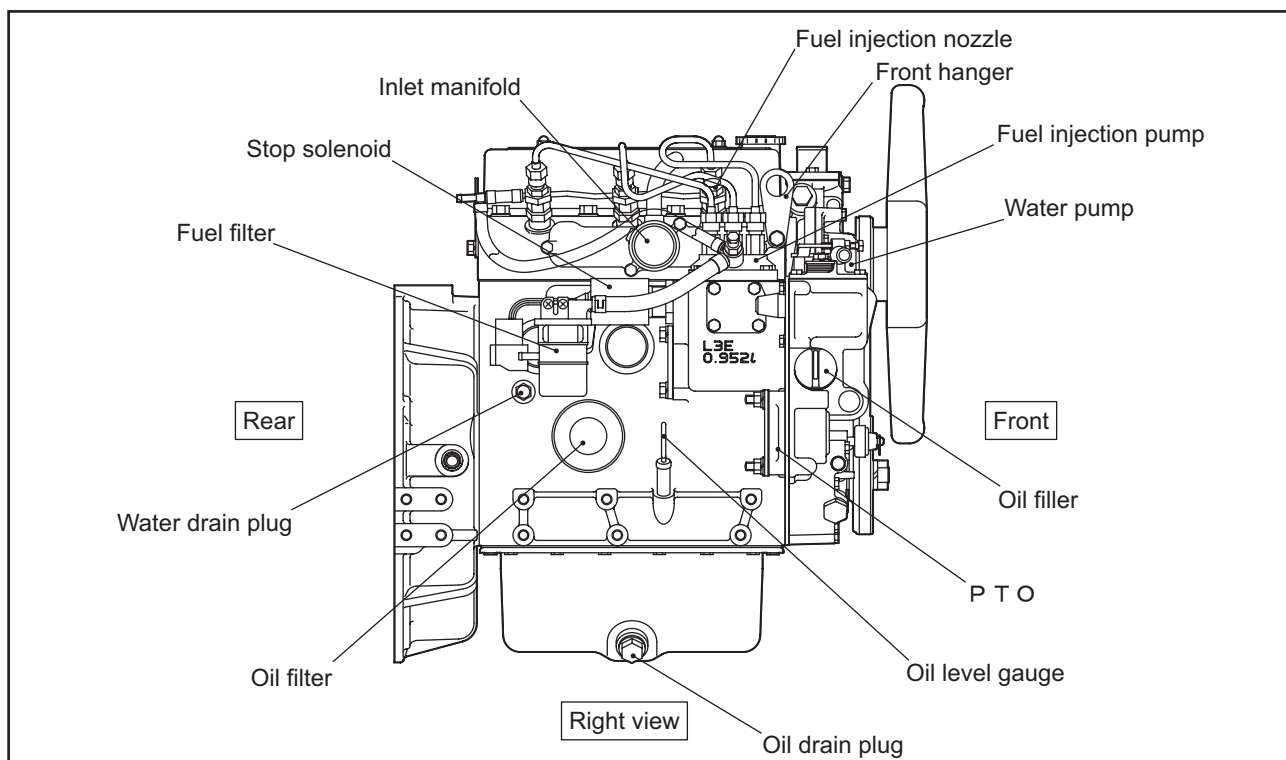


Engine right view

1.2 External view of L3A, L3C and L3E



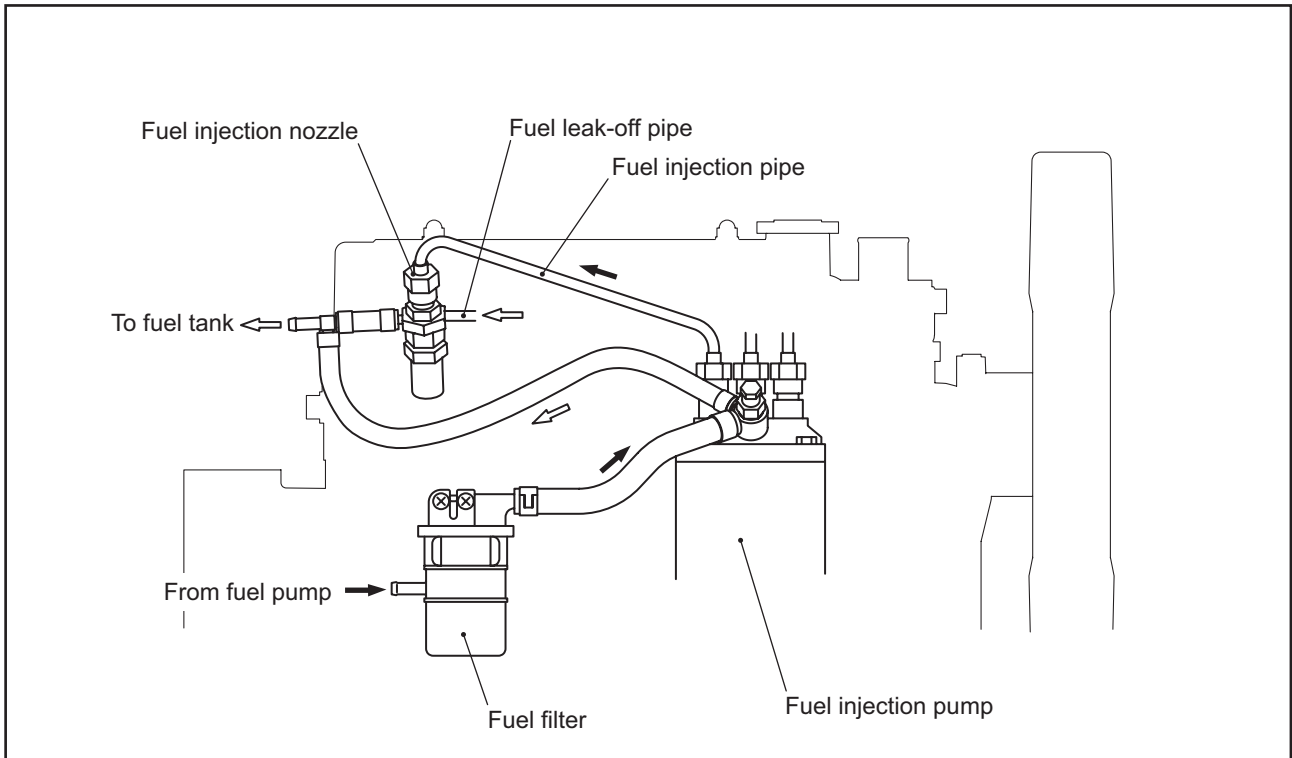
Engine left view



Engine right view

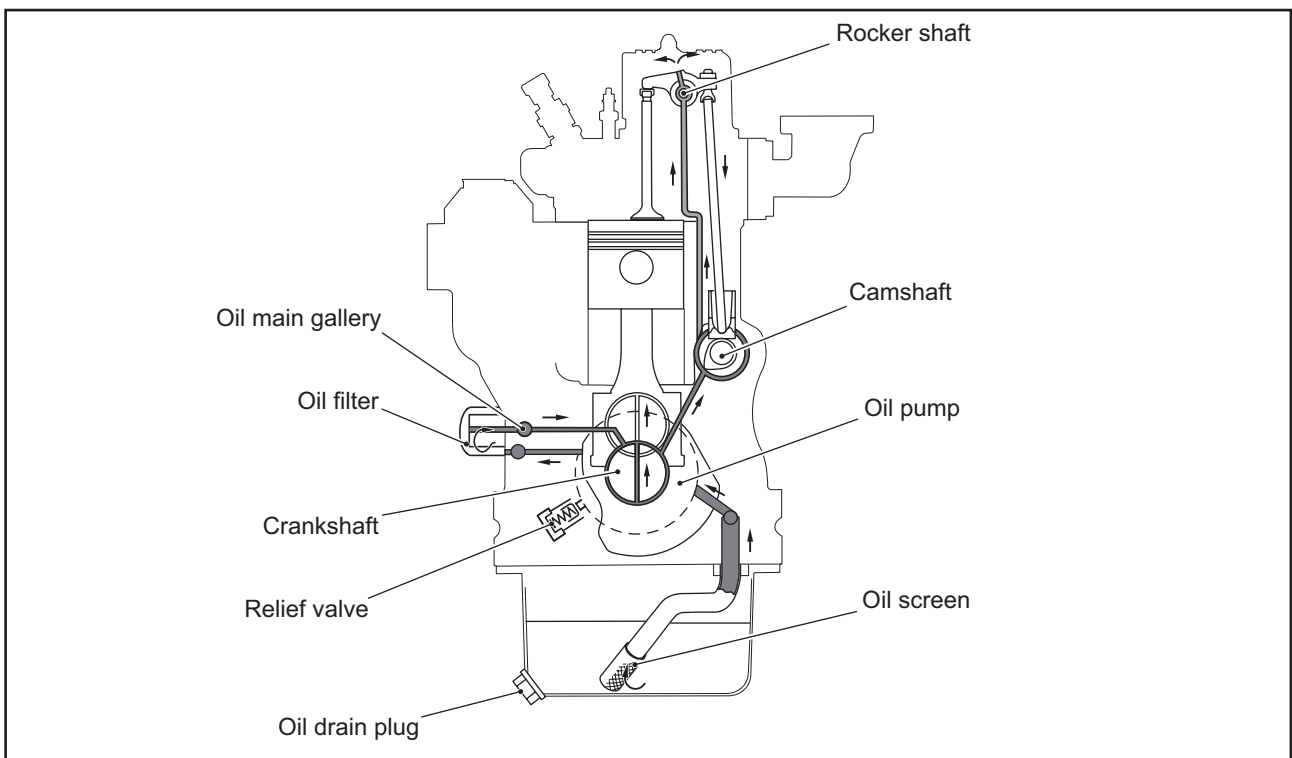
## 2. System flow diagrams

### 2.1 Fuel system - flow diagram



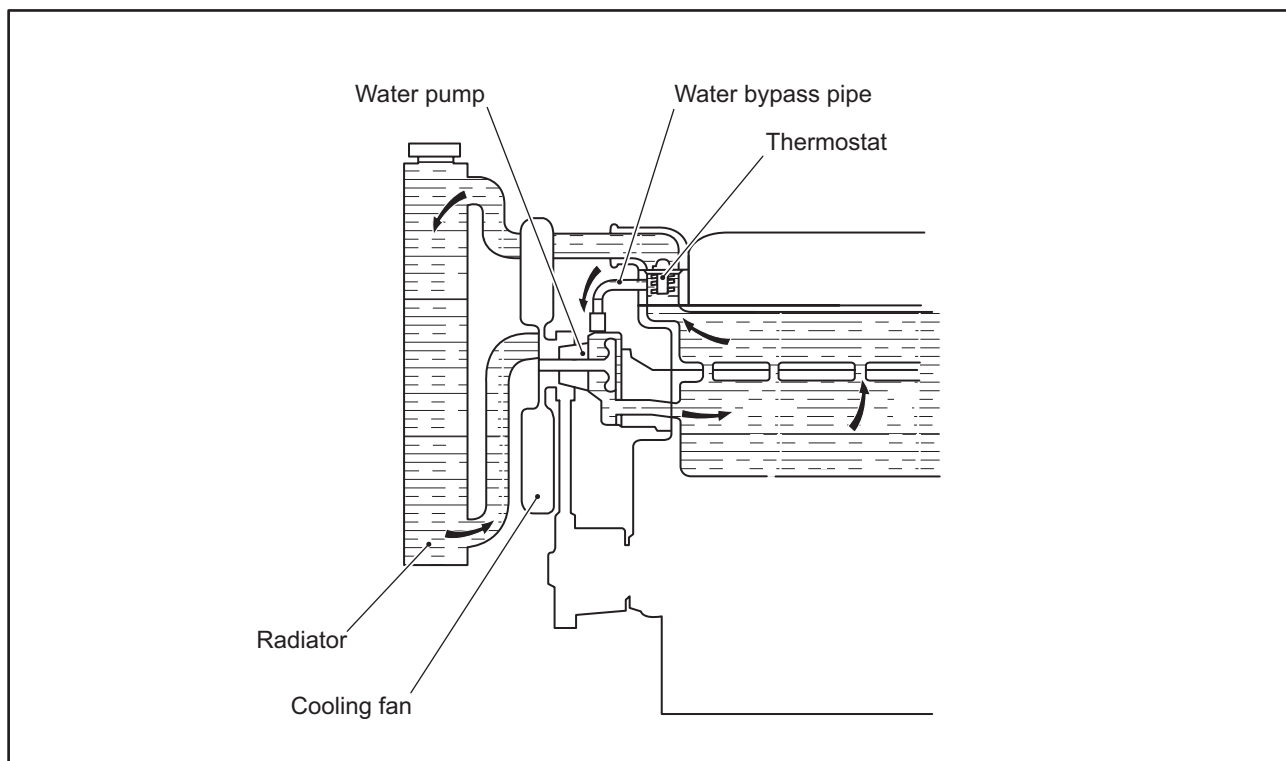
Fuel system - flow diagram

### 2.2 Lubrication system - flow diagram



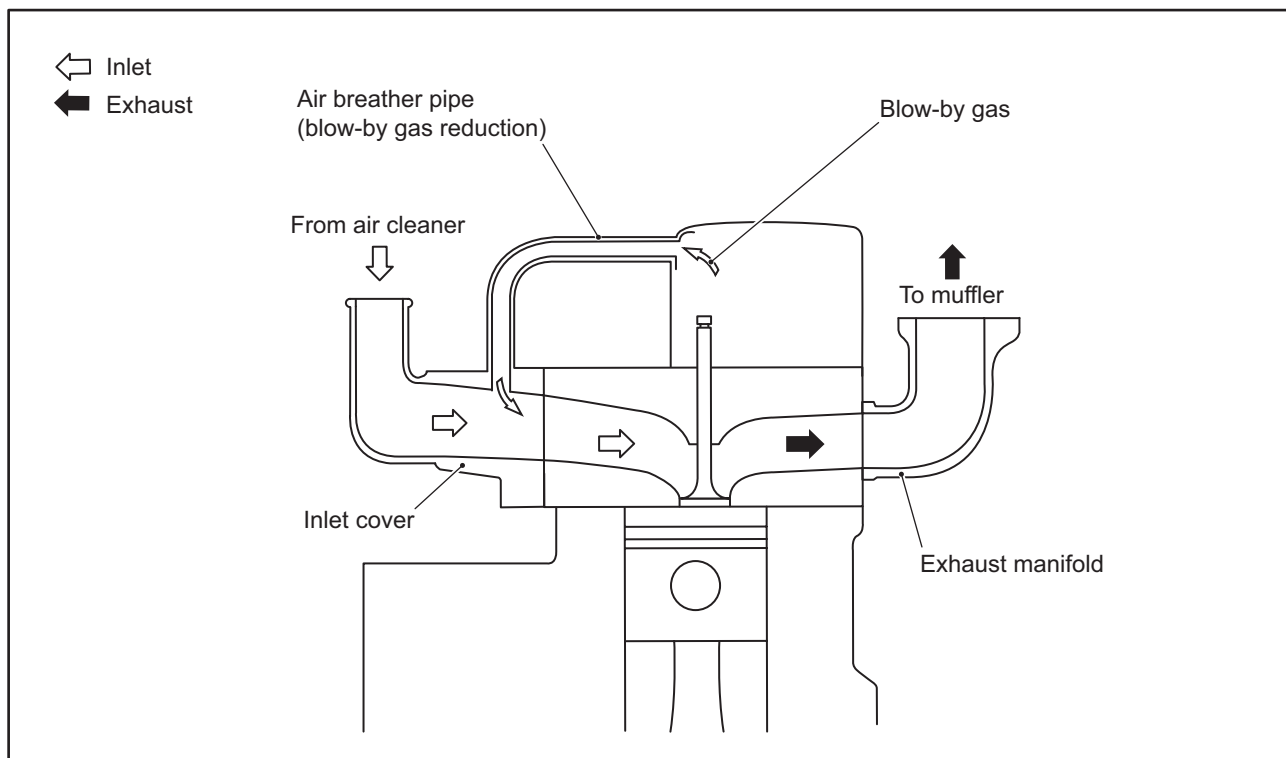
Lubrication system - flow diagram

2.3 Cooling system - flow diagram



Cooling system - flow diagram

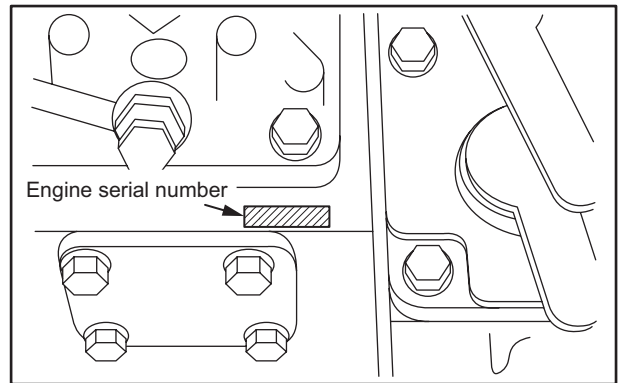
2.4 Inlet and exhaust system - flow diagram



Inlet and exhaust system - flow diagram

### 3. Engine serial number location

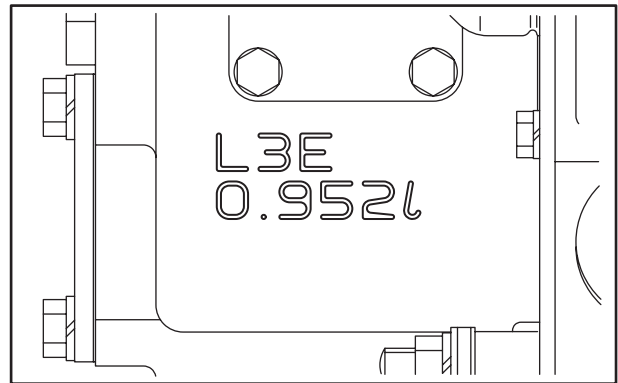
The engine serial number is stamped on the injection pump mount (upper side of tie rod cover) of the cylinder block.



Stamp location of engine serial number

### 4. Indication of engine model and total displacement

The engine type and displacement are stamped on the side of the injection pump mount of the cylinder block.



Engine model and cylinder capacity

## 5. Specifications

### 5.1 Specifications of L2A, L2C and L2E

Table 1-1 Specifications of L2A, L2C and L2E (1 / 4)

Engine model			L2A	L2C	L2E	
Main specifications	Type		Vertical type, water-cooled, 4 cycle diesel			
	No. of cylinders		2			
	Combustion type		Swirl chamber type			
	Valve mechanism		Overhead valve type			
	Cylinder bore × stroke		65 × 70 mm [2.56 × 2.76 in.]	70 × 70 mm [2.76 × 2.76 in.]	76 × 70 mm [2.97 × 2.76 in.]	
	Total displacement		0.464 L [0.126 U.S. gal.]	0.538 L [0.142 U.S. gal.]	0.635 L [0.168 U.S. gal.]	
	Compression ratio		23 : 1			
	Fuel used		Diesel oil (JIS K2204 Special No.1 - Special No.3)			
	Order of ignition		1-2			
	Direction of rotation		Counterclockwise as viewed from flywheel side			
	Dry mass		61 kg [134 lb]			
Basic engine	Piston ring	Number		Compression ring: 2 Oil ring (with expander): 1		
	Valve timing (when warm)	Inlet valve	Open	BTDC 18°		
			Close	ABDC 46°		
		Exhaust valve	Open	BBDC 46°		
			Close	ATDC 18°		
	Starting system		Electric starting			
Fuel system	Fuel injection pump	Type		ND-PFR type		
		Manufacturer		DENSO CORPORATION		
		Plunger diameter		ø 5.5 mm [0.22 in.], ø 6.0 mm [0.24 in.]		
		MS retard (crank angle)		4°, 8°		
		Cam lift		6 mm [0.24 in.]		
	Governor	Speed governing type		Centrifugal weight system		
	Fuel injection nozzle	Type		Throttle type		
		Manufacturer		DENSO CORPORATION		
		Spray angle		15°		
		Valve opening pressure		13.73 <sup>+1.0</sup> <sub>0</sub> MPa { 140 <sup>+10</sup> <sub>0</sub> kgf/cm <sup>2</sup> } [1992 <sup>+142</sup> <sub>0</sub> psi]		
	Fuel filter	Type		Paper-element cartridge or paper-element switch cock		
	Fuel pump (option)	1	Type		Electromagnetic diaphragm	
			Discharge rate		0.3 L [0.08 U.S. gal.]/min or more (at 12V - 1.3A)	
2		Type		Electromagnetic plunger type		
		Discharge rate		1 L [0.26 U.S. gal.]/min or more (at 12V - 1.5A)		
3		Type		Electromagnetic plunger type		
		Discharge rate		1.4 L [0.37 U.S.gal.]/min or more (at 24V - 1.5A)		
4		Type		Electromagnetic plunger type (compact type)		
		Discharge rate		0.4 L [0.11 U.S. gal.]/min or more (at 12V - 1.5A)		

Table 1-1 Specifications of L2A, L2C and L2E (2 / 4)

Engine model		L2A	L2C	L2E
Lubrication system	Lubrication system		Pressure feed, full flow filter system	
	Engine oil	Speci fication	API service category CF and CF-4	
		Capacity (engine total)	Upper limit: 2.0 L [0.53 U.S. gal]/ Lower limit: 1.2 L [0.32 U.S. gal] (Upper limit: 2.5 L [0.66 U.S.gal]/ Lower limit: 1.7 L [0.45 U.S. gal])	
	Oil pump	Type	Gear type (internal and external teeth engagement), built into gear case	
		Discharge rate	3 L [0.79 U.S. gal]/min or more (at 1000 min <sup>-1</sup> )	
	Relief valve	Type	Plunger valve type	
		Valve opening pressure	0.29 ± 0.029 MPa { 3.0 ± 0.3 kgf/cm <sup>2</sup> } [42.68 ± 4.3 psi] (1000 min <sup>-1</sup> )	
	Oil filter	Type	Paper-element cartridge	
Cooling system	Cooling system		Forced-feed circulation type	
	Coolant capacity (main unit of engine)		1.2 L [0.32 U.S. gal]	
	Water pump	Type	Centrifugal volute type	
		Discharge rate	50 L [13.21 U.S. gal]/min (at pump rotation of 4500 min <sup>-1</sup> )	
	Thermostat	Type	Wax pellet	
		Valve opening pressure	76.5 ± 1.5°C [169.7 ± 2.7°F]	
	Cooling fan	Type	Suction (PP fan)	
No. of blades/ Outside diameter		4 variable pitch blades/260 mm [10.24 in.]		
Inlet system	Air cleaner	Type	Paper element	



Table 1-1 Specifications of L2A, L2C and L2E (3 / 4)

Engine model		L2A	L2C	L2E
Electrical system	Voltage - polarity	12V - negative (-) ground, 24V - negative (-) ground		
	Starter (1)	Type	M000T60481	
		Manufacturer	Mitsubishi Electric Corporation	
		Pinion engagement type	Pinion shift (reduction type)	
		Output	12V - 1.2 kW	
		Number	1	
		Pinion/ring gear ratio	14/106	
	Starter (2)	Type	M001T68381	
		Manufacturer	Mitsubishi Electric Corporation	
		Pinion engagement type	Pinion shift (reduction type)	
		Output	12V - 1.7 kW	
		Number	1	
		Pinion/ring gear ratio	14/106	
	Starter (3)	Type	M002T66071	
		Manufacturer	Mitsubishi Electric Corporation	
		Pinion engagement type	Pinion shift (reduction type)	
		Output	24V - 3.2 kW	
		Number	1	
		Pinion/ring gear ratio	15/106	
	Alternator (1)	Type	A007TA0171B	
		Type	Three-phase current generator, integral with IC regulator	
		Manufacturer	Mitsubishi Electric Corporation	
		Output V - A	12V - 40A	
		Rated voltage generating speed	5000 min <sup>-1</sup> (at 13.5V, 37A, when hot)	
		Regulator adjusting voltage	14.7 ± 0.3V	
	Alternator (2)	Type	A007TA8271A	
		Type	Three-phase current generator, integral with IC regulator	
Manufacturer		Mitsubishi Electric Corporation		
Output		24V - 25A		
Rated voltage generating speed		5000 min <sup>-1</sup> (at 27.0V, 22A, when hot)		
Regulator adjusting voltage		28.5 ± 0.5V		
Glow plug (1)	Type	Sheathed		
	Rated voltage-current	10.5V - 9.7A ± 1.0A (30-second duration)		
Glow plug (2)	Type	Sheathed		
	Rated voltage-current	22.5V - 4.8A ± 0.5A (30-second duration)		

Table 1-1 Specifications of L2A, L2C and L2E (4 / 4)

Engine model		L2A	L2C	L2E
Electrical system	Stop solenoid (1)	Working voltage	12V - ETR: 8V or less	
		Insulation resistance	100 MΩ or more at DC 500 V megger (normal temperature, normal relative humidity)	
		Stroke	13.5 ± 0.5 mm [0.53 ± 0.02 in.]	
		Ambient temperature for use	-40 to 120°C [-40 to 248°F]	
	Stop solenoid (2)	Working voltage	12V - ETS: 10 to 15V	
		Insulation resistance	100 MΩ or more at DC 500 V megger (normal temperature, normal relative humidity)	
		Stroke	10 ± 0.5 mm [0.39 ± 0.02 in.]	
		Ambient temperature for use	-30 to 120°C [-22 to 248°F]	
	Stop solenoid (3)	Working voltage	24V - ETR: 16V or less	
		Insulation resistance	100 MΩ or more at DC 500V megger (normal temperature, normal relative humidity)	
		Stroke	13.5 ± 0.5 mm [0.53 ± 0.02 in.]	
		Ambient temperature for use	-40 to 120°C [-40 to 248°F]	
	Stop solenoid (4)	Working voltage	24V - ETS: 20V to 30V	
		Insulation resistance	100 MΩ or more at DC 500V megger (normal temperature, normal relative humidity)	
		Stroke	10 ± 0.5 mm [0.39 ± 0.02 in.]	
		Ambient temperature for use	-30 to 120°C [-22 to 248°F]	

## 5.2 Specifications of L3A, L3C and L3E

Table 1-2 Specifications of L3A, L3C and L3E (1 / 4)

Engine model			L3A	L3C	L3E	
Main specifications	Type		Vertical type, water-cooled, 4 cycle diesel			
	No. of cylinders		3			
	Combustion type		Swirl chamber type			
	Valve mechanism		Overhead valve type			
	Cylinder bore × stroke		65 × 70 mm [2.56 × 2.76 in.]	70 × 70 mm [2.76 × 2.76 in.]	76 × 70 mm [2.99 × 2.76 in.]	
	Total displacement		0.696 L [0.184 U.S. gal.]	0.808 L [0.213 U.S. gal.]	0.952 L [0.251 U.S. gal.]	
	Compression ratio		23 : 1			
	Fuel used		Diesel oil (JIS K2204 Special No.1 - Special No.3)			
	Order of ignition		1 - 3 - 2			
	Direction of rotation		Counterclockwise as viewed from flywheel side			
	Dry mass		75 kg [165 lb]			
Basic engine	Piston ring	Number		Compression ring: 2 Oil rings (with expander): 1		
	Valve timing (when warm)	Inlet valve	Open	BTDC 18°		
			Close	ABDC 46°		
		Exhaust valve	Open	BBDC 46°		
			Close	ATDC 18°		
Starting system		Electric starting				
Fuel system	Fuel injection pump	Type		ND-PFR type		
		Manufacturer		DENSO CORPORATION		
		Plunger diameter		ø 5.5 mm [0.22 in.], ø 6.0 mm [0.24 in.]		
		MS retard (crank angle)		4°, 8°		
		Cam lift		6 mm [0.24 in.]		
	Governor	Speed governing type		Centrifugal weight system		
	Fuel injection nozzle	Type		Throttle type		
		Manufacturer		DENSO CORPORATION		
		Spray angle		15°		
		Valve opening pressure		13.73 <sup>+1.0</sup> <sub>0</sub> MPa { 140 <sup>+10</sup> <sub>0</sub> kgf/cm <sup>2</sup> } [1992 <sup>+142</sup> <sub>0</sub> psi]		
	Fuel filter	Type		Paper-element cartridge or paper-element switch cock		
	Fuel pump (option)	1	Type		Electromagnetic diaphragm	
			Discharge rate		0.3 L [0.08 U.S. gal.]/min or more (at 12V - 1.3A)	
		2	Type		Electromagnetic plunger type	
Discharge rate			1 L [0.26 U.S. gal.]/min or more (at 12V - 1.5A)			
3		Type		Electromagnetic plunger type		
		Discharge rate		1.4 L [0.57 U.S. gal.]/min or more (at 24V - 1.5A)		
4		Type		Electromagnetic plunger type (compact type)		
		Discharge rate		0.4 L [0.11 U.S. gal.]/min or more (at 12V - 1.5A)		

Table 1-2 Specifications of L3A, L3C and L3E (2 / 4)

Engine model		L3A	L3C	L3E
Lubrication system	Lubrication system		Pressure feed, full flow filter system	
	Engine oil	Speci fication	API service category CF and CF-4	
		Capacity (engine total)	Upper limit: 3.1 L [0.82 U.S. gal]/ Lower limit: 1.8 L [0.48 U.S. gal] (Upper limit: 3.6 L [0.95 U.S. gal]/ Lower limit: 2.3 L [0.61 U.S. gal])	
			Upper limit: 4.2 L [1.11 U.S. gal]/ Lower limit: 3.0 L [0.79 U.S. gal] (Upper limit: 4.7 L [1.24 U.S. gal]/ Lower limit: 3.5 L [0.92 U.S. gal])	
	Oil pump	Type	Gear type (internal and external teeth engagement), built into gear case	
		Discharge rate	3 L [0.79 U.S. gal]/min or more (at 1000 min <sup>-1</sup> )	
	Relief valve	Type	Plunger valve type	
		Valve opening pressure	0.29 ± 0.029 MPa { 3.0 ± 0.3 kgf/cm <sup>2</sup> } [42.68 ± 4.3 psi] (1000 min <sup>-1</sup> )	
	Oil filter	Type	Paper-element cartridge	
	Cooling system	Cooling system		Forced-feed circulation type
Coolant capacity (main unit of engine)		1.8 L [0.48 U.S. gal]		
Water pump		Type	Centrifugal volute type	
		Discharge rate	50 L [13.21 U.S. gal]/min (at pump rotation of 4500 min <sup>-1</sup> )	
Thermostat		Type	Wax pellet	
		Valve opening pressure	76.5 ± 1.5°C [169.7 ± 34.7°F]	
Cooling fan		Type	Suction (PP fan)	
		No. of blades/ Outside diameter	4 variable pitch blades/290 mm [11.42 in.]	
	5 variable pitch blades/320 mm [12.60 in.]			
6 variable pitch blades/320 mm [12.60 in.]				
Inlet system	Air cleaner	Type	Paper element	

Table 1-2 Specifications of L3A, L3C and L3E (3 / 4)

Engine model		L3A	L3C	L3E
Electrical system	Voltage - polarity	12V - negative (-) ground, 24V - negative (-) ground		
	Starter (1)	Type	M000T60481	
		Manufacturer	Mitsubishi Electric Corporation	
		Pinion engagement type	Pinion shift (reduction type)	
		Output	12V - 1.2 kW	
		Number	1	
		Pinion/ring gear ratio	14/106	
	Starter (2)	Type	M001T68381	
		Manufacturer	Mitsubishi Electric Corporation	
		Pinion engagement type	Pinion shift (reduction type)	
		Output	12V - 1.7 kW	
		Number	1	
		Pinion/ring gear ratio	14/106	
	Starter (3)	Type	M002T66071	
		Manufacturer	Mitsubishi Electric Corporation	
		Pinion engagement type	Pinion shift (reduction type)	
		Output	24V - 3.2 kW	
		Number	1	
		Pinion/ring gear ratio	15/106	
	Alternator (1)	Type	A007TA0171B	
		Type	Three-phase current generator, integral with IC regulator	
		Manufacturer	Mitsubishi Electric Corporation	
		Output	12V - 40A	
Rated voltage generating speed		5000 min <sup>-1</sup> (at 13.5V, 37A, when hot)		
Regulator adjusting voltage		14.7 ± 0.3V		
Alternator (2)	Type	A007TA8271A		
	Type	Three-phase current generator, integral with IC regulator		
	Manufacturer	Mitsubishi Electric Corporation		
	Output	24V - 25A		
	Rated voltage generating speed	5000 min <sup>-1</sup> (at 27.0V, 22A, when hot)		
	Regulator adjusting voltage	28.5 ± 0.5V		
Glow plug (1)	Type	Sheathed		
	Rated voltage - current	10.5V - 9.7A ± 1.0A (30-second duration)		
Glow plug (2)	Type	Sheathed		
	Rated voltage - current	22.5V - 4.8A ± 0.5A (30-second duration)		

Table 1-2 Specifications of L3A, L3C and L3E (4 / 4)

Engine model		L3A	L3C	L3E	
Electrical system	Stop solenoid (1)	Working voltage	12V - ETR: 8V or less		
		Insulation resistance	100 MΩ or more at DC 500V megger (normal temperature, normal relative humidity)		
		Stroke	13.5 ± 0.5 mm [0.53 ± 0.02 in.]		
		Ambient temperature for use	-40 to 120°C [-40 to 248°F]		
	Stop solenoid (2)	Working voltage	12V - ETS: 10V to 15V		
		Insulation resistance	100 MΩ or more at DC 500V megger (normal temperature, normal relative humidity)		
		Stroke	10 ± 0.5 mm [0.39 ± 0.02 in.]		
		Ambient temperature for use	-30 to 120°C [-22 to 248°F]		
	Stop solenoid (3)	Working voltage	24V - ETR: 16V or less		
		Insulation resistance	100 MΩ or more at DC 500V megger (normal temperature, normal relative humidity)		
		Stroke	13.5 ± 0.5 mm [0.53 ± 0.02 in.]		
		Ambient temperature for use	-40 to 120°C [-40 to 248°F]		
	Stop solenoid (4)	Working voltage	24V - ETS: 20V - 30V		
		Insulation resistance	100 MΩ or more at DC 500V megger (normal temperature, normal relative humidity)		
		Stroke	10 ± 0.5 mm [0.39 ± 0.02 in.]		
		Ambient temperature for use	-30 to 120°C [-22 to 248°F]		

## 6. 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:

### 6.1 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.)

### 6.2 Reassembling

- (1) Wash all engine parts, except such parts as oil seals, O-rings and rubber sheets, in cleaning oil and dry them with compressed air.
- (2) Use correct tools and instruments.
- (3) Use only high-quality lubricating oils and greases of appropriate types. Be sure to apply oil, grease or adhesive to the part wherever specified.
- (4) Use a torque wrench to tighten parts correctly when their tightening torques are specified.  
Refer to "List of Tightening Torque."
- (5) Replace all gaskets and packings with new ones unless specified otherwise. Apply adhesive if necessary. Use only the proper amount of adhesive.





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## 1. Maintenance service data

### 1.1 Engine general

Table 2-1 Maintenance service data table - Engine general

Unit: mm [in.]

Inspection point		Nominal	Standard	Limit	Remark
Maximum rotation speed (rated rotation speed used as reference)		(Varies depending on specification of destination)			Adjusted by the governor.
Minimum rotation speed					
Compression pressure (at 280 min <sup>-1</sup> )			2.7 MPa { 28 kgf/cm <sup>2</sup> } [398 psi]	Not acceptable at or below 2.2 MPa { 22 kgf/cm <sup>2</sup> } [313 psi]	When oil and water temperatures at 20 to 30 °C [68 to 86 °F]
Lubricating oil pressure	Rotated speed		0.29 to 0.39 MPa { 3 to 4 kgf/cm <sup>2</sup> } [42.7 to 56.9 psi]		Oil temperature at 60 to 70 °C [140 to 158 °F]
	Low idling		0.10 MPa { 1.0kgf/cm <sup>2</sup> } [14.2 psi]		
Valve timing	Inlet open		BTDC 18°		Values for checking valve timing Different from actual valve opening and closing timing
	Inlet open		ABDC 46°		
	Exhaust open		BBDC 46°		
	Exhaust open		ATDC 18°		
Valve clearance	Inlet		0.25 [0.0098]		When engine is cold
	Exhaust		0.25 [0.0098]		
Fuel injection timing (before TDC)			(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 arm	Rocker arm inside diameter	ø 12 [0.47]	12.013 to 12.035 [0.4730 to 0.4738]			
	Rocker shaft outside diameter	ø 12 [0.47]	11.470 to 11.984 [0.4516 to 0.4718]			
	Clearance between rocker arm and rocker shaft		0.029 to 0.065 [0.0011 to 0.0026]	0.200 [0.0079]	Replace rocker arm	
Valve	Valve stem outside diameter	Inlet	ø 6.6 [0.260]	6.565 to 6.580 [0.2585 to 0.2591]	6.500 [0.2559]	
		Exhaust	ø 6.6 [0.260]	6.530 to 6.550 [0.2571 to 0.2579]	6.500 [0.2559]	
	Valve guide inside diameter	Inlet	ø6.6 [0.260]	6.600 to 6.615 [0.2598 to 0.2604]		
		Exhaust				
	Clearance between valve stem and valve guide	Inlet		0.020 to 0.050 [0.0008 to 0.0020]	0.100 [0.0039]	Replace valve and valve guide
		Exhaust		0.050 to 0.085 [0.0020 to 0.0034]	0.150 [0.0059]	

Table 2-2 Maintenance service data table - Basic engine(2 / 4)

Unit mm [in.]

Inspection point		Nominal	Standard	Limit	Remark	
Valve seat and valve	Valve seat angle	44°				
	Valve sinkage	0.5 [0.0197]	0.4 to 0.6 [0.0158 to 0.0236]			
	Valve margin		1.0 [0.0394]	0.5 [0.0197]		
	Valve guide mounting length	14 [0.5516]	13.5 to 14.5 [0.5319 to 0.5516]			
Valve spring	Free length	40 [1.57]		38.5 [1.516]		
	Squareness		 $\theta = 2^\circ$ $\Delta = 1.4$ [0.055] $L_f = 40$ [1.57]	$\Delta = 2.0$ [0.079] overentire length		
	Mounting length/load		35.5 [1.3976]/55.3 to 61.2 N {5.64 to 6.24 kgf} [12.4 to 13.8 lbf] 28.0 [1.1024]/138.2 to 152.9 N {14.09 to 15.59 kgf} [31.1 to 34.4 lbf]	-15%		
Cylinder	Pushrod	Runout		0.3 [0.012] or less	0.3 [0.012]	TIR, Replace
	Cylinder head	Distortion of cylinder head bottom surface		0.05 [0.0020] or less	0.10 [0.0039]	Repair
		Distortion of block top surface		0.05 [0.0020] or less	0.10 [0.0039]	Repair
	Cylinder inside diameter	L2A, L3A	$\phi$ 65 [2.56]	65.00 to 65.03 [2.5591 to 2.5602]	+0.7 [+0.0276]	Repair limit is +0.2 [+0.0079]
		L2C, L3C	$\phi$ 70 [2.76]	70.00 to 70.03 [2.7559 to 2.7571]		
L2E, L3E		$\phi$ 76 [2.99]	76.00 to 76.03 [2.9921 to 2.9933]			
Cylindricity			0.01 [0.039] or less			

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Table 2-2 Maintenance service data table - Basic engine(3 / 4)

Unit mm [in.]

Inspection point		Nominal	Standard	Limit	Remark	
Piston	Outside diameter	L2A L3A	STD	ø 65 [2.559]	64.919 to 64.939 [2.5559 to 2.5566]	
			0.25 OS	ø 65.25 [2.569]	65.169 to 65.189 [2.5657 to 2.5665]	
			0.50 OS	ø 65.50 [2.579]	65.419 to 65.439 [2.5755 to 2.5763]	
		L2C L3C	STD	ø 70 [2.756]	69.913 to 69.933 [2.7525 to 2.7533]	
			0.25 OS	ø 70.25 [2.766]	70.163 to 70.183 [2.7623 to 2.7631]	
			0.50 OS	ø 70.50 [2.776]	70.413 to 70.433 [2.7722 to 2.7729]	
		L2E L3E	STD	ø 76 [2.992]	75.906 to 75.926 [2.9884 to 2.9892]	
			0.25 OS	ø 76.25 [3.002]	76.156 to 76.176 [2.9983 to 2.9990]	
			0.50 OS	ø 76.50 [3.012]	76.406 to 76.426 [3.0081 to 3.0089]	
	Piston pin outside diameter	L2A, L3A L2C, L3C	ø 18 [0.71]	18.001 to 18.007 [0.7087 to 0.7089]		
		L2E, L3E	ø 21 [0.83]	21.002 to 21.005 [0.8269 to 0.8270]		
	Clearance between piston pin bore and piston pin	L2A, L3A L2C, L3C		0.006 to 0.018 [0.0002 to 0.0007]	0.08 [0.0031]	
		L2E, L3E		0.007 to 0.015 [0.0003 to 0.0006]		
	Clearance between piston and cylinder (clearance)	L2A, L3A		0.061 to 0.111 [0.0024 to 0.0044]	0.2 [0.0079]	Repair to oversize or replace
		L2C, L3C		0.067 to 0.117 [0.0026 to 0.0046]		
L2E, L3E			0.074 to 0.124 [0.0029 to 0.0049]			
Piston ring	Clearance between ring and ring groove	No.1 Compression ring		-	0.3 [0.0118]	Replace
		No.2 Compression ring		0.05 to 0.09 [0.0020 to 0.0035]	0.2 [0.0079]	
		Oil ring		0.03 to 0.07 [0.0019 to 0.0028]	0.2 [0.0079]	
	Closed gap of ring	No.1 Compression ring		0.15 to 0.30 [0.0059 to 0.0118]	1.5 [0.0591]	Replace
		No.2 Compression ring		0.15 to 0.30 [0.0059 to 0.0118]		
		Oil ring		0.15 to 0.35 [0.0059 to 0.0138]		
Connecting rod	Bend and torsion		0.05/100 [0.0020/3.94] or less	0.15/100 [0.0059/ 3.94]		
	End play		0.10 to 0.35 [0.0039 to 0.0138]	0.5 [0.0197]		

Table 2-2 Maintenance service data table - Basic engine(4 / 4)

Unit mm [in.]

Inspection point		Nominal	Standard	Limit	Remark	
Crankshaft	Journal outside diameter (STD)	ø 43 [1.69]	42.965 to 42.980 [1.6915 to 1.6921]	-0.70 [-0.0276]	Repair limit is -0.15 [-0.0059]	
	Pin outside diameter (STD)	ø 40 [1.57]	39.965 to 39.980 [1.5734 to 1.5740]			
	Runout		0.06 [0.0024] or less		TIR	
	Clearance between main bearing and crankshaft		0.030 to 0.075 [0.0012 to 0.0030]	0.10 [0.0039]		
	Clearance between connecting rod bearings		0.028 to 0.071 [0.0011 to 0.0028]	0.150 [0.0059]		
	End play		0.050 to 0.175 [0.0020 to 0.0069]	0.500 [0.0197]		
Timing gear backlash	Between crank gear and idler gear		0.010 to 0.136 [0.0004 to 0.0054]	Spur gear	0.300 [0.0118]	Replace
			0.040 to 0.118 [0.0016 to 0.0047]	Helical gear		
	Between idler gear and valve camshaft gear		0.010 to 0.136 [0.0004 to 0.0054]	Spur gear		
			0.037 to 0.117 [0.0015 to 0.0046]	Helical gear		
	Between idler gear and pump camshaft gear		0.010 to 0.220 [0.0004 to 0.0087]	Spur gear		
			0.007 to 0.235 [0.0003 to 0.0091]	Helical gear		
Between valve camshaft gear and PTO gear		27.27 to 27.47 [1.0736 to 1.0815]	26.37 [1.0382]			
		27.37 [1.08]				
Cam height of camshaft (major axis)						
Cam height of fuel injection pump camshaft (major axis)	30 [1.18]	29.9 to 30.1 [1.177 to 1.185]	29 [1.1417]	Replace		
Flywheel flatness		0.08 [0.0031] or less	0.50 [0.0197]			
Clearance between tappet and cylinder block bore		0.007 to 0.049 [0.0003 to 0.0019]	0.150 [0.0059]	Replace tappet.		
Clearance between camshaft journal and cylinder block bore		0.050 to 0.100 [0.0020 to 0.0039]	0.150 [0.0059]	Replace camshaft or cylinder block		
Clearance between idler gear bushing and idler shaft	ø 20 [0.79]	0.030 to 0.066 [0.0012 to 0.0026]	0.200 [0.0079]			

### 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 pressure	13.73 MPa {140 kgf/cm <sup>2</sup> } [1992 psi]	13.73 to 14.73 MPa {140 to 150 kgf/cm <sup>2</sup> } [1992 to 2134 psi]		Adjust with washers.

## SERVICE DATA

### 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 oil pump housing inside diameter and oil pump outer gear outside diameter	$\phi$ 75.5 [2.972]	0.100 to 0.196 [0.0039 to 0.0077]	0.3 [0.012]	Replace
	Clearance between oil pump outer gear width and oil pump housing	10 [0.04]	0.040 to 0.100 [0.0016 to 0.0039]	0.25 [0.0099]	Replace
Relief valve opening pressure (1000 min <sup>-1</sup> )			0.29 ± 0.029 MPa {3.0 ± 0.3 kgf/cm <sup>2</sup> } [43 ± 4.3 psi]		Replace
Oil pressure at which oil pressure switch illuminates			0.05 ± 0.01 MPa {0.5 ± 0.1 kgf/cm <sup>2</sup> } [7 ± 0.7 psi]		Replace

### 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 [167 to 172°F]		Replace
	Temperature at which valve lift becomes 6 [0.24] or more		90°C [194°F]		
Thermoswitch	111 ± 3.5°C [225 to 238°F]		30 mΩ (in oil of 120°C [248°F])		
Deflection amount of belt (when it is pushed between crankshaft pulley and alternator pulley with a force of approx. 98 N {10 kgf} [22 lbf])			Approx. 10 [0.39]		

### 1.6 Inlet/Exhaust system

Table 2-6 Maintenance service data table - Inlet/Exhaust system

Unit: mm [in.]

Inspection point		Nominal	Standard	Limit	Remark
Distortion on mounting surfaces of intake cover and exhaust manifold				0.15 [0.0059]	Repair by grinding or replace

## 1.7 Electrical system

Table 2-7 Maintenance service data table - Electrical system(1 / 3)

Unit: mm [in.]

Inspection point		Nominal	Standard	Limit	Remark
Starter M000T60481 (12V-1.2kW)	Pinion clearance		0.5 to 2.0 [0.0197 to 0.0787]		
	Brush length		16.5 [0.650]	10.0 [0.394]	
	Brush spring load	20.58 N {2.10 kgf} [4.6 lbf]	17.5 to 23.7 N {1.78 to 2.42 kgf} [3.92 to 5.34 lbf]	6.86 N {0.70 kgf} [1.54 lbf]	
	Commutator radial runout		0.03 [0.0012]	0.10 [0.0039]	
	Commutator outside diameter		∅ 29.4 [1.158]	∅ 28.8 [1.134]	
	Depth of undercuts between segments	0.75 [0.030]	0.5 to 1.0 [0.0197 to 0.0394]	0.2 [0.0079] or less	
	No-load characteristics	Terminal voltage		11 V	
Current			90 A or less		
Rotation speed			2500 min <sup>-1</sup> or more		
Starter M001T68381 (12V-1.7kW)	Pinion clearance		0.5 to 2.0 [0.0197 to 0.0787]		
	Brush length		16.5 [0.650]	10 [0.394]	
	Brush spring load	20.58 N {2.10 kgf} [4.6 lbf]	17.5 to 23.7 N {1.78 to 2.42 kgf} [3.92 to 5.34 lbf]	6.86 N {0.70 kgf} [1.54 lbf]	
	Commutator radial runout		0.03 [0.0012]	0.10 [0.0039]	
	Commutator outside diameter		∅ 29.4 [1.158]	∅ 28.8 [1.134]	
	Depth of undercuts between segments	0.75 [0.030]	0.5 to 1.0 [0.0197 to 0.0394]	0.2 [0.0079] or less	
	No-load characteristics	Terminal voltage		11 V	
Current			110 A or less		
Rotation speed			2400 min <sup>-1</sup> or more		

SERVICE DATA

Table 2-7 Maintenance service data table - Electrical system(2 / 3)

Unit: mm [in.]

Inspection point		Nominal	Standard	Limit	Remark	
Starter M002T66071 (24V - 3.2kW)	Pinion shaft end play		0.5 [0.0197]			
	Pinion gap		0.5 to 2.0 [0.0197 to 0.0787]			
	Brush length		18 [0.709]	11 [0.4331]		
	Brush spring load		34 N {3.47 kgf} [2 lbf]	28.9 to 39.1 N {2.95 to 3.99 kgf} [6.5035 to 8.7963 lbf]	20 N {2.04 kgf} [4.4974 lbf]	
	Commutator radial runout			0.03 [0.0012]	0.10 [0.0039]	
	Commutator outside diameter			∅ 32.0 [1.2598]	∅ 31.4 [1.2362]	
	Depth of undercuts between segments		0.5 [0.020]	0.4 to 0.6 [0.0158 to 0.0236]	0.2 [0.0079] or less	
	No-load characteristics	Terminal voltage		23 V		
Current		80 A or less				
Rotation speed		3400 min <sup>-1</sup> or more				
Alternator A007TA0171B (12V - 40A)	Brush spring load		4.8 to 6.0 N {0.49 to 0.61 kgf} [1.1 to 1.3 lbf]	2.2 N {0.22 kgf} [0.5 lbf]		
	Brush length		18.5 [0.7283]	5.0 [0.197]		
	Resistance between slip rings		2.95 Ω	2.7 to 3.2 Ω		
	Slip ring outside diameter			∅ 22.7 [0.8937]	∅ 22.1 [0.8701]	
	Output characteristics (when hot)	2500 min <sup>-1</sup>	Terminal voltage	13.5 V		
			Current	21 A or more		
		5000 min <sup>-1</sup>	Terminal voltage	13.5 V		
			Current	37 A or more		
IC regulator adjusting voltage (at 20°C [68°F] )			14.7 ± 0.3 V			
Alternator A007TA8271A (24V - 25A)	Brush spring load		4.8 to 6.0 N {0.49 to 0.61 kgf} [1.1 to 1.3 lbf]	2.2 N {0.22 kgf} [0.5 lbf]		
	Brush length		18.5 [0.7283]	5.0 [0.197]		
	Resistance between slip rings		12.4 Ω	11.4 to 13.4 Ω		
	Slip ring outside diameter			∅ 22.7 [0.8937]	∅ 22.1 [0.8701]	
	Output characteristics (when hot)	2500 min <sup>-1</sup>	Terminal voltage	27.0 V		
			Current	18 A or more		
		5000 min <sup>-1</sup>	Terminal voltage	27.0 V		
			Current	22 A or more		
IC regulator adjusting voltage (at 20°C [68°F] )			28.5 ± 0.5V			



Table 2-7 Maintenance service data table - Electrical system(3 / 3)

Unit: mm [in.]

Inspection point		Nominal	Standard		Limit	Remark
			ETR	ETS		
Clearance of stop solenoid to plunger rack			0.3 to 0.7 [0.0118 to 0.0276]	0.15 to 0.20 [0.0059 to 0.0079]		
Resistance value of glow plug	12 V		0.2 $\Omega$			
	24 V		4.5 $\Omega$			

## 2. List of tightening torque

### 2.1 Major bolts and nuts tightening torque

#### 2.1.1 Basic engines

Table 2-8 Tightening torque list - Basic engines

Description		Threads Dia × Pitch (mm)	Torque			Remark
			N·m	kgf·m	lbf·ft	
Cylinder head bolt	Main	M10 × 1.25	73.5 to 83.4	7.5 to 8.5	54.2 to 61.5	
	Sub	M8 × 1.25	19.6 to 29.4	2.0 to 3.0	14.5 to 21.7	
Rocker cover nut		M6 × 1.0	4.9 to 6.9	0.5 to 0.7	3.6 to 5.1	
Rocker stay bolt		M8 × 1.25	14.7 to 21.6	1.5 to 2.2	10.8 to 15.9	
Main bearing cap bolt		M10 × 1.25	49.0 to 53.9	5.0 to 5.5	36.2 to 39.8	
Connecting rod cap nut		M8 × 1.0	31.4 to 34.3	3.2 to 3.5	23.1 to 25.3	
Flywheel bolt		M10 × 1.25	83.4 to 93.2	8.5 to 9.5	61.5 to 68.7	
Crankshaft pulley nut		M16 × 1.5	98.1 to 117.7	10 to 12	72.3 to 86.8	
Rocker nut	4T (3.6 mm [0.1417 in] thick)	M6 × 1.0	8.8 to 10.8	0.9 to 1.1	6.5 to 8.0	
	6T (5.0 mm [0.1969 in] thick)	M6 × 1.0	11.8 to 13.7	1.2 to 1.4	8.7 to 10.1	

#### 2.1.2 Fuel system

Table 2-9 Tightening torque list - Fuel system

Description		Threads Dia × Pitch (mm)	Torque			Remark
			N·m	kgf·m	lbf·ft	
Hollow screw (fuel injection pump)		M10 × 1.0	9.8 to 14.7	1.0 to 1.5	7.2 to 10.8	
Delivery valve holder (fuel injection pump)			34.3 to 38.2	3.5 to 3.9	25.3 to 28.2	
Air-bleeding plug (fuel injection pump)			4.9 to 6.9	0.5 to 0.7	3.6 to 5.1	
Lock plate (fuel injection pump)			3.2 to 4.0	0.3 to 0.4	2.2 to 2.9	
Stop wire bracket (fuel injection pump)			3.2 to 4.0	0.3 to 0.4	2.2 to 2.9	
Fuel injection nozzle retaining nut		M16 × 0.75	34.3 to 39.2	3.5 to 4.0	25.3 to 28.9	
Fuel injection nozzle holder		M20 × 1.5	49.0 to 68.6	5.0 to 7.0	36.2 to 50.6	
Fuel injection pipe nuts		M12 × 1.5	24.5 to 29.4	2.5 to 3.0	18.1 to 21.7	
Fuel return pipe nut		M12 × 1.5	20.6 to 24.5	2.1 to 2.5	15.2 to 18.1	
Nut for setting torque spring		M12 × 1.0	14.7 to 24.5	1.5 to 2.5	10.8 to 18.1	
Adjusting screw nut for setting torque spring		M8 × 1	7.8 to 11.8	0.8 to 1.2	5.8 to 8.7	

**2.1.3 Lubrication system**

Table 2-10 Tightening torque list - Lubrication system

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Oil relief valve	M18 × 1.5	39.2 to 49.0	4.0 to 5.0	28.9 to 36.2	
Oil pan drain plug	M18 × 1.5	49.0 to 58.8	5.0 to 6.0	36.2 to 43.4	
Oil pressure switch	PT1/8	7.85 to 11.8	0.8 to 1.2	5.8 to 8.7	
Oil pump	M6 × 1.0	7.8 to 9.8	0.8 to 1.0	5.8 to 7.2	

**2.1.4 Cooling system**

Table 2-11 Tightening torque list - Cooling system

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Thermoswitch	M16 × 1.5	19.6 to 29.4	2.0 to 3.0	14.5 to 21.7	
Thermostat cover bolt	M6 × 1.0	8 to 10	0.8 to 1.0	5.8 to 7.2	
Hole plug for thermoswitch	M16 × 1.5	19.6 to 24.5	2.0 to 2.5	14.5 to 18.1	

**2.1.5 Inlet and exhaust systems**

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

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Intake cover bolt	M6 × 1.0	7.8 to 9.8	0.8 to 1.0	5.8 to 7.2	
Exhaust manifold bolt	M8 × 1.25	14.7 to 21.6	1.5 to 2.2	10.8 to 15.9	

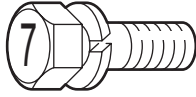
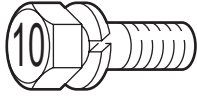
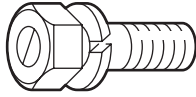
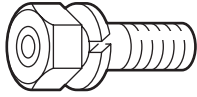
**2.1.6 Electrical system**

Table 2-13 Tightening torque list - Electrical system

Description	Threads Dia × Pitch (mm)	Torque			Remark
		N·m	kgf·m	lbf·ft	
Starter through bolt		4.4 to 7.1	0.45 to 0.72	3.3 to 5.2	
Starter brush holder tightening screw		2.4 to 4.4	0.24 to 0.45	1.7 to 3.3	
Stater magnetic switch screw		4.1 to 7.6	0.42 to 0.77	3.0 to 5.6	
Starter terminal M		8.8 to 12.7	0.90 to 1.30	6.5 to 9.4	
Starter terminal B	M8 × 1.25	7.8 to 11.8	0.8 to 1.2	5.8 to 8.7	
Stop solenoid fixing nut	M30 × 1.5	39.2 to 49.0	4.0 to 5.0	28.9 to 36.2	
Blind plug for stop solenoid	M30 × 1.5	39.2 to 49.0	4.0 to 5.0	28.9 to 36.2	
Glow plug	M10 × 1.25	14.7 to 19.6	1.5 to 2.5	10.8 to 18.1	
Glow plug lead wire nut	M4 × 0.7	0.98 to 1.47	0.10 to 0.15	0.7 to 1.1	
Alternator terminal B	M5 × 0.8	2.9 to 4.9	0.3 to 0.5	2.2 to 3.6	

**2.2 Standard bolt and nut tightening torque**

Table 2-14 Standard bolt and nut tightening torque

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

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

### 2.3 Standard eyebolt tightening torque

Table 2-15 Standard eyebolt tightening torque

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

(Dry)

### 2.4 Standard union nut tightening torque

Table 2-16 Standard union nut tightening torque

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

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

### 2.5 High-pressure fuel injection pipe tightening torque

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

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

(Dry)



# SERVICE TOOLS

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

1. Basic tools

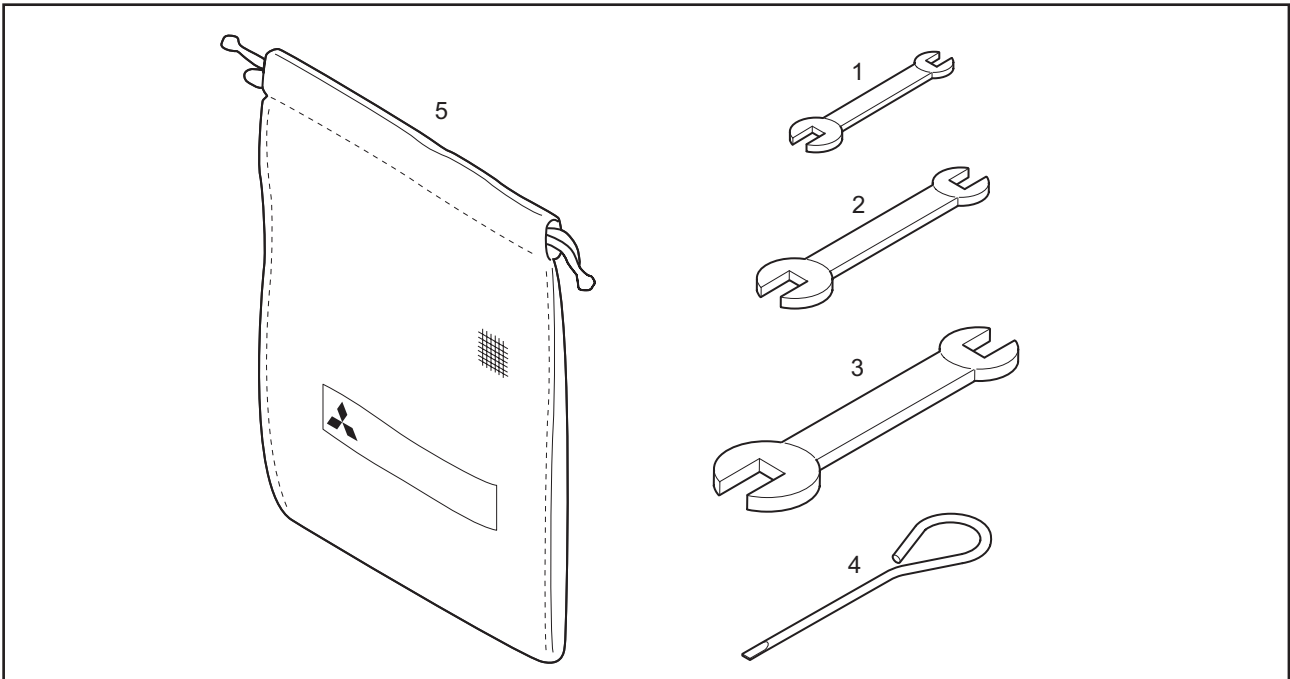
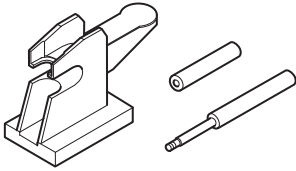
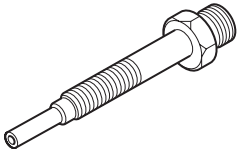
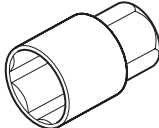
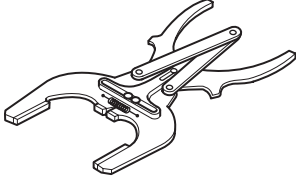


Table 3-1 Basic tools list

No.	Tool name	Part No.	Use
-	Tool set	MM413900	Includes 1 to 5
1	Spanner	MK96008010	Width across flats (8 mm × 10 mm) [0.32 × 0.39 in.]
2	Spanner	MK96012014	Width across flats (12 mm × 14 mm) [0.47 × 0.55 in.]
3	Spanner	MK96017019	Width across flats (17 mm × 19 mm) [0.69 × 0.75 in.]
4	Screwdriver	MM300110	(-)
5	Tool bag	MM300783	



## 2. Special tools

Tool name	Part No.	Shape	Use
Piston pin setting tool	30L91-00030 (L2A, L3A)		For pulling out and press fitting piston pins
	30L91-00020 (L2C, L3C)		
	30L91-10010 (L2E, L3E)		
Compression gauge adapter	ST332270		For measuring compression
Oil pressure switch socket wrench (26)	MD998054		For removing and installing oil pressure switch
Piston ring pliers	31391-12900		Range applicable for removing and installing piston rings: 60 to 95 mm [2.36 to 3.74 in.]



# DETERMINATION OF OVERHAUL

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

### 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

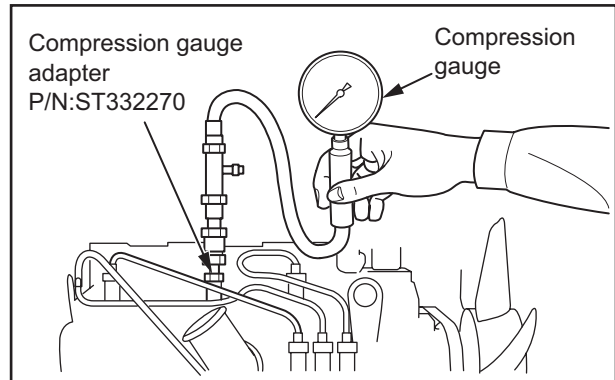
The engine can exhibit these conditions in various combinations. Some of these problems are directly caused by worn engine parts, while others are not. Phenomena described in items (2) and (6) will result from improper fuel injection volume, fuel injection timing, worn plunger, faulty nozzles and also 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) When measuring the compression pressure for cylinders one by one, do not remove other fuel injection nozzles from their positions, except for the one being measured.

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



Testing compression pressure

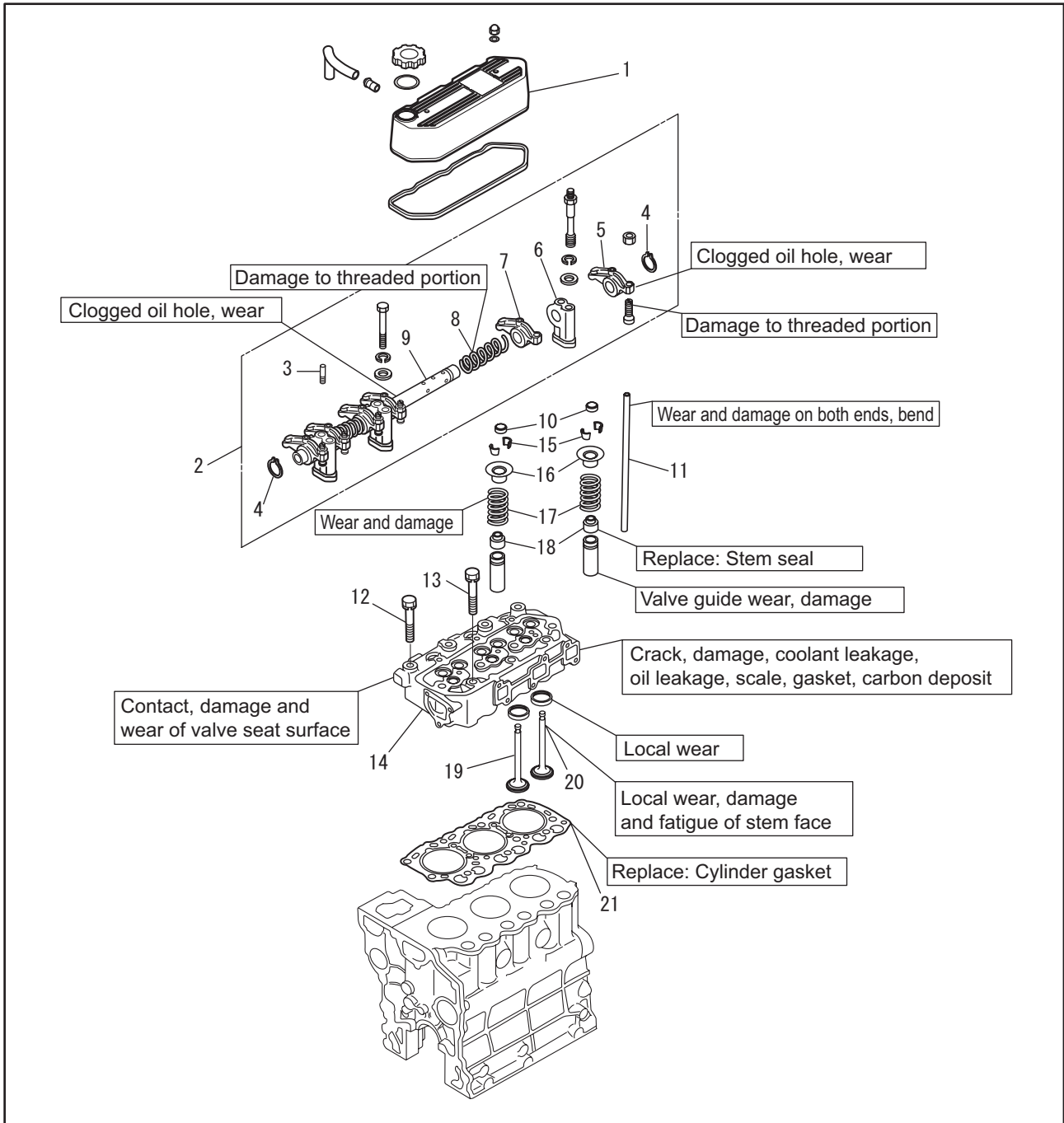
Item	Standard	Limit
Engine speed	280 min <sup>-1</sup>	-
Compression pressure	2.7 MPa { 28 kgf/cm <sup>2</sup> } [398 psi]	Not acceptable at or below 2.2 MPa { 22 kgf/cm <sup>2</sup> } [313 psi]
Difference between each cylinder	Within 0.25 MPa { 2.5 kgf/cm <sup>2</sup> } [36 psi]	-



# DISASSEMBLY OF BASIC ENGINE

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1. Disassembling and inspecting cylinder head and valve mechanism



Disassembling and inspecting cylinder head and valve mechanism

Disassembling sequence

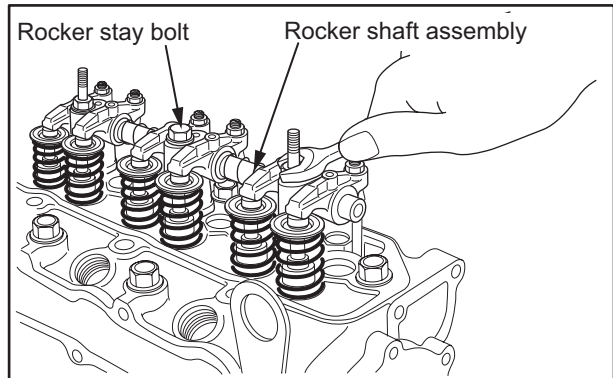
- |   |                              |                         |
|---|------------------------------|-------------------------|
| 1 Rocker cover                            | 8 Rocker shaft spring        | 15 Valve lock           |
| 2 Rocker shaft assembly (including 3 - 9) | 9 Rocker shaft               | 16 Retainer             |
| 3 Grooved pin                             | 10 Valve cap                 | 17 Valve spring         |
| 4 Snap ring                               | 11 Push rod                  | 18 Valve stem seal      |
| 5 Exhaust rocker arm                      | 12 Cylinder head bolt (main) | 19 Intake valve         |
| 6 Rocker stay                             | 13 Cylinder head bolt (sub)  | 20 Exhaust valve        |
| 7 Intake rocker arm                       | 14 Cylinder head             | 21 Cylinder head gasket |



### 1.1 Removing rocker shaft assembly

- (1) Loosen the rocker arm adjusting screw by about one turn.
- (2) Loosen the rocker stay bolts and remove the rocker shaft assembly.

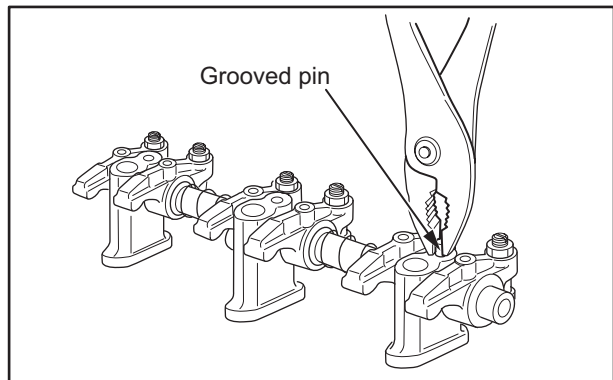
Note: When removing the rocker shaft assembly, remove it together with the rocker stay bolts, and keep them together for reassembling.



Removing rocker shaft assembly

### 1.2 Disassembling rocker shaft assembly

- (1) Pull out the grooved pin with a pair of pliers.

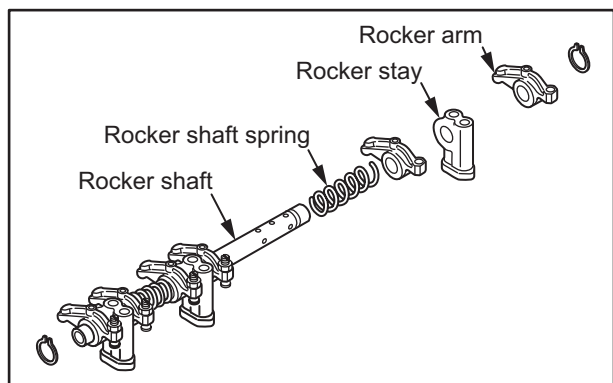


Removing grooved pin

- (2) Remove snap rings from both ends of the rocker shaft. Disassemble the rocker shaft assembly into the rocker arms, rocker stays, rocker shaft springs and rocker shaft.

Note: Be sure to arrange the parts of rocker shaft assembly in the order of disassembling.

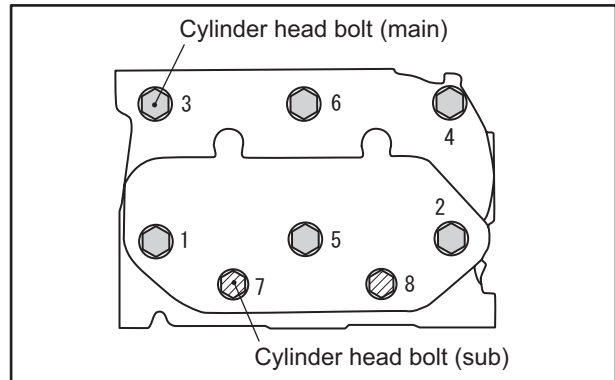
Reassemble the rocker shaft assembly in the reverse order of disassembly by making sure of the original combination of rocker arm and shaft assembly so that the same clearance between the rocker shaft and arms is restored when reassembling.



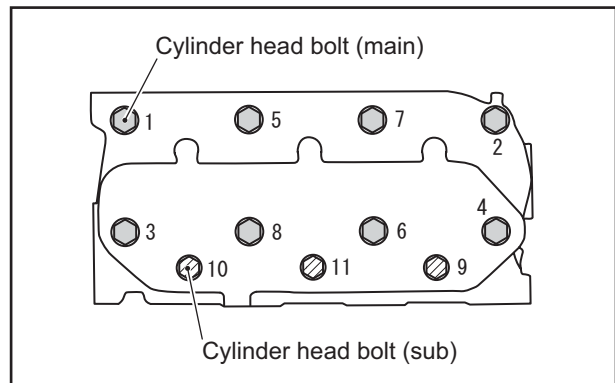
Disassembling rocker shaft assembly

### 1.3 Removing cylinder head bolt

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



Loosening order of cylinder head bolt (L2)



Loosening order of cylinder head bolt (L3)

### 1.4 Removing cylinder head assembly

**CAUTION**

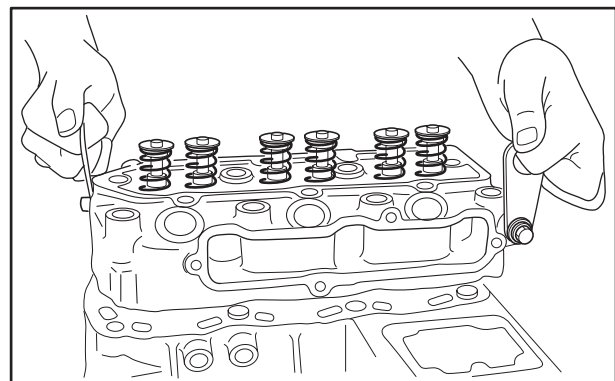
When removing the cylinder head gasket, be careful not to damage the cylinder head or crankcase surface by tools such as a screwdriver.

- (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.

- (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.



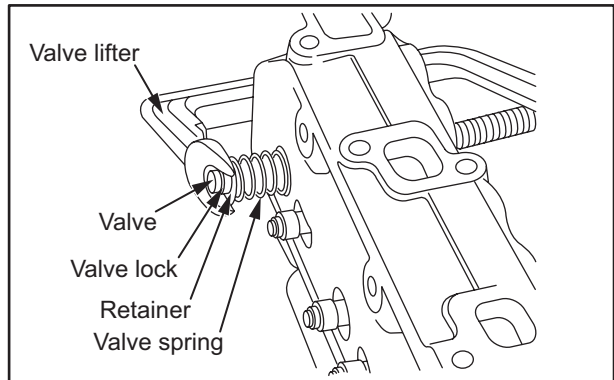
Removing cylinder head assembly

### 1.5 Removing valves and valve spring

(1) Use a valve lifter to compress the valve spring and remove the valve lock.

(2) Remove the retainer, valve spring and valve.

Note: Put match marks for easy identification of the installing position if the valve is to be reused. When reassembling, do not change the combination of the valve and valve seat.

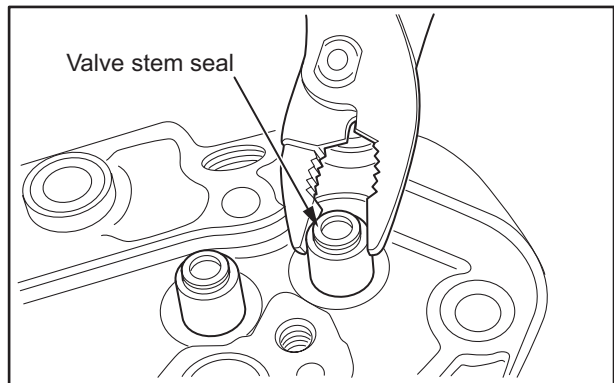


Removing valve and valve spring

### 1.6 Removing valve stem seal

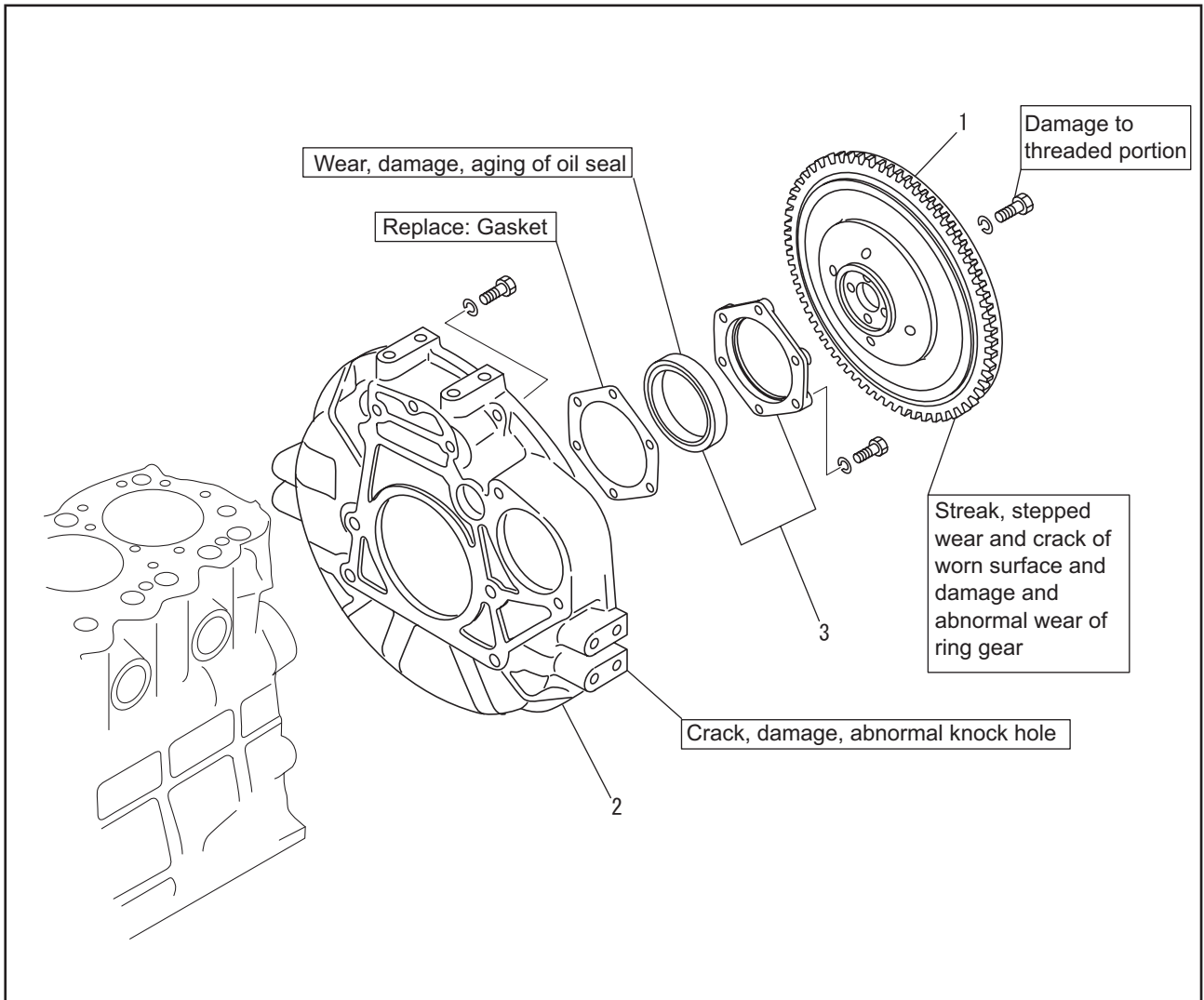
Grab the stem seal with pliers and remove.

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



Removing valve stem seal

## 2. Disassembling and inspecting flywheel



Disassembling and inspecting flywheel

### Disassembling sequence

- 1 Flywheel
- 2 Flywheel housing
- 3 Oil seal case, oil seal

## 2.1 Removing flywheel

### CAUTION

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

Be careful not to drop or hit the flywheel when removing.

(b) The personnel who holds the pulley must pay due attention to safety.

Also, personnel must stay in close contact with each other during work.

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

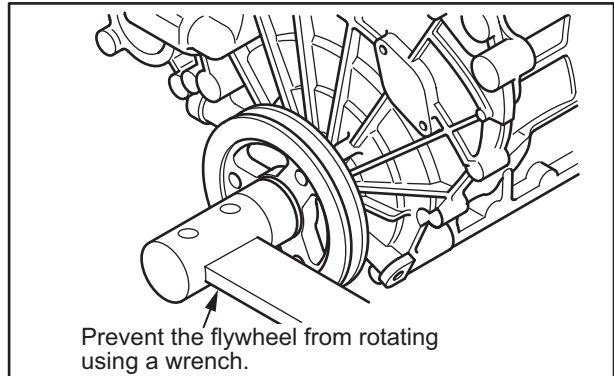
(2) Remove one bolt from the flywheel.

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

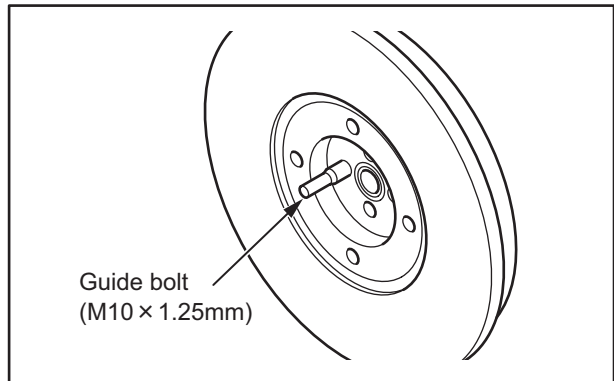
(4) Remove remaining bolts from the flywheel.

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

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



Detent of flywheel



Removing flywheel

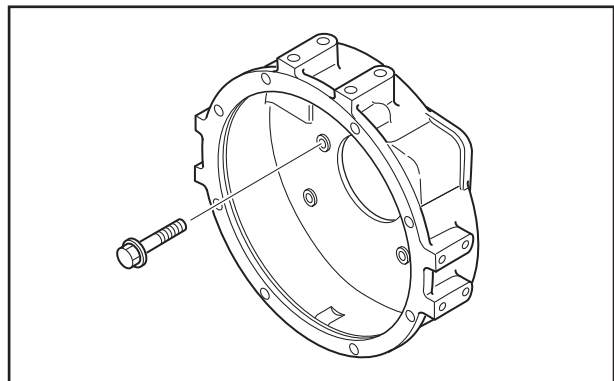
## 2.2 Removing flywheel housing

### CAUTION

Be careful not to damage the oil seal.

(1) Remove bolts from the flywheel housing.

(2) Remove the flywheel housing.



Removing flywheel housing

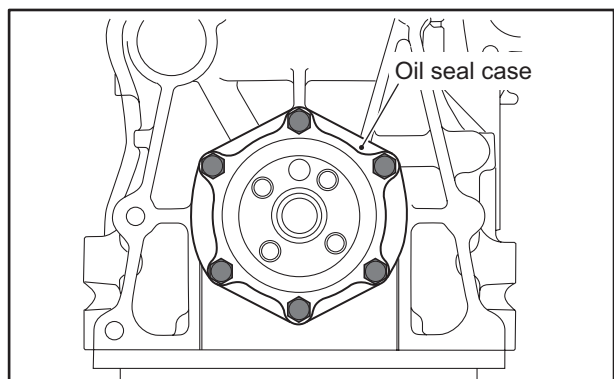
## 2.3 Removing oil seal case

### CAUTION

Be very careful not to damage the oil seal.

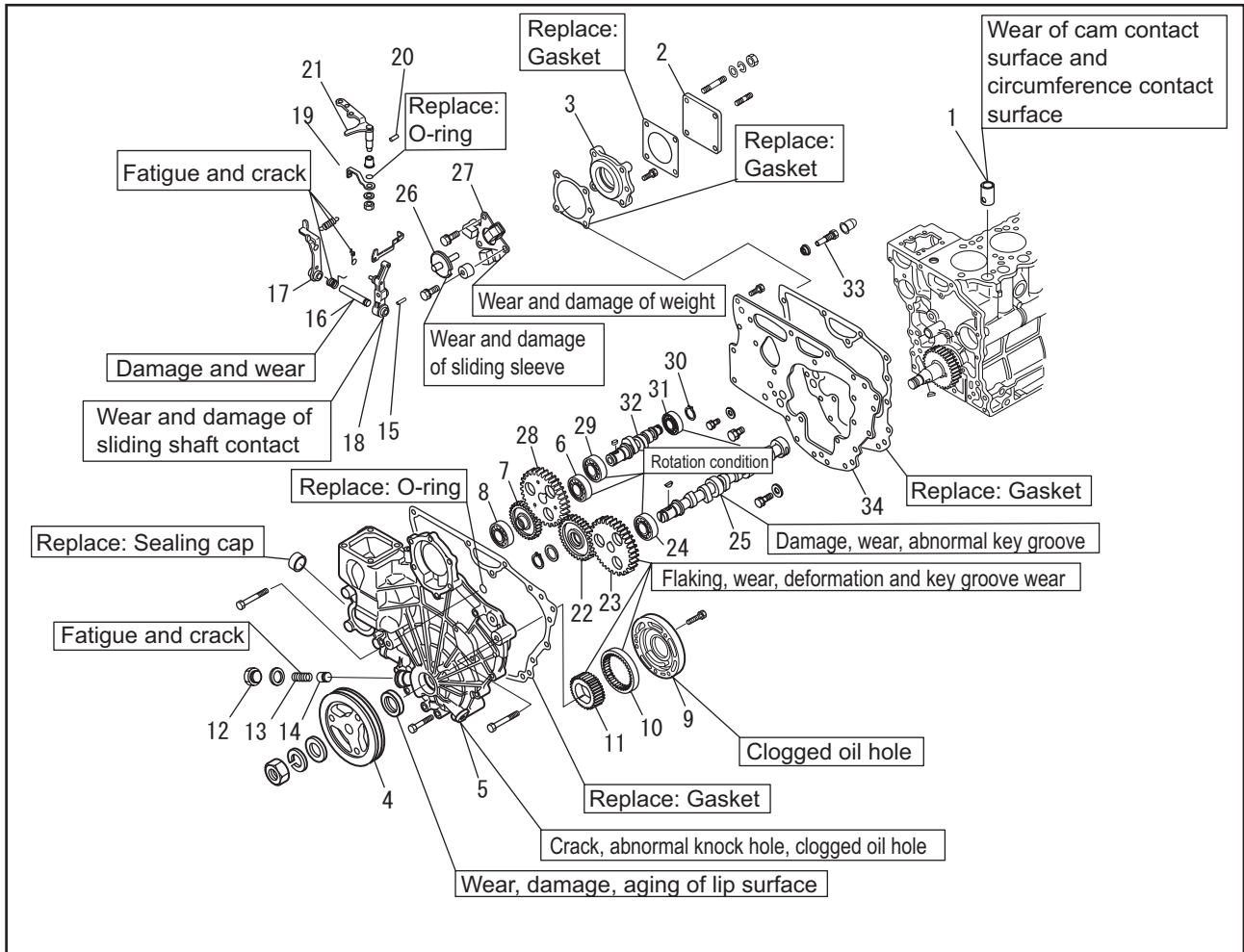
(1) Remove bolts from the oil seal case.

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



Removing oil seal case

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



Disassembling and inspecting gear case, timing gears and camshaft

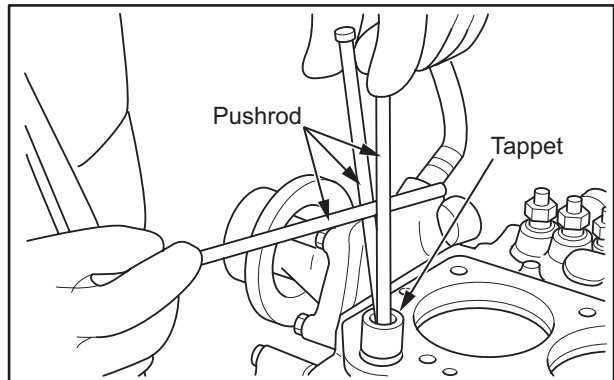
Disassembling sequence

- |   |                          |  |
|---|--------------------------|--|
| 1 Tappet  | 13 Relief spring         | 25 Camshaft<br>(Remove parts 23 to 25 as a unit)                     |
| 2 Oil pump cover                                  | 14 Relief plunger        |  |
| 3 Gear pump housing                               | 15 Grooved pin           | 26 Sliding shaft   |
| 4 Crankshaft pulley                               | 16 Governor shaft        | 27 Governor weight   |
| 5 Gear case                                       | 17 Tension lever         | 28 Fuel injection pump camshaft gears                                |
| 6 Ball bearing                                    | 18 Governor lever        | 29 Ball bearing  |
| 7 PTO gear  | 19 Governor spring lever | 30 Snap ring   |
| 8 Ball bearing<br>(Remove parts 6 to 8 as a unit) | 20 Grooved pin           | 31 Ball bearing  |
| 9 Oil pump housing                                | 21 Speed control lever   | 32 Fuel injection pump camshaft<br>(Remove parts 28 to 32 as a unit) |
| 10 Oil pump outer gear                            | 22 Idler gear            |  |
| 11 Oil pump inner gear                            | 23 Camshaft gear         | 33 Torque spring set   |
| 12 Plug   | 24 Ball bearing          | 34 Front plate   |

### 3.1 Removing tappet

Remove the tappet from the cylinder block using the push rods.

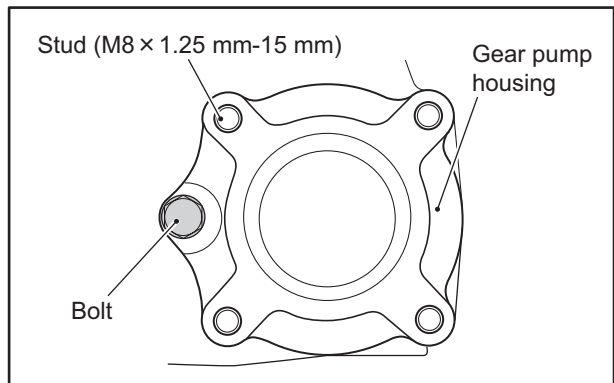
Note: If the camshaft is removed before the tappet, the tappet will fall in the oil pan.



Removing tappet

### 3.2 Removing gear pump housing

- (1) Remove the bolts and one stud (M8×1.25mm-15mm) shown in the illustration from the gear pump housing.
- (2) Screw a jack bolt into the stud threaded hole, and remove the gear pump housing.



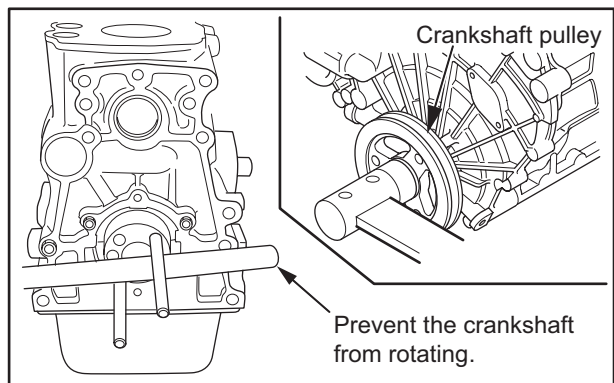
Removing gear pump housing

### 3.3 Removing crankshaft pulley

**CAUTION**

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

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



Removing crankshaft pulley

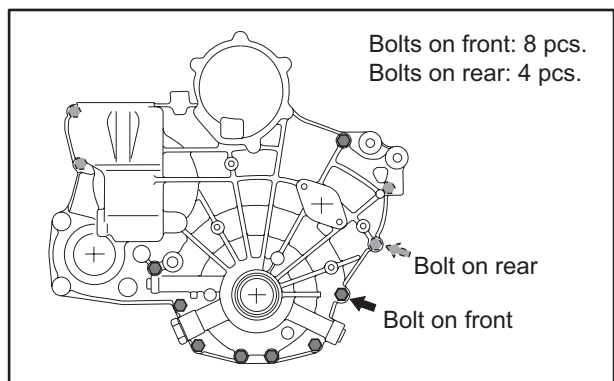
### 3.4 Removing timing gear case

**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.

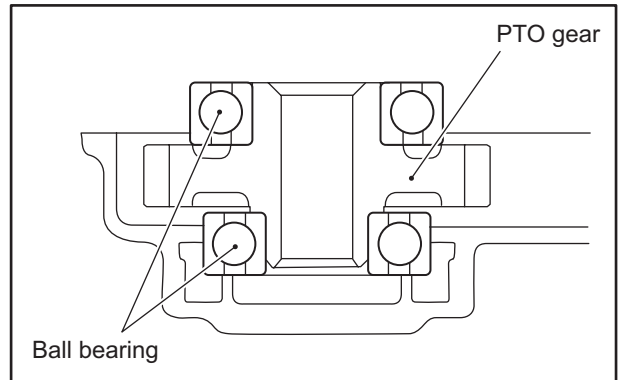
Note: Bolts have different lengths. Pay attention to the positions of bolts to ensure correct reassembling.



Removing gear case

### 3.5 Removing PTO gear

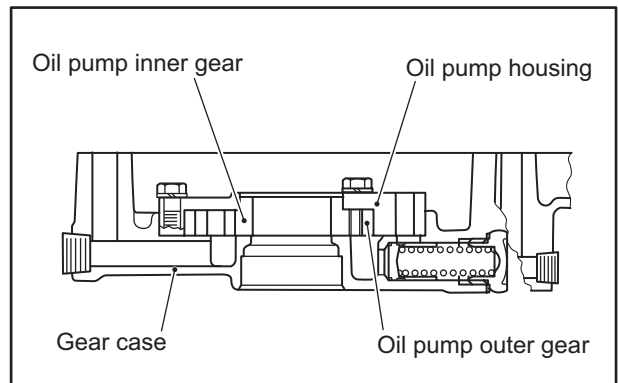
Pull out the PTO gear together with two ball bearings from the gear case.



Removing PTO gear

### 3.6 Removing oil pump

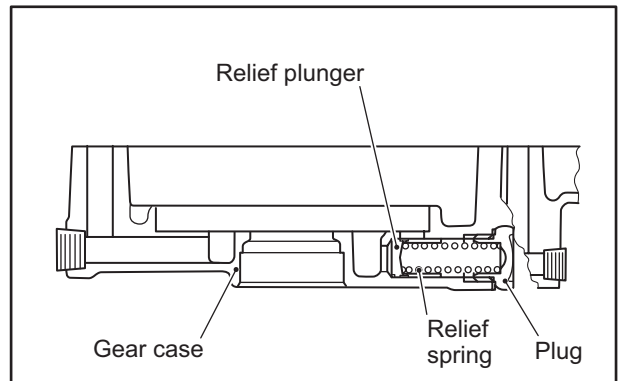
Remove the oil pump housing from the gear case, and then remove the oil pump outer gear and oil pump inner gear.



Removing oil pump

### 3.7 Removing relief valve

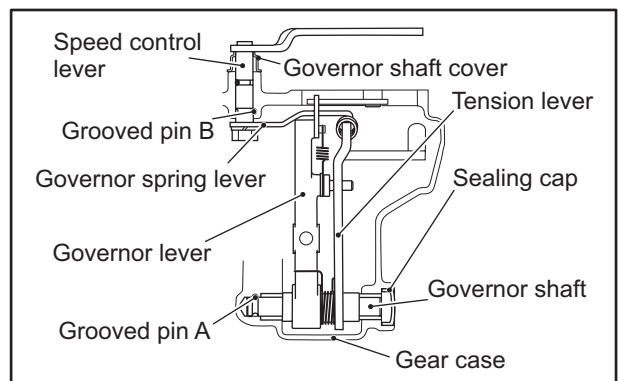
- (1) Remove the plug from the gear case.
- (2) Remove the oil relief spring and relief plunger.



Removing relief valve

### 3.8 Removing governor shaft and speed control lever

- (1) Remove the sealing cap from the side of the gear case.
- (2) Pull out the grooved pin A.
- (3) Remove the governor shaft.
- (4) Remove the tension lever and governor lever.
- (5) Remove the governor spring lever.
- (6) Remove the grooved pin B.
- (7) Remove the speed control lever.
- (8) Remove the governor cover.



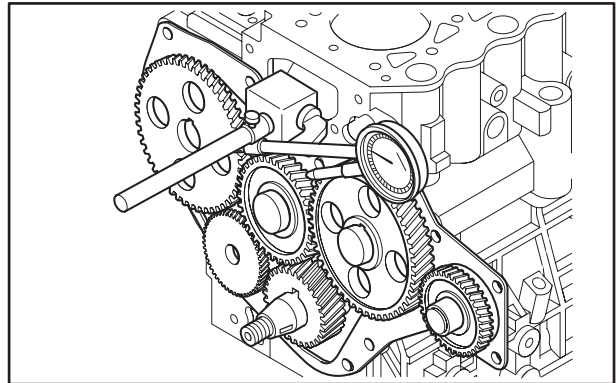
Removing governor shaft and speed control lever



### 3.9 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.

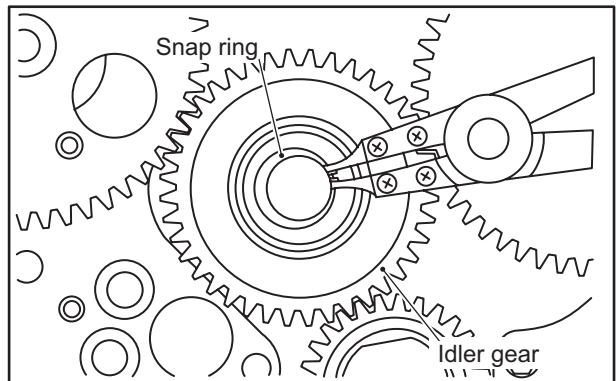
Item	Standard	Limit	
Timing gear backlash	Between crankshaft gear and idler gear	0.010 to 0.136 mm [0.0004 to 0.0054 in.]	Spur gear
		0.040 to 0.118 mm [0.0016 to 0.0047 in.]	Helical gear
	Between idler gear and valve camshaft gear	0.010 to 0.136 mm [0.0004 to 0.0054 in.]	Spur gear
	Between idler gear and pump camshaft gear	0.037 to 0.117 mm [0.0015 to 0.0046 in.]	Helical gear
	Between valve camshaft gear and PTO gear	0.010 to 0.220 mm [0.0004 to 0.0087 in.]	Spur gear
		0.007 to 0.235 mm [0.0003 to 0.0091 in.]	Helical gear
		0.300 mm [0.0118 in.]	



Measuring timing gear backlash

### 3.10 Removing idler gear

- (1) Remove the snap ring.
- (2) Remove the idler gear.



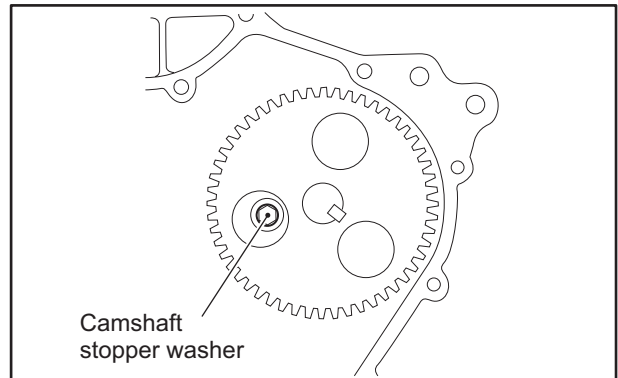
Removing idler gear

### 3.11 Removing camshaft

**CAUTION**

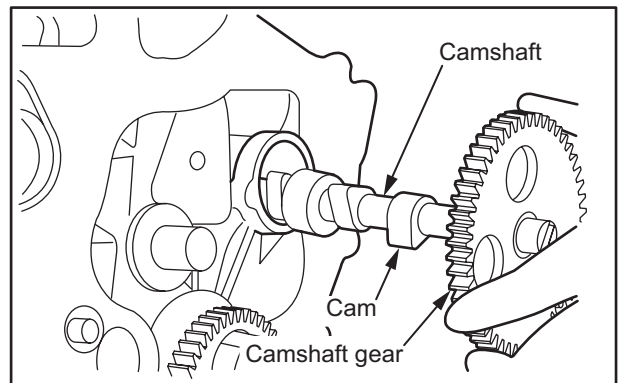
Be careful not to cause damage to the cam lobe of the camshaft and the cam shaft hole of the cylinder block when removing the camshaft.

(1) Remove the camshaft stopper washer.



Removing camshaft (1)

(2) Pull out the camshaft together with camshaft gear ball bearings.



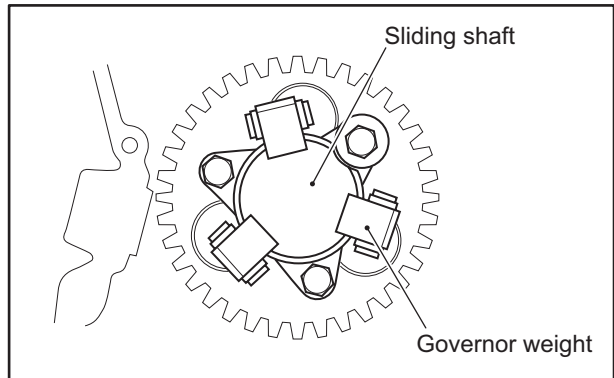
Removing camshaft (2)

### 3.12 Removing fuel injection pump camshaft

#### CAUTION

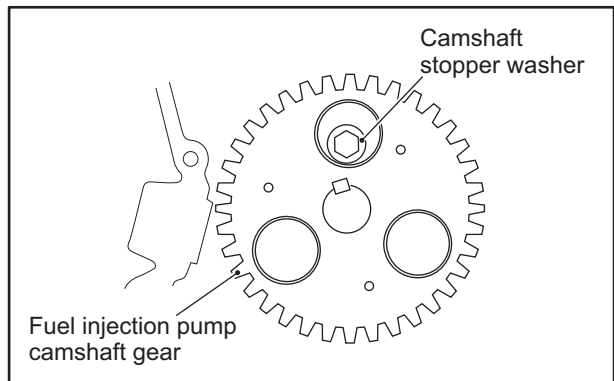
When pulling out the fuel injection pump camshaft, be careful not to cause damage to the cam portion of the fuel injection pump camshaft and the cam hole of the cylinder block.

(1) Remove the sliding shaft and the governor weight.



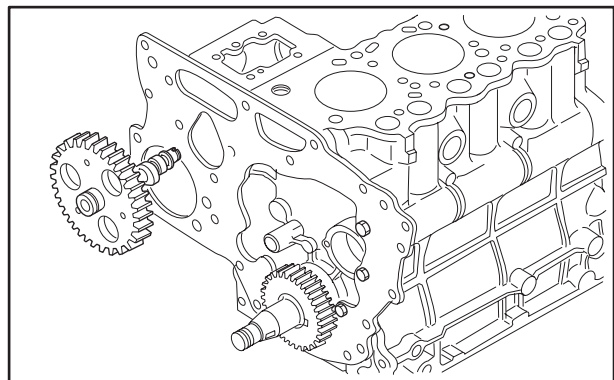
Removing sliding shaft and governor weight

(2) Remove the camshaft stopper washer.



Removing fuel injection pump camshaft (1)

(3) Remove the fuel injection pump camshaft together with the fuel injection pump camshaft gear and ball bearings.

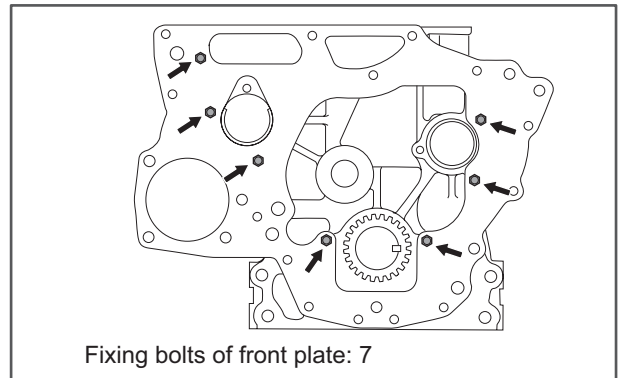


Removing fuel injection pump camshaft (2)

### 3.13 Removing front plate

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

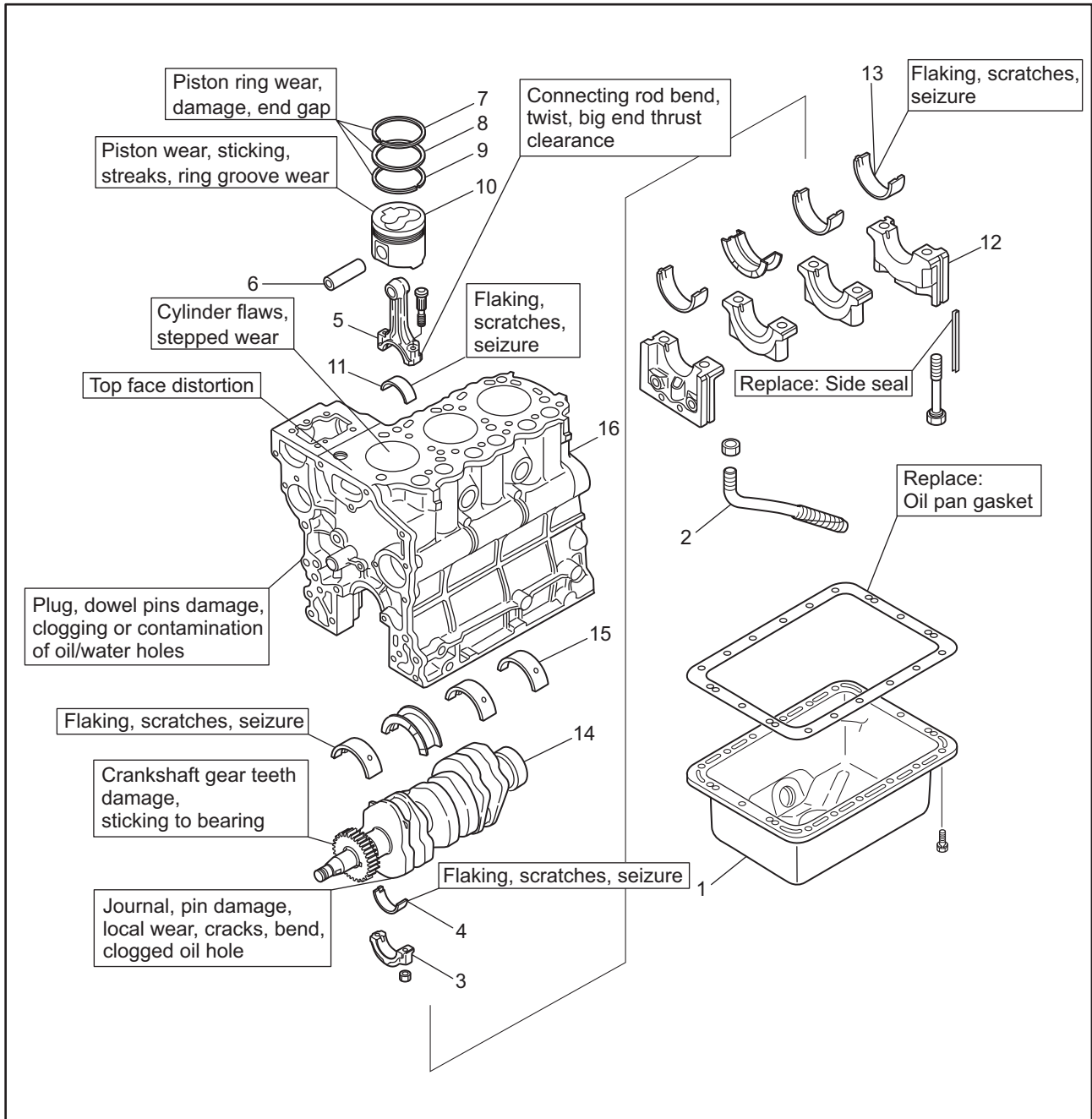
Note: If it is difficult to remove the front plate, lightly tap it with a plastic hammer.



Fixing bolts of front plate: 7

Removing front plate

4. Disassembling and inspecting cylinder block, crankshaft, piston and oil pan



Disassembling and inspecting cylinder block, crankshaft, piston and oil pan

Disassembling sequence

- |                                |   |                       |
|--------------------------------|---|-----------------------|
| 1 Oil pan                      | 7 No.1 compression                            | 12 Main bearing cap   |
| 2 Oil screen                   | 8 No.2 compression                            | 13 Lower main bearing |
| 3 Connecting rod cap           | 9 Oil ring                                    | 14 Crankshaft         |
| 4 Lower connecting rod bearing | 10 Piston<br>(Remove parts 5 to 10 as a unit) | 15 Upper main bearing |
| 5 Connecting rod               | 11 Upper connecting rod bearing               | 16 Cylinder block     |
| 6 Piston pin                   |   |                       |

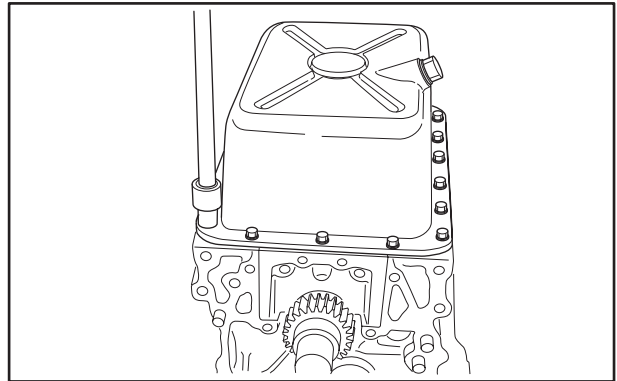
Note: When replacing the crankcase, carefully remove parts (relief valve, etc.) mounted on the non-reusable crankcase so that they can be reused.

#### 4.1 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.

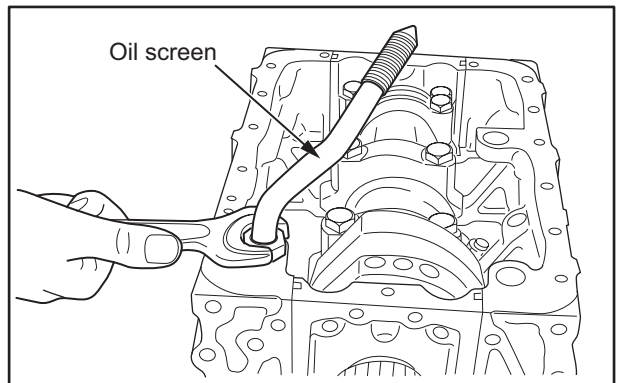
- (1) Turn the engine around.
- (2) Remove bolts from the oil pan.
- (3) To remove oil pan, tap bottom corners of the oil pan with a plastic hammer.



Removing oil pan

#### 4.2 Removing oil screen

Loosen the nut, and remove the oil screen and gasket.

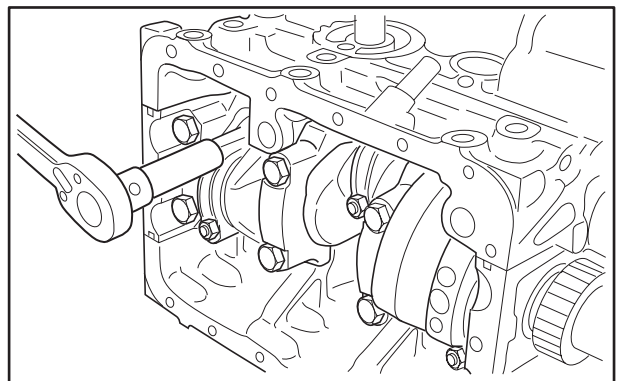


Removing oil screen

#### 4.3 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.

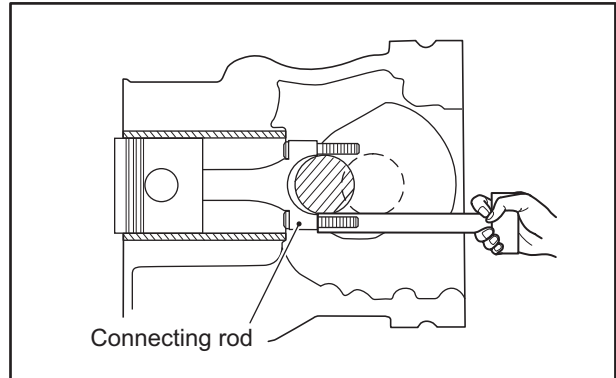
Note: Mark the cylinder No. and upper/lower on connecting rod bearings to ensure correct reassembling.



Removing connecting rod cap

#### 4.4 Pulling out piston

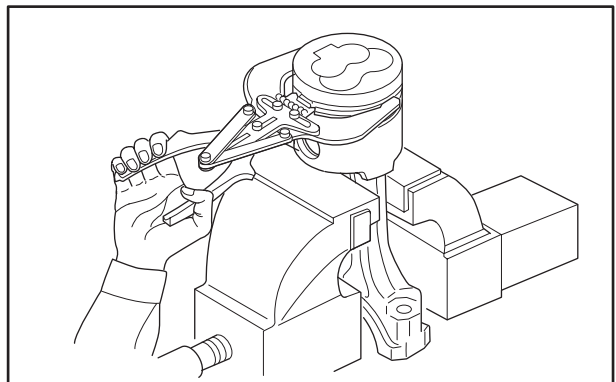
- (1) Turn the crankshaft to bring the piston to the top dead center.
- (2) Using a piece of wood such a hammer handle, push the mating surface of the connecting rod cap, and pull the piston and connecting rod upward from the cylinder.



Pulling out piston

#### 4.5 Removing piston ring

Remove the piston rings using piston ring pliers.

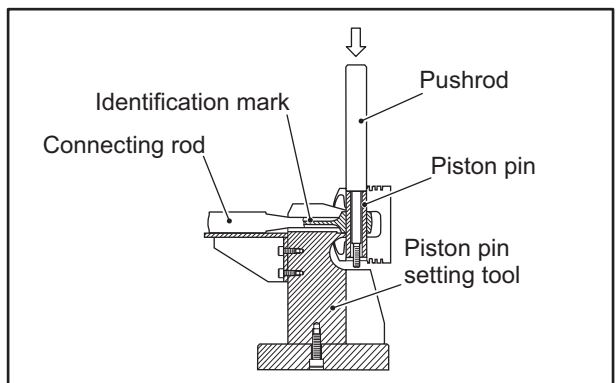


Removing piston ring

#### 4.6 Removing piston pin

Remove the piston pin using a piston pin setting tool.

Special tool name		Part No.
Piston pin setting tool	For L2A, L3A	30L91-00030
	For L2C, L3C	30L91-00020
	For L2E, L3E	30L91-10010



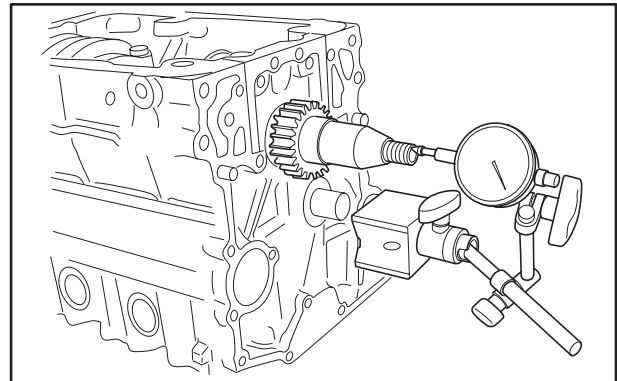
Removing piston pin

Part description	Identification mark	Applicable to
Push rod	D18	For 18mm [0.70868 in.] piston pin
	D21	For $\phi$ 21mm [0.82677 in.] piston pin

**4.7 Measuring crankshaft end play**

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

Item	Standard	Limit
Crankshaft end play	0.050 to 0.175 mm [0.0020 to 0.0069 in.]	0.500 mm [0.0197 in.]



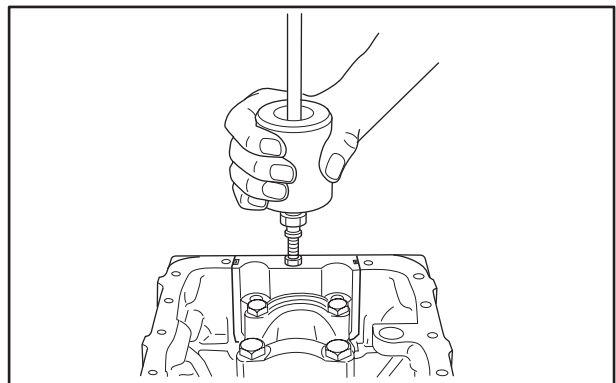
Measuring crankshaft end play

**4.8 Removing main bearing cap**

- (1) Remove the main bearing cap bolts.
- (2) Remove the main bearing caps.

To remove the main bearing caps of front and rear sides, use a driver as leverage. Place the tip of driver in the oil hole, and remove the cap using the crankshaft balance weight as the fulcrum.

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



Removing main bearing cap

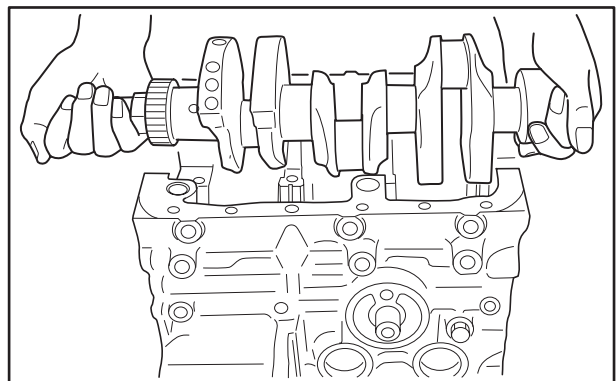
**4.9 Removing crankshaft**

**CAUTION**

Be careful not to damage bearings when removing the crankshaft.

- (1) Slowly lift the crankshaft straight up.
- (2) Arrange the bearings in the order of disassembly so that their original positions are restored when reassembling.

- Note: (a) When raising the crankshaft, do not allow wire chain to come into contact with the crankshaft.  
 To avoid damage to the crankshaft when raising, use a cloth belt or pad.  
 (b) Mark the bearings for their cylinder numbers.



Removing crankshaft



# INSPECTION AND REPAIR OF BASIC ENGINE

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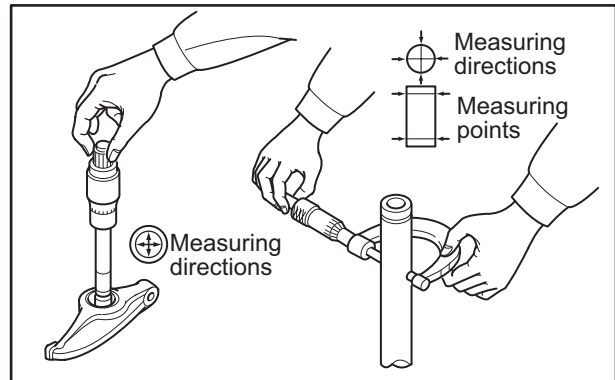
## 1. Inspecting and repairing cylinder head and valve mechanism

### 1.1 Measuring clearance between rocker arm and rocker shaft

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

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

Item	Nominal	Standard	Limit
Rocker arm inside diameter	ø 12 mm [0.47 in.]	12.013 to 12.035 mm [0.4730 to 0.4738 in.]	-
Rocker shaft outside diameter	ø 12 mm [0.47 in.]	11.470 to 11.984 mm [0.4516 to 0.4718 in.]	-
Clearance between rocker arm and shaft	-	0.029 to 0.065 mm [0.0011 to 0.0026 in.]	0.200 mm [0.0079 in.]

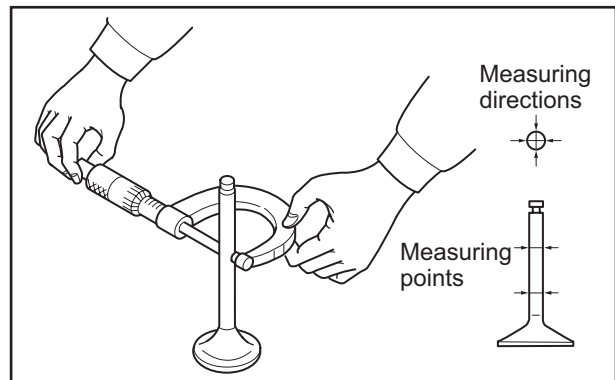


Measuring rocker arm inside diameter and rocker shaft outside diameter

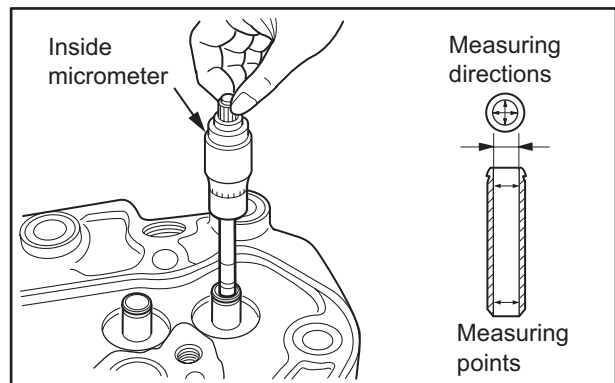
### 1.2 Measuring valve stem outside diameter and valve guide inside diameter

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 6.6 mm [0.260 in.]	6.565 to 6.580 mm [0.2585 to 0.2591 in.]	6.500 mm [0.2559 in.]
	Exhaust	ø 6.6 mm [0.260 in.]	6.530 to 6.550 mm [0.2571 to 0.2579 in.]	6.500 mm [0.2559 in.]
Clearance between valve stem and valve guide	Inlet	-	0.020 to 0.050 mm [0.0008 to 0.0020 in.]	0.100 mm [0.0039 in.]
	Exhaust	-	0.050 to 0.085 mm [0.0020 to 0.0034 in.]	0.150 mm [0.0059 in.]
Valve guide inside diameter	Inlet	ø 6.6 mm [0.260 in.]	6.600 to 6.615 mm [0.2598 to 0.2604 in.]	-
	Exhaust	ø 6.6 mm [0.260 in.]		



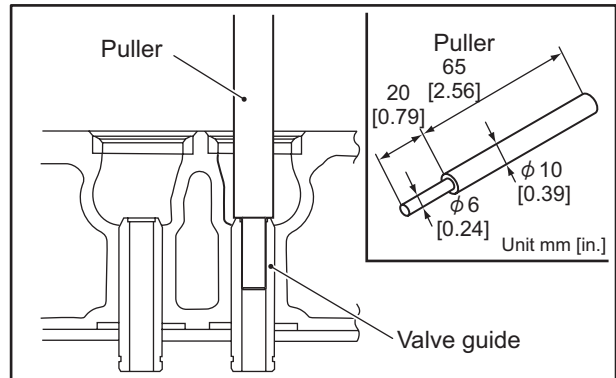
Measuring valve stem outside diameter



Measuring valve guide inside diameter

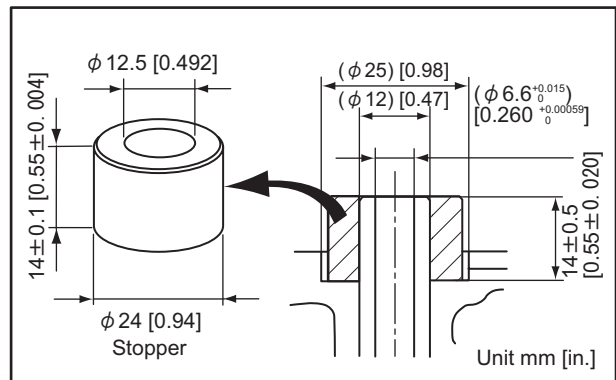
### 1.3 Replacing valve guide

- (1) Pull out the valve guide from the bottom to the top face of the cylinder head with a press using a blanking tool.



Pulling out valve guide

- (2) Using a stopper, press-fit the new valve guide from the top surface of cylinder head.  
After press-fitting, make sure the dimensions of valve position are as shown in the illustration.
- (3) After press-fitting the guide, insert new valve and make sure that it slides.
- (4) Inspect contact between the valve and valve seat.



Press fitting valve guide

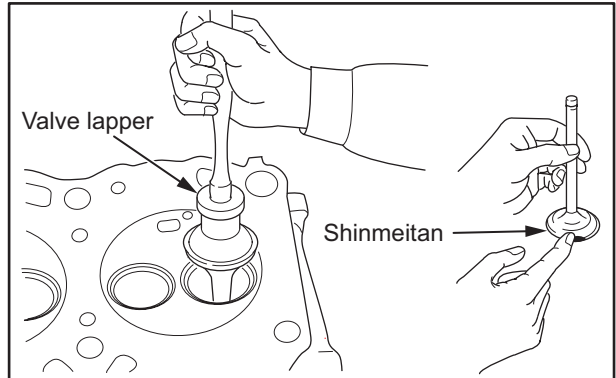
**1.4 Inspecting valve face**

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.

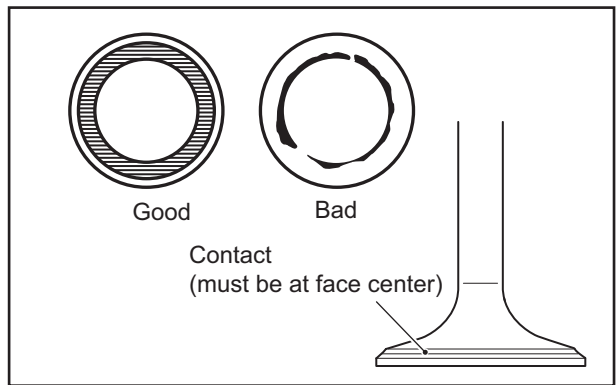
Note: (a) Inspect the valve face after the valve guide is repaired or replaced.

(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.

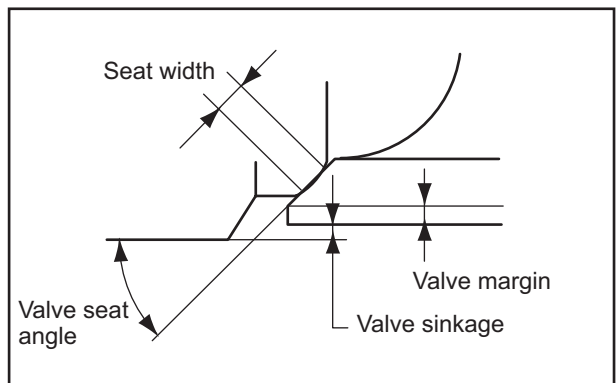


Checking valve face



Valve-to-valve seat contact

Item		Standard	Limit
Valve seat	Valve seat angle	44°	-
	Valve sinkage	0.4 to 0.6 mm [0.0158 to 0.0236 in.]	
Valve margin		1.0 mm [0.0394 in.]	0.5 mm [0.0197 in.]



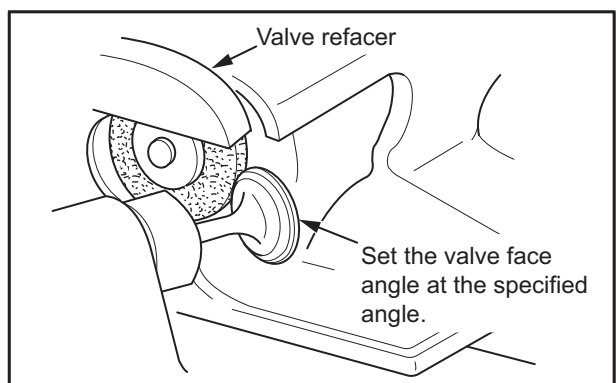
Valve-to-valve seat contact position

**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.

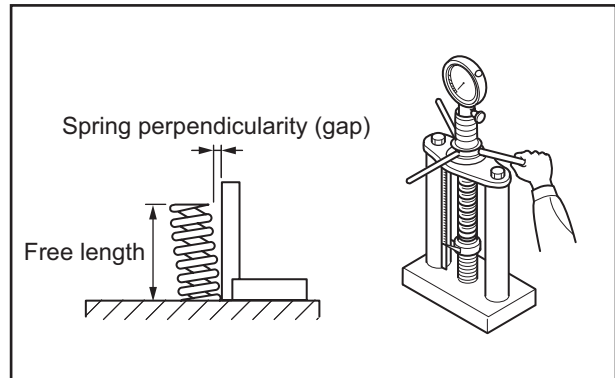


Refacing valve face

### 1.6 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	40 mm [1.57 in.]	38.5 mm [1.516 in.]
Perpendicularity	 $\theta = 2.0^\circ$ or less $\Delta$ (gap) = 1.4 mm [0.055 in.] or less $L_f = 40$ mm [1.57 in.]	$\Delta = 2.0$ mm [0.079 in.] over entire length
Set length/set force	35.5 [1.3976] / 55.3 to 61.2 N { 5.64 to 6.24 kgf } [12.4 to 13.8 lbf]	-15 %
	28.0 [1.1024] / 138.2 to 152.9 N { 14.09 to 15.59 kgf } [31.1 to 34.4 lbf]	



Squareness and free length of spring

### 1.7 Lapping valve and valve seat

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

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

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

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

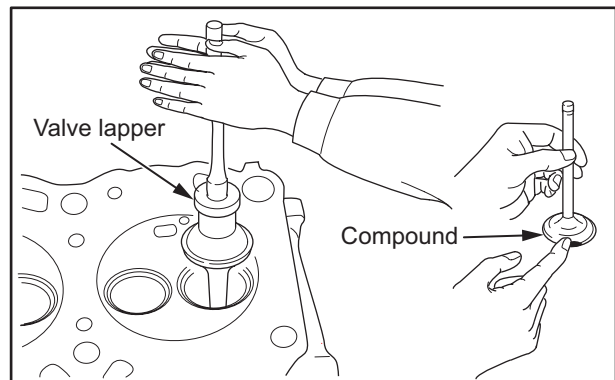
(c) Use medium-grain compound (120 to 150 mesh) for initial lapping, then use fine-grain compound (200 mesh or finer) for finishing.

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

(3) Wash off the compound using diesel fuel.

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

(5) Check valve-to-seat contact.



Lapping valve and valve seat

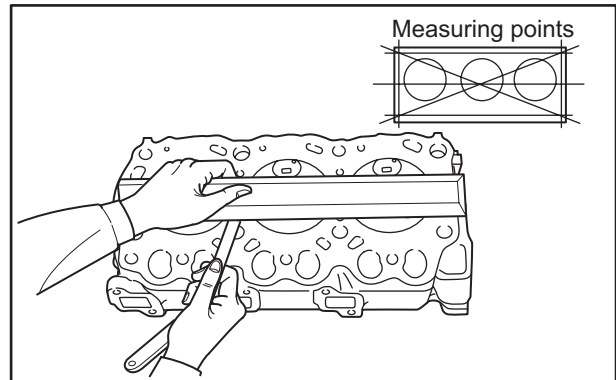
**1.8 Measuring distortion of the bottom surface of the cylinder head**

**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.



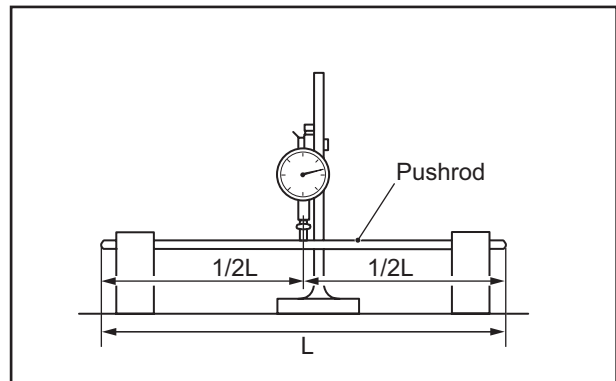
Measuring distortion of the bottom surface of the cylinder head

Item	Standard	Limit
Bottom surface distortion	0.05 mm [0.0020 in.]	0.10 mm [0.0039 in.]

**1.9 Measuring push rod runout**

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

Item	Standard	Limit	Remark
Push rod runout	Less than 0.3 mm [0.012 in.]	0.3 mm [0.012 in.]	Total indicated reading (TIR)



Measuring runout of push rod

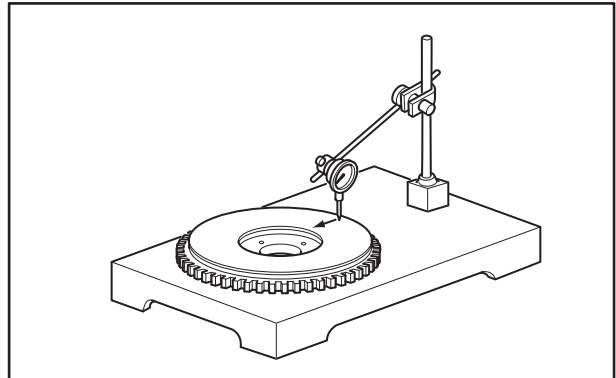
## 2. Inspecting and repairing flywheel

### 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	0.08 mm [0.0031 in.] or less	0.50 mm [0.0197 in.]



Measuring flatness of flywheel

### 2.2 Inspecting ring gear

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

### 2.3 Replacing ring gear

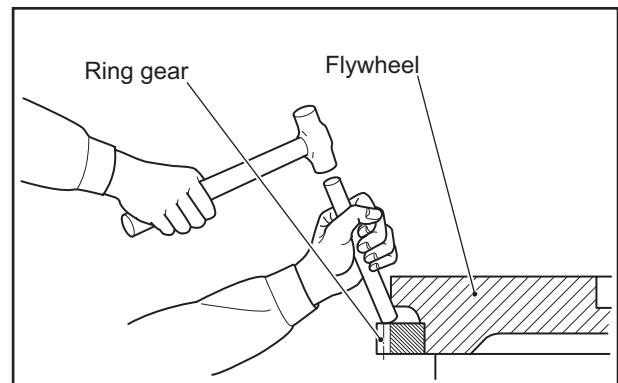
#### 2.3.1 Removing ring gear

- (1) Heat the ring gear evenly with an acetylene torch or other appropriate heat source.
- (2) Remove the ring gear by striking it evenly around the periphery with a hammer through a rod.

#### 2.3.2 Installing ring gear

- (1) Heat the ring gear evenly up to approx. 100°C [212°F] with an appropriate heater.
- (2) Install the ring gear onto the flywheel with the no-gear-chamfering side facing to the flywheel.

Note: Do not heat the ring gear excessively.

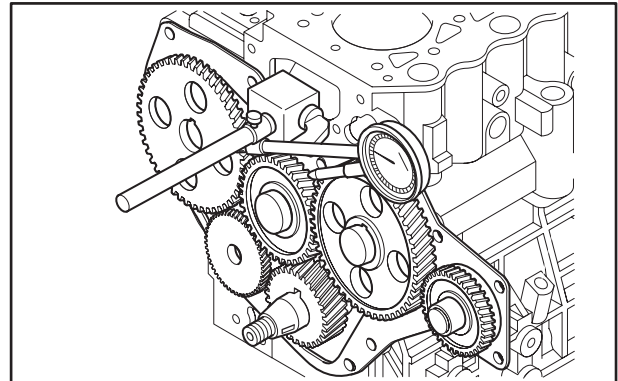


Removing ring gear

### 3. Inspecting and repairing gear case, 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.



Measuring timing gear backlash

Item	Standard	Limit
Between crankshaft gear and idler gear	0.010 to 0.136 mm [0.0004 to 0.0054 in.]	Spur gear
	0.040 to 0.118 mm [0.0016 to 0.0047 in.]	Helical gear
Between idler gear and valve camshaft gear	0.010 to 0.136 mm [0.0004 to 0.0054 in.]	Spur gear
Between idler gear and pump camshaft gear	0.037 to 0.117 mm [0.0015 to 0.0046 in.]	Helical gear
Between valve camshaft gear and PTO gear	0.010 to 0.220 mm [0.0004 to 0.0087 in.]	Spur gear
	0.007 to 0.235 mm [0.0003 to 0.0091 in.]	Helical gear

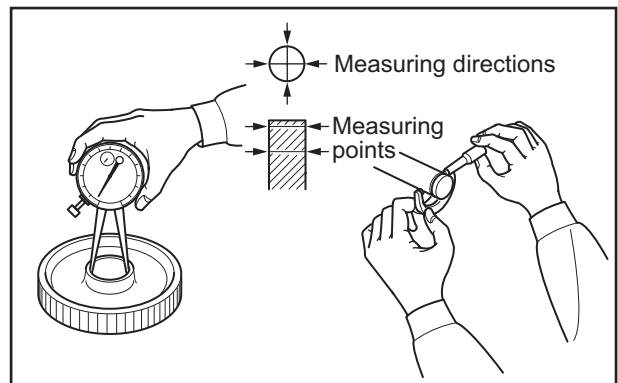
Timing gear backlash

0.300 mm  
[0.0118 in.]

#### 3.2 Measuring clearance between idler gear and idler shaft

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

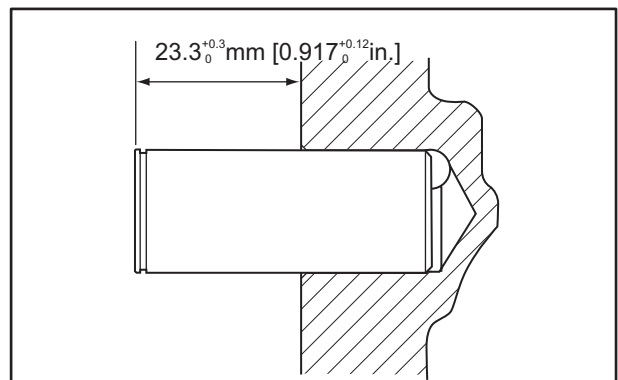
Item	Standard	Limit
Clearance between idler gear and idler shaft	0.030 to 0.066 mm [0.0012 to 0.0026 in.]	0.200 mm [0.0079 in.]



Measuring idler gear inside diameter and idler shaft outside diameter

#### 3.3 Replacing idler shaft

Press-fit the idler shaft into the cylinder block to the dimension in the illustration.



Replacing idler shaft

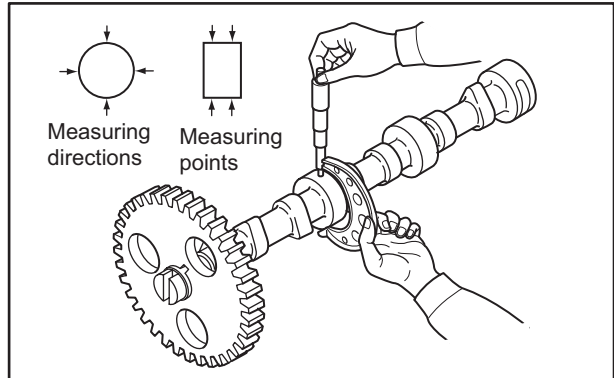


### 3.4 Measuring clearance between camshaft journal and cylinder block bore

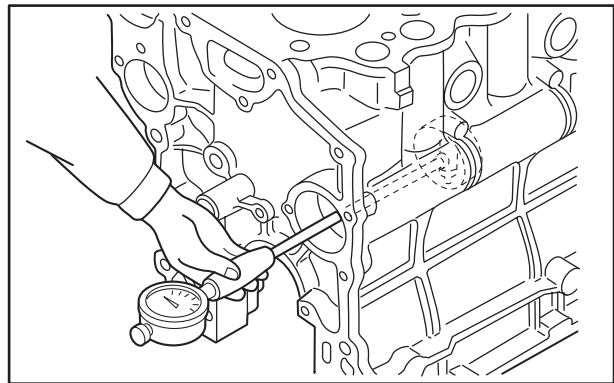
Calculate the clearance between the outside diameter of the camshaft journal and inside diameter of the cylinder block bore. Replace the camshaft or cylinder block if the clearance exceeds the limit.

Note: Start measurement from the No.2 camshaft hole because the No.1 camshaft hole is for ball bearings.

Item	Standard	Limit
Clearance between camshaft journal and cylinder block bore	0.050 to 0.100 mm [0.0020 to 0.0039 in.]	0.150 mm [0.0059 in.]



Measuring outside diameter of camshaft journal

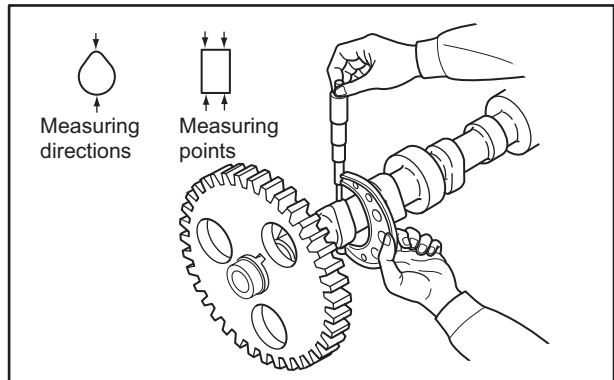


Measuring inside diameter of cylinder block camshaft holes

### 3.5 Measuring cam lift

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

Item	Standard	Limit
Cam height of camshaft (major axis)	27.27 to 27.47 mm [1.0736 to 1.0815 in.]	26.37 mm [1.0382 in.]

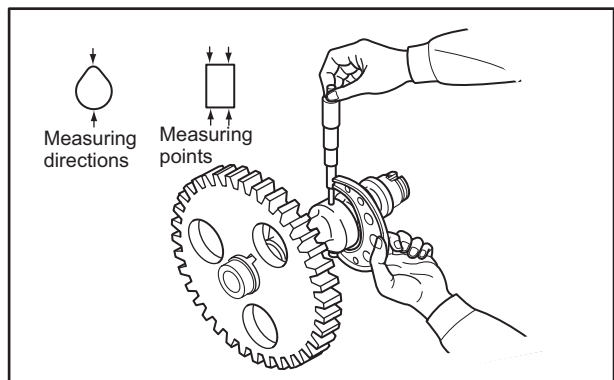


Measuring cam height of camshaft

### 3.6 Measuring cam height of fuel injection pump camshaft

Measure the cam height. Replace the camshaft if the height is less than the limit.

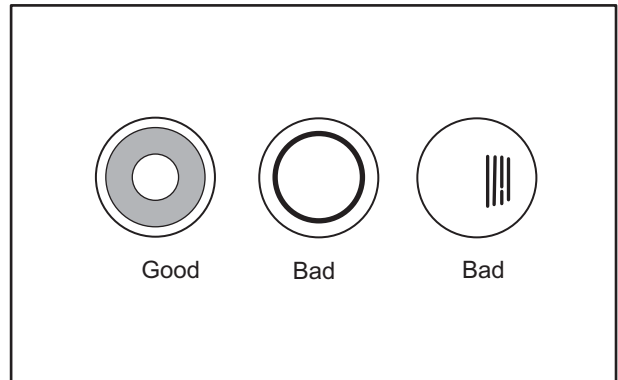
Item	Standard	Limit
Cam height of fuel injection pump camshaft (longer diameter)	29.9 to 30.1 mm [1.177 to 1.185 in.]	29 mm [1.1417 in.]



Measuring cam height of fuel injection pump camshaft

**3.7 Inspecting tappet**

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

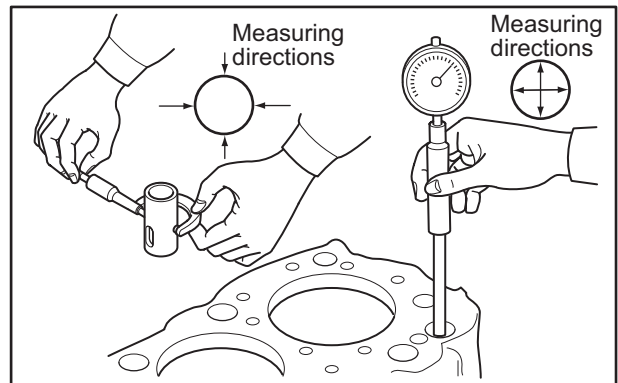


Inspecting tappets

**3.8 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
Clearance between camshaft journal and cylinder block bore	0.007 to 0.049 mm [0.0003 to 0.0019 in.]	0.150 mm [0.0059 in.]



Measuring clearance between tappet and tappet guide hole

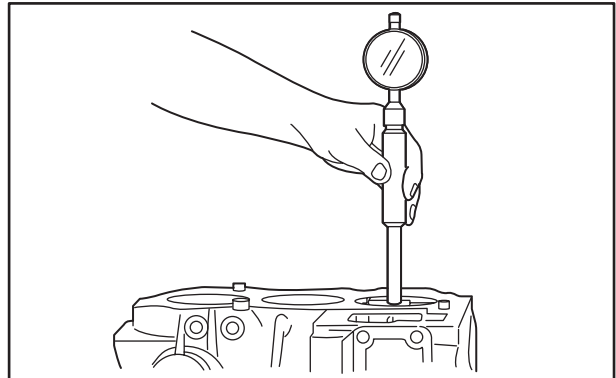
## 4. Inspecting and repairing cylinder block, crankshaft, piston and oil pan

### 4.1 Measuring cylinder inside diameter

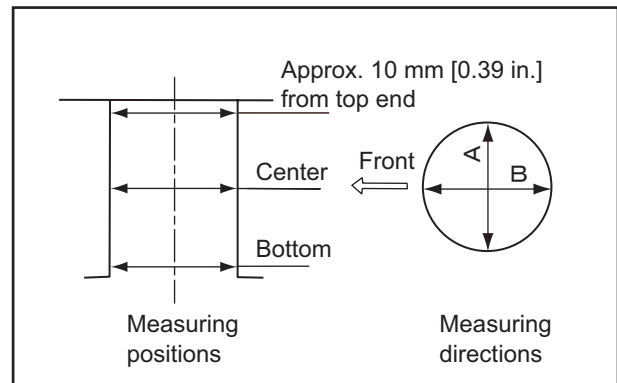
Use a cylinder gauge to measure the inside diameter and cylindricity of the cylinder at three locations in the A and B directions as shown in the illustration.

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

Replace the cylinder block if the limit is exceeded.



Measuring cylinder inside diameter



Measuring position of cylinder inside diameter

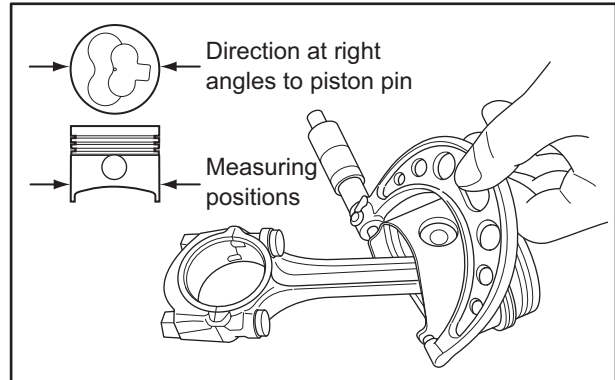
Item	Nominal	Standard	Limit	Remark
Cylinder inside diameter	L2A, L3A ø 65 mm [2.56 in.]	65.00 to 65.03 [2.5591 to 2.5602 in.]	+0.7 mm [+0.0276 in.]	Repair limit is +0.2 mm [+0.0079 in.]
	L2C, L3C ø 70 mm [2.76 in.]	70.00 to 70.03 [2.7559 to 2.7571 in.]		
	L2E, L3E ø 76 mm [2.99 in.]	76.00 to 76.03 [2.9921 to 2.9933 in.]		
Cylindricity of cylinder	-	0.01 mm [0.0004 in.] or less	-	-

**4.2 Reboring cylinder**

Cylinders shall be rebored according to the following procedure.

**4.2.1 Measuring piston outside diameter**

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



Measuring piston outside diameter

Item		Nominal	Standard
L2A L3A	STD	ø 65 mm [2.559 in.]	64.919 to 64.939 mm [2.5559 to 2.5566 in.]
	0.25 OS	ø 65.25 mm [2.569 in.]	65.169 to 65.189 mm [2.5657 to 2.5665 in.]
	0.50 OS	ø 65.50 mm [2.579 in.]	65.419 to 65.439 mm [2.5755 to 2.5763 in.]
L2C L3C	STD	ø 70 mm [2.756 in.]	69.913 to 69.933 mm [2.7525 to 2.7533 in.]
	0.25 OS	ø 70.25 mm [2.766 in.]	70.163 to 70.183 mm [2.7623 to 2.7631 in.]
	0.50 OS	ø 70.50 mm [2.776 in.]	70.413 to 70.433 mm [2.7722 to 2.7729 in.]
L2E L3E	STD	ø 76 mm [2.992 in.]	75.906 to 75.926 mm [2.9884 to 2.9892 in.]
	0.25 OS	ø 76.25 mm [3.002 in.]	75.156 to 76.176 mm [2.9983 to 2.9990 in.]
	0.50 OS	ø 76.50 mm [3.012 in.]	76.406 to 76.426 mm [3.0081 to 3.0089 in.]

**4.2.2 Boring finish dimension**

= [piston diameter] + [clearance] - [honing allowance (0.02 mm [0.0008 in.])]

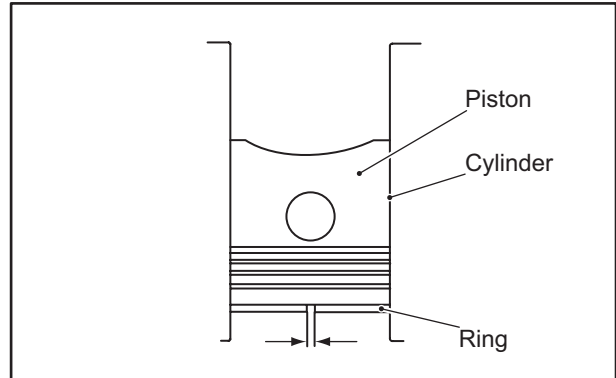
Item		Standard	Limit	Remark
Clearance (clearance between piston and cylinder)	L2A, L3A	0.061 to 0.111 mm [0.0024 to 0.0044 in.]	0.2 mm [0.0079 in.]	Repair to oversize or replace
	L2C, L3C	0.067 to 0.117 mm [0.0026 to 0.0046 in.]		
	L2E, L3E	0.074 to 0.124 mm [0.0029 to 0.0049 in.]		

**4.3 Measuring piston ring end gap**

**CAUTION**

- (a) When replacing rings without boring (honing), measure the end gap at the bottom of the cylinder where the wear is minimum.
- (b) When replacing the ring, use the ring of the same size as the piston.

Insert the piston ring into the cylinder bore and push it with the piston to achieve squareness. Then measure the end gap with feeler gauges. Replace the piston ring if the limit is exceeded.



Measuring piston ring end gap

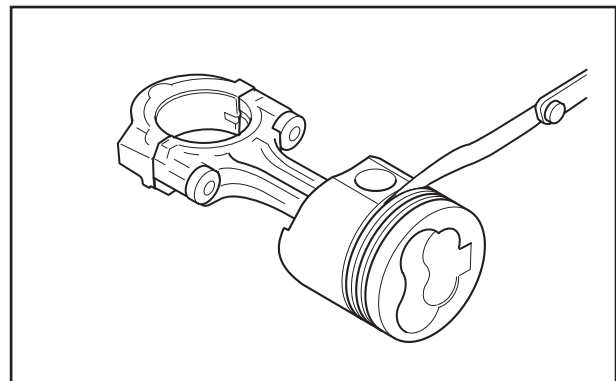
Item		Standard	Limit
End gap of ring	No.1 compression ring	0.15 to 0.30 mm [0.0059 to 0.0118 in.]	1.5 mm [0.0591 in.]
	No.2 compression ring	0.15 to 0.30 mm [0.0059 to 0.0118 in.]	
	Oil ring	0.15 to 0.35 mm [0.0059 to 0.0138 in.]	

**4.4 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.



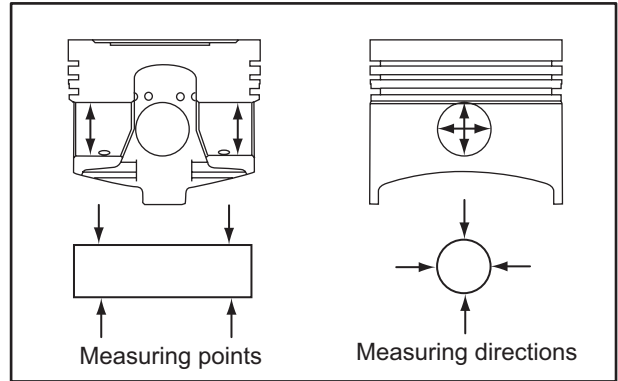
Measuring piston ring groove

Item		Standard	Limit
Clearance between ring and ring groove	No.1 compression ring	-	0.3 mm [0.0118 in.]
	No.2 compression ring	0.05 to 0.09 mm [0.0020 to 0.0035 in.]	0.2 mm [0.0079 in.]
	Oil ring	0.03 to 0.07 mm [0.0019 to 0.0028 in.]	0.2 mm [0.0079 in.]

**4.5 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	
Outside diameter of piston pin	L2A,L3A L2C,L3C	ø 18 mm [0.71 in.]	18.001 to 18.007 mm [0.7087 to 0.7089 in.]	-
	L2E,L3E	ø 21 mm [0.83 in.]	21.002 to 21.005 mm [0.8269 to 0.8270 in.]	-
Clearance between piston pin bore and piston pin outside diameter	L2A,L3A L2C,L3C	-	0.006 to 0.018 mm [0.0002 to 0.0007 in.]	0.08 mm [0.0031 in.]
	L2E,L3E	-	0.007 to 0.015 mm [0.0003 to 0.0006 in.]	

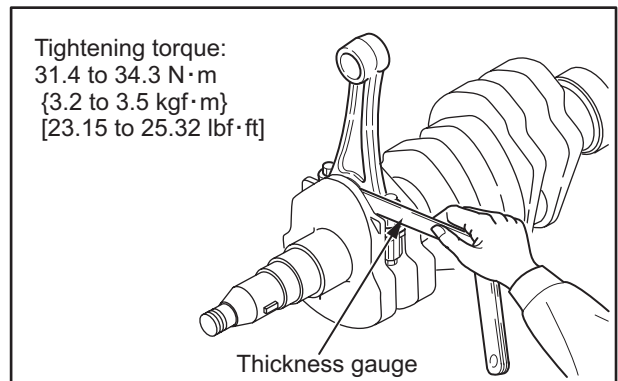


Measuring piston pin bore and piston pin outside diameter

**4.6 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	0.10 to 0.35 mm [0.0039 to 0.0138 in.]	0.50 mm [0.0197 in.]



Measuring end play of connecting rod

**4.7 Inspecting connecting rod bend and twist**

(1) Measure the dimensions of C and L in the illustration to check bend and twist of the connecting rod. Straighten the connecting rod with a press to meet the standard.

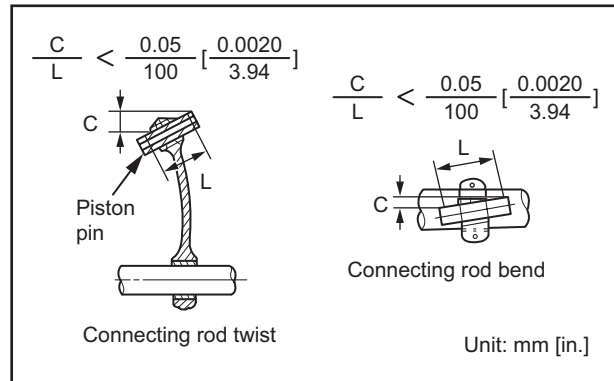
If the standard is exceeded after correction, replace the connecting rod with a new one.

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

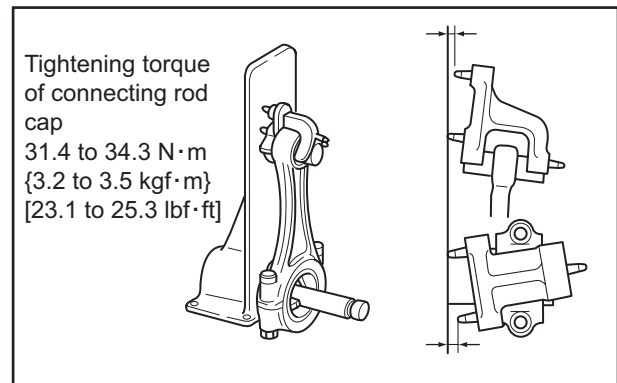
Note: Before checking bend, tighten the connecting rod cap to the specified torque.

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

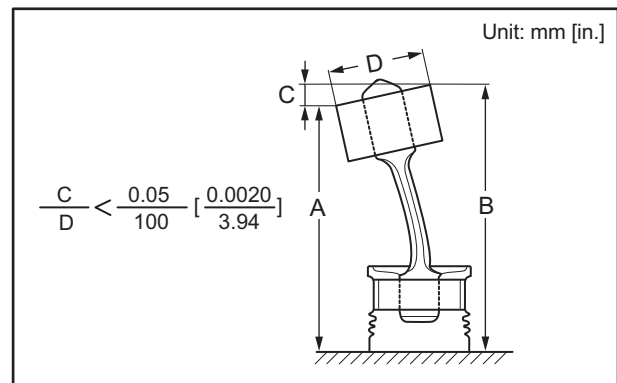
Item	Standard	Limit
Bend and twist of connecting rod	0.05/100 mm [0.0020/3.94 in.] or less	0.15/100 mm [0.0059/3.94 in.]



Inspecting connecting rod bend and twist



Measurement with connecting rod aligner



Measuring bend of connecting rod

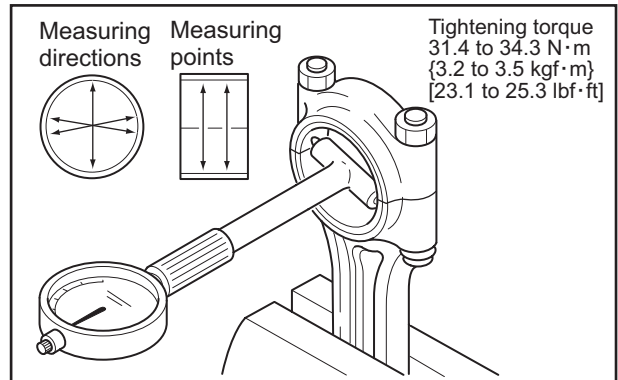
**4.8 Measuring clearance between connecting rod bearing and crankpin**

**CAUTION**

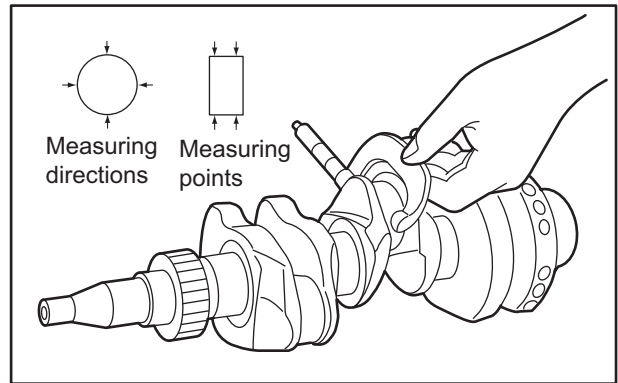
When grinding crank pins, be sure to grind all the pins to the same size.

Finish the fillet radius to the specified dimension.

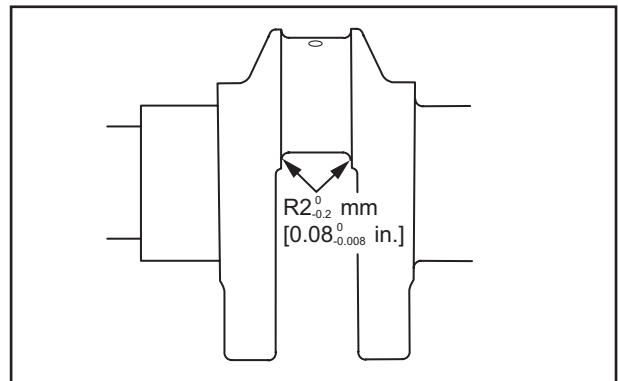
- (1) Reassemble the bearing into the big end of the connecting rod.
- (2) Tighten the connecting rod cap bolts to the specified torque.
- (3) Measure the inside diameter of the connecting rod bearing.
- (4) Measure the outside diameter of the crank pin.
- (5) Calculate the clearance from the difference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



Measuring inside diameter of connecting rod bearing



Measuring crank pin outside diameter



Finish dimension of fillet radius

Item	Nominal	Standard	Limit
Crankpin outside diameter (STD)	ø 40 mm [1.57 in.]	39.965 to 39.980 mm [1.5734 to 1.5740 in.]	-0.70 mm [-0.0276 in.]
Clearance between crankpin and connecting rod bearing	-	0.028 to 0.071 mm [0.0011 to 0.0028 in.]	0.150 mm [0.0059 in.]

Undersize grinding dimensions of crankshaft		
Item	Undersize	Finish dimension
Crankpin undersize	0.25 mm [0.0098 in.]	ø 39.75 <sup>-0.020</sup> <sub>-0.035</sub> mm [1.5650 <sup>-0.0008</sup> <sub>-0.0014</sub> in.]
	0.50 mm [0.0197 in.]	ø 39.50 <sup>-0.020</sup> <sub>-0.035</sub> mm [1.5551 <sup>-0.0008</sup> <sub>-0.0014</sub> in.]



**4.9 Measuring clearance between main bearing and crankshaft journal**

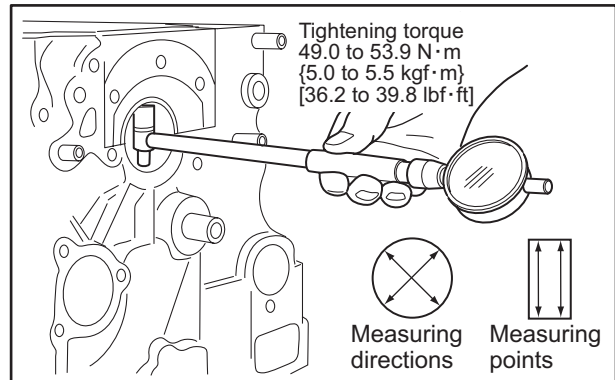
**CAUTION**

- (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.
- (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.

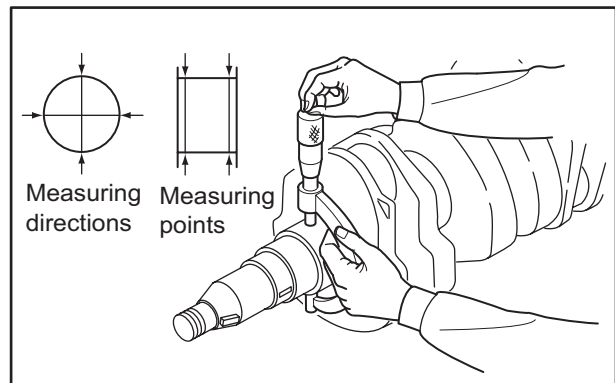
Item	Nominal	Standard	Limit
Outside diameter of crankshaft journal (STD)	ø 43 mm [1.69 in.]	42.965 to 42.980 mm [1.6915 to 1.6921 in.]	-
Clearance between main bearing and crankshaft journal	-	0.030 to 0.075 mm [0.0012 to 0.0030 in.]	0.10 mm [0.0039 in.]

**Undersize grinding dimensions of crankshaft**

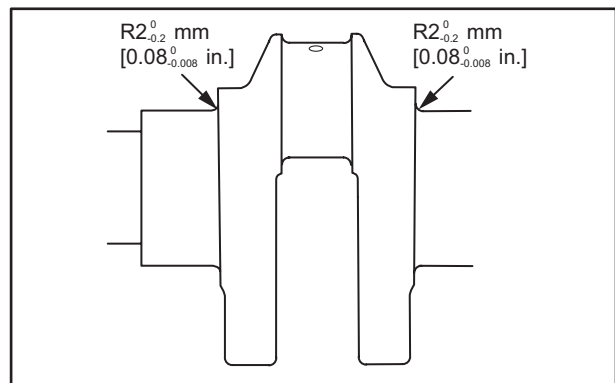
Item	Undersize	Finish dimension
Crank journal undersize	0.25 mm [0.0098 in.]	ø 42.75 <sup>-0.020</sup> <sub>-0.035</sub> mm [1.6831 <sup>-0.0008</sup> <sub>-0.0014</sub> in.]
	0.50 mm [0.0197 in.]	ø 42.50 <sup>-0.020</sup> <sub>-0.035</sub> mm [1.6732 <sup>-0.0008</sup> <sub>-0.0014</sub> in.]



Measuring main bearing fitting bore



Measuring crank journal outside diameter



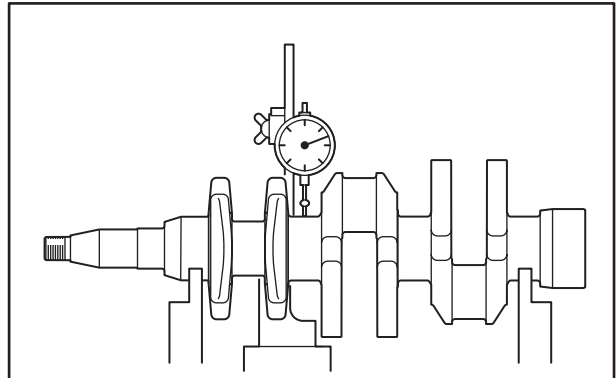
Finish dimension of fillet radius

**4.10 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 bend of crankshaft

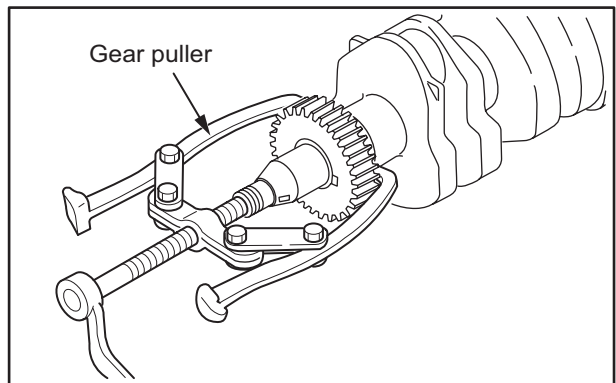
Item	Standard	Remark
Crankshaft runout	0.06 mm [0.0024 in.]	TIR

**4.11 Replacing crankshaft gear**

**4.11.1 Removing crankshaft gear**

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

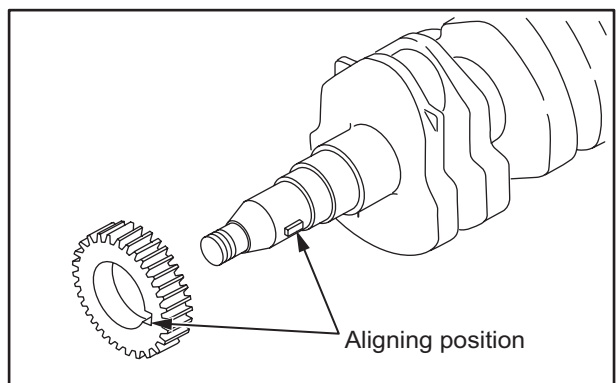
Note: Do not strike the gear with a hammer.



Removing crankshaft gear

**4.11.2 Installing crankshaft gear**

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



Installing crankshaft gear

#### 4.12 Measuring distortion cylinder block top surface

##### CAUTION

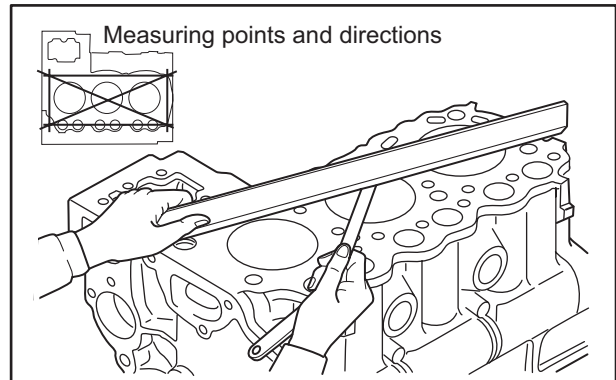
Refacing of cylinder head should be kept to an absolute minimum.

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

Apply a straight edge to the top surface of the cylinder block and measure its distortion using a feeler gauge.

If the distortion exceeds the limit, grind the cylinder block using a surface grinder.

Item	Standard	Limit
Distortion of cylinder block top surface	0.05 mm [0.0020 in.] or less	0.10 mm [0.0039 in.]



Measuring crankcase top surface distortion



# REASSEMBLY OF BASIC ENGINE

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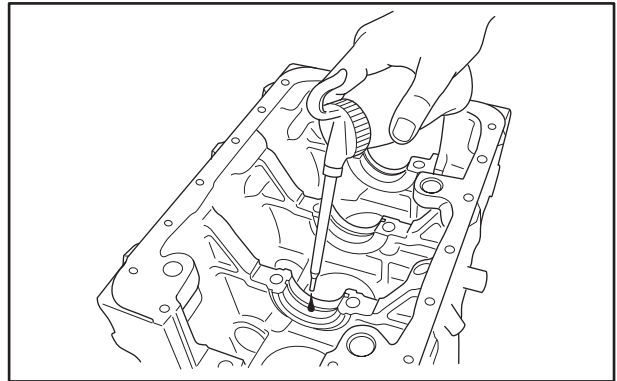
## 1. Reassembling cylinder block, crankshaft, piston and oil pan

### 1.1 Installing main bearing

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

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

- (2) Install the flange main bearing to the rearmost crankcase mating surface.
- (3) Apply a small amount of engine oil to each bearing.



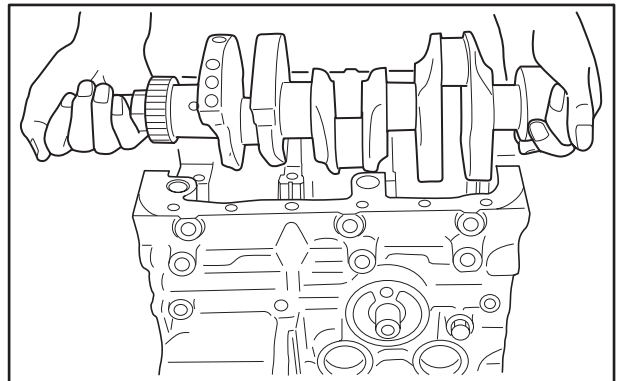
Installing main bearing

### 1.2 Installing crankshaft

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

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

- (2) Hold the crankshaft horizontally and slowly install it to the cylinder block.
- (3) Apply a small quantity of engine oil to the crankshaft journals.



Installing crankshaft

### 1.3 Installing main bearing cap

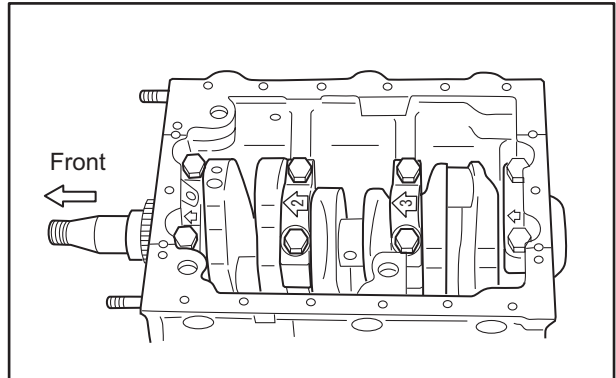
**CAUTION**

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

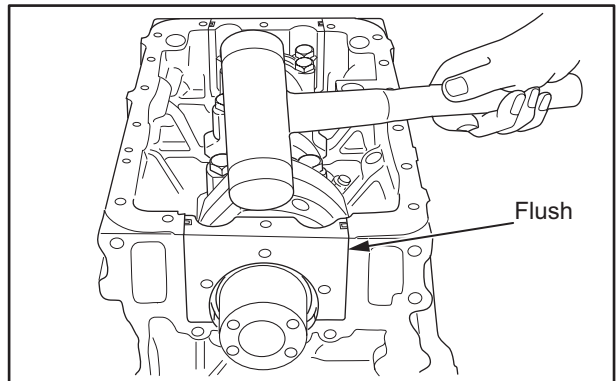
- (1) Apply sealant to the mating surface of the foremost and rearmost caps and the cylinder block mating faces before installing the main bearing caps.

Sealant or lubricant	THREEBOND 1212 or 1211
----------------------	------------------------

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



Reassembled position of main bearing cap



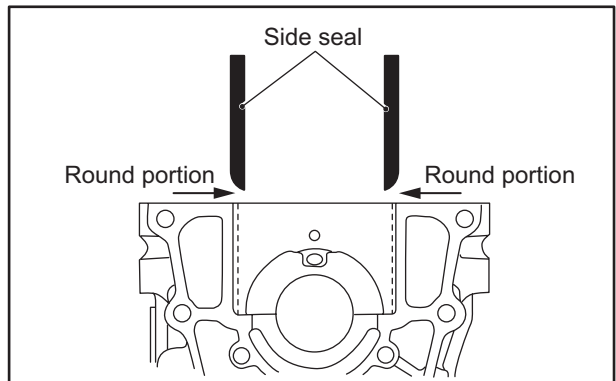
Installing main bearing cap

### 1.4 Inserting side seal

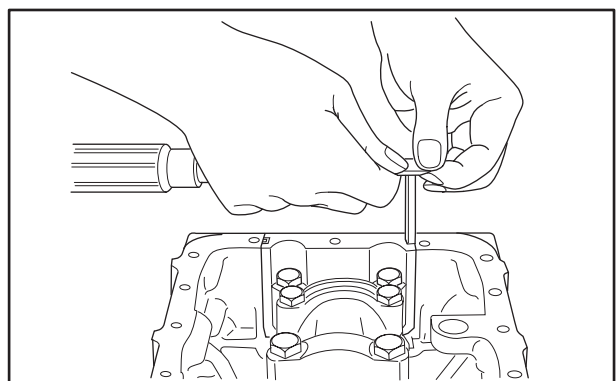
- (1) Apply a sealant to the outer periphery of new side seals.

Sealant	THREEBOND 1212 or 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 flat-head screwdriver to install completely, taking care not to bend them.



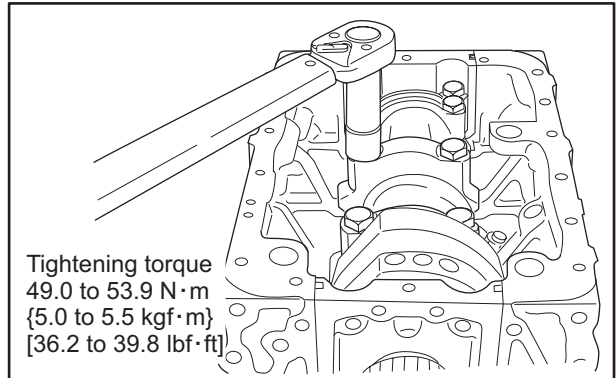
Installed direction of side seal



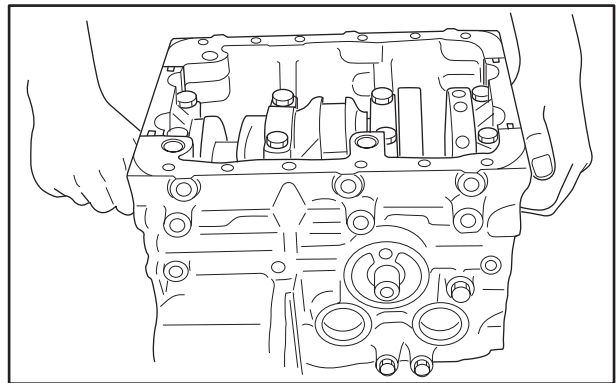
Inserting side seal

**1.5 Installing main bearing cap bolt**

- (1) Tighten the main bearing cap bolts alternately and progressively to the specified torque.
- (2) Make sure that the crankshaft rotates smoothly.



Tightening main bearing cap bolt



Checking crankshaft for rotation

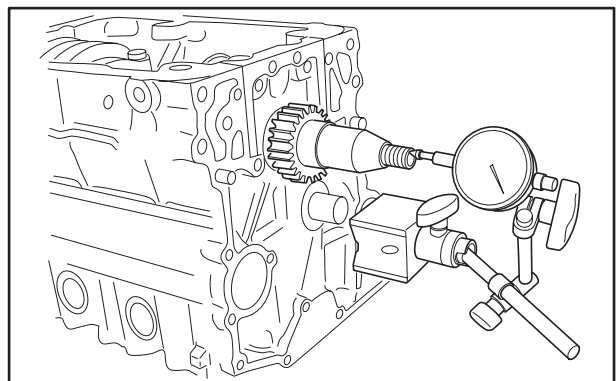
**1.6 Measuring crankshaft end play**

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

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

Make sure that the camshaft turns freely.

Item	Standard	Limit
Measuring crankshaft end play	0.050 to 0.175 mm [0.0020 to 0.0069 in.]	0.500 mm [0.0197 in.]

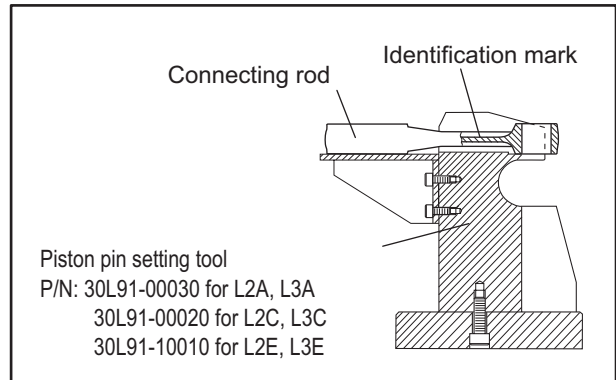


Measuring crankshaft end play



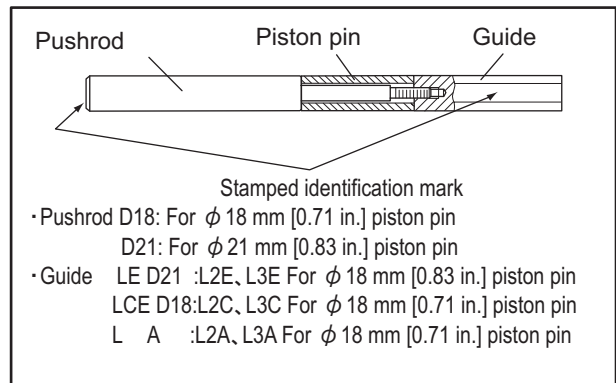
**1.7 Reassembling piston and connecting rod**

- (1) With the identification mark of connecting rod facing upward, place the rod on the piston pin setting tool.



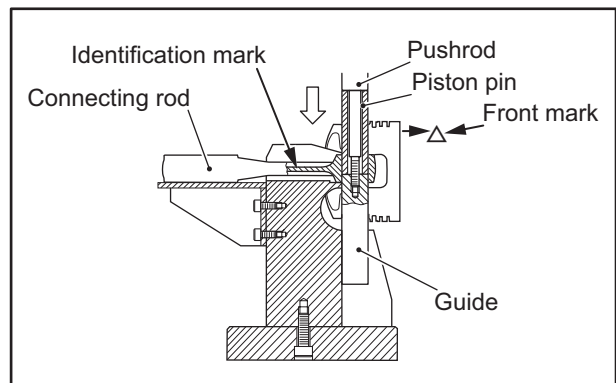
Reassembling piston and connecting rod (1)

- (2) Set the piston pin push rod and guide to the piston pin.



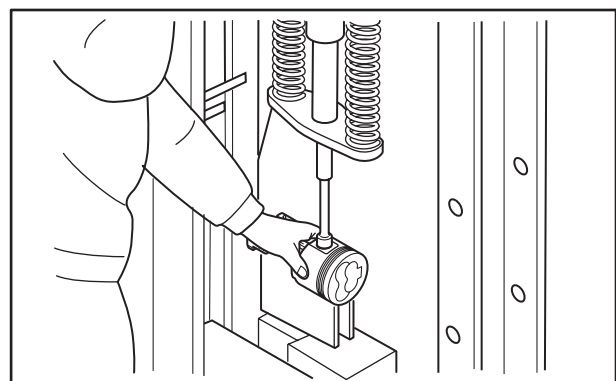
Reassembling piston and connecting rod (2)

- (3) Reassemble the piston to the connecting rod with the front mark (  $\Delta$  ) on the piston top and the identification mark of the connecting rod facing upward. Install the piston pin from the piston pin guide.



Reassembling piston and connecting rod (3)

- (4) Press-in the piston pin with the push rod using hydraulic press (pin press-in load 9807±4903 N {1000±500 kgf} [2205±1102 lbf]) until the guide contacts the piston setting tool.
- (5) After reassembling, make sure that the piston and the connecting rod move lightly on the piston pin.



Reassembling piston and connecting rod (4)

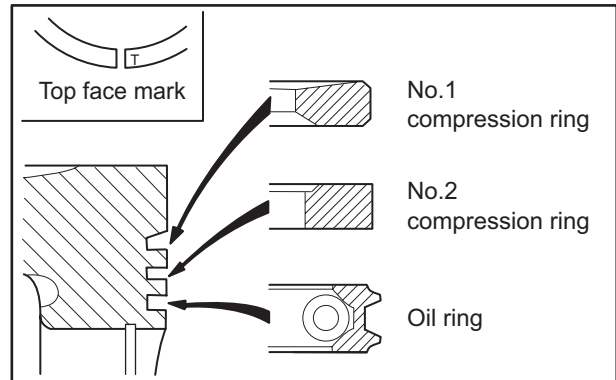
1.8 Installing piston

**CAUTION**

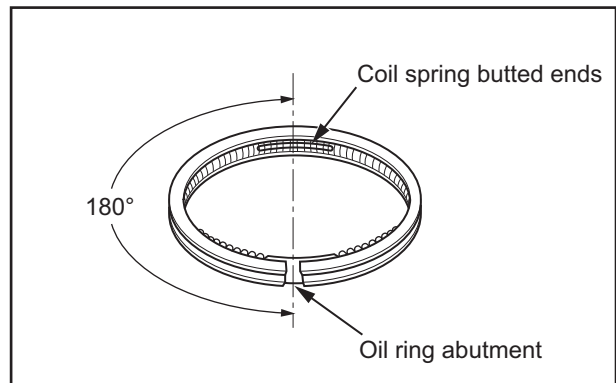
Every piston ring has a top mark such as "R" near the end gap. Install all piston rings with this mark facing upward.

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

- (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.



Reassembling pistons and piston rings



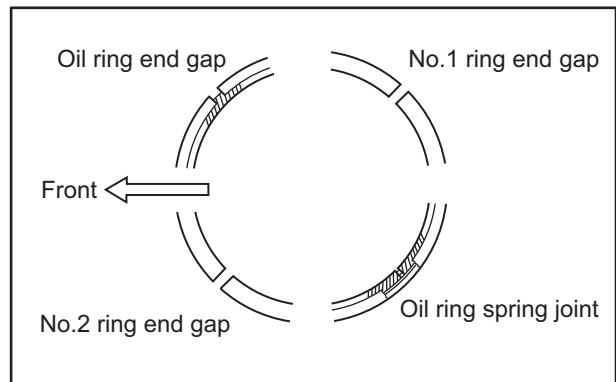
Oil ring end gap/coil spring joint orientation

1.9 Installing piston and connecting rod

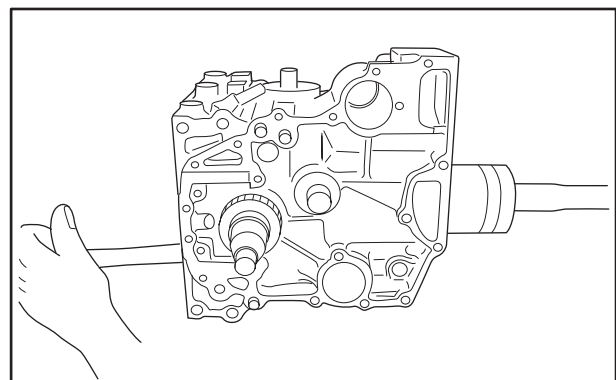
**CAUTION**

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) Place the ring end gaps in diagonal positions avoiding the piston pin direction and its right angle direction.
- (3) Fit the connecting rod bearing (upper) to the connecting rod aligning the lug and lug groove.
- (4) Turn the crankshaft to place the crank pin of the assembling cylinder to the top dead center.
- (5) Face the front mark (arrow) stamped on the piston top toward the timing gear case side (forward of the engine).
- (6) Insert the piston from the top face of cylinder block using a piston guide (commercially available).



Orienting piston ring end gaps



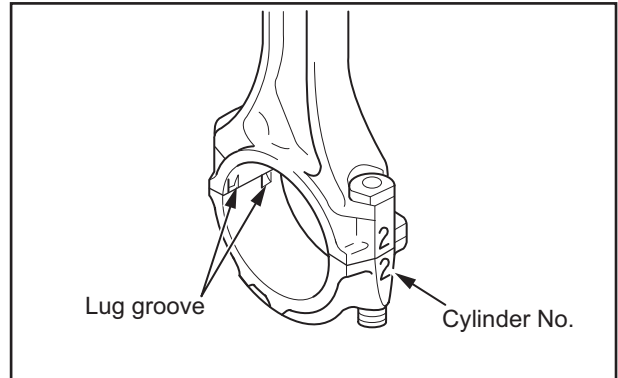
Installing pistons and connecting rods

**1.10 Installing connecting rod cap**

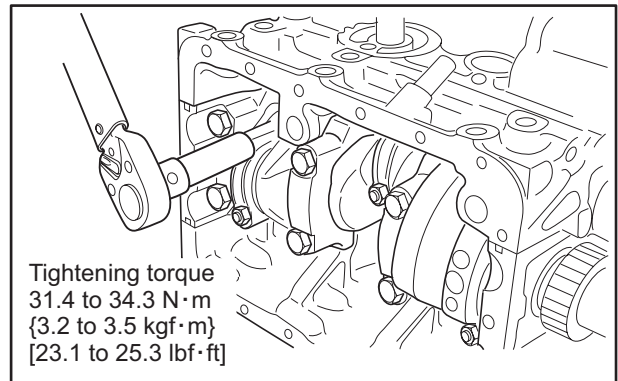
- (1) When the big end of the connecting rod comes into close contact with the crank pin, turn the crankshaft 180° while pressing the piston head.
- (2) Fit the connecting rod bearing (lower) to the rod cap with the lug aligned with the lug groove.
- (3) Install the cap to the connecting rod, aligning the mating marks made during disassembly.

Note: For new connecting rod on which there is no mating mark, orient the lugs of upper and lower bearings on the same side as shown in the illustration.

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



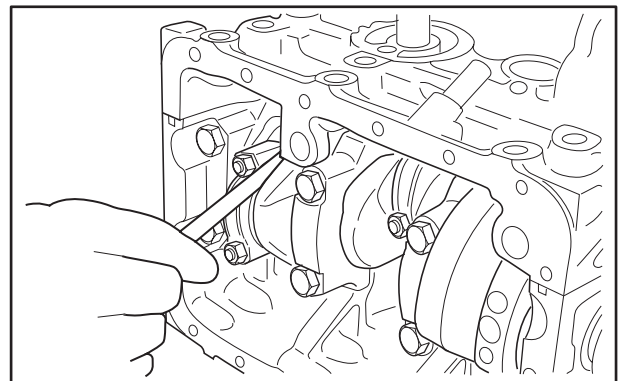
Installing connecting rod caps



Tightening connecting rod cap nuts

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

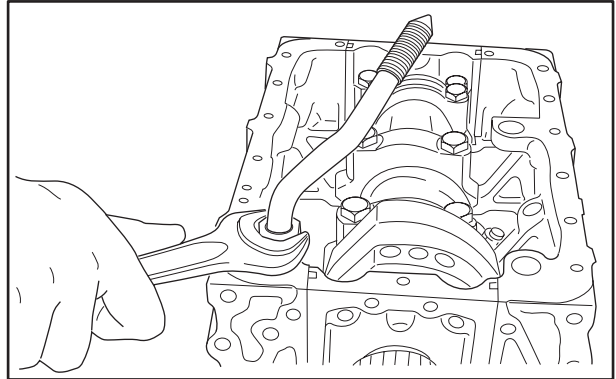
Item	Standard	Limit
End play of connecting rods	0.10 to 0.35 mm [0.0039 to 0.0138 in.]	0.5 mm [0.0197 in.]



Measuring end play of connecting rod

**1.11 Installing oil screen**

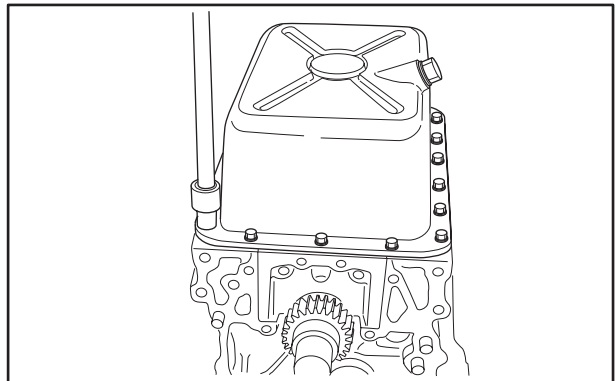
- (1) Turn the engine upside-down so that the oil pan mounting surface is facing up.
- (2) Install the oil screen so that the tip of the screen does not contact the oil pan.



Installing oil screen

**1.12 Installing oil pan**

- (1) Install new oil pan gasket.
- (2) Tighten oil pan bolts evenly and diagonally.

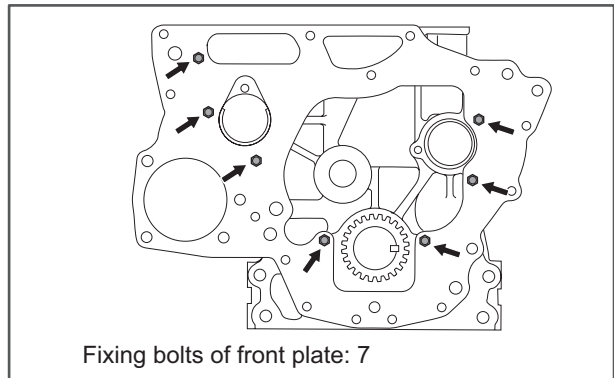


Installing oil pan

## 2. Reassembling gear case, timing gear and camshaft

### 2.1 Installing front plate

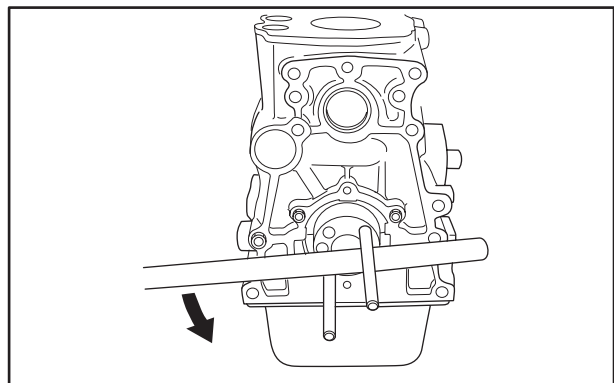
- (1) Clean the mounting surface of the gasket.
- (2) Apply sealant to the gasket to prevent it from falling.
- (3) With aligning to the dowel pin, install the gasket and the front plate.
- (4) Secure the front plate with mounting bolts.



Installing front plate

### 2.2 Rotating crankshaft

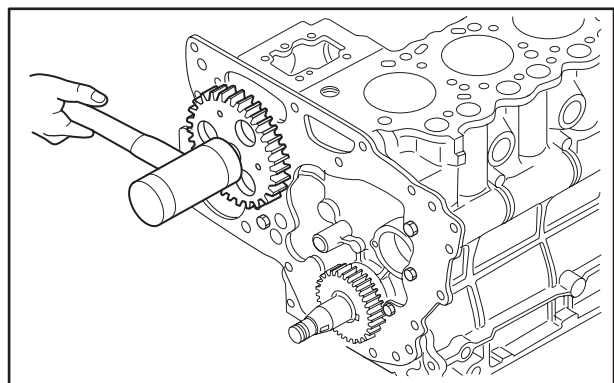
- (1) Install two bolts in the flywheel mounting holes of the crankshaft.
- (2) Rotate the crankshaft with a bar using the bolts to bring the No.1 cylinder at the top dead center.



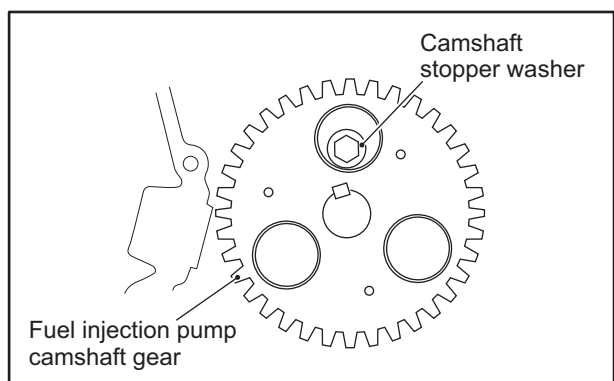
Turning engine

### 2.3 Installing fuel injection pump camshaft

- (1) Insert the fuel injection pump camshaft (with the bearing and gear installed) into the cylinder block hole.
- (2) Install the bearing into the cylinder block hole completely by tapping the gear with a plastic hammer.
- (3) Make sure that the fuel injection pump camshaft rotates lightly.
- (4) Tighten the camshaft stopper bolts.



Driving in fuel injection pump camshaft



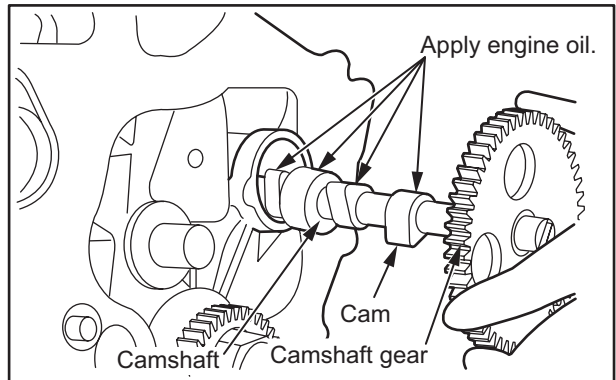
Installing camshaft stopper washers

### 2.4 Installing camshaft

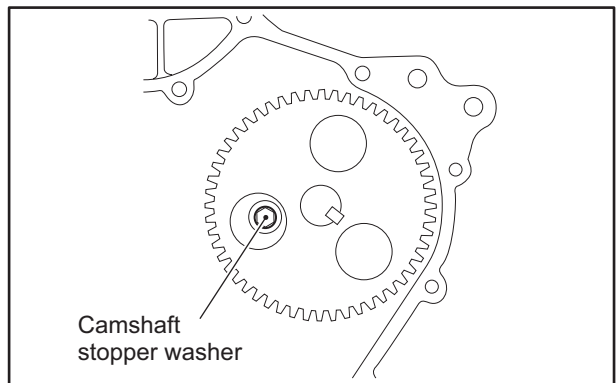
**CAUTION**

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) Install the camshaft stopper.
- (4) Make sure that the camshaft rotates freely.  
Move the camshaft gear back and forth, and make sure there is end play.



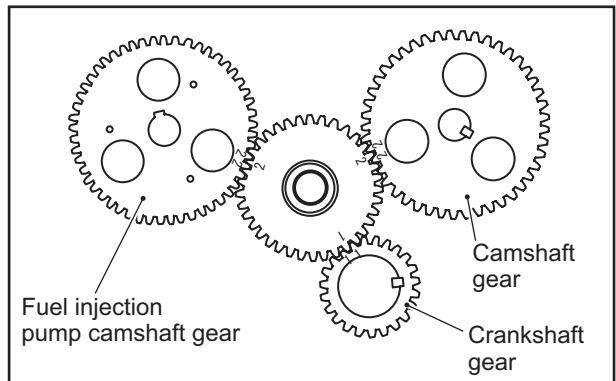
Installing camshaft



Installing camshaft stoppers

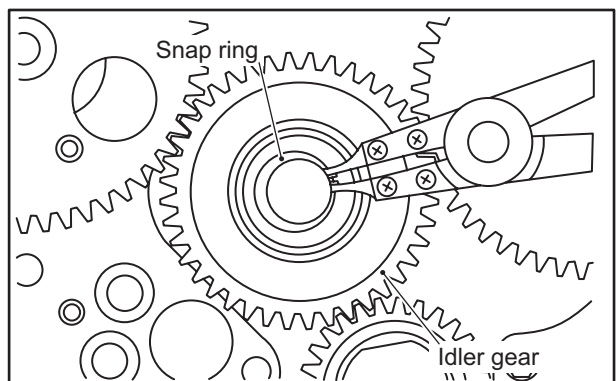
### 2.5 Installing idler gear

- (1) Apply engine oil to the idler gear shaft.
- (2) Install the idler gear while aligning all match marks on it and the other gears.



Align the timing marks

- (3) Fix the idler gear shaft with a snap ring.
- (4) Move the idler gear back and forth, and make sure there is end play.



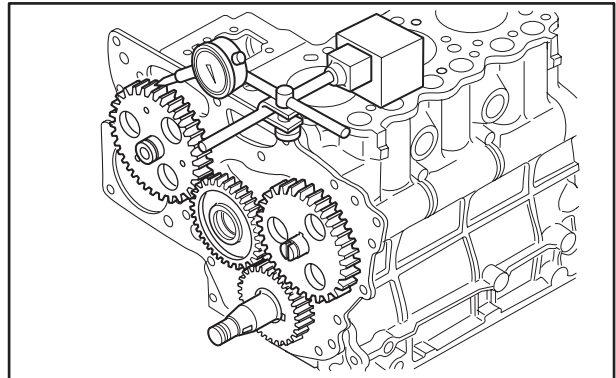
Installing idler gear

**2.6 Inspecting and adjusting timing gear after installation**

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

**2.6.1 Inspecting backlash**

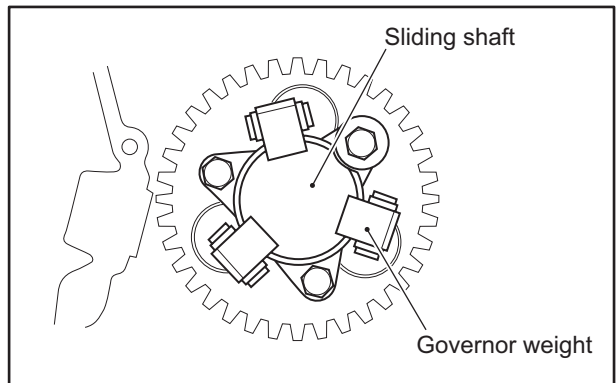
Check backlash between each gear after installing the timing gears.



Measuring timing gear backlash

**2.7 Installing governor weights and sliding shaft**

Install the governor weights and sliding shaft on the fuel injection pump camshaft gear.

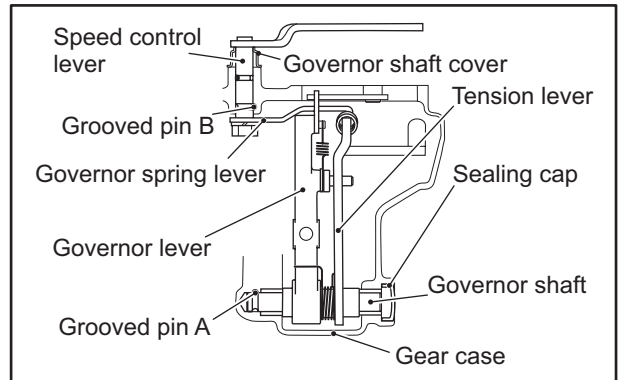


Installing governor weight and sliding shaft

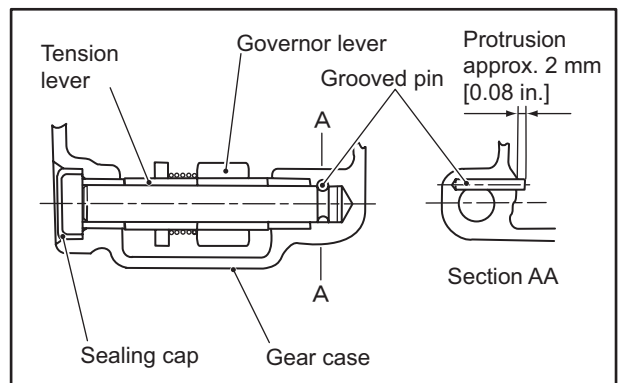
**2.8 Installing speed control lever and governor shaft**

- (1) Insert the governor shaft into the gear case with the governor lever and the tension lever positioned in place.
- (2) Drive the grooved pin into the gear case.
- (3) Drive new sealing cap into the gear case.
- (4) Thoroughly apply Alvania Grease #2 or #3 to the governor shaft cover.
- (5) Install new O-ring on the speed control lever and insert it into the gear case through the governor shaft.
- (6) Drive the grooved pin into the gear case.
- (7) Install the governor spring lever.

Note: Install the governor spring lever to the speed control lever with the minimum assembling angle.



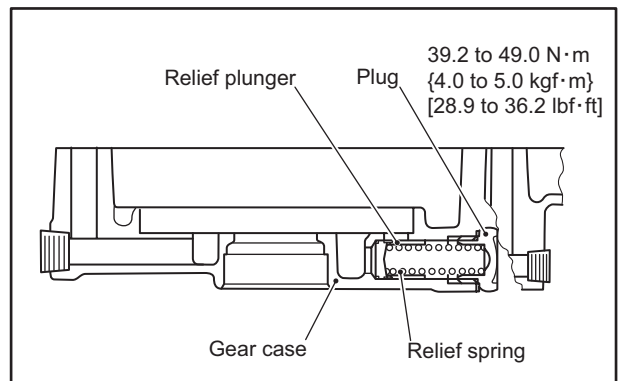
Installing speed control lever and governor shaft



Reassembling speed control lever

**2.9 Installing relief valve**

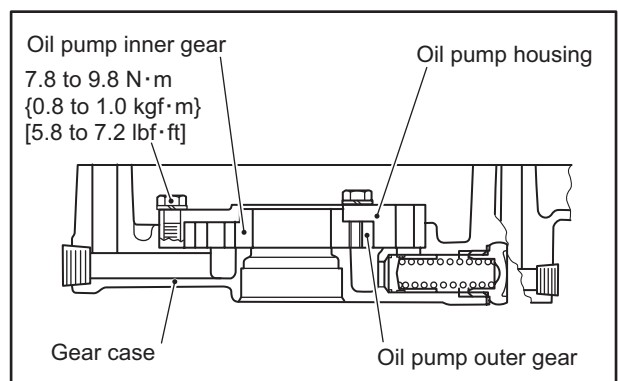
Insert the relief plunger and relief spring into the gear case, and tighten the plug to the specified torque.



Installing relief valve

**2.10 Installing oil pump**

Install the oil pump inner gear, oil pump outer gear and oil pump housing to the gear case, and tighten the bolts to the specified torque.

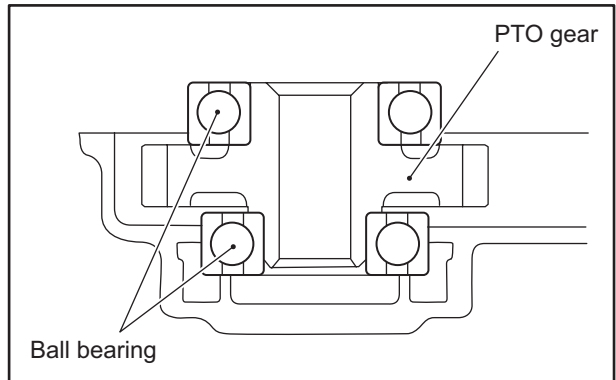


Installing oil pump



### 2.11 Installing PTO gear

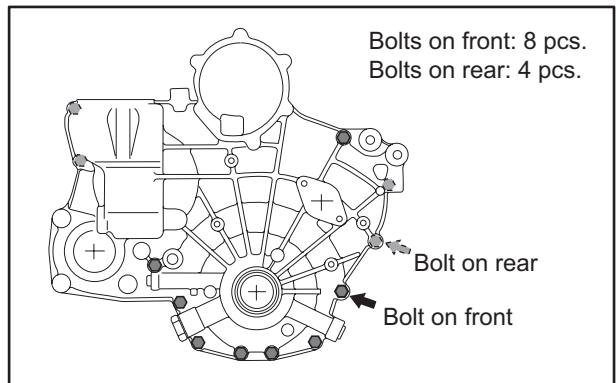
Install ball bearings on both sides of PTO gear, and install the PTO gear into the gear case.



Installing PTO gear

### 2.12 Installing timing gear case

- (1) Apply sealant to the gasket to prevent it from displacing and install the gasket on the front plate.
- (2) Apply engine oil to the oil seal lip.
- (3) Install the timing gear case and tighten the bolts.

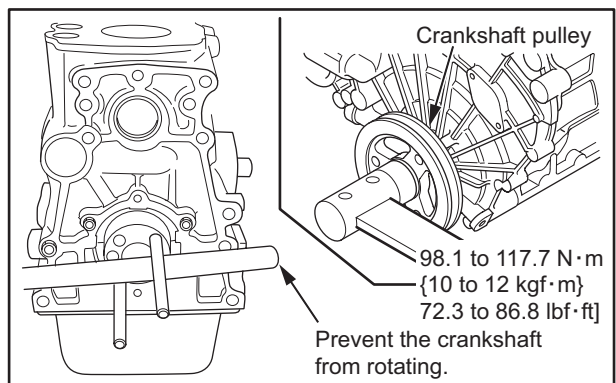


Installing gear case

### 2.13 Installing crankshaft pulley

**CAUTION**  
The bar could come off. Be very careful.

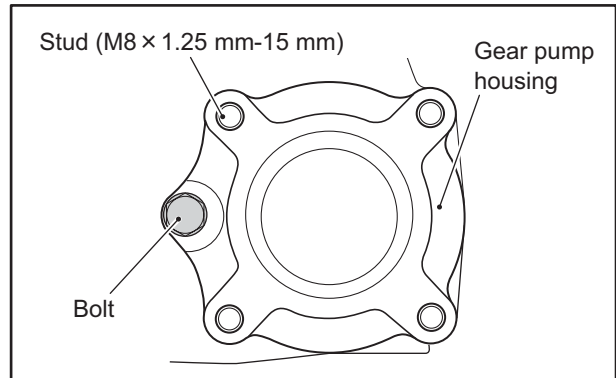
- (1) Screw two guide bolts into the threaded holes at the rear end of the crankshaft. Place a bar across the two guide bolts so that the crankshaft does not turn.
- (2) Install the woodruff key on the crankshaft.
- (3) Install the crankshaft pulley and tighten the nuts to the specified torque.



Installing crankshaft pulley

### 2.14 Installing gear pump housing

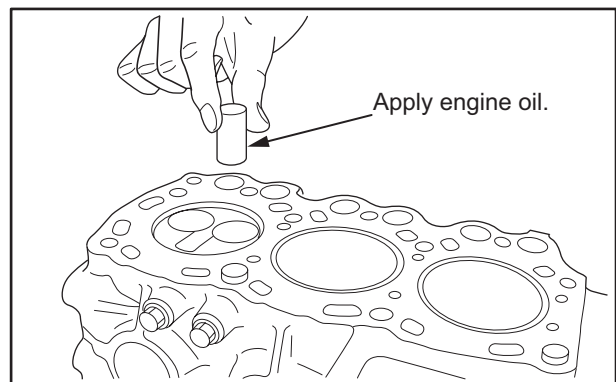
- (1) Install the gear pump housing to the stud bolts on the gear case.
- (2) Tighten the gear pump housing bolt.
- (3) Install the last stud bolt to the gear pump housing.



Installing gear pump housing

### 2.15 Installing tappet

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



Inserting tappet

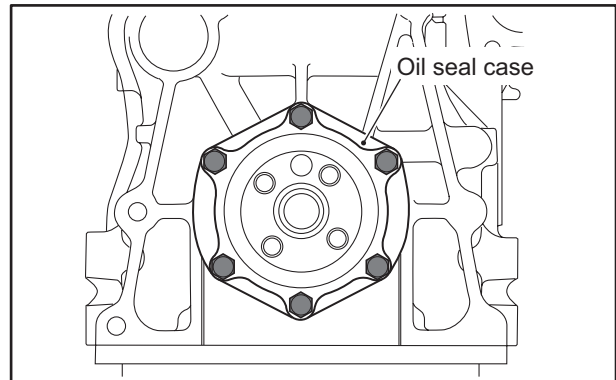
### 3. Reassembling flywheel

#### 3.1 Installing oil seal case

**CAUTION**

Be careful not to damage the oil seal.

- (1) Install the new oil seal gasket.
- (2) After applying engine oil to the entire circumference of the oil seal lips, install the oil seal case on the cylinder block.

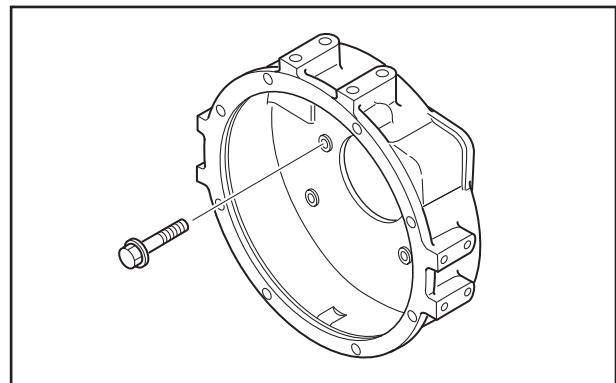


Installing oil seal case

#### 3.2 Installing flywheel housing

- (1) Clean the mounting surface of the gasket.
- (2) Apply sealant to the gasket 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.



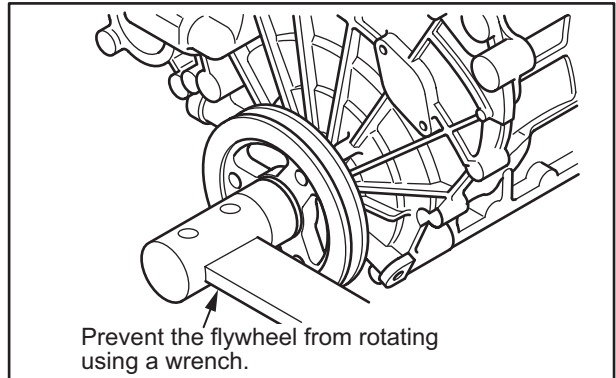
Installing flywheel housing

### 3.3 Installing flywheel

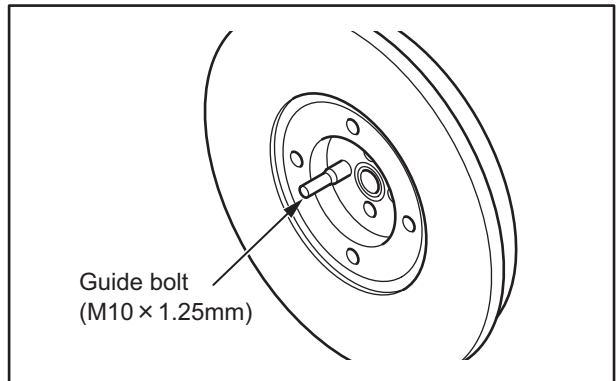
**CAUTION**

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

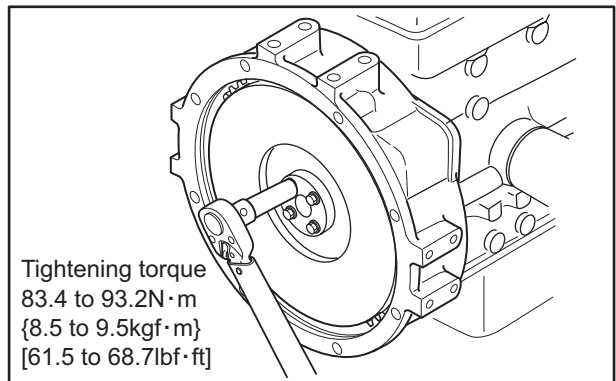
- (1) One person must firmly hold the pulley with a wrench to prevent the crankshaft from turning.
- (2) Screw the guide bolt into the rear end of the crankshaft.
- (3) Align the bolt hole of flywheel with the guide bolt and install the flywheel to the crankshaft.
- (4) Temporarily tighten bolts.
- (5) Remove the guide bolt and temporarily tighten the last bolt.
- (6) Tighten the flywheel bolts to the specified torque.



Detent of flywheel



Installing flywheel



Tightening flywheel bolts

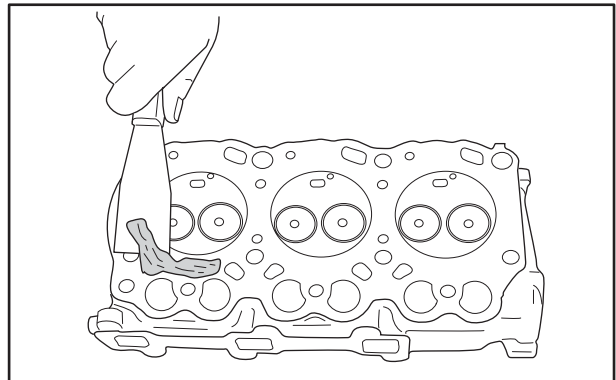
## 4. Reassembling cylinder head and valve mechanism

Reassemble the cylinder head and valve mechanisms in the reverse order of the disassembly procedures.

### 4.1 Cleaning cylinder head bottom surface

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

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



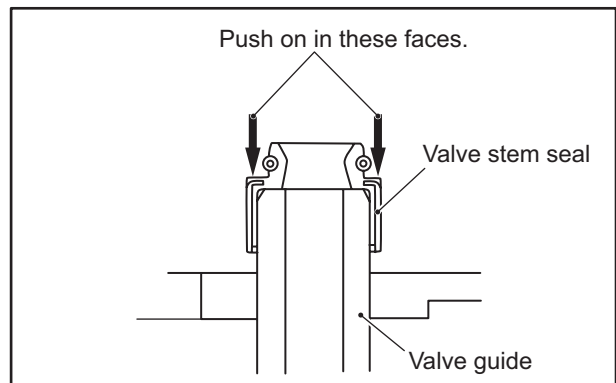
Scraping gasket

### 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.

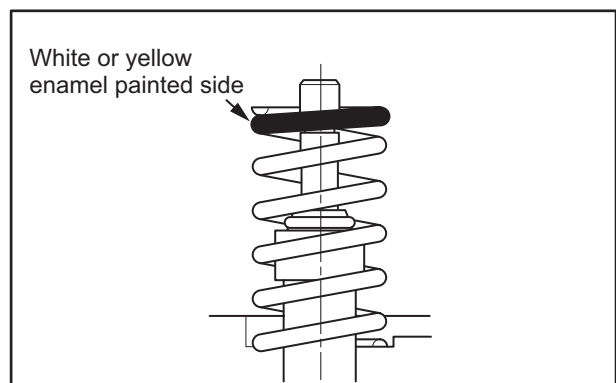
- (1) Apply engine oil to the lip of the valve stem seal.
- (2) Push the shoulder of the valve stem seal and fit the valve stem seal into the valve guide.
- (3) Make sure the valve stem seal is fully inserted into the valve guide.



Installing valve stem seal

### 4.3 Installing valve spring

Install the valve spring with its white or yellow enamel painted side facing upward.



Installing valve spring

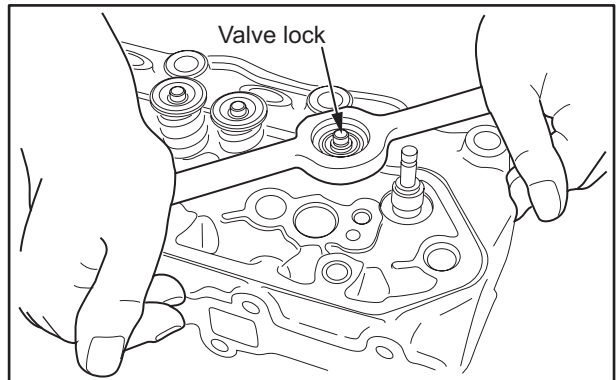
#### 4.4 Installing valve lock

**CAUTION**

If valve spring is overcompressed, the lower end of the retainer comes into contact with the stem seal, and causes damage to the stem seal.

Install the retainer on the valve spring.

Compress the valve spring using a valve lifter, and install the valve locks.



Installing valve lock

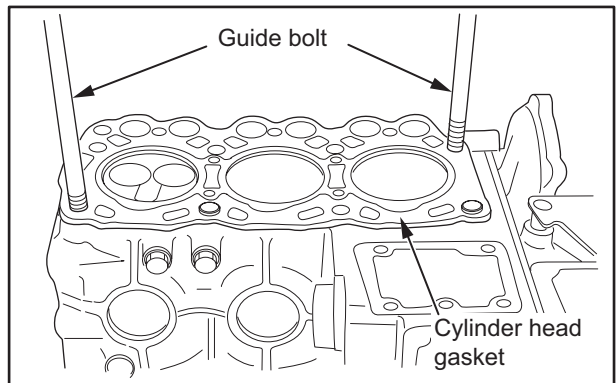
#### 4.5 Installing cylinder head gasket

**CAUTION**

Do not use liquid gasket.

- (1) Make sure that there is no dirt or dents on the top surfaces of the cylinder block and pistons.
- (2) Screw in two guide bolts in the bolt holes of the cylinder block.
- (3) Place the new cylinder head gasket on the cylinder block aligning to the guide bolts.

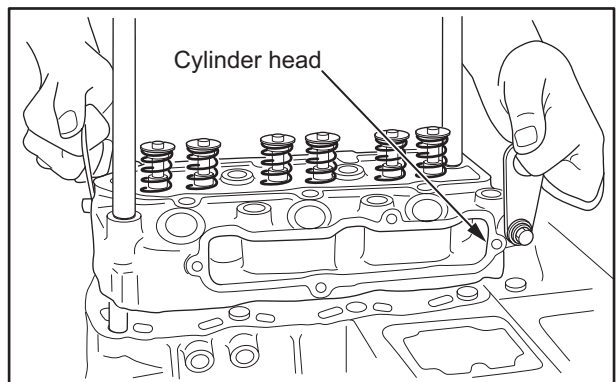
Note: The model name is stamped on the front top face of the gasket so that it is not confused with one for other model.



Installing cylinder head gasket

#### 4.6 Installing cylinder head assembly

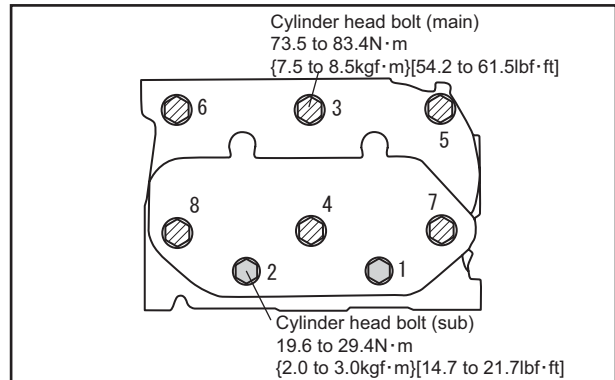
Align the cylinder head to the locating guide bolts, and install the cylinder head.



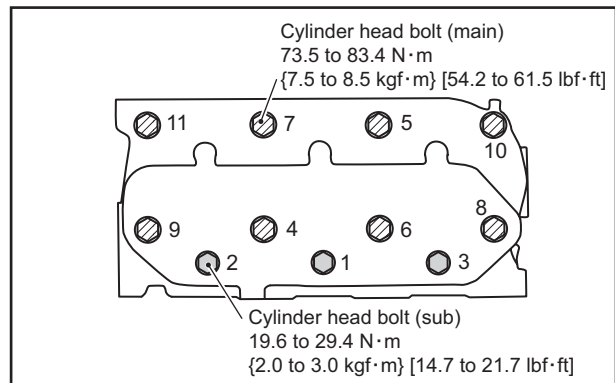
Installing cylinder head assembly

#### 4.7 Tightening cylinder head bolts

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



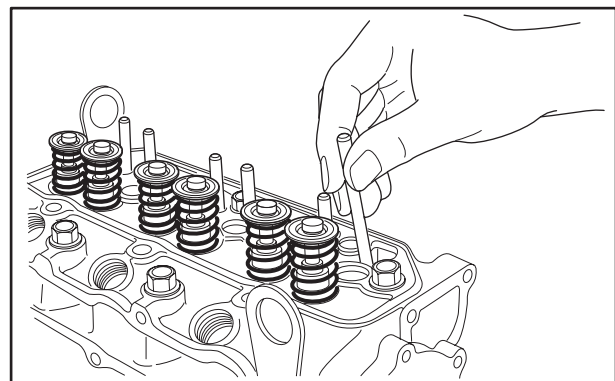
Tightening order of cylinder head bolts (L2)



Tightening order of cylinder head bolts (L3)

#### 4.8 Inserting push rod

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



Inserting push rods

#### 4.9 Reassembling rocker shaft assembly

Install the rocker shaft assembly in the reverse order of the disassembly sequence, observing the followings:

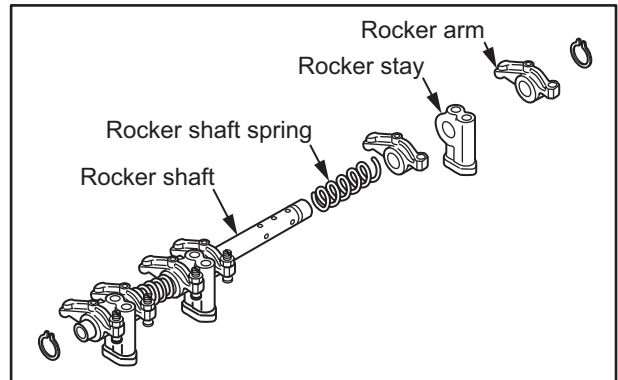
- (1) Apply engine oil to the rocker shaft.
- (2) Install the rocker shaft assembly in the same position as it was.

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

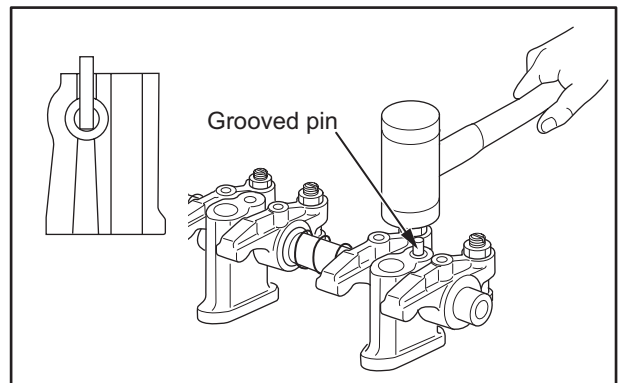
- (3) Align oil holes of the rocker shaft with those of the rocker stay, and drive a grooved pin into the front rocker stay.

Note: Drive in the grooved pin until it comes into contact with the inside of the rocker shaft.

- (4) After reassembling, make sure the rocker arms move freely.



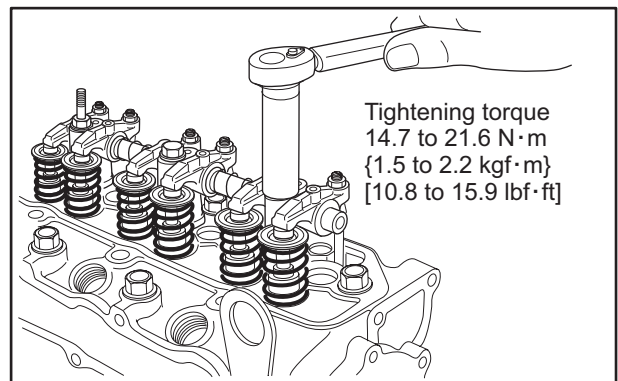
Reassembling rocker shaft assembly



Driving in grooved pin

#### 4.10 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.



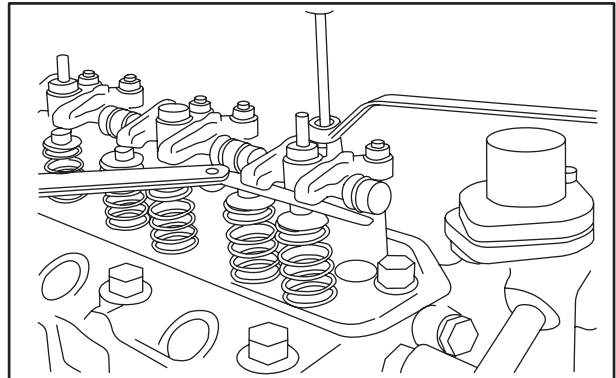
Installing rocker shaft assembly



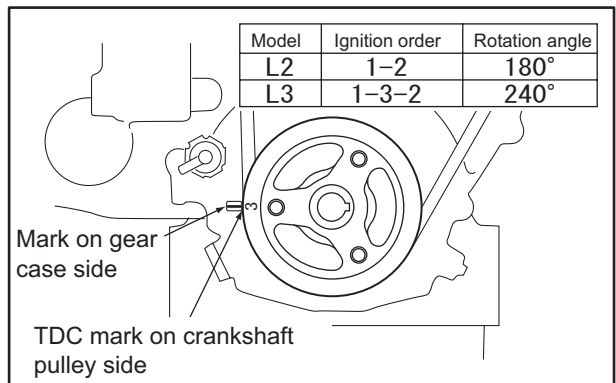
#### 4.11 Adjusting valve clearance

Adjust the valve clearance.

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



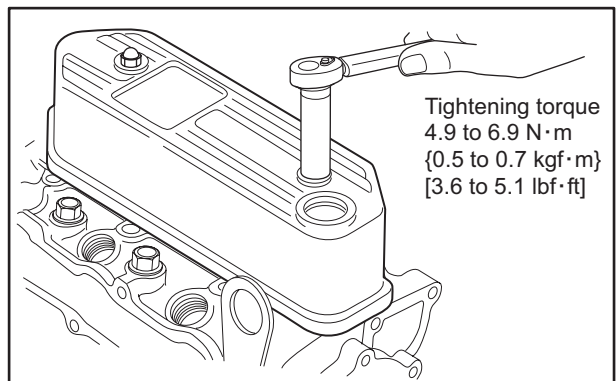
Adjusting valve clearance



Timing mark

#### 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

#### 4.13 Installing torque spring set

For installing procedures of the torque spring set, refer to item "Installing Fuel System."



# FUEL SYSTEM

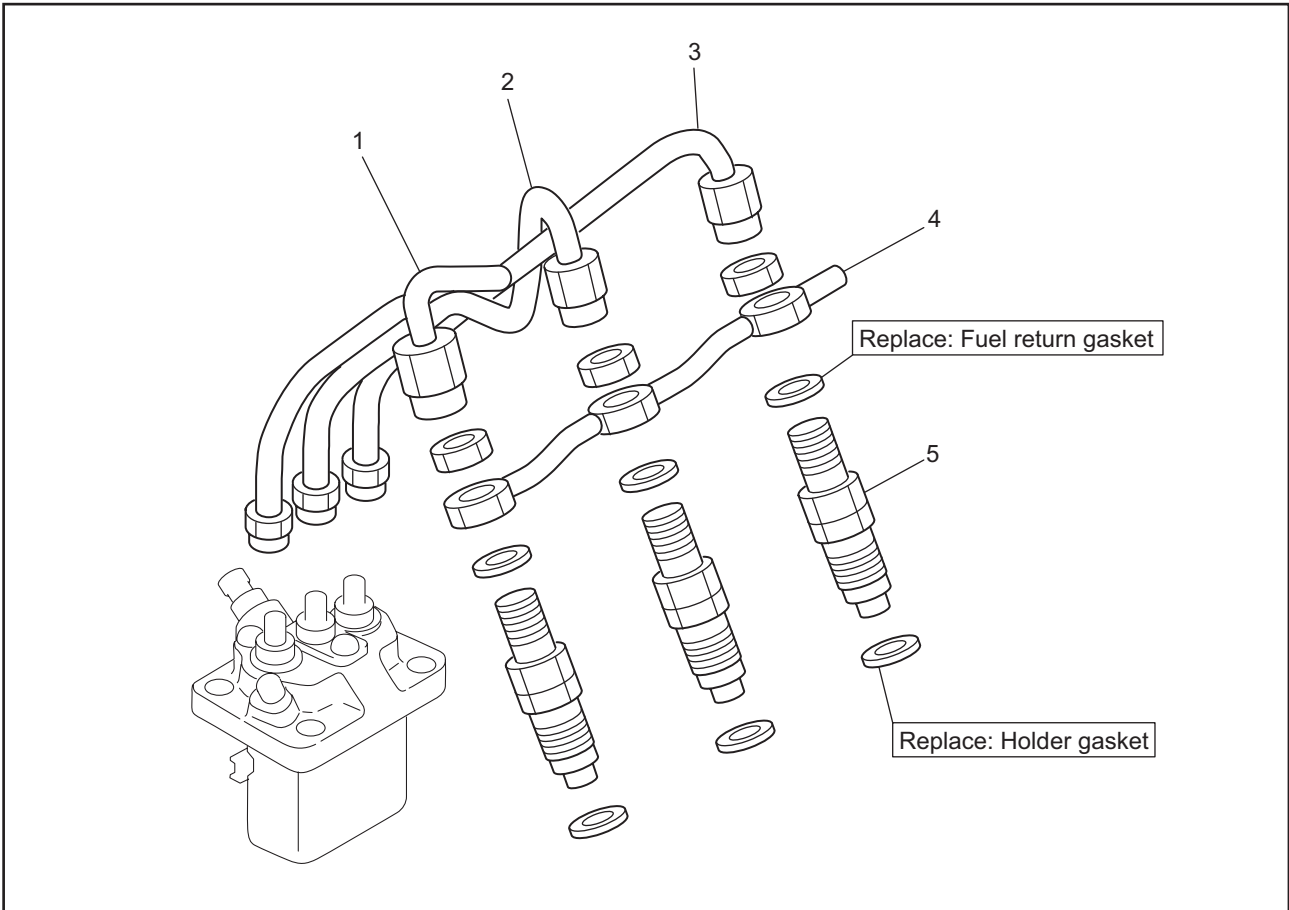
1. Removing fuel system.....	8-2	2.9.2 Reassembling torque spring set, double spring type .....	8-22
1.1 Removing fuel pipe and fuel injection nozzle.....	8-2	2.10 Inspecting fuel pump .....	8-23
1.1.1 Removing fuel injection pipe .....	8-3	2.11 Disassembling, inspecting and reassembling fuel filter (cock switch type, push botton).....	8-24
1.1.2 Removing fuel injection nozzle.....	8-3	2.12 Disassembling, inspecting and reassembling fuel filter (cock switch type, changover).....	8-25
1.2 Removing fuel filter .....	8-4		
1.3 Removing governor.....	8-5		
1.3.1 Disconnecting tie rod from control rack.....	8-6		
1.3.2 Removing governor shaft and speed control lever .....	8-6		
1.4 Removing fuel injection pump.....	8-7		
		3. Installing fuel system .....	8-26
2. Disassembling, inspecting and reassembling fuel system.....	8-8	3.1 Installing fuel injection pump .....	8-26
2.1 Disassembling and inspecting fuel injection nozzles.....	8-8	3.2 Installing governor.....	8-27
2.1.1 Inspecting and adjusting fuel injection valve opening pressure .....	8-9	3.2.1 Installing speed control lever and governor shaft.....	8-28
2.1.2 Inspecting fuel spray pattern of fuel injection nozzle.....	8-10	3.2.2 Connecting tie rod .....	8-28
2.1.3 Cleaning and replacing faulty nozzle .....	8-10	3.2.3 Installing torque spring set (Single spring, double spring).....	8-29
2.2 Reassembling fuel injection nozzles.....	8-11	3.2.4 Installing torque set spring (Double spring, two point control).....	8-29
2.3 Inspecting fuel injection pump on engine	8-12	3.2.5 Installing rack set screw .....	8-30
2.4 Disassembling and inspecting fuel injection pump .....	8-12	3.3 Installing fuel filter .....	8-31
2.4.1 Removing swivel nipple.....	8-13	3.4 Installing fuel pipe and fuel injection nozzles.....	8-32
2.4.2 Removing tappets .....	8-13	3.4.1 Installing fuel injection nozzle.....	8-32
2.4.3 Removing plunger .....	8-13	3.4.2 Installing fuel return pipe and fuel injection pipe.....	8-32
2.4.4 Removing delivery valve .....	8-14		
2.5 Reassembling fuel injection pump .....	8-15		
2.5.1 Installing plunger barrel.....	8-15		
2.5.2 Assembling delivery valve .....	8-16		
2.5.3 Assembling control sleeve .....	8-16		
2.5.4 Assembling plunger.....	8-16		
2.5.5 Installing tappet.....	8-17		
2.5.6 Installing control rack .....	8-17		
2.5.7 Tightening delivery valve holder.....	8-18		
2.5.8 Inspecting control rack for smooth operation .....	8-18		
2.5.9 Installing lock plate.....	8-18		
2.5.10 Installing swivel nipple.....	8-18		
2.6 Disassembling and inspecting governor cover .....	8-19		
2.7 Reassembling governor cover .....	8-19		
2.8 Disassembling and inspecting torque spring set .....	8-20		
2.9 Reassembling torque spring set .....	8-20		
2.9.1 Torque spring set, single spring type .....	8-21		

## 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 pipe and fuel injection nozzle



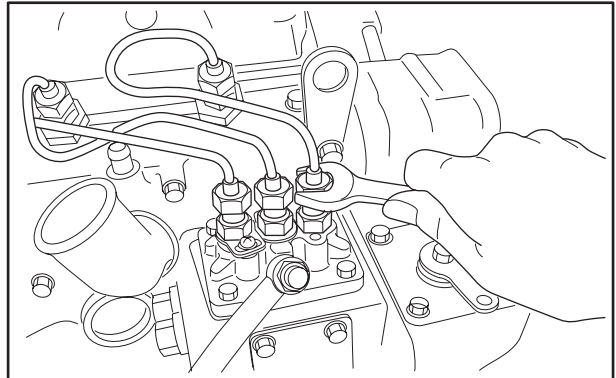
Removing fuel pipe and fuel injection nozzle

#### Removing sequence

- |                             |                         |
|-----------------------------|-------------------------|
| 1 No. 1 fuel injection pipe | 4 Fuel return pipe      |
| 2 No. 2 fuel injection pipe | 5 Fuel injection nozzle |
| 3 No. 3 fuel injection pipe |                         |

### 1.1.1 Removing fuel injection pipe

Remove the fuel injection pipe and fuel return pipe.

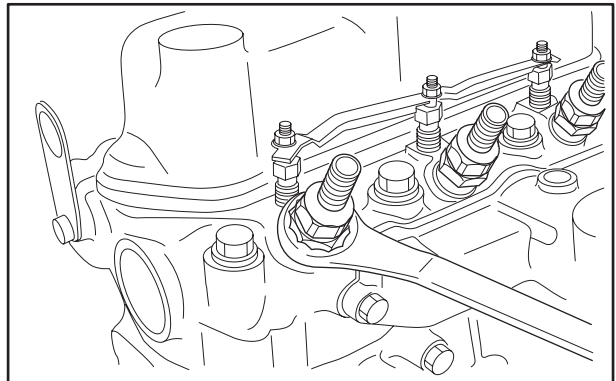


Removing fuel injection pipe

### 1.1.2 Removing fuel injection nozzle

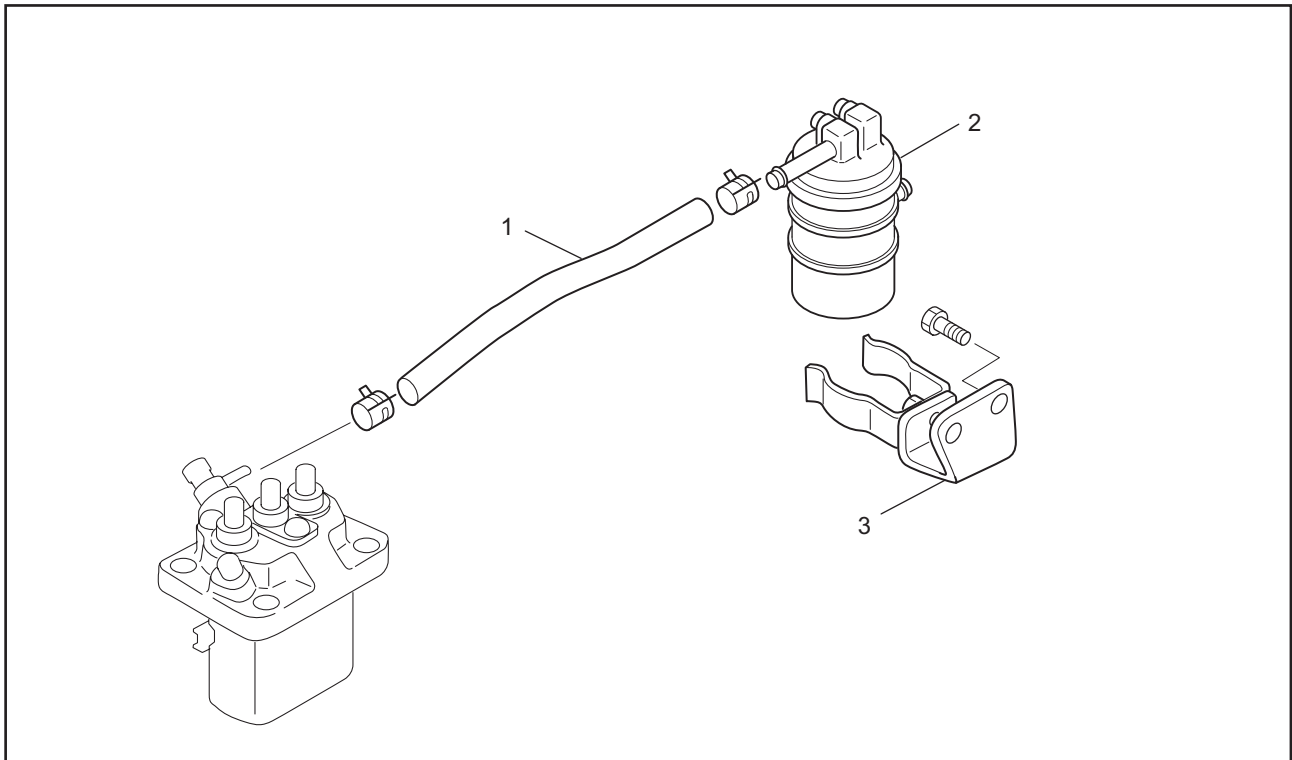
Using a wrench, loosen the nozzle, and remove the fuel injection nozzle and holder gasket.

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



Removing fuel injection nozzle

### 1.2 Removing fuel filter



Removing fuel filter

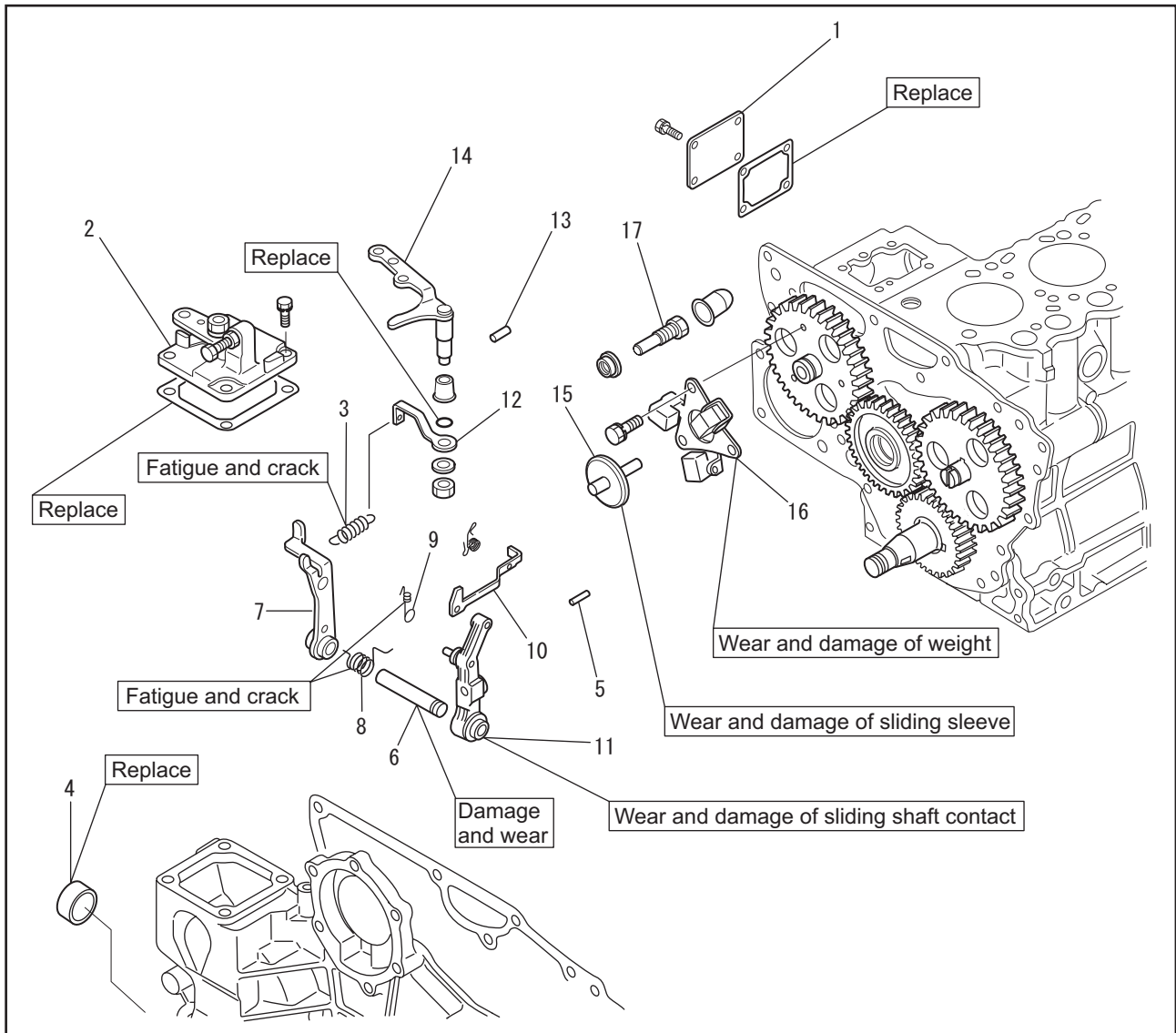
Removing sequence

1 Fuel hose

2 Fuel filter

3 Fuel filter support

1.3 Removing governor



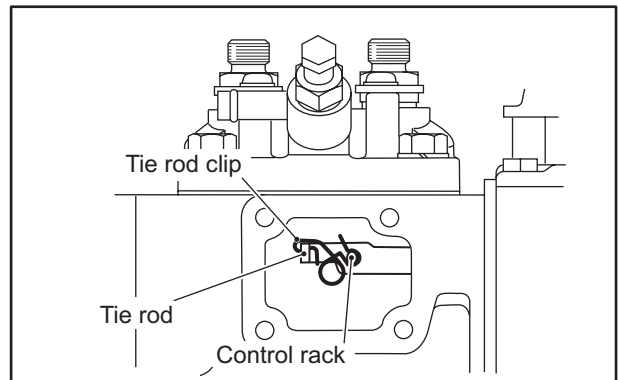
Removing governor

Removing sequence

- |                   |                   |                                       |
|-------------------|-------------------|---------------------------------------|
| 1 Tie rod cover   | 7 Tension lever   | 13 Governor lever                     |
| 2 Governor lever  | 8 Start spring    | 14 Grooved pin                        |
| 3 Governor spring | 9 Tie rod spring  | 15 Speed control lever                |
| 4 Sealing cap     | 10 Tie rod        | 16 Sliding shaft                      |
| 5 Grooved pin     | 11 Tie rod crip   | 17 Governor weight                    |
| 6 Governor shaft  | 12 Governor lever | 18 Torque spring set (rack set screw) |

**1.3.1 Disconnecting tie rod from control rack**

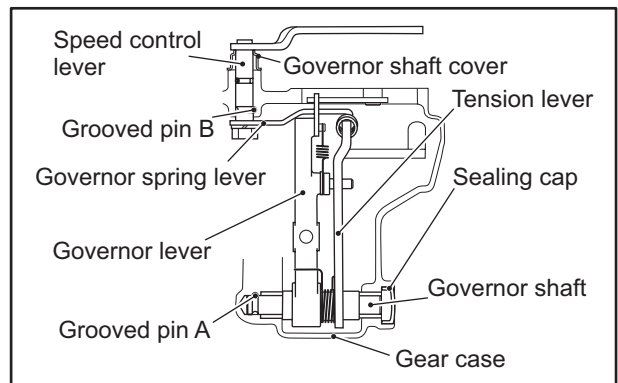
- (1) Remove the tie rod cover.
- (2) Remove the tie rod clip and disconnect the tie rod from the control rack.



Disconnecting tie rod from control rack

**1.3.2 Removing governor shaft and speed control lever**

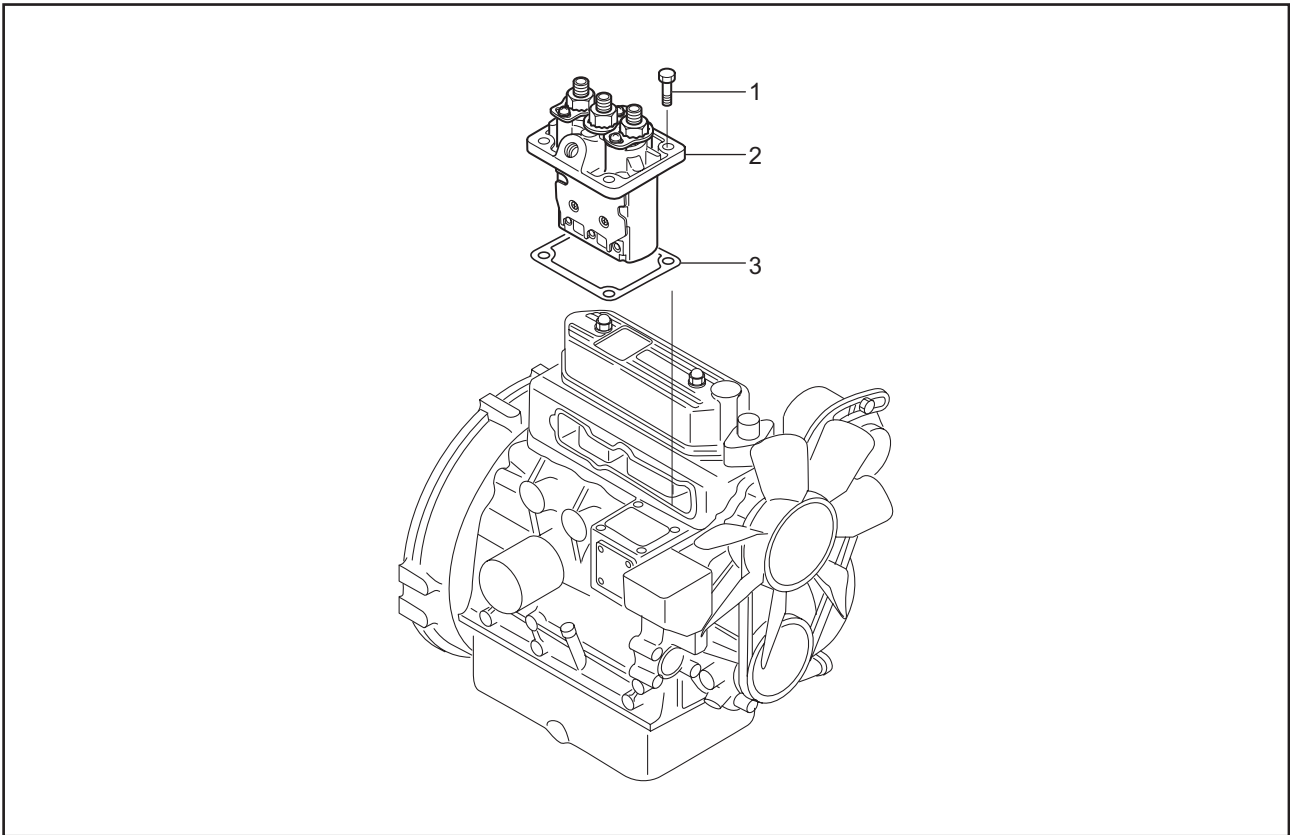
- (1) Remove the sealing cap from the side of the gear case.
- (2) Pull out the grooved pin A.
- (3) Remove the governor shaft, and remove tension lever and governor lever.
- (4) Remove the governor spring lever.
- (5) Remove the grooved pin B and remove speed control lever.
- (6) Remove the governor cover.



Removing governor shaft and speed control lever



### 1.4 Removing fuel injection pump



Removing fuel injection pump

**CAUTION**

Check thickness of the fuel injection timing adjusting shim.

Removing sequence

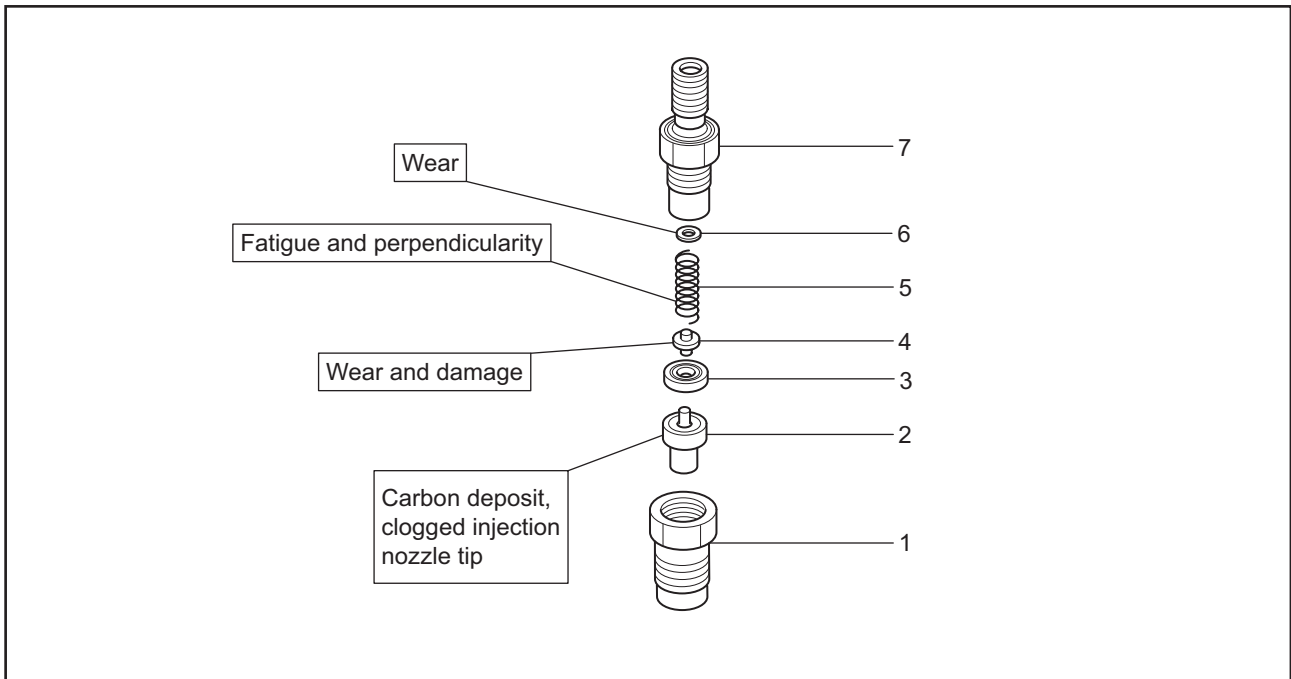
1 Bolt

2 Fuel injection pump

3 Shim

## 2. Disassembling, inspecting and reassembling fuel system

### 2.1 Disassembling and inspecting fuel injection nozzles



Disassembling and inspecting fuel injection nozzles

#### Disassembling sequence

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

**2.1.1 Inspecting and adjusting fuel injection valve opening pressure**

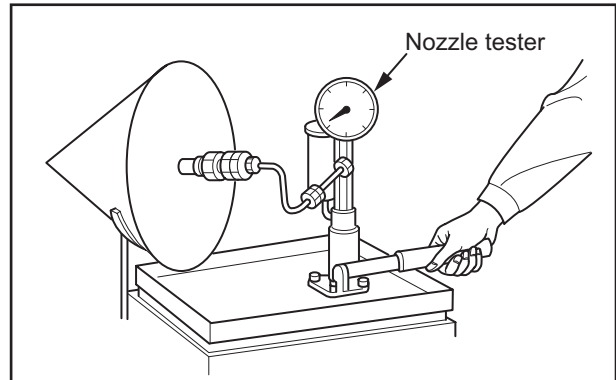
**CAUTION**

Never touch the injection nozzle tip during nozzle injection test.

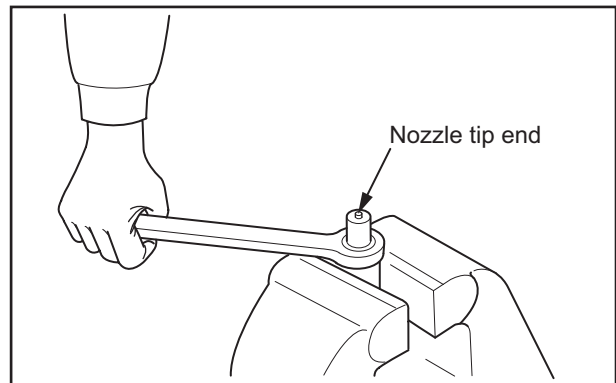
- (1) Mount the nozzle on the nozzle tester.
- (2) Push down the handle at a speed of once a second and read the pressure when injection starts. Make adjustment if it is outside the standard.
- (3) To adjust the injection start pressure, remove the set screw on the nozzle holder, loosen the cap nut and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

Item	Standard
Valve opening pressure	13.73 to 14.73 MPa { 140 to 150 kgf/cm <sup>2</sup> } [1992 to 2134 psi]

Note: Change in washer thickness by 0.1 mm [0.004 in.] results in a pressure change of 1.0 MPa {10 kgf/cm<sup>2</sup>} [142 psi]. Washers are available in 10 different thicknesses at intervals of 0.05 mm [0.0020 in.] in the range between 1.25 and 1.70 mm [0.0492 and 0.0669 in.].



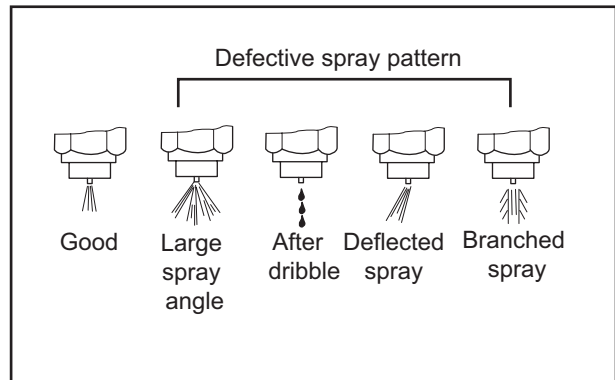
Checking valve opening pressure



Replacing fuel injection nozzle tips

**2.1.2 Inspecting fuel spray pattern of fuel injection nozzle**

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



Checking fuel spray pattern from fuel injection nozzle

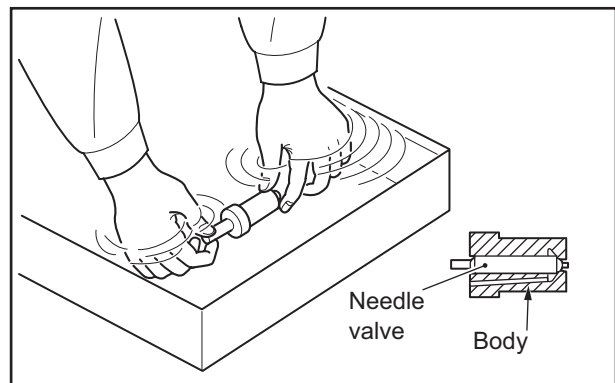
**2.1.3 Cleaning and replacing faulty nozzle**

**CAUTION**

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

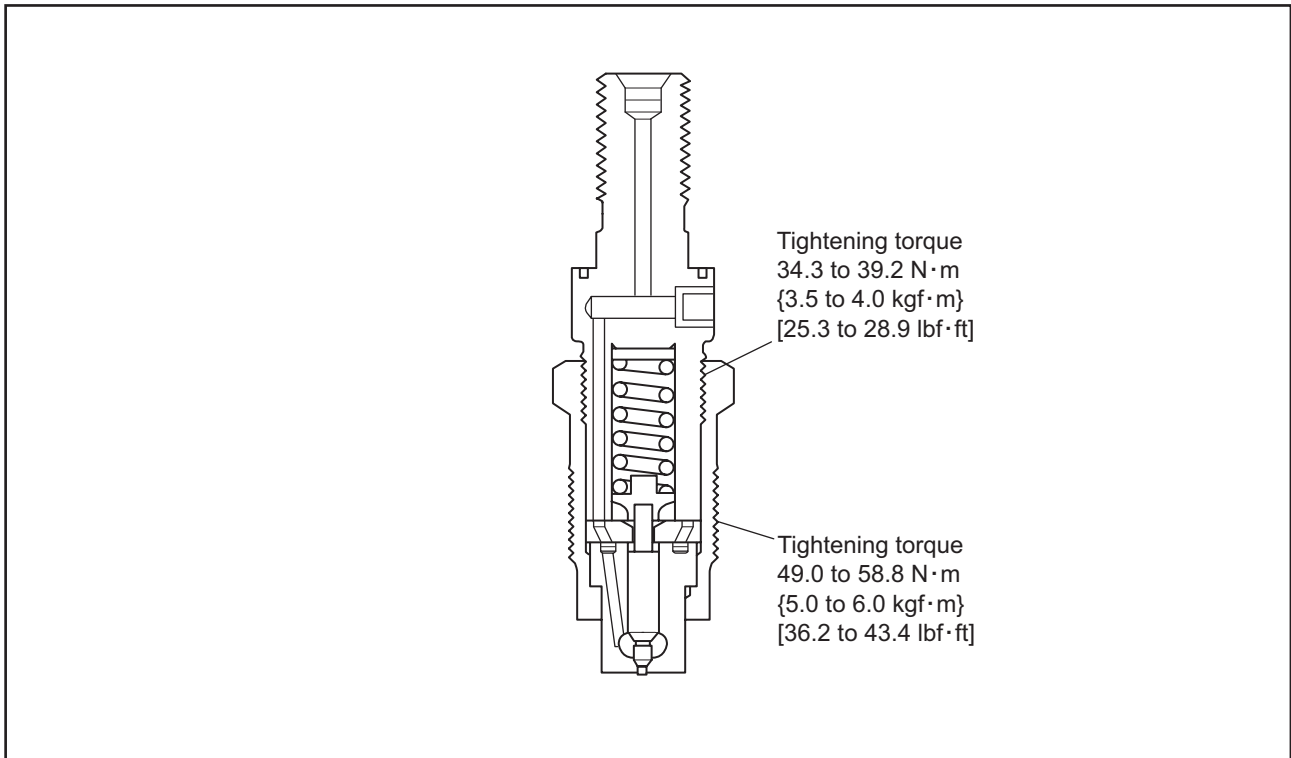
- (1) Loosen the retaining nut, then remove the nozzle tip, and clean the needle valve and body.
  - (2) Clean the nozzle tip in clean wash oil. After cleaning, assemble the needle valve and body in clean diesel fuel.
- Note: The needle valve and body are precision parts. Handle them carefully, and do not change the combination of the valve and body.
- (3) Tighten the nozzle tip retaining nut to the specified torque.
  - (4) If the spray pattern is still faulty after cleaning and adjusting, replace the nozzle tip.

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



Cleaning nozzle tip assembly

## 2.2 Reassembling fuel injection nozzles



Reassembling fuel injection nozzles

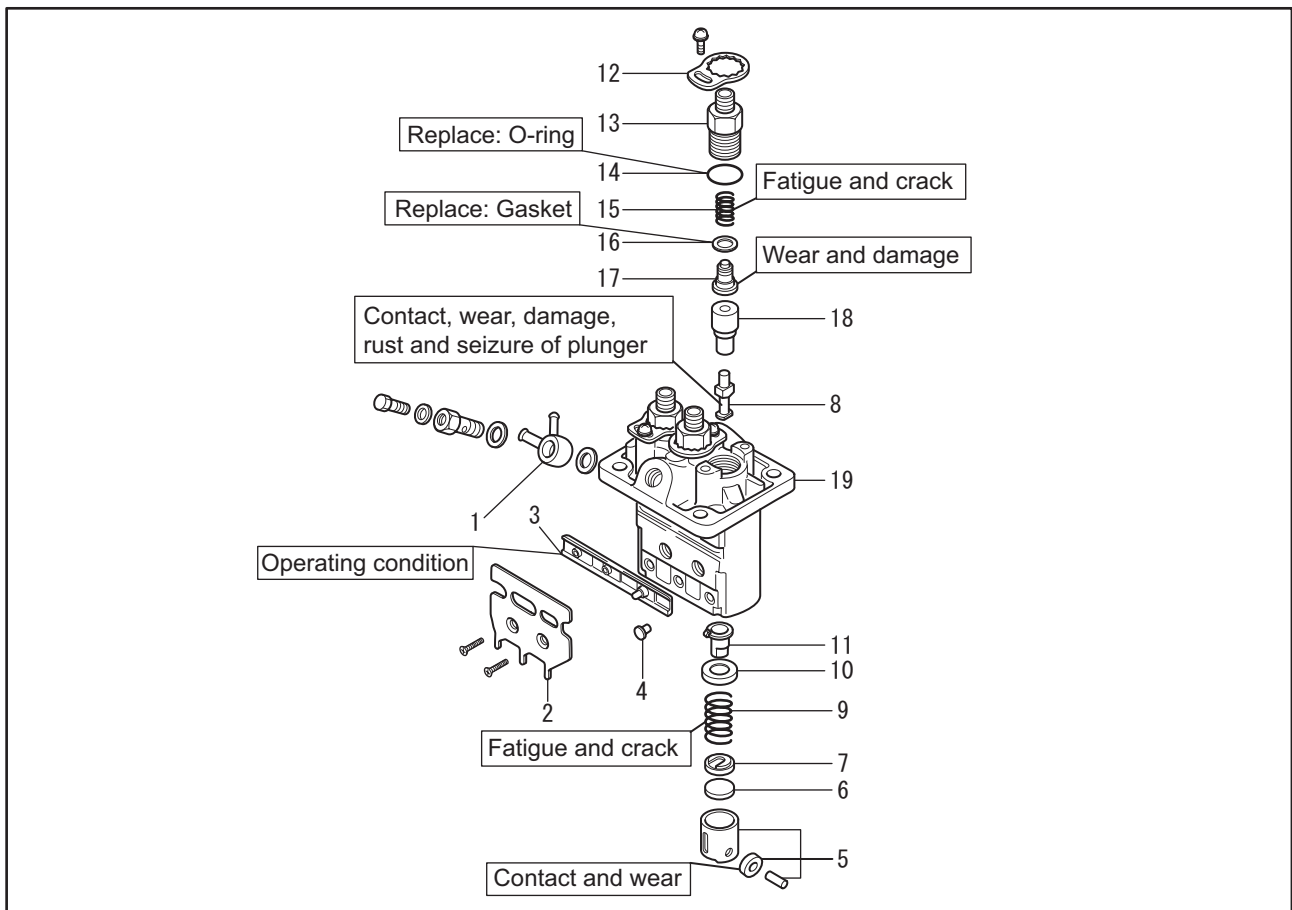
**2.3 Inspecting fuel injection pump on engine**

Do not disassemble the fuel injection pump unless it is absolutely necessary.

If faulty, it is desirable to replace it as an assembly.

Inspection item	Inspection procedure	Judgment
Low idling	Judgment by rotation speed	(Varies depending on specification)
Exhaust color	Observe exhaust color during sudden acceleration under no load. Observe exhaust color under load.	No remarkable black smoke is emitted.
Nozzle injection condition	Remove the nozzle and reassemble them so that spray holes face outward. Rotate the starter to carefully observe the spray pattern.	The spray pattern must be good.

**2.4 Disassembling and inspecting fuel injection pump**



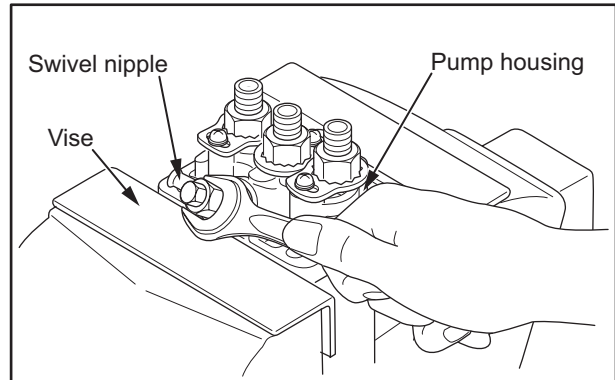
Disassembling and inspecting fuel injection pump

Disassembling sequence

- |                     |                          |                          |
|---------------------|--------------------------|--------------------------|
| 1 Swivel nipple     | 8 Plunger                | 15 Delivery valve spring |
| 2 Stop wire bracket | 9 Plunger spring         | 16 Delivery valve gasket |
| 3 Control rack      | 10 Spring upper seat     | 17 Delivery valve        |
| 4 Tappet guide pin  | 11 Control sleeve        | 18 Plunger barrel        |
| 5 Tappet            | 12 Lock plates           | 19 Pump housing          |
| 6 Tappet shim plate | 13 Delivery valve holder |                          |
| 7 Spring lower seat | 14 O-rings               |                          |

**2.4.1 Removing swivel nipple**

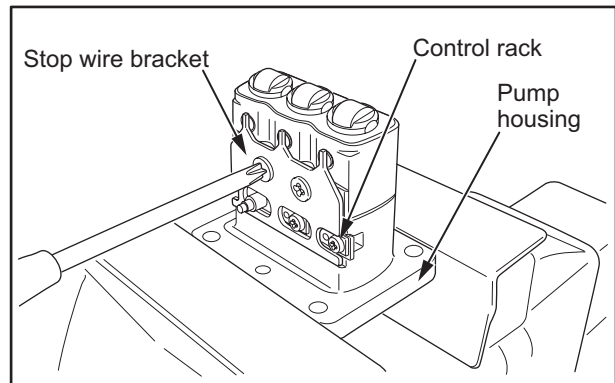
- (1) Grab the plunger of the pump housing with a vise.
- (2) Remove the swivel nipple from the pump housing.



Removing swivel nipple

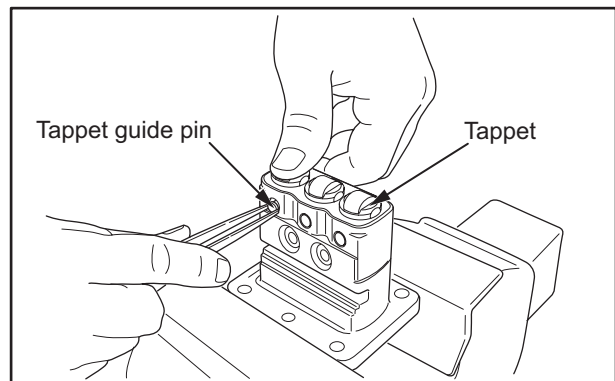
**2.4.2 Removing tappets**

- (1) Turn the pump housing upside down and grab the housing with a vise.
- (2) Remove the stop wire bracket and remove the control rack.



Removing stop wire bracket

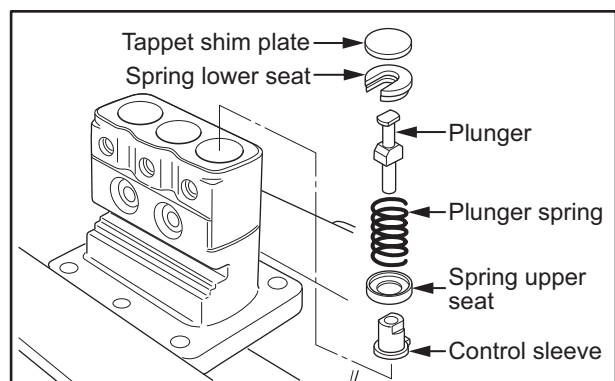
- (3) Push in the tappet and, pull out the tappet guide pin with tweezers.
- (4) Remove the tappet.



Removing tappet guide pin

**2.4.3 Removing plunger**

Using tweezers, remove the tappet shim plate, spring lower seat, plunger, plunger spring, spring upper seat and control sleeve from the pump housing.



Removing plunger

2.4.4 Removing delivery valve

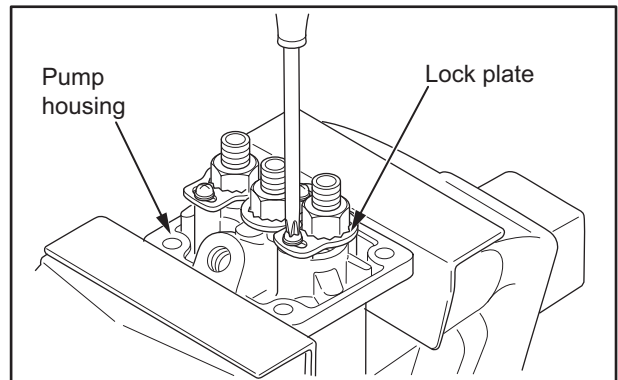
**CAUTION**

- (a) The delivery valve, plunger and plunger barrel are precision-machined parts. Do not smear or scratch them.
- (b) Keep the combination of the plunger barrel and plunger for each cylinder when removing. Do not mix the plunger barrel with the plunger of a different cylinder.

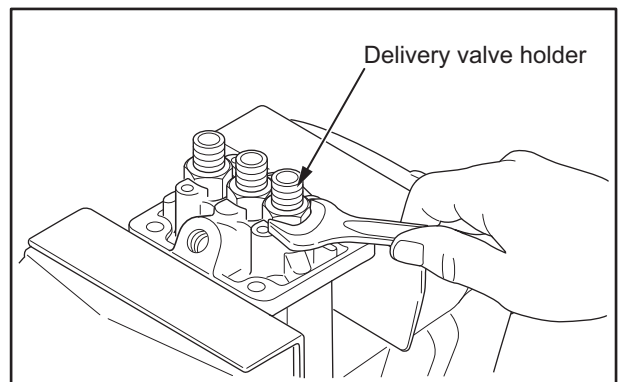
- (1) With pump housing faced up, grab the housing with a vise.
- (2) Remove outside lock plates first and remove center lock plate at the last.
- (3) Remove the delivery valve holder.

- (4) Remove the delivery valve spring.

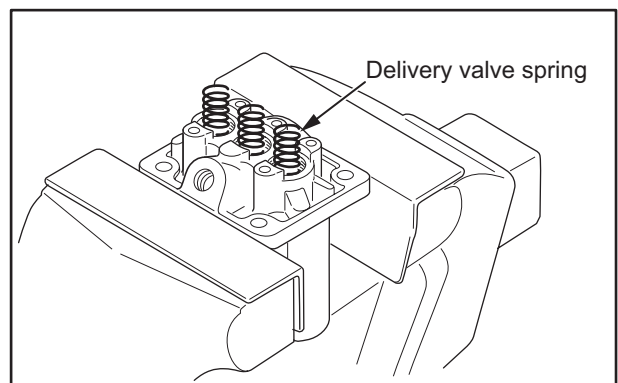
- (5) Using tweezers, remove the delivery valve gasket, delivery valve and plunger barrel from the pump housing.



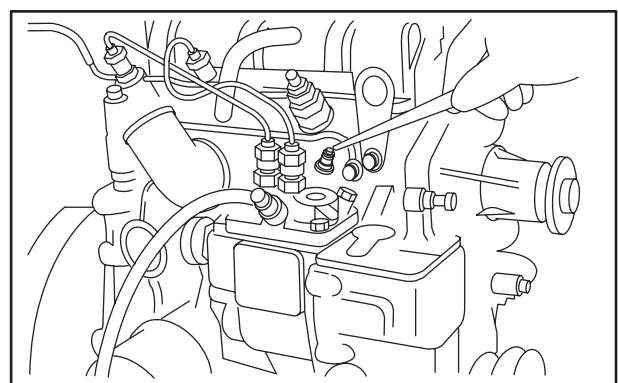
Removing lock plate



Removing delivery valve holder



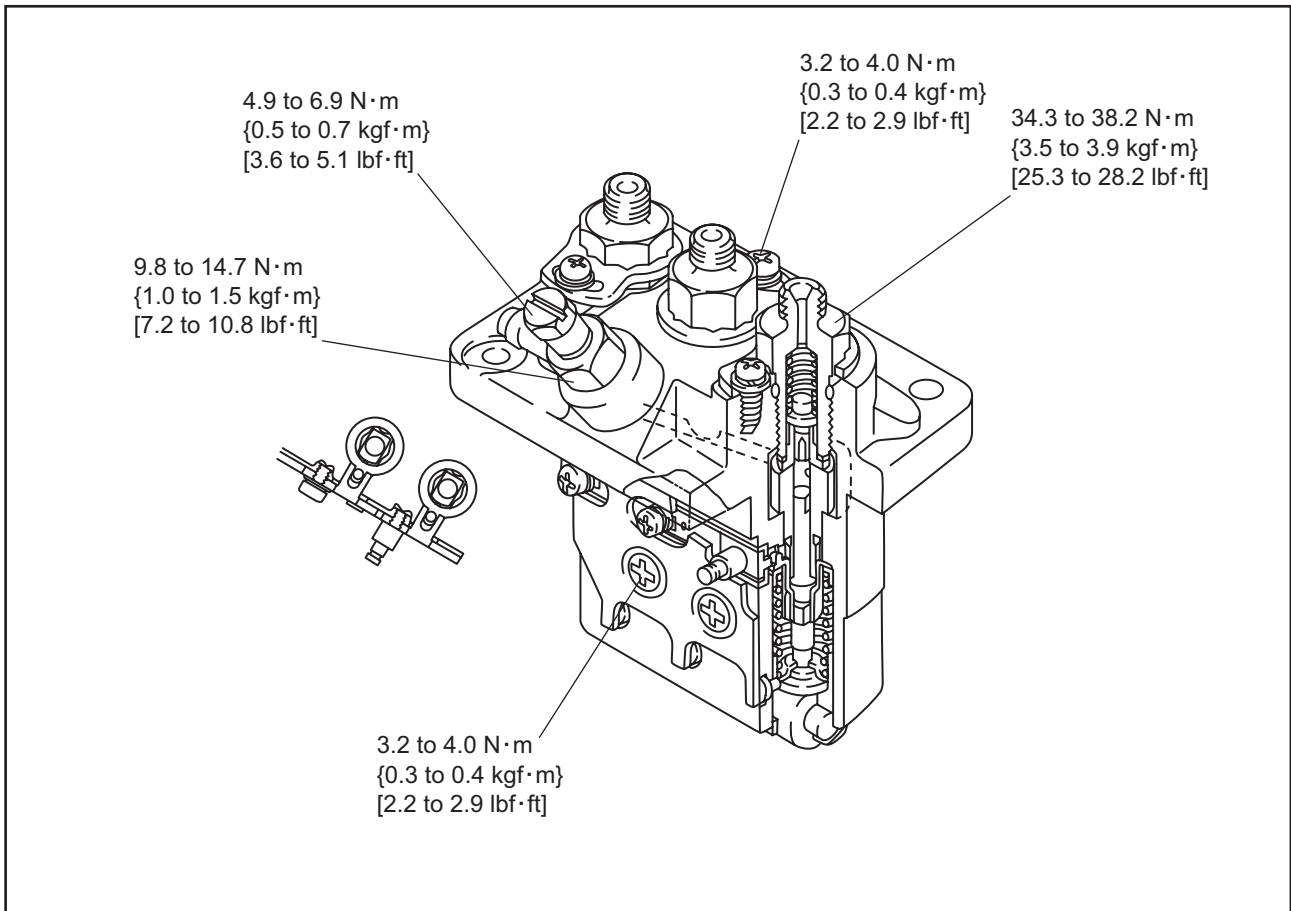
Removing delivery valve spring



Removing delivery valve



## 2.5 Reassembling fuel injection pump

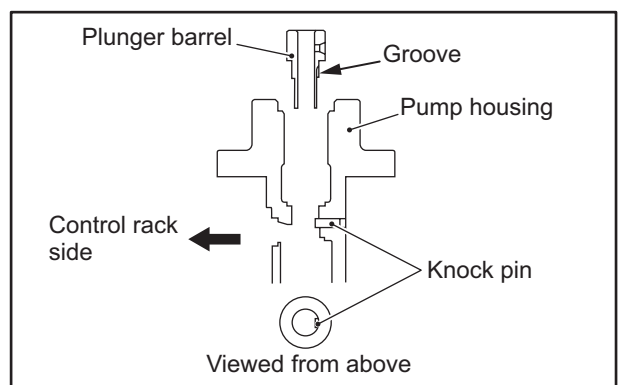


Reassembling fuel injection pump

### 2.5.1 Installing plunger barrel

Align the plunger barrel groove with the knock pin of the pump housing, and insert the plunger barrel into the pump housing.

Note: If the knock pin is not aligned with the plunger barrel groove, the plunger barrel will not be installed correctly. Make sure that O-ring is not protruded from the pump housing when the delivery valve holder is snugly tightened.



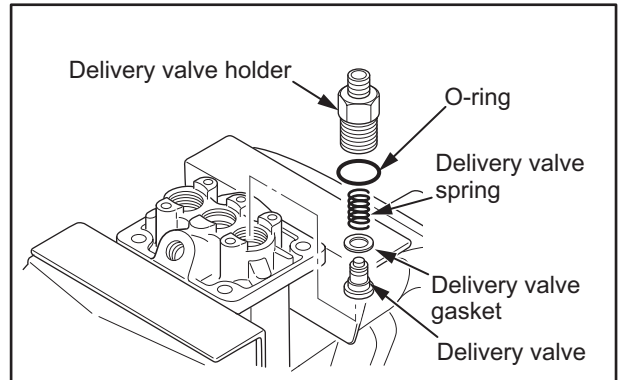
Inserting plunger barrel

**2.5.2 Assembling delivery valve**

**CAUTION**

- (a) Do not reuse the O-ring.
- (b) Install a new O-ring so that it is not cut with threads of the valve holder.

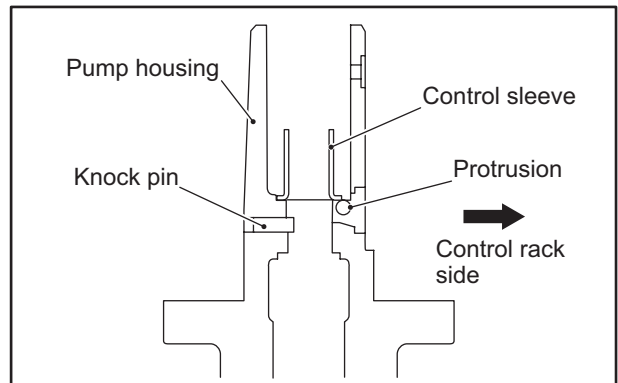
Assemble the delivery valve, delivery valve gasket and delivery valve spring. Then with the O-ring installed, temporarily tighten the delivery valve holder.



Assembling delivery valve

**2.5.3 Assembling control sleeve**

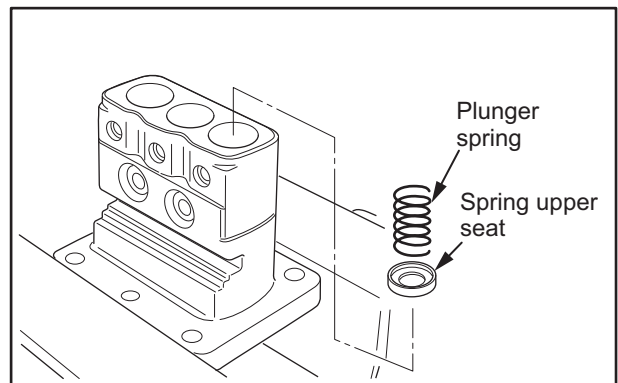
- (1) Reverse the pump housing and grab the housing with a vise.
- (2) Install the sleeve with the protrusion of the control sleeve the control rack side (opposite side to the knock pin). The protrusion can be seen through the housing hole.



Assembling control sleeve

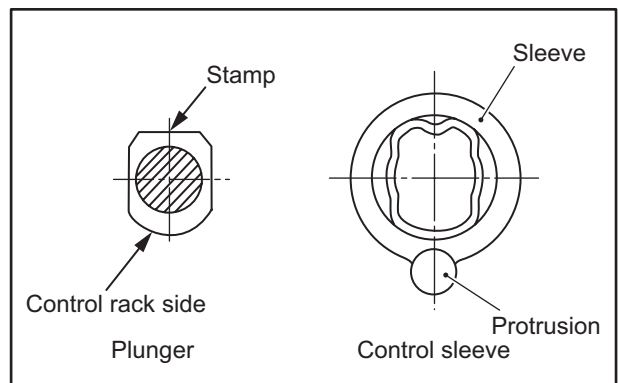
**2.5.4 Assembling plunger**

- (1) Assemble the spring upper seat and plunger spring.



Assembling plunger spring

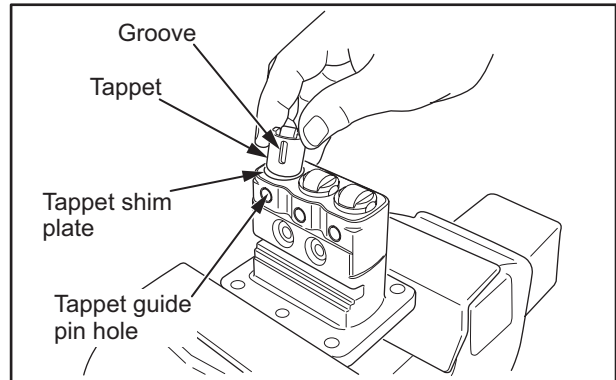
- (2) Place the stamped side of the collar of the plunger to the opposite side to the protrusion of the control sleeve (opposite side to the control rack side). Assemble the spring lower seat to the plunger and insert the plunger into the control sleeve.



Assembling direction of plunger

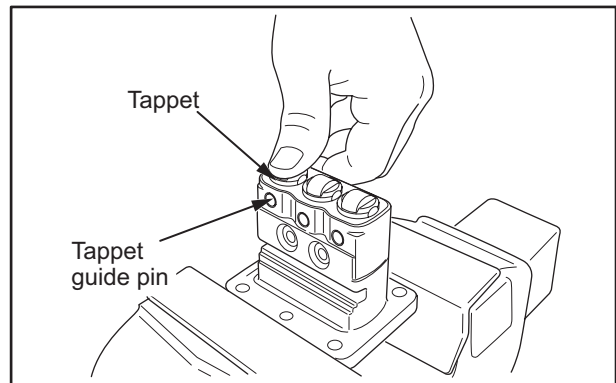
### 2.5.5 Installing tappet

- (1) Install the tappet shim plate.
- (2) Install the tappet so that its groove is positioned to face the tappet guide pin hole.



Installing tappet

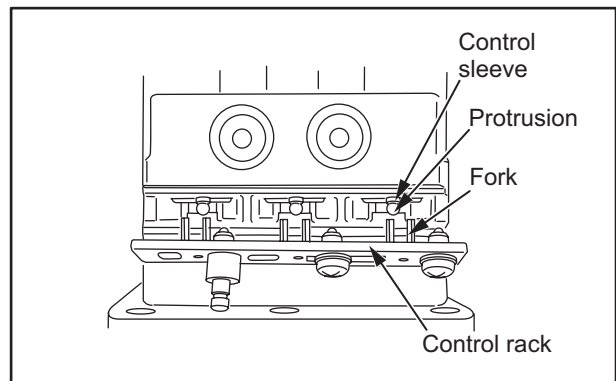
- (3) Push down the tappet, and install the tappet guide pin.



Installing tappet guide pin

### 2.5.6 Installing control rack

- (1) Align the control sleeve position so that the protrusion of the control sleeve fits into the fork of the control rack.
- (2) Install the control rack.



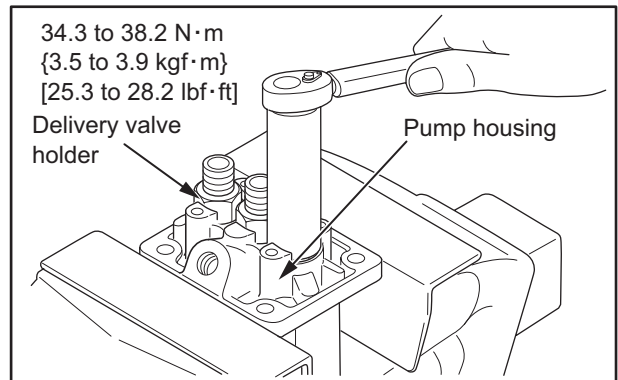
Installing control rack

- (3) Install the stop wire bracket.
- (4) Tighten the countersunk head screws to the specified torque.

Note: When reusing the countersunk head screws, apply adhesive to the threaded portion.

**2.5.7 Tightening delivery valve holder**

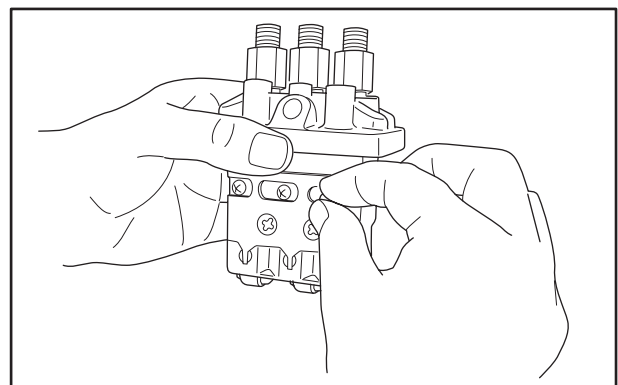
- (1) Place the pump housing upright, and grab the housing with a vise.
- (2) Tighten the delivery valve holder to the specified torque.



Tightening delivery valve holder

**2.5.8 Inspecting control rack for smooth operation**

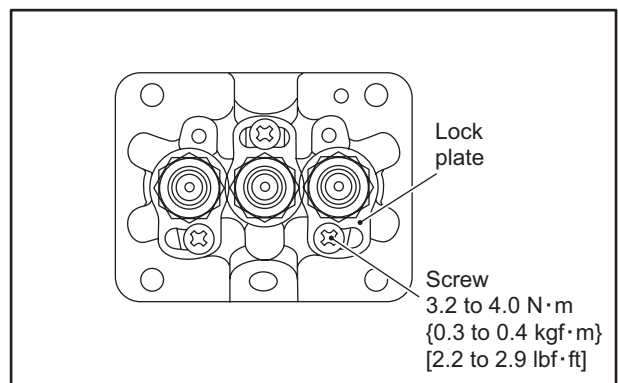
- (1) Remove the pump housing from the vise and check the control rack for smooth movement.  
If the movement is not smooth, the following defects are suspected:
  - Sliding of the element is poor.
  - A foreign substance is present in the teeth of rack or sleeve.
  - The valve holder is overtightened.
- (2) Check the injection timing.



Checking sliding of control rack

**2.5.9 Installing lock plate**

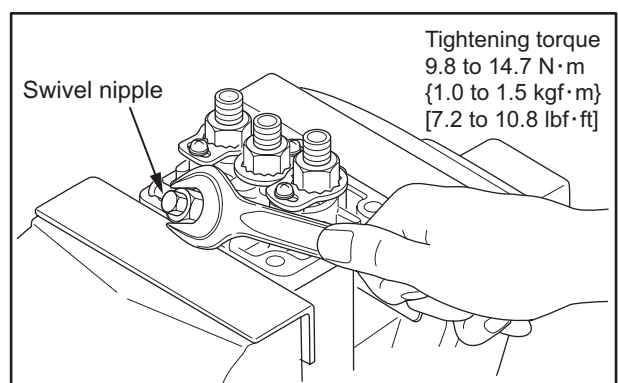
- (1) Grab the pump housing with a vise.
- (2) Install the center lock plate first and then side lock plates later.
- (3) Tighten the screws to the specified torque.



Installing lock plate

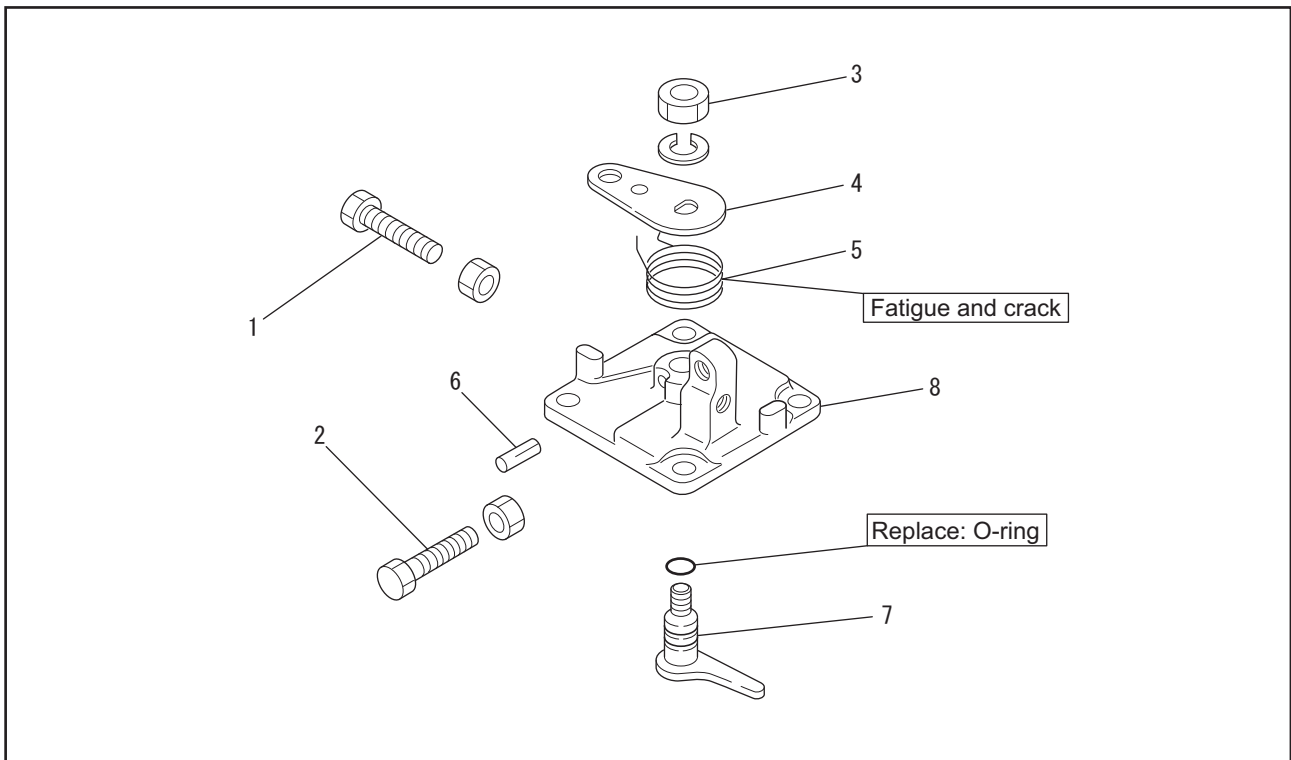
**2.5.10 Installing swivel nipple**

- (1) Install the swivel nipple on the pump housing
- (2) Tighten the hollow screw to the specified torque.



Installing swivel nipple

## 2.6 Disassembling and inspecting governor cover

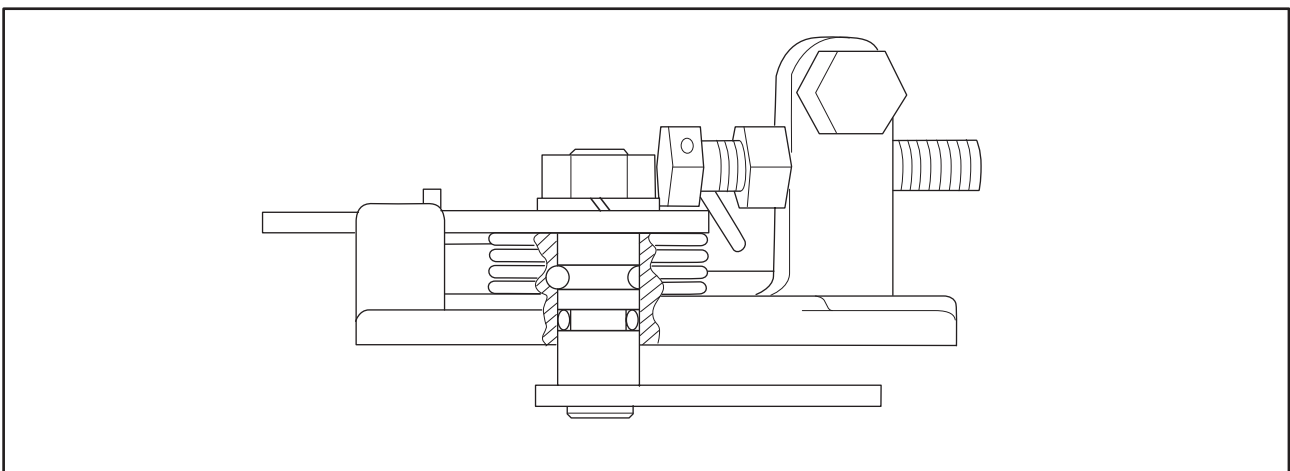


Disassembling and inspecting governor cover

### Disassembling sequence

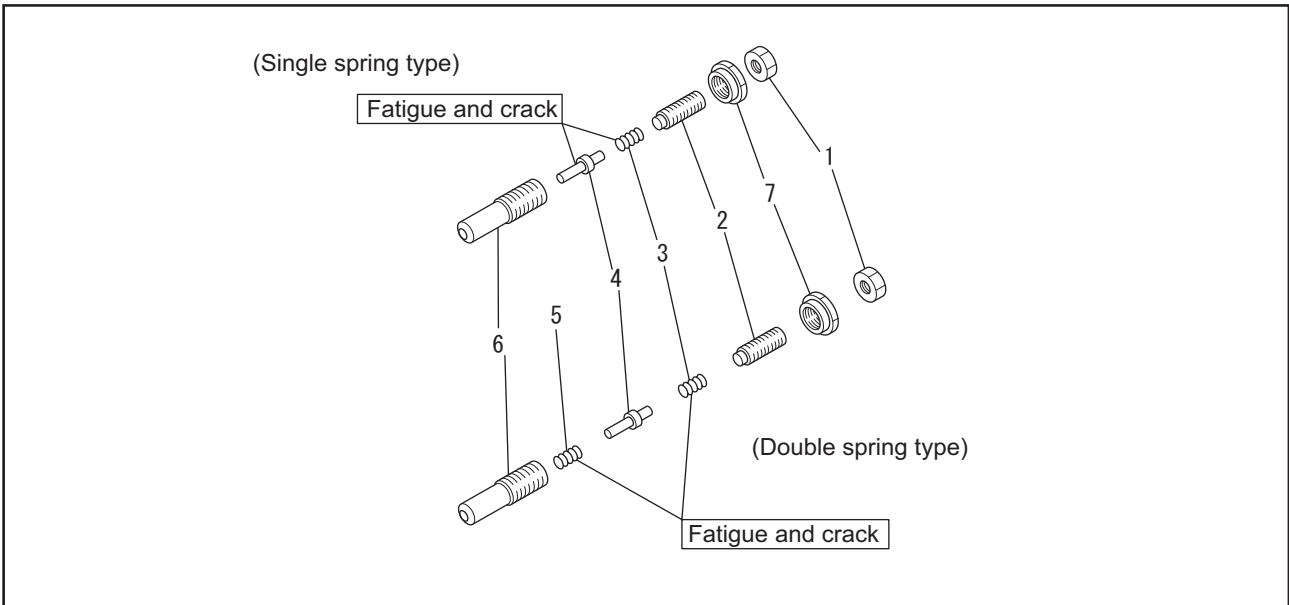
- |            |                 |                  |
|------------|-----------------|------------------|
| 1 Set bolt | 4 Stop lever    | 7 Lever          |
| 2 Set bolt | 5 Return spring | 8 Governor lever |
| 3 Jam nut  | 6 Grooved pin   |                  |

## 2.7 Reassembling governor cover



Reassembling governor cover

**2.8 Disassembling and inspecting torque spring set**

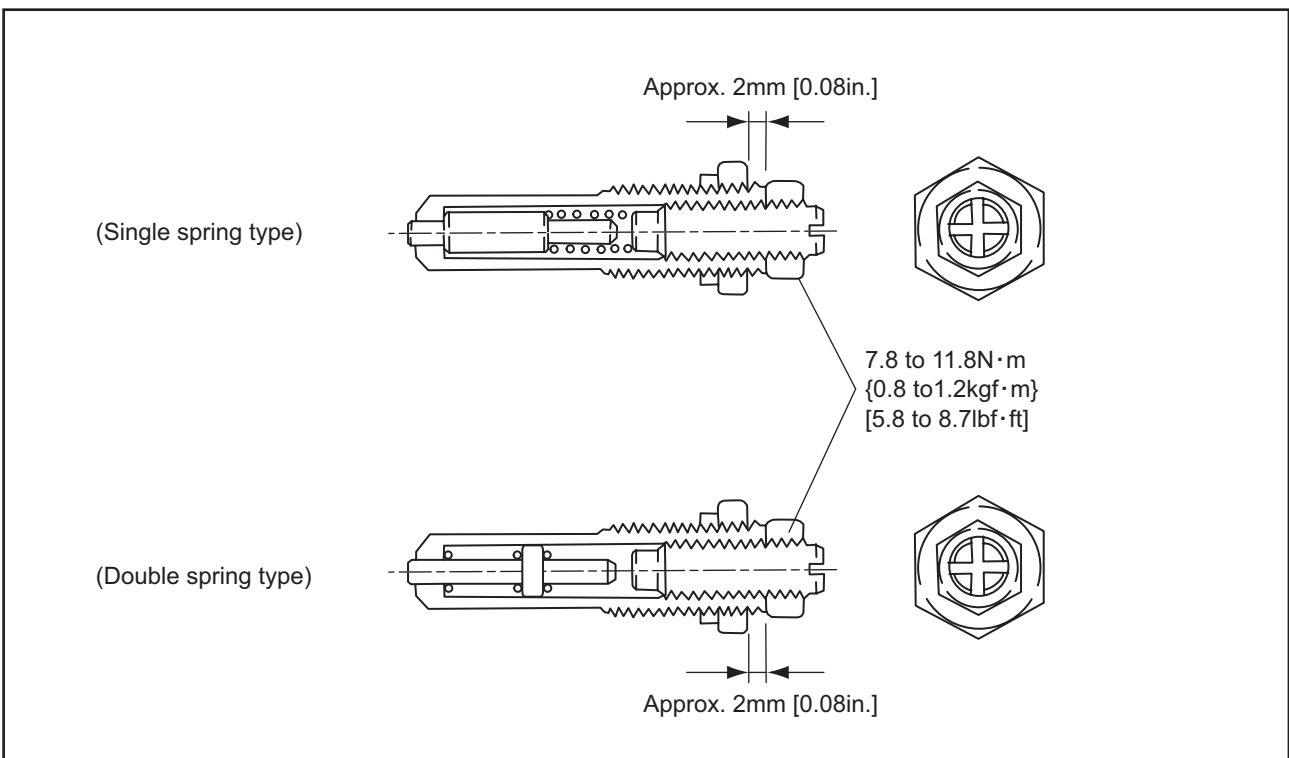


Disassembling and inspecting torque spring set

Disassembling sequence

- |                   |                                 |
|-------------------|---------------------------------|
| 1 Locknut         | 4 Spring stopper                |
| 2 Adjusting screw | 5 Torque spring (2 spring type) |
| 3 Torque spring   | 6 Torque spring case            |

**2.9 Reassembling torque spring set**



Reassembling torque spring set

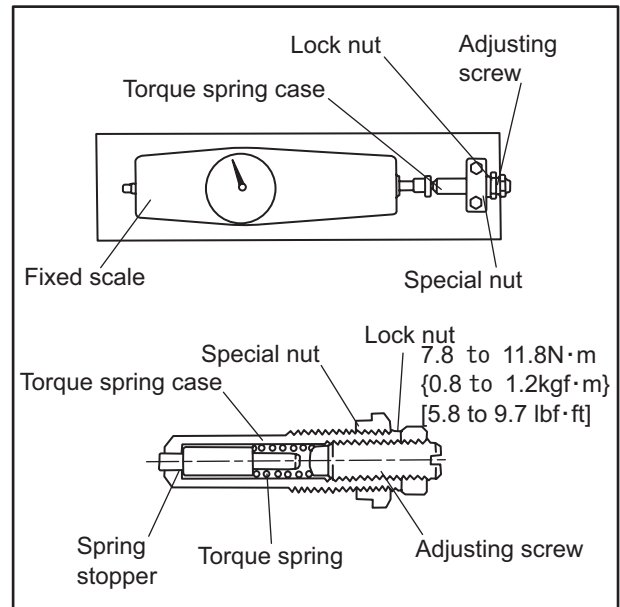
**2.9.1 Torque spring set, single spring type**

Reassemble the torque spring set of the single spring type as described in the following:

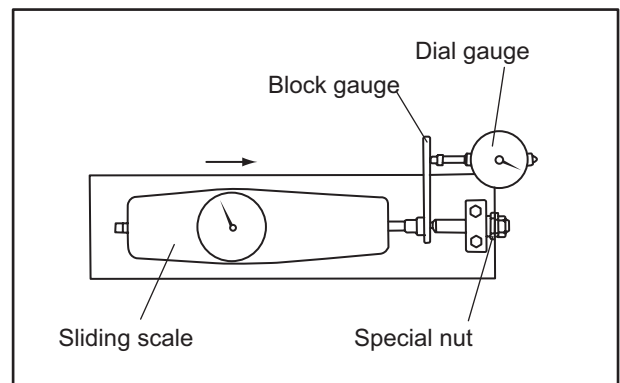
- (1) To lightly tighten adjusting screw, turn the adjusting screw with a screwdriver until you feel resistance. At the position where you feel resistance, secure the adjusting screw lightly using lock nut.
- (2) Set the scale to zero. Turn the torque spring case until the scale reading reaches the load value "A" g in the table below. At this position, secure the adjusting screw using the special nut.
- (3) Temporarily loose the adjusting screw until "A" g load decreases by approx. 200 g [7.05 oz.] and then tighten the adjusting screw again until the load reaches "B" g in the table below. At this position, tighten the lock nut to the specified torque to secure the adjusting screw.
- (4) To check that the torque spring set is adjusted to the appropriate load, place the torque spring set as shown in the illustration. Slowly push the scale to the torque spring set until the spring stopper moves or the pointer of the dial gauge swings. Check the load against the torque spring at that moment is equal to "C" g of the table below.

A	B	C	Color
570 <sup>+10</sup> <sub>0</sub> g [20.11 <sup>+0.35</sup> <sub>0</sub> oz.]	570 <sup>+10</sup> <sub>0</sub> g [20.11 <sup>+0.35</sup> <sub>0</sub> oz.]	570 <sup>+20</sup> <sub>-30</sub> g [19.40 <sup>+0.71</sup> <sub>-1.06</sub> oz.]	Green
1520 <sup>+10</sup> <sub>0</sub> g [53.62 <sup>+0.35</sup> <sub>0</sub> oz.]	1520 <sup>0</sup> <sub>-10</sub> g [53.62 <sup>0</sup> <sub>-0.35</sub> oz.]	1500 <sup>+20</sup> <sub>-30</sub> g [52.91 <sup>+0.71</sup> <sub>-1.06</sub> oz.]	Red
970 <sup>+10</sup> <sub>0</sub> g [34.22 <sup>+0.35</sup> <sub>0</sub> oz.]	970 <sup>0</sup> <sub>-10</sub> g [34.22 <sup>0</sup> <sub>-0.35</sub> oz.]	950 <sup>+20</sup> <sub>-30</sub> g [33.51 <sup>+0.71</sup> <sub>-1.06</sub> oz.]	Yellow
1270 <sup>+10</sup> <sub>0</sub> g [44.80 <sup>+0.35</sup> <sub>0</sub> oz.]	1270 <sup>0</sup> <sub>-10</sub> g [44.80 <sup>0</sup> <sub>-0.35</sub> oz.]	1250 <sup>+20</sup> <sub>-30</sub> g [44.09 <sup>+0.71</sup> <sub>-1.06</sub> oz.]	Purple

Note: Load values (A, B and C) vary based on models.



Setting of torque spring of single spring type



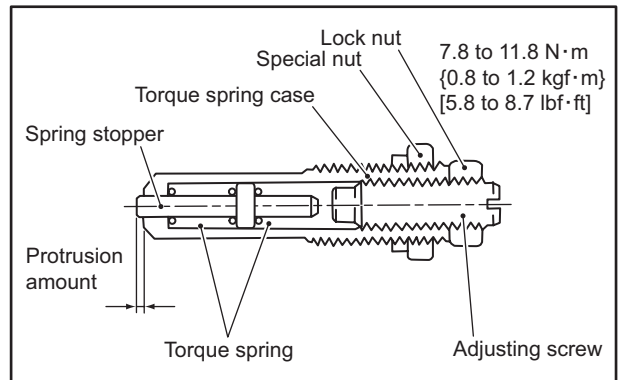
Inspecting torque spring of single spring type

**2.9.2 Reassembling torque spring set, double spring type**

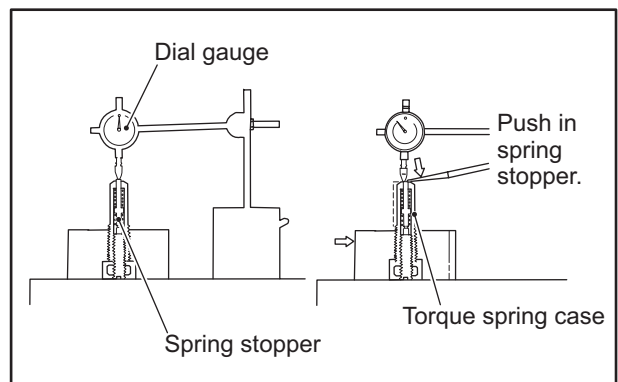
Reassemble the torque spring set of the double spring type as described in the following.

- (1) Screw in the adjusting screw so that the end of the spring stopper protrudes from the torque spring case as the protrusion table below.
- (2) Then, tighten the locknut to the specified torque to secure the adjusting screw.
- (3) With the spring stopper pushed in as described above (1), make sure the spring stopper moves smoothly and is properly retracted to the end face of the torque spring case.
- (4) To check the protrusion of the spring stopper is correctly adjusted, place the torque spring set as shown in the illustration. Apply a dial gauge to the end of the spring stopper and set the pointer to zero. Then, push in the spring stopper and slightly displace the torque spring set to the side. Read extension of the dial gauge to the end of the torque spring case.

Protrusion mm	Color
0.2 to 0.3 mm [0.008 to 0.012 in.]	None
0 to 0.4 mm [0 to 0.016 in.]	White
0.3 to 0.4 mm [0.012 to 0.016 in.]	Blue
0.4 to 0.5 mm [0.016 to 0.020 in.]	Black
0.6 to 0.7 mm [0.024 to 0.028 in.]	Pink
0.5 to 0.6 mm [0.020 to 0.024 in.]	Orange



Setting of torque spring of double spring type



Measuring protrusion of spring stopper of double spring type



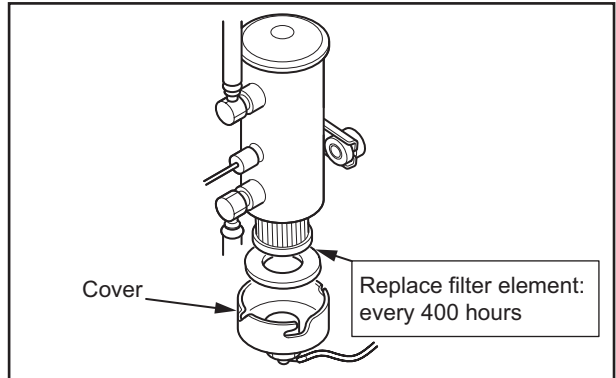
**2.10 Inspecting fuel pump**

The fuel pump is available in 3 types and the type differs based on engine specifications.

**(1) Electromagnetic plunger-type fuel pump**

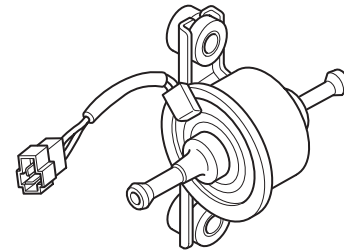
For this pump, a large-sized pump of normal type with a filter element and a small-sized pump of compact type without a filter element are available. In either type, apply the specified voltage, and check for operation and fuel leakage.

For the type with filter element, remove the cover and clean or replace the filter element.



Electromagnetic plunger-type fuel pump (normal type)

Check for damage on external surfaces and fuel leakage.

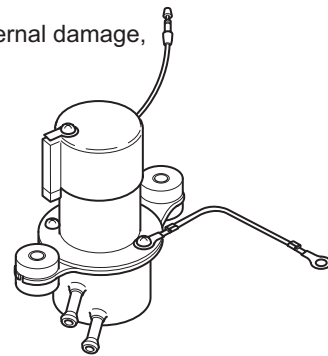


Electromagnetic plunger-type fuel pump type (compact type)

**(2) Electromagnetic diaphragm-type fuel pump**

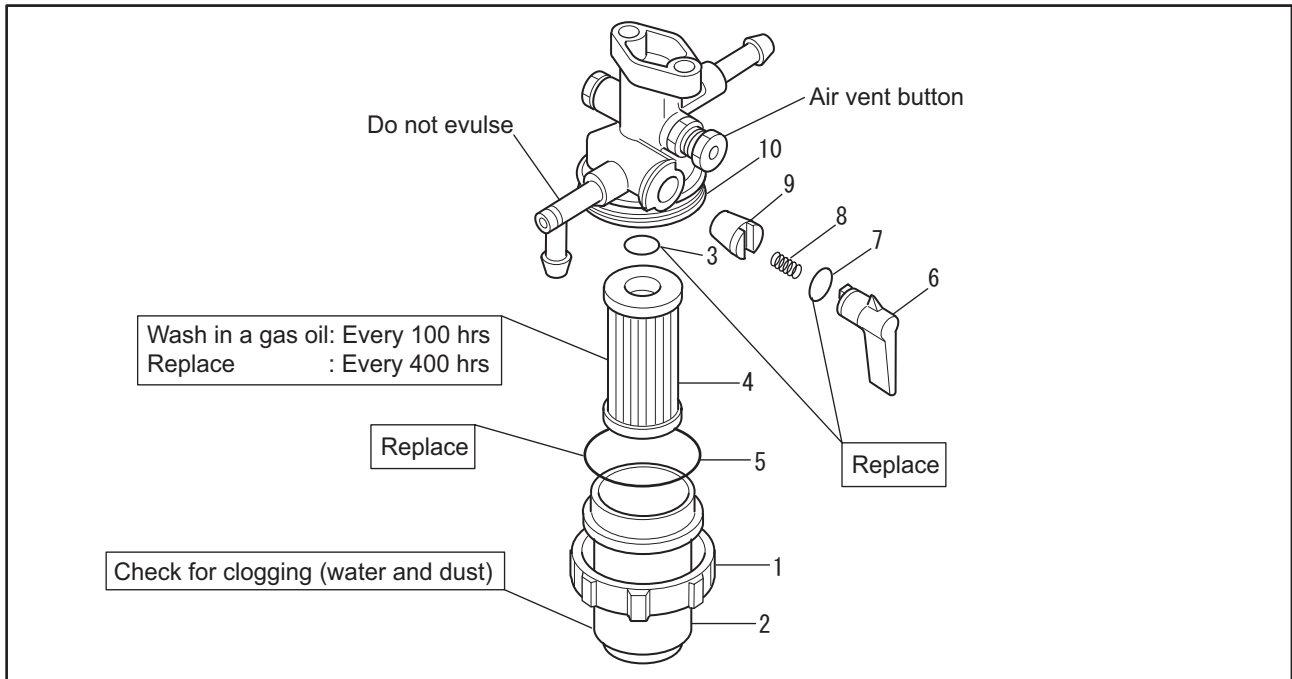
Do not disassemble this pump. Apply the specified voltage, and check for operation and fuel leakage.

Check for external damage, fuel leakage



Electromagnetic diaphragm-type fuel pump

**2.11 Disassembling, inspecting and reassembling fuel filter (cock switch type, push botton)**



Disassembling, inspecting and reassembling fuel filter (cock switch type, push botton)

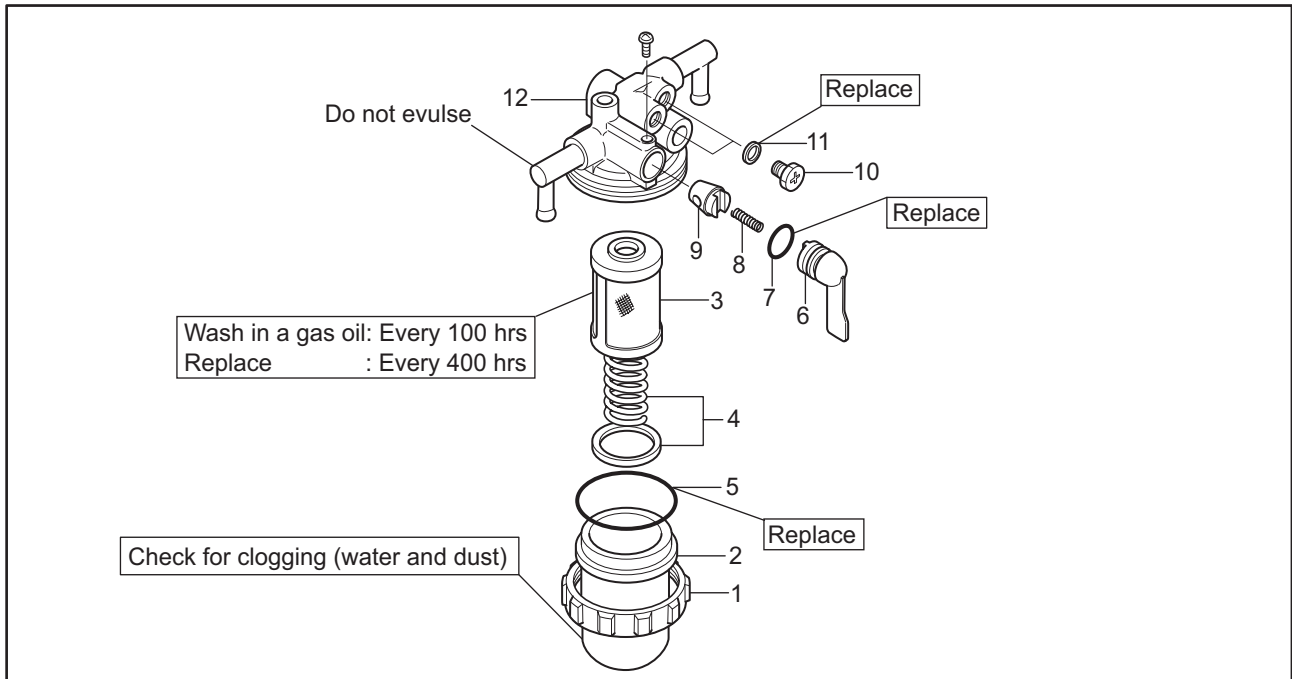
Disassembling sequence

- |            |              |                |
|------------|--------------|----------------|
| 1 Ring nut | 5 O-rings    | 9 Valve        |
| 2 Cup      | 6 Cock lever | 10 Filter body |
| 3 O-rings  | 7 O-rings    |                |
| 4 Element  | 8 Spring     |                |

Note: (a) Disassemble the fuel filter only when removing the element. Do not disassemble the cock lever unless absolutely necessary.

(b) When removing the cock lever and reassembling it after cleaning, apply silicon oil to the O-ring of the lever.

2.12 Disassembling, inspecting and reassembling fuel filter (cock switch type, changeover)



Disassembling, inspecting and reassembling fuel filter (cock switch type, changeover)

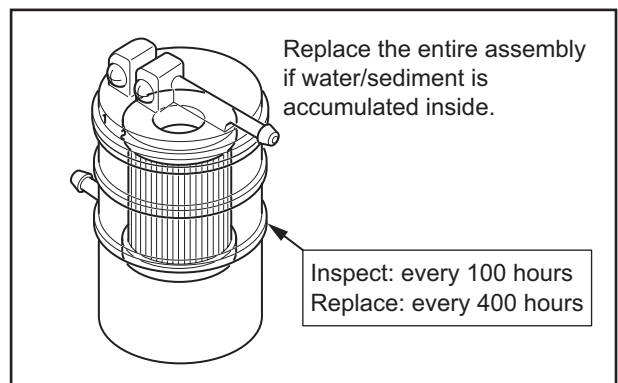
Disassembling sequence

- |                         |              |                   |
|-------------------------|--------------|-------------------|
| 1 Ring nut              | 5 O-rings    | 9 Valve           |
| 2 Cup                   | 6 Cock lever | 10 Air bleed plug |
| 3 Element               | 7 O-rings    | 11 Packing        |
| 4 Element spring, float | 8 Spring     | 12 Filter body    |

Note: (a) Disassemble the fuel filter only when removing the element. Do not disassemble the cock lever unless absolutely necessary.

(b) When removing the cock lever and reassembling it after cleaning, apply silicon oil to the O-ring of the lever.

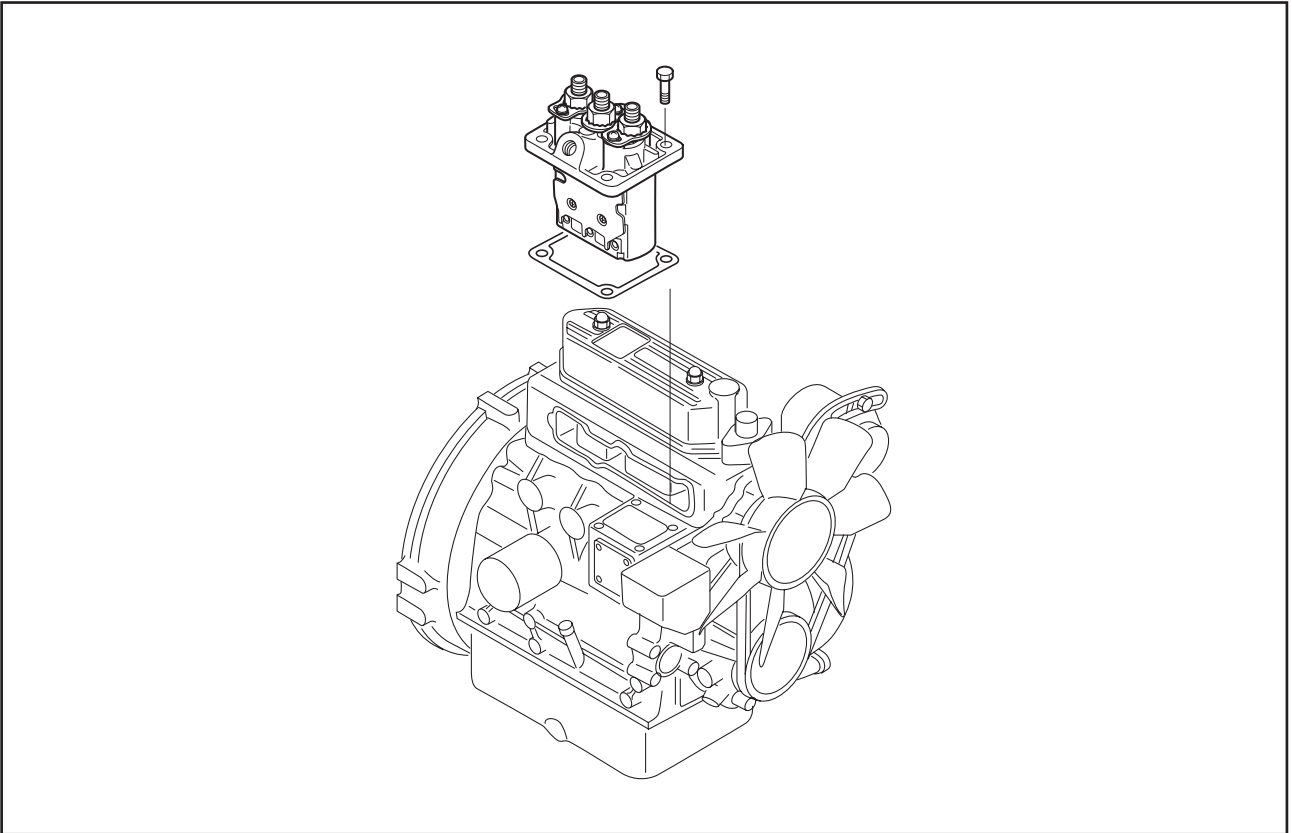
When dust or water is accumulated at the case bottom or in the element, replace the filter as an assembly. Replace the fuel filter every 400 hours. Check the filter every 100 hours. If defective, replace the filter regardless of the replacement interval.



Inspecting fuel filter (cartridge type)

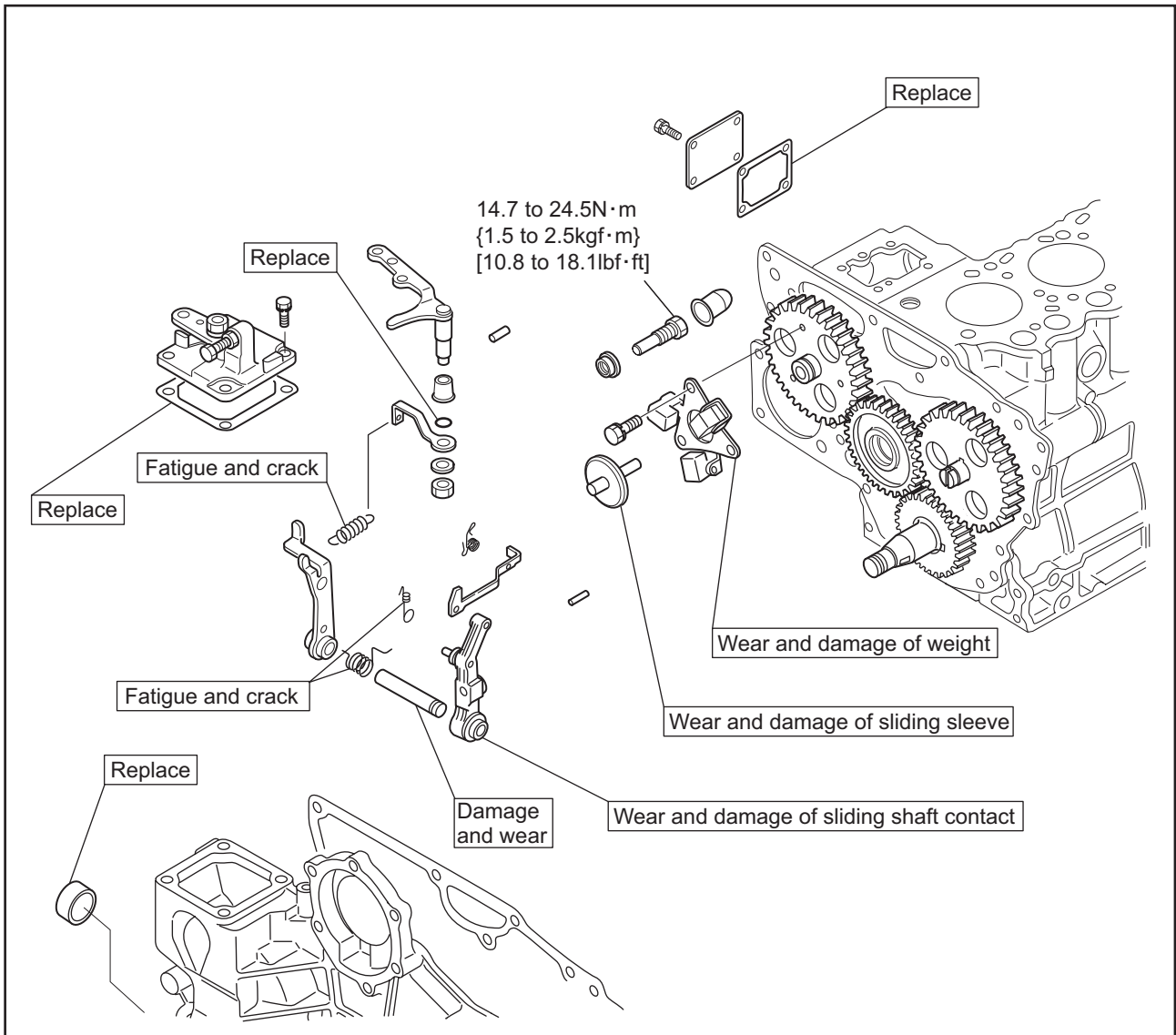
### 3. Installing fuel system

#### 3.1 Installing fuel injection pump



Installing fuel injection pump

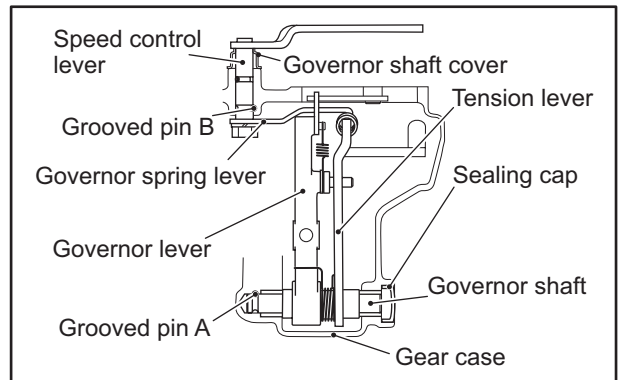
3.2 Installing governor



Installing governor

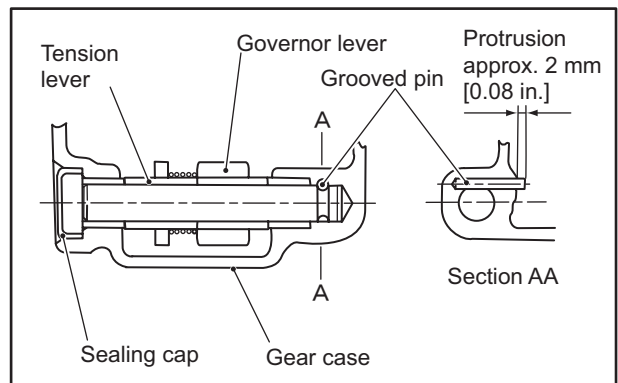
**3.2.1 Installing speed control lever and governor shaft**

- (1) Insert the governor shaft into the gear case while placing the governor lever and the tension lever.
- (2) Drive the grooved pin A into the gear case.
- (3) Drive new sealing cap into the gear case.
- (4) Thoroughly apply Alvania Grease #2 or #3 to the governor shaft cover.
- (5) With governor shaft cover installed on speed control lever, install a new O-ring on the speed control lever and insert it into the gear case.



Installing speed control lever and governor shaft

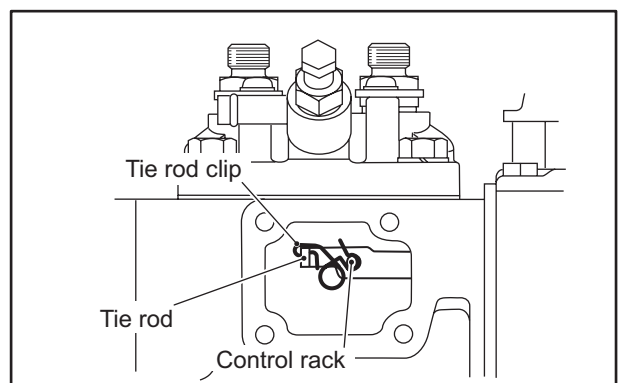
- (6) Drive the grooved pin B into the gear case.
  - (7) Install the governor spring lever.
- Note: Assemble the speed control lever and the governor spring lever with the minimum assembling angle.



Reassembling speed control lever

**3.2.2 Connecting tie rod**

Connect the tie rod to the control rack of fuel injection pump and fix them with the tie rod clip.



Connecting tie rod

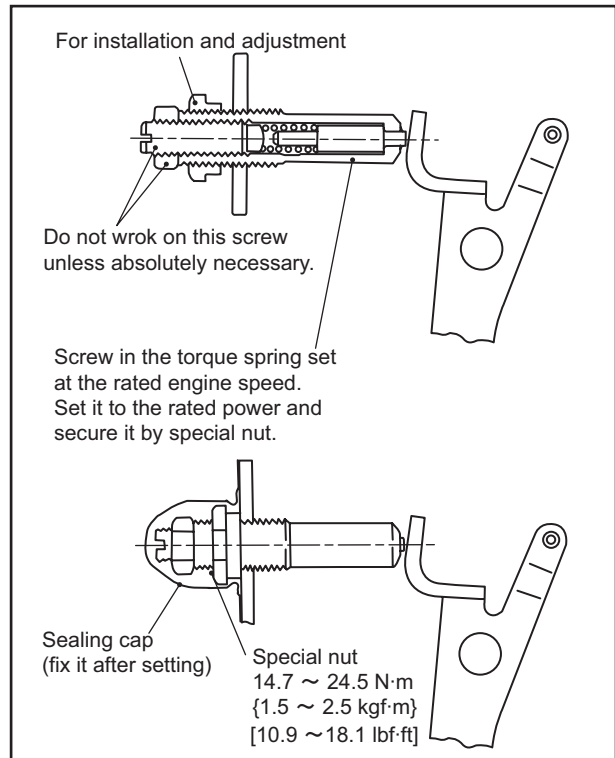
**3.2.3 Installing torque spring set  
(Single spring, double spring)**

**CAUTION**

The torque spring set is properly adjusted at the factory before shipment. Do not work on the torque spring set unless absolutely necessary.

Adjust and reassemble the torque spring set as described in the following.

- (1) Adjust the speed control lever with the high speed set bolt. After setting it at the high idle engine speed, secure it by nut.
- (2) Screw in the torque spring set at the rated engine speed. Set it to the rated engine power and secure it by special nut.
- (3) Put a torque spring set sealing cap on the torque spring and firmly tighten the sealing cap.

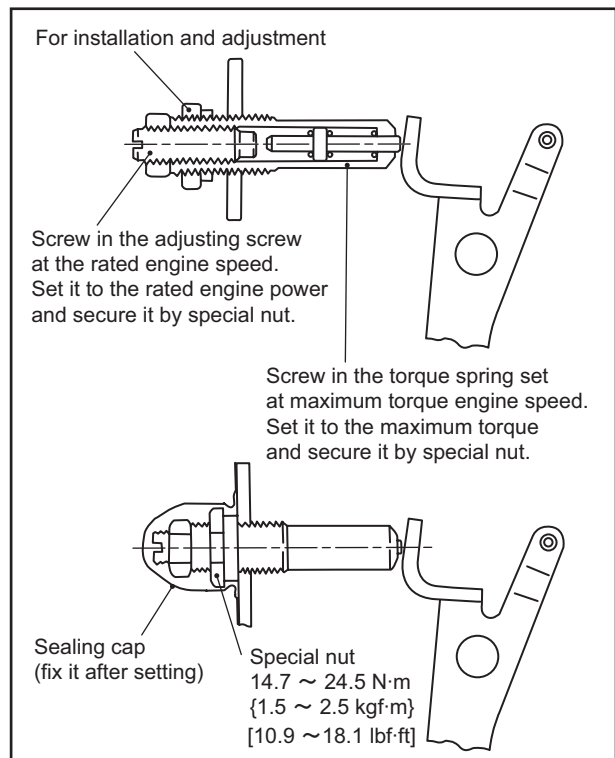


Installing torque spring set (single spring)

**3.2.4 Installing torque set spring  
(Double spring, two point control)**

Adjust and reassemble the torque spring set as described in the following.

- (1) Adjust the speed control lever with the high speed set bolt. After setting it to the high idle engine speed, secure it by nut.
- (2) Screw in the torque spring set at maximum torque engine speed. Set it to the maximum torque and secure it by special nut.
- (3) Screw in the adjusting screw at the rated engine speed. Set it to the rated engine power and secure it by special nut.
- (4) Put a torque spring set sealing cap on the torque spring and firmly tighten the sealing cap.



Installing torque spring set (double spring)

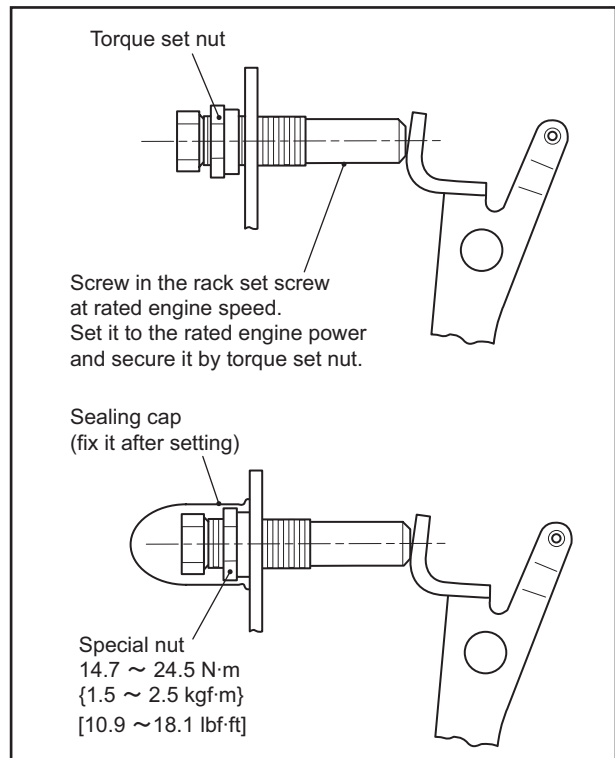
### 3.2.5 Installing rack set screw

**CAUTION**

The rack set screw are properly adjusted at the factory before shipment. Do not work on the rack set screw unless absolutely necessary.

Adjust and reassemble the rack set screw as described in the following.

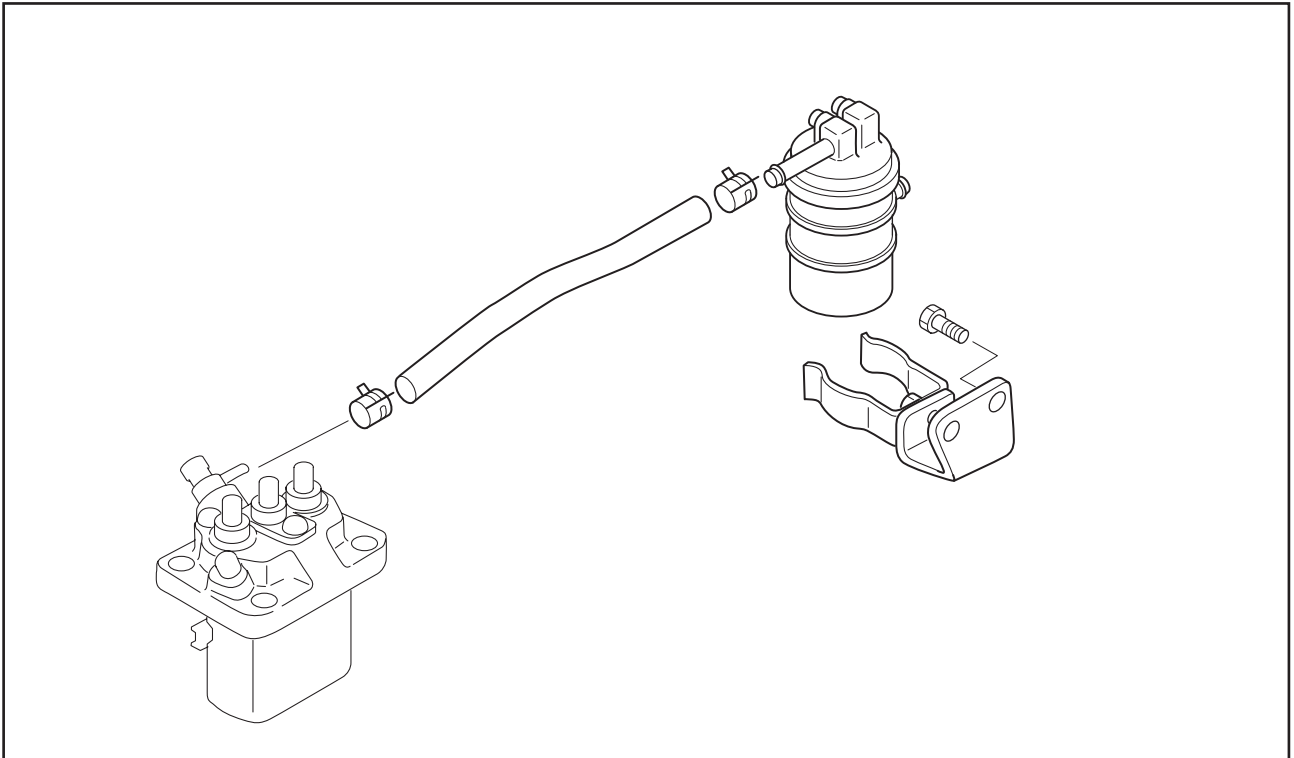
- (1) Adjust the speed control lever with the high speed set bolt. After setting it to the high idle engine speed, secure it by nut.
- (2) Screw in the rack set screw at rated engine speed, set it to the rated engine power.
- (3) Secure it by torque set nut.
- (4) Put the rack set screw sealing cap and firmly tighten the sealing cap.



Installing rack set screw

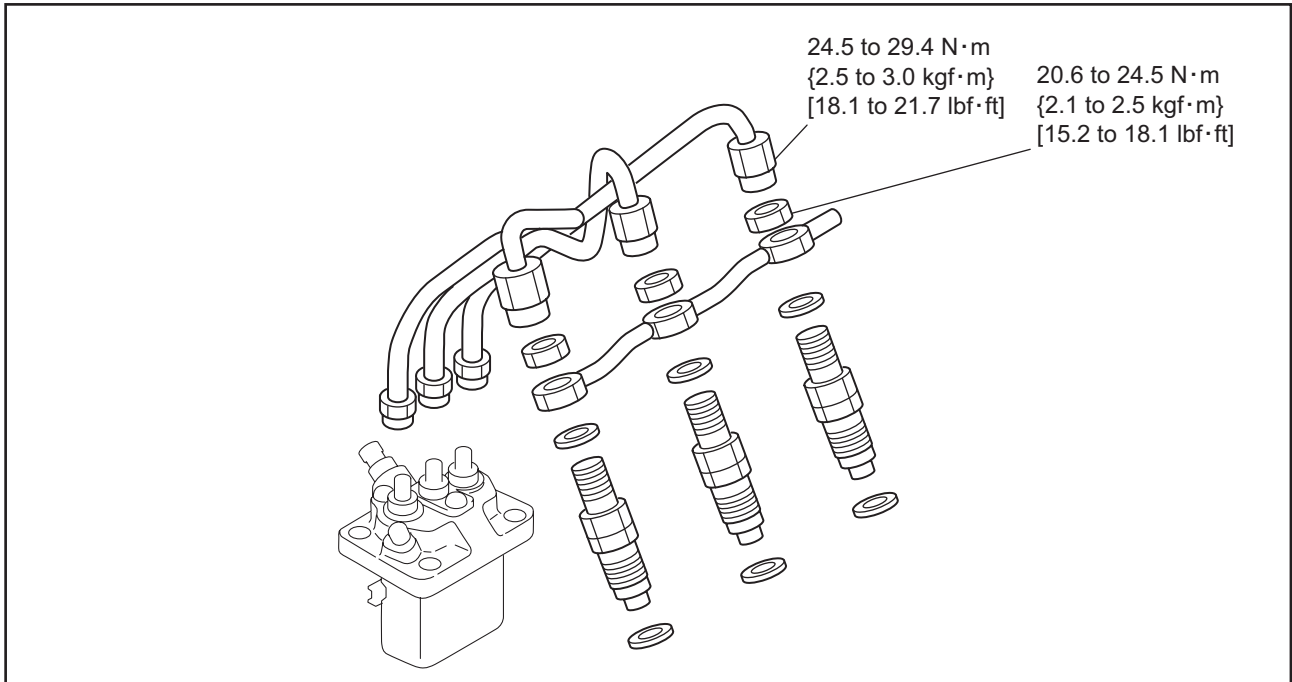


### 3.3 Installing fuel filter



Installing fuel filter

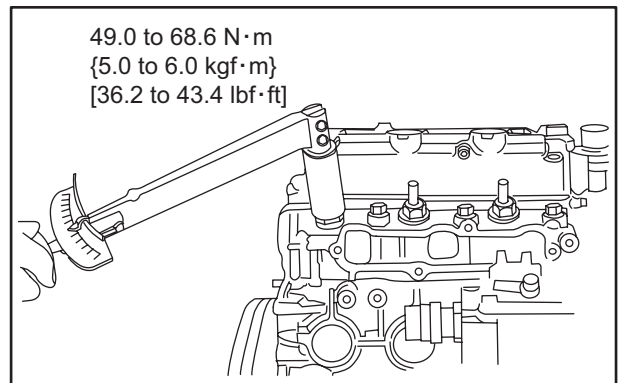
### 3.4 Installing fuel pipe and fuel injection nozzles



Installing fuel pipe and fuel injection nozzles

#### 3.4.1 Installing fuel injection nozzle

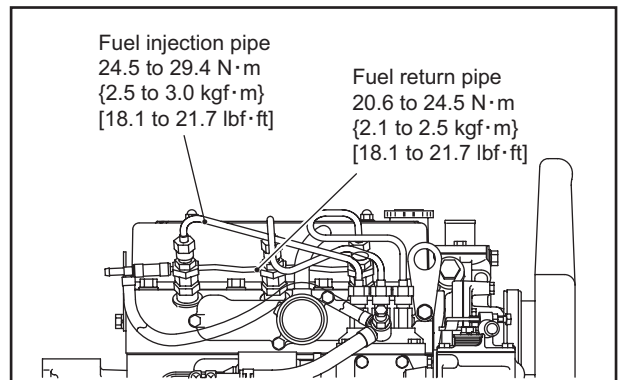
- (1) Clean the nozzle holder hole of cylinder head.
- (2) Install the gasket to the nozzle tip and tighten the fuel injection nozzle.



Installing fuel injection nozzles

#### 3.4.2 Installing fuel return pipe and fuel injection pipe

Install the fuel return pipe and fuel injection pipe.



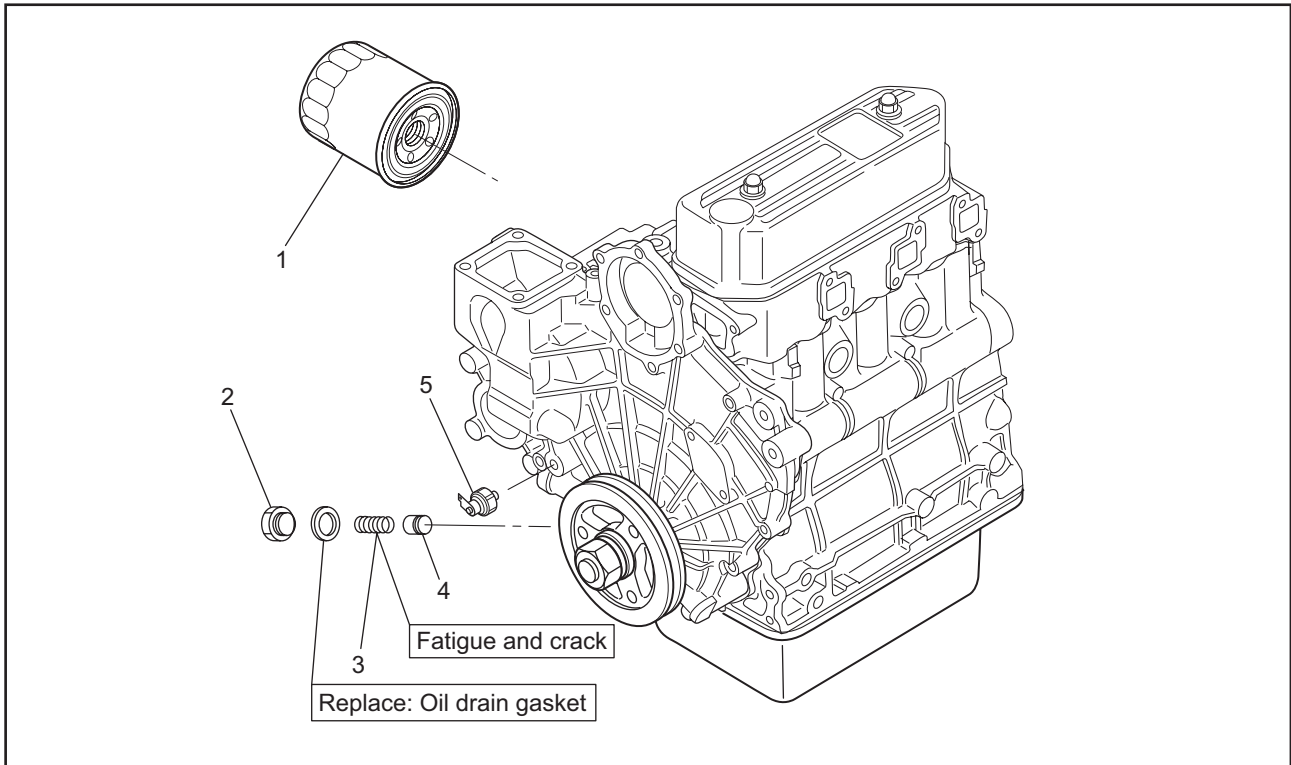
Installing fuel return pipe and  
Installing fuel injection pipe

# LUBRICATION SYSTEM

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## 1. Removing lubrication system

### 1.1 Removing oil filter, relief valve and oil pressure switch



Removing oil filter, relief valve and oil pressure switch

#### Removing sequence

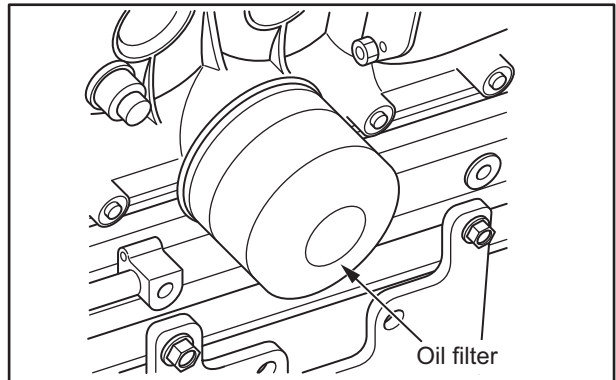
- 1 Oil filter
- 2 Plug

- 3 Relief spring
- 4 Relief plunger

- 5 Oil pressure switch

**1.1.1 Removing oil filter**

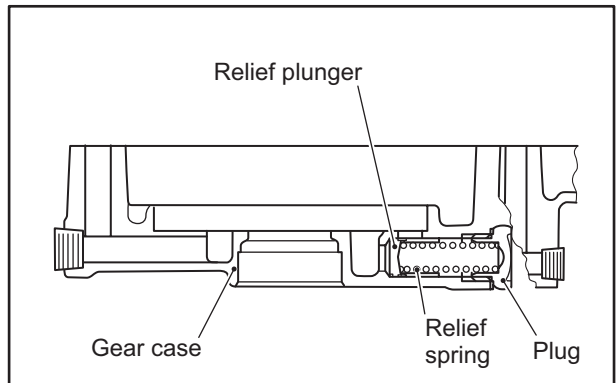
- (1) Place a drip pan under the oil filter.
- (2) Remove the oil filter using a filter wrench.



Removing oil filter

**1.1.2 Removing relief valve**

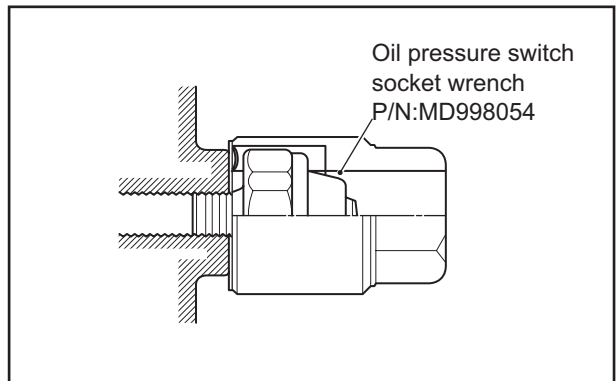
Remove the plug from the gear case and take out the relief spring and relief plunger.



Removing relief valve

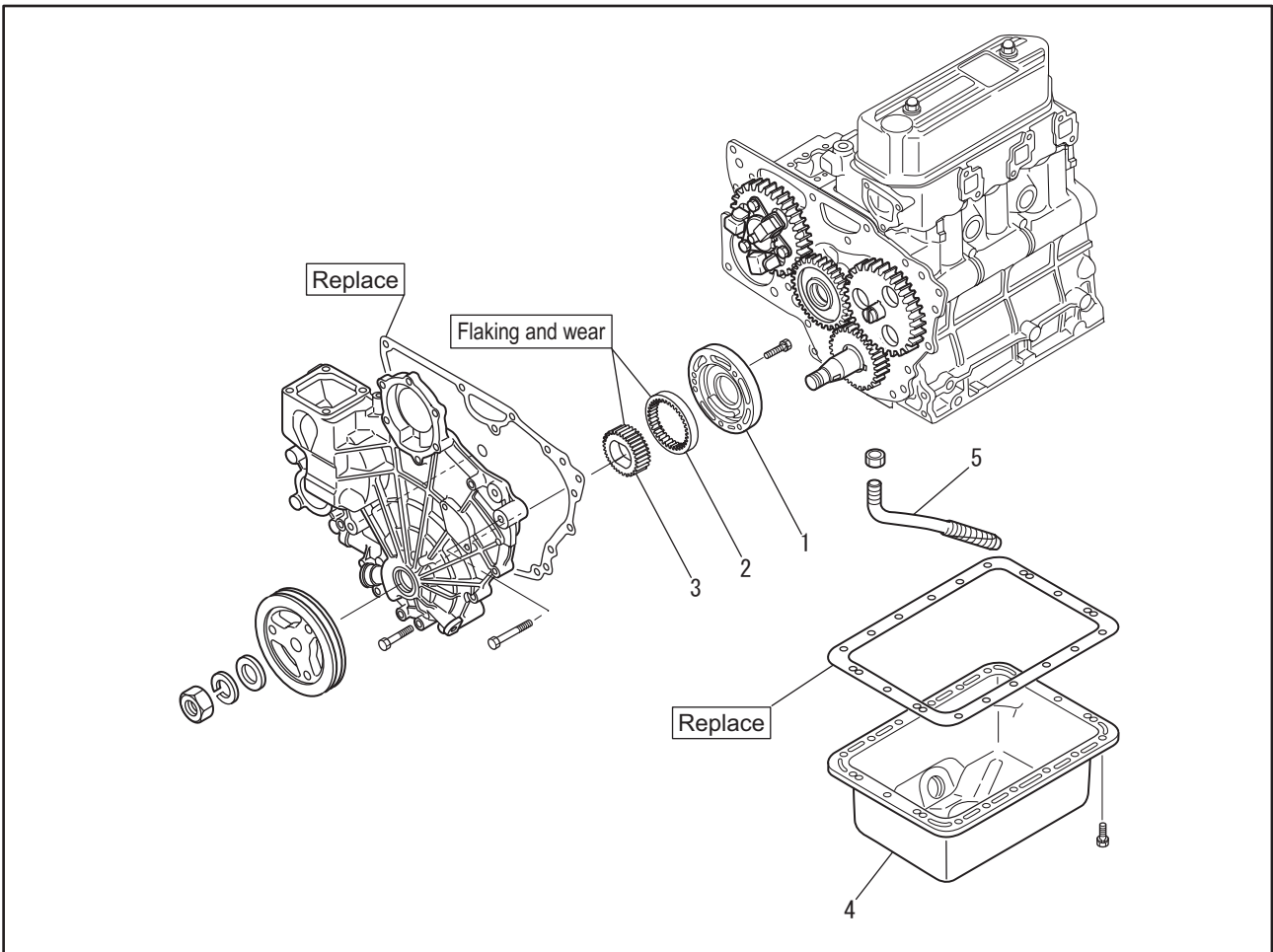
**1.1.3 Removing oil pressure switch**

Using an oil pressure switch socket wrench, remove oil pressure switch.



Removing oil pressure switch

**1.2 Removing oil pump, oil pan and oil screen**



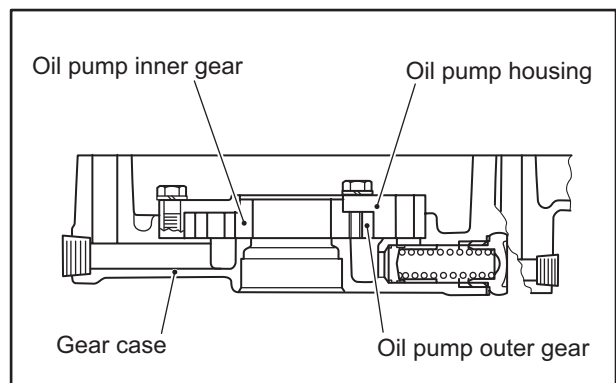
Removing oil pump, oil pan and oil screen

Removing sequence

- |                       |                       |              |
|-----------------------|-----------------------|--------------|
| 1 Oil pump housing    | 3 Oil pump inner gear | 5 Oil screen |
| 2 Oil pump outer gear | 4 Oil pan             |              |

**1.2.1 Removing oil pump**

- (1) Remove the oil pump housing from the gear case.
- (2) Remove the oil pump outer gear and oil pump inner gear from the oil pump housing.



Removing oil pump

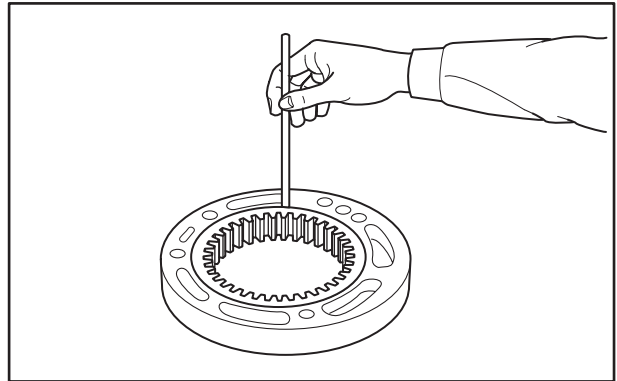
## 2. Disassembling, inspecting and reassembling lubrication system

### 2.1 Inspecting oil pump

#### 2.1.1 Measuring clearance between oil pump housing inside diameter and oil pump outer gear outside diameter

Measure the clearance using thickness gauges. Replace the gear or housing if the limit is exceeded.

Item	Standard	Limit
Clearance between oil pump housing inside diameter and oil pump outer gear outside diameter	0.100 to 0.196 mm [0.0039 to 0.0077 in.]	0.3 mm [0.012 in.]

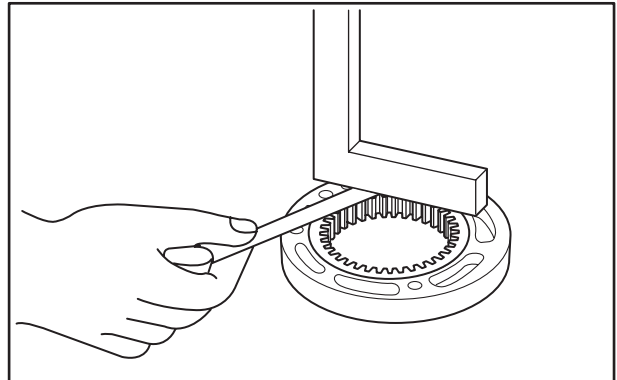


Measuring clearance between oil pump housing inside diameter and oil pump outer gear outside diameter

#### 2.1.2 Measuring the end clearance between oil pump outer gear width and oil pump housing depth

Measure the end clearance using feeler gauges. Replace the gear or housing if the limit is exceeded.

Item	Standard	Limit
End clearance between oil pump outergear width and oil pump housing depth	0.040 to 0.100 mm [0.0016 to 0.0039 in]	0.25 mm [0.0099 in]



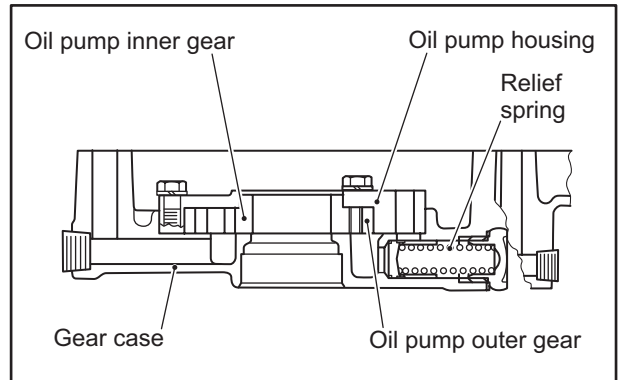
Measuring the difference between oil pump outer gear width and oil pump housing

**2.2 Inspecting relief valve**

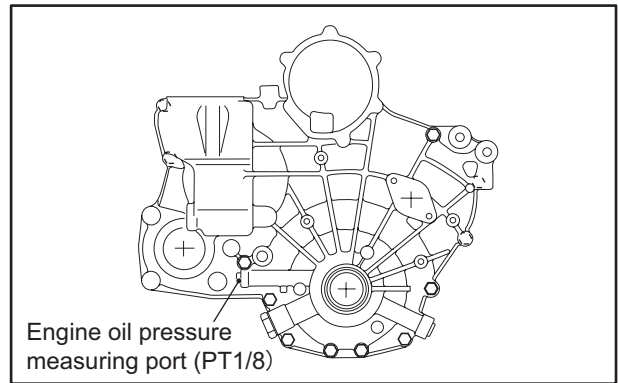
- (1) Check the relief valve and its seat for contact. Check the spring for fatigue and damage. If faulty, replace the relief valve with new one.
- (2) Measure the relief valve opening pressure. If the pressure does not fall within the standard range, replace the relief valve with new one.

Item	Standard
Relief valve opening pressure	$0.29 \pm 0.029$ MPa $\{3.0 \pm 0.3$ kgf/cm <sup>2</sup> $[43 \pm 4.3$ psi]

Note: Start oil pressure measurement at the engine front side (gear case).



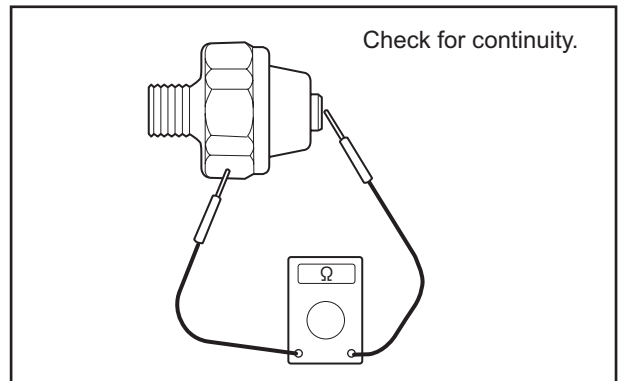
Inspecting relief valve



Engine oil pressure measuring port

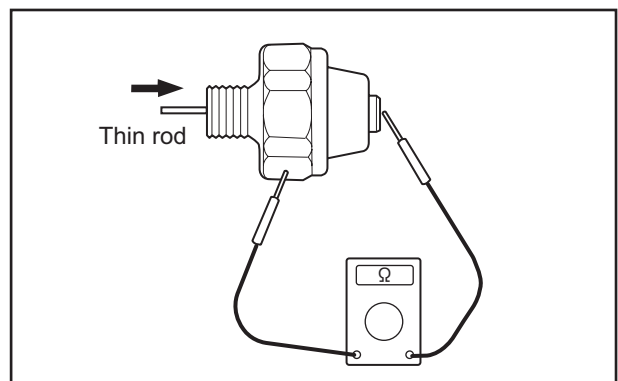
**2.3 Inspecting oil pressure switch**

- (1) Connect a tester (ohm range) between the terminal and body to check for continuity. The switch is normal if there is continuity between them. If there is no continuity, replace the switch.



Inspecting oil pressure switch (1)

- (2) Insert a thin rod from the oil hole and lightly push it. The switch is normal if there is no continuity between them. If there is continuity when the rod is pushed in, replace the switch.
- (3) When air pressure of 0.05 MPa {0.5 kgf/cm<sup>2</sup>} [7.1 psi] is applied from the oil hole and there is no continuity, the switch is normal. Also check for air leaks. If there are air leaks, the diaphragm is damaged. Replace the switch.

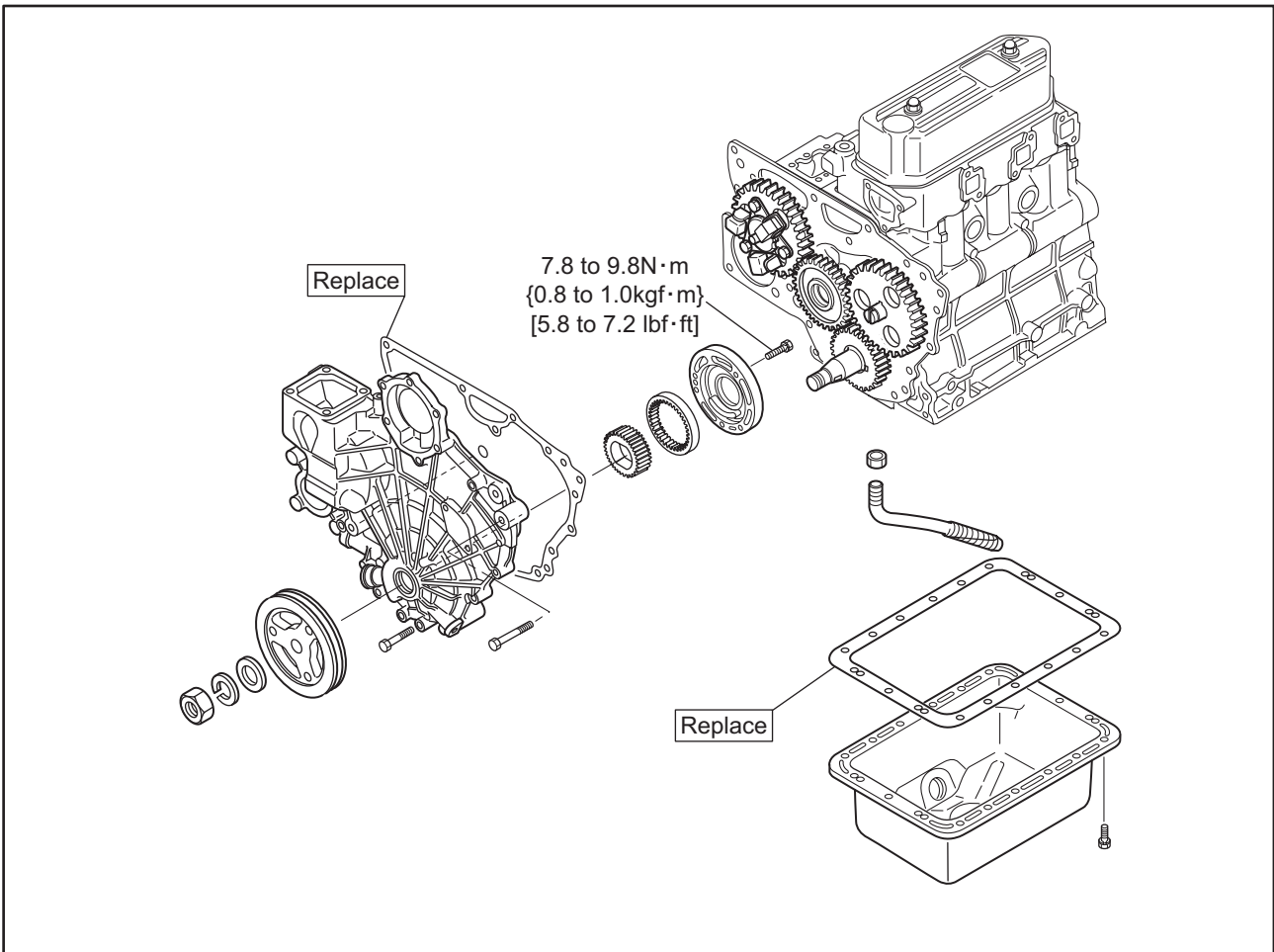


Inspecting oil pressure switch (2)



### 3. Installing lubrication system

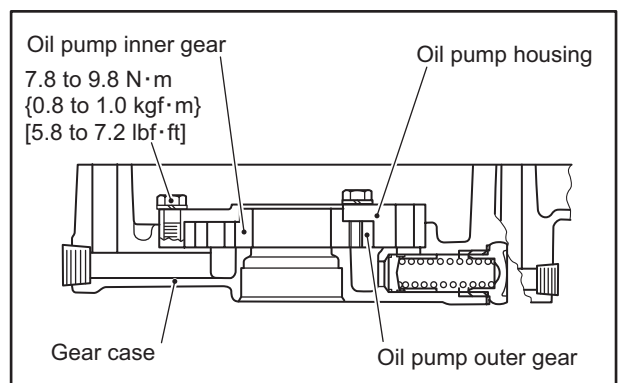
#### 3.1 Installing oil pump, oil pan and oil screen



Installing oil pump, oil pan and oil screen

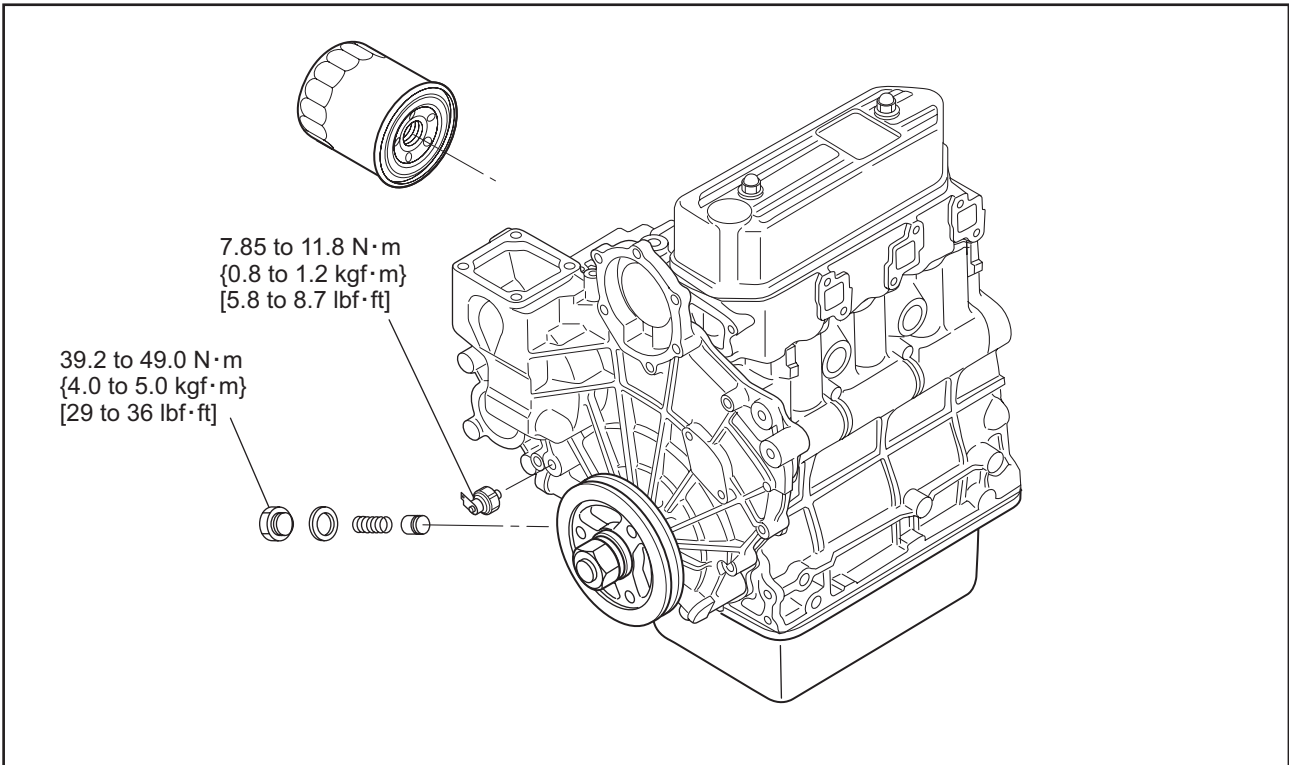
#### 3.1.1 Installing oil pump

Install the oil pump inner gear, oil pump outer gear and oil pump housing, and tighten the bolts to the specified torque.



Installing oil pump

### 3.2 Installing oil filter, relief valve and oil pressure



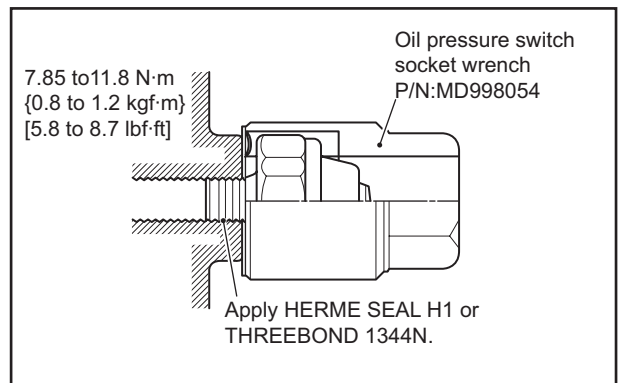
Installing oil filter, relief valve and oil pressure

#### 3.2.1 Installing oil pressure switch

**CAUTION**

Do not allow sealant to squeeze out at the thread end.  
Do not overtighten.

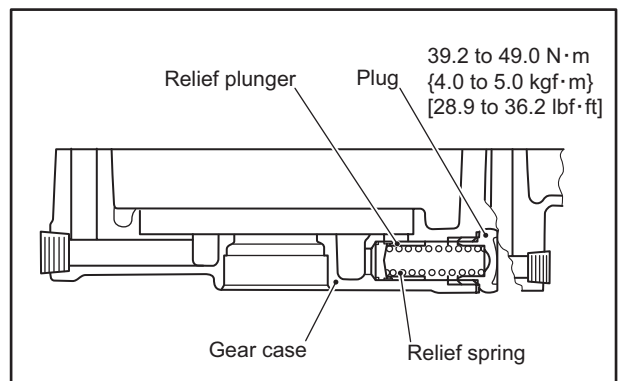
- (1) Using an oil pressure switch socket wrench, tighten the oil pressure switch to the specified torque.
- (2) Apply a sealant to the threaded portion when installing the switch.



Installing oil pressure switch

#### 3.2.2 Installing relief valve

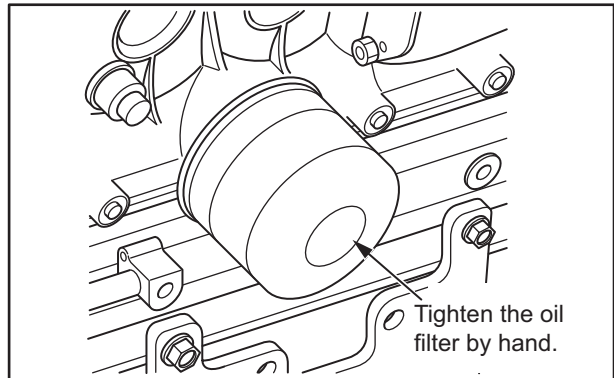
Insert the relief plunger and relief spring into the gear case and tighten the plug to the specified torque.



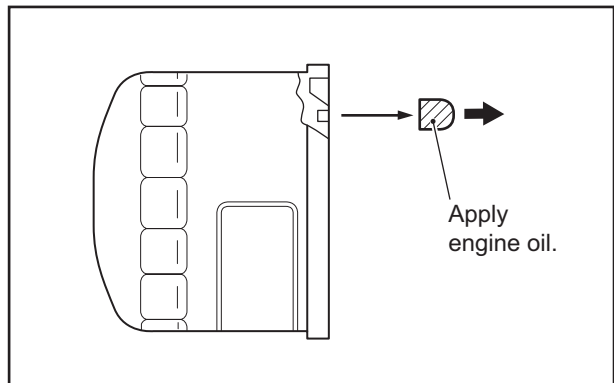
Installing relief valve

### 3.2.3 Installing oil filter

- (1) Apply a light coating of engine oil to the filter gasket.
- (2) Screw the filter in by hand. When the filter gasket contacts the mounting surface, screw the filter in another turn.



Installing oil filter (1)



Installing oil filter (2)

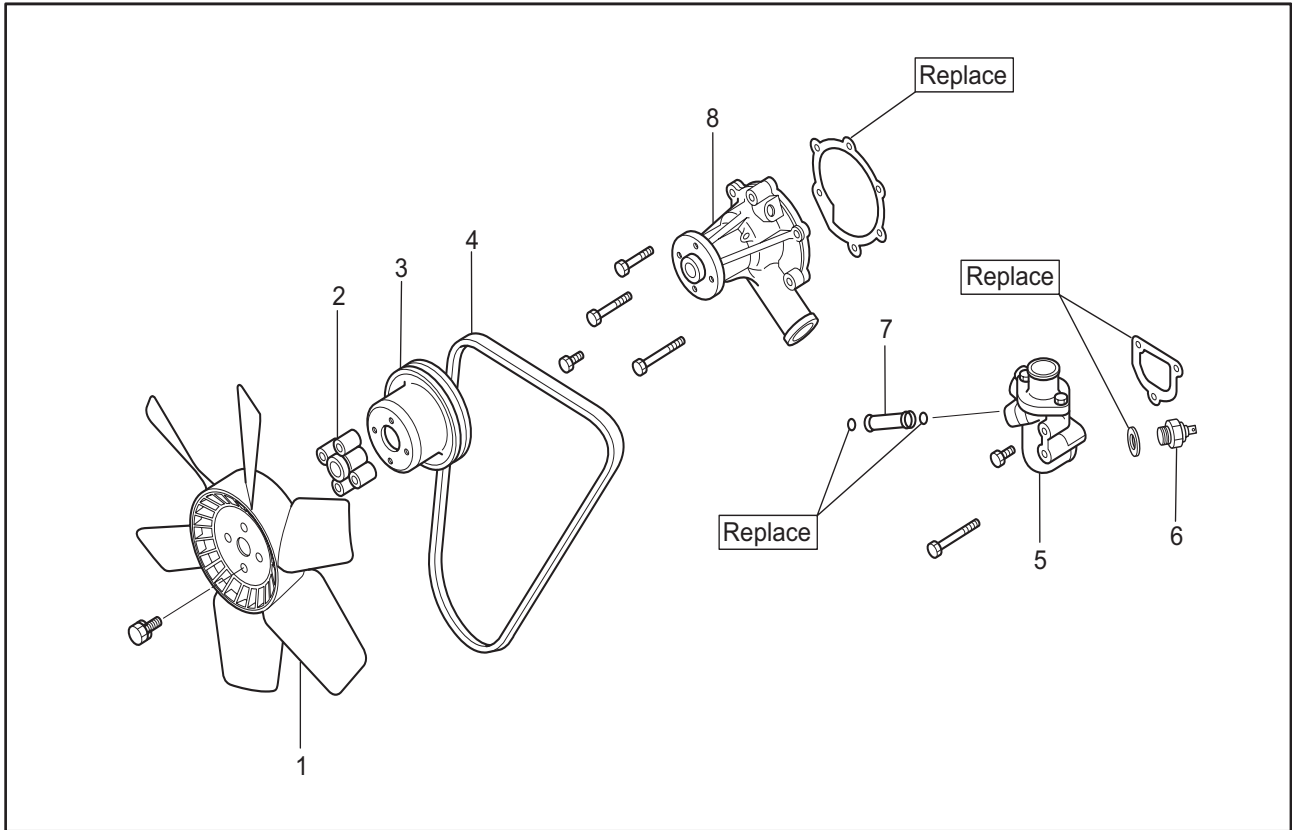


# COOLING SYSTEM

- 1. Removing cooling system ..... 10-2
  - 1.1 Removing cooling fan, fan pulley, V-belt, thermostat, thermostich and water pump ..... 10-2
  
- 2. Disassembling, inspecting and reassembling cooling system ..... 10-3
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  - 3.1 Installing cooling fan, fan pulley, V-belt, thermostat, thermostich and water pump ..... 10-5

## 1. Removing cooling system

### 1.1 Removing cooling fan, fan pulley, V-belt, thermostat, thermostatic switch and water pump



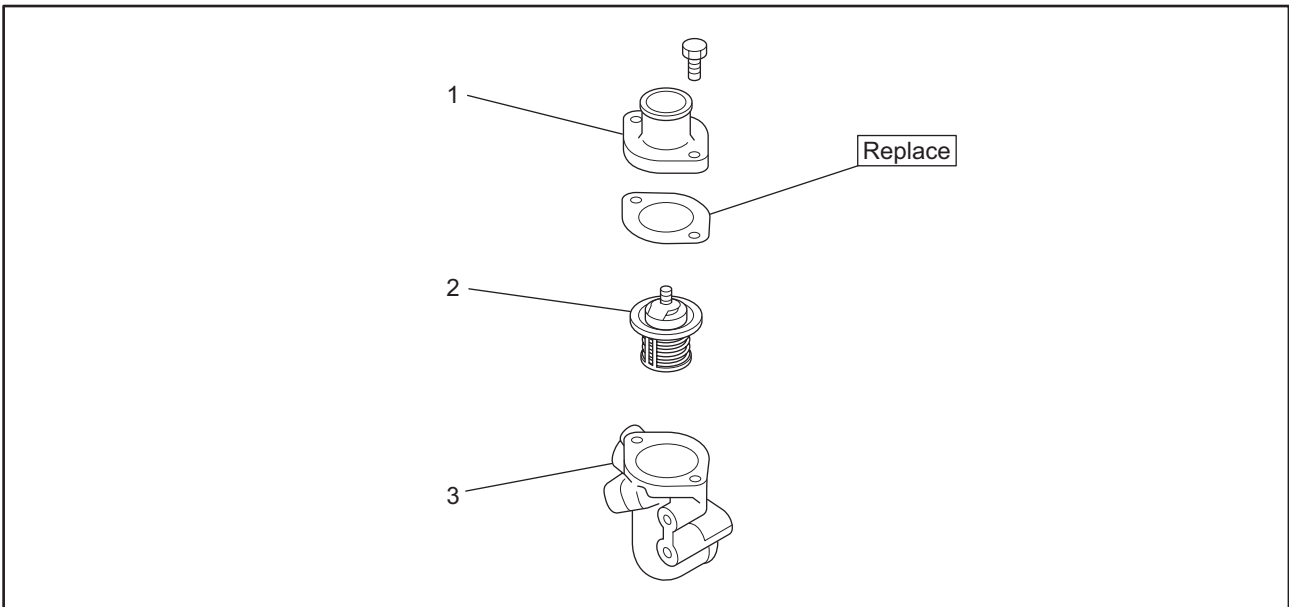
Removing cooling fan, fan pulley, V-belt, thermostat, thermostatic switch and water pump

#### Removing sequence

- |              |                       |              |
|--------------|-----------------------|--------------|
| 1 Fan        | 4 V-belt              | 7 Pipe       |
| 2 Fan spacer | 5 Thermostat case     | 8 Water pump |
| 3 Fan pulley | 6 Thermostatic switch |              |

## 2. Disassembling, inspecting and reassembling cooling system

### 2.1 Disassembling and inspecting thermostat



Disassembling and inspecting thermostat

Disassembling sequence

1 Thermostat cover

2 Thermostat

3 Thermostat case

### 2.2 Inspecting thermostat

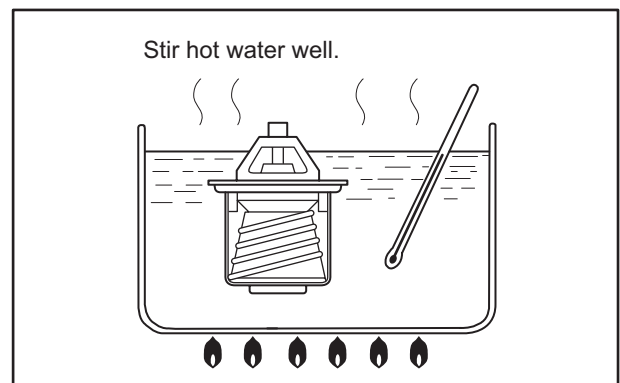
**CAUTION**

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.

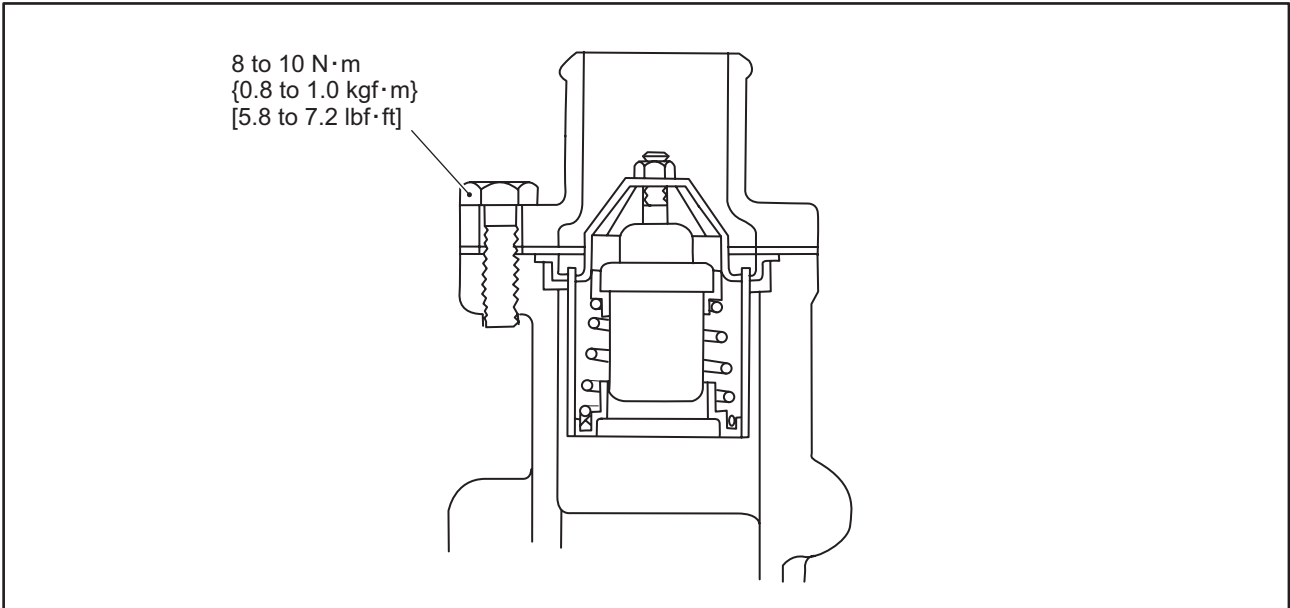
(b) Before installing the thermostat, be sure to check the valve opening temperature stamped on the thermostat valve side face.



Inspecting thermostat

Item	Standard
Temperature at which valve starts opening	76.5 ± 1.5°C [167 to 172°F]
Temperature at which valve lift becomes 6 mm [0.24 in.] or more	90°C [194°F]

**2.3 Reassembling thermostat**



Reassembling thermostat

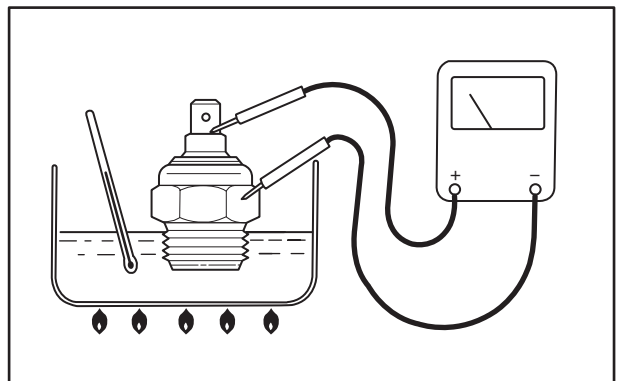
**2.4 Inspecting thermostatic switch**

**CAUTION**

Both water and the thermostatic switch become hot. Pay attention to prevent burn and fire.

Immerse the temperature-senser in oil and measure the resistance while raising the oil temperature. If the resistance extremely deviates from the standard, replace the thermostatic switch.

Temperature	Standard
120°C [248°F]	30 mΩ

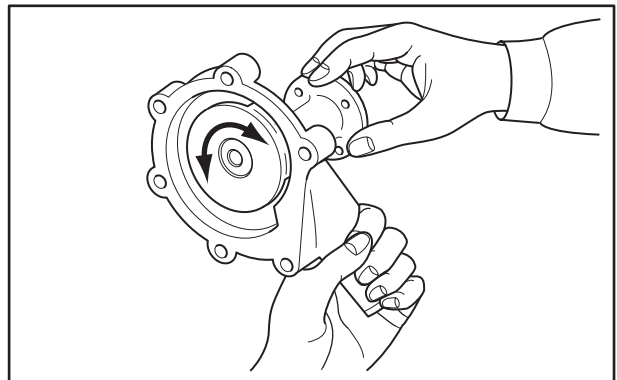


Inspecting thermostat

**2.5 Inspecting water pump**

**2.5.1 Checking water pump for smooth rotation**

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

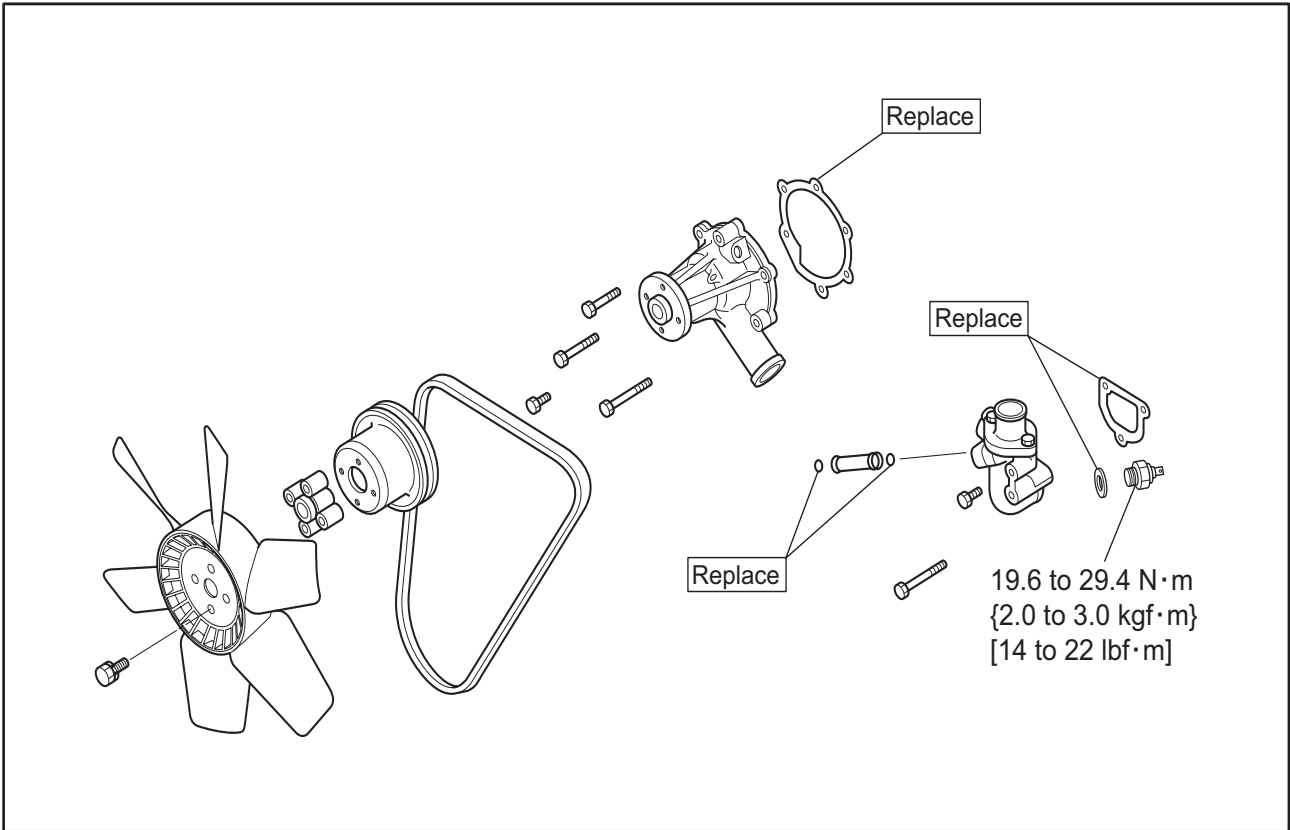


Checking impeller and shaft for smooth rotation



### 3. Installing cooling system

#### 3.1 Installing cooling fan, fan pulley, V-belt, thermostat, thermostatic switch and water pump



Installing cooling fan, fan pulley, V-belt, thermostat, thermostatic switch and water pump

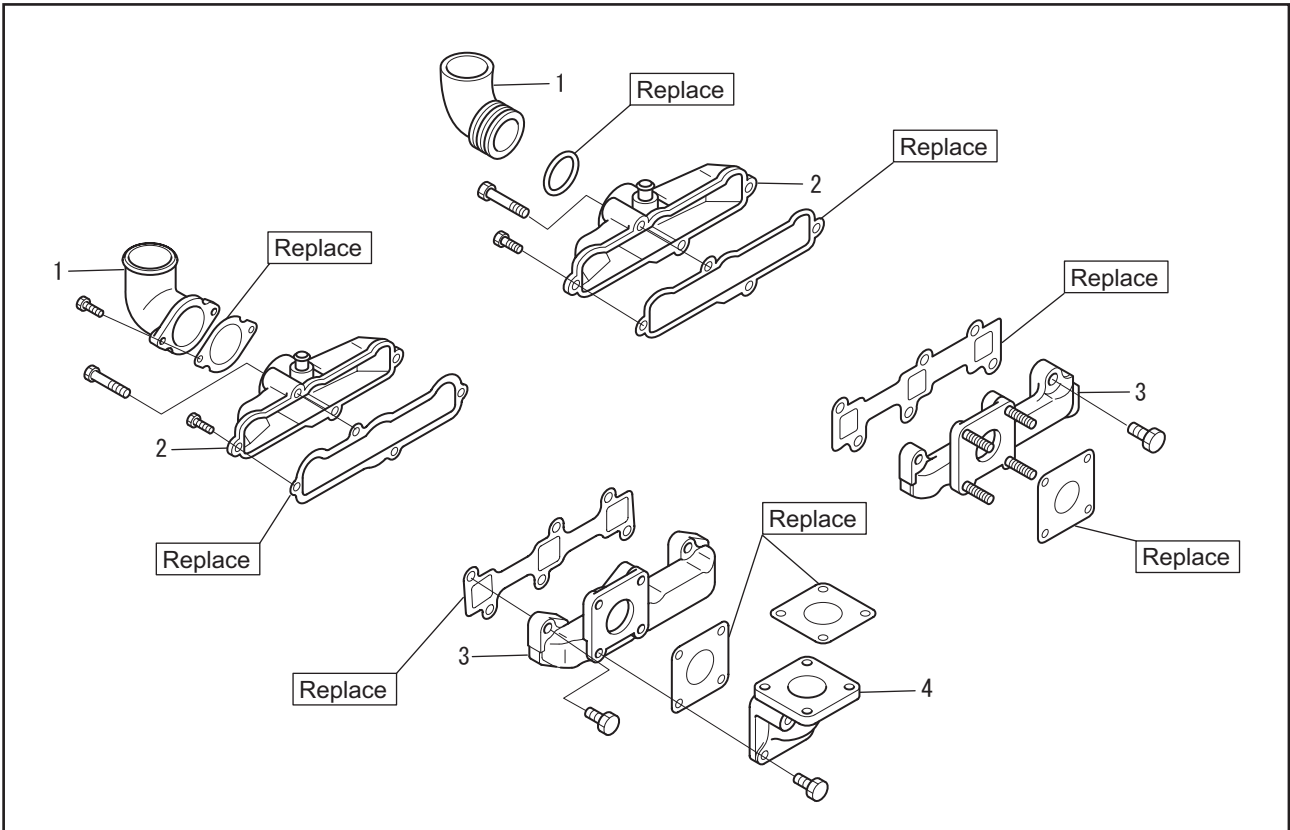


# INLET AND EXHAUST SYSTEMS

1. Removing inlet and exhaust systems .....11-2
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3. Installing inlet and exhaust systems .....11-4
  - 3.1 Installing inlet cover and exhaust manifold..... 11-4

# 1. Removing inlet and exhaust systems

## 1.1 Removing inlet cover and exhaust manifold



Removing inlet cover and exhaust manifold

Removing sequence

1 Inlet pipe

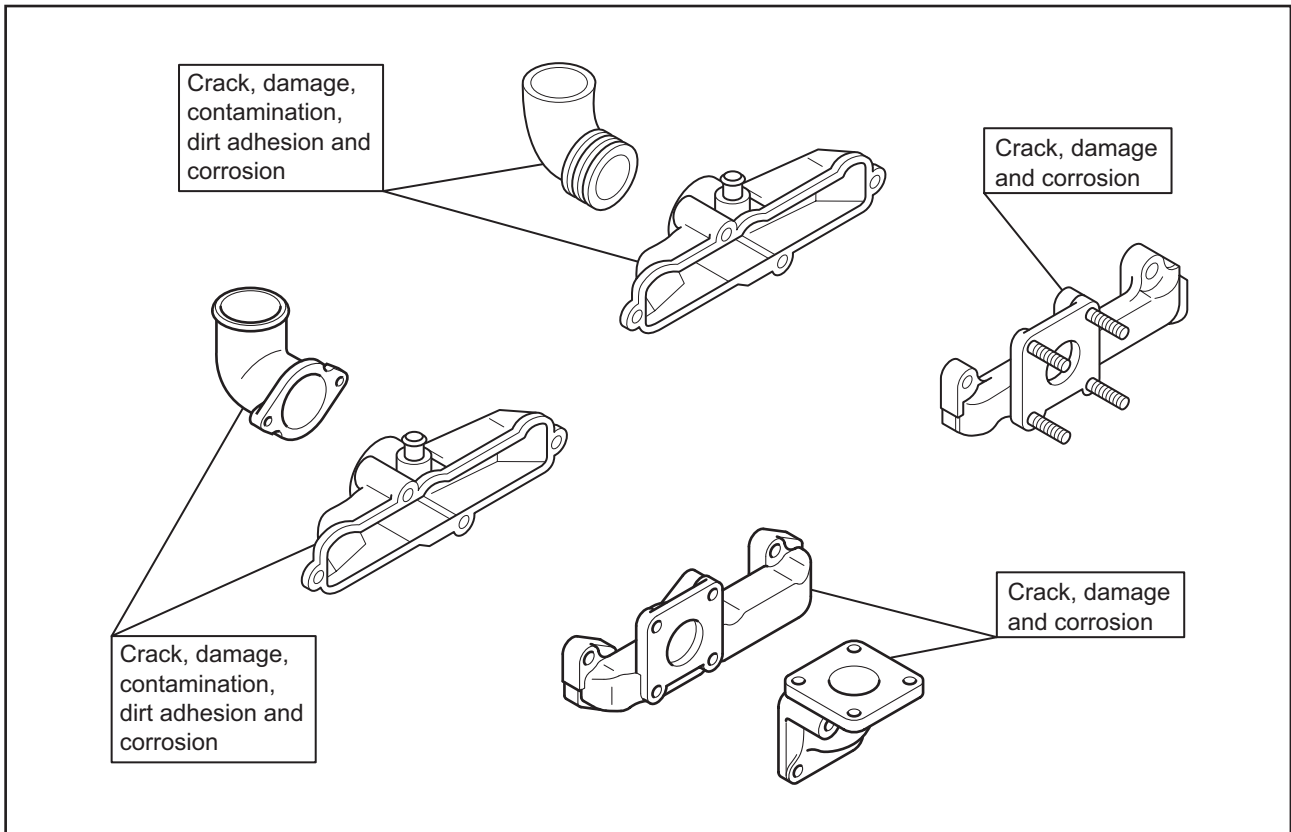
2 Inlet cover

3 Exhaust manifold

4 Exhaust elbow

## 2. Disassembling, inspecting and reassembling inlet and exhaust systems

### 2.1 Inspecting inlet cover and exhaust manifold

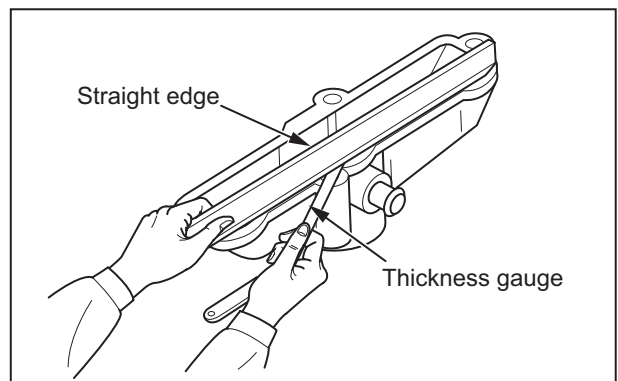


Inspecting inlet cover and exhaust manifold

### 2.2 Measuring distortion of inlet and exhaust manifold

Using a straight edge and thickness gauges, measure distortion across the cylinder head mounting surfaces of the inlet cover and exhaust manifold. If the measured distortion exceeds the limit, correct by grinding or replace the part.

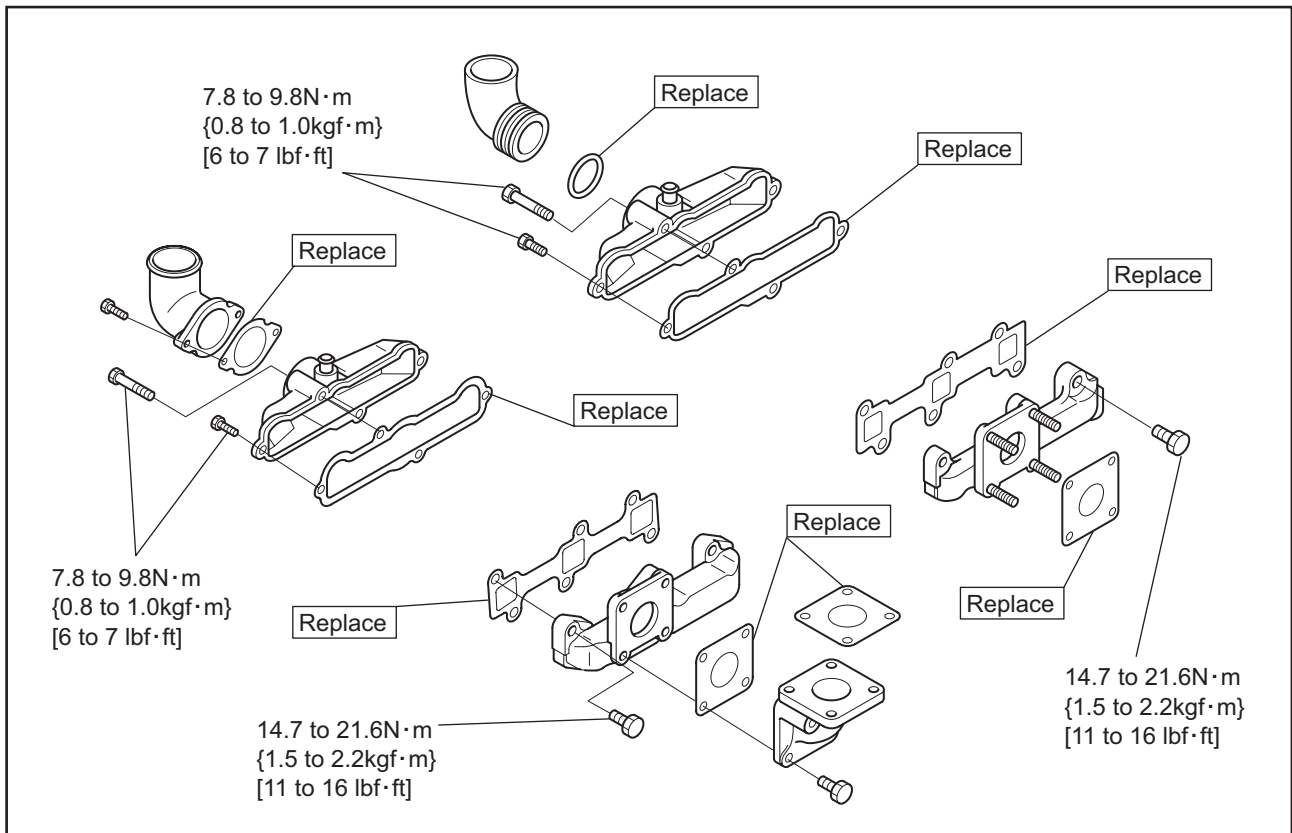
Item	Limit
Distortion on mounting surfaces of intake cover and exhaust manifold	0.15 mm [0.0059 in.]



Measuring distortion on inlet cover

### 3. Installing inlet and exhaust systems

#### 3.1 Installing inlet cover and exhaust manifold



Installing inlet cover and exhaust manifold

# ELECTRICAL SYSTEM

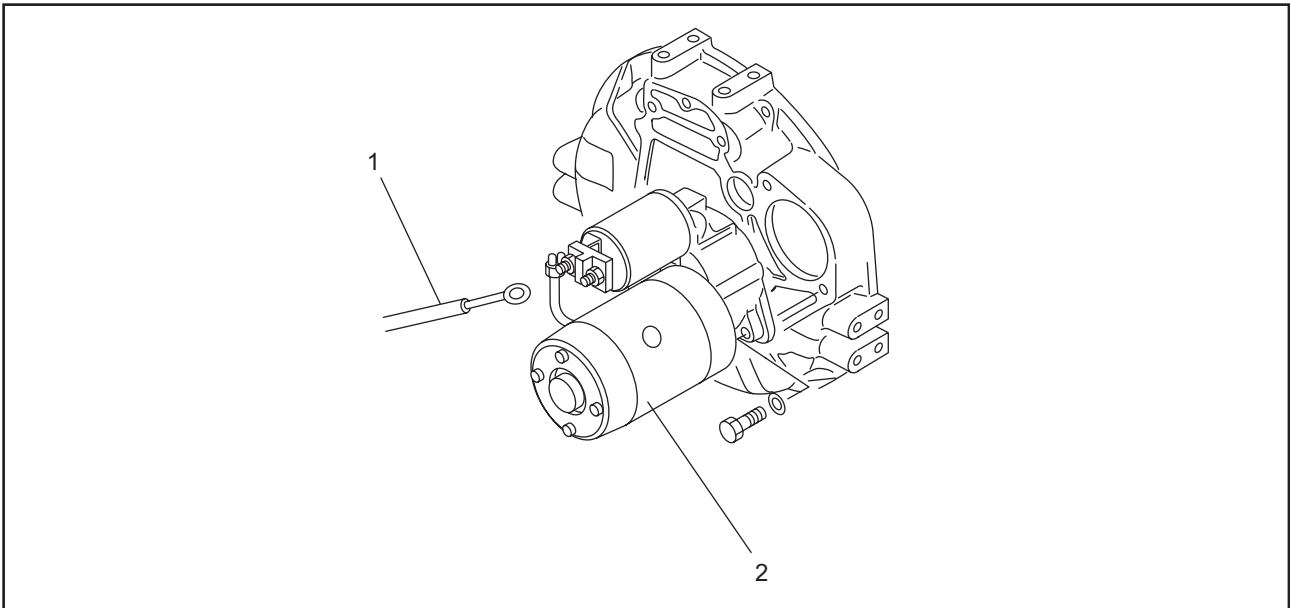
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## 1. Removing electrical system

### 1.1 Removing starter



Removing starter

Removing sequence

1 Harness

2 Starter

**1.2 Inspection before removing alternator (A007TA0171B (12V-40A), A007TA8271A (24V-25A))**

**1.2.1 Inspecting alternator operation**

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

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

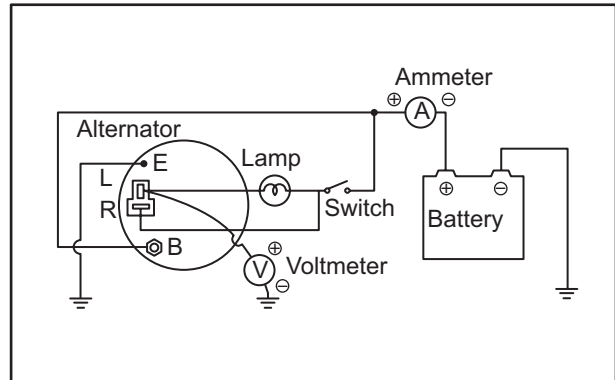
**1.2.2 Handling precaution**

Improper handling could cause damage or failure to the alternator.

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

**1.2.3 Inspecting regulated voltage**

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

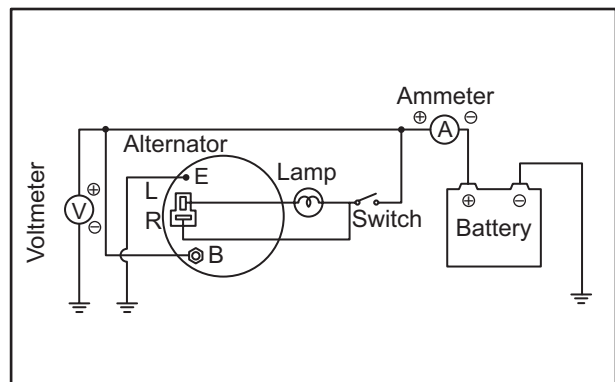


Checking regulated voltage

Item		Standard	V-A
Regulated voltage (at 20°C) [68°F]	A007TA0171B	14.7±0.3 V	12-40
	A 007TA8271A	28.5±0.5 V	24-25

**1.2.4 Inspecting output**

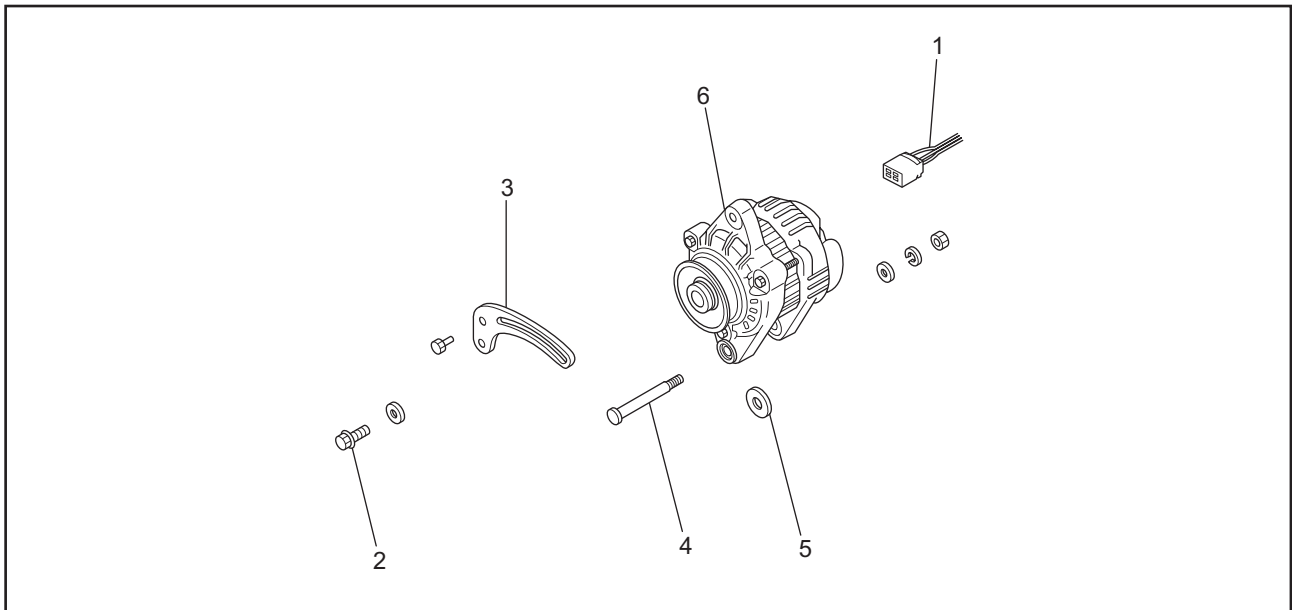
- (1) Disconnect the battery ground cable.
- (2) Connect B terminal of the alternator to the ammeter, then connect the voltmeter between B terminal and ground.
- (3) Connect the battery ground cable.
- (4) Start the engine.
- (5) Immediately apply all loads such as lamps.
- (6) Increase the engine speed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



Inspecting regulated voltage

Item		Standard	
		Terminal voltage/current	Alternator rotation speed
Output characteristics (when hot)	A007TA0171B	13.5 V/21 A or higher	2500 min <sup>-1</sup>
		13.5 V/37 A or higher	5000 min <sup>-1</sup>
	A007TA8271A	27.0 V/18 A or higher	2500 min <sup>-1</sup>
		27.0 V/22 A or higher	5000 min <sup>-1</sup>

### 1.3 Removing alternator

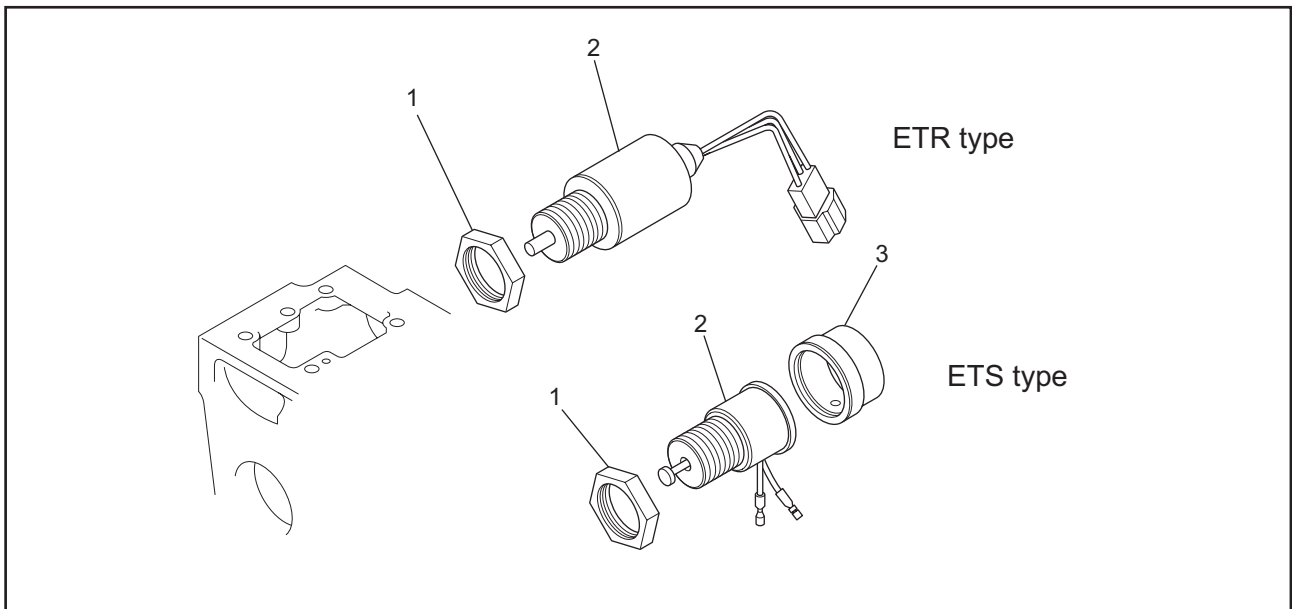


Removing alternator

#### Removing sequence

- |               |                   |              |
|---------------|-------------------|--------------|
| 1 Harness     | 3 Generator brace | 5 Washer     |
| 2 Flange bolt | 4 Bolt            | 6 Alternator |

### 1.4 Removing stop solenoid

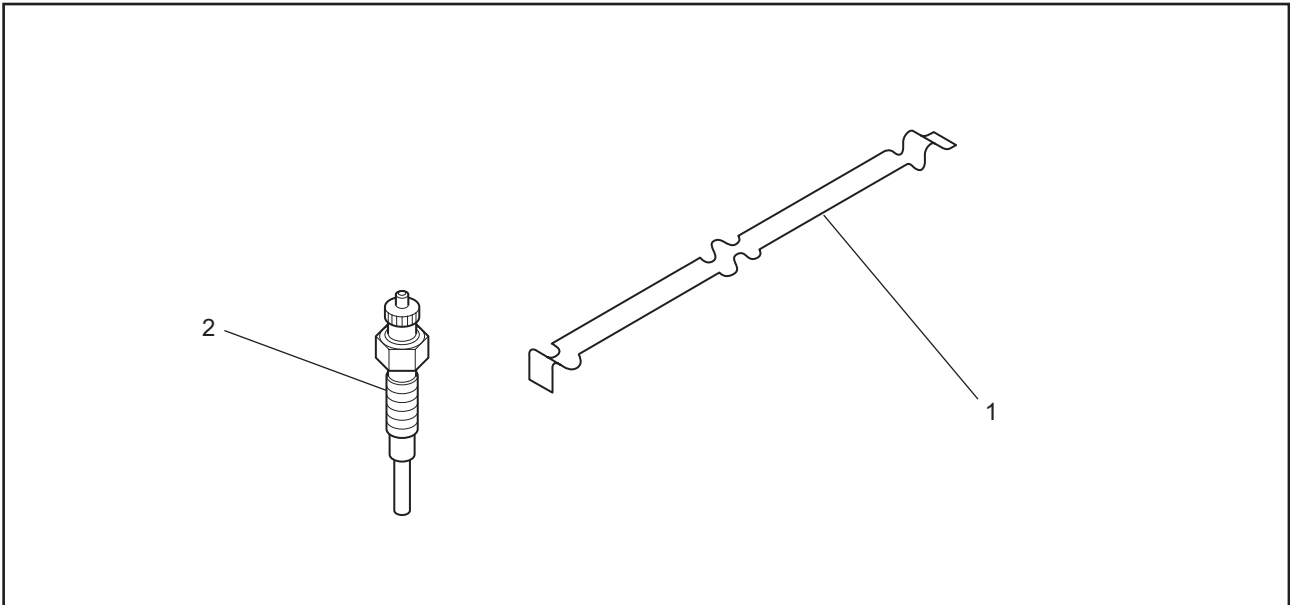


Removing stop solenoid

#### Removing sequence

- |       |                 |                         |
|-------|-----------------|-------------------------|
| 1 Nut | 2 Stop solenoid | 3 Rubber cap (ETS type) |
|-------|-----------------|-------------------------|

### 1.5 Removing glow plug



Removing glow plug

Removing sequence

1 Glow plug plate

2 Glow plug

**2. Disassembling, inspecting and reassembling electrical system**

**2.1 Inspection before disassembling starter (M000T60481 (12V-1.2kW), M001T68381 (12V-1.7kW))**

**2.1.1 Inspecting pinion clearance**

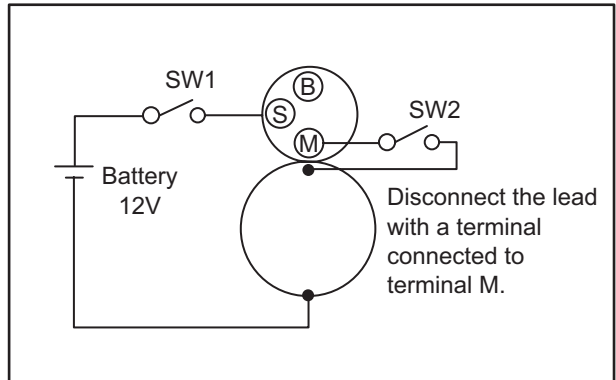
**CAUTION**

Do not apply current continuously for longer than 10 seconds.

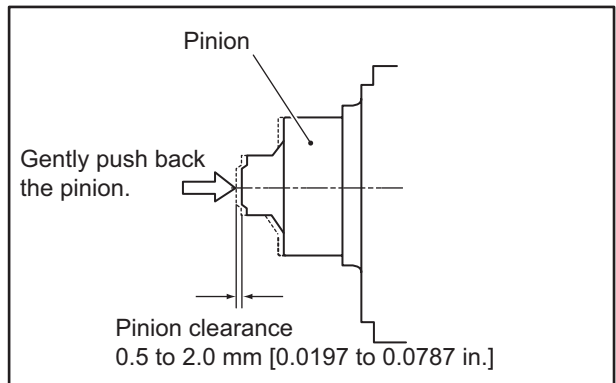
- (1) Connect the starter to the circuit as shown in the illustration.
- (2) When the switches SW1 and SW2 are turned ON, the pinion springs out to the cranking position and the armature rotates.
- (3) Turn the switch SW2 OFF to stop the rotation of the armature.
- (4) Gently push back the pinion in the out position with a finger and measure the distance over which the pinion has returned (movement amount).
- (5) If the measured value is out of the standard, increase or decrease the number of packings between the magnetic switch and the front bracket for adjustment, or replace the lever with a new one.

Note: When the number of packings is increased, the pinion clearance becomes small.

Item	Standard
Pinion gap	0.5 to 2.0 mm [0.0197 to 0.0787 in.]



Wiring during inspection of pinion clearance



Inspecting pinion clearance

### 2.1.2 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

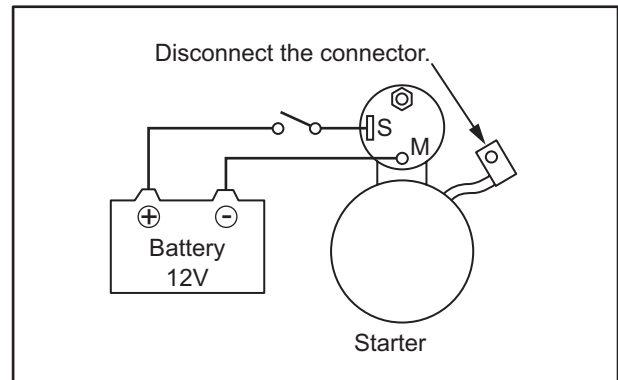
Connect the starter to the circuit as shown in the illustration. The magnetic switch is normal if the pinion springs out when the switch is turned ON.

(3) Holding test

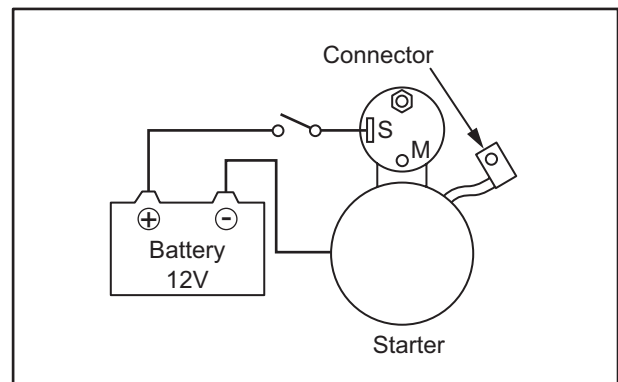
Connect the starter to the circuit as shown in the illustration. Pull out the pinion fully by hand. The magnetic switch is normal if the pinion does not return when it is released.

(4) Return test

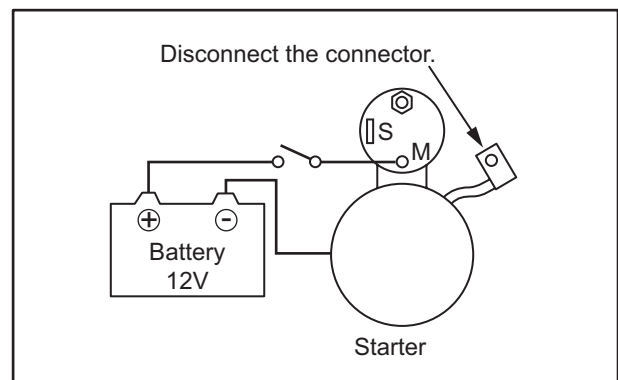
Connect the starter to the circuit as shown in the illustration. Pull out the pinion fully by hand. The magnetic switch is normal if the pinion returns immediately when it is released.



Pull-in test



Holding test



Return test

2.1.3 No load test

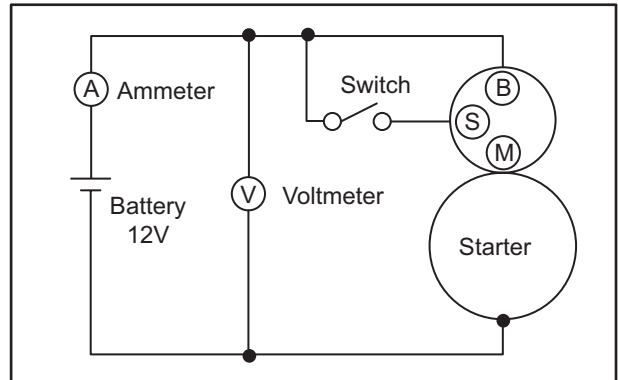
**CAUTION**

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

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

- (1) Connect the starter to the circuit as shown in the illustration.
- (2) In normal condition, the pinion pops out when the switch is turned ON, and the starter rotates at or more the specified rotation speed.

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

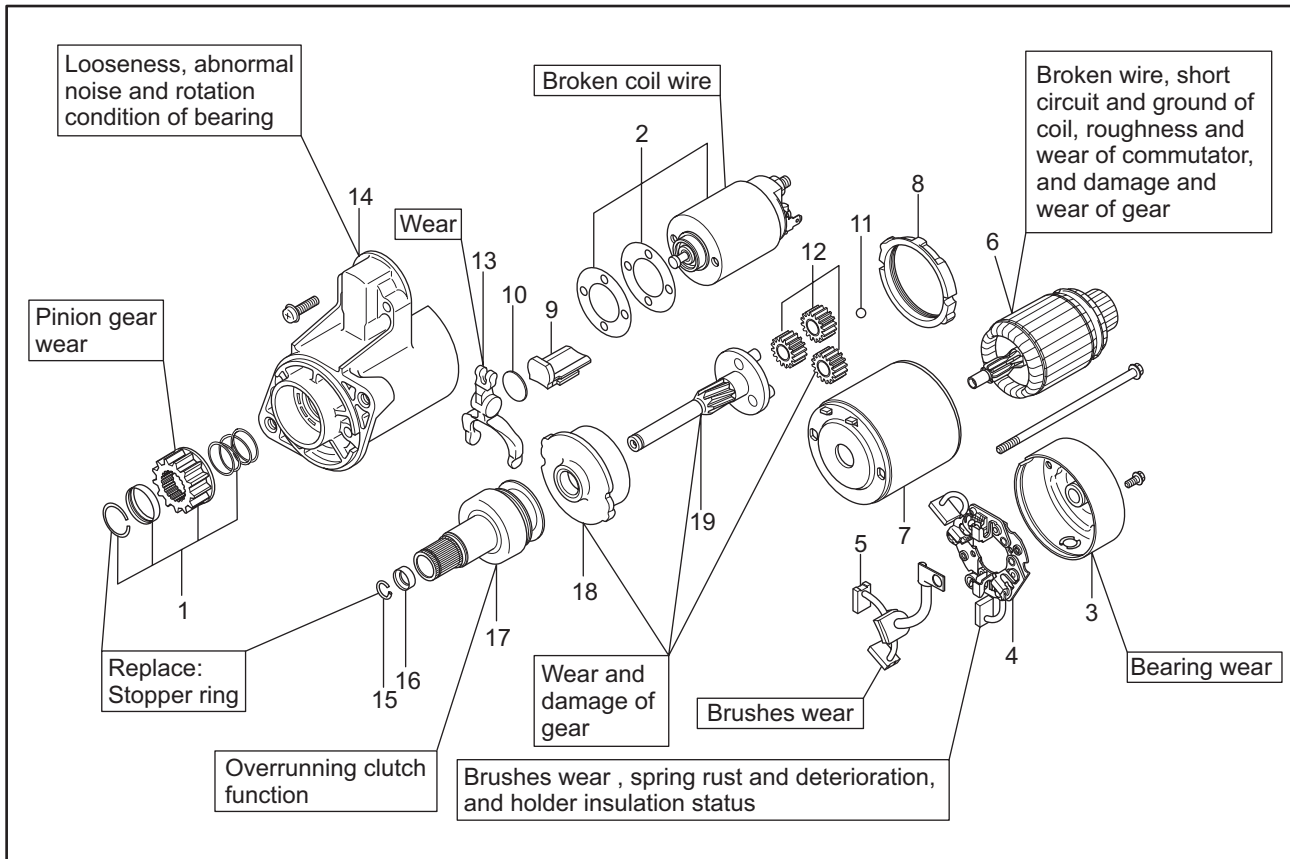


Test at no load

Item		Standard	
Starter model name		M000T60481	M001T68381
Nominal output V-kW		12-1.2	12-1.7
No-load characteristics	Terminal voltage V	11	11
	Current A	90 or less	110 or less
	Rotation speed min <sup>-1</sup>	2500 or more	2400 or more



## 2.2 Disassembling and inspecting starter (M000T60481 (12V-1.2kW), M001T68381 (12V-1.7kW))



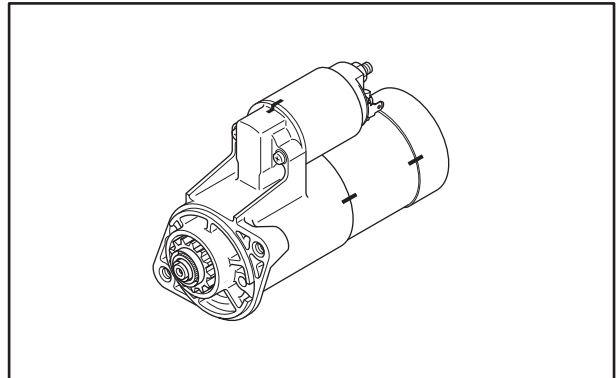
Disassembling and inspecting starter (M000T60481 (12V-1.2kW), M001T68381 (12V-1.7kW))

### Disassembling sequence

- |                  |                   |                       |
|------------------|-------------------|-----------------------|
| 1 Pinion set     | 8 Packing         | 15 Snap ring          |
| 2 Magnet switch  | 9 Packing         | 16 Stopper            |
| 3 Rear bracket   | 10 Plate          | 17 Overrunning clutch |
| 4 Brush holder   | 11 Ball           | 18 Internal gear      |
| 5 Brush assembly | 12 Planetary gear | 19 Gear shaft         |
| 6 Armature       | 13 Lever          |                       |
| 7 Yoke           | 14 Front bracket  |                       |

**2.3 Preparation before disassembling**

Mark the mating marks on magnetic switch, front bracket, center bracket, yoke and rear bracket to each other for reassembly.



Preparatory work before disassembly

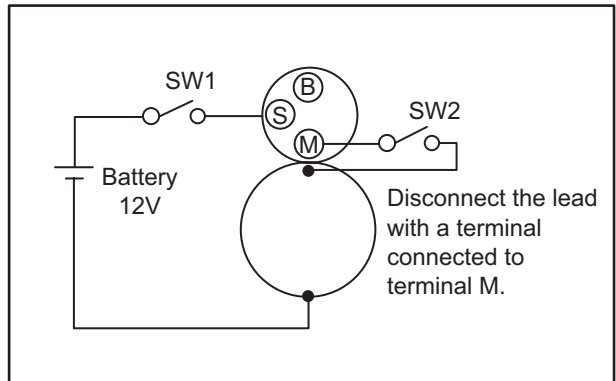
**2.3.1 Removing pinion set**

**CAUTION**

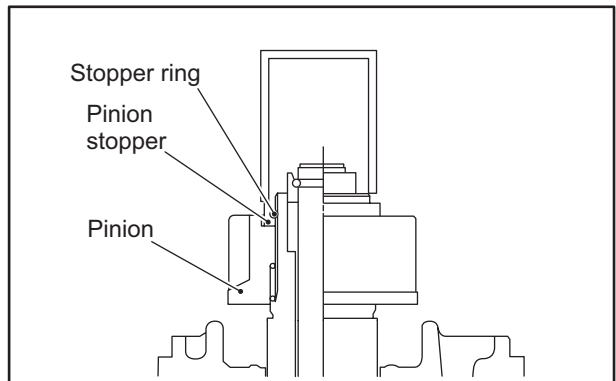
The starter generates heat if it is left with current being applied. Remove the pinion within 10 seconds.

- (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.



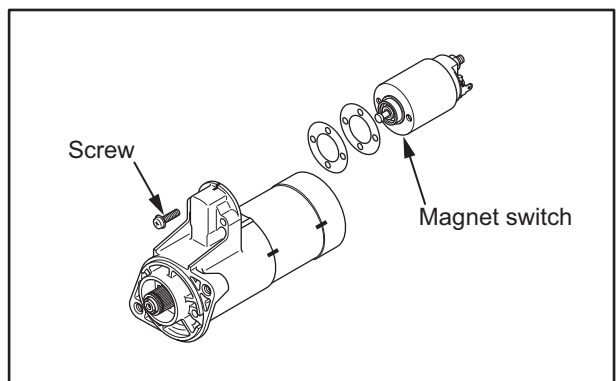
Connection to move the pinion forward



Removing pinion

**2.3.2 Removing magnetic switch**

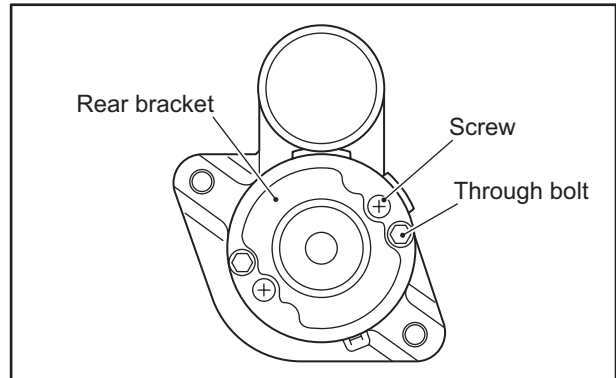
Disconnect the leads, and remove the magnetic switch.



Removing magnetic switch

### 2.3.3 Removing rear bracket

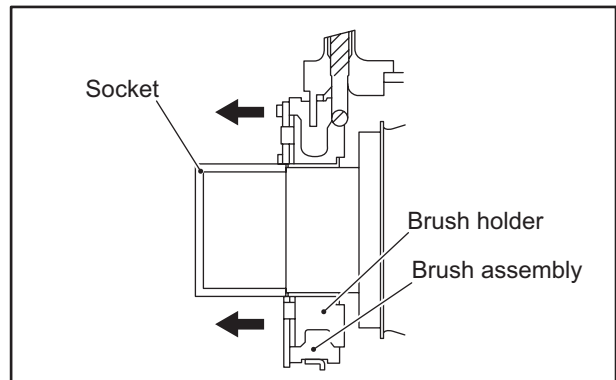
Remove the through bolts and screws of the brush holder, and then remove the rear bracket.



Removing rear bracket

### 2.3.4 Removing brush holder and brush assembly

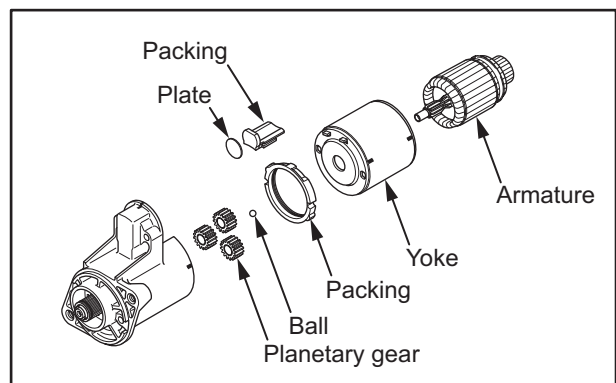
Apply a socket (of the same diameter as the commutator) to the commutator of the armature. Remove the brush holder and brush assembly by sliding on the socket.



Removing brush holder and brush assembly

### 2.3.5 Removing armature and yoke

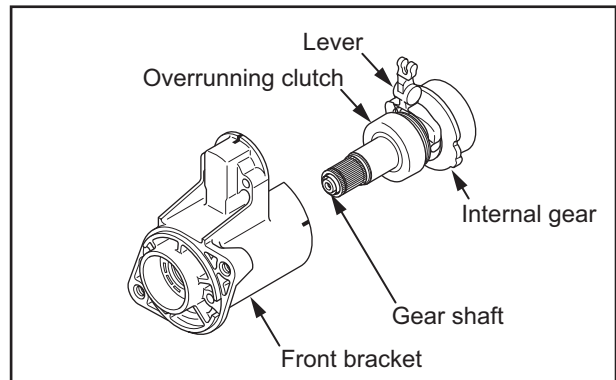
- (1) Remove the armature and the yoke.
- (2) Remove the packing from the internal gear.
- (3) Remove the packing and plate on the lever support.
- (4) Remove the ball from the internal gear.
- (5) Remove the planetary gears.



Removing armature and yoke

### 2.3.6 Removing overrunning clutch

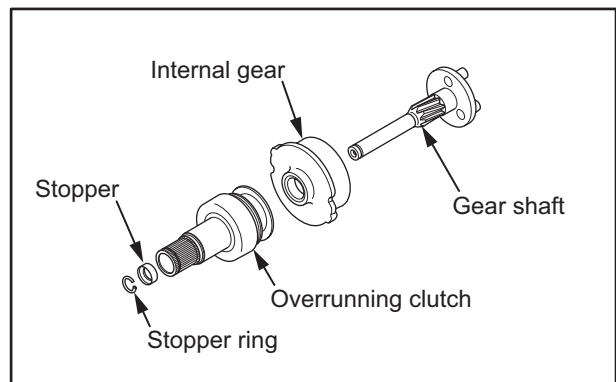
Pull out the internal gear, gear shaft, overrunning clutch and lever as an assembly from the front bracket, and remove the lever.



Removing overrunning clutch

### 2.3.7 Removing gear shaft

- (1) Remove the stopper ring and then the stopper.
- (2) Separate the overrunning clutch, internal gear and gear shaft.



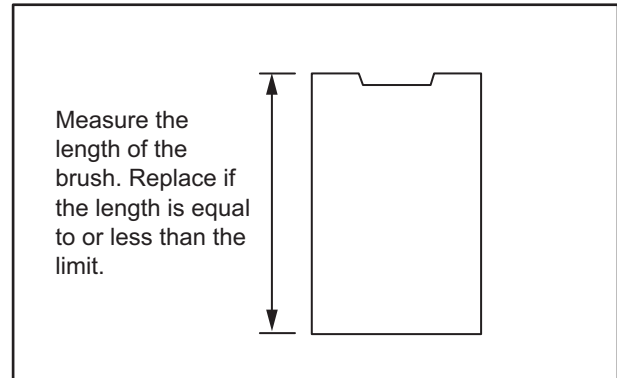
Removing gear shaft

## 2.4 Inspecting and repairing starter (M000T60481 (12V-1.2kW), M001T68381 (12V-1.7kW))

### 2.4.1 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	16.5 mm [0.650 in.]	10.0 mm [0.394 in.]

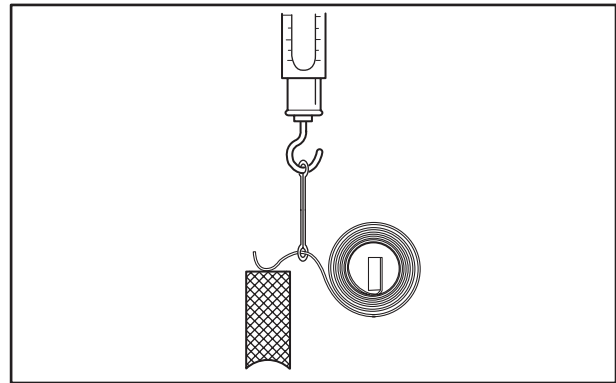


Inspecting brushes for wear

### 2.4.2 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	17.5 to 23.7 N { 1.78 to 2.42 kgf } [3.92 to 5.34 lbf]	6.86 N { 0.70 kgf } [1.54 lbf]

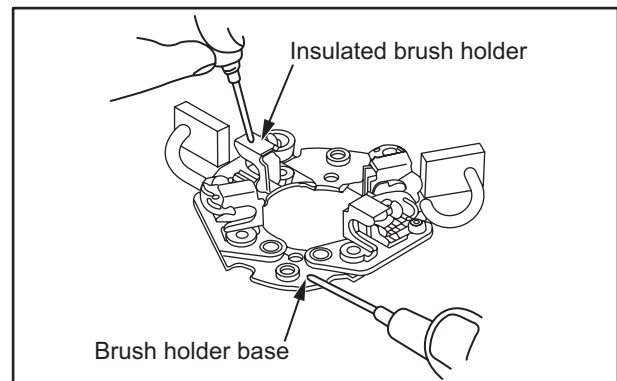


Measuring brush spring load

### 2.4.3 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.

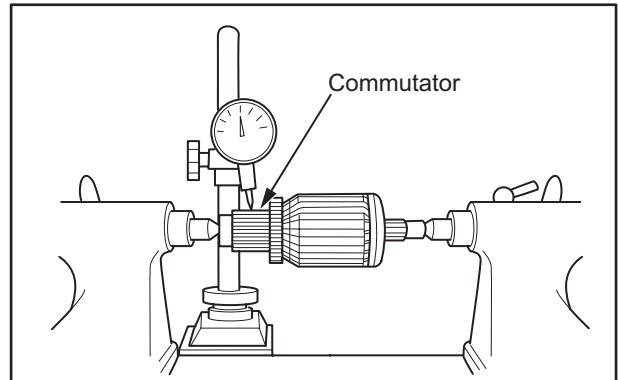


Checking brush holder for grounding

**2.4.4 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 radial runout	0.03 mm [0.0012 in.]	0.10 mm [0.0039 in.]

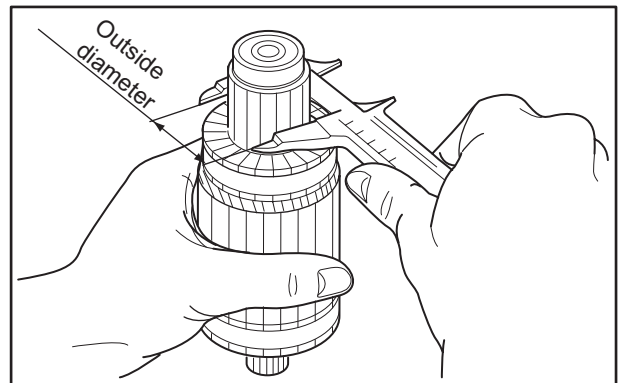


Measuring commutator radial runout

**2.4.5 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	Standard	Limit
Commutator outside diameter	29.4 mm [1.158 in.]	28.8 mm [1.134 in.]

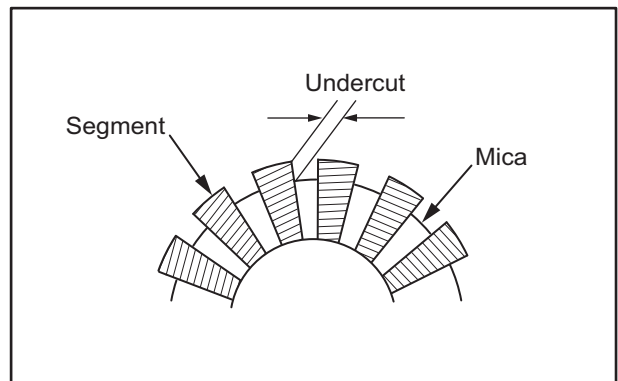


Measuring commutator outside diameter

**2.4.6 Measuring undercut depth**

Measure the depth of undercutting between the commutator segments. If the measured value is less than the limit, repair or replace with a new part.

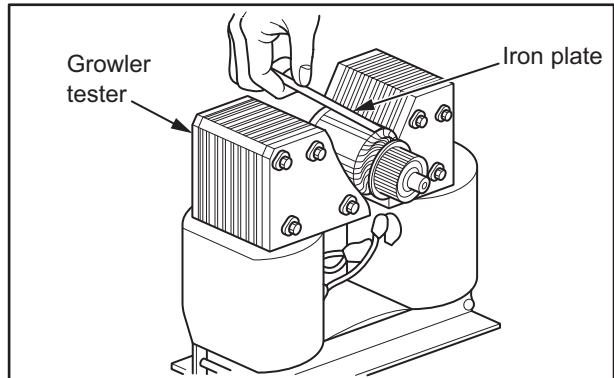
Item	Standard	Limit
Undercutting depth	0.5 to 1.0 mm [0.0197 to 0.0394 in.]	0.2 mm [0.0079 in.]



Measuring commutator mica depth

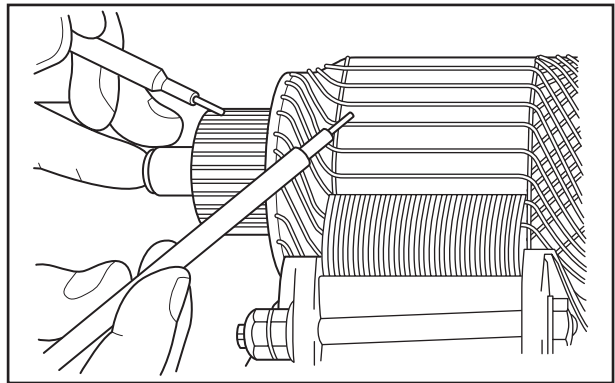
### 2.4.7 Checking armature coil

- (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.



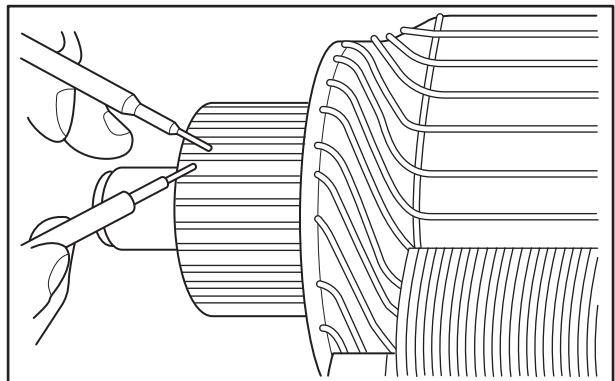
Inspecting armature coil for short circuit

- (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.



Checking armature coil for grounding

- (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.



Checking armature coil for breaks

### 2.4.8 Inspecting rear bracket

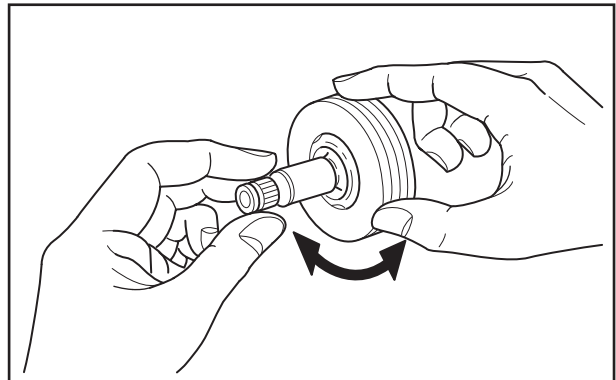
Replace the rear bracket if the bearing is worn.

**2.4.9 Inspecting overrunning clutch**

**CAUTION**

Do not clean the overrunning clutch in wash oil.

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



Inspecting overrunning clutch

**2.4.10 Inspecting pinion**

Check the pinion for wear and damage.  
If faulty, replace the pinion with a new one.

**2.4.11 Inspecting front bracket**

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

**2.4.12 Inspecting gears of starter**

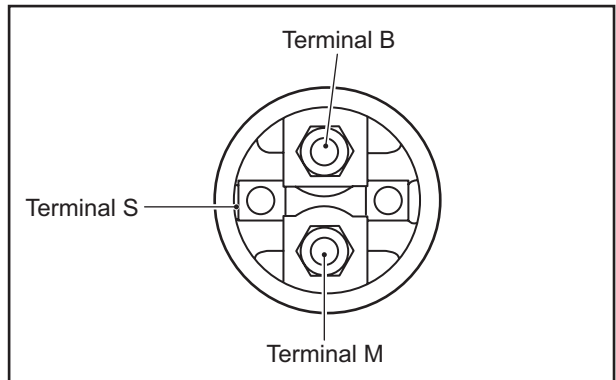
Check gears of the starter for wear or damage. If faulty, replace the starter.

**2.4.13 Inspecting continuity of magnetic switch (between M terminal and case)**

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

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

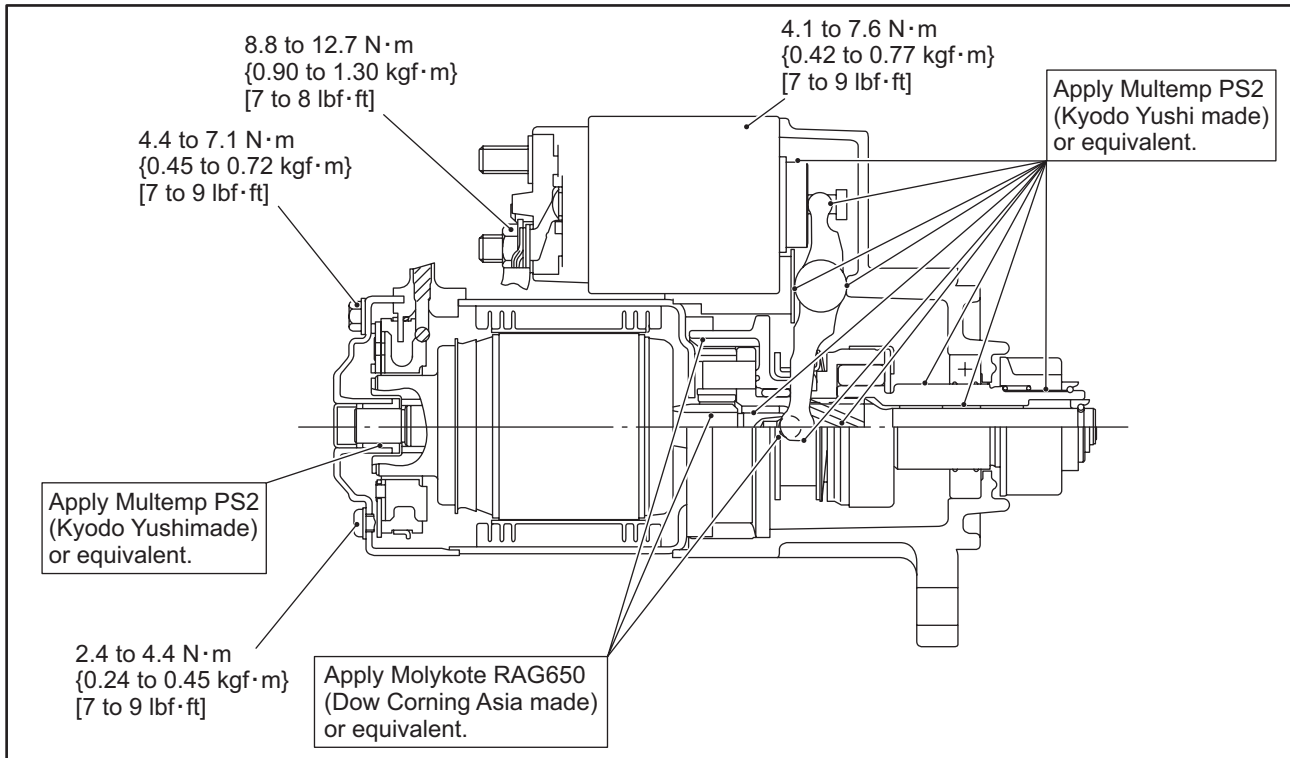
Check that there is no continuity between M terminal and B terminal. If continuity is observed, replace the magnetic switch with a new one.



Inspecting magnetic switch



## 2.5 Reassembling starter (M000T60481 (12V-1.2kW), M001T68381 (12V-1.7kW))



Reassembling starter (M000T60481 (12V-1.2kW), M001T68381 (12V-1.7kW))

### 2.5.1 Applying grease

#### CAUTION

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

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

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

(1) Areas to which Multemp PS2 (Kyodo Yushi made) or the equivalent is applied

Plunger surface (a small amount)	Spline of gear shaft
Shaft sliding area of overrunning clutch	Sliding area between lever and overrunning clutch
Gear shaft	Bearing of gear shaft
Pinion gear fitting surface	Rear bearing

(2) Areas to which Molykote AG-650 (Dow Corning Asia made) or the equivalent is applied

Ball	Gear shaft, gear and internal gear of armature
------	--

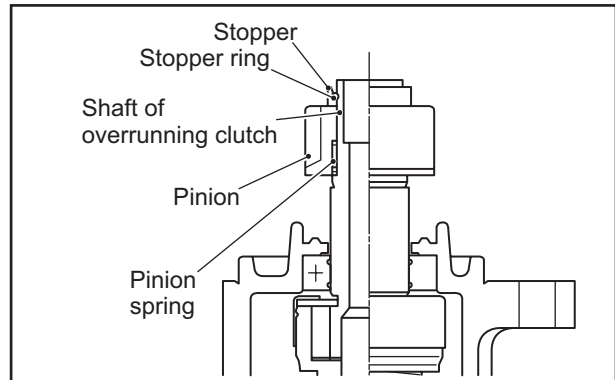
### 2.5.2 Installing pinion

**CAUTION**

Before assembling, apply grease to the inner race groove of the front bracket bearing.

Be sure to use a new stopper ring. Do not reuse the stopper ring that has been removed.

- (1) Put the overrunning clutch through the front bracket.
- (2) Fit the internal gear into the gear shaft.
- (3) Put the gear shaft through the overrunning clutch and install the stopper on it.
- (4) Install the stopper ring firmly to the shaft groove of overrunning clutch.
- (5) Using a gear puller, firmly pull the pinion stopper closer to the stopper ring to fix.



Installing pinion

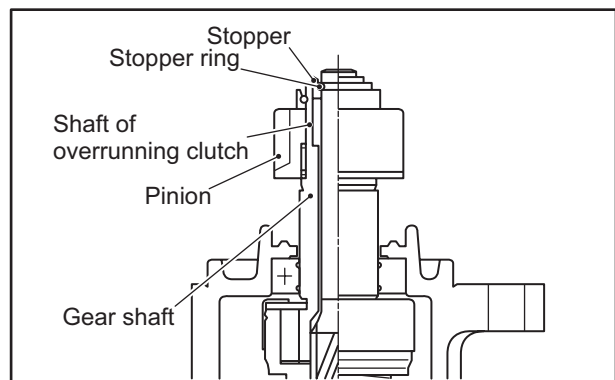
### 2.5.3 Installing gear shaft

**CAUTION**

Be sure to use a new stopper ring. Do not reuse a removed one.

- (1) Reassemble the lever to the overrunning clutch.
- (2) Fit the internal gear into the gear shaft.
- (3) Put the gear shaft through the overrunning clutch and install the stopper on it.
- (4) Fit the stopper ring into the groove of the stopper ring and firmly pinch it.
- (5) Using a gear puller, firmly pull the pinion and fit the stopper into the stopper ring.

Note: The adjustment of play in the axial direction of the gear shaft is not necessary because its required amount is automatically secured.

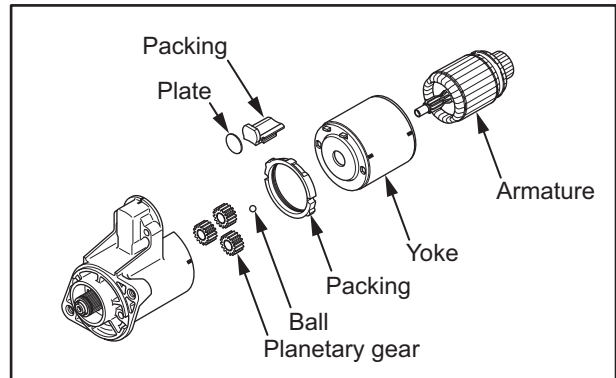


Installing gear shaft

### 2.5.4 Installing yoke and armature

- (1) Install the planetary gears on the gear shaft.
- (2) Install the packing on the internal gear.
- (3) Install the plate and packing.
- (4) Install the yoke on the front bracket.
- (5) Apply grease to the armature shaft end and install a ball on it.
- (6) Install the armature.

Note: The adjustment of play in the axial direction of the armature shaft is not necessary.

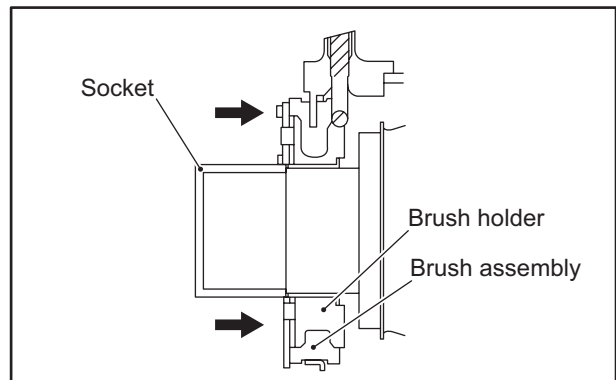


Installing yoke and armature

### 2.5.5 Installing brush holder and brush assembly

Attach the socket to the commutator of the armature.

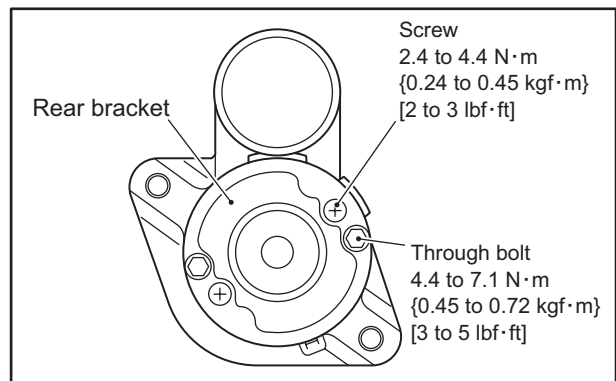
While sliding the brushes on the socket, install the brush holder and brush assembly on the armature.



Installing brush holder and brush assembly

### 2.5.6 Installing rear bracket

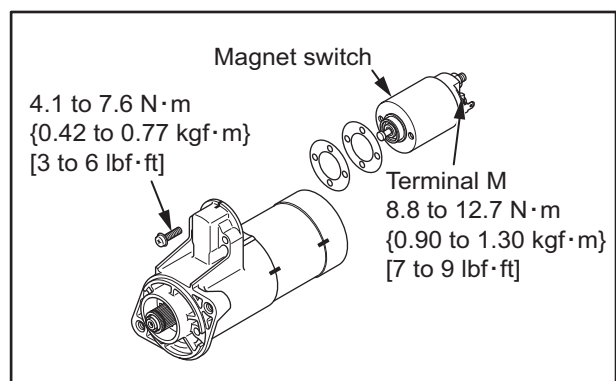
Install the rear bracket to the yoke, and tighten the through bolt and the brush holder screws.



Installing rear bracket

### 2.5.7 Installing magnetic switch

- (1) Install the magnetic switch and tighten the screws.
- (2) Connect the lead to the terminal M and secure it with the fixing nut.



Installing magnetic switch

2.5.8 Inspecting pinion clearance

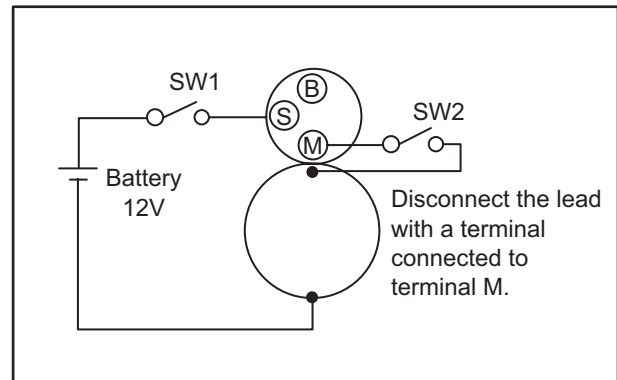
**CAUTION**

Do not apply current continuously for longer than 10 seconds.

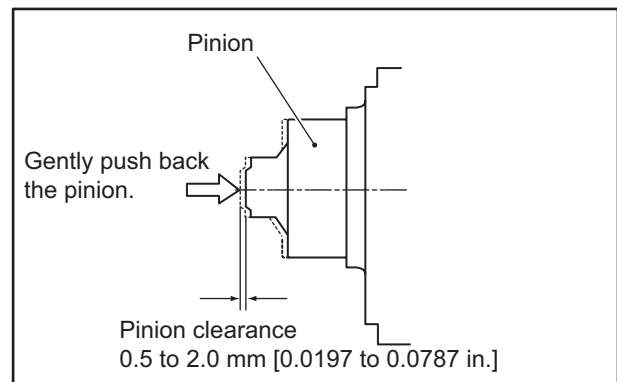
- (1) Connect the starter to the circuit as shown in the illustration.
- (2) When the switches SW1 and SW2 are turned ON, the pinion springs out to the cranking position and the armature rotates.
- (3) Turn the switch SW2 OFF to stop the rotation of the armature.
- (4) Gently push back the pinion in the out position with a finger and measure the distance over which the pinion has returned (movement amount).
- (5) If the measured value is out of the standard, increase or decrease the number of packings between the magnetic switch and the front bracket for adjustment, or replace the lever with a new one.

Note: When the number of packings is increased, the pinion clearance becomes small.

Item	Standard
Pinion gap	0.5 to 2.0 mm [0.0197 to 0.0787 in.]



Wiring during inspection of pinion clearance



Inspecting pinion clearance

## 2.6 Inspection before disassembling starter (M002T66071 (24V-3.2kW))

### 2.6.1 Inspecting pinion clearance

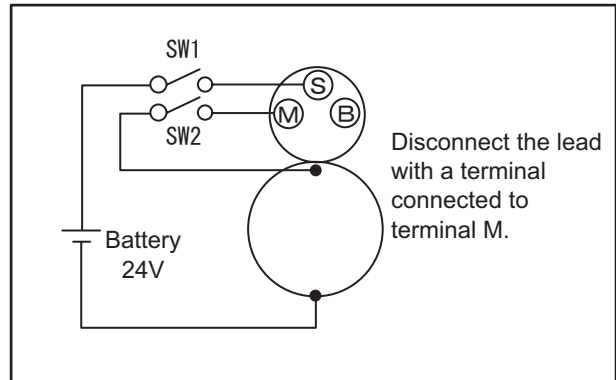
#### CAUTION

Do not apply current continuously for longer than 10 seconds.

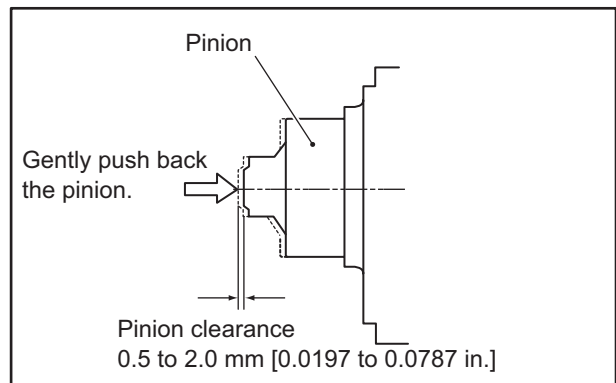
- (1) Connect the starter to the circuit as shown in the illustration.
- (2) When the switches SW1 and SW2 are turned ON, the pinion springs out to the cranking position and the armature rotates.
- (3) Turn the switch SW2 OFF to stop the rotation of the armature.
- (4) Gently push back the pinion in the out position with a finger and measure the distance over which the pinion has returned (movement amount).
- (5) If the measured value is out of the standard, increase or decrease the number of packings between the magnetic switch and the front bracket for adjustment, or replace the lever with a new one.

Note: When the number of packings is increased, the pinion clearance becomes small.

Item	Standard
Pinion gap	0.5 to 2.0 mm [0.0197 to 0.0787 in.]



Wiring during inspection of pinion clearance



Inspecting pinion clearance

**2.6.2 Inspecting magnetic switch**

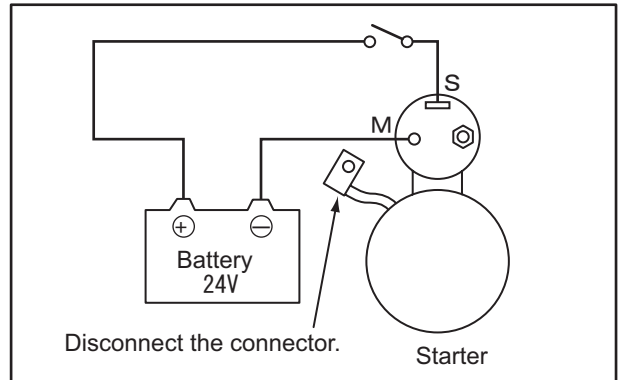
Perform the inspection as described below. If faulty, replace the magnetic switch with a new one.

**CAUTION**

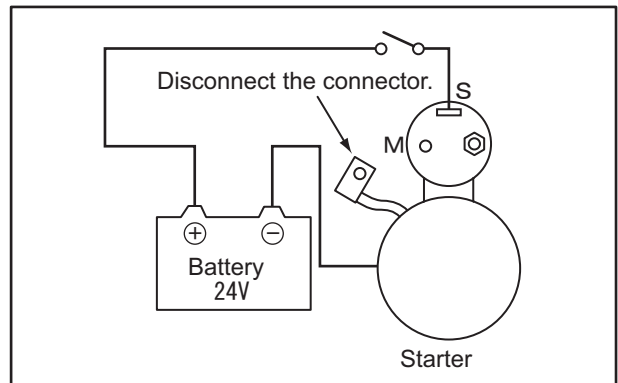
Do not apply current continuously for longer than 10 seconds.

- (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.
- (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.

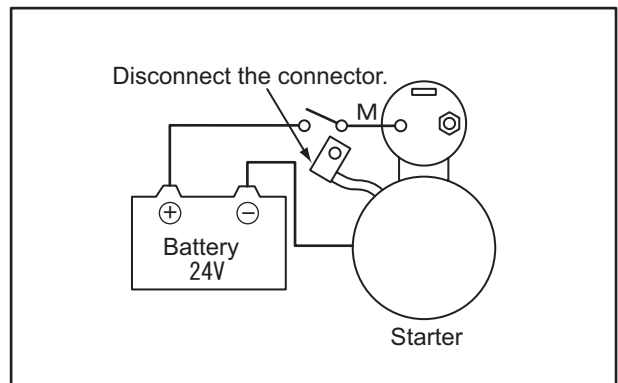
- (4) Return test  
Connect the starter to the circuit as shown in the illustration. Pull out the pinion fully by hand. The magnetic switch is normal if the pinion returns immediately when it is released.



Pull-in test



Holding test



Return test

### 2.6.3 No load test

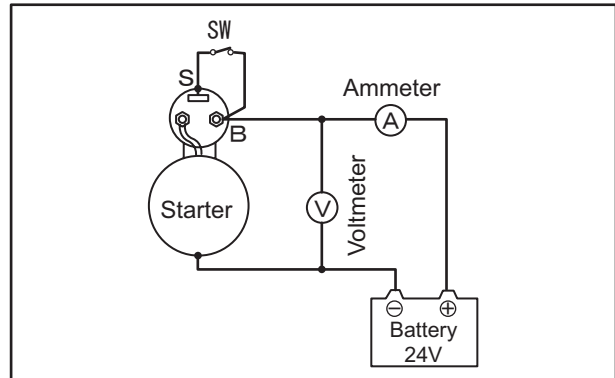
#### CAUTION

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

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

- (1) Connect the starter to the circuit as shown in the illustration.
- (2) In normal condition, the pinion pops out when the switch is turned ON, and the starter rotates at or more the specified rotation speed.

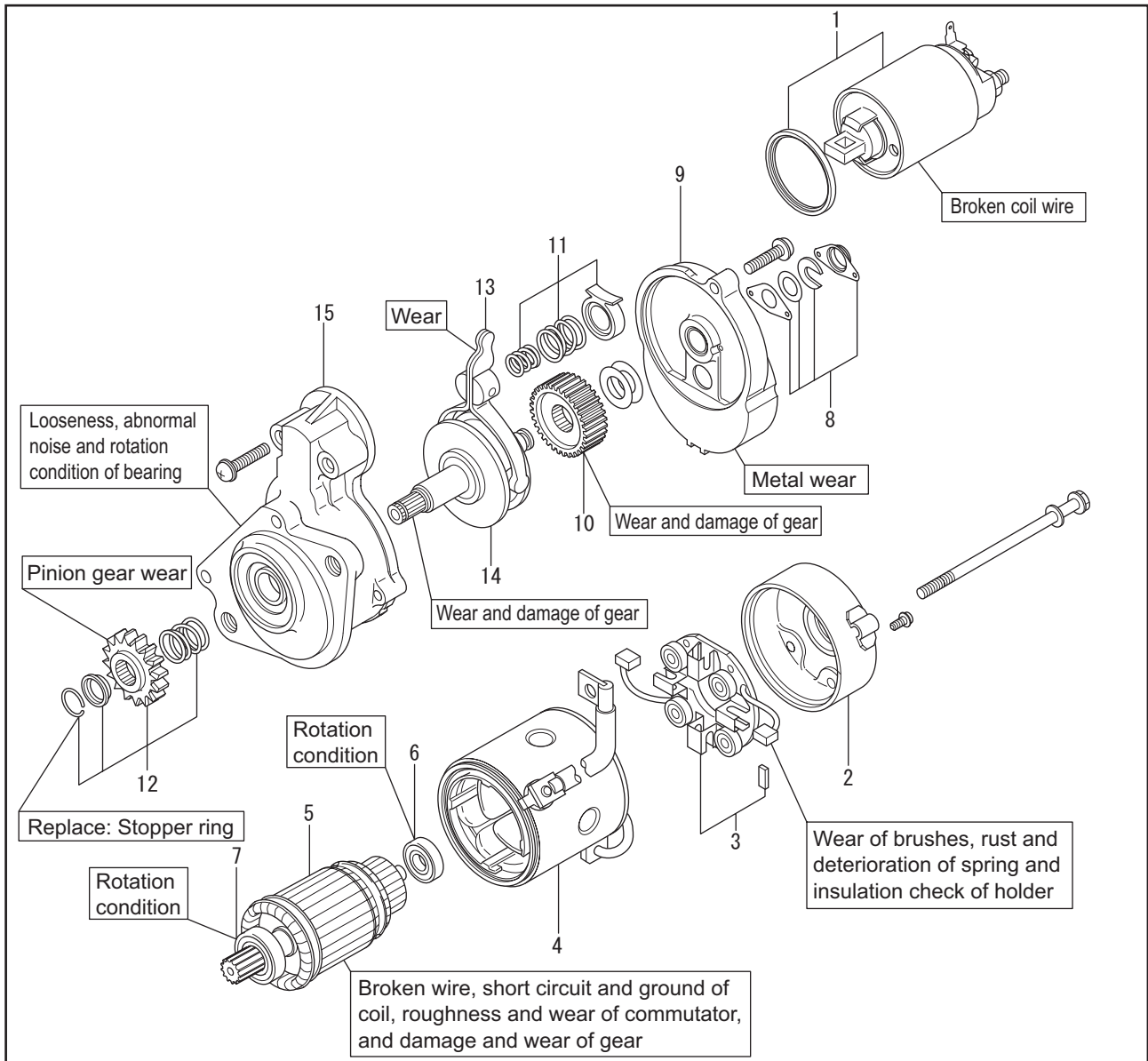
If the terminal voltage, current or rotation speed does not meet the standard, disassemble, inspect and repair the starter.



Test at no load

Item	Standard	
Starter model	M002T66071	
Nominal output V-kW	24-3.2	
No-load characteristics	Terminal voltage V	23
	Current A	80 or less
	Rotation speed min <sup>-1</sup>	3400 or more

2.7 Disassembling and inspecting starter (M002T66071 (24V-3.2kW))



Disassembling and inspecting starter (M002T66071 (24V-3.2kW))

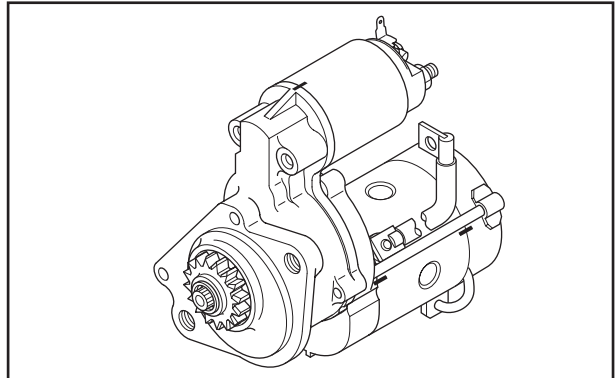
Disassembly sequence

- |                          |                   |                  |
|--------------------------|-------------------|------------------|
| 1 Magnet switch          | 6 Rear bearing    | 11 Spring set    |
| 2 Rear bracket           | 7 Front bearing   | 12 Pinion set    |
| 3 Brush and brush holder | 8 Cover set       | 13 Lever         |
| 4 Yoke                   | 9 Center bracket  | 14 Pinion shaft  |
| 5 Armature               | 10 Reduction gear | 15 Front bracket |



### 2.7.1 Preparation before disassembling

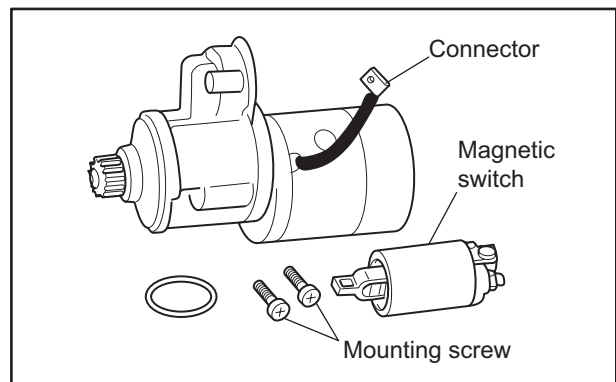
Mark the mating marks on magnetic switch, front bracket, center bracket, yoke and rear bracket to each other for reassembly.



Preparation before disassembling

### 2.7.2 Removing magnetic switch

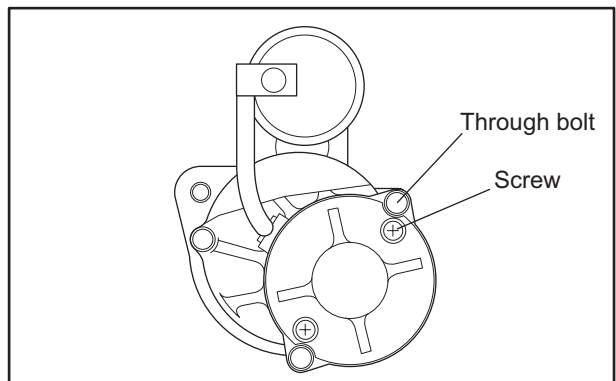
Disconnect the leads, and remove the magnetic switch.



Removing magnetic switch

### 2.7.3 Removing rear bracket

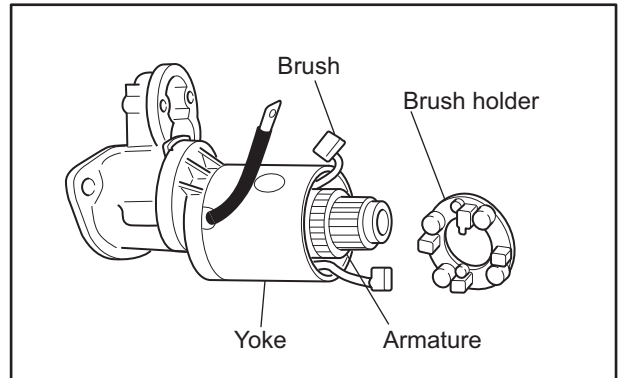
Remove the through bolts and screws of the brush holder, and then remove the rear bracket.



Removing rear bracket

**2.7.4 Removing brushes, brush holder, yoke and armature**

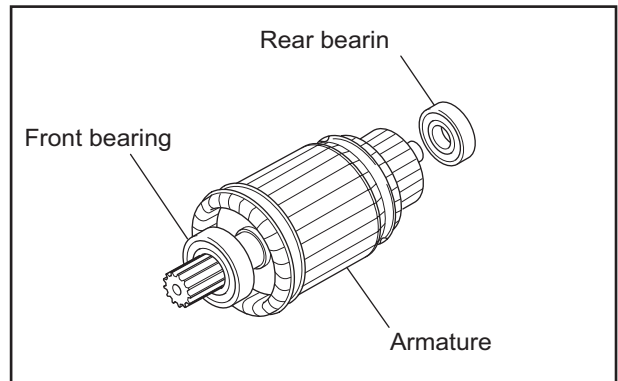
While lifting the two brushes, remove the yoke and brush holder assembly. Then, pull out the armature.



Removing brushes, brush holder, yoke and armature

**2.7.5 Removing ball bearing**

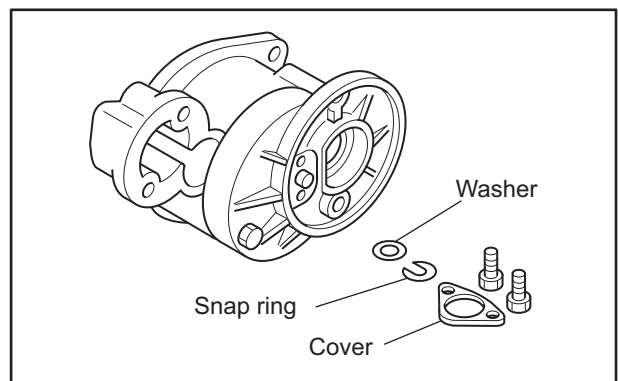
Remove the bearings from both ends of the armature using a puller.



Removing ball bearings

**2.7.6 Removing cover set**

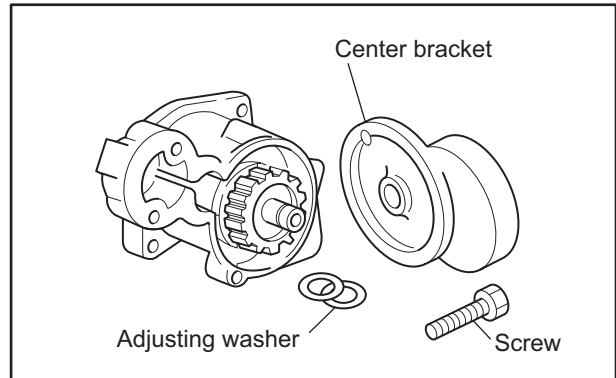
Remove the cover, and pull out the snap ring and the washer.



Removing cover

### 2.7.7 Removing center bracket

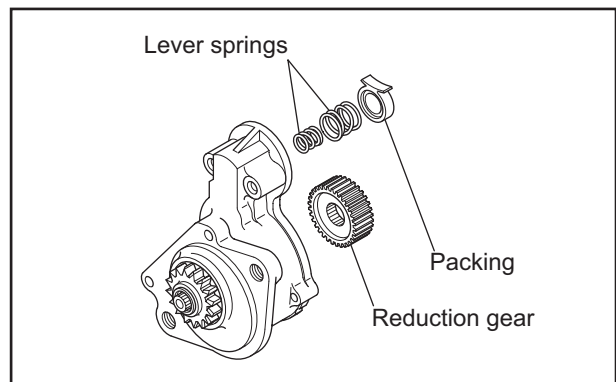
Remove the screw, then remove the center bracket. Once the center bracket is removed, the adjusting washer that adjusts the pinion shaft end play can be removed.



Removing center bracket

### 2.7.8 Removing reduction gear and spring set

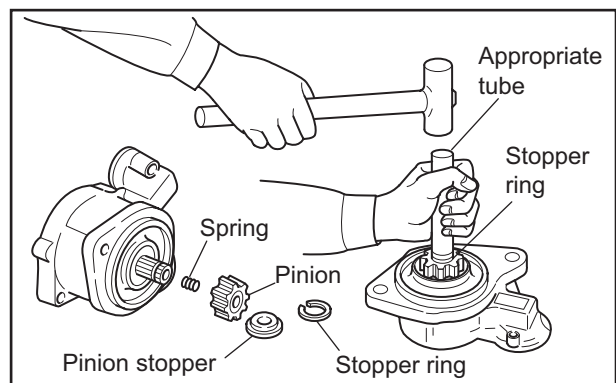
- (1) Remove the reduction gear from the pinion shaft.
- (2) Remove the packing and lever spring from the lever.



Removing reduction gear and spring set

### 2.7.9 Removing pinion set

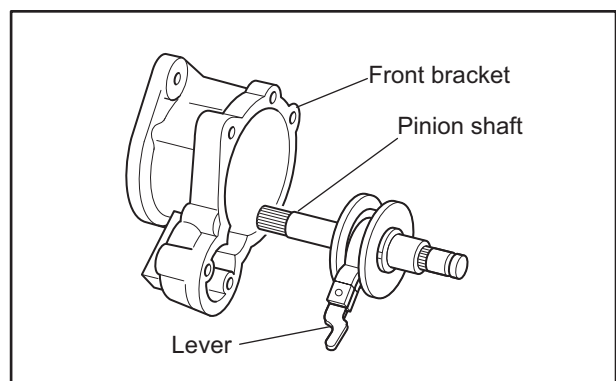
- (1) Place an appropriate tube on the pinion stopper. Tap the tube with a hammer to drop the pinion stopper to the clutch side. This will expose the stopper ring.
  - (2) Ply out the stopper ring, and remove the pinion.
- Note: Do not reuse the stopper ring for reassembly.



Removing pinion

### 2.7.10 Removing lever and pinion shaft

Pull out the lever and pinion shaft from the front bracket.



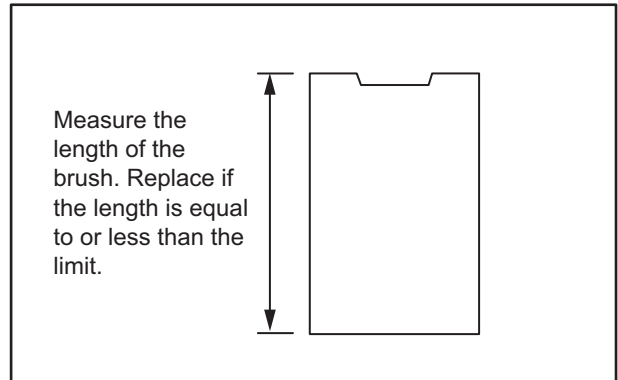
Removing lever and pinion shaft

**2.8 Inspecting and repairing starter (M002T66071 (24V-3.2kW))**

**2.8.1 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 [0.709 in.]	11 mm [0.4331 in.]

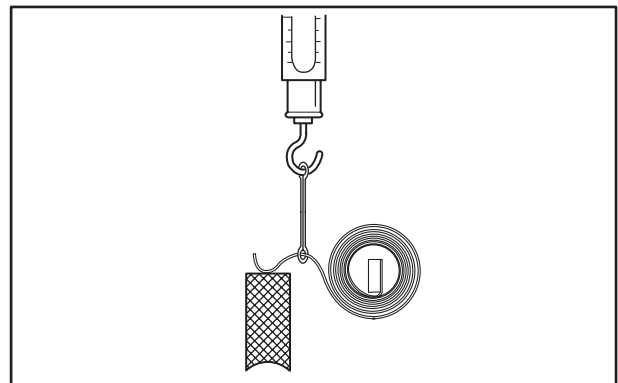


Inspecting brushes for wear

**2.8.2 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	28.9 to 39.1N {2.95 to 3.99kgf} [6.5035 to 8.7963 lbf]	20N {2.04kgf} [4.4974 lbf]

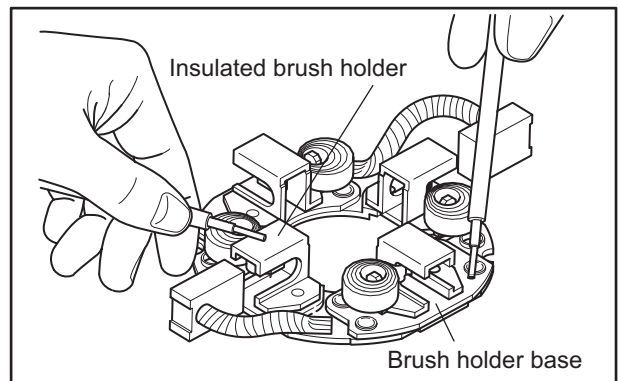


Measuring brush spring load

**2.8.3 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.

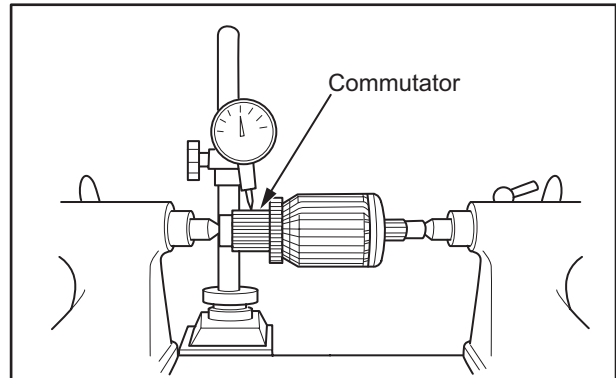


Checking brush holder for grounding

### 2.8.4 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 radial runout	0.03 mm [0.0012 in.]	0.10 mm [0.0039 in.]



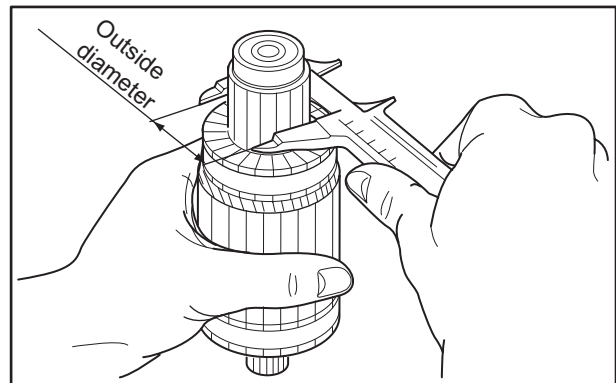
Measuring commutator radial runout

### 2.8.5 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	Standard	Limit
Commutator outside diameter	32.0 mm [1.2598 in.]	31.4 mm [1.2362 in.]



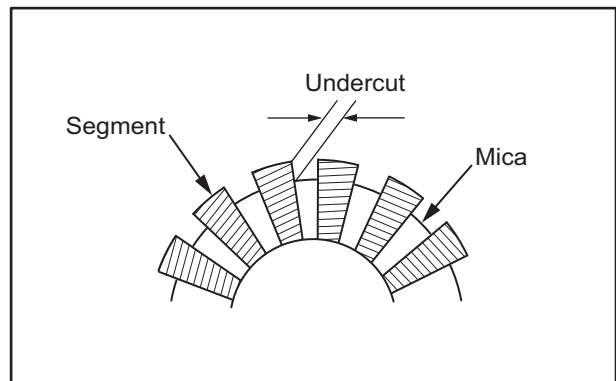
Measuring commutator outside diameter

### 2.8.6 Measuring undercut depth

Measure the depth of undercutting between the commutator segments.

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

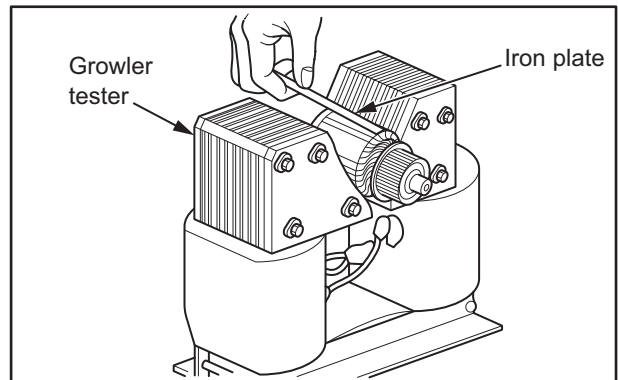
Item	Standard	Limit
Undercutting depth	0.4 to 0.6 mm [0.0158 to 0.0236 in.]	0.2 mm [0.0079 in.]



Measuring commutator mica depth

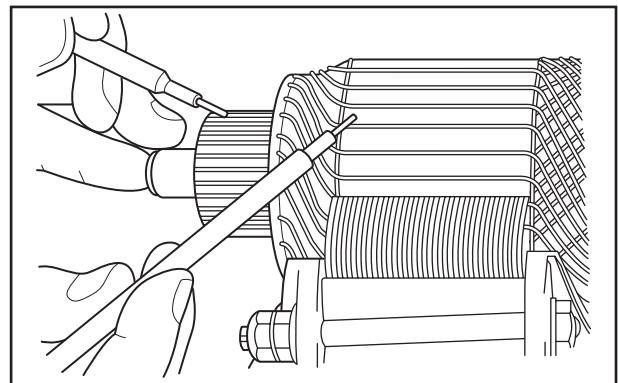
### 2.8.7 Checking armature coil

- (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.



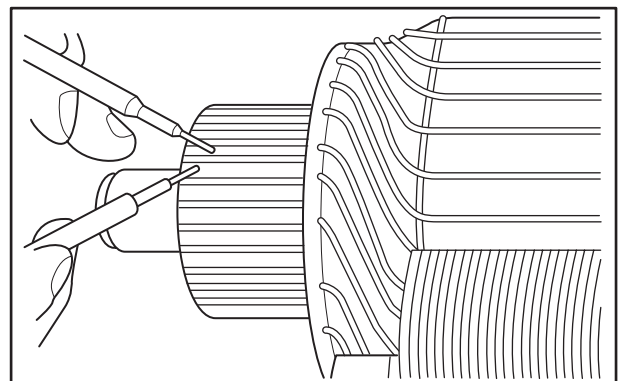
Checking armature coil for short circuit

- (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.



Checking armature coil for grounding

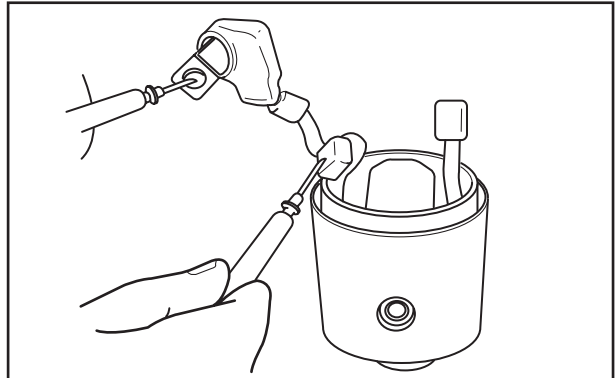
- (3) Check that there is continuity between segments in various combinations.  
If poor or no continuity is observed, replace the armature with a new one.



Testing breaks of armature coil

**2.8.8 Inspecting continuity of yoke assembly**

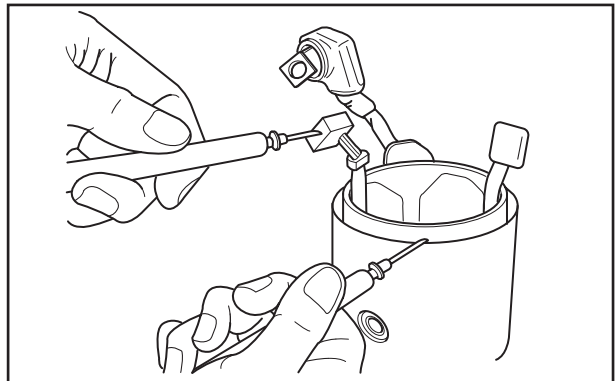
Check that there is continuity between M terminal of field coil and the lead wire for the brush. If no continuity is observed, replace the yoke assembly with a new one.



Checking field coils for breaks

**2.8.9 Inspecting insulation between yoke body and brush**

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



Checking field coils for grounding

**2.8.10 Inspecting center bracket**

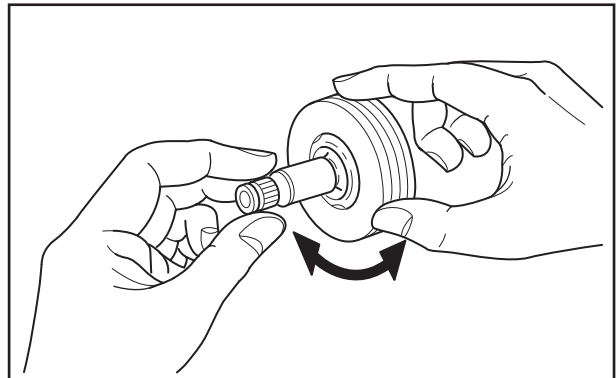
Check the bearing. If the bearing is worn, replace the center bracket .

**2.8.11 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

**2.8.12 Inspecting pinion**

Check the pinion for wear and damage.

If faulty, replace the pinion with a new one.

**2.8.13 Inspecting front bracket**

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

**2.8.14 Inspecting gears of starter**

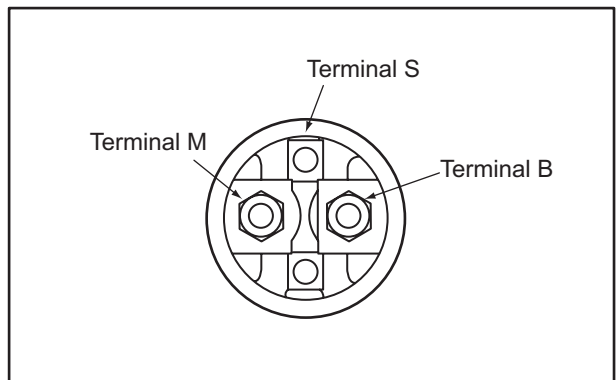
Check gears of the starter for wear or damage. If faulty, replace the starter.

**2.8.15 Inspecting continuity of magnetic switch (between M terminal and case)**

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

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

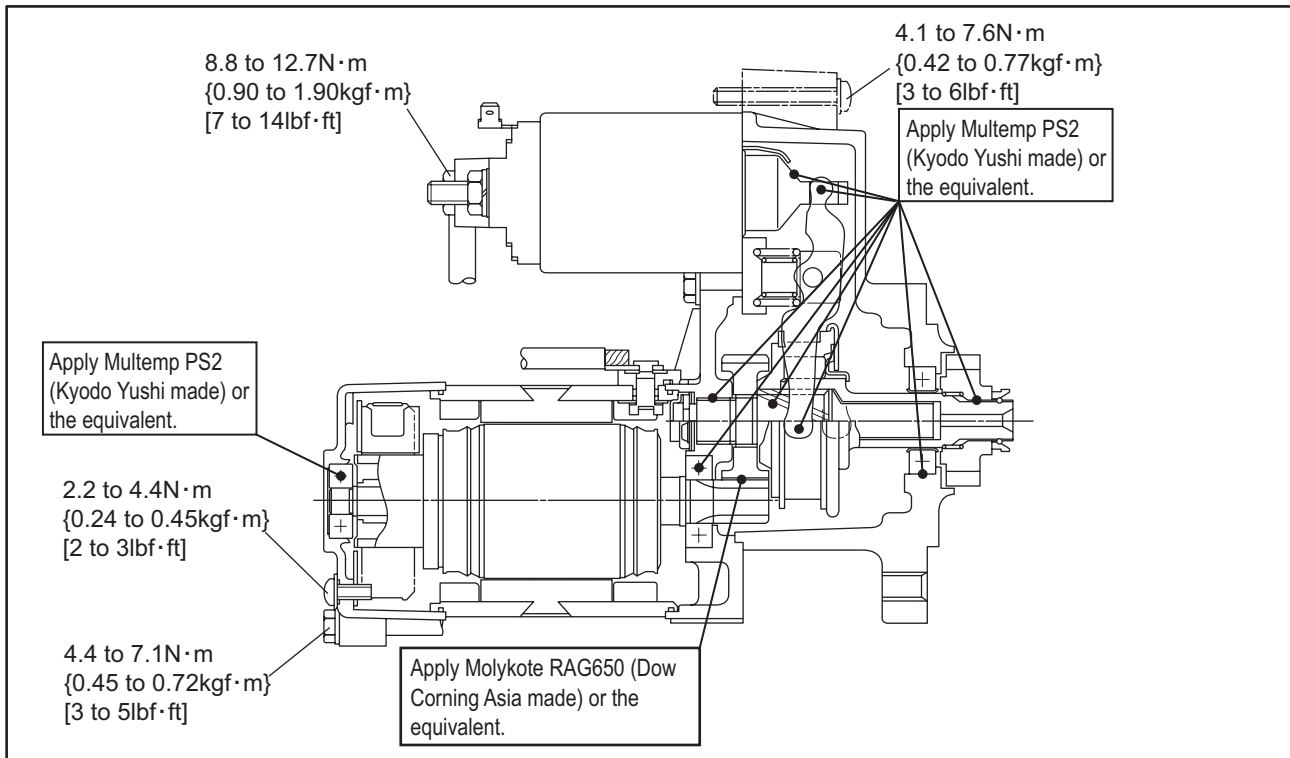
Check that there is no continuity between M terminal and B terminal. If continuity is observed, replace the magnetic switch with a new one.



Checking magnetic switch for continuity



## 2.9 Reassembling starter (M002T66071 (24V-3.2kW))



Reassembling starter (M002T66071 (24V-3.2kW))

### 2.9.1 Applying grease

#### CAUTION

- (a) To avoid mixing of different greases, remove old grease before applying new grease.
- (b) Make sure that the starter mounting surface, brushes, commutator and other electric current conducting components are free from grease.

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

- (1) Parts or areas to which Multemp PS2 (Kyodo Yushi made) or the equivalent is applied

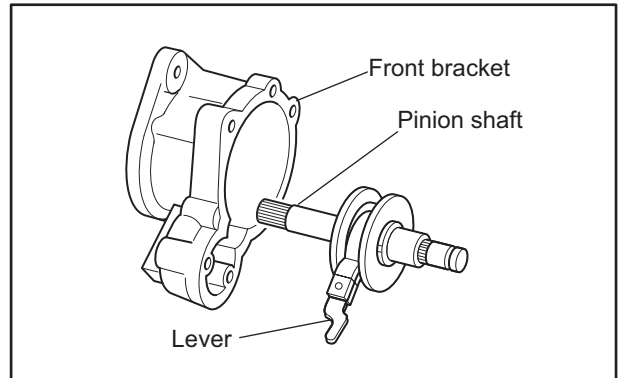
Plunger surface (a small amount)	Sliding area between lever and pinion shaft
Lever (at the point of contact with plunger and point of support)	Front bearing of armature shaft
Shaft sliding area of pinion shaft	Rear bearing of armature shaft
Pinion gear fitting surface	Center bracket bearing
Pinion shaft spline	

- (2) Parts to which Molykote AG-650 (Dow Corning Asia made) or the equivalent is applied

Gear shaft, gear and internal gear of armature

**2.9.2 Installing lever and pinion shaft**

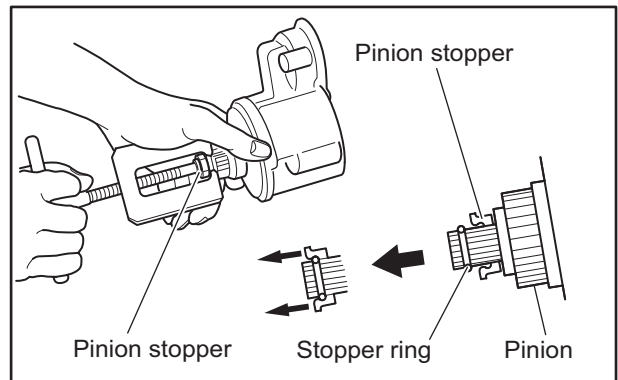
Reassemble the lever to the pinion shaft and insert them into the front bracket.



Installing lever and pinion shaft

**2.9.3 Installing pinion**

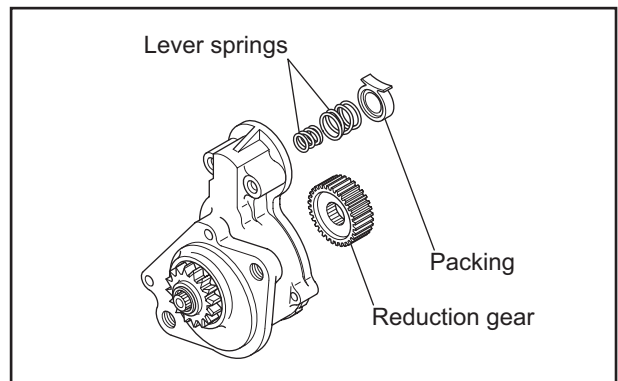
- (1) Install the spring, pinion and pinion stopper on the pinion shaft.
- (2) Install a stopper ring into the ring groove on the pinion shaft. Using a puller, pull the pinion stopper until its groove engages with the stopper ring.



Installing pinion

**2.9.4 Installing spring set and reduction gear**

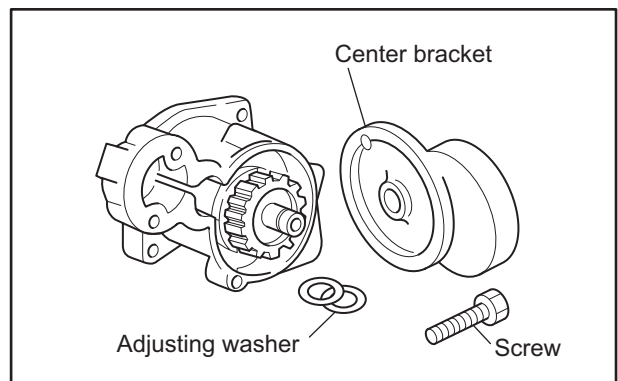
- (1) Install the two lever springs and packing on the lever.
- (2) Install the reduction gear on the pinion shaft.



Installing spring set and reduction gear

**2.9.5 Installing center bracket**

Install adjusting washers on the pinion shaft and secure the center bracket with a screw.



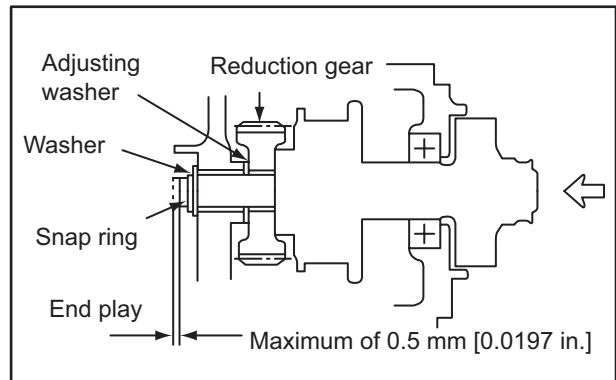
Installing center bracket

### 2.9.6 Adjusting pinion shaft end play

Adjust the end play (thrust gap) to 0.5 mm [0.0197 in.] or less by inserting adjusting washers between the center bracket and reduction gear.

- (1) Install the pinion shaft, reduction gear, washer and snap ring onto the center bracket.
- (2) Measure the pinion shaft end play by moving the shaft in the axial direction.

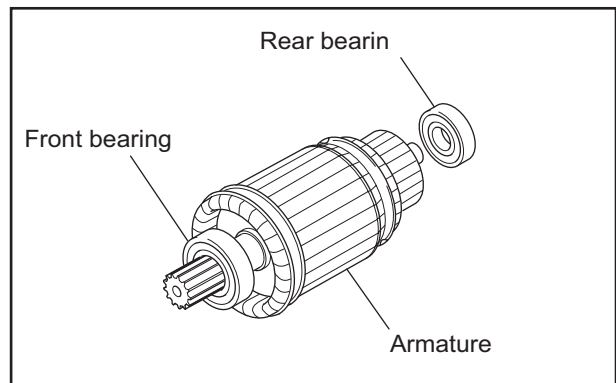
If the measured value exceeds 0.5 mm [0.0197 in.], make an adjustment by adding adjusting washer(s).



Adjusting pinion shaft end play

### 2.9.7 Installing bearing

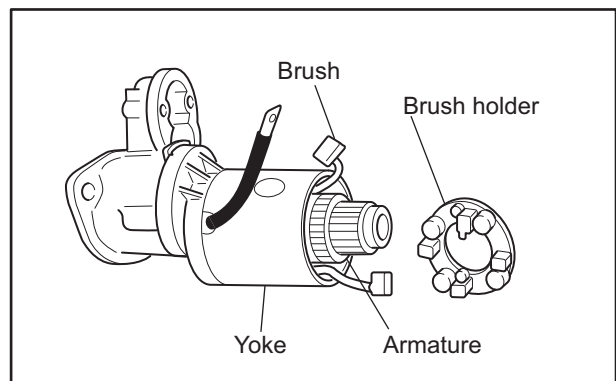
Install the bearings on both ends of the armature.



Installing bearings

### 2.9.8 Installing armature, yoke, brush and brush holder

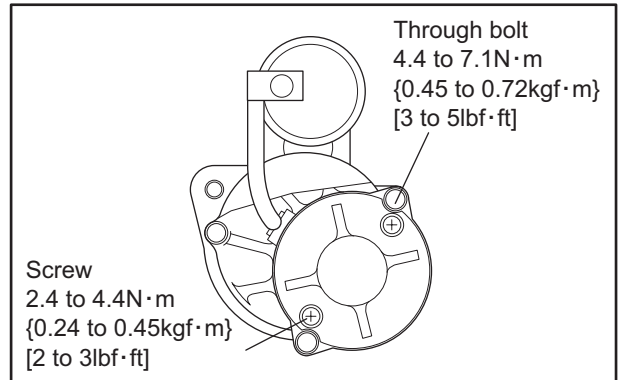
- (1) Align the knock pin with the center bracket and reassemble the armature to the yoke.
- (2) Reassemble the brush holder and brushes.



Installing brush holder

**2.9.9 Installing rear bracket**

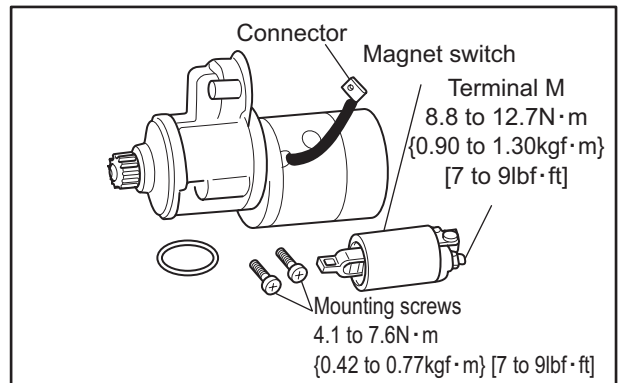
Install the rear bracket to the yoke, and tighten the through bolt and the brush holder screws.



Installing rear bracket

**2.9.10 Installing magnetic switch**

- (1) Install the magnetic switch and tighten the screws.
- (2) Connect the lead to the terminal M and secure it with the fixing nut.



Installing magnetic switch

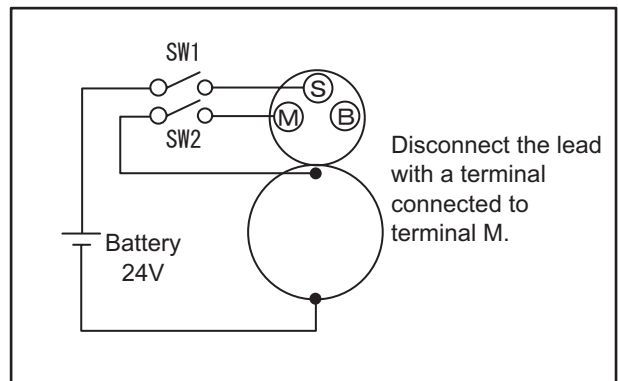
**2.9.11 Inspecting pinion clearance**

**CAUTION**

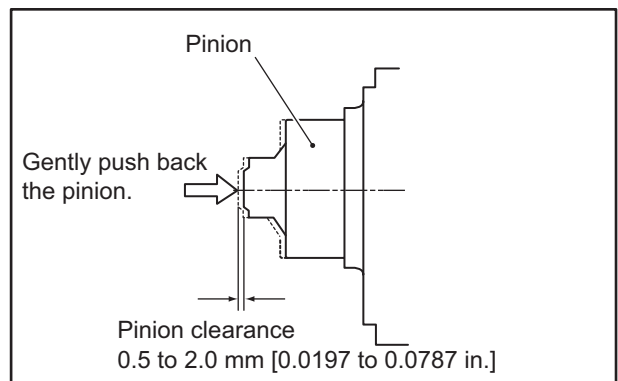
Do not apply current continuously for longer than 10 seconds.

- (1) Connect the starter to the circuit as shown in the illustration.
- (2) When the switches SW1 and SW2 are turned ON, the pinion springs out to the cranking position and the armature rotates.
- (3) Turn the switch SW2 OFF to stop the rotation of the armature.
- (4) Gently push back the pinion in the out position with a finger and measure the distance over which the pinion has returned (movement amount).
- (5) If the measured value is out of the standard, increase or decrease the number of packings between the magnetic switch and the front bracket for adjustment, or replace the lever with a new one.

Note: When the number of packings is increased, the pinion clearance becomes small.



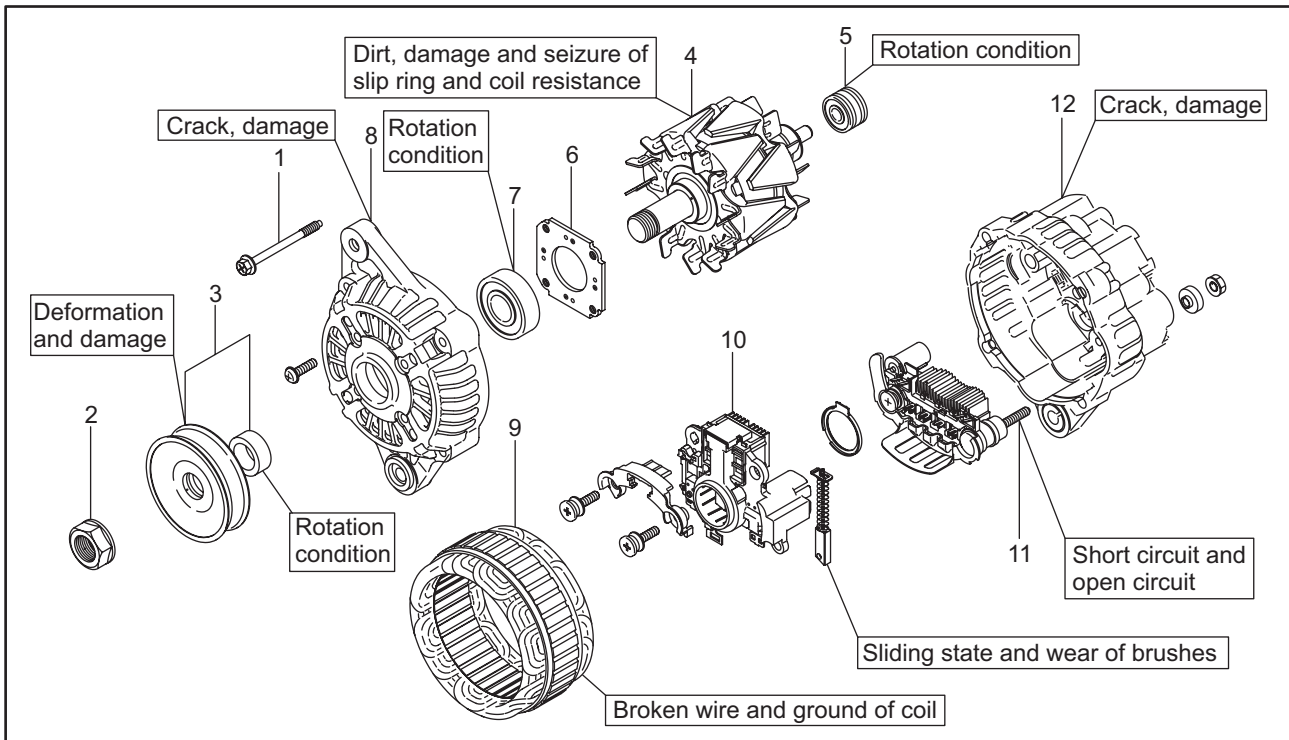
Wiring during inspection of pinion clearance



Inspecting pinion clearance

Item	Standard
Pinion gap	0.5 to 2.0 mm [0.0197 to 0.0787 in.]

## 2.10 Disassembling and inspecting alternator



Disassembling and inspecting alternator

### Disassembling sequence

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

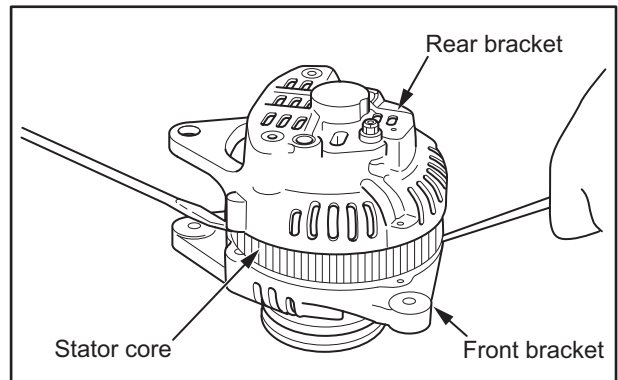
### 2.10.1 Separating front bracket from stator

**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.



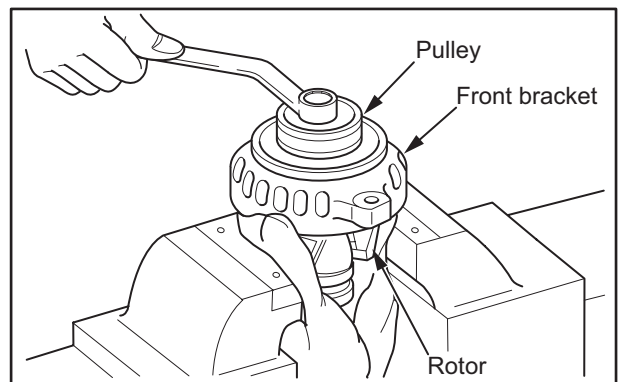
Separating front bracket from stator

### 2.10.2 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.

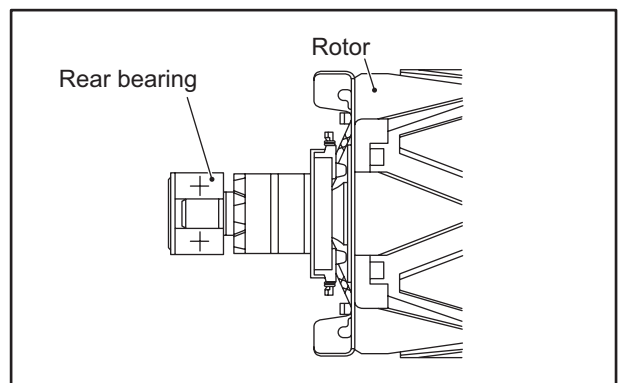
- (1) Apply a cloth to the rotor and set it in a vise.
- (2) Remove the pulley nut and then pull out the pulley.



Removing pulley

### 2.10.3 Removing rear bearing

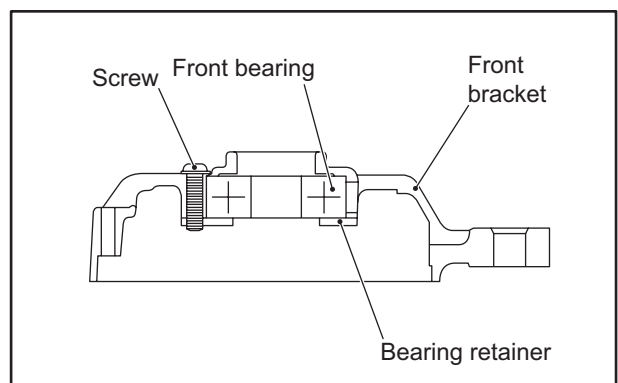
Remove the rear bearing from the rotor using a bearing puller.



Removing rear bearing

### 2.10.4 Removing front bearing

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



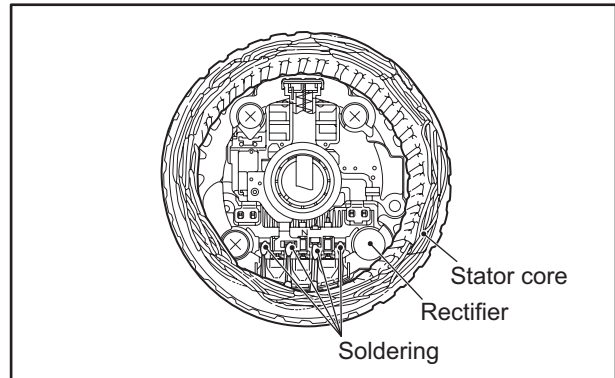
Removing front bearing

### 2.10.5 Removing stator

#### CAUTION

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

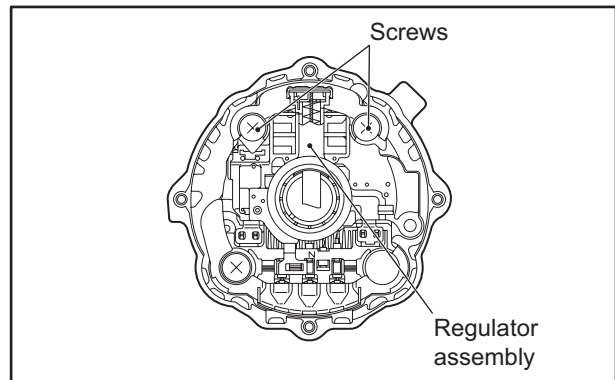
Cut off the joint of the stator and remove the stator from the rectifier.



Removing stator

### 2.10.6 Removing regulator assembly

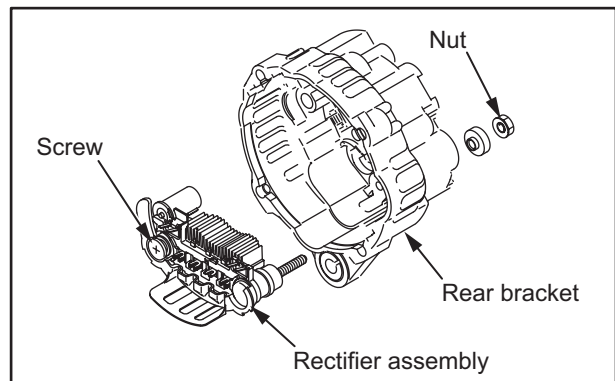
Remove the screws of the regulator assembly and then remove the regulator assembly.



Removing regulator assembly

### 2.10.7 Removing rectifier assembly

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



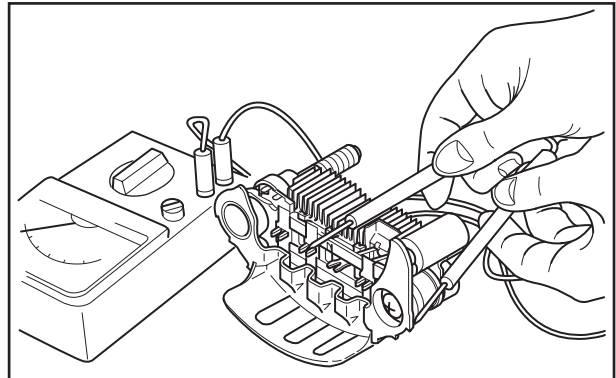
Removing rectifier assembly

## 2.11 Inspecting and repairing alternator

### 2.11.1 Inspecting rectifier

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

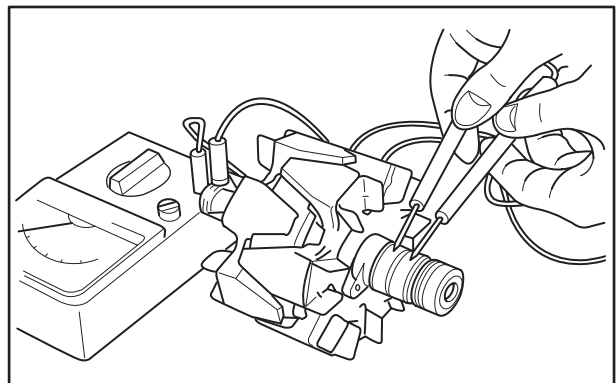
Note: Use a wide measuring range as much as possible. The current flow during test is significantly lower than the current that normally flows in the rectifier, by which the accurate resistance may not be measured using a tester, and this tendency is noticeable if the measuring range is small.



Checking rectifier

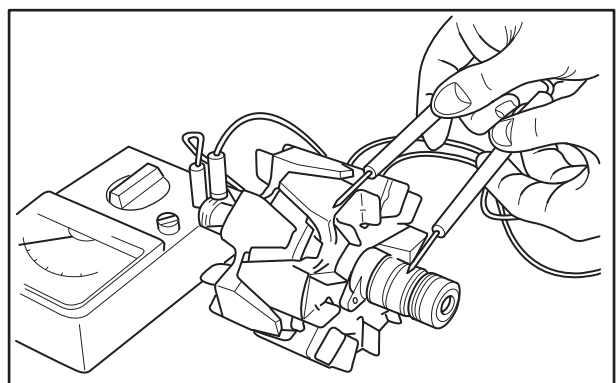
### 2.11.2 Inspecting rotor

(1) Check that there is continuity between slip rings. If no continuity is observed, replace the rotor with a new one.



Inspecting field coils for continuity

(2) Check that there is no continuity between the slip ring and the shaft (or the core). If continuity is observed, replace the rotor with a new one.



Checking field coils for grounding



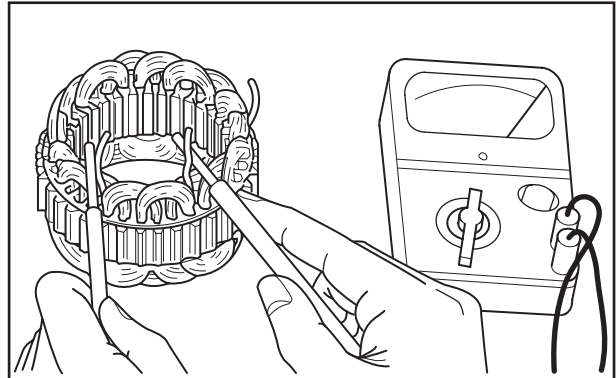
### 2.11.3 Inspecting stator

#### (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.

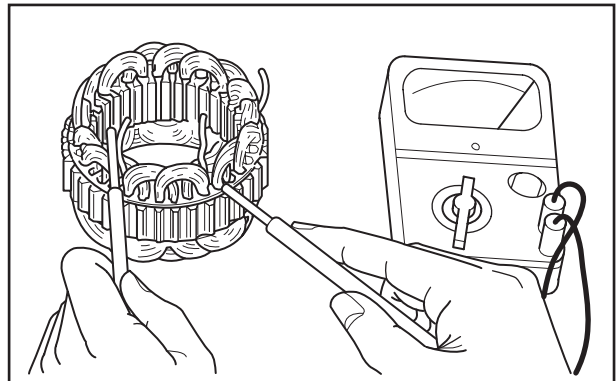


Checking for continuity between leads

#### (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.

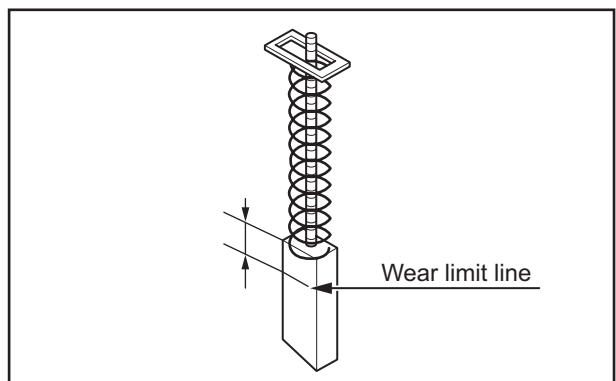


Checking for grounding between the leads and the core

### 2.11.4 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.

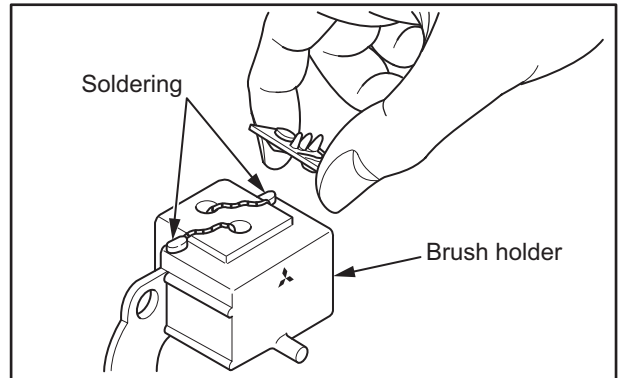
Item	Standard	Limit
Brush length	18.5 mm [0.7283 in.]	5.0 mm [0.197 in.]



Inspecting brushes

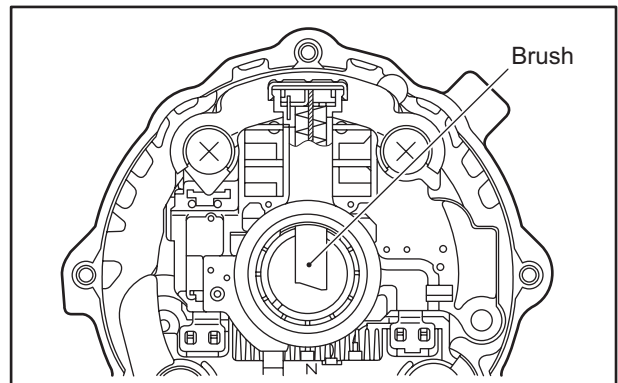
### 2.11.5 Replacing brushes

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



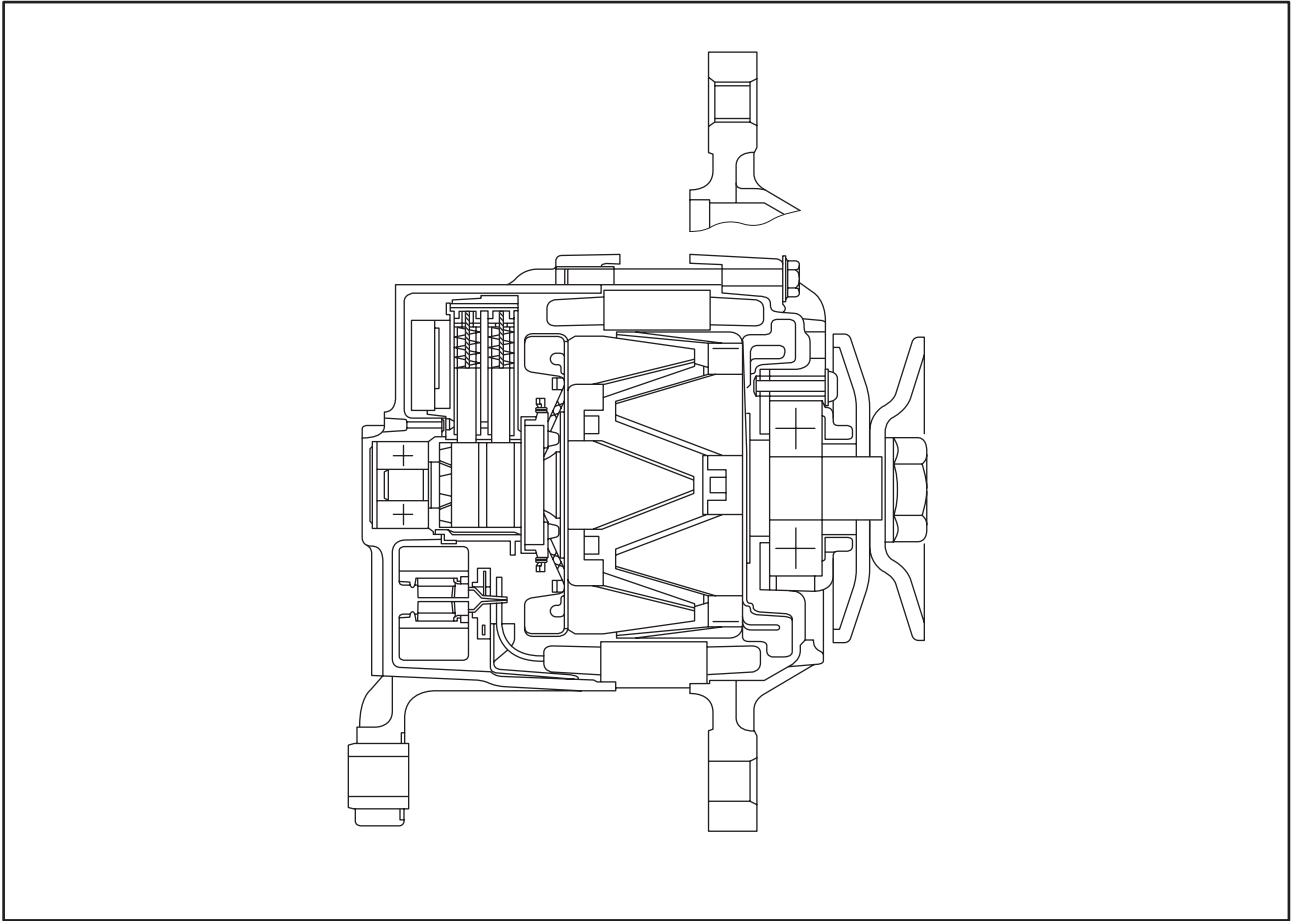
Replacing brushes

(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

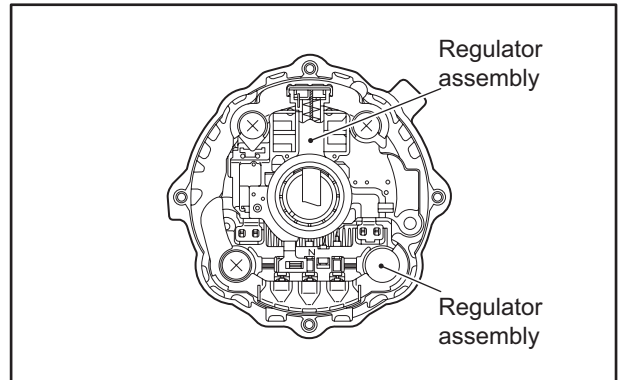
2.12 Reassembling alternator



Reassembling alternator

### 2.12.1 Installing rectifier assembly and regulator assembly

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



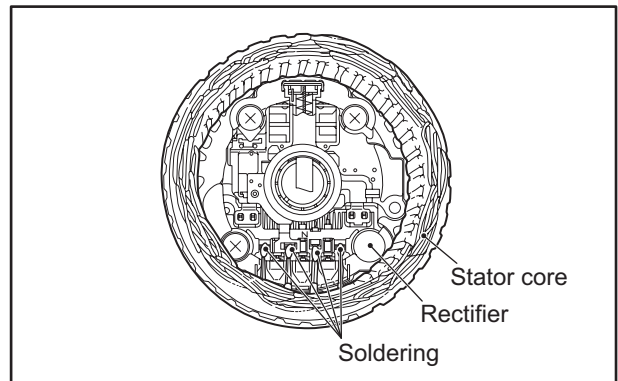
Installing rectifier assembly and regulator assembly

### 2.12.2 Installing stator

**CAUTION**

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

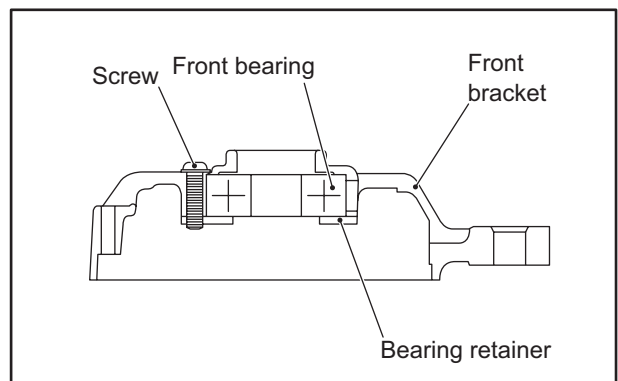
Install the stator and solder the leads of the stator to the rectifier.



Installing stator

### 2.12.3 Installing front bearing

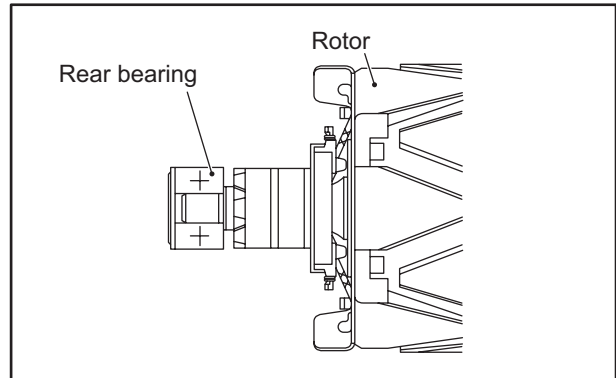
Drive the front bearing into the front bracket and secure the bearing retainer with a screw.



Installing front bearing

### 2.12.4 Installing rear bearing

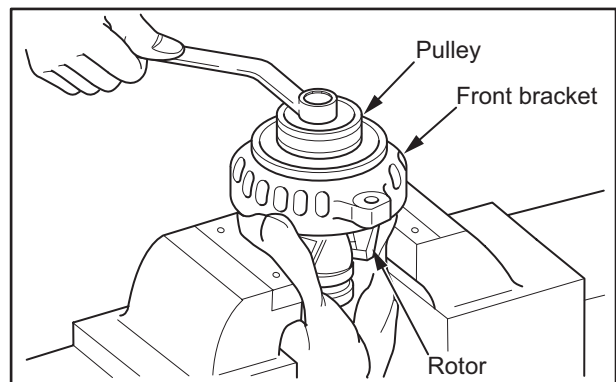
Press-fit the rear bearing to the rotor.



Installing rear bearing

### 2.12.5 Installing pulley

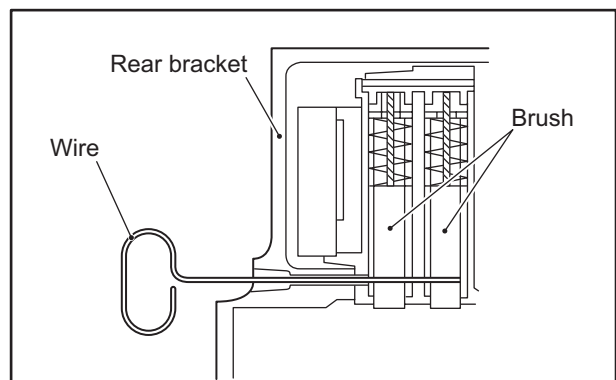
- (1) Insert the rotor into the front bracket.  
Apply a cloth to the rotor and set it in a vise.
- (2) Install the spacer and pulley, and secure the pulley with a nut.



Installing pulley

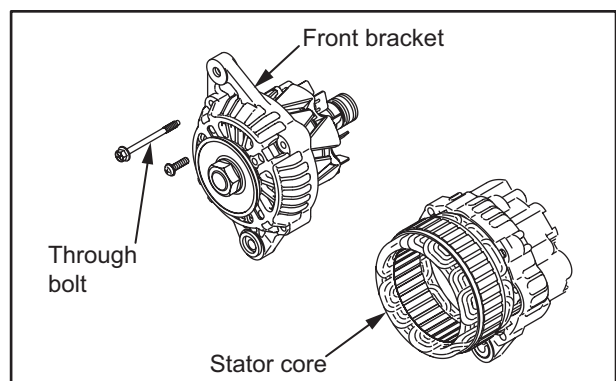
### 2.12.6 Assembling stator and front bracket

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



Securing brushes

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

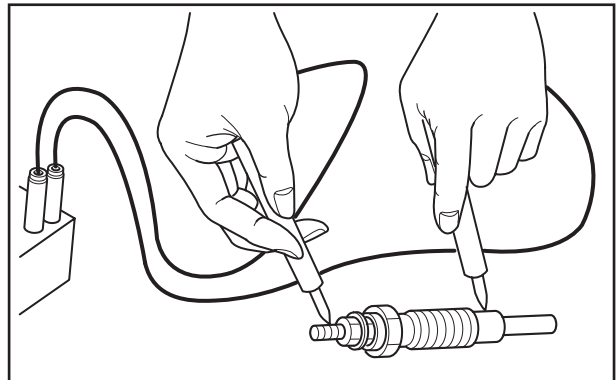


Joining stator and front bracket

### 2.13 Inspecting glow plug

Check continuity between the terminal and the body as shown in the illustration. If no continuity is indicated, or the resistance is large, replace the glow plug with a new one.

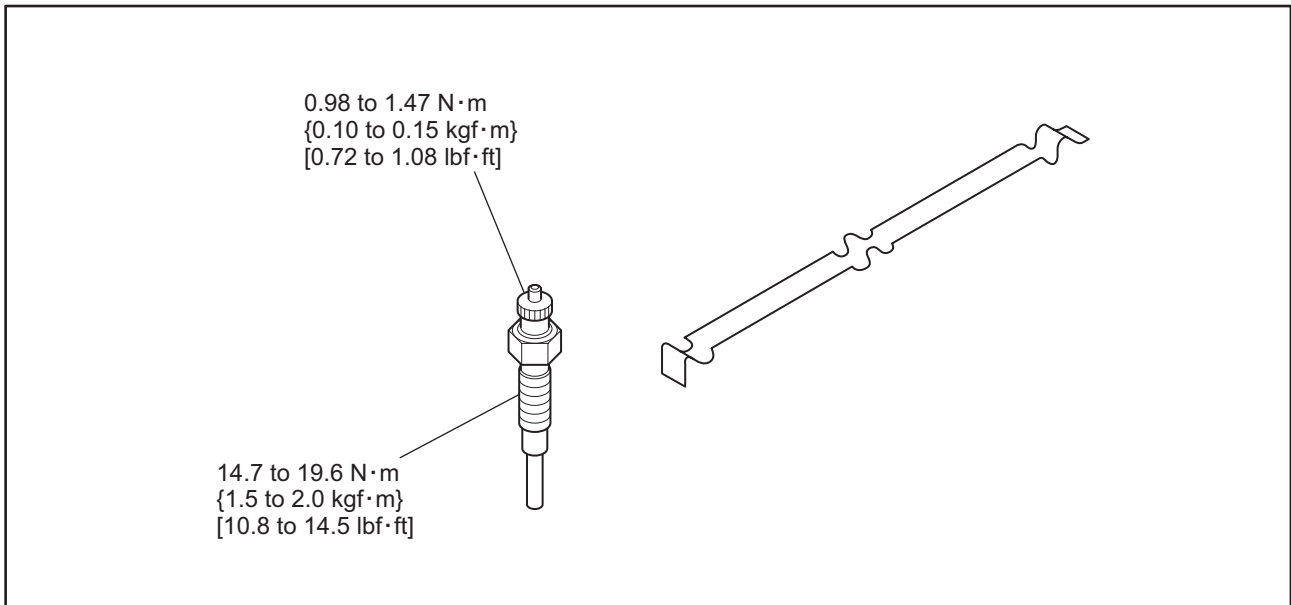
Item		Standard
Resistance value	12 V	0.2 $\Omega$
	24 V	4.5 $\Omega$



Inspecting glow plug

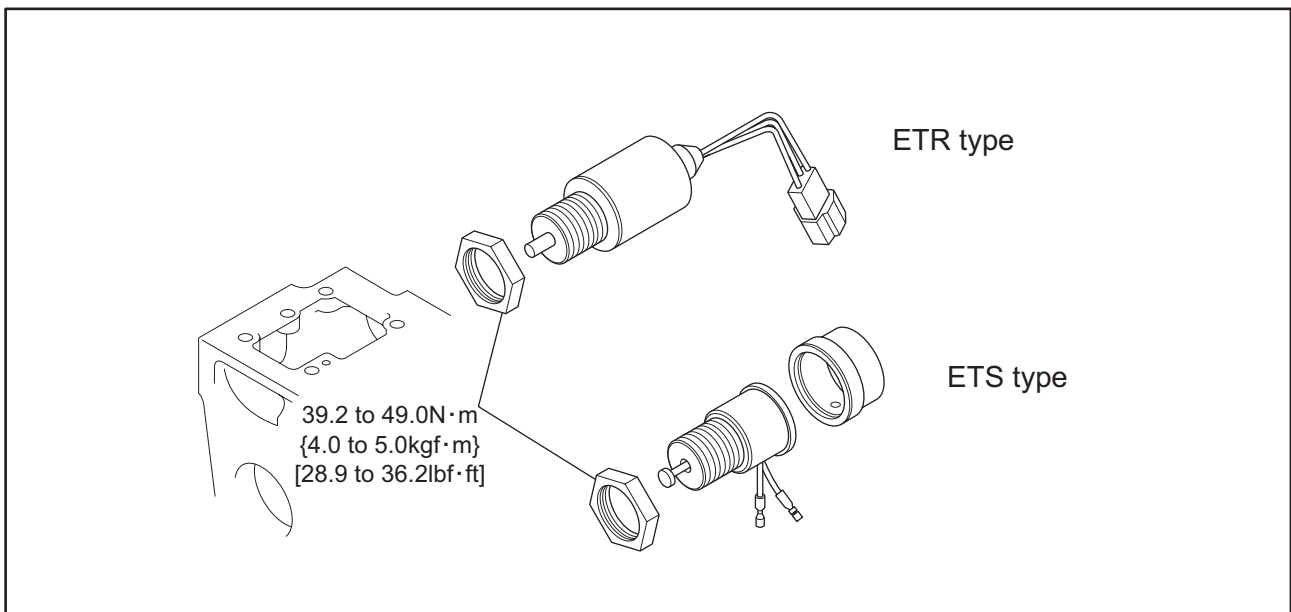
### 3. Installing electrical system

#### 3.1 Installing glow plug



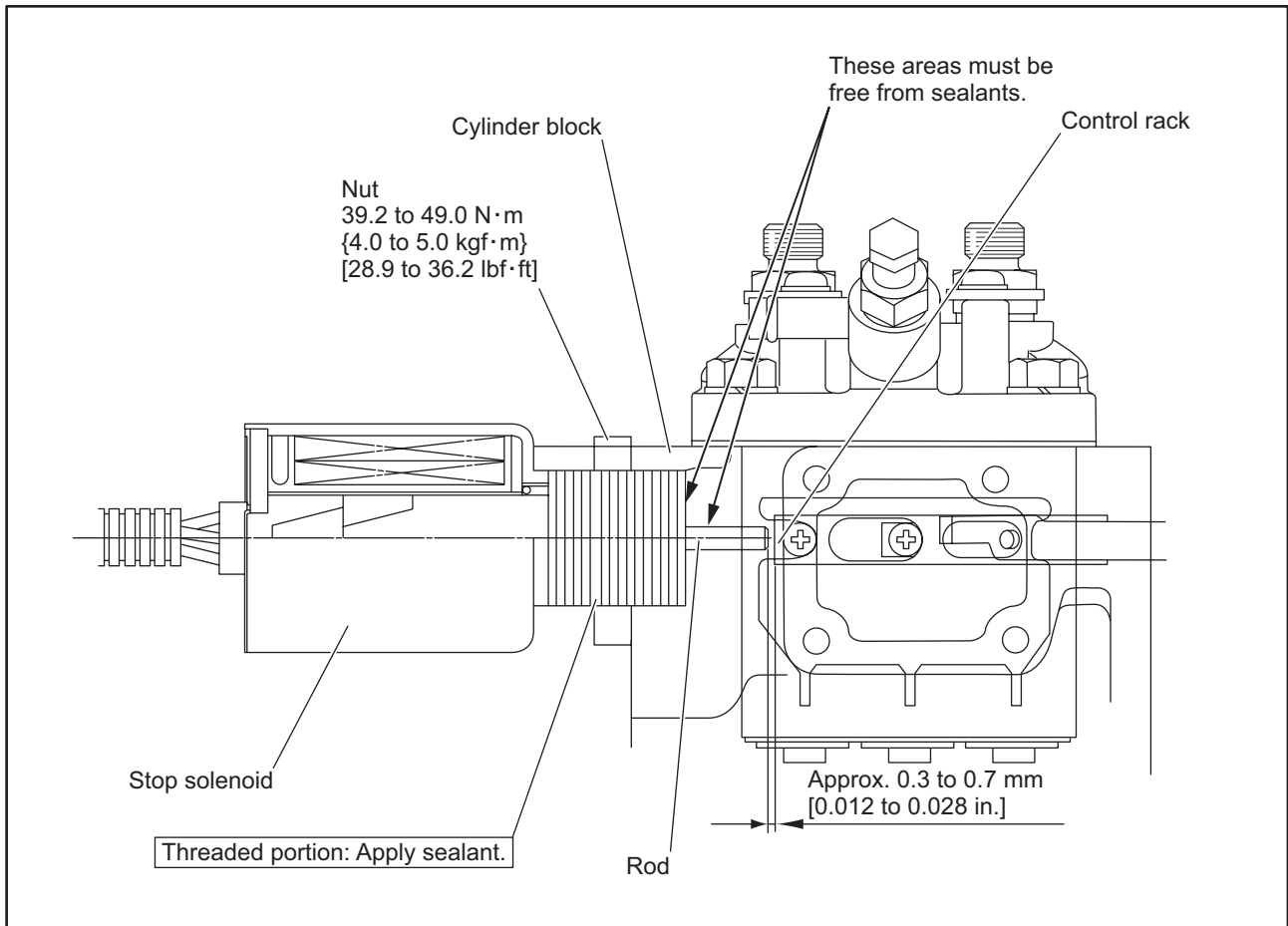
Installing glow plug

#### 3.2 Installing stop solenoid



Installing stop solenoid

### 3.3 Installing stop solenoid (ETR type)



Installing stop solenoid (ETR type)

#### 3.3.1 Procedure for installing stop solenoid (ETR type)

- (1) Apply a sealant to the threaded portion of the stop solenoid.

Note: Apply the sealant up to the position where the stop solenoid is screwed into the cylinder block.

Sealant or lubricant	THREEBOND 1212 or 1211
----------------------	------------------------

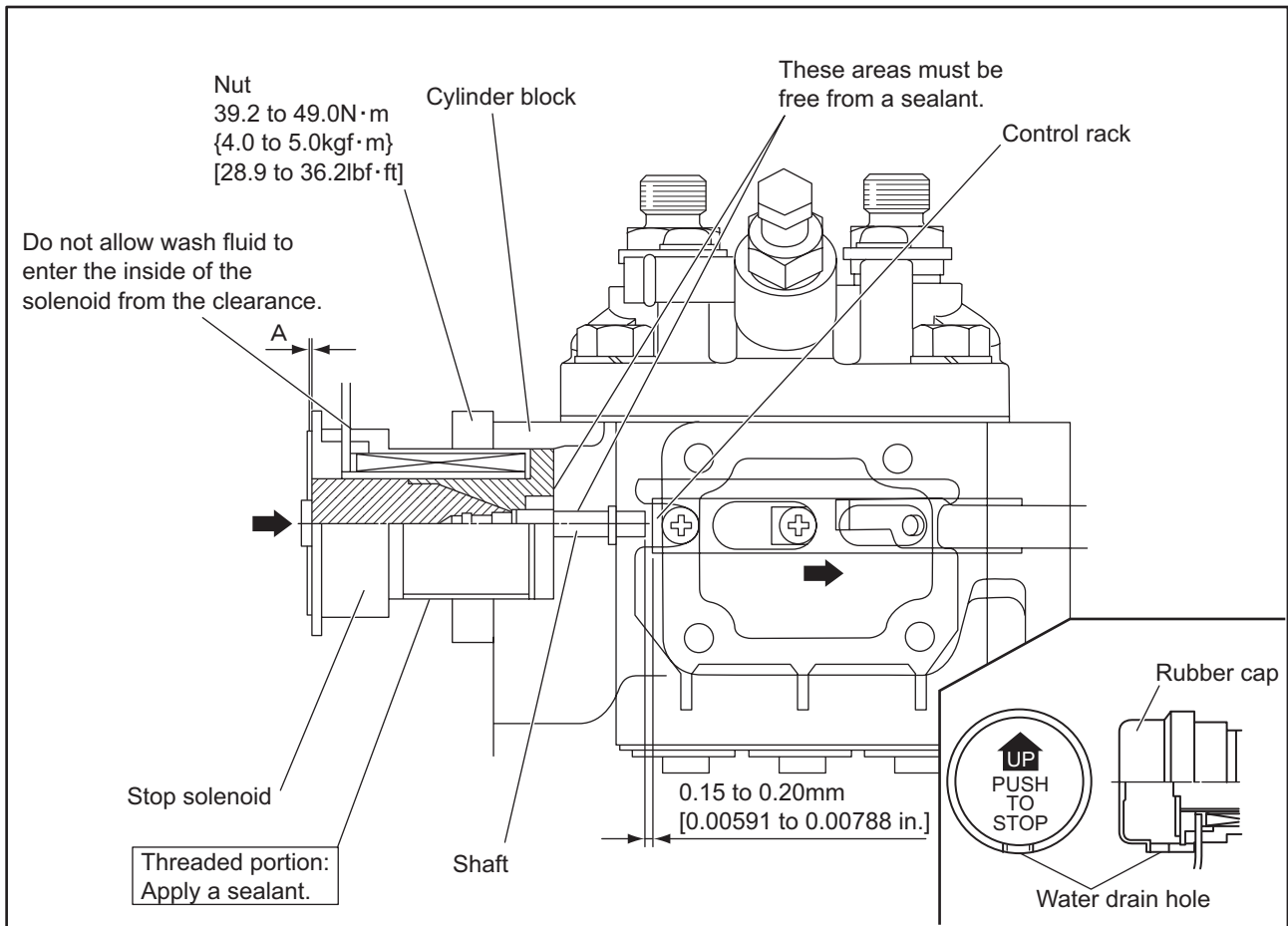
- (2) Temporarily reassemble the stop solenoid and the nut to the cylinder block.
- (3) Move the control rack of the fuel injection pump fully in the stop direction.
- (4) Screw in the stop solenoid until the rod contacts the control rack.
- (5) Turn the stop solenoid in the reverse direction by 90 to 180° from the above condition and temporarily tighten the nut.
- (6) Move the control rack side to side and make sure that there is play of approx. 0.3 to 0.7 mm [0.012 to 0.028 in.].
- (7) Tighten the nut to the specified torque.

#### 3.3.2 Verification after reassembling (ETR type)

- (1) After starting the engine, turn the starter switch key to the OFF position, and make sure that the stop solenoid activates and the engine stops.
- (2) After starting the engine, make a short circuit between the terminal of the oil pressure switch and the switch body, and make sure that the engine stops.



### 3.4 Installing stop solenoid (ETS type)



Installing stop solenoid (ETS type)

#### 3.4.1 Procedure for installing stop solenoid (ETS type)

##### CAUTION

Do not allow wash fluid to enter the terminal and the inside (cord and shaft) of the solenoid.

- (1) Apply a sealant to the threaded portion of the stop solenoid.

Note: Apply the sealant up to the position where the stop solenoid is screwed into the cylinder block.

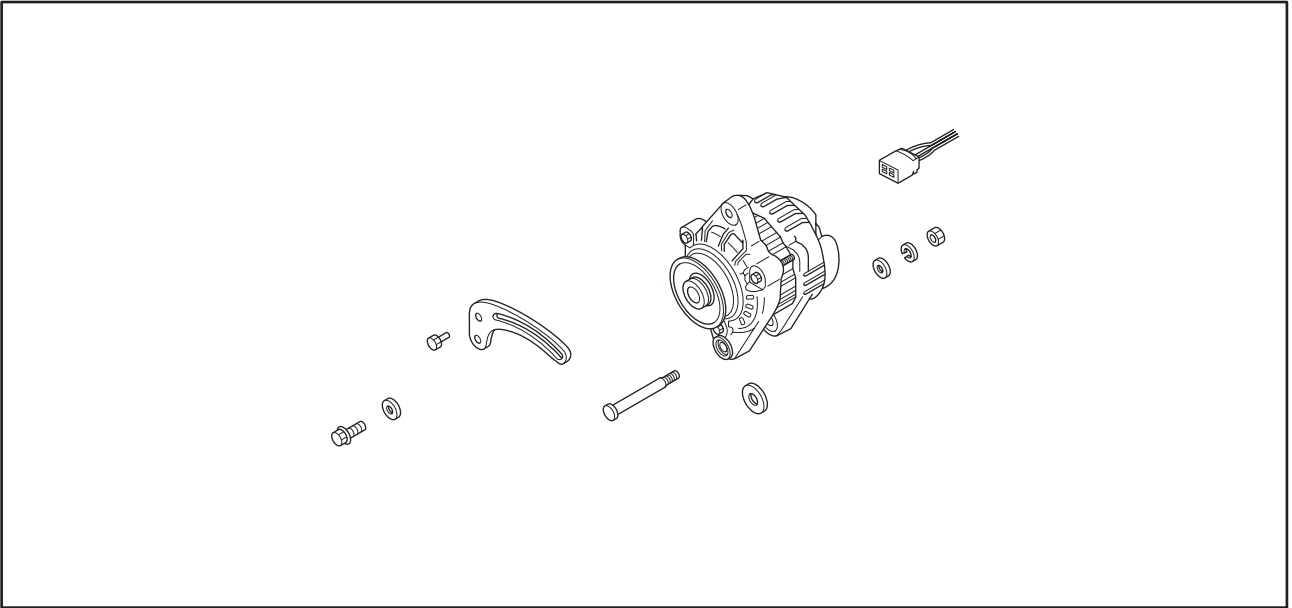
Sealant or lubricant	THREEBOND 1212 or 1211
----------------------	------------------------

- (2) Temporarily reassemble the stop solenoid and the nut to the cylinder block.
- (3) Move the control rack of the fuel injection pump fully in the stop direction.
- (4) Screw in the stop solenoid while pushing in the plunger until the shaft contacts the control rack.  
At this time the clearance of A should be 0 mm [0 in.] (position where the plunger is also turned by screwing in the stop solenoid).
- (5) Turn the stop solenoid in the reverse direction by 30 to 45° from the above condition (at this time the clearance between the control rack and shaft is 0.15 to 0.20 mm [0.00591 to 0.00788 in.]) and tighten the nut to the specified torque.
- (6) Finally, reassemble the rubber cap with the arrow facing upward (water drain hole facing downward) as illustrated.

### **3.4.2 Verification after reassembly (ETS type)**

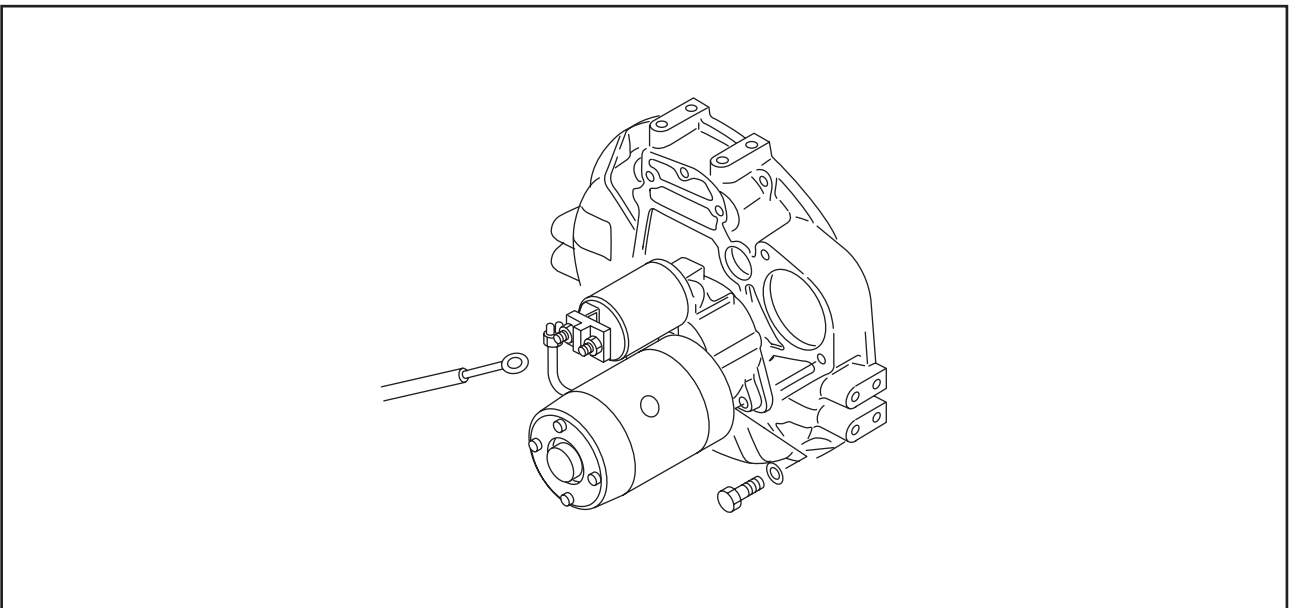
- (1) After starting the engine, turn the starter switch key to the OFF position, and make sure that the solenoid activates and the engine stops.
- (2) During engine start, turn the starter switch key to the ON position, and make sure that the solenoid activates and the engine enters a stopped state.
- (3) Turn the starter switch key from the OFF position to ON, and then to START position. Make sure that the solenoid activates with the key turned to ON and that the solenoid instantly stops to activate with the key turned to START.

### 3.5 Installing alternator



Installing alternator

### 3.6 Installing starter



Installing starter



# ADJUSTMENT AND OPERATION

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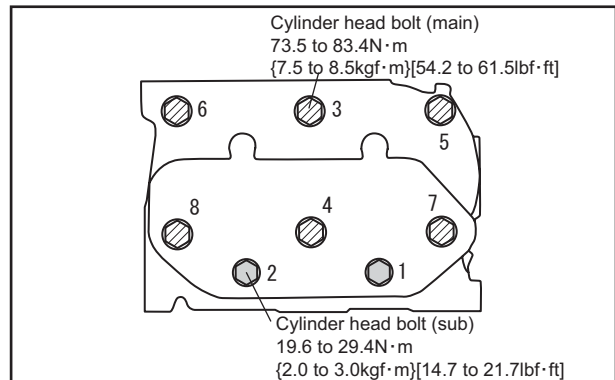
## 1. Inspection and adjustment of engine

### 1.1 Inspecting and adjusting valve clearance

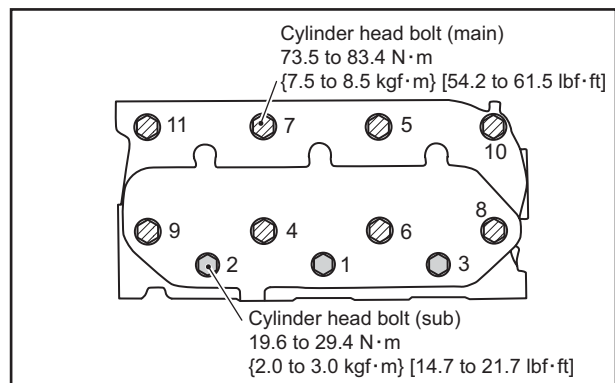
#### 1.1.1 Preparation for valve clearance inspection

- (1) Inspect and adjust the valve clearance when the engine is cold.
- (2) Slightly loosen cylinder head bolts and tighten them to the specified torque in the order as shown in the illustration.

Note: Be careful that the tightening torque of cylinder head bolts is different between main bolts and sub bolts.



Tightening order of cylinder head bolts(L2)



Tightening order of cylinder head bolts(L3)

**1.1.2 Inspecting valve clearance**

- (1) Set No. 1 cylinder to the top dead center in compression stroke.

This position is where the TDC mark on the crankshaft pulley aligns with the mark on the gear case.

Note: The compression top is where the rocker arm does not move when the crankshaft is rotated in the forward and backward direction by both 20° approx.

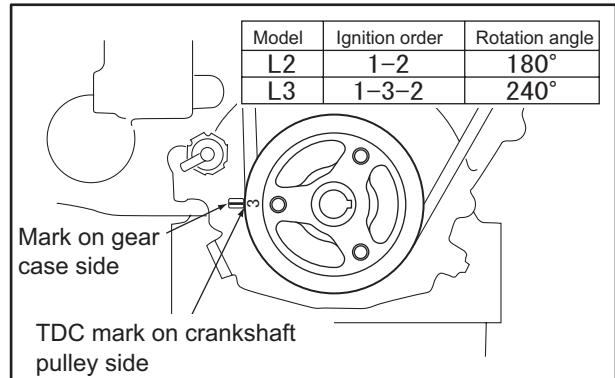
If the rocker arm moves, it is the top dead center in exhaust stroke. Rotate the crankshaft another full turn to set the No. 1 cylinder to the top dead center in compression stroke.

- (2) Start adjusting the valve clearance from the No. 1 cylinder and adjust the valve clearance of other cylinders according to the ignition order.

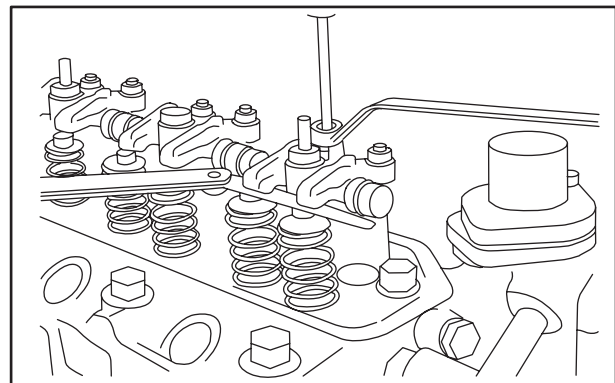
Note: To set the next cylinder to the compression top after adjustment of No. 1 cylinder, rotate the crankshaft in the forward direction (clockwise toward the timing gear case) by the angle corresponding to the number of cylinders.

- (3) Insert a thickness gauge between the rocker arm and bridge cap. Turn the adjusting screw while measuring the clearance, and adjust the clearance so that the thickness gauge can move with slight stiffness.

- (4) After adjustment, tighten the lock nut firmly. Then, check the clearance again.



Timing mark



Adjusting valve clearance

Item		Standard
Valve clearance	Inlet	0.25 mm [0.0098 in.]
	Exhaust	0.25 mm [0.0098 in.]

1.2 Inspecting fuel injection timing

**CAUTION**

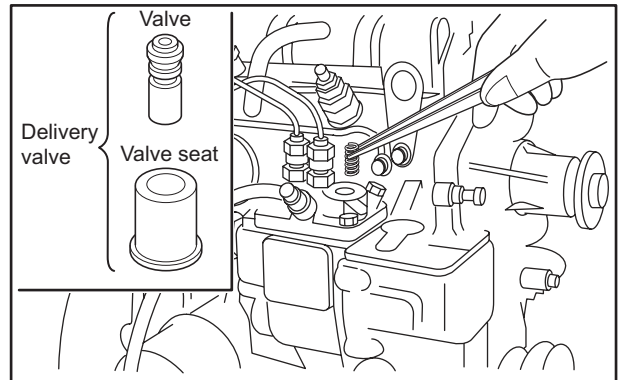
To prevent the outflow of fuel, stop the fuel supply before removing the delivery valve.

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

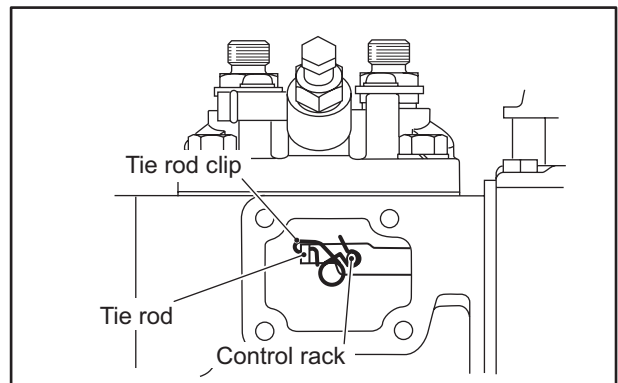
- (1) Remove the No. 1 fuel injection pipe.
- (2) Remove the No.1 delivery valve holder of the fuel injection pump.
- (3) Pull out the spring and delivery valve. Then do not remove the delivery valve seat.
- (4) Install the delivery valve holder.
- (5) Remove the tie rod cover.
- (6) Disconnect the tie rod from the control rack.
- (7) Set the control rack to the medium position of the operating range.
- (8) Feed fuel from the fuel hose and check that the fuel flows out from the delivery holder.
- (9) Rotate the crankshaft forward (clockwise). The fuel injection timing is the moment when the fuel stops flowing from the delivery valve holder outlet.

Note: When the fuel stops flowing, rotate the crankshaft backward (counterclockwise) to allow the fuel flowing again. And then, rotate the crankshaft forward (clockwise) to ensure the accurate timing when the fuel stops flowing.

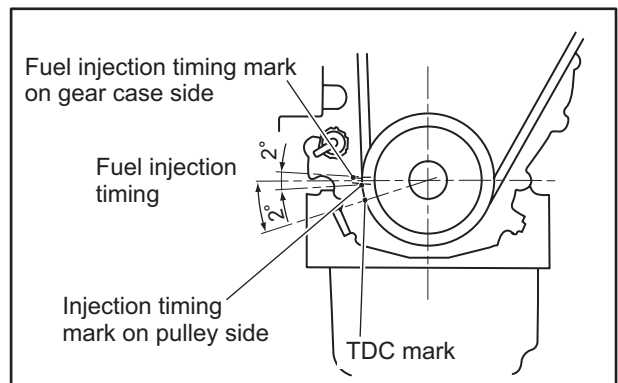
- (10) It is normal that IT mark of the crankshaft pulley aligns the mark on the gear case at the position that fuel flow stopped.



Removing delivery valve



Connecting and disconnecting tie rod



Fuel injection timing



### 1.3 Adjusting fuel injection timing

**CAUTION**

When using the shim, apply sealant to both side of the shim to prevent oil leakage.

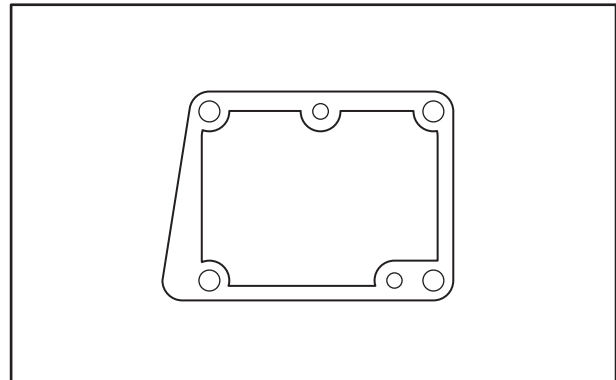
- (1) If the fuel injection timing does not meet the specified value, increase or decrease the thickness of the fuel injection pump adjusting shim to adjust the timing. (adjusting value: standard value  $\pm 1.5$ )

Note: A change in thickness of the shim by 0.1 mm [0.004 in.] results in a change in the fuel injection timing by approx 1°.

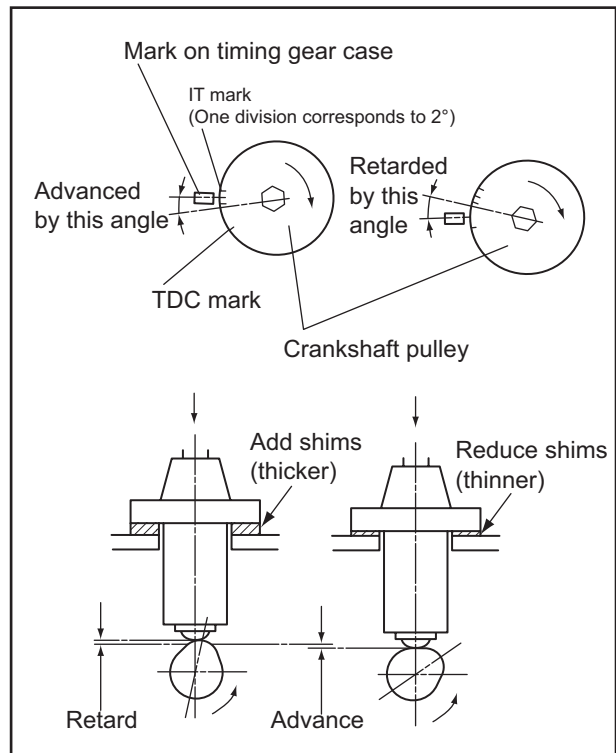
- (2) After adjusting, check that the fuel injection timing is properly adjusted.
- (3) Close the cock of the fuel filter, and reassemble the delivery valve, spring, fuel injection pipe.
- (4) With the delivery valve installed, check the fuel injection timing as follows:

Note: If the fuel injection pump and the engine are dirty, removing the delivery valve allows dirt and dust to enter the fuel injection pump.

- (5) Remove the tie rod cover and disconnect the tie rod from the control rack.
- (6) Set the control rack to the medium position in the operating range and then remove the No. 1 fuel injection pipe on the nozzle side. When the crankshaft is gradually rotated forward (clockwise), fuel begins to swell at the tip of the pipe. This timing is the fuel injection timing. In this case, the timing is delayed by 1° as compared to the normal fuel injection timing.



Adjusting shim



Adjusting fuel injection timing

## 1.4 Inspecting and adjusting low idle speed and high idle speed

### CAUTION

- (a) The minimum no-load speed (low idle speed) and the maximum no-load speed (high idle speed) of each engine have been checked on test bench and then their setting bolts have been sealed by sealing cap at the factory. Only the service shops designated by Mitsubishi are authorized to perform checking and adjustment of these settings.
- (b) Be sure to seal all the external stoppers in the same manner as they were sealed at the factory if adjustments have been made on the governor.  
Whether the seals are intact or not has important bearing on the validity of claims under warranty. Be sure to seal all of the specified locations.
- (c) When inspecting and adjusting the governor, be prepared to operate the engine stop lever manually in anticipation of engine overrevving (running at an extremely high speed).

#### 1.4.1 Preparation

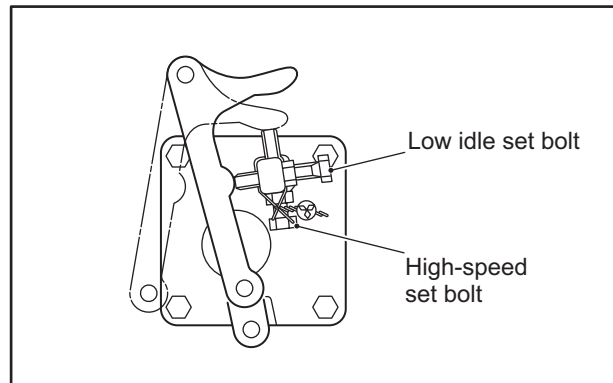
- (1) Operate the engine to warm up until coolant temperature reaches 60°C or higher.
- (2) Make sure that valve clearance, fuel injection timing, nozzle opening pressure, spray condition, and oil sealing are normal.

#### 1.4.2 Adjusting low idle speed

- (1) Loosen the lock nut of idling set bolt.
- (2) By turning the bolt, adjust the low idling speed.
- (3) Secure the set bolt with the lock nut.

#### 1.4.3 Adjusting high idle speed

- (1) Loosen the lock nut of high speed set bolt.
- (2) By turning the bolt, adjust the high idling speed.
- (3) Secure the set bolt with the lock nut.



Adjusting engine speed

## 1.5 Bleeding fuel system

**WARNING**

Completely wipe off any spilled fuel from air vent plug with a cloth, as spilled fuel can cause a fire.

Bleeding of the fuel system must be started from the place closest to the fuel tank: the fuel filter the first and the fuel injection pump the last.

### 1.5.1 Bleeding air from fuel filter

(1) Cartridge type paper element

Loosen the air vent screw marked by the letter "1."  
Tighten the air vent screw when fuel does not show air bubbles.

Loosen the air vent screw marked by the letter "2."  
Tighten the air vent screw when fuel does not show air bubbles.

Note: Place the starter key in the ON position for the fuel pump type.

When the fuel supply is gravity type, fuel will flow into the filter by itself.

(2) Cock type paper element (1)

Place the fuel filter cock lever in the OPEN position and push the button several times to bleed the filter.

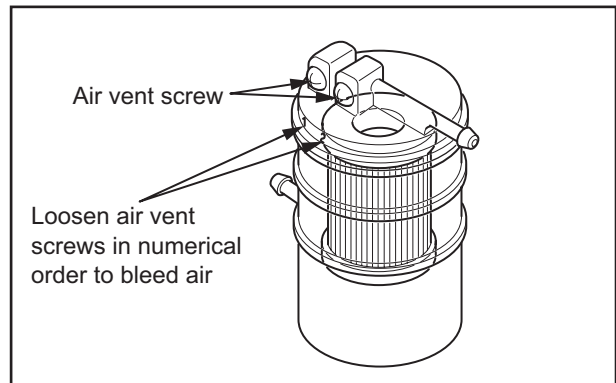
Note: When the fuel supply is gravity type, fuel will drop by itself, and when the fuel supply is the pump type, fuel and air in the filter will flow out with the starter key positioned ON.

(3) Cock type paper element (2)

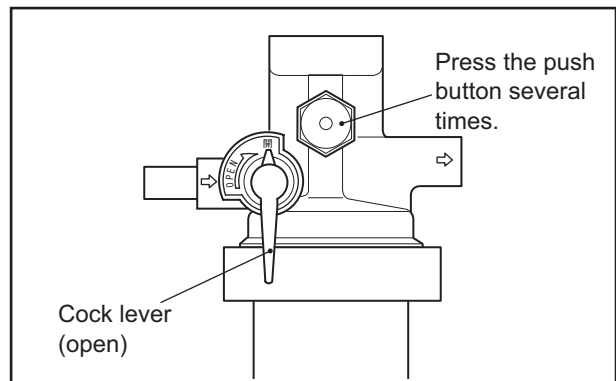
Loosen the left side air vent screw. Tighten the air vent screw when fuel does not show air bubbles.

Loosen the right side air vent screw. Tighten the air vent screw when fuel does not show air bubbles.

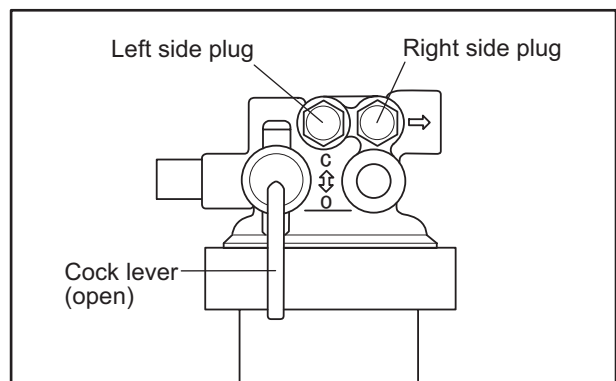
Note: When the fuel supply is gravity type, fuel will flow into the filter by itself, and when the fuel supply is the pump type, fuel and air in the filter will flow out with the starter key positioned ON.



Bleeding air from fuel filter (cartridge type)



Bleeding air from fuel filter (switch cock type)

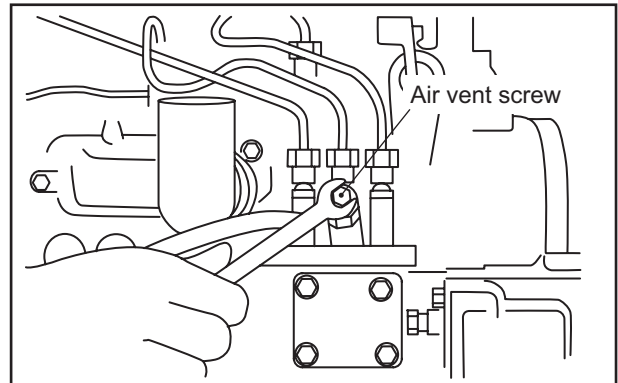


Bleeding air from fuel filter

**1.5.2 Bleeding air from fuel injection pump**

Loosen the air vent screw of pump to discharge air in the fuel pipe and fuel injection pump.

Note: Air in the fuel injection pipe and fuel injection nozzle is automatically discharged by cranking of the engine.

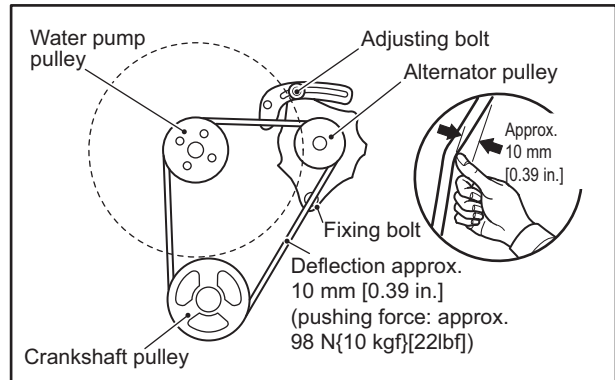


Bleeding air from fuel injection pump

**1.6 Adjusting V-belt tension**

- (1) Loosen the adjusting bolt and fixing bolt of the alternator. Loop the V-belt over the water pump pulley, alternator pulley and crankshaft pulley.
- (2) With the alternator pushed toward the V-belt tension side, tighten the adjusting bolt at an appropriate position.
- (3) Inspect the V-belt tension to make sure it is within the specified value.

Belt tension (with pushing force of approx. 98 N {10 kgf} [22 lbf])	Approx. 10 mm [0.39 in.]
---	-----------------------------



Adjusting deflection of V-belt

## 2. Break-in operation

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

### 2.1 Starting up

- (1) Before starting the engine, check the levels of coolant, engine oil and fuel.  
Bleed air from the fuel and cooling systems.
- (2) Stop the fuel supply, and crank the engine with the starter for about 10 seconds to lubricate the engine.
- (3) Move the control lever slightly in the fuel increase direction (but not to the "full injection" position), and then turn the starter switch key to the [START] position to start the engine.
- (4) After the engine is started, adjust the control lever to let the engine operate at a minimum no-load speed (low idle speed).
- (5) Turn the starter switch key to the [OFF] position and make sure that the engine is stopped.

### 2.2 Inspecting engine condition after starting up

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

- (1) The oil pressure must be within the specified value.
- (2) The coolant temperature must be within the specified value.
- (3) The engine must be free from any leakages such as oil, coolant and fuel. Pay special attention to oil leakage from the fitting face of turbocharger lube oil pipe.
- (4) Check for an abnormal noise.

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

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

### 2.3 Break-in operation time

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

Break-in operation time			
	Engine speed (min <sup>-1</sup> )	Load	Duration (min)
1	Low rotation speed 600 to 900	No-load	5
2	Medium rotation speed 1000 to 1200	No-load	5
3	High rotation speed 1400 to rated speed	No-load	10
4	Rated speed	25 %	10
5		50 %	10
6		75 %	30
7		100 %	20

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

### 2.4 Inspection and adjustment after break-in operation

- (1) Valve clearance adjustment
- (2) Ignition timing inspection
- (3) Exterior bolt and nut tightness check

### 3. Performance test (JIS standard)

The following describes the procedures specified in "Earth moving machinery - Engines - Part 1: Test code of net power (JIS D0006-1)" and "Earth moving machinery - Engines - Part 2: Standard format of specifications and testing methods of diesel engines (JIS D0006-2)."

Other test items may be required in some applications. All test results should be evaluated comprehensively in order to determine the engine performance.

#### 3.1 Engine equipment condition

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

#### 3.2 Test items and purposes

##### 3.2.1 Operation load test

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

##### 3.2.2 Continuous load test

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

##### 3.2.3 Low idle test

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

#### 3.3 Other inspections

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

#### 3.4 Engine output adjustment

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

##### 3.4.1 Standard atmospheric conditions:

Base temperature: 298 K (25°C) [77°F]

Total pressure: 100 kPa (750 mmHg)

Dry pressure: 99 kPa [743 mmHg]

**3.4.2 Calculation of corrected power**

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

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

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

• Atmospheric conditions during test

Temperature( $T$ ): $283\text{K}$  ( $10^\circ\text{C}$ ) [ $50^\circ\text{F}$ ]  $\leq T \leq 313\text{K}$  ( $40^\circ\text{C}$ ) [ $104^\circ\text{F}$ ]

Dry atmospheric pressure( $P_d$ ): $80\text{kPa}$  ( $600\text{mmHg}$ )  $\leq P_d \leq 110\text{kPa}$  ( $825\text{mmHg}$ )

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

• Range of correction equation use

The range of correction factor ( $\alpha_c$ ) is as follows:

$0.9 \leq \alpha_c \leq 1.1$ .

Calculation of correction factor ( $f_a$ )

- Natural aspiration engine and engine with mechanically driven air charger

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

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

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

- Turbocharged engine with air-to-liquid cooler

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

Calculation of engine factor ( $f_m$ )

$$f_m = 0.036q_c - 1.14$$

$q_c$ : Corrected fuel supply volume

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

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

$z = 120000$  (4-cycle engine)

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

- Applicable range of engine factor ( $f_m$ )

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

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

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



# TROUBLESHOOTING

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## 1. Troubleshooting

### 1.1 Before troubleshooting

#### CAUTION

- (a) For the fuel injection pump, the injection quantity of each cylinder can be measured only with a pump tester. Do not adjust or disassemble the fuel injection pump even during troubleshooting unless absolutely necessary.
- (b) To inspect the combustion state of each cylinder, loosen the fuel injection pipe of any cylinder to stop injection, and compare the extent of a drop in the engine speed with that of other cylinders

- (1) Troubles of the diesel engine often occur in combination of various problem causes, and therefore it is often very difficult to determine the defect from a problem phenomenon.

Especially a similar phenomenon occurs in troubles of the fuel injection pump, fuel injection nozzles and compression pressure. It is, therefore, necessary to conduct a careful study to determine the cause.

From the reason above, troubleshooting described in this section is summarized as the inspecting order from items which are more likely to cause problems or items easy to inspect in sequence.

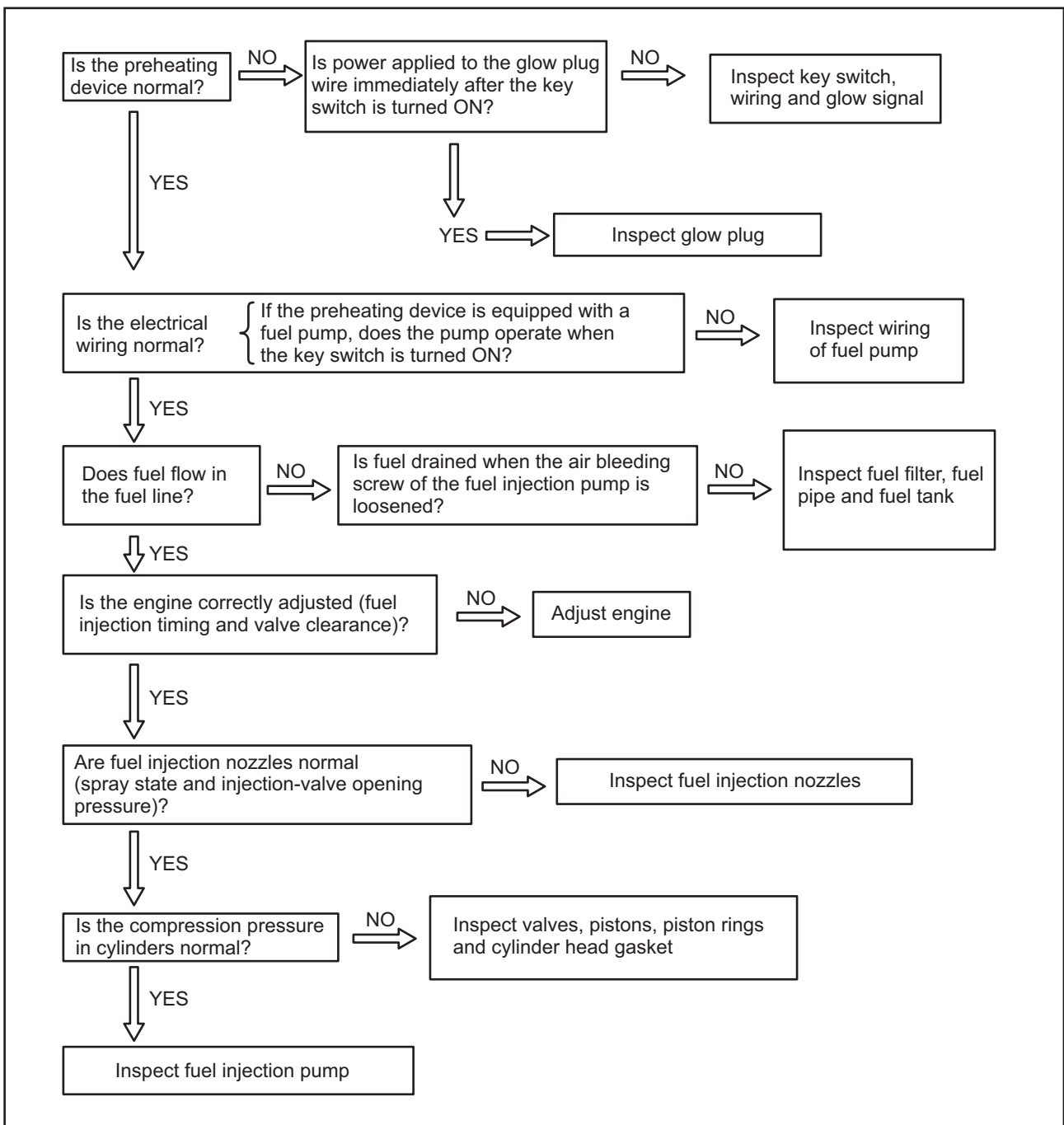
- (2) The diesel engine has the following characteristics from its structure and combustion system. It is necessary to fully understand these characteristics before performing troubleshooting.
- The engine produces unique combustion noise (diesel knock) in the normal condition.
  - The engine discharges slight black smoke at heavy load.
  - High compression and high torque cause vibration on a single unit of the engine.
  - Slight hunting is caused during acceleration and deceleration.

**1.2 Starting trouble**

**1.2.1 Check items before troubleshooting**

- (1) Clogging of air cleaner element
- (2) Coagulation of engine oil
- (3) Use of poor quality fuel
- (4) Drop in cranking speed

**1.2.2 Problem: Starting trouble**



Problem: Starting trouble

**1.3 Knocking**

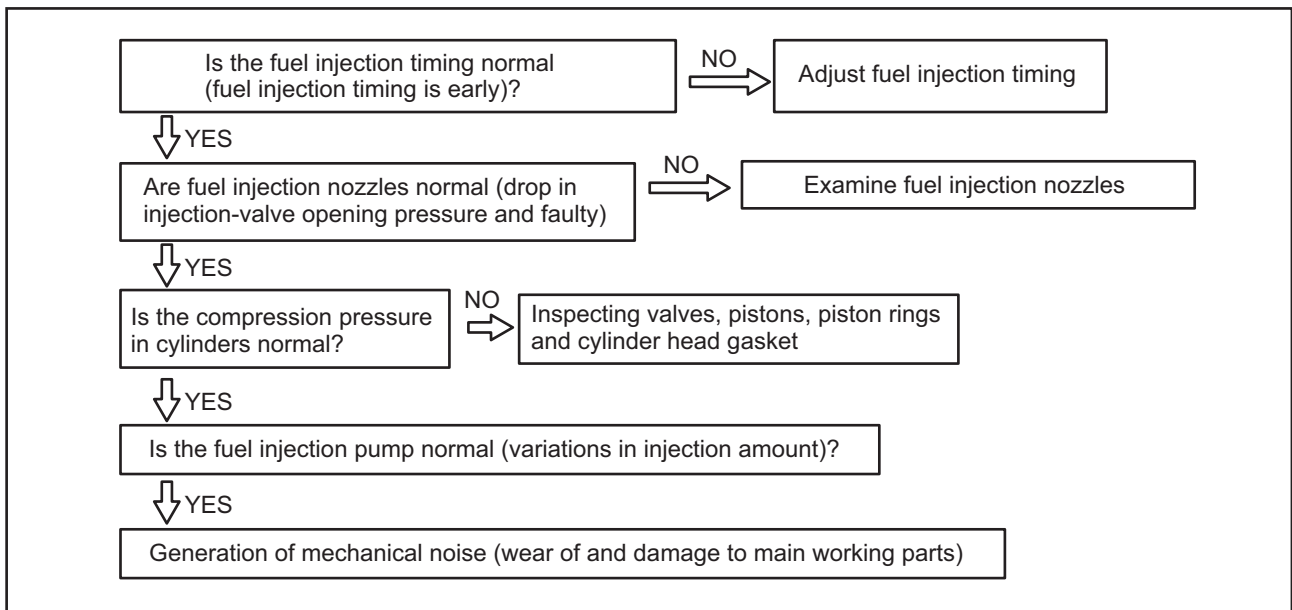
The diesel engine rotates producing unique combustion noise (diesel knock) due to its combustion system. This knock noise is normal unless it is especially loud.

**1.3.1 Check items before troubleshooting**

(1) Clogging of air cleaner element

(2) Use of poor quality fuel (low cetane number fuel such as kerosene)

**1.3.2 Problem: Knocking**



Problem: Knocking

## 1.4 Overheating

### 1.4.1 Check items before troubleshooting

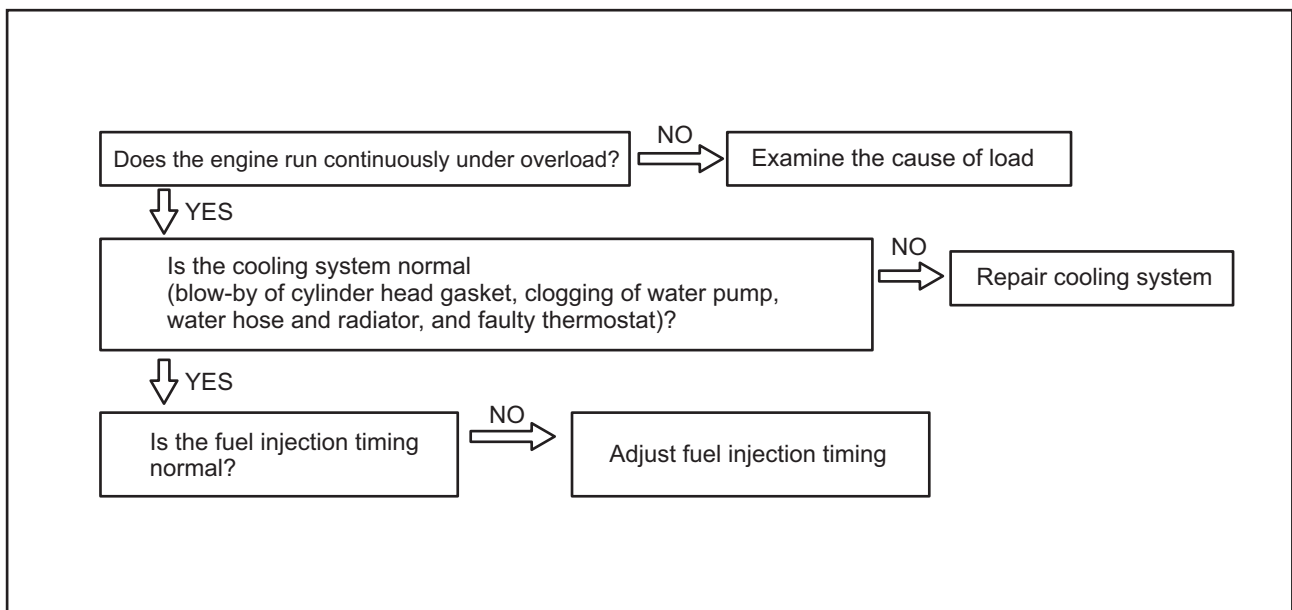
- (1) Quantity and leakage of coolant
- (2) Loosening of fan belt
- (3) Clogging of radiator fins
- (4) Concentration of LLC
- (5) Clogging of muffler
- (6) Quantity and degradation of engine oil
- (7) Swirling of cooling air
- (8) Thermostat malfunction

### 1.4.2 Problem: Overheating

Overheat often occurs by engine load mismatching when the engine is set up.

If the engine itself is normal and overheat occurs, measure the ambient and coolant temperatures in the loaded condition (thermostat full open).

If the temperature difference is greater than 60°C [140°F], the investigation into other components as well as the engine is suggested.



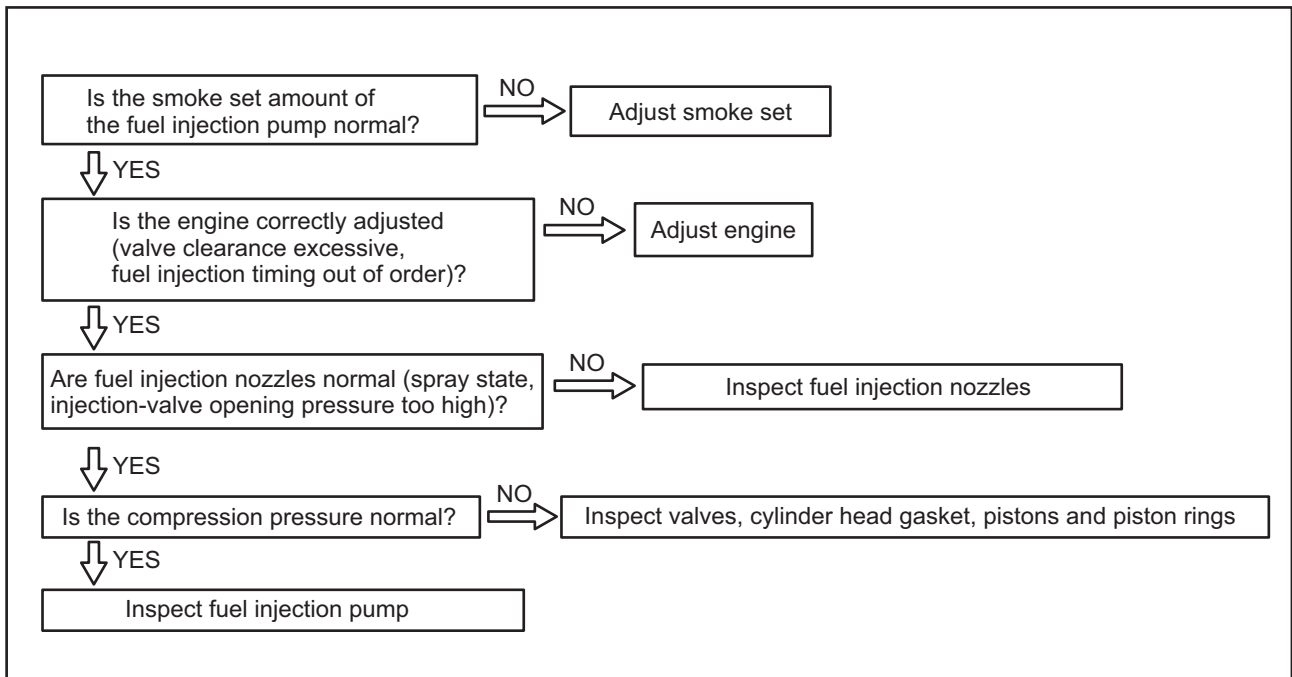
Problem: Overheating

**1.5 Excessive black smoke**

**1.5.1 Check items before troubleshooting**

- (1) Clogging of air cleaner element
- (2) Use of poor quality fuel
- (3) Overload

**1.5.2 Problem: Excessive black smoke**



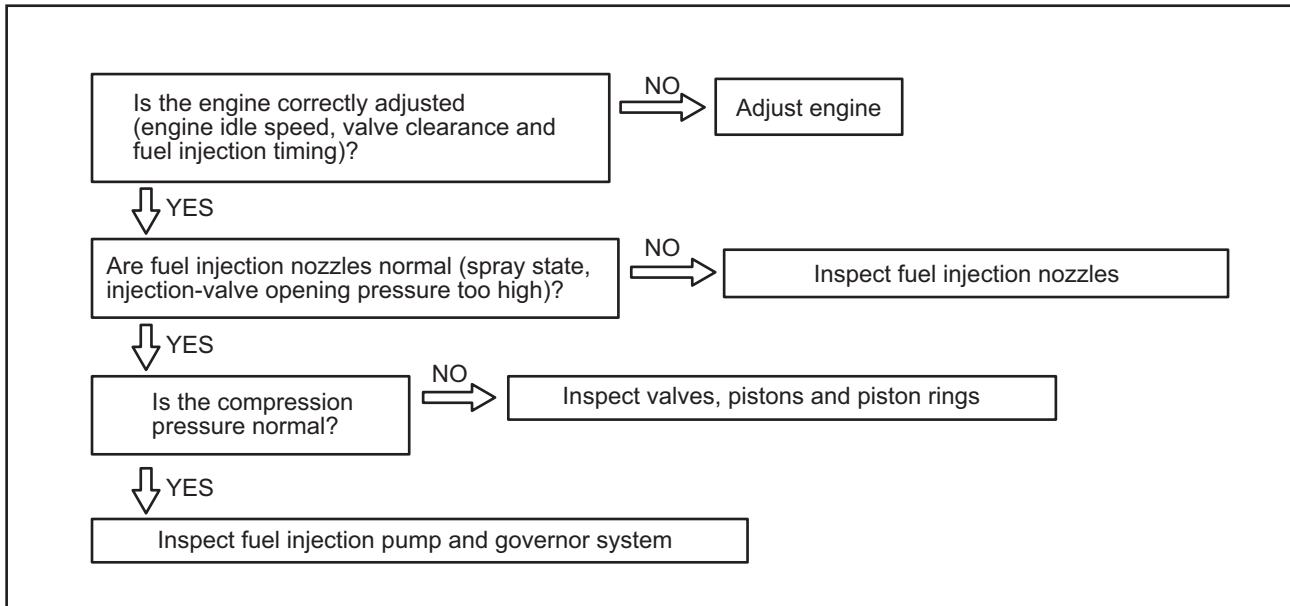
Problem: Excessive black smoke

## 1.6 Idling malfunction

### 1.6.1 Check items before troubleshooting

- (1) Engine control system malfunction
- (2) Viscosity of engine oil too high
- (3) Use of poor quality fuel

### 1.6.2 Problem: Unstable idling



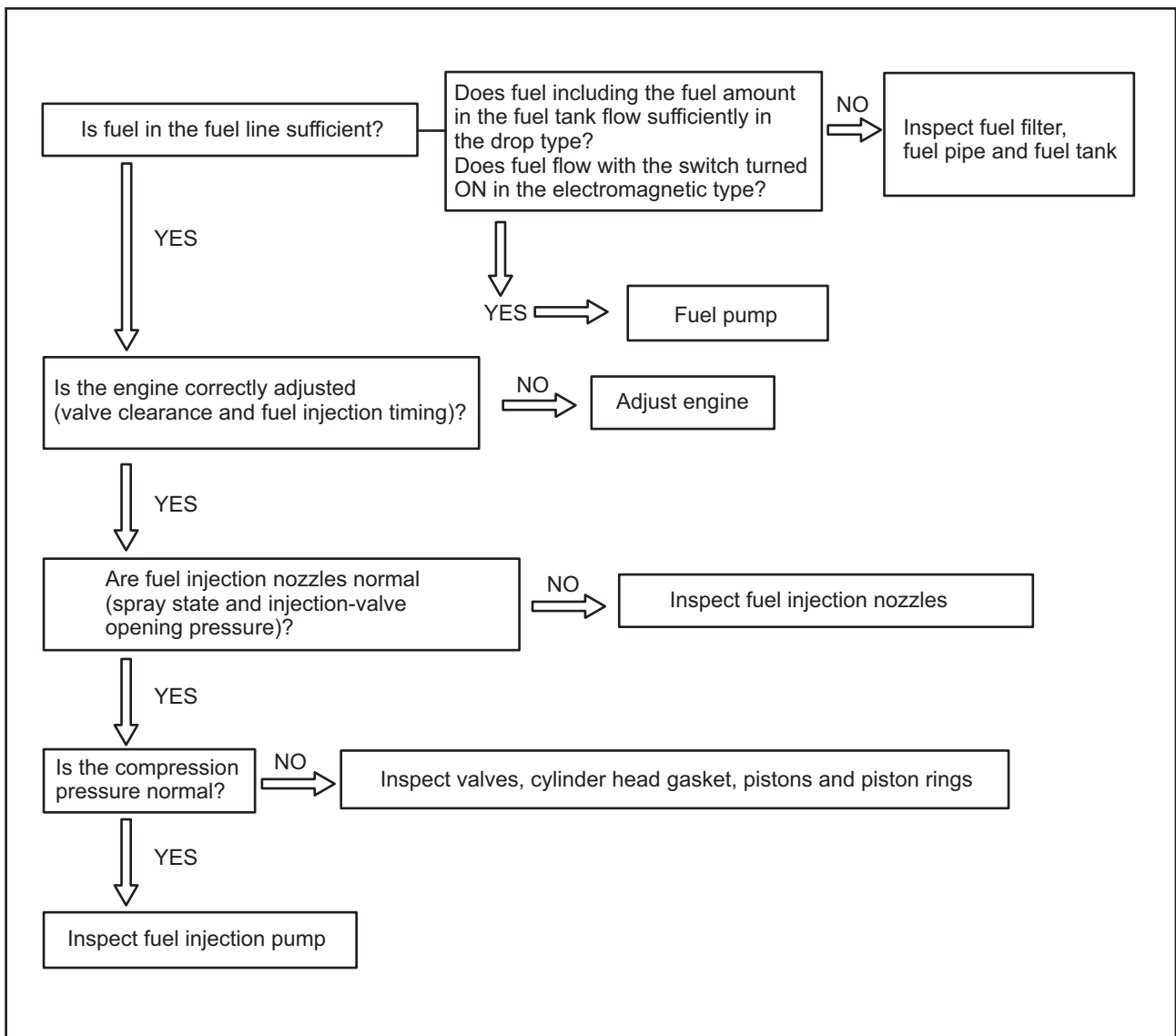
Problem: Unstable idling

**1.7 Low output**

**1.7.1 Check items before troubleshooting**

- (1) Seizure of engine moving parts
- (2) Viscosity of engine oil too high
- (3) Use of poor quality fuel
- (4) Clogging of air cleaner element
- (5) Clogging of muffler
- (6) Powertrain malfunction

**1.7.2 Problem: Low output**



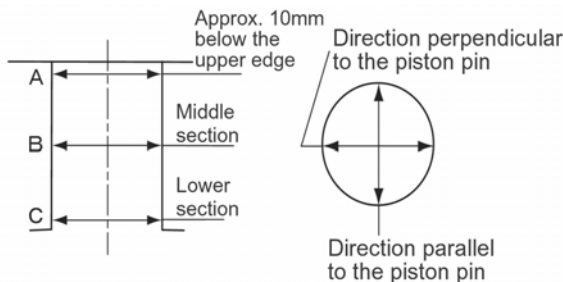
Problem: Low output



## SUPPLEMENT INSPECTION RECORD SHEET (L-SERIES)

No.1	Measurement of Cylinder Inside Diameter .....	Supplement- 2
No.2	Measurement of Valve Guide Inside Diameter and Valve Stem Outside Diameter.....	Supplement- 3
No.3	Measurement of Valve Seat Angle, Valve Sinkage and Valve Margin .....	Supplement- 4
No.4	Measurement of Distortion of Cylinder Head Bottom Surfaces .....	Supplement- 5
No.5	Measurement of Clearance Between Connecting Rod Bearing Inside Diameter and Crankshaft Pin Outside.....	Supplement- 6
No.6	Measurement of Rocker Arm Inside Diameter and Rocker Shaft Outside Diameter.....	Supplement- 7
No.7	Measurement of Piston Pin Bore Diameter and Piston Pin Outside Diameter .....	Supplement- 8
No.8	Measurement of Valve Clearance.....	Supplement- 9
No.9	Measurement of Valve Opening Pressure of Fuel Injection Nozzle.....	Supplement-10
No.10	Measurement of Camshaft Journal Outside Diameter to Cylinder Block Camshaft Bore Clearance (L2).....	Supplement-11
No.11	Measurement of Camshaft Journal Outside Diameter to Cylinder Block Camshaft Bore Clearance (L3).....	Supplement-12
No.12	Measurement of Crankshaft End Play .....	Supplement-13

# INSPECTION RECORD SHEET

				L	
Company			Engine Model		
			Serial No.		
				Date	
Inspection Point	Measurement of Cylinder Inside Diameter			Unit	
mm [in.]					
<p>Measuring Positions</p> 					
Standard					
		Nominal Value	Standard	Limit	Remarks
Cylinder Inside Diameter	L2A, L3A	φ65 [2.56]	65.00 to 65.03 [2.5591 to 2.5602]	+0.7 [+0.0276]	Repair. limit: +0.20 [+0.0079]
	L2C, L3C	φ70 [2.76]	70.00 to 70.03 [2.7559 to 2.7571]		
	L2E, L3E	φ76 [2.99]	76.00 to 76.03 [2.9921 to 2.9933]		
Measured Values					
Part Name		Cylinder Inside Diameter			
No.	Position	A	B	C	
1	X				
	Y				
2	X				
	Y				
3	X				
	Y				
Remark				Approved by	Checked by
				Measured by	

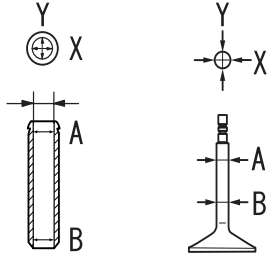
# INSPECTION RECORD SHEET

No.2

Company		Engine Model		Date	
		Serial No.			
Inspection Point	Measurement of Valve Guide Inside Diameter and Valve Stem Outside Diameter			Unit	mm [in.]

Measuring Positions

Standard



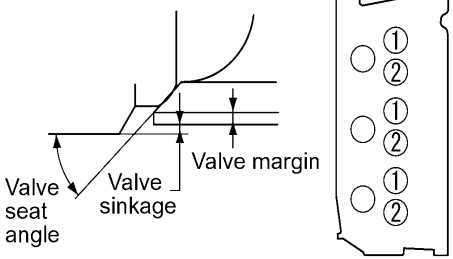
		Nominal Value	Standard	Limit
Valve Guide Inside Diameter	Inlet	φ6.6 [0.260]	6.600 to 6.615 [0.2598 to 0.2604]	-
	Exhaust	φ6.6 [0.260]	6.600 to 6.615 [0.2598 to 0.2604]	-
Valve Stem Outside Diameter	Inlet	φ6.6 [0.260]	6.565 to 6.580 [0.2585 to 0.2591]	6.500 [0.2559]
	Exhaust	φ6.6 [0.260]	6.530 to 6.550 [0.2571 to 0.2579]	6.500 [0.2559]
Clearance between Valve Stem and Valve Guide	Inlet	-	0.020 to 0.050 [0.0008 to 0.0020]	0.100 [0.0039]
	Exhaust	-	0.050 to 0.085 [0.0020 to 0.0034]	0.150 [0.0059]

Measured Values

Part Name		Valve Guide Inside Diameter				Valve Stem Outside Diameter				Clearance			
No.	Position	A		B		A		B		A		B	
		X	Y	X	Y	X	Y	X	Y	Max.	Min.	Max.	Min.
1	Inlet												
	Exhaust												
2	Inlet												
	Exhaust												
3	Inlet												
	Exhaust												

	Approved by	Checked by	Measured by

# INSPECTION RECORD SHEET

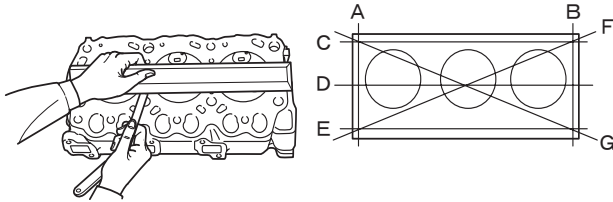
			L																																										
Company			Date																																										
	Engine Model																																												
	Serial No.																																												
Inspection Point	Measurement of Valve Seat Angle, Valve Sinkage and Valve Margin		Unit																																										
			mm [in.]																																										
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Part Name			Valve Seat Angle	Valve Sinkage	Valve Margin																																								
No.	Valve																																												
1	Inlet	1																																											
	Exhaust	2																																											
2	Inlet	3																																											
	Exhaust	4																																											
3	Inlet	5																																											
	Exhaust	6																																											
Remark			Approved by	Checked by	Measured by																																								

# INSPECTION RECORD SHEET

No.4

Company		Engine Model		Date	L
		Serial No.			
Inspection Point	Measurement of Distortion of Cylinder Head Bottom Surfaces			Unit	mm [in.]

Measuring Positions



Standard

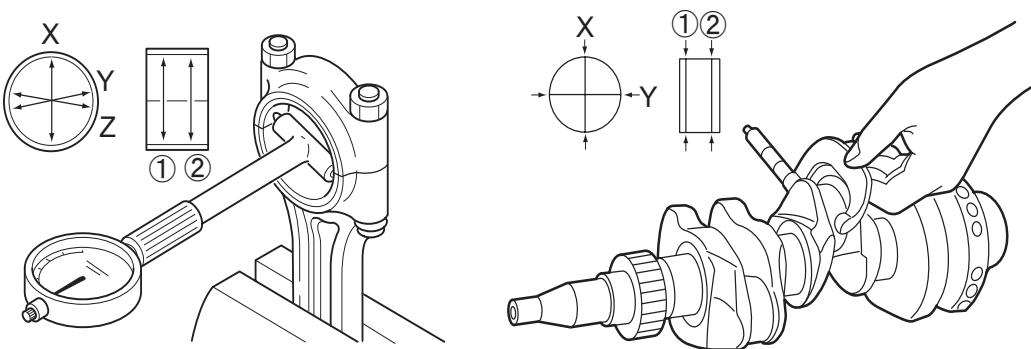
	Standard	Limit
Distortion of Cylinder Head Bottom Surfaces	0.05 or less [0.0020]	0.10 [0.0039]

Measured Values

Part Name	Distortion of Cylinder Head Bottom Surfaces						
No.	A	B	C	D	E	F	G
1							
2							
3							

	Approved by	Checked by	Measured by

# INSPECTION RECORD SHEET

				L																																																																									
Company				Engine Model		Date																																																																							
				Serial No.																																																																									
Inspection Point	Measurement of Clearance Between Connecting Rod Bearing Inside Diameter and Crankshaft Pin Outside					Unit	mm [in.]																																																																						
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2	①																																																																												
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3	①																																																																												
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Remark						Approved by	Checked by	Measured by																																																																					

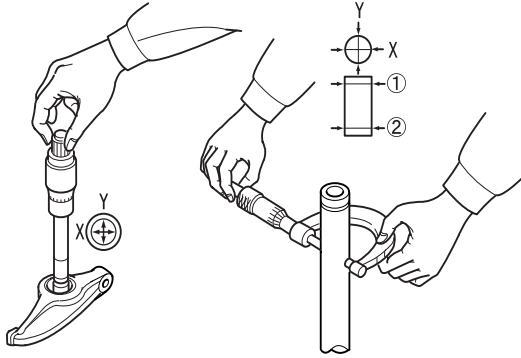
# INSPECTION RECORD SHEET

No.6

					L
Company	Engine Model		Date		
	Serial No.				
Inspection Point	Measurement of Rocker Arm Inside Diameter and Rocker Shaft Outside Diameter		Unit	mm [in.]	

Measuring Positions

Standard



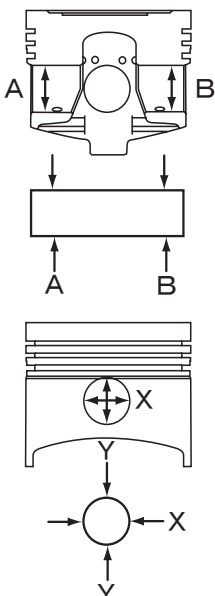
	Nominal Value	Standard	Limit
Rocker Arm Inside Diameter	φ12 [0.47]	12.013 to 12.035 [0.4730 to 0.4738]	-
Rocker Shaft Outside Diameter	φ12 [0.47]	11.470 to 11.984 [0.4516 to 0.4718]	-
Clearance between Rocker Arm and Shaft	-	0.029 to 0.065 [0.0011 to 0.0026]	0.200 [0.0079]

Measured Values

Part Name		Rocker Arm Inside Diameter		Rocker Shaft Outside Diameter		Clearance	
No.	Position	X	Y	X	Y	Max.	Min.
1	Inlet						
	Exhaust						
2	Inlet						
	Exhaust						
3	Inlet						
	Exhaust						

Remark	Approved by	Checked by	Measured by

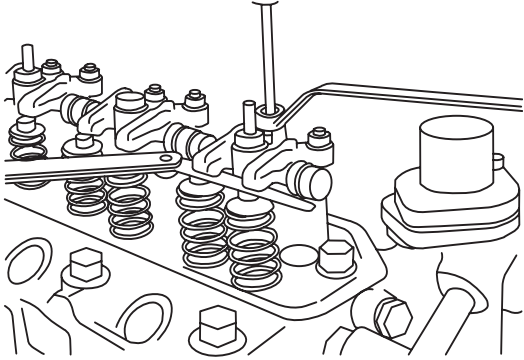
# INSPECTION RECORD SHEET

				L																																		
Company			Engine Model		Date																																	
			Serial No.																																			
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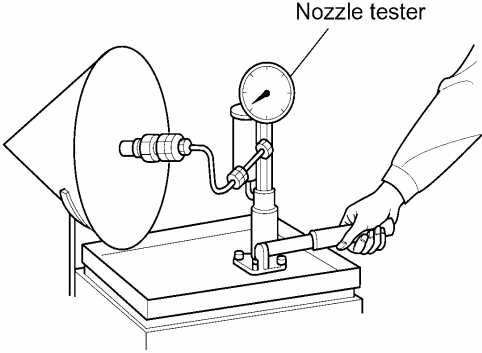


# INSPECTION RECORD SHEET

No.8

				L																											
Company			Engine Model																												
			Serial No.																												
			Date																												
Inspection Point	Measurement of Valve Clearance			Unit mm [in.]																											
<p>Measuring Positions</p> 		<p>Standard</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="2"></th> <th>Standard</th> </tr> </thead> <tbody> <tr> <td rowspan="2" style="text-align: center;">Valve Clearance (Cold Setting)</td> <td style="text-align: center;">Inlet</td> <td style="text-align: center;">0.25 [0.0098]</td> </tr> <tr> <td style="text-align: center;">Exhaust</td> <td style="text-align: center;">0.25 [0.0098]</td> </tr> </tbody> </table>					Standard	Valve Clearance (Cold Setting)	Inlet	0.25 [0.0098]	Exhaust	0.25 [0.0098]																			
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	After Adjustment																														
Remark			Approved by	Checked by																											
			Measured by																												

# INSPECTION RECORD SHEET

				L																													
Company		Engine Model		Date																													
		Serial No.																															
Inspection Point	Measurement of Valve Opening Pressure of Fuel Injection Nozzle			Unit																													
				MPa {kgf/cm <sup>2</sup> } [psi]																													
Measuring Positions		Standard																															
		<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 30%;"></th> <th style="width: 35%;">Nominal Value</th> <th style="width: 35%;">Standard</th> </tr> </thead> <tbody> <tr> <td>Valve Opening Pressure</td> <td style="text-align: center;">13.73 {140} [1992]</td> <td style="text-align: center;">13.73 to 14.73 {140 to 150} [1992 to 2134]</td> </tr> </tbody> </table>				Nominal Value	Standard	Valve Opening Pressure	13.73 {140} [1992]	13.73 to 14.73 {140 to 150} [1992 to 2134]																							
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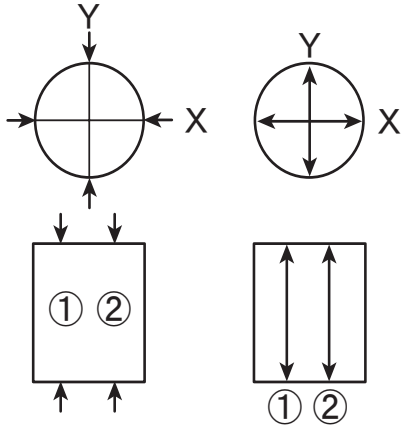
# INSPECTION RECORD SHEET

No.10

					L
Company	Engine Model		Date		
	Serial No.				
Inspection Point	Measurement of Camshaft Journal Outside Diameter to Cylinder Block Camshaft Bore Clearance (L2)		Unit	mm [in.]	

Measuring Positions

Standard



		Nominal Value	Standard	Limit
Camshaft Journal Outside Diameter	No.2	φ34 [1.34]	33.925 to 33.950 [1.3356 to 1.336]	-
	No.3	φ33 [1.30]	32.925 to 32.950 [1.2963 to 1.2972]	-
Cylinder Block Camshaft Bore Inside Diameter	No.2	φ34 [1.34]	34.000 to 34.025 [1.3386 to 1.3396]	-
	No.3	φ33 [1.30]	33.000 to 33.025 [1.2992 to 1.3002]	-
Camshaft Journal Outside Diameter to Cylinder Block Camshaft Bore Clearance	No.2 No.3	-	0.050 to 0.100 [0.0020 to 0.0039]	0.150 [0.0059]

Measured Values

Part Name		Camshaft Journal Outside Diameter		Cylinder Block Camshaft Bore Inside Diameter		Clearance	
No.	Position	X	Y	X	Y	Max.	Min.
2	①						
	②						
3	①						
	②						

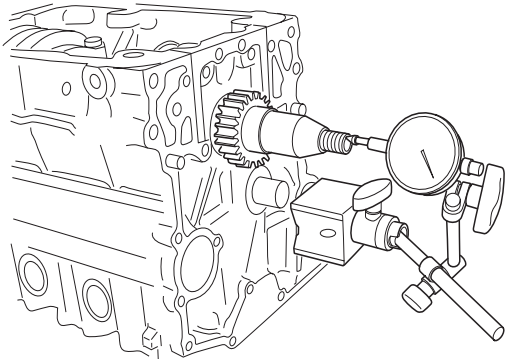
Remark	Approved by	Checked by	Measured by

# INSPECTION RECORD SHEET

				L																																																																
Company				Engine Model		Date																																																														
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# INSPECTION RECORD SHEET

No.12

		L												
Company	Engine Model		Date											
	Serial No.													
Inspection Point	Measurement of Crankshaft End Play		Unit	mm [in.]										
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