# FOREWORD

This service manual describes the specifications as well as the maintenance and adjustment procedures for Mitsubishi diesel engines. This manual also includes the detailed information on basic and special tools as the need arises.

The Mitsubishi diesel engines can offer highly efficient and reliable performance for many years to come, which, however, only can be achieved through the proper handling and the periodical inspection/maintenance work exercised in according to the procedures of disassembly, inspection/adjustment and reassembly described in this manual.

Before attempting any work on your engine, thoroughly read this manual to familiarize with the engine and the required procedures of the work.

All information contained in this manual is based on the engine produced at the time of publication and is subject to change as the engine improved without notice.

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# HOW TO USE THIS MANUAL

This Service Manual describes the specifications of Mitsubishi diesel engines (land and standard applications) and relevant service standards, as well as the procedures for servicing the engines such as for disassembly, inspection, repair and reassembly. This manual is divided into Groups. Each Group covers a specific area of the engine.
The fuel injection pump, the governor and the turbocharger are handled in a separate manual.

Major contents of Groups are listed on the "General Contents" page. Detailed contents of each Group are listed on the first page of that Group.

For information on the operations and recommended inspection/maintenance schedule of forklift trucks, please refer to the operator's manual for the forklift truck. For information on components/parts and spares ordering procedures, refer to the parts catalogue. For information on structures and functions, refer to appropriate training materials.

## 1. Notes on descriptions

(1) Parts shown in Figures as well as in the text are numbered in the order of disassembly.

(2) Inspecting points during disassembly are shown in the Disassembly figures by enclosing in the box.

(3) Service standards for inspection and repair are listed on the appropriate pages of this manual where the relevant descriptions are made. Also, a comprehensive listing of service standards is provided in Group 1.

(4) Parts reassembly sequence is provided below the Figure of that reassembly in the form of ⑤→④→③→②→①.

(5) In this manual, the following marks are provided to draw the reader's attention to the safety notes described under the marks.

**⚠ DANGER** ····This indicates a dangerous situation which can highly likely result in death or serious injury unless avoided.

**⚠ WARNING** ····This indicates a potentially dangerous situation which may possibly lead to death or serious injury unless avoided.

**⚠ CAUTION** ····This indicates a potentially dangerous situation which may cause minor to moderate injury unless avoided.

**CAUTION** ····This indicates a potential danger in which property damage may result unless avoided.

Note: ····This stresses important points or provides useful tips on engine operations and service.

(6) Wherever hardware tightening requires the application of engine oil, "WET" is mentioned. If not mentioned, tighten the hardware "dry" (engine oil should not be applied).

## 2. Terms

Nominal value ·····This is the nominal dimension of the part being measured.

Standard value ·····This is the dimension of the individual part being measured, the clearance between the parts in question, or the standard performance in question. Standard values have been arranged within the range appropriate for the inspection being carried out, and are not necessarily the design values.

Limit ·····Parts that have reached the limit value should be replaced or repaired whichever is appropriate.

## 3. Abbreviations and standards

- BTDC = Before Top Dead Center
- ATDC = After Top Dead Center
- BBDC = Before Bottom Dead Center
- ABDC = After Bottom Dead Center
- TIR = Total Indicator Reading
- API = American Petroleum Institute
- ASTM = American Society for Testing and Materials
- JIS = Japan Industrial Standards
- LLC = Long Life Coolant
- MIL = Military Specifications
- MSDS = Material Safety Data Sheets
- SAE = Society of Automotive Engineers

## 4. Units

Values shown in this manual are based on SI units (International System of Units). The corresponding metric values are shown in ( ) immediately after the SI values. The SI to metric conversions are based on the following.

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

# GENERAL CONTENTS



Supplement

Engine Inspection Sheets

# SAFETY CAUTIONS

# ⚠Warning Risk of fire and explosion

## ●Never use open fire

When topping up or replacing fuel or engine oil, or cleaning parts in wash oil, do not light a match, smoke or use any other open fire nearby. Doing these is extremely dangerous as fuel and oils can catch fire.
Completely wipe off any spilt fuel or engine oil as they are flammable and can be a fire hazard.
Store fuel and engine oil in a well-ventilated place. Firmly tighten the cap of the container.

## ●Keep things tidy around the engine

Keep fuel, engine oil or any other flammables as well as explosives and other dangerous materials away from the engine. These materials can ignite and explode.
Keep the engine and the surrounding area free of waste, dirt, foreign matter, etc. These substances can be a fire hazard and invite overheating. In particular, ensure that the top of the battery is clean after service operations. Any waste left on the battery can cause short circuit.
Keep a running engine at least 1 m (3.3 ft.) away from the surrounding building or equipment to eliminate the risk of fire.

## ●Do not open the crankcase until it has cooled down

Do not attempt to open the crankcase side cover immediately after the engine is stopped. Wait at least 10 minutes until the engine has sufficiently cooled down.
If fresh air flows into the crankcase with the engine still hot, the remaining mist of oil may ignite and cause explosion.

## ●Pay attention to fuel and oil leakage

If leakage of fuel or oil is found, immediately take measures to stop it.
If leaking fuel or engine oil spills over the heated engine, fire may start, possibly leading to bodily injury or equipment damage.

## ●Use explosion-proof light

When checking fuel, engine oil, coolant, battery electrolyte, etc., use explosion-proof light. If ordinary light is used, these fluids may ignite and explode.

## ●Prevent short circuit

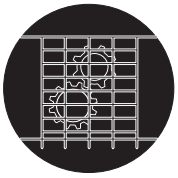
Before inspecting or servicing the electrical/electronic system, disconnect the negative (-) cable from the battery terminal. Failure to observe this can cause the circuit to short, possibly starting a fire.
Loose terminals and damaged cables/wires can cause short circuit or even fire. Before carrying out service operation, check for loose or damaged components and repair or replace as required.

## ●Keep fire extinguisher and first-aid kit at hand

Keep a fire extinguisher at hand. Become familiar with the handling of the fire extinguisher.
Store a first-aid kit at the designated place. The kit should be kept fully supplied so that it can serve the purpose at any time.
Establish a set of actions to take in the event of fire or accident, including emergency contact numbers and means of communication.

# ⚠Warning Risk of entanglement into the machine

## ●Keep guards on the rotating parts



Ensure that all guards are correctly installed over the rotating parts of the engine. Damaged or loose guards should be repaired.

Never attempt to remove the camshaft cover, rocker cover or any other guards form rotating parts while the engine is running.

Never leave exposed the drive belts and related couplers for auxiliaries and radiator. They should also be covered with guards.

Never remove these guards.

## ●Ensure safety in the surrounding area when starting the engine

Before starting the engine, ensure that no one is near the electric power generator and that no tools or foreign matter are left behind. Shout to people around you so that they will know you are starting the engine.

Never start the engine if a “Do not start” tag or any other similar message is posted on the starter switch, etc.

## ●Keep away from rotating parts while the engine is running

Never stand near the rotating parts while the engine is running.

Do not place objects near the rotating parts that are likely to be caught by these parts.

Should any part of human body (or tool) is caught by the rotating parts, dismemberment or other bodily injury will result.

## ●Lockout/tagout

Perform lockout/tagout before carrying out any inspection/service.

Lockout/tagout is an ideal way of disconnecting the machine/equipment from the power source.

To lockout/tagout, remove the starter switch key, place the battery switch in the “OFF” position, and post a “Do not start” tag or other similar message on the starter switch.

The starter switch key should then be carried by the person who is going to perform inspection/service.

If an air start system is used, close the air tank source valve and post a “Do not open” tag or other similar message.

## ●Always stop the engine before any inspection/service

Always stop the engine before performing any inspection/service. Never attempt to adjust belt tension while the engine is running. Otherwise, the operator runs a great risk of becoming entangled into the rotating parts and seriously injured.

## ●Remove the turning gear after use

Be sure to remove the turning gear after use. Never start the engine with the turning gear still installed or “engaged.” Otherwise, the engine will break and possibly someone may become injured.

## ⚠Warning Risk of burn

### ●Do not touch the engine while it is running or for a while after it is stopped

Never touch any part of the engine while it is running or for a while after it is stopped. Otherwise, you may become burned.

Use a coolant temperature gauge to confirm that the engine has sufficiently cooled down before performing any inspection/service.

### ●Be careful when opening/closing the radiator cap

Never attempt to open the radiator cap while the engine is running and for a while after it is stopped. Stop the engine and wait until the coolant temperature has sufficiently dropped before opening the cap.

Slowly open the radiator cap to allow the internal pressure to escape. To prevent possible burn, wear thick rubber gloves or cover the cap with cloth to protect your hands from escaping vapor.

Tighten the radiator cap firmly.

Coolant is extremely hot while the engine is running or for a while after the engine is stopped. You may become burned by extremely hot vapor or coolant that will gush out if the radiator cap is opened.

### ●Replenish coolant only when the coolant in the system is cold

Do not replenish coolant for a while after the engine is stopped. Replenish coolant when the coolant in the system is sufficiently cold. Otherwise, you may become burned.

### ●Do not remove heat insulating material

The exhaust system components become extremely hot and therefore are covered with heat insulating material. Never remove the material. If the material needs to be removed at all for inspection/service, be sure to install it again after the operation.

## ⚠Warning Exhaust gas is poisonous

### ●Ensure good ventilation while the engine is running

If the engine is installed inside a building and the exhaust gas is directed outside through a duct, regularly check the duct for any leakage through the joints etc.

Do not run the engine in a building (warehouse, tunnel, etc.), confined space, or other poorly ventilated places if the engine is used for a portable generator. If the engine needs to be run in a building at all, ensure to direct the exhaust gas outside and provide sufficient ventilation. Also, take care not to direct the exhaust gas towards nearby plants or animals, if any.

Engine exhaust gas contains carbon monoxide and other substances that are harmful to humans. Running the engine in a poorly ventilated place can cause exhaust gas poisoning.

## ⚠Warning Hearing difficulty

### ●Wear ear protector

Wear ear protector whenever entering the engine room. Otherwise, the combustion and mechanical noises may cause you to develop hearing difficulty.

## ⚠Warning Beware of falling engine

### ●Exercise caution when lifting the engine

The wire rope used to lift the engine should have enough strength to withstand the weight of the engine.
Attach the specified lifting gear onto the lifting hangers on the engine.
Ensure that the engine is well balanced when it is lifted by taking into account the engine's center of gravity.
The angle of wire rope relative to the lifting hangers should be maintained at 60º or less. Above this, the hangers may be subjected to overload and break.
If direct contact between the wire rope and the engine is anticipated, protect them from damage by covering them with cloth or other soft material.

### ●Do not climb on the engine

Do not climb onto the engine, nor place a foot on the components on the side of the engine.
Otherwise, you may not only break the engine components but also fall and become injured.
Use a stool or a platform to work on the top of the engine. Be careful not to slip and fall.

### ●Secure your foothold when carrying out service

Use a stable stool or platform when working on the top of the engine or other areas of the engine difficult to reach.
Do not use a rickety stool nor substitute a box of parts. Otherwise, you may fall and become injured.
Do not leave anything on the stool.

## ⚠Caution Use correct engine oil and LLC

### ●Only use the specified fuel, engine oil and coolant (LLC)

Only use the fuel, engine oil and coolant (LLC) that are specified in this manual. Handle them with sufficient care.
Using fluids other than those specified in this manual or incorrect use of those specified in this manual will lead to many problems and may possibly cause failures.
Use the specified engine oil and LLC according to the instructions of MSDS (Material Safety Data Sheets) issued by and available from the manufacturers.

### ●Handle LLC with care

LLC is a strong alkali. Be careful not to drink it by mistake or allow it to contact your eyes.
Old coolant (containing LLC) that has been drained off is toxic. Do not dispose of it carelessly. Dispose of it in accordance with the applicable laws and regulations.

### ●Lawful disposal of waste oil and coolant

Do not dispose of waste oil or coolant carelessly.
Doing so is harmful to the environment and is prohibited by law.
Harmful substances such as waste oil and coolant should be disposed of in a manner that complies with the applicable laws and regulations.

## ⚠Caution Handling of battery

### ●Handle the battery with care

- Batteries emit hydrogen and oxygen gases, both of which are flammable. Never use open fire or generate sparks near the battery. Otherwise, these gases may ignite and explode.
- Do not use the battery if the electrolyte level has dropped below the minimum line. Otherwise, the battery may explode.
- Be careful not to inadvertently place a metal object such as tool between the battery terminals.
- Always disconnect the negative (-) terminal first, then the positive (+) terminal, from the battery. Always connect the positive (+) terminal first, then the negative (-) terminal, to the battery.
- Recharge the battery in a well ventilated place, with all battery plugs removed.
- The battery terminals should have a positive connection. Loose terminals can generate sparks, possibly causing the battery to explode.
- Before servicing or performing electric welding on the electrical/electronic system, position the battery switch in the "OPEN/OFF" position or disconnect the negative (-) terminal of the battery to isolate the electrical/electronic circuit.
- The battery electrolyte contains dilute sulfuric acid. Incorrect handling may lead to loss of eyesight or burn. Never drink battery electrolyte.
- Wear protective goggles and rubber gloves when maintaining the battery (replenishing, recharging, etc.).
- If your skin or clothing has come into contact with battery electrolyte, immediately wash the affected area with plenty of water and then thoroughly clean with soap.
- Should your eyes come into contact with battery electrolyte, loss of eyesight may result. Immediately wash your eyes with plenty of fresh water and seek medical attention immediately.
- Should you inadvertently drink battery electrolyte, repeatedly gargle with plenty of water and then drink plenty of water. Seek medical attention immediately.

## ⚠Caution How to handle emergencies

### ●Engine overheat - Idle to cool down, then stop the engine

In the event of engine overheat, do not stop the engine immediately. Doing so may cause the coolant temperature to rise quickly and the engine may seize. Instead, run the engine at low idle for a while to cool it down. Then, stop the engine. Do not attempt to replenish coolant for a while after the engine is stopped. Otherwise, the cylinder head etc., which may still be hot, is cooled down rapidly and may break. Wait until the engine is sufficiently cold and then top up slowly.

### ●Never restart the engine after a sudden stop unless the cause is eliminated

If the engine has suddenly stopped with some alert signals, do not restart immediately. Otherwise, the engine may seriously become damaged. Locate and eliminate the cause before restarting.

### ●Stop the engine immediately upon oil pressure drop

If the oil pressure has dropped, immediately stop the engine. Otherwise, bearings etc. may seize. Inspect the oil system and components.

### ●Stop the engine immediately upon broken fan belt

If the fan belt has broken, immediately stop the engine. Otherwise, the engine will overheat. Also, coolant vapor will gush out from the reserve tank and radiator and you may get burned.

# ⚠Caution Other considerations

## ●Never alter or modify the engine

Altering or modifying the engine in any way will nullify the warranty.

A modified engine may not only break but also lead to injury.

## ●Do not tamper with sealing

To help ensure trouble-free operation of the engine, the fuel control link has been sealed to achieve the correct fuel injection volume and engine speed. If the sealed setting is tampered with, the following will result and the correct functioning of the engine is no longer guaranteed.

- Sliding and rotating parts will wear faster.
- Various parts will seize/become damaged.
- The engine will consume more fuel and oil.
- The governor and fuel injection volume go out of balance, reducing the engine performance.

## ●Daily and periodical inspection

Perform the daily and periodical inspection in accordance with the Operation and Maintenance Manual.

Failure to observe the instructions of the manual may lead to many problems, and the various engine parts may eventually fail, possibly causing a serious accident.

## ●Running-in period

A brand new engine requires a running-in period of 50 hours, during which never put the engine under severe load. Otherwise, the service life of the engine will be reduced.

## ●Warming up the engine

Before starting work, warm up the engine by running it at low idle for 5 to 10 minutes.

Warming up the engine will not only smoothen the operation of various engine parts but also help extend its service life. It also helps maximize the performance and achieve economical running of the engine.

Do not warm up the engine longer than necessary. Doing so facilitates carbon deposit on the cylinders, possibly leading to poor combustion.

## ●Do not overload the engine

Do not continue to run the engine if it emits black smoke.

Overloaded running of the engine (accompanied by black smoke) not only consumes excessive fuel but also facilitates carbon deposit and thus shortens the service life of the engine.

## ●Cooling down the engine

Before stopping the engine, cool it down (by running it at low idle) for 5 to 6 minutes.

Stopping the engine suddenly while it is heavily loaded will result in some areas of the engine remaining extremely hot for a while, which is detrimental to the long service life of an engine.

While the engine is being run at low idle for cooling, check the engine for any problems.

## ●Do not spill water onto the engine

Ensure that no rainwater etc. enters into the engine from the exhaust or inlet manifold, or via any other routes.

Do not run the engine while at the same time washing it. Otherwise, cleaning fluid (water) may be sucked into the engine.

If the engine is started with water trapped in the combustion chambers, water hammering will result, causing the engine to fail and possibly leading to a serious accident.

## ●Air cleaner maintenance precautions

Wear of engine parts is accelerated largely by the dust contained in the intake air. Worn engine parts will lead to various problems such as increased oil consumption, reduced power and poor starting. Air cleaner is effective in removing dust in the intake air. When maintaining the air cleaner, observe the following precautions.

- Never attempt to service the air cleaner while the engine is running.
- When removing the air cleaner, take care not to allow the dust trapped on the air cleaner to enter into the inlet port.
- If the engine is equipped with the dust indicator, clean the air filter only when the indicator shows clogging. Unnecessary maintenance (removal/ installation of the filter element) runs the risk of allowing dust into the inlet port or damaging/ deforming the filter element.

## ●Observe safety rules at work sites

Whenever running or servicing the engine, always observe the relevant safety rules in place.

If you are not in good shape, do not operate the engine. Consult the site supervisor.

Poor physical conditions are accompanied by reduced attention. Do not operate the engine if you are not feeling well. Otherwise, you may incorrectly handle the engine and cause an accident.

When working jointly with other people on the same task, use signals to coordinate actions involved.

## ●Wear appropriate clothes and protective gear

Whenever appropriate, including when using compressed air, wear protective gear such as helmet, face mask, safety shoes, dust mask, goggles and gloves.

Working without appropriate protective gear may lead to serious injury.

## ●Use appropriate tools when carrying out service

When carrying out any service, use appropriate tools and in correct ways.

Damaged tools should be replaced with new ones.

## ●Do not operate the starter continuously

Do not operate the starter more than 10 seconds per starting attempt. If the engine fails to start at the first attempt, wait for at least 30 seconds before trying again.

Do not run the starter continuously if the engine will not start. Otherwise, the battery will go flat or the starter will seize.

## ●The battery switch must be kept ON while the engine is running

Do not turn off the battery switch while the engine is running.

Otherwise, the instruments will become inoperative and the diode or transistor of the alternator may deteriorate.

## ●Precautions for road transport

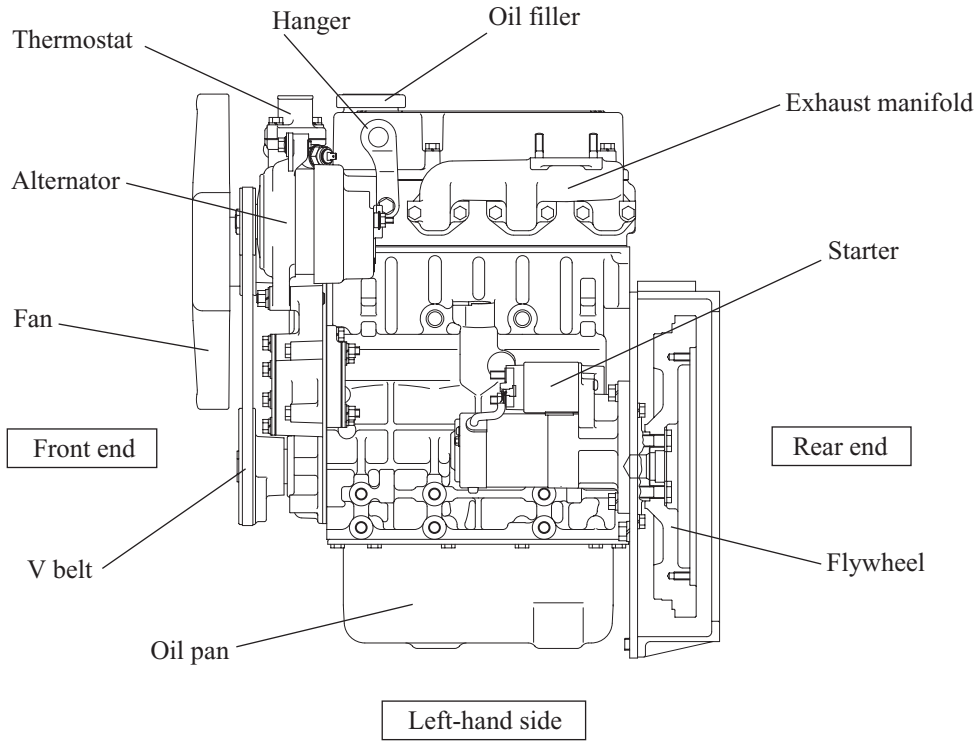
When transporting the engine on public roads, the weight, width and height of the electric power generator should be taken into account while observing the relevant laws regarding road traffic and haulage, and vehicle restrictions and requirements.

# GENERAL

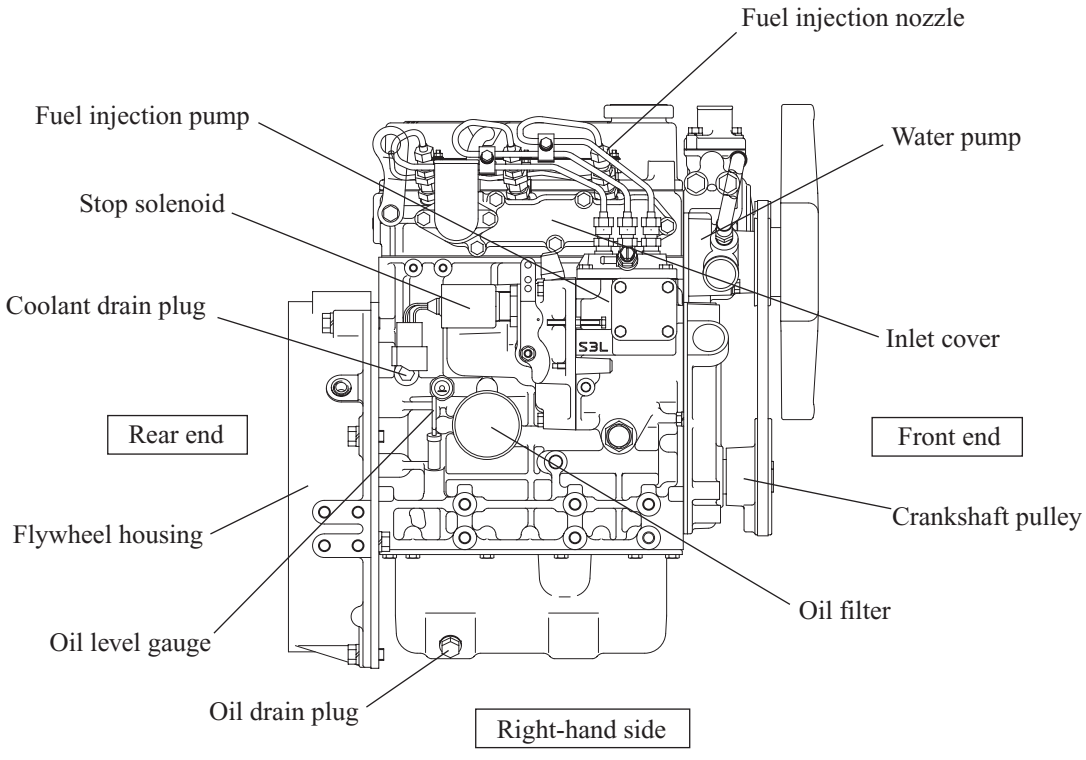
# 1. Overview

## 1.1 Outline Drawing

S3L, S3L2

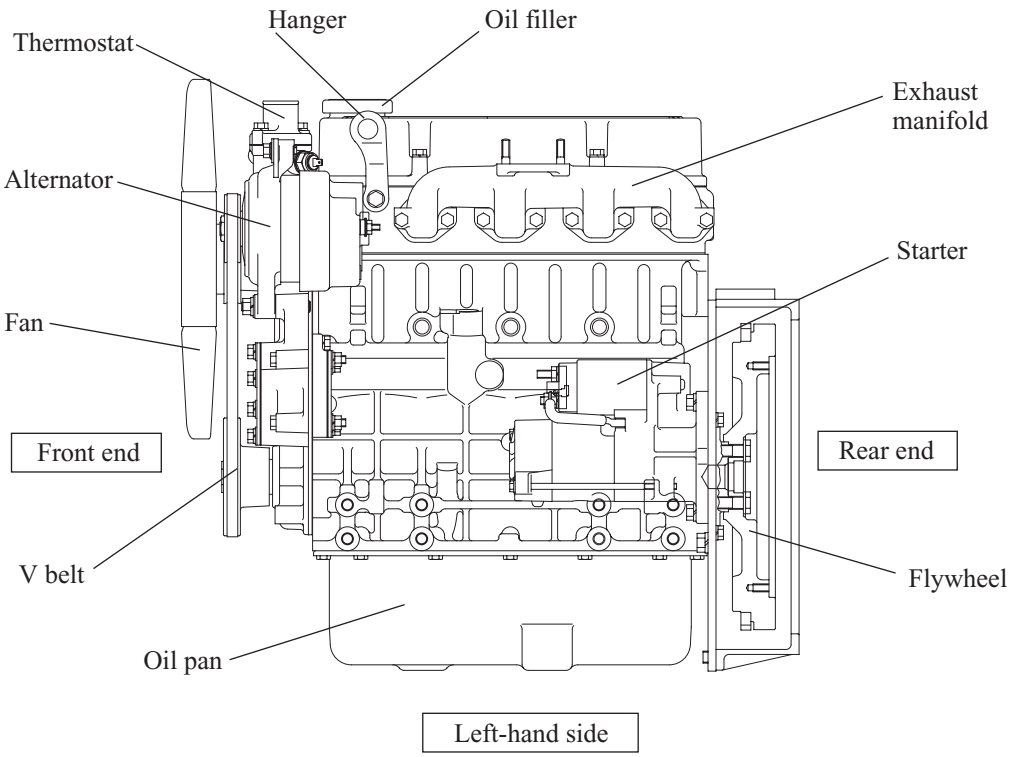



Engine LH side view

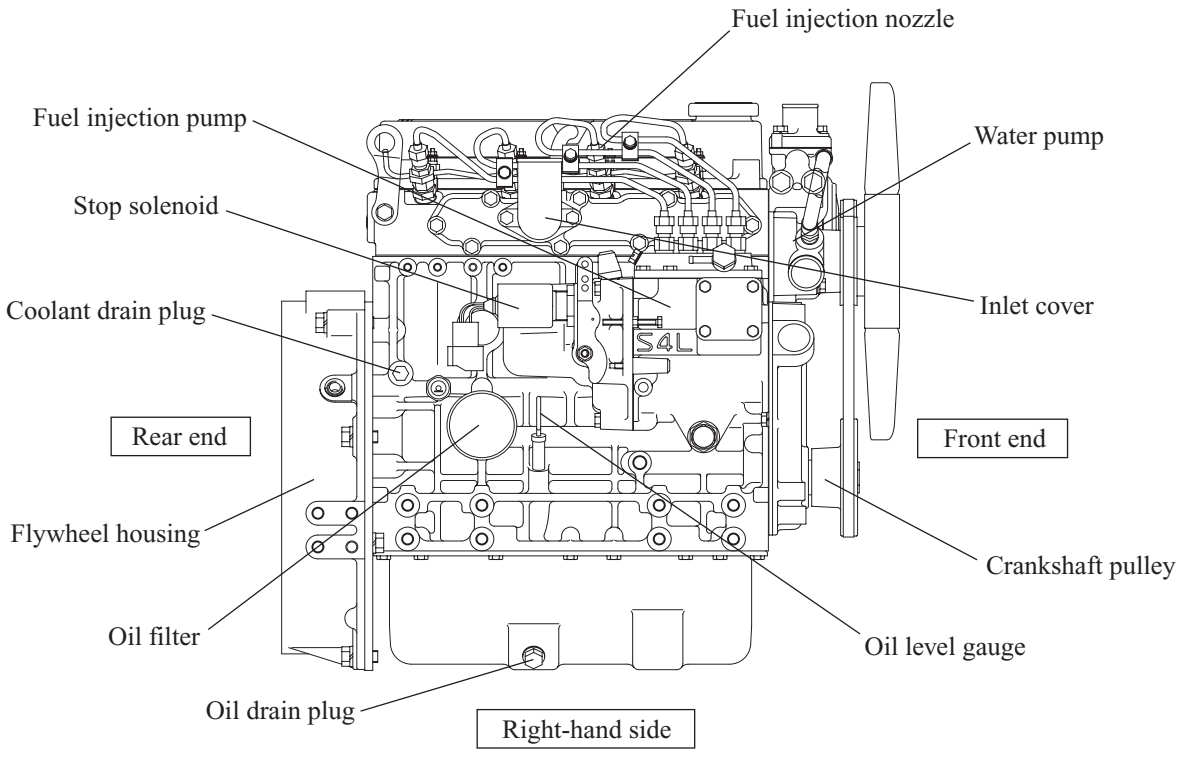



Engine RH side view

S4L, S4L2

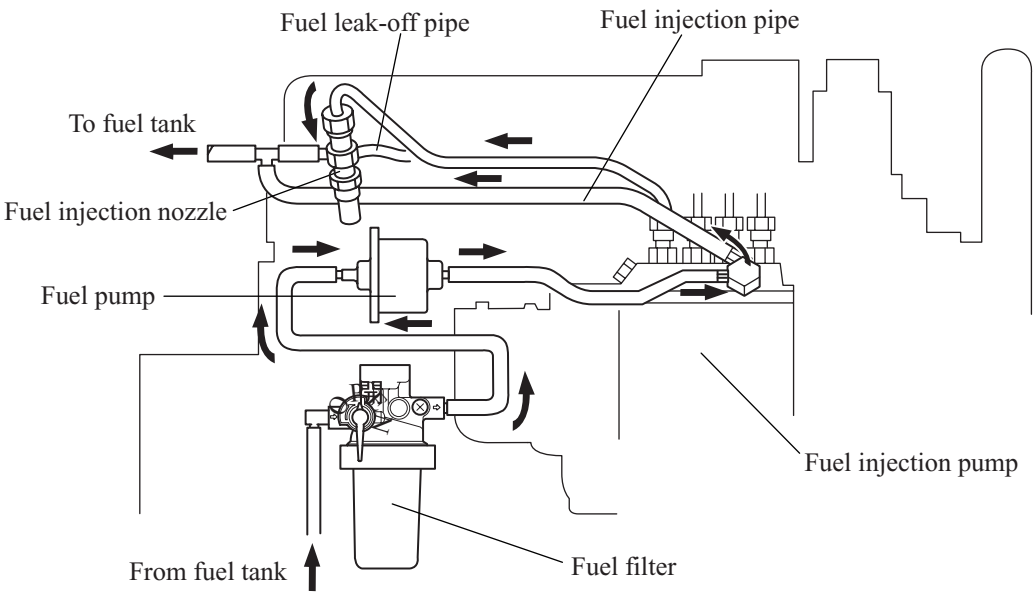



Engine LH side view



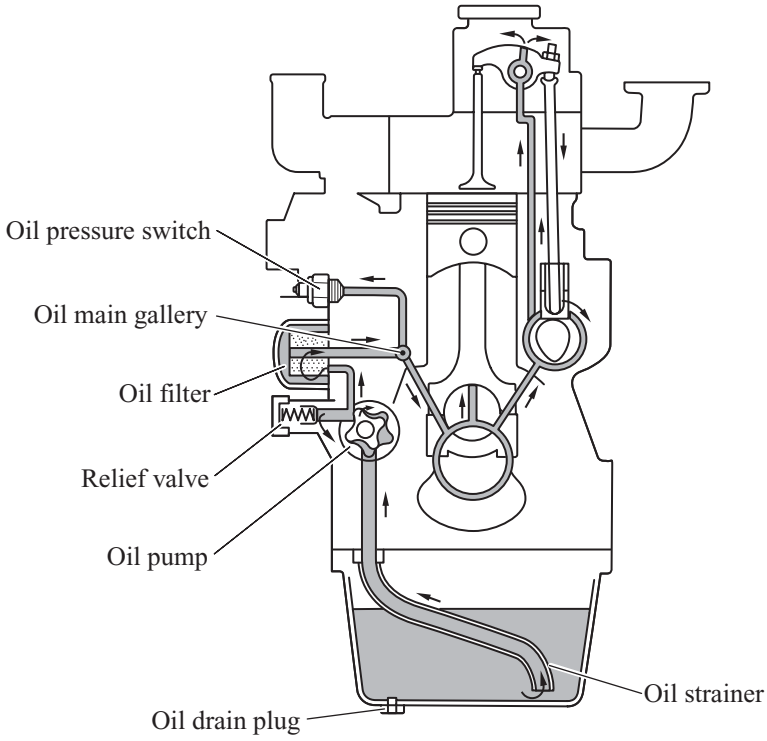

Engine RH side view

## 1.2 Fuel System Schematic



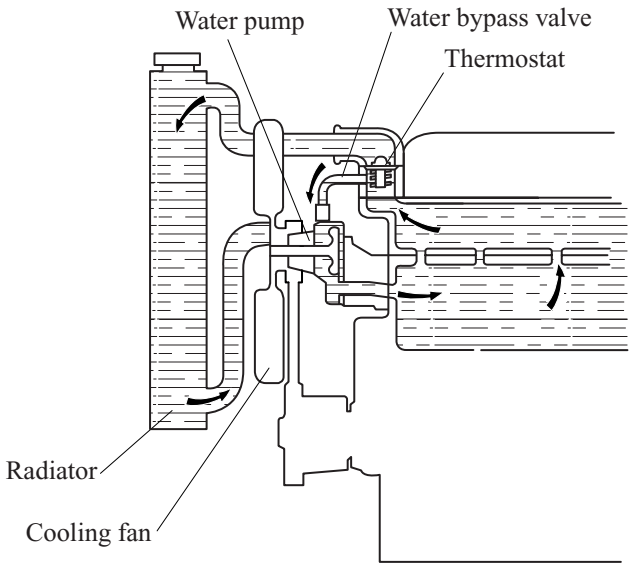

Fuel system schematic

## 1.3 Oil System Schematic



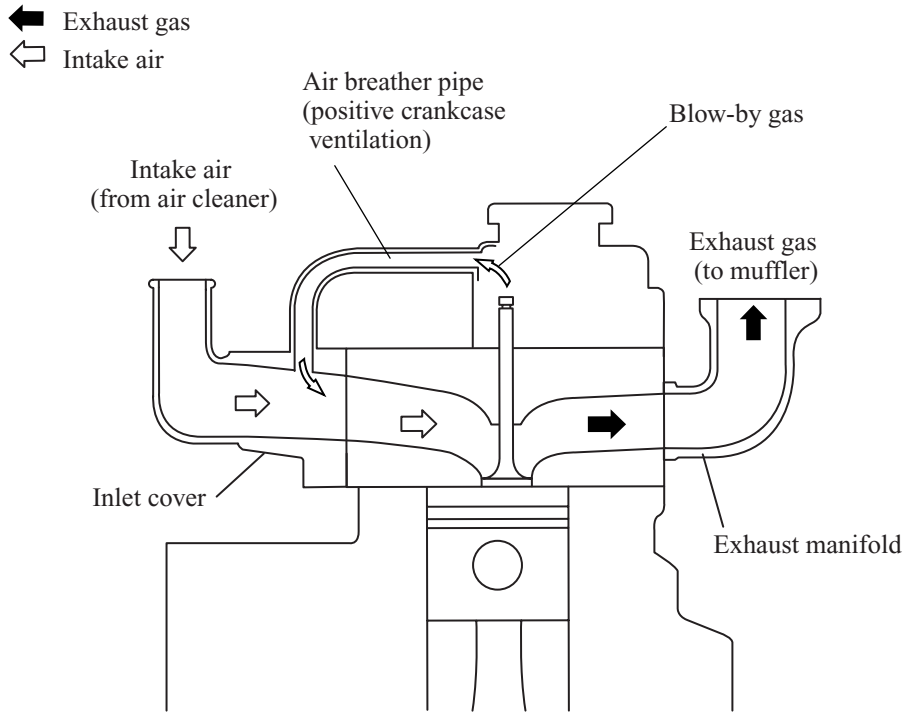

Oil system schematic

## 1.4 Cooling System Schematic




Cooling system schematic

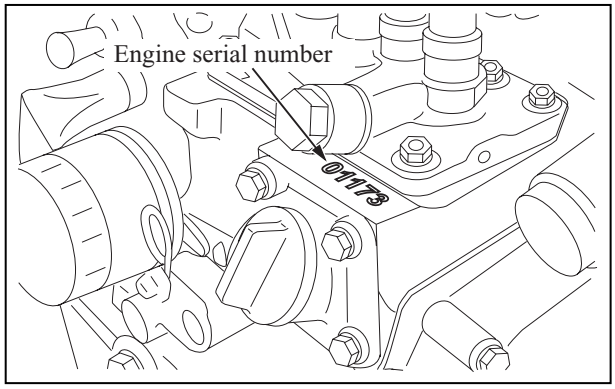
## 1.5 Inlet / Exhaust System Schematic




Inlet / exhaust system schematic

## 1.6 Engine Serial Number

The engine serial number is stamped on the top face of the fuel injection pump bracket on the right-hand side of the cylinder block.

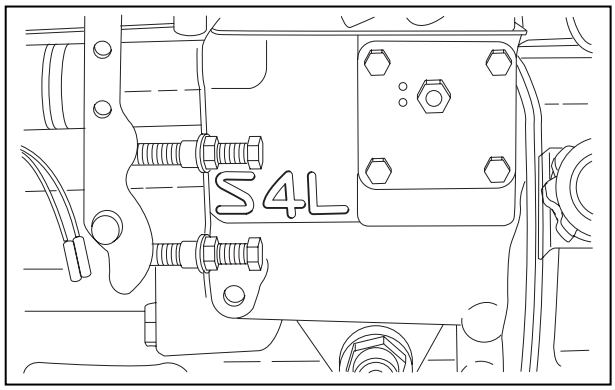



Engine serial number location

## 1.7 Engine Model and Application Codes

(1) The engine model code is embossed on the side of the fuel injection pump mount on the right-hand side of the cylinder block.

(2) The engine model code consists of the following alphanumerical digits.




Engine model code

### Model coding

(Example) S 4 L 2

- 2 — Type (2 = Type 2)
- L — Series [L = bore size 78 mm (3.07 in.)]
- 4 — No. of cylinders (4 = 4 cylinders)
- S — S = Sagamihara Machinery Works

## 2. Specifications

| Engine Type | | | | S3L | S3L2 | S4L | S4L2 |
|---|---|---|---|---|---|---|---|
| General | Type | | | Water-cooled; 4-stroke cycle; Diesel powered | | | |
| | No. of cylinders | | | 3 | | 4 | |
| | Combustion | | | Swirl chamber type | | | |
| | Valve mechanism | | | Overhead valve type | | | |
| | Cylinder bore × stroke mm (in.) | | | 78×78.5 (3.07×3.09) | 78×92 (3.07×3.62) | 78×78.5 (3.07×3.09) | 78×92 (3.07×3.62) |
| | Total displacement ℓ (U.S. gal) | | | 1.125 (0.297) | 1.318 (0.348) | 1.500 (0.396) | 1.758 (0.464) |
| | Compression ratio | | | 22.0 : 1 | | | |
| | Fuel | | | Diesel fuel (JIS K2204 Special 1 - 3) | | | |
| | Firing order | | | 1-3-2 | | 1-3-4-2 | |
| | Direction of rotation | | | Counterclockwise when viewed from the flywheel end | | | |
| | Dimensions | Overall length mm (in.) | | 536 (21.10) | | 620 (24.40) | |
| | | Overall width mm (in.) | | 433 (17.04) | | 433 (17.04) | |
| | | Overall height mm (in.) | | 572 (22.52) | | 572 (22.52) | |
| | Dry mass kg (lb) | | | 135 (297.6) | | 155 (341.7) | |
| Engine main parts | Piston ring | No. of rings | | Compression ring :2<br>Oil ring (w/expander) : 1 | | | |
| | Valve timing (hot engine) | Inlet valve | Open | BTDC 15° | | | |
| | | | Close | ABDC 41° | | | |
| | | Exhaust valve | Open | BBDC 54° | | | |
| | | | Close | ATDC 10° | | | |
| | Engine mounting | | | 4 mounts | | | |
| | Starting method | | | Starter | | | |
| Fuel system | Injection pump | Type | | Bosch M | | | |
| | | Manufacturer | | DENSO | | | |
| | | Plunger diameter mm (in.) | | ϕ5.5 (0.21) | | | |
| | | MS retard (crank angle) | | 8° | | | |
| | | Cam lift mm(in.) | | 15 (0.59) | | | |
| | Governor | Governing method | | Centrifugal fly-weight type | | | |
| | Injection nozzle | Type | | Throttle nozzle | | | |
| | | Manufacturer | | Bosch Automotive Systems Corporation | | | |
| | | Spray angle mm (in.) | | 15° | | | |
| | | Opening pressure MPa ($kgf/cm^2$) [psi] | | 14.22 to 15.00 (145 to 153) [2062 to 2176] | | | |
| | Fuel filter | Type | | Paper-element cartridge; Separate type w/ cock | | | |
| Oil system | Lubrication method | | | Forced circulation (pressure feed by trochoid pump) | | | |
| | Engine oil | Grade | | CD Class (API Classification) | | | |
| | | Capacity (entire engine) ℓ (U.S. gal) | | 3.7 (1.0) | 4.2 (1.1) | 5.4 (1.4) | 6.0 (1.6) |
| | Oil pump | Type | | Gear pump | | | |
| | | Displacement ℓ (U.S. gal) /min | | 18 (4.8) | | | |
| | Relief valve | Type | | Piston valve | | | |
| | | Opening pressure MPa ($kgf/cm^2$) [psi] | | 0.35±0.05 (3.6±0.5) [51±7] | | | |
| | Oil filter | Type | | Paper element (spin-on type) | | | |

| Engine Type | | | S3L | S3L2 | S4L | S4L2 |
|---|---|---|---|---|---|---|
| Cooling system | Cooling method | | Water-cooled, forced circulation | | | |
| | Capacity (engine proper) ℓ (U.S. gal) | | 1.8 (0.5) | | 2.5 (0.7) | |
| | Water pump | Type | Centrifugal pump | | | |
| | | Displacement ℓ (U.S. gal) /min | 30 (8.0) up (@ 2000 $min^{-1}$ engine speed) | | | |
| | Thermostat | Type | Wax | | | |
| | | Opening temperature ℃ ( ℉) | 82±1.5 (179.6±2.7) | | | |
| | Cooling fan | Type | Pusher suction (PP fan) | | | |
| | | No. of blades / OD mm (in.) | 5 / 340 (13.39), 6 / 320 (12.6), 6 / 340 (13.39), 6 / 360 (14.17), 6 / 380 (14.96), 7 / 380 (14.96) | | | |
| Inlet system | Air cleaner | Type | Paper element | | | |
| Electrical system | Voltage - Polarity | | 12 V - Θ ground, 24 V - Θ ground | | | |
| | Starter | Type | M001T68281, M008T70471A, M008T81071A | | | |
| | | Manufacturer | Mitsubishi Electric Corporation | | | |
| | | Pinion engagement | Pinion shift (reduction) | | | |
| | | Output V-kW | 12 V-1.7, 12 V-2.0, 24 V-3.2 | | | |
| | | No. of units | 1 | | | |
| | | Reduction ratio (pinion / ring gear) | 13 / 120 | | | |
| | Alternator | Type | 3-phase alternator w/ built-in IC regulator | | | |
| | | Manufacturer | Mitsubishi Electric Corporation | | | |
| | | Output V-A | 12-50, 24-25 | | | |
| | | Speed at which rated voltage is generated $min^{-1}$ | 5000 (@ 13.5 V, 47 A), 5000 (@ 27.0 V, 22 A) | | | |
| | | Regulated voltage V | 14.7±0.3 (12-50), 26.5±0.5 (24-25) | | | |
| | Glow plug | Type | Sheathed plug | | | |
| | | Rated voltage - current V-A | 12 V plug | | 24 V plug | |
| | | | 10.5-9.7 (30-second application) | | 22.5-5 (25-second application) | |
| | Stop solenoid | Operating voltage V | 12 V-ETR | 12 V-ETS | 24 V-ETR | 24 V-ETS |
| | | | 8 or less | 10 to 15 | 16 or less | 20 to 30 |
| | | Insulation resistance | 100 MΩ or more at DC500 V (at ordinary temperature and humidity) | | | |
| | | Stroke mm (in.) | 13.5±0.5 (0.53±0.01) | | | |
| | | Working ambient temperature ℃ ( ℉) | -40 to 120 (-40 to 248) | -30 to 120 (-22 to 248) | -40 to 120 (-40 to 248) | -30 to 120 (-22 to 248) |

# 3. Disassembly / Reassembly Notes

This Service Manual specifies various procedures recommended by Mitsubishi Heavy Industries, Ltd. for servicing Mitsubishi diesel engines. These procedures include, wherever appropriate, required special tools and related safety precautions.

The instructions provided in this manual, however, cannot fully guarantee safety as potential risks beyond ordinary imagination are hidden everywhere.

When conduct any work, the following points should also be observed in addition to the instructions this manual.

## 3.1 Disassembly

(1) Use tools and equipment that are appropriate for the work being carried out.

(2) Whenever necessary, use workbenches to work on or sort parts out. Disassemble in accordance with the disassembly sequence given in the manual.

(3) As parts are disassembled, place them neatly in the order of removal to eliminate missing parts on reassembly.

(4) During disassembly, note the assembly marks. Remember to respect these marks on reassembly. Whenever appropriate, put additional assembly marks to aid reassembly.

(5) Before and during disassembly as well as during subsequent washing, carefully check for any abnormality or other fault which otherwise may likely remain unnoticed afterwards.

(6) Pay sufficient attention to ensure safety, especially when lifting or carrying heavy components and parts. (Use a jack or a chain block as required.)

## 3.2 Reassembly

(1) Parts excluding oil seals, O-rings, rubber sheets, etc. should be thoroughly washed in wash oil and completely dried using compressed air.

(2) Use appropriate tools and equipment.

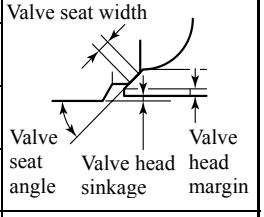
(3) Use good-quality oil and grease. Never fail to apply oil, grease, sealant and adhesive to the relevant locations if so instructed in the manual.

(4) Tighten hardware to the specified torque, if provided in the manual. Be sure to use a torque wrench.
(5) Gaskets, packing and O-rings should be replaced with new parts unless specified otherwise.

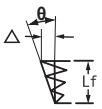
# SERVICE STANDARDS

# 1. Service Standards Table

Unit: mm (in.)

| Group | Item | | | Nominal value | Standard value | Limit | Remarks |
|---|---|---|---|---|---|---|---|
| Engine general | Max. speed (based on the rated speed) | | | | $2700^{+30}_{-10}$ min$^{-1}$ | | |
| | Min. speed | | | | 1000±25 min$^{-1}$ | | |
| | Compression pressure (at 290 min$^{-1}$) | | | | 2.9 MPa (30 kgf/cm$^2$) [421 psi] or above | 2.6 MPa (27 kgf/cm$^2$) [377 psi] or less | Both oil and coolant temperatures at 20 to 30°C (68 to 86°F) |
| | Engine oil pressure | Rated speed | | | 0.29 to 0.39 MPa (3.0 to 4.0 kgf/cm$^2$) [42.07 to 56.57 psi] | | Oil temperature at 60 to 95°C (140 to 194°F) |
| | | Low idle speed | | | 0.098 MPa (1.0 kgf/cm$^2$) [14.22 psi] | | |
| | Valve timing [with 2 mm (0.079 in.) clearance on the valve side; cold engine] | | Inlet valve open | | BTDC 15° | | The theoretical valve timing figures for inspection vary from the actual valve timing. |
| | | | Inlet valve closed | | ABDC 41° | | |
| | | | Exhaust valve open | | BBDC 54° | | |
| | | | Exhaust valve closed | | ATDC 10° | | |
| | Valve clearance | | Inlet valve | | 0.25 (0.01) | | Cold engine |
| | | | Exhaust valve | | 0.25 (0.01) | | |
| | Fuel injection timing (BTDC) | | | | 17 ° | | |
| Engine main parts | Rocker | Rocker arm inner diameter | | φ19 (0.749) | 18.910 to 18.930 (0.7450 to 0.7458) | — | |
| | | Rocker shaft diameter | | φ19 (0.749) | 18.880 to 18.898 (0.7438 to 0.7445) | — | |
| | | Arm-to-shaft clearance (oil clearance) | | | 0.012 to 0.050 (0.0004 to 0.0019) | 0.200 (0.0079) | Replace rocker arm. |
| | Valve | Valve stem diameter | Inlet | φ6.6 (0.260) | 6.565 to 6.580 (0.2586 to 0.2592) | 6.500 (0.256) | |
| | | | Exhaust | φ6.6 (0.260) | 6.530 to 6.550 (0.2572 to 0.2580) | 6.500 (0.256) | |
| | | Valve guide inner diameter | Inlet | φ6.6 (0.260) | 6.600 to 6.615 (0.2600 to 0.2606) | | |
| | | | Exhaust | φ6.6 (0.260) | 6.600 to 6.615 (0.2600 to 0.2606) | | |
| | | Valve stem-to-guide clearance | Inlet | | 0.020 to 0.050 (0.0008 to 0.0020) | 0.100 (0.004) | Replace valve and valve guide. |
| | | | Exhaust | | 0.050 to 0.085 (0.0020 to 0.0033) | 0.150 (0.006) | |
| | Valve seat and valve | Valve seat angle | | 45° | | |   |
| | | Valve head sinkage | | 0 | 0.25 to 0.75 (0.0098 to 0.0295) | 1.5 (0.0591) | |
| | | Valve seat width | | 1.6 (0.063) | 1.30 to 1.80 (0.0512 to 0.0709) | 2.5 (0.0985) | |
| | | Valve head margin | | 1.5 (0.0591) | 1.35 to 1.65 (0.0531 to 0.0650) | 0.5 (0.0197) | |
| | | Installed valve guide protrusion | | 10 (0.394) | 9.5 to 10.5 (0.3743 to 0.4137) | — | |

Unit: mm (in.)

| Group | Item | | | Nominal value | Standard value | Limit | Remarks |
|---|---|---|---|---|---|---|---|
| Engine main parts | Valve spring | Free length | | | 47 (1.85) | 46 (1.81) | |
| | | Squareness | | |  θ =2.0° Δ =0.2 (0.0079) Lf=47 (1.8518) | △= 0.5 (0.0197) across the entire length | |
| | | Installed length / load mm (in.)/N (kgf) [lbf] | | | 39.0 (1.536)/ 131 to 145 (13.3 to 14.7) [29 to 33] \| 30.1 (1.185)/ 279 to 309 (28.5 to 31.5) [63 to 69] | -15 % | |
| | Cylinder | Push rod | Bend | | — | 0.3 (0.011) | Replace |
| | | Cylinder head | Bottom face distortion | | 0.05 (0.002) or less | 0.10 (0.004) | Correct |
| | | Cylinder block top face distortion | | | 0.05 (0.002) or less | 0.10 (0.004) | Correct |
| | | Bore | | φ78 (3.07) | $78.0^{+0.03}_{0}$ ($3.07^{+0.0012}_{0}$) | 78.2 (3.08) | Bore or replace |
| | | Out of roundness | | | ±0.01 (0.0004) or less | — | |
| | Piston | Diameter | STD | 78.00 (3.07) | 77.93 to 77.95 (3.070 to 3.071) | 77.80 (3.065) | |
| | | | 0.25 OS | 78.25 (3.08) | 78.18 to 78.20 (3.080 to 3.081) | 78.05 (3.075) | |
| | | | 0.50 OS | 78.50 (3.09) | 78.43 to 78.45 (3.090 to 3.090) | 78.30 (3.085) | |
| | | Max. allowable variation in weight among pistons on the same engine | | | ±5 g (0.177 oz) or less | — | |
| | | Piston pin diameter | | φ23 (0.9062) | 22.944 to 23.000 (0.9039 to 0.9062) | — | |
| | | Piston pin-to-boss clearance | | | 0.006 to 0.018 (0.0002 to 0.0007) | 0.050 (0.002) | |
| | | Piston-to-cylinder clearance | | | 0.035 to 0.086 (0.0014 to 0.0034) | 0.300 (0.012) | Bore or replace |
| | Piston ring | Piston ring-to-groove clearance | No. 1 ring | | 0.09 to 0.11 (0.0035 to 0.0043) | 0.300 (0.012) | Replace piston ring |
| | | | No. 2 ring | | 0.07 to 0.11 (0.0028 to 0.0043) | 0.200 (0.008) | |
| | | | Oil ring | | 0.03 to 0.07 (0.0012 to 0.0028) | 0.200 (0.008) | |
| | | Piston ring gap | No. 1 ring | | 0.15 to 0.30 (0.006 to 0.012) | 1.50 (0.06) | Replace |
| | | | No. 2 ring | | 0.15 to 0.35 (0.006 to 0.014) | | |
| | | | Oil ring | | 0.20 to 0.40 (0.008 to 0.016) | | |
| | Connecting rod | Bend and twist | | | 0.05/100 (0.002/3.940) | 0.15/100 (0.006/3.940) | |
| | | End play | | | 0.10 to 0.35 (0.004 to 0.014) | 0.50 (0.020) | Replace connecting rod |

Unit: mm (in.)

| Group | Item | | Nominal value | Standard value | Limit | Remarks |
|---|---|---|---|---|---|---|
| Engine main parts | Crankshaft | Crank journal diameter (STD) | φ52 (2.0488) | 51.985 to 52.000 (2.0482 to 2.0488) | — | |
| | | Crank pin diameter | φ48 (1.8912) | 47.950 to 47.964 (1.8892 to 1.8897) | — | |
| | | Crankshaft bend | | 0.025 (0.0010) | 0.050 (0.0020) | Correct or replace |
| | | Main bearings oil clearance | | 0.030 to 0.077 (0.0012 to 0.0030) | 0.100 (0.0040) | Replace main bearings |
| | | Connecting rod bearings oil clearance | | 0.025 to 0.072 (0.0010 to 0.0028) | 0.150 (0.0059) | Replace connecting rod bearings |
| | | End play | | 0.050 to 0.175 (0.0020 to 0.0069) | 0.500 (0.0197) | Replace flanged No. 3 main bearings |
| | Timing gear backlash | Crank gear to idler gear | | 0.040 to 0.120 (0.0015 to 0.0047) | 0.300 (0.0120) | Replace |
| | | Idler gear to valve camshaft gear | | | | |
| | | Idler gear to pump camshaft gear | | | | |
| | | Valve camshaft gear to PTO gear | | 0.080 to 0.190 (0.0032 to 0.0075) | | |
| | | Pump camshaft gear to oil pump gear | | 0.070 to 0.200 (0.0028 to 0.0079) | | |
| | Camshaft cam height (including lobe) | | | 35.720±0.1 (1.4073±0.0394) | 34.720 (1.3679) | Replace |
| | Fuel injection pump shaft cam height (including lobe) | | | 44±0.1 (1.7336±0.0039) | 43 (1.6942) | Replace |
| | Flywheel flatness | | | 0.150 (0.0059) or less | 0.500 (0.0197) | Correct |
| | Tappet-to-guide clearance | | | — | 0.150 (0.0059) | Replace tappet |
| | Camshaft journal-to-bushing clearance | | | 0.050 to 0.125 (0.0020 to 0.0049) | 0.150 (0.0059) | Replace bushing |
| | Idler gear-to-shaft clearance | | | 0.020 to 0.070 (0.0008 to 0.0028) | 0.200 (0.0079) | Replace idler gear or idler shaft |
| Fuel system | Injection valve opening pressure MPa (kgf/cm$^2$) [psi] | | 14.22 (145) [2062] | 14.22 to 15.00 (145 to 153) [2062 to 2176] | — | Adjust with washer |
| Oil system | Relief valve opening pressure MPa (kgf/cm$^2$) [psi] | | | 0.35±0.05 (3.5±0.5) [50±7.2] | — | Replace |
| | Oil pressure switch closing pressure MPa (kgf/cm$^2$) [psi] | | | 0.05±0.01 (0.5±0.1) [7±1.4] | — | Replace |
| Cooling system | Thermostat | Valve opening temperature | | 82±1.5°C (179.6±2.7 °F) | — | Replace |
| | | 8 mm (0.32 in.) valve lift temperature | | 95°C (203 °F) | — | |
| | Thermoswitch | At 111±3.5°C (231.8±6.3 °F) | | 30 MΩ [when dipped in oil of 105°C (221 °F)] | — | Replace |
| | Fan belt deflection {when pressed with a force of approx. 98 N (10 kgf) [22] between crankshaft and alternator pulleys and between crankshaft and fan pulleys} | | | 10 to 12 (0.4 to 0.5) | — | Replace |

Unit: mm (in.)

| Group | Item | | | Nominal value | Standard value | | | Limit | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| Inlet and exhaust systems | Paper-element type air cleaner | | | | Clean every 100 hours | | | Replace every 500 hours | | |
| | Inlet / exhaust manifold mounting face distortion | | | | — | | | 0.15 (0.006) or less | | Grind or replace |
| Electrical system | Starter | Pinion gap | | | 0.5 to 2.0 (0.02 to 0.08) | | | — | | Adjust with packing |
| | | No-load characteristics | Terminal voltage | | M001T68281: 11 V | M008T70471A: 11 V | M008T81071A: 23 V | — | | Inspect |
| | | | Current | | 110 A or less | 130 A or less | 80 A or less | — | | |
| | | | Rotation speed | | 2400 $min^{-1}$ | 3600 $min^{-1}$ | 3000 $min^{-1}$ | — | | |
| | | Brush length | | | 16.5 (0.65) | 18.0 (0.71) | | M001T68281: 10.0 (0.39) | M008T70471A, M008T81071A: 11.0 (0.43) | Replace |
| | | Brush spring load | | | 17.5 to 23.7 N (1.78 to 2.41 kgf) [3.9 to 5.3 lbf] | 29.4 to 39.2 N (3.0 to 4.0 kgf) [6.6 to 8.8 lbf] | | 6.90 N (0.70 kgf) [1.6 lbf] | 13.7 N (1.40 kgf) [3.1 lbf] | Replace |
| | | Commutator radial runout | | | 0.05 (0.002) | 0.03 (0.001) | | 0.10 (0.004) | | Correct or replace |
| | | Commutator diameter | | | 29.4 (1.16) | 32.0 (1.26) | | 28.8 (1.13) | 31.4 (1.24) | Replace |
| | | Mica undercutting depth | | | 0.5 (0.02) | | | 0.2 (0.01) | | Correct |
| | Alternator | IC regulator controlled voltage [at 20°C (68°F)] | | | A007T02071C: 14.7±0.3 V | A007TA8571: 28.5±0.5 V | | — | | |
| | | Output characteristics (when hot) | 2500 $min^{-1}$ or less, Terminal voltage | | 13.5 V | 27.0 V | | — | | |
| | | | 2500 $min^{-1}$ or less, Current | | 32 A or above | 18 A or above | | — | | |
| | | | 5000 $min^{-1}$ or less, Terminal voltage | | 13.5 V | 27.0 V | | — | | |
| | | | 5000 $min^{-1}$ or less, Current | | 47 A or above | 22 A or above | | — | | |
| | | Brush length | | | 18.5 (0.73) | | | 5.0 (0.20) | | Replace |
| | Clearance between stop solenoid plunger and rack | | | | 0.15 to 0.20 (0.006 to 0.008) | | | | | Correct |
| | Glow plug resistance | | | | 0.55 Ω | | | — | | Replace |

# 2. Tightening Torques Table

## 2.1 Major Bolts and Nuts

| Fittings | | Thread diameter ×pitch (mm) | Tightening torque | | | Remarks |
|---|---|---|---|---|---|---|
| | | | N・m | kgf・m | lbf・ft | |
| Engine proper | | | | | | |
| Cylinder head bolt | | M10×1.75 | 83.4 to 93.2 | 8.5 to 9.5 | 61.5 to 68.7 | |
| Rocker cover bolt | | M8×1.25 | 9.81 to 12.7 | 1.0 to 1.3 | 7.2 to 9.4 | |
| Rocker shaft bracket bolt | | M8×1.25 | 9.81 to 19.6 | 1.0 to 2.0 | 7.2 to 14.5 | |
| Thrust plate bolt | | M8×1.25 | 9.8 to 11.8 | 1.0 to 1.2 | 7.2 to 8.7 | |
| 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 | | M9×1.0 | 32.4 to 37.3 | 3.3 to 3.8 | 23.9 to 27.5 | |
| Flywheel bolt | | M12×1.25 | 127 to 137 | 13.0 to 14.0 | 94.0 to 101.3 | |
| Crankshaft pulley nut | | M18×1.5 | 147 to 196 | 15.0 to 20.0 | 108.5 to 144.6 | |
| Rear plate mounting bolt | | M12×1.25 | 53.9 to 73.5 | 5.5 to 7.5 | 39.8 to 54.2 | Equivalent to 7T |
| Fuel system | | | | | | |
| Hollow screw (fuel injection pump) | | M14×1.5 | 19.6 to 24.5 | 2.0 to 2.5 | 14.5 to 18.1 | |
| Delivery valve holder (fuel injection pump) | | — | 39.2 to 49.0 | 4.0 to 5.0 | 28.9 to 36.1 | |
| Air bleeder plug (fuel injection pump) | | M8×1.25 | 9.81 to 13.7 | 1.0 to 1.4 | 7.2 to 10.1 | |
| Nozzle retaining nut | IDI | M16×0.75 | 34.3 to 39.2 | 3.5 to 4.0 | 25.3 to 28.9 | |
| Nozzle holder | IDI | M20×1.5 | 49.0 to 58.8 | 5.0 to 6.0 | 36.2 to 43.4 | |
| Fuel injection pipe nut | | M12×1.5 | 24.5 to 34.3 | 2.5 to 3.5 | 18.1 to 25.3 | |
| Fuel leak-off pipe nut | | M12×1.5 | 20.6 to 24.5 | 2.1 to 2.5 | 15.2 to 18.1 | |
| Sliding sleeve shaft | | M10×1.25 | 29.4 to 41.2 | 3.0 to 4.2 | 21.7 to 30.4 | |
| Torque spring set special nut | | M12×1.0 | 14.7 to 24.5 | 1.5 to 2.5 | 10.8 to 18.1 | |
| Oil system | | | | | | |
| Oil relief valve | | M22×1.5 | 44.1 to 53.9 | 4.5 to 5.5 | 32.5 to 39.8 | |
| Oil pan drain plug | | M14×1.5 | 34.3 to 44.1 | 3.5 to 4.5 | 25.3 to 32.5 | |
| Oil filter | | M20×1.5 | 10.8 to 12.7 | 1.1 to 1.3 | 8.0 to 9.4 | |
| Oil pressure switch | | PT1/8 | 7.85 to 11.8 | 0.8 to 1.2 | 5.8 to 8.7 | |
| Oil pan mounting bolt | | M8×1.25 | 9.80 to 12.7 | 1.0 to 1.3 | 7.2 to 9.4 | Equivalent to 4T |
| Oil strainer nut | | M16×1.5 | 24.5 to 29.4 | 2.5 to 3.0 | 18.1 to 21.7 | |
| Cooling system | | | | | | |
| Thermoswitch | | M16×1.5 | 18.6 to 26.5 | 1.9 to 2.7 | 13.7 to 19.6 | |
| Thermostat cover bolt | | M8×1.25 | 16 to 20 | 1.6 to 2.0 | 11.8 to 14.8 | |
| Thermo case bolt | | M16×1.5 | 39.2 to 49.0 | 4.0 to 5.0 | 28.9 to 36.1 | |
| Inlet and exhaust systems | | | | | | |
| Inlet cover bolt | | M8×1.25 | 14.7 to 21.6 | 1.5 to 2.2 | 10.8 to 15.9 | |
| Exhaust manifold bolt | | M8×1.25 | 14.7 to 21.6 | 1.5 to 2.2 | 10.8 to 15.9 | |
| Electrical system | | | | | | |
| Starter terminal B | | M8×1.25 | 9.81 to 11.8 | 1.0 to 1.2 | 7.2 to 8.7 | |
| Stop solenoid fixing nut | | M30×1.5 | 39.2 to 49.0 | 4.0 to 5.0 | 28.9 to 36.1 | |
| Stop solenoid blind plug | | M30×1.5 | 39.2 to 49.0 | 4.0 to 5.0 | 28.9 to 36.1 | |
| Glow plug | | M10×1.25 | 14.7 to 19.6 | 1.5 to 2.0 | 10.8 to 14.5 | |

## 2.2 Standard Bolts and Nuts

| Thread diameter ×pitch (mm) | 4T | | | 7T | | |
|---|---|---|---|---|---|---|
| | N・m | kgf・m | lbf・ft | N・m | kgf・m | lbf・ft |
| M6×1.0 | 2.94 to 4.90 | 0.3 to 0.5 | 2.2 to 3.6 | 7.85 to 9.80 | 0.8 to 1.0 | 5.8 to 7.2 |
| M8×1.25 | 9.80 to 12.7 | 1.0 to 1.3 | 7.2 to 9.4 | 14.7 to 21.6 | 1.5 to 2.2 | 10.8 to 15.9 |
| M10×1.25 | 17.7 to 24.5 | 1.8 to 2.5 | 0.7 to 1.0 | 29.4 to 41.2 | 3.0 to 4.2 | 21.7 to 30.4 |
| M12×1.25 | 29.4 to 41.2 | 3.0 to 4.2 | 21.7 to 30.4 | 53.9 to 73.5 | 5.5 to 7.5 | 39.8 to 54.2 |

Note: (a) The above table shows the tightening torques for standard bolts and nuts.
(b) The values in the table apply when tightened together with spring washers.
(c) The above table shows standard values, for which a tolerance of ±10% is allowed.
(d) Unless otherwise specified, standard bolts and nuts should be tightened to the torques in the table.
(e) Do not apply oil to threaded portions (Tighten under dry conditions).

## 2.3 Standard Eyebolts

| Thread diameter ×pitch (mm) | Property class | | |
|---|---|---|---|
| | N・m | kgf・m | lbf・ft |
| M8×1.25 | 8±1 | 0.8±0.1 | 5.9±0.7 |
| M10×1.25 | 15±2 | 1.5±0.2 | 11.1±1.5 |
| M12×1.25 | 25±3 | 2.5±0.3 | 18.4±2.2 |
| M14×1.5 | 34±4 | 3.5±0.4 | 25.1±3.0 |
| M16×1.5 | 44±5 | 4.5±0.5 | 32.5±3.7 |
| M18×1.5 | 74±5 | 7.5±0.5 | 54.6±3.7 |
| M20×1.5 | 98±10 | 10.0±1.0 | 72.3±7.4 |
| M24×1.5 | 147±15 | 15.0±1.5 | 108.4±10.8 |
| M27×1.5 | 226±20 | 23.0±2.0 | 166.7±14.8 |

(Dry conditions)

## 2.4 Standard Union Nuts

| Nominal diameter | Cap nut size | N·m | kgf·m | lbf·ft |
|---|---|---|---|---|
| 63 | M14×1.5 | 39 | 4 | 28.8 |
| 80 | M16×1.5 | 49 | 5 | 36.1 |
| 100 | M20×1.5 | 78 | 8 | 57.5 |
| 120 | M22×1.5 | 98 | 10 | 72.3 |
| 150 | M27×1.5 | 157 | 16 | 115.8 |
| 180 | M30×1.5 | 196 | 20 | 144.6 |
| 200 | M30×1.5 | 196 | 20 | 144.6 |
| 220 | M33×1.5 | 245 | 25 | 180.7 |
| 254 | M36×1.5 | 294 | 30 | 216.8 |

(Dry conditions)

## 2.5 Taper Bolts

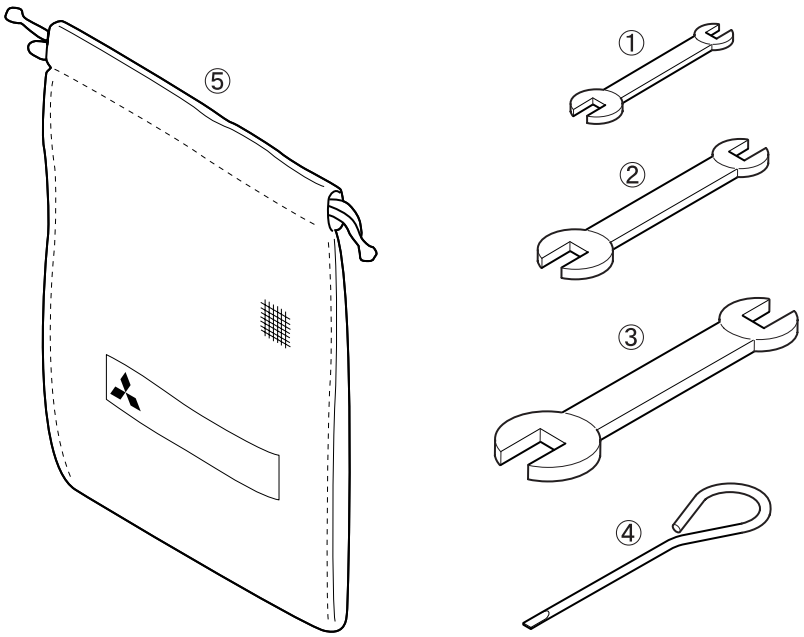
| Size | Tightening into aluminum | | | Tightening into iron | | |
|---|---|---|---|---|---|---|
| | N·m | kgf·m | lbf·ft | N·m | kgf·m | lbf·ft |
| NPTF1/16 | 4.90 to 7.85 | 0.5 to 0.8 | 3.6 to 5.8 | 7.85 to 11.8 | 0.8 to 1.2 | 5.8 to 8.7 |
| PT1/8 | 7.85 to 11.8 | 0.8 to 1.2 | 5.8 to 8.7 | 14.7 to 21.6 | 1.5 to 2.2 | 10.8 to 15.9 |
| PT1/4, NPTF1/4 | 19.6 to 29.4 | 2.0 to 3.0 | 14.5 to 21.7 | 34.3 to 44.1 | 3.5 to 4.5 | 25.3 to 32.5 |
| PT3/8 | — | — | — | 53.9 to 73.5 | 5.5 to 7.5 | 39.8 to 54.2 |

## 3. Sealants List

| | Sealing item | Sealant | Mating component | Applied location |
|---|---|---|---|---|
| Threaded part | Stop solenoid | ThreeBond 1212 | Governor case | Threaded portion |
| | Water drain joint | ThreeBond 1102 | Block | |
| | Oil pressure switch | | | |
| | Torque spring set | ThreeBond 1212 | Governor case | |
| Press - fit part | Sealing cap | ThreeBond 1102 | Cylinder block | Holes in the cylinder head and block |
| | | | Cylinder head | |
| | | | Cylinder head, Cylinder block | |
| | Expansion plug | | Cylinder block | |
| | Oil level gauge guide | | | |
| Other | Side seal | ThreeBond 1212 | Cylinder block, Main bearing cap | Outer periphery |
| | Main bearing cap (front and rear) | | Cylinder block | Contact faces with the cylinder block |
| | Oil pan | ThreeBond 1207C | | Oil pan sealing face |

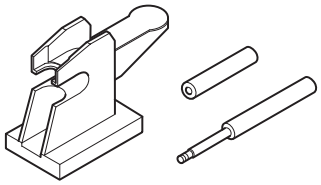
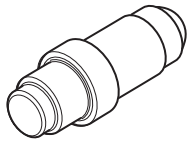
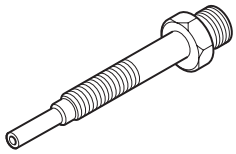
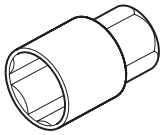
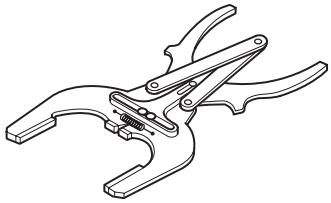
# TOOLS LIST

## 1. General Tools




| No. | Description | Part number | Remarks |
|---|---|---|---|
| — | Tool set | MM413-900 | Consists of items ① to ⑤ |
| ① | Spanner | MK96008010 | Width across flats [8×10 mm (0.31×0.39 in.)] |
| ② | Spanner | MK96012014 | Width across flats [12×14 mm (0.47×0.55 in.)] |
| ③ | Spanner | MK96017019 | Width across flats [17×19 mm (0.67×0.75 in.)] |
| ④ | Screwdriver | MM300110 | (-) |
| ⑤ | Tool bag | MM300783 | |

## 2. Special Tools

| Description | Part number | Shape | Application |
|---|---|---|---|
| Piston Pin Setting Tool | 31A91-00100 |  | Piston pin removal / installation |
| Camshaft Bushing Installer | ST332340 |  | Punching / press-fitting of front camshaft bushing |
| Compression Gauge Adapter | ST332270 |  | Compression measuring |
| Oil Pressure Switch Socket Wrench (26) | MD998054 |  | Oil pressure switch removal / installation |
| Piston Ring Pliers | 31391-12900 |  | Piston ring removal / installation |

# OVERHAUL TIMING

## 1. Identifying the Timing for Overhaul

Generally, when the compression pressure has dropped below the specified value, overhaul of the engine needs to be considered. Other parameters should also be considered in making the decision as to whether or not to overhaul the engine, such as engine oil consumption and blow-by gas volume.

Some of the phenomena that may suggest, but are not necessarily the criteria for, the need to overhaul the engine include reduced power, increased fuel consumption, oil pressure drop, difficulty in starting and higher noise level.

More specifically, reduction in compression pressure creates various types of phenomena in various combinations, and this is why it is difficult to make a correct decision. Typical phenomena include:

(a) Reduced power
(b) Increased fuel consumption
(c) Increased engine oil consumption
(d) Increased blow-by gas through the breather due to worn parts such as cylinder liners and pistons
(e) Increased blow-by gas due to poor seating of inlet / exhaust valves
(f) Poor starting
(g) Increased noise levels of various engine parts
(h) Abnormal color of exhaust gas after warm-up

Some of those listed above are directly related to the deterioration of the engine and some are not.

Items (b) and (f) are heavily influenced by fuel injection pump displacement, fuel injection timing, wearing of plungers, nozzle conditions, and conditions of electrical equipment such as battery and starter.

The most reliable criterion for engine overhaul is reduced compression pressure due to the wearing of cylinder liners and pistons [item (d)]. This should be combined with other items for comprehensive review to reach a rational conclusion.

## 2. Measuring the Compression Pressure

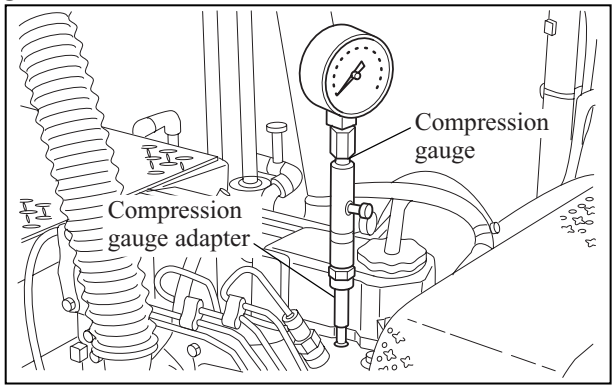
(1) Move the control lever to STOP position.

(2) Remove the glow plugs from all cylinders. Install the special tool Compression Gauge Adapter and a compression gauge onto the cylinder being measured.

| Special tool | Part number |
|---|---|
| Compression Gauge Adapter | ST332270 |

(3) While cranking the engine with the starter, read the compression gauge. Note the reading at which the gauge needle stabilizes.

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




Measuring the compression pressure

**⚠ CAUTION**

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

(b) Compression pressure varies depending on the engine speed. Keep the specified engine speed when measuring the compression pressure.

| | Standard value | Limit |
|---|---|---|
| Engine speed | 290 $min^{-1}$ | |
| Compression pressure | 2.9 MPa (30 $kgf/cm^2$) [421 psi] | 2.6 MPa (27 $kgf/cm^2$) [377 psi] |
| Tolerable difference between cylinders | 0.29 MPa (3.0 $kgf/cm^2$) [42 psi] or less | |

**⚠ CAUTION**

It is important to regularly check the compression pressure so that you can tell the difference.

- New or overhauled engines have slightly higher compression pressure.
- The compression pressure settles to the standard value as the piston rings and valve seats fit in.
- As wear progresses further, the compression pressure drops.

# REMOVAL PREPARATIONS

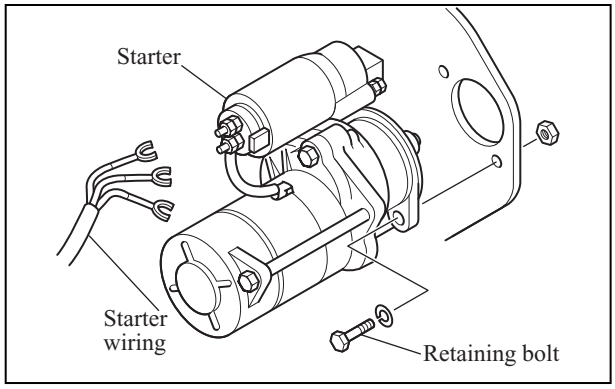
# 1. Preparations

## 1.1 Removing the Electric Wiring

Remove the wiring harnesses from the following equipment.

Before removal, attach mating tags etc. onto the terminals to aid reassembly.

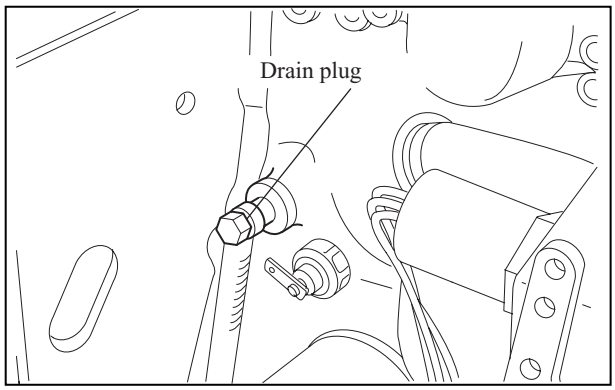
- Starter
- Switches




Removing the electric wiring

## 1.2 Draining the Coolant

Loosen the coolant drain plug on the right-hand side face of the cylinder block to drain coolant from the engine.




Coolant drain cock

## 1.3 Draining the Engine Oil

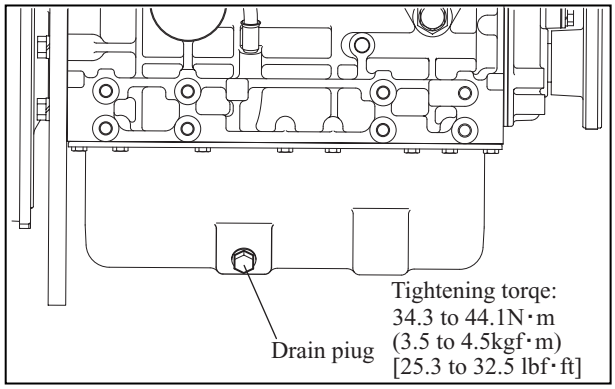
Remove the engine oil drain plug from the oil pan to drain the engine oil.

Install and tighten the drain plug to the specified torque.

Oil pan capacity: 3.7 to 6.0 ℓ
(1.0 to 1.6 U.S. gal)

**⚠ CAUTION**

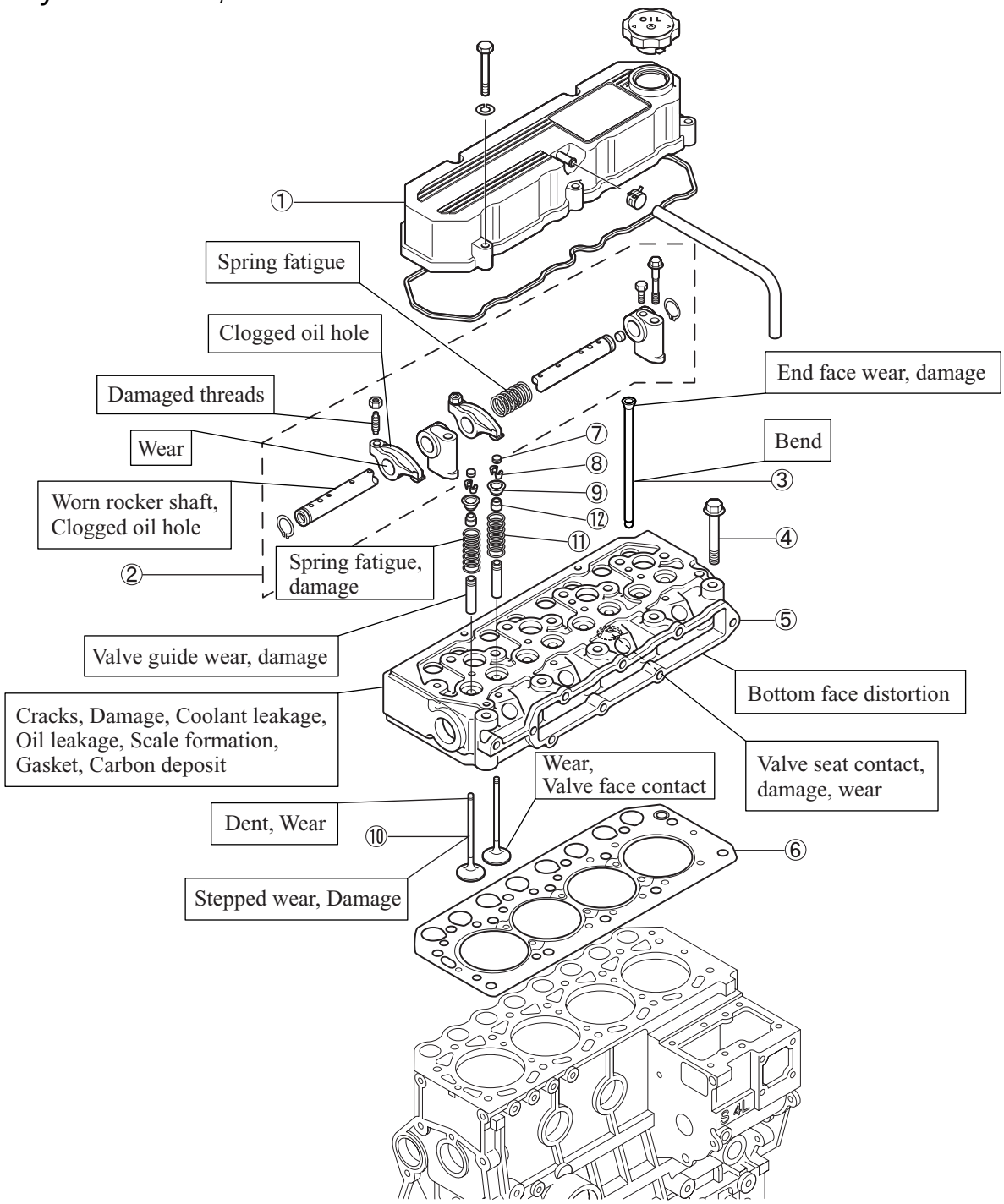
Do not touch the engine oil which may be extremely hot as it can cause burns.




Drain plug on the oil pan

# ENGINE MAIN PARTS - DISASSEMBLY

# 1. Cylinder Head, Valve Mechanism



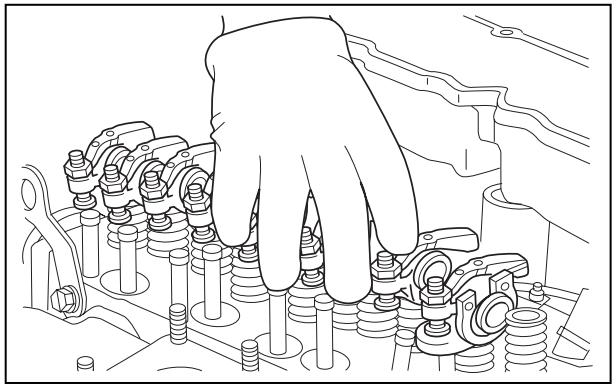

Disassembly of cylinder head and valve mechanism

<Disassembly sequence>

| | | |
|---|---|---|
| ① Rocker cover | ⑤ Cylinder head | ⑨ Retainer |
| ② Rocker shaft assembly | ⑥ Cylinder head gasket | ⑩ Valve |
| ③ Push rod | ⑦ Valve cap | ⑪ Valve spring |
| ④ Cylinder head bolt | ⑧ Valve lock | ⑫ Valve stem seal |

## 1.1 Removing the rocker shaft assembly

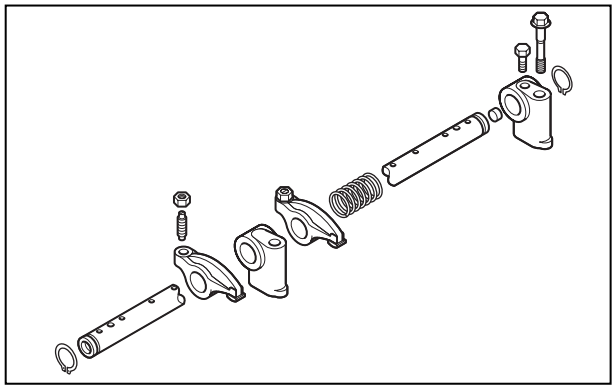
(1) Loosen the rocker stay bolts. Remove the rocker shaft assembly together with the rocker stay bolts.
(2) Remove the valve caps.
(3) Keep the rocker shaft assembly with the rocker stay bolts.



Removing the rocker shaft assembly

## 1.2 Disassembling the rocker shaft assembly

In the course of disassembly, place removed valve rockers as well as the other parts neatly in the order of disassembly so that they can be reassembled back onto their original locations. Doing so, original clearances between the valve rockers and the rocker shaft is restored upon reassembly.

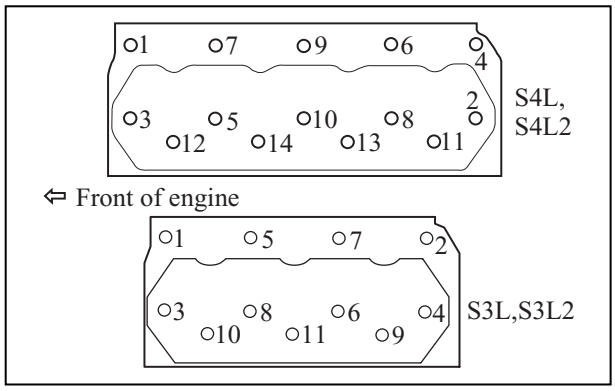


Disassembling the rocker shaft assembly

## 1.3 Removing the cylinder head bolts

Loosen the cylinder head bolts in the order of the numbers illustrated. Do not loosen one bolt completely before moving to the next bolt. Loosen the bolts in a couple of steps.

Note: Before removing the cylinder head bolts, check the cylinder head components for any fault. If faulty, check the bolts for tightness with a torque wrench.

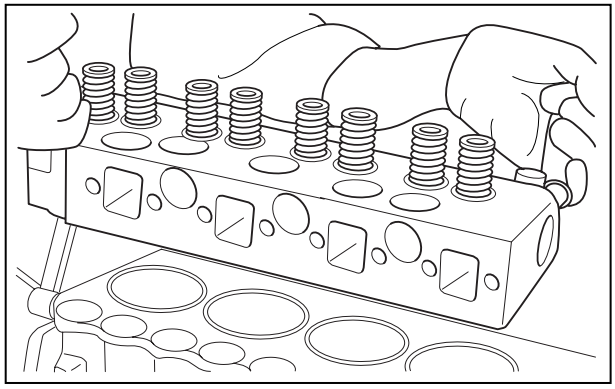



Tightening order for cylinder head bolts

## 1.4 Removing the cylinder head assembly

Remove the cylinder head assembly by lifting it straight up.

Note: If the bonding of the cylinder head gasket prevents the head assembly from being separated from the cylinder block, tap the cylinder head side face on a relatively thick portion with a plastic hammer.



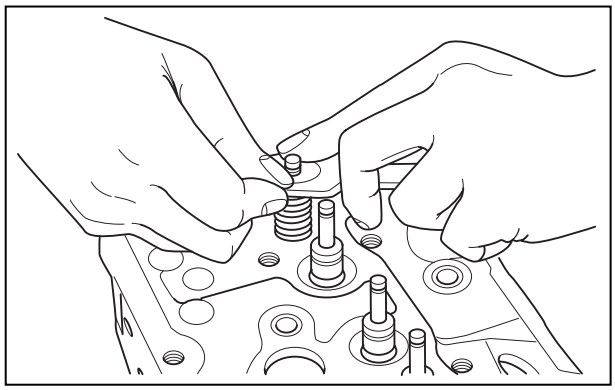
Removing the cylinder head assembly

## 1.5 Removing the valves and valve springs

(1) Remove the valve caps and locks by compressing the springs using a valve lifter.

(2) Remove the retainers, valve springs and valves.

Note: If the valves are reusable, mark them so that they can be reassembled back onto their original locations. This will ensure that the mated pairs of valves and their seats are maintained.

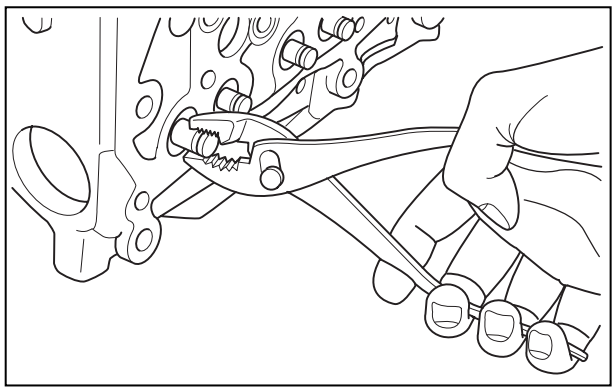


Removing the valve spring

## 1.6 Removing the valve stem seals

Remove the valve stem seals by holding each of them with a pair of pliers.

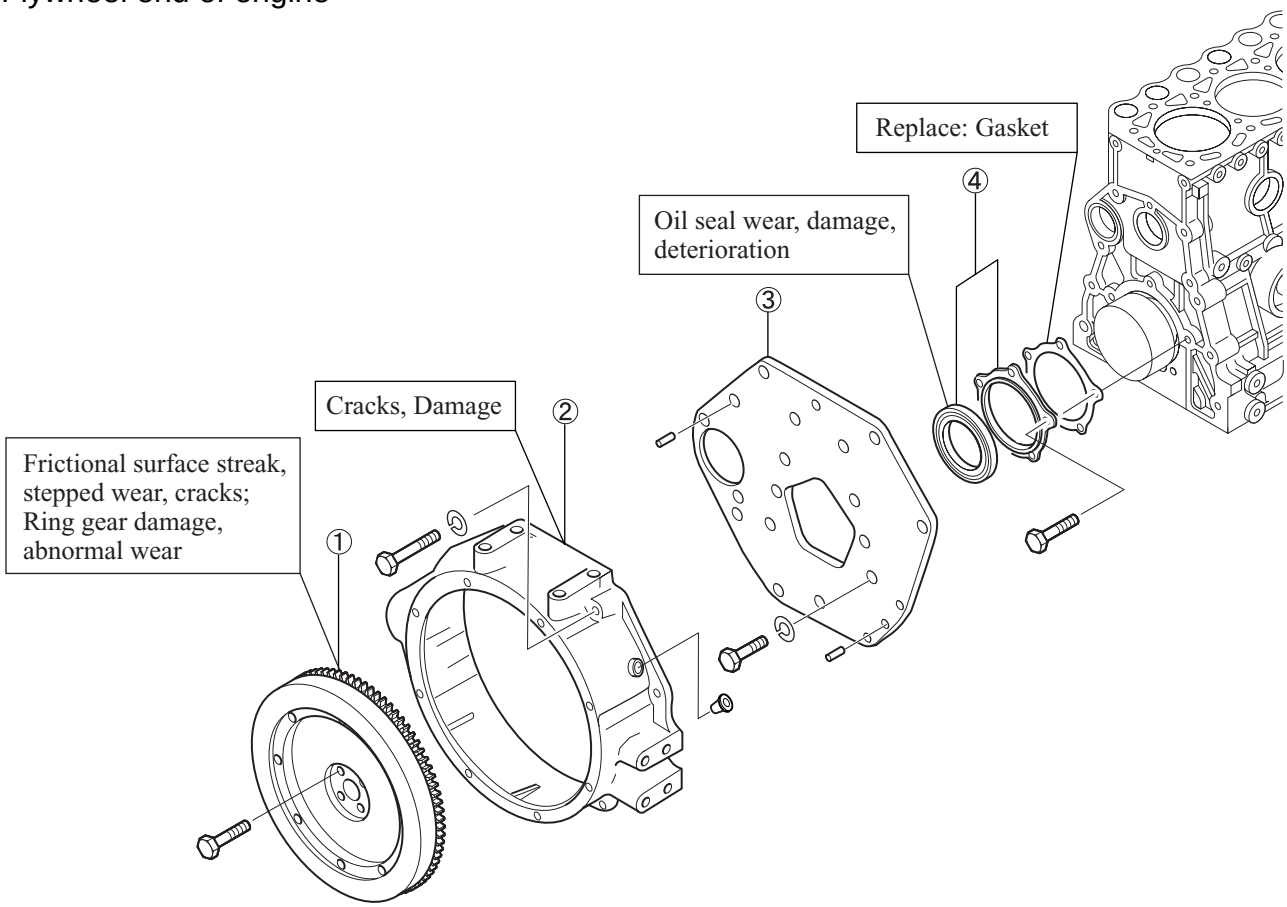
Note: Replace the old valve stem seals with new parts upon reassembly.



Removing the valve stem seal

## 2. Flywheel, Timing Gear, Camshaft

Flywheel end of engine

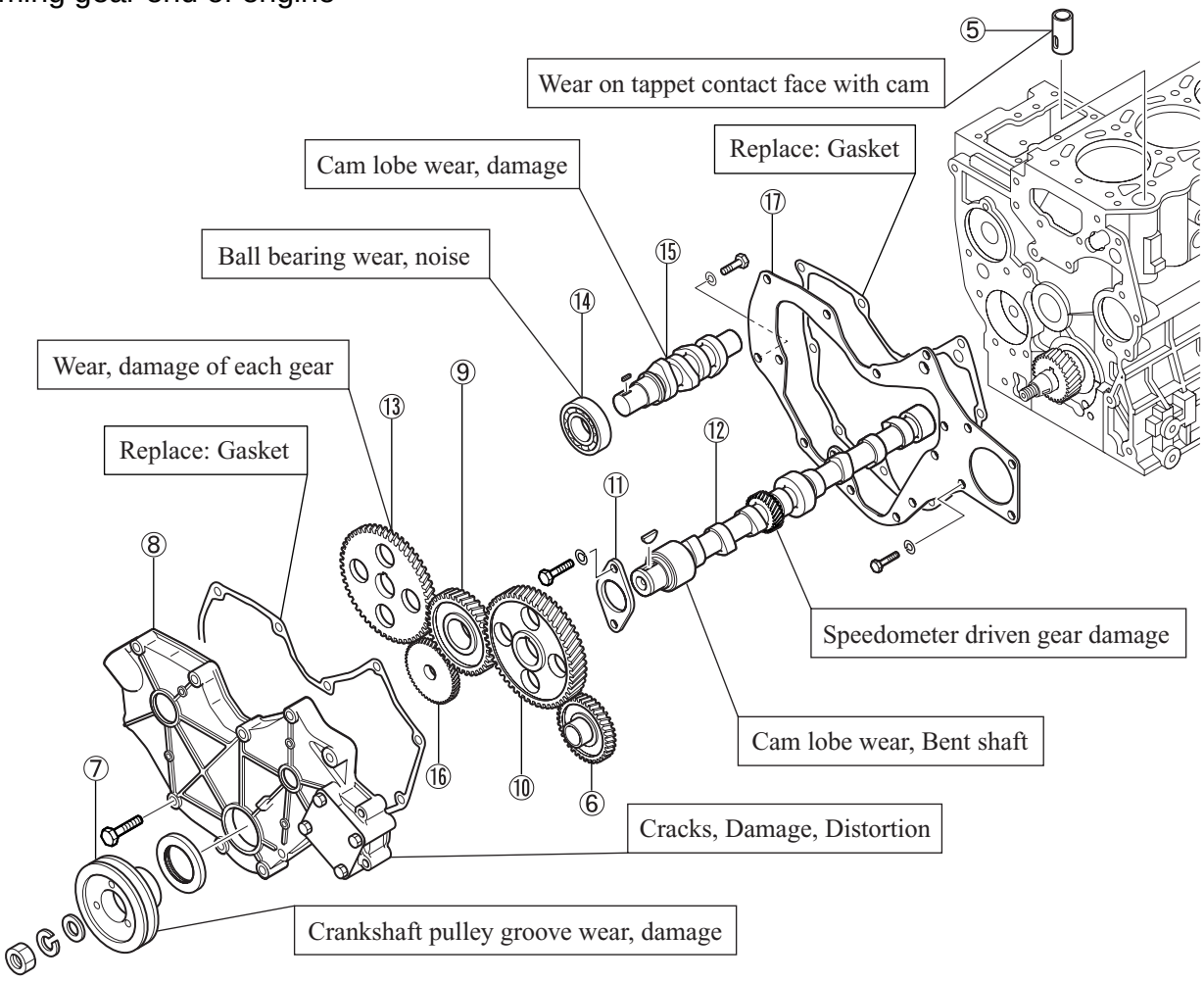



Disassembly of flywheel

<Disassembly sequence>

① Flywheel
② Flywheel housing
③ Rear plate
④ Oil seal case, Oil seal

Timing gear end of engine




Disassembly of timing gear and camshaft

<Disassembly sequence>

⑤ Tappet
⑥ PTO gear
⑦ Crankshaft pulley
⑧ Timing gear case
⑨ Idler gear
⑩ Camshaft gear
⑪ Thrust plate
⑫ Camshaft
(Remove ⑩ to ⑫ as an assembly.)
⑬ Fuel injection pump camshaft gear
⑭ Ball bearing
⑮ Fuel injection pump camshaft
(Remove ⑬ to ⑮ as an assembly.)
⑯ Oil pump
⑰ Front plate

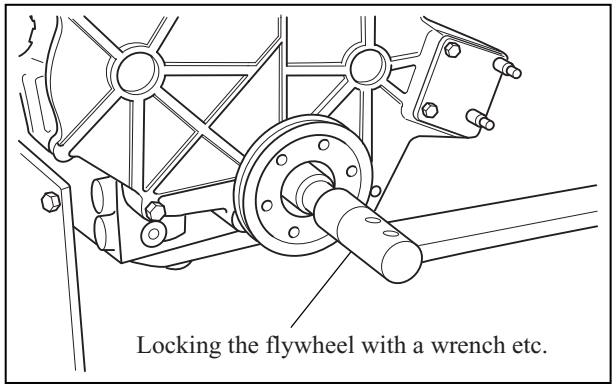
## 2.1 Removing the flywheel

(1) Have an assistant lock the flywheel pulley using a wrench or other similar tool to prevent the flywheel from rotating.

(2) Remove one of the flywheel retaining bolts.

**⚠ CAUTION**

The person who locks the crankshaft pulley should do so with extreme care. Each worker should pay attention to the safety of the other.




Locking the flywheel

(3) Install a safety stud (M12×1.25) into the hole from which the retaining bolt has just been removed. With the stud installed, remove the remaining flywheel retaining bolts.

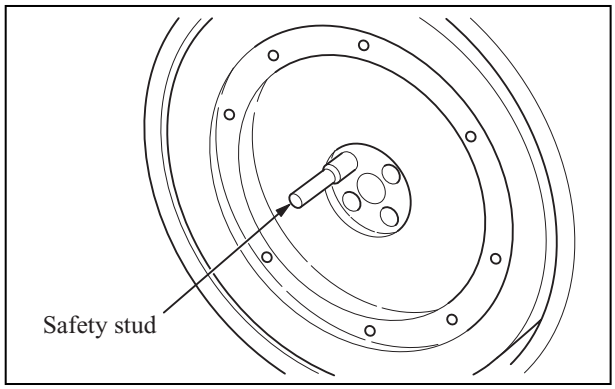
(4) While holding the flywheel with both hands, rock the flywheel towards you and away to pull it out straight towards you.

**⚠ CAUTION**

(a) When pulling off the flywheel, be careful not to cut your hands with the ring gear.

(b) Be careful not to damage the flywheel by dropping it or bumping it against hard objects.

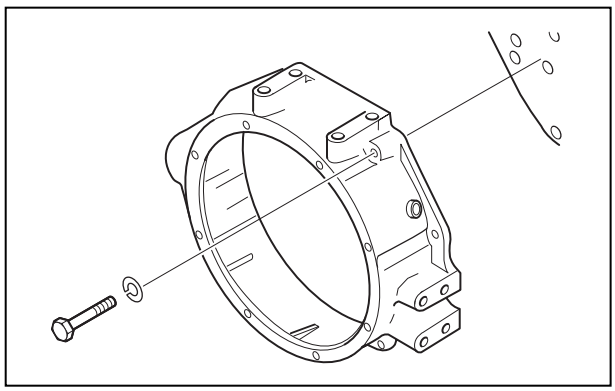
(c) The ring gear has been shrink-fit onto the flywheel. Do not attempt to remove the ring gear unless it is faulty.




Removing the flywheel

## 2.2 Removing the flywheel housing

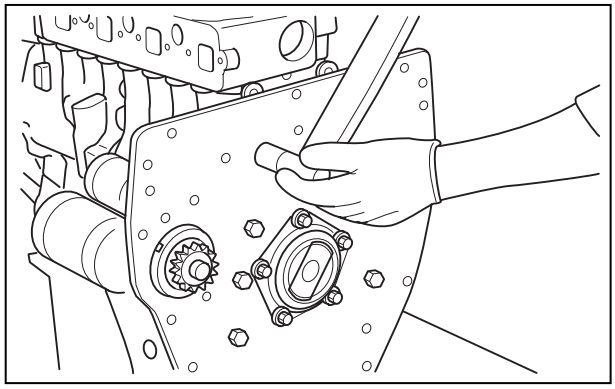
Remove the flywheel housing retaining bolts. Remove the flywheel housing.



Removing the flywheel housing

## 2.3 Removing the rear plate

The rear plate has been located into position with knock pins. Therefore, the plate needs to be removed by pulling it straight towards you.



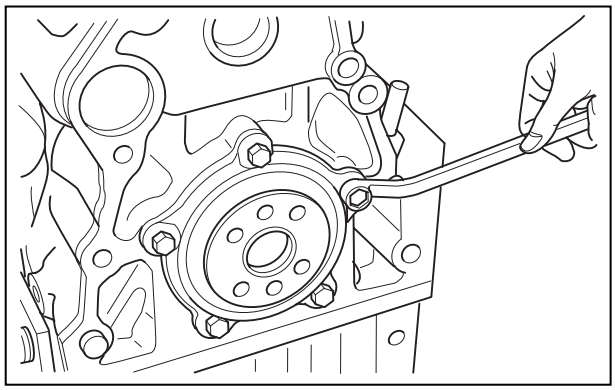
Removing the rear plate

## 2.4 Removing the oil seal case

Remove the oil seal case retaining bolts. Then, ply away the case from the cylinder block using a screwdriver or other similar tool.

**⚠ CAUTION**

When removing the oil seal case, be careful not to damage the oil seal.

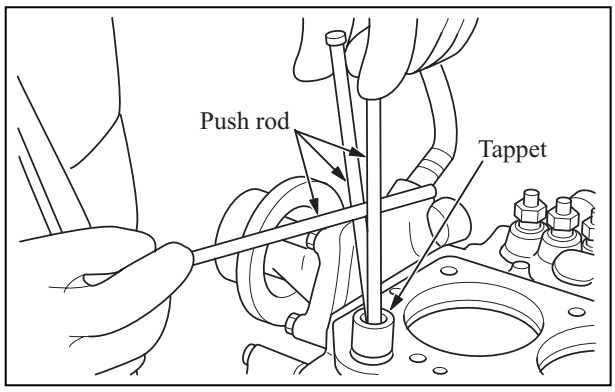


Removing the oil seal case

## 2.5 Removing the tappets

While holding the push rods, remove the tappets from the cylinder block.

Note: The camshaft should not be removed before removing the tappets. Otherwise, the tappets will drop into the oil pan.




Removing the tappet

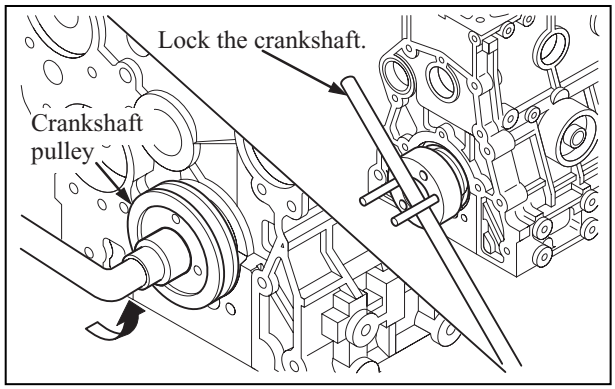
## 2.6 Removing the crankshaft pulley

(1) Lock the crankshaft so that it will not rotate. To rock the camshaft, install two safety studs (M12×1.25) into the threaded holes at the rear end of the crankshaft and then place a bar between the studs.

(2) Remove the crankshaft pulley.

**⚠ CAUTION**

While trying to remove the crankshaft pulley, the bar may dislodge from the studs. Pay sufficient attention to ensure safety.



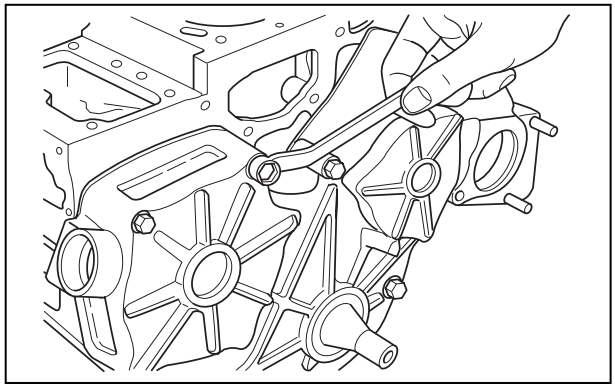

Removing the crankshaft pulley

## 2.7 Removing the timing gear case

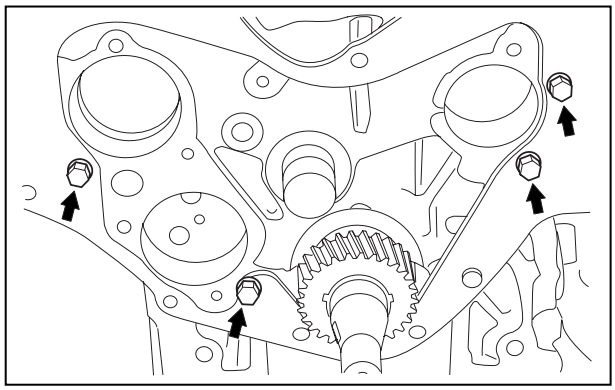
Remove the timing gear case retaining bolts. Then, remove the timing gear case.

**⚠ CAUTION**

The front plate is bolted in place separately from the timing gear case. Do not attempt to tap away the front plate together with the timing gear case.



Removing the timing gear case



Front plate retaining bolts

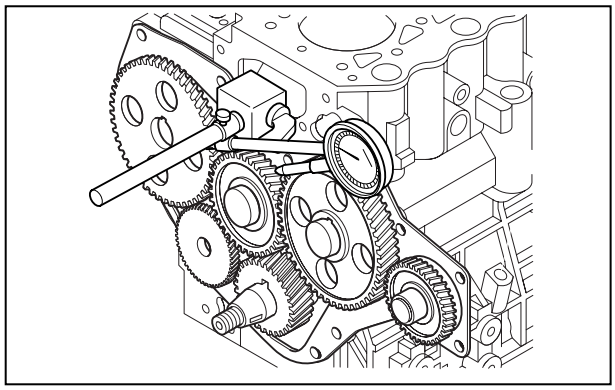
## 2.8 Measuring the timing gear backlash

Measure the backlash between the gears and use the measurements as references upon reassembly.

If any of the measured values exceeds the limit, replace all gears unless otherwise specified.

Unit: mm (in.)

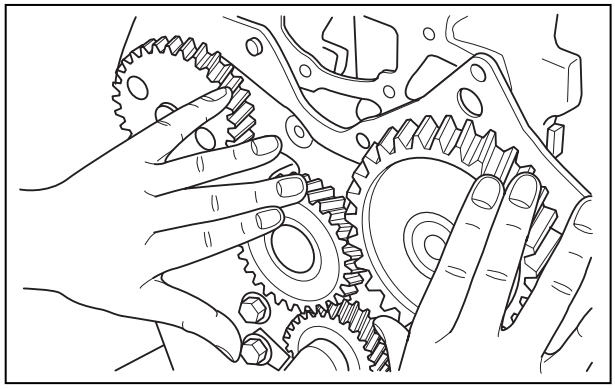
| | | Standard value | Limit |
|---|---|---|---|
| Timing gear backlash | Crank gear - idler gear | 0.04 to 0.12 (0.0016 to 0.0047) | 0.30 (0.0118) |
| | Idler gear - valve camshaft gear | | |
| | Idler gear - pump camshaft gear | | |
| | Valve camshaft gear - PTO gear | 0.08 to 0.19 (0.0031 to 0.0075) | |
| | Pump camshaft gear - oil pump gear | 0.07 to 0.20 (0.0028 to 0.0079) | |



Measuring the timing gear backlash

### 2.9 Removing the idler gear

Remove the idler gear by sliding it out along the helical teeth.



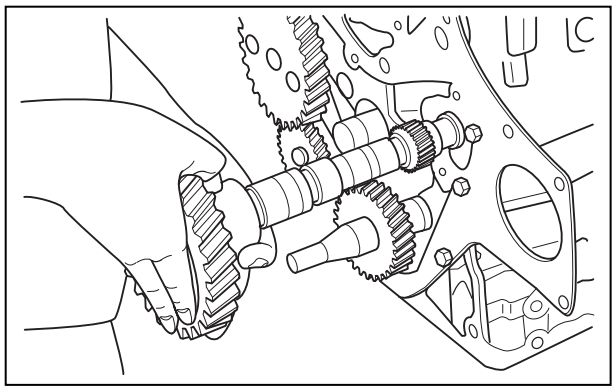
Removing the idler gear

### 2.10 Removing the camshaft

(1) Remove the thrust plate retaining bolts.
(2) Gently pull out the camshaft, taking care not to damage it.

**⚠ CAUTION**

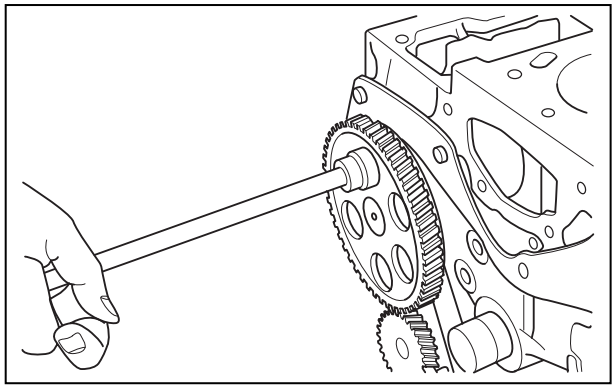
When pulling out the camshaft, pay attention to the cams as they tend to be caught by the surrounding parts.



Pulling out the camshaft

### 2.11 Removing the fuel injection pump camshaft

(1) Remove the stopper bolt (one place).

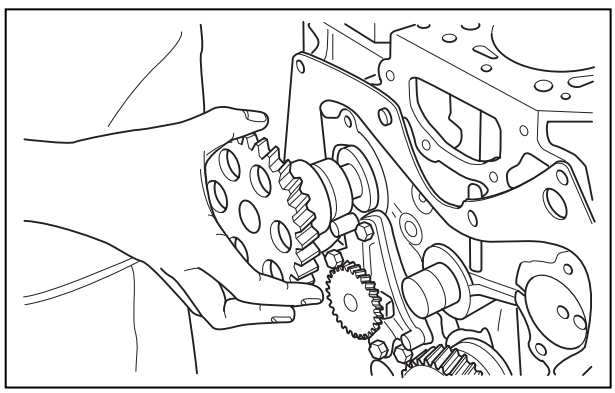


Removing the pump camshaft stopper bolt

(2) Using a copper rod or other similar tool, tap the rear end of the fuel injection pump camshaft. Then, pull it out to the front of the engine.

### 2.12 Separating the gears from the shafts (as required)

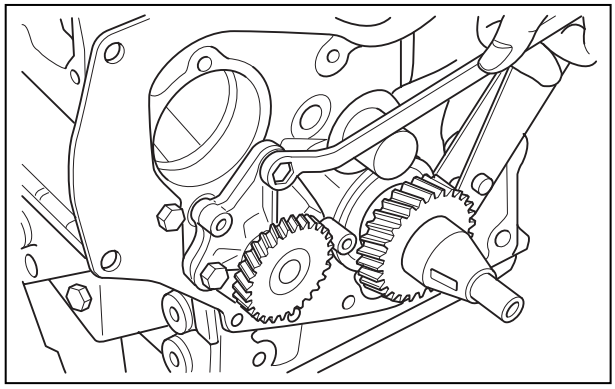
Using a hydraulic jack, remove the camshaft gear and the fuel injection pump camshaft gear from the respective shafts.



Removing the pump camshaft

## 2.13 Removing the oil pump

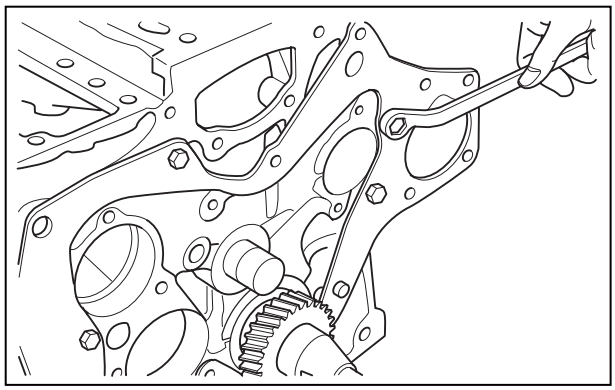
Remove the oil pump retaining bolts. Then, remove the oil pump from the cylinder block.



Removing the oil pump

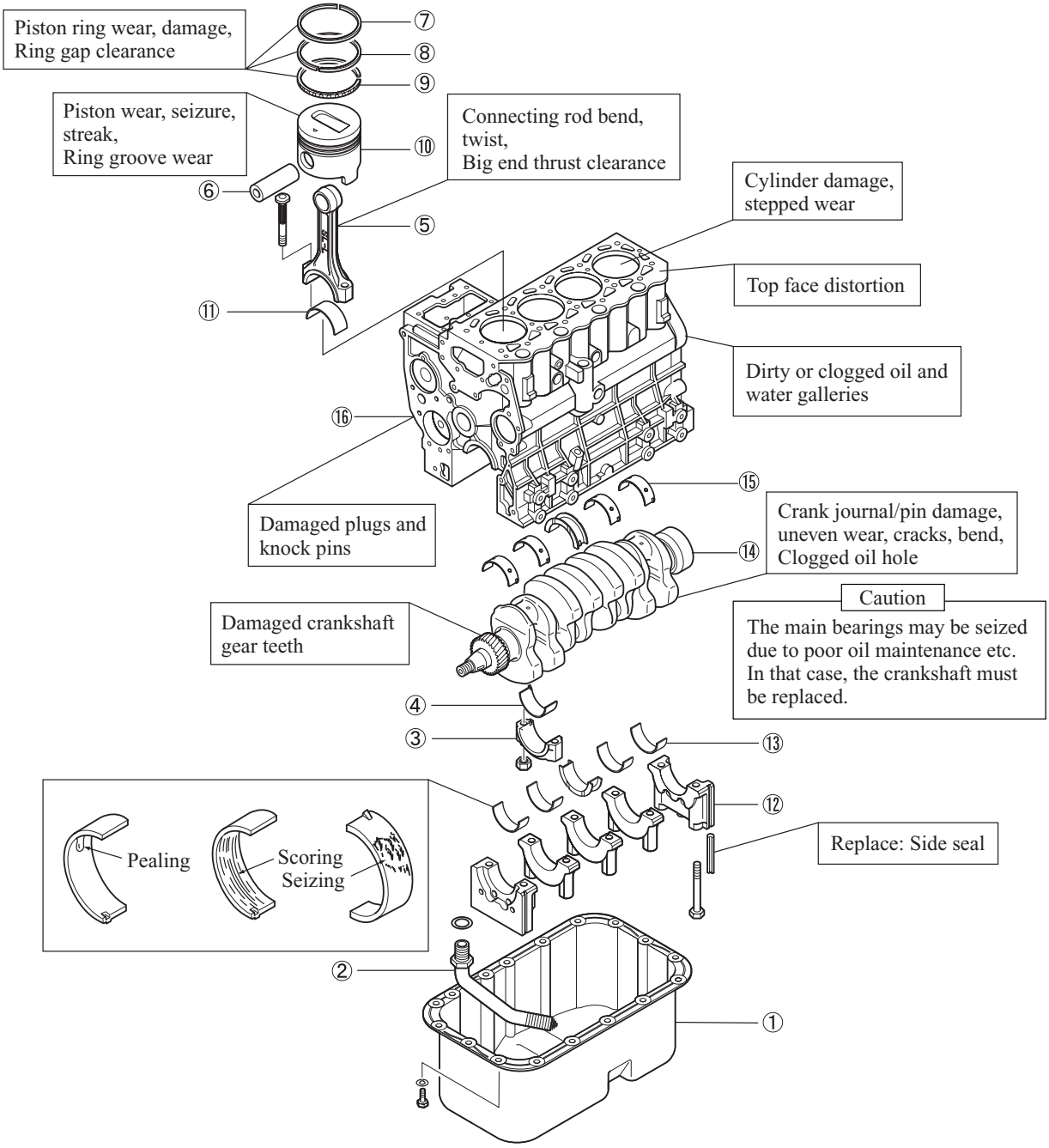
## 2.14 Removing the front plate

Remove the four front plate retaining bolts. Then, gently tap the plate with a plastic hammer to remove the gasket.



Removing the front plate

## 3. Cylinder Block, Crankshaft, Pistons, Oil Pan




Disassembly of cylinder block, crankshaft, pistons and oil pan

<Disassembly sequence>

① Oil pan
② Oil strainer
③ Connecting rod cap
④ Connecting rod bearing (lower)
⑤ Connecting rod
⑥ Piston pin
⑦ No. 1 ring
⑧ No. 2 ring
⑨ Oil ring
⑩ Piston
(Remove ⑤ to ⑩ as an assembly.)
⑪ Connecting rod bearing (upper)
⑫ Main bearing cap
⑬ Main bearing (lower)
⑭ Crankshaft
⑮ Main bearing (upper)
⑯ Cylinder block

Note: If the crankcase is to be replaced, carefully remove the relief valve and other parts from the old crankcase for reassembly onto the new crankcase.

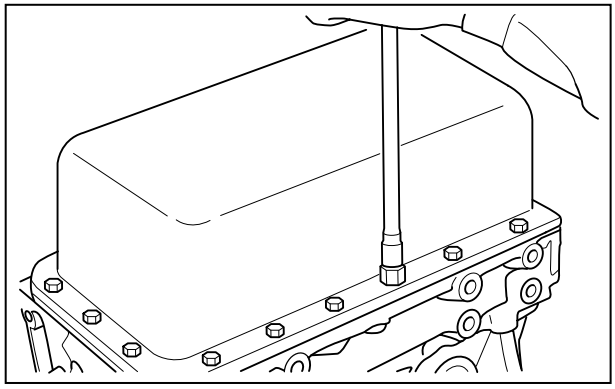
### 3.1 Removing the oil pan

(1) Turn the engine upside down.

(2) Remove the oil pan by tapping it on the bottom corners with a plastic hammer.

**⚠ CAUTION**

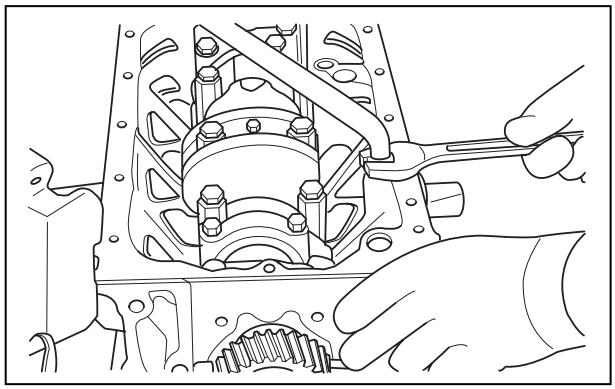
Do not insert a chisel or a screwdriver between the oil pan and the cylinder block to remove the oil pan. Otherwise, the oil pan flange face will be deformed.



Removing the oil pan

### 3.2 Removing the oil strainer

Loosen the nut to remove the oil strainer.



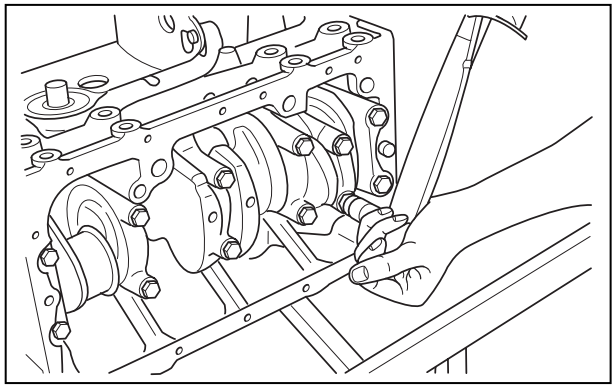
Removing the oil strainer

### 3.3 Removing the connecting rod caps

(1) Place the cylinder block on the side.

(2) Mark the cylinder numbers on the connecting rods and caps to ensure that they will be reassembled in original pairs.

(3) Remove the connecting rod caps.

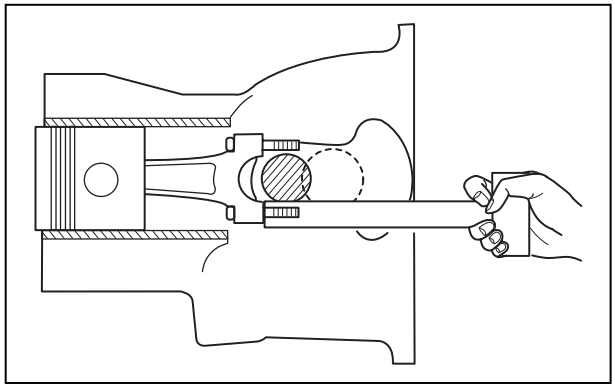


Removing the connecting rod caps

### 3.4 Removing the pistons

(1) Rotate the crankshaft to place the piston being removed at the top dead center.

(2) Using a wooden piece such as the stem of a hammer, push the piston and connecting rod assembly on the mating face with the connecting rod cap to remove the assembly from the cylinder block.



Removing the piston

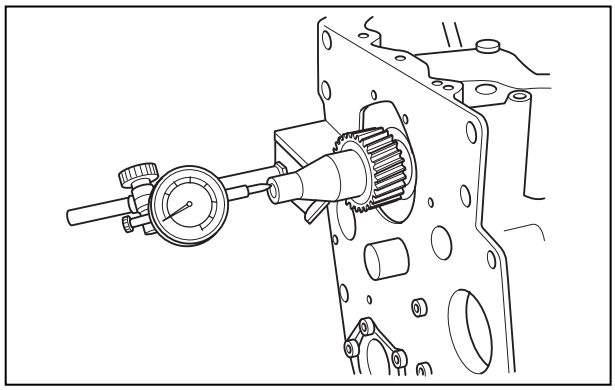
### 3.5 Measuring the crankshaft end play

With a dial gauge installed onto the end of the crankshaft, measure the shaft end play.

If the measured value exceeds the limit, replace the flanged No. 3 bearing.

Unit: mm (in.)

| | Standard value | Limit |
|---|---|---|
| Crankshaft end play | 0.050 to 0.175 (0.0020 to 0.0069) | 0.500 (0.0197) |



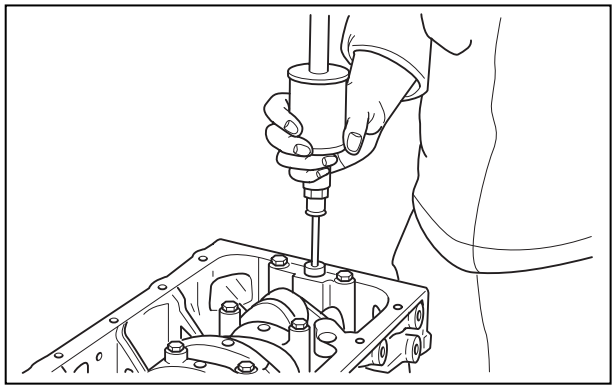
Measuring the crankshaft end play

### 3.6 Removing the main bearing caps

(1) Place the engine so that the cylinder block mating surface with the oil pan faces upwards.

(2) Loosen the main bearing cap bolts. Then, remove the caps.

(3) On the front and rear main bearing caps, remove these using a sliding hammer.



Removing the main bearing cap

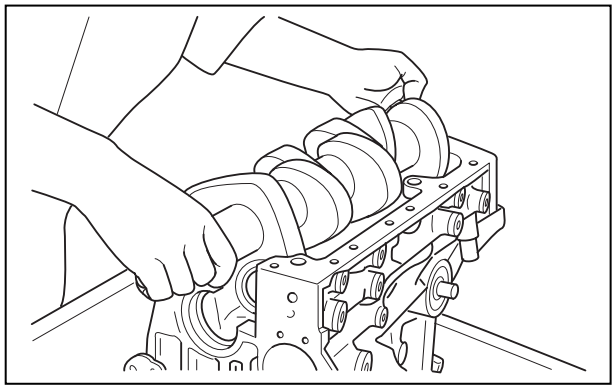
### 3.7 Removing the crankshaft

(1) Remove the crankshaft by slowly lifting it straight up.

**⚠ CAUTION**

When lifting the crankshaft, take care not to damage the main bearings.

(2) The main bearings may fall down, making it not possible to identify their original locations. Once the crankshaft is removed, place the main bearings neatly and in the original pairs so that they can be reassembled back onto their original locations.

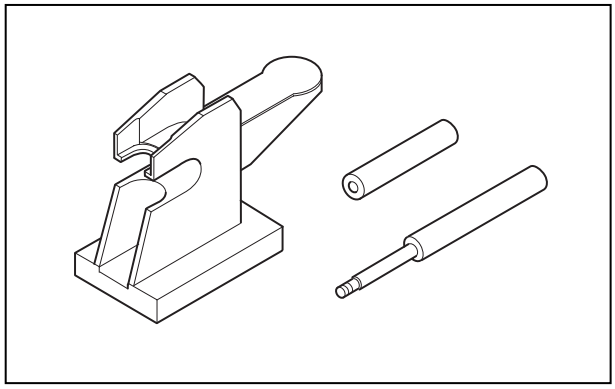


Removing the crankshaft

## 3.8 Separating the piston from the connecting rod

(1) Remove the piston pin using the special tool Piston Pin Setting Tool.

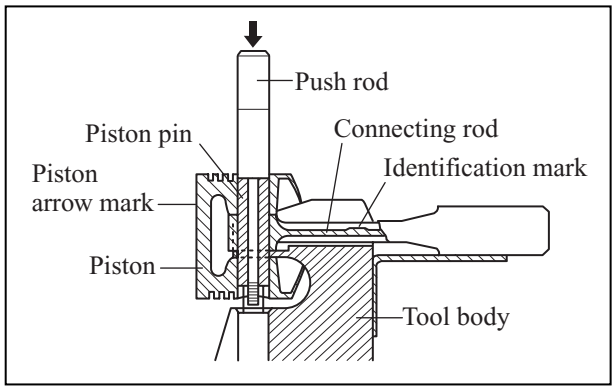
| Special tool | Part number |
|---|---|
| Piston Pin Setting Tool | 31A91-00100 |



Piston Pin Setting Tool

(2) Insert the tool's push rod into the piston pin hole. Using a press against the push rod, extract the piston pin.

(3) Use the Piston Pin Setting Tool again to reassemble the piston and the connecting rod.

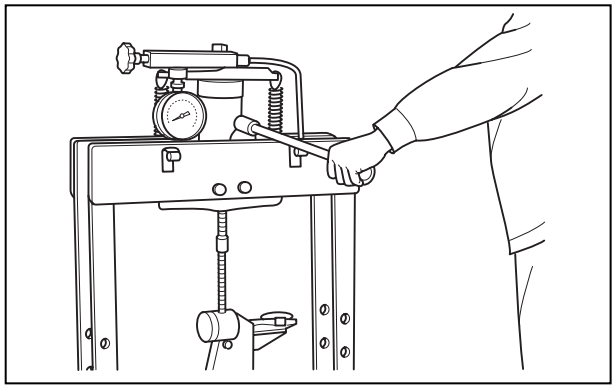



Removing the piston pin (1)

**⚠ CAUTION**

Do not try to remove the piston pin by tapping it.

If the piston has been agglutinated and requires a great force to remove, replace it with a new part.



Removing the piston pin (2)

# ENGINE MAIN PARTS - INSPECTION AND CORRECTION

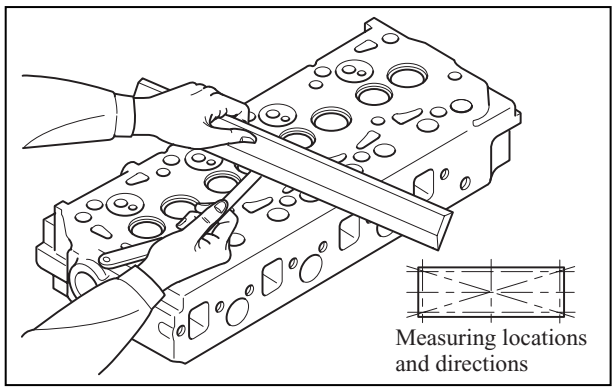
# 1. Cylinder Head, Valve Mechanism

## 1.1 Measuring the cylinder head bottom face distortion

Using a straight edge across the bottom face of the cylinder head and a thickness gauge, measure for any distortion. If the measured distortion exceeds the limit, correct with a surface grinder.

Unit: mm (in.)

| | Standard value | Limit |
|---|---|---|
| Cylinder head bottom face distortion | 0.05 less (0.002 less) | 0.10 (0.004) |



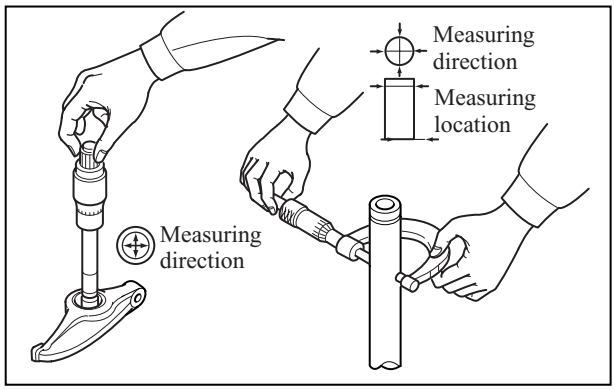

Measuring the cylinder head bottom face for distortion

## 1.2 Measuring the rocker arm bore and the rocker shaft diameter

Measure the rocker arm bore and the rocker shaft diameter to obtain the arm-to-shaft clearance. If the clearance is between the standard value and the limit, replace the rocker arm. If the clearance is equal to or exceeds the limit, replace both the rocker arm and shaft.

Unit: mm (in.)

| | Nominal value | Standard value | Limit |
|---|---|---|---|
| Rocker arm inner diameter | ϕ19 (0.749) | 18.910 to 18.930 (0.7450 to 0.7458) | — |
| Rocker shaft diameter | ϕ19 (0.749) | 18.880 to 18.898 (0.7438 to 0.7445) | — |
| Arm-to-shaft clearance | — | 0.012 to 0.050 (0.0005 to 0.002) | 0.200 (0.0079) |



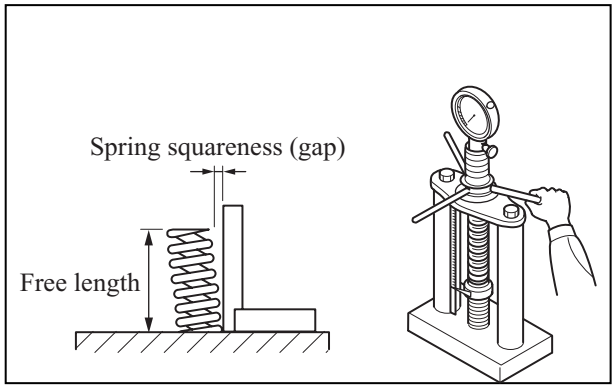

Measuring the rocker arm inner diameter and the rocker shaft diameter

## 1.3 Measuring the valve spring for squareness and free length

Measure the valve spring for squareness, free length, etc. If any of the measured values exceeds the limit, replace the spring.

Unit: mm (in.)

| | Standard value | | Limit |
|---|---|---|---|
| Free length | 47 (1.85) | | 46 (1.81) |
| Squareness | θ =2.0° or less<br>△(gap)=0.2 (0.0079) or less<br>Lf=47 (1.8504) | | △=0.5 (0.0197) across the entire length |
| Installed length/load mm (in.)/N (kgf) [lbf] | 39.0 (1.536)/ 131 to 145 (13.3 to 14.7) [29 to 33] | 30.1 (1.185)/ 279 to 309 (28.5 to 31.5) [63 to 69] | -15% |




Measuring the spring for squareness and free length

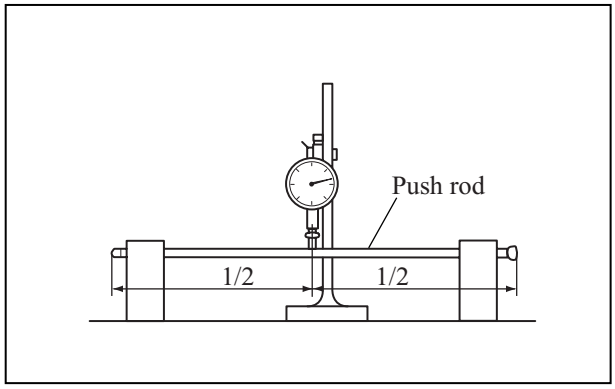
## 1.4 Measuring the push rod for bend

If the measured value exceeds the limit, replace the push rod.

Unit: mm (in.)

| | Limit |
|---|---|
| Push rod bend | 0.3 (0.012) |

Note: Use a dial gauge to measure the push rod for bend.



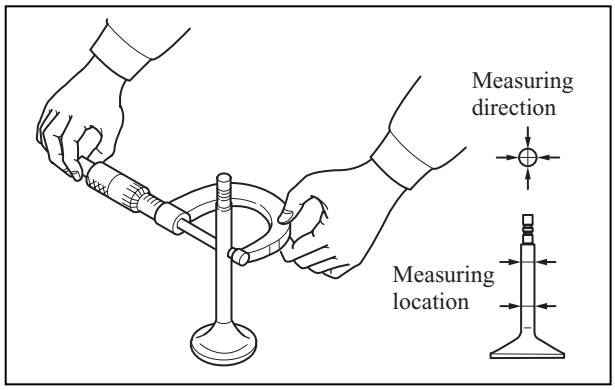

Measuring the push rod bend

## 1.5 Measuring the valve stem diameter

Measure the valve stem diameter. If the measured value is less than the limit, replace with a new part. Replace also when the valve stem has excessively uneven wear.

Unit: mm (in.)

| | | Nominal value | Standard value | Limit |
|---|---|---|---|---|
| Valve stem diameter | Inlet | ϕ6.6 (0.260) | 6.565 to 6.580 (0.2586 to 0.2592) | 6.500 (0.256) |
| | Exhaust | ϕ6.6 (0.260) | 6.530 to 6.550 (0.2572 to 0.2580) | 6.500 (0.256) |




Measuring the valve stem diameter

## 1.6 Measuring the clearance between the valve stem and guide

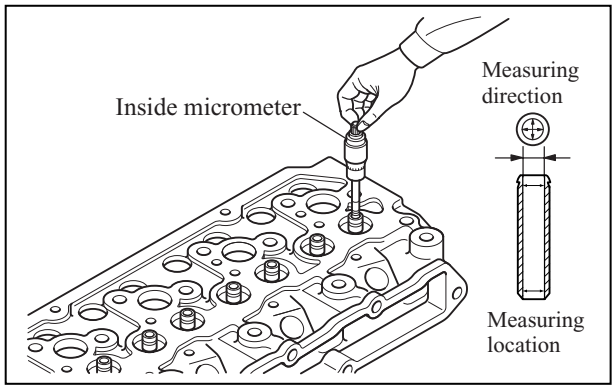
Measure the valve guide inner diameter using an inside micrometer.

The valve guide wears at the top and bottom ends. Therefore, both ends need to be measured orthogonally. If the measured value exceeds the limit, replace with a new part.

Unit: mm (in.)

| | | Nominal value | Standard value | Limit |
|---|---|---|---|---|
| Valve stem -to-guide clearance | Inlet | — | 0.020 to 0.050 (0.0008 to 0.002) | 0.100 (0.004) |
| | Exhaust | — | 0.050 to 0.085 (0.002 to 0.003) | 0.150 (0.006) |
| Installed valve guide protrusion | | 10 (0.394) | 9.5 to 10.5 (0.3743 to 0.4137) | — |

Note: Before measuring the valve stem-to-guide clearance, remove carbon from the valve and the valve guide.




Measuring the valve guide inner diameter

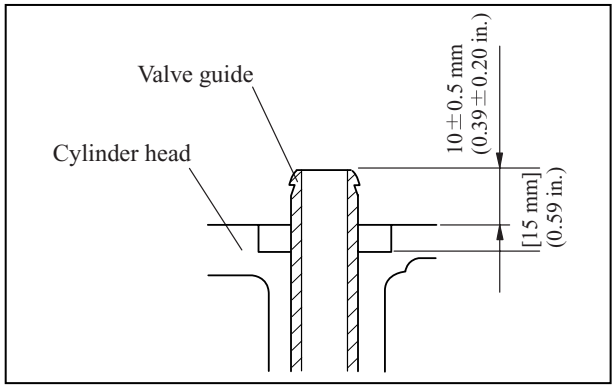
## 1.7 Replacing the valve guide

(1) Using a punching tool, remove the valve guide from the bottom to the top of the cylinder head.

(2) Using a press, insert a new valve guide from the top of the cylinder head so that the valve guide protrusion above the cylinder head face is to the indicated dimension.

(3) With the valve guide press-fit into position, insert a new valve to verify that it slides smoothly inside the valve guide.

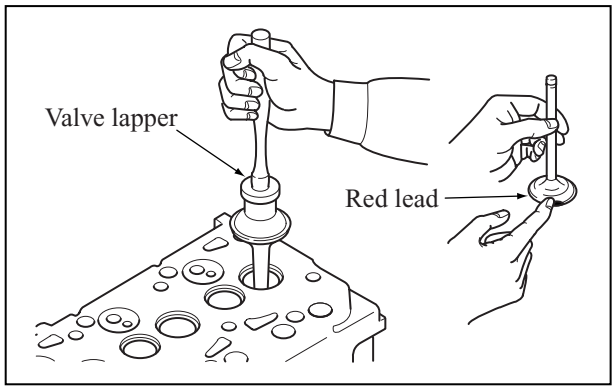
(4) Check the valve face-to-seat contact.




Valve guide protrusion
above the cylinder head face

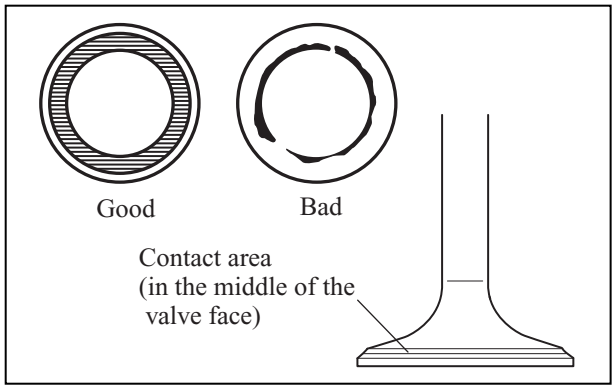
## 1.8 Inspecting the valve face

(1) Apply a thin coating of red lead onto the valve face. Then, using a valve lapper (available on the market), check the valve face-to-seat contact.




Inspecting the valve face

(2) The valve face contact area with the valve seat should be uniform and in the middle of the face. If not, reface with valve facer.

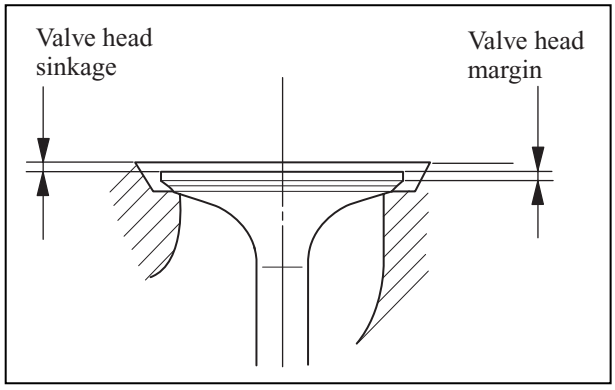



Valve seat-to-face contact

(3) If the measured valve head margin (valve head thickness) is less than the limit, replace the valve.

Unit: mm (in.)

| | Standard value | Limit |
|---|---|---|
| Valve head margin | 1.35 to 0.65<br>(0.0531 to 0.0650) | 0.5<br>(0.0197) |




Valve head sinkage

(4) If the measured valve head sinkage exceeds the limit, correct the valve seat or replace the cylinder head assembly.

Unit: mm (in.)

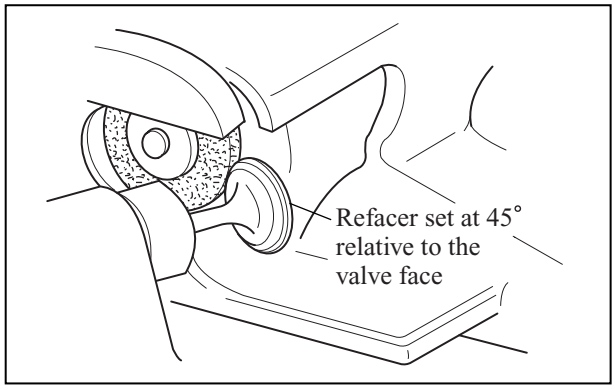
| | Standard value | Limit |
|---|---|---|
| Valve head sinkage | 0.25 to 0.75 (0.0098±0.0295) | 1.5 (0.0600) |

## 1.9 Correcting the valve face

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

Note: (a) When grinding, set the refacer at 45º relative to the valve face.

(b) The valve head margin should be maintained above the limit. If it appears that the minimum margin cannot be maintained after refacing, replace the valve.



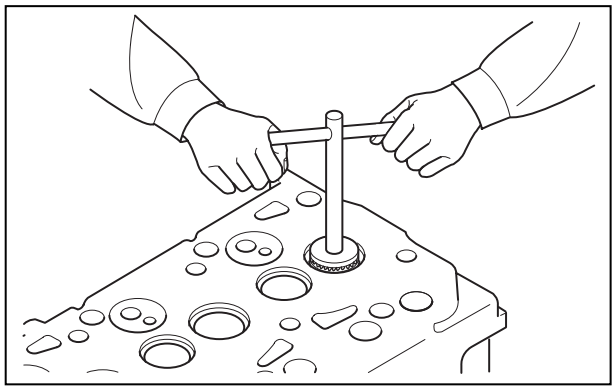

Correcting the valve face

## 1.10 Correcting the valve seat

(1) Before correcting the valve seat, check the valve stem-to-guide clearance and, if necessary, replace the valve guide.

(2) Grind with a valve seat cutter (available on the market) or a valve seat grinder until the valve seat width and angle meet specification.

Note: Valve seat correction should be limited as minimum as possible.

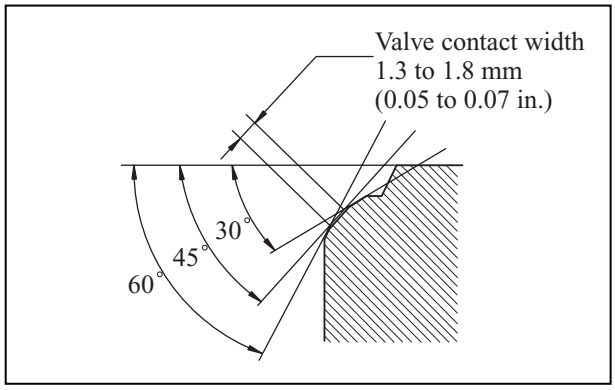


Correcting the valve seat

Unit: mm (in.)

| | Standard value | Limit |
|---|---|---|
| Valve seat angle | 45° | — |
| Valve seat width | 1.30 to 1.80 (0.0512 to 0.0709) | 2.5 (0.0985) |

(3) After correction, lap the valve face against the valve seat using lapping compound.




Valve seat angle and width

## 1.11 Lapping the valve face against the valve seat

If the valve seat is corrected or the valve is replaced, be sure to lap the valve face against the valve seat in the following manner.

(1) Apply a light coating of lapping compound evenly over the valve face.

Note: (a) Take care not to allow lapping compound to attach to the valve stem.

(b) Use medium lapping compound (120 to 150 mesh) first, then finish off with fine lapping compound (200 mesh or above).

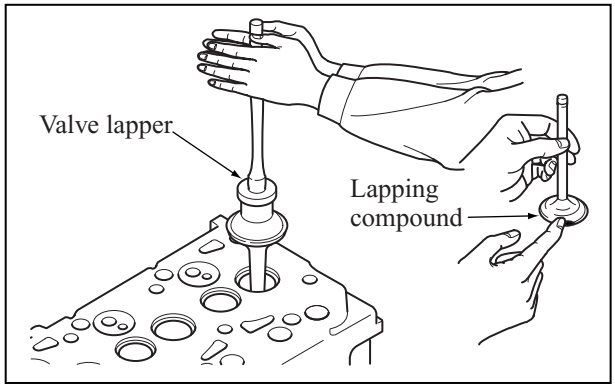
(c) Lapping compound spreads more evenly if it is mixed with a small amount of engine oil.

(2) Using a valve lapper, lap the valve face against the valve seat repeatedly while rotating it gradually.

(3) Wash away the lapping compound in light oil or other similar liquid.

(4) Apply engine oil onto the lapped faces and lap them again.

(5) Check the lapped faces for correct contact.

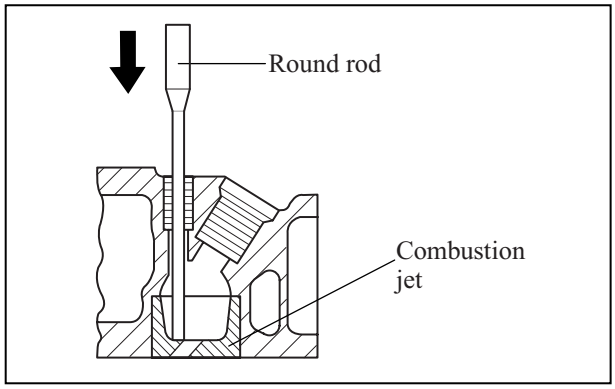



Lapping the valve face against the valve seat

## 1.12 Replacing the combustion jets

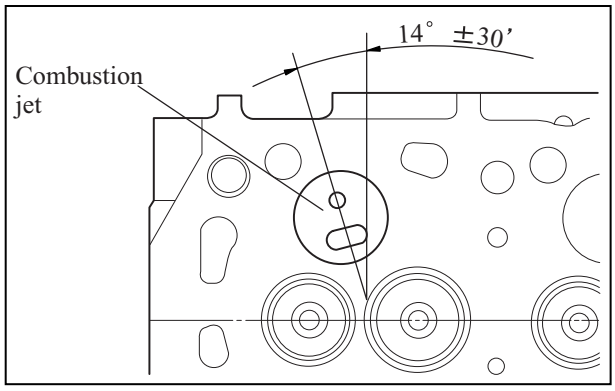
Replace the combustion jets only when they are cracked or faulty.

(1) To extract the combustion jet, insert a round rod with a diameter of approx. 6 mm (0.23 in.) into the glow plug mounting hole and gently tap the periphery of the combustion jet bore.




Extracting the combustion jet

(2) To install the jet, tap it into the mounting hole using a plastic hammer or other similar tool. Ensure that the nozzle hole faces the center of the cylinder.




Tapping the combustion jet into place

# 2. Flywheel, Timing Gear, Camshaft

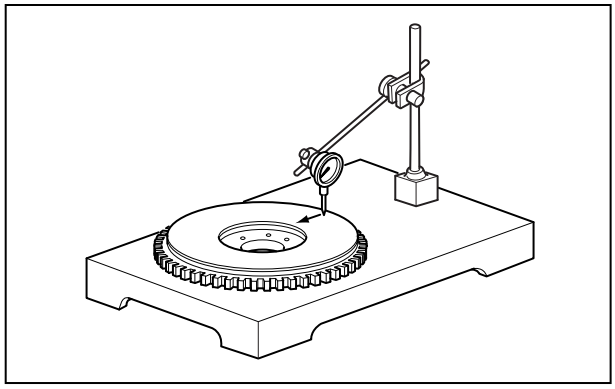
## 2.1 Measuring the flywheel flatness

Place the flywheel on a surface plate. Run a dial gauge over the frictional surface of the flywheel to measure the flatness.

If the measured value exceeds the limit, grind the frictional surface.

Unit: mm (in.)

| | Standard value | Limit |
|---|---|---|
| Flywheel flatness | 0.150 (0.0059) or less | 0.50 (0.0197) |



Measuring the flywheel flatness

## 2.2 Replacing the ring gear

Check the ring gear for fractured or excessively worn gear teeth. If faulty, replace in the following manner.

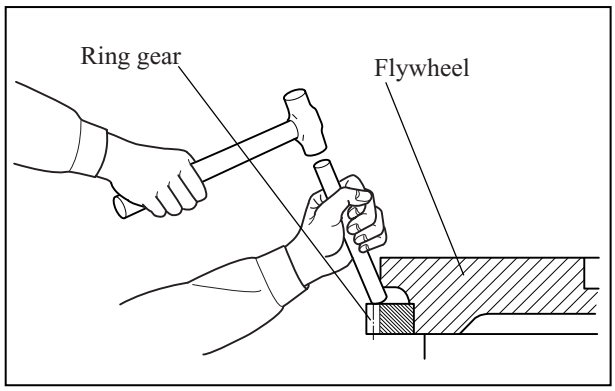
(1) Removing the ring gear

(a) Using an acetylene torch or other similar equipment, heat the ring gear evenly.

(b) Using a hammer and a rod, tap the ring gear evenly on the entire periphery until the gear comes off.

(2) Installing the ring gear

Using a piston heater or other similar equipment, heat the ring gear [to approximately 150℃ (302 ℉) or less]. With the gear warmed up, install it onto the flywheel with the un-chamfered side first.



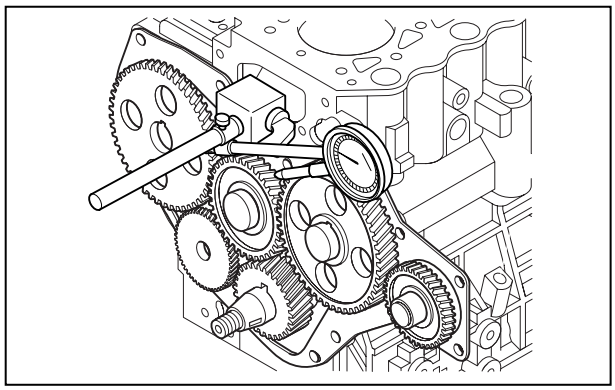

Removing the ring gear

## 2.3 Measuring the timing gear backlash

Measure the backlash between the gears and use the measurements as references upon reassembly. If any of the measured values exceeds the limit, replace all gears unless otherwise specified.

Unit: mm (in.)

| | | Standard value | Limit |
|---|---|---|---|
| Timing gear backlash | Crank gear - idler gear | 0.040 to 0.120 (0.0015 to 0.0047) | 0.300 (0.0120) |
| | Idler gear - valve camshaft gear | | |
| | Idler gear - pump camshaft gear | | |
| | Valve camshaft gear - PTO gear | 0.080 to 0.190 (0.0032 to 0.0075) | |
| | Pump camshaft gear - oil pump gear | 0.070 to 0.200 (0.0028 to 0.0079) | |



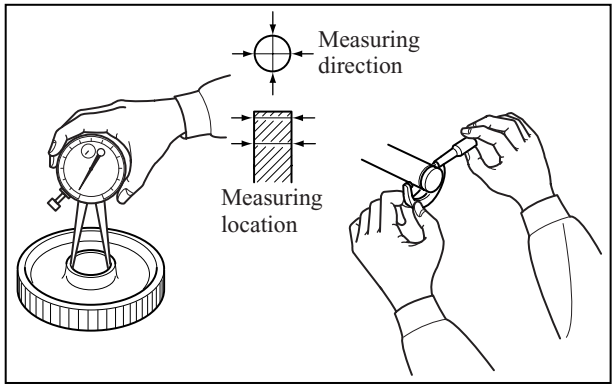
Measuring the timing gear backlash

## 2.4 Measuring the clearance between the idler gear and the idler shaft

Measure the inner diameter of the idler gear. Measure the idler shaft diameter. If the difference between the two exceeds the limit, replace the idler gear or the idler shaft.

Unit: mm (in.)

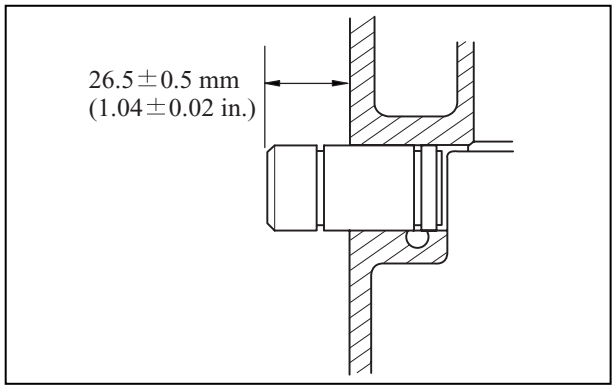
| | Standard value | Limit |
|---|---|---|
| Idler gear-to-shaft clearance | 0.020 to 0.070 (0.0008 to 0.0028) | 0.200 (0.0079) |




Measuring the idler gear-to-shaft clearance

## 2.5 Replacing the idler shaft

When installing the idler shaft into the cylinder block, observe the dimension indicated.



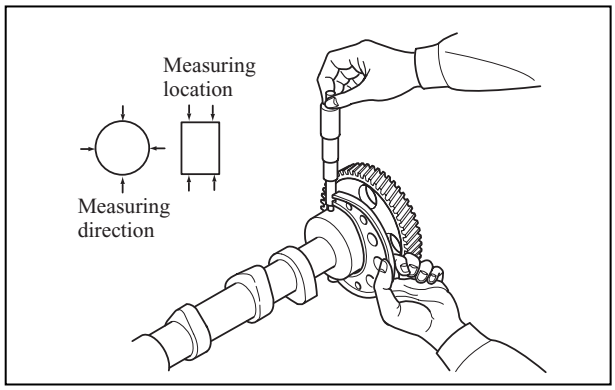

Replacing the idler shaft

## 2.6 Measuring the clearance between the camshaft journal and the bushing

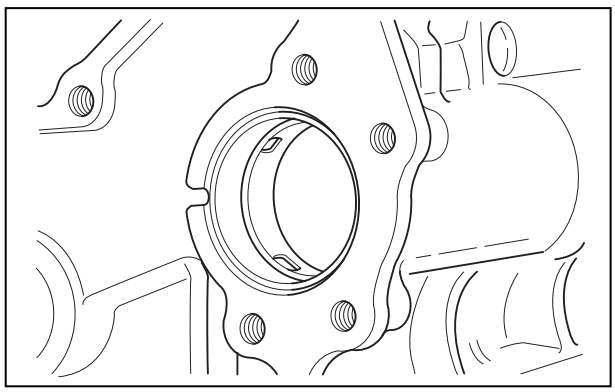
Measure the camshaft journal diameter. Measure the inner diameter of the bushing on the cylinder block. If the difference between them exceeds the limit, replace the bushing.

Unit: mm (in.)

| | Standard value | Limit |
|---|---|---|
| Camshaft journal-to-bushing clearance | 0.050 to 0.125 (0.0020 to 0.0049) | 0.150 (0.0059) |




Measuring the camshaft journal diameter



Measuring the camshaft bushing inner diameter

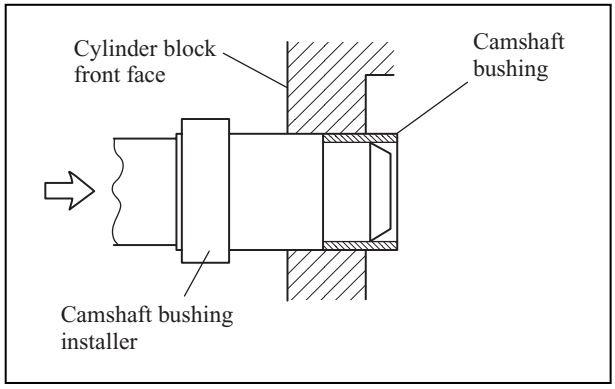
## 2.7 Extracting the camshaft bushing

(1) Remove the camshaft bushing using the special tool Camshaft Bushing Installer in the following manner.

| Special tool | Part number |
|---|---|
| Camshaft Bushing Installer | ST332340 |

(2) Remove the oil pan.

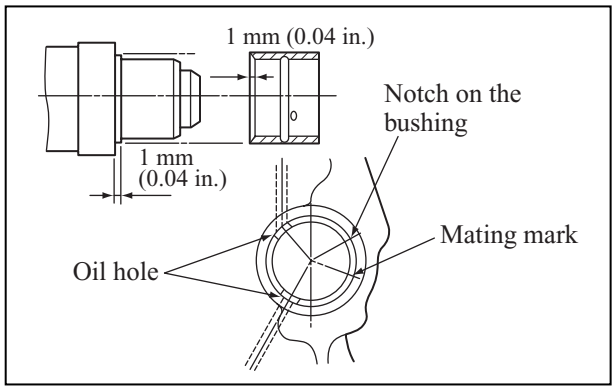
(3) Using the punching side of the installer, punch the bushing off and into the cylinder block. Take it out of the block by slightly deforming it.




Extracting the camshaft bushing

## 2.8 Press-fitting the camshaft bushing

Press-fit the bushing while ensuring that the oil holes of the bushing align with the oil galleries in the cylinder block.



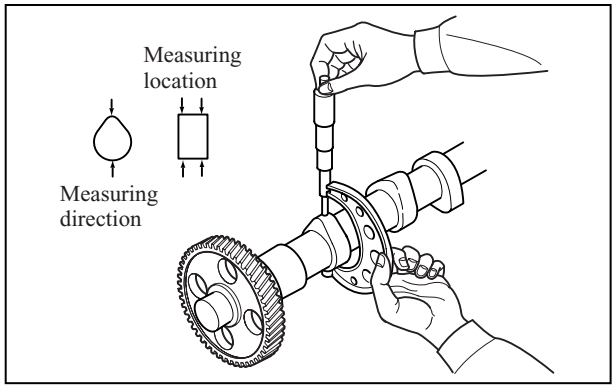

Press-fitting the camshaft bushing

## 2.9 Measuring the camshaft cam height

Measure the camshaft cam height as illustrated. If the measured value is less than the limit, replace the camshaft.

Unit: mm (in.)

| | Standard value | Limit |
|---|---|---|
| Camshaft cam height (including lobe) | 35.720±0.1 (1.4073±0.0039) | 34.720 (1.3679) |



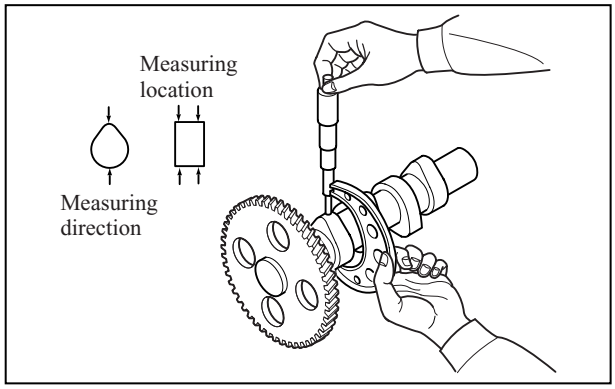

Measuring the camshaft cam height

## 2.10 Measuring the fuel injection pump shaft cam height

Measure the cam height as illustrated. If the measured value is less than the limit, replace the fuel injection pump shaft.

Unit: mm (in.)

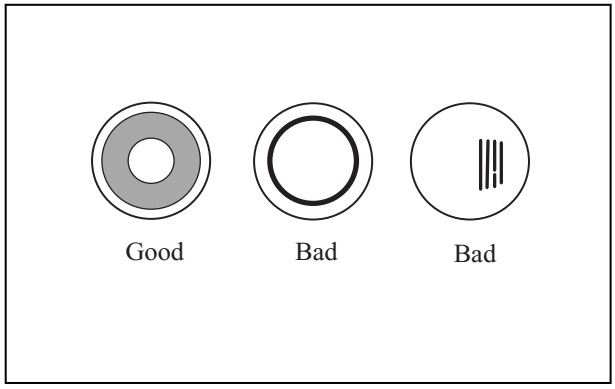
| | Standard value | Limit |
|---|---|---|
| Fuel injection pump shaft cam height (including lobe) | 44±0.1 (1.736±0.0039) | 43 (1.6942) |




Measuring the fuel injection pump shaft cam height

## 2.11 Inspecting the cam-to-tappet contact

Inspect the tappet contact face with the cam. If abnormally worn, replace the tappet.



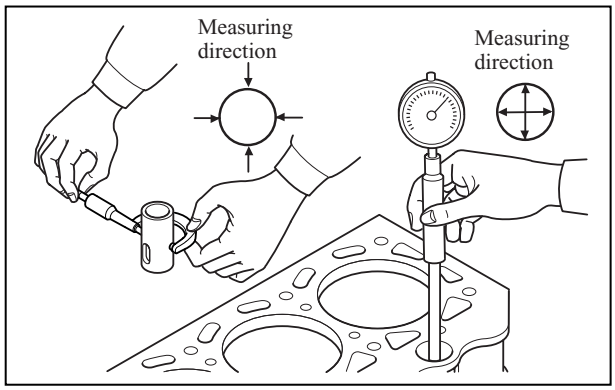

Cam-to-tappet contact

## 2.12 Measuring the clearance between the tappet and the tappet guide

Measure the tappet diameter. Measure the tappet guide bore in the cylinder block. If the difference between them exceeds the limit, replace the tappet.

Unit: mm (in.)

| | Limit |
|---|---|
| Tappet-to-guide clearance | 0.150 (0.0059) |



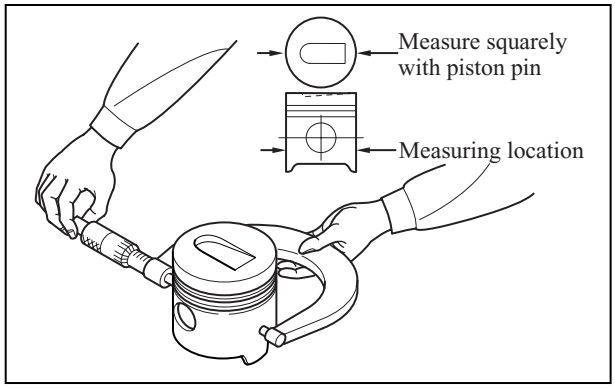

Measuring the clearance between the tappet and the tappet guide

# 3. Cylinder Block, Crankshaft, Pistons, Oil Pan

## 3.1 Measuring the piston diameter

Using a micrometer, measure the piston diameter across the piston skirt and squarely with the piston pin, as illustrated.

If the measured value is less than the limit, replace with a new part. The maximum allowable variation in weight among the pistons on the same engine is 5 grams (0.18 oz).



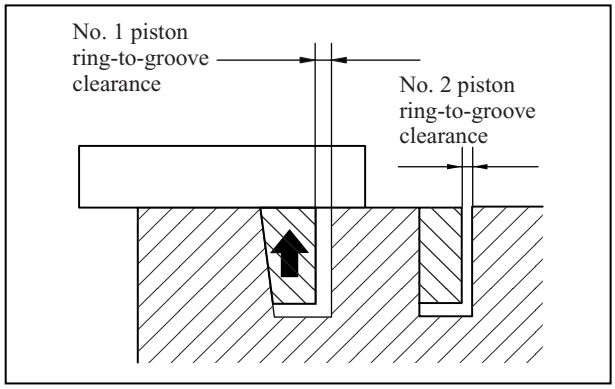

Measuring the piston diameter

Unit: mm (in.)

| | | Nominal value | Standard value | Limit |
|---|---|---|---|---|
| Piston diameter | STD | 78.00 (3.07) | 77.93 to 77.95 (3.070 to 3.071) | 77.80 (3.065) |
| | 0.25 OS | 78.25 (3.08) | 78.18 to 78.20 (3.080 to 3.081) | 78.05 (3.075) |
| | 0.50 OS | 78.50 (3.09) | 78.43 to 78.45 (3.090 to 3.090) | 78.30 (3.085) |
| Max. allowable variation in weight among pistons on the same engine: | | | 5 g (0.18 oz) or less | — |

## 3.2 Measuring the clearance between the piston ring and the ring groove

(1) Measure the piston ring-to-groove clearance. If the measured value exceeds the limit, replace the piston ring.




Measuring the piston ring-to-groove clearance

Unit: mm (in.)

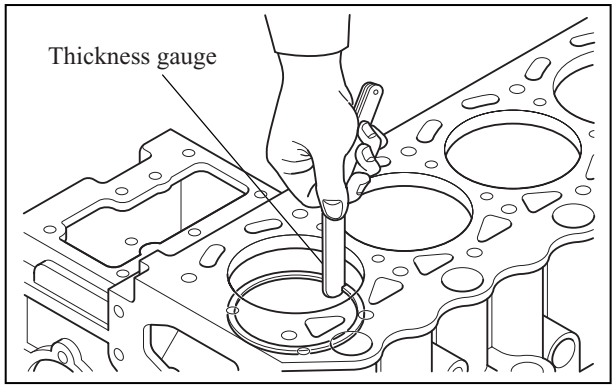
| | Standard value | Limit |
|---|---|---|
| No. 1 ring | 0.09 to 0.11 (0.0035 to 0.0043) | 0.300 (0.012) |
| No. 2 ring | 0.07 to 0.11 (0.0028 to 0.0043) | 0.200 (0.008) |
| Oil ring | 0.03 to 0.07 (0.0012 to 0.0028) | 0.200 (0.008) |

(2) With the new piston ring installed, measure the ring-to-groove clearance again. If the measured value still exceeds the limit, replace the piston.

## 3.3 Measuring the piston ring gap

Install the piston ring being measured into the gauge or a new cylinder. Then, using a thickness gauge, measure the piston ring gap. If the measured value exceeds the limit, replace all rings of the relevant piston as a set.

Gauge bore size
- STD=$78^{+0.03}_{0}$ mm ($3.07^{+0.0012}_{0}$ in.)
- 25 OS=$78.25^{+0.03}_{0}$ mm ($3.08^{+0.0012}_{0}$ in.)
- 50 OS=$78.50^{+0.03}_{0}$ mm ($3.09^{+0.0012}_{0}$ in.)




Measuring the piston ring gap

Note: To install a piston ring into the gauge, use a piston to push the ring evenly.

Unit: mm (in.)

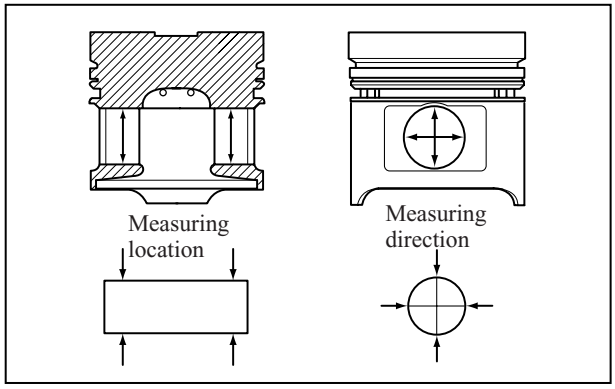
| | | Standard value | Limit |
|---|---|---|---|
| Piston ring gap | No. 1 ring | 0.15 to 0.30 (0.006 to 0.012) | 1.50 (0.06) |
| | No. 2 ring | 0.15 to 0.35 (0.006 to 0.014) | |
| | Oil ring | 0.20 to 0.40 (0.008 to 0.016) | |

### 3.4 Measuring the clearance between the piston pin and the pin boss

Measure the piston pin diameter. Measure the bore size of the piston pin boss. If the difference between them exceeds the limit, replace with new parts.

Unit: mm (in.)

| | Nominal value | Standard value | Limit |
|---|---|---|---|
| Piston pin diameter | ϕ23 (0.9062) | 22.944 to 23.000 (0.9039 to 0.9062) | — |
| Piston pin-to-boss clearance | — | 0.006 to 0.018 (0.0002 to 0.0007) | 0.050 (0.002) |



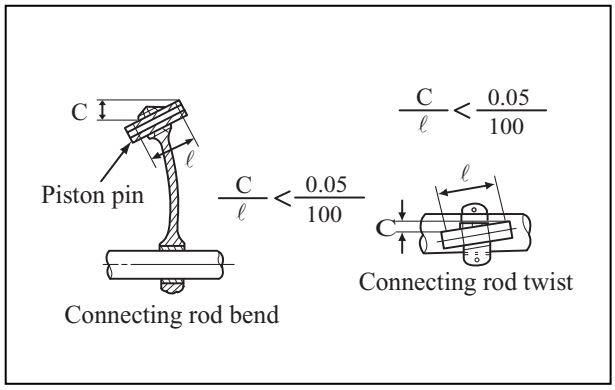

Measuring the piston pin-to-boss clearance

### 3.5 Measuring the connecting rod bend and twist

(1) Measure C and ℓ as illustrated. If measured C is more than 0.05 mm (0.0020 in.) per 100 mm (3.937 in.) of measured ℓ, correct the connecting rod using a press.

Unit: mm (in.)

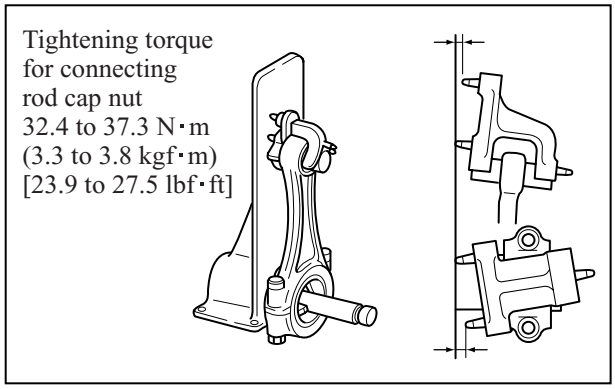
| | Standard value | Limit |
|---|---|---|
| Connecting rod bend and twist | 0.05/100 (0.002/3.940) or less | 0.15/100 (0.006/3.940) |




Measuring the connecting rod bend and twist

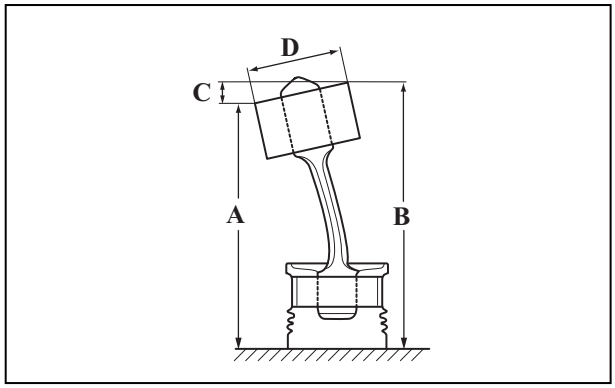
(2) Normally, a connecting rod aligner is used to measure the connecting rod for bend and twist.

Note: Before measuring the connecting rod for bend, tighten the connecting rod cap nuts to the specified torque.




Using a connecting rod aligner to measure the rod bend and twist

(3) When measuring connecting rod bend with the piston installed to the connecting rod, place the piston/rod assembly on a surface plate such that the top of piston lies on the plate. Then, insert a round rod with the same diameter as the crank pin into the connecting rod large end. Using a dial gauge, measure the top of the round rod for any variation in height.




Using a dial gauge to measure the connecting rod for bend

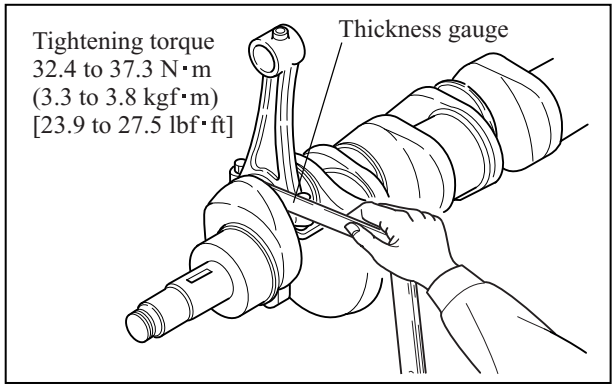
## 3.6 Measuring the connecting rod end play

Install the connecting rod and the rod cap onto the mating crank pin. Tighten the cap nuts to the specified torque. Using a thickness gauge, measure the gap (end play).

If the measured value exceeds the limit, replace the connecting rod and the rod cap.

Unit: mm (in.)

| | Standard value | Limit |
|---|---|---|
| Connecting rod end play | 0.10 to 0.35 (0.004 to 0.014) | 0.50 (0.012) |




Measuring the connecting rod end play

## 3.7 Inspecting the oil clearance for connecting rod bearings

(1) Install the connecting rod bearings (upper and lower) into the connecting rod large end. Tighten the cap nuts to the specified torque. Measure the inner diameter of the bearings.

(2) Measure the diameter of the mating crank pin. The difference between the bearing inner diameter and the crank pin diameter is the oil clearance for the bearings.

Unit: mm (in.)

| | Nominal value | Standard value | Limit |
|---|---|---|---|
| Crank pin diameter | ϕ48 (1.8912) | 47.950 to 47.964 (1.8892 to 1.8897) | — |
| Oil clearance for connecting rod bearings | — | 0.025 to 0.072 (0.0010 to 0.0028) | 0.150 (0.0059) |

(3) If the measured oil clearance exceeds the limit, replace the bearings. With the new bearings installed, measure the oil clearance again.

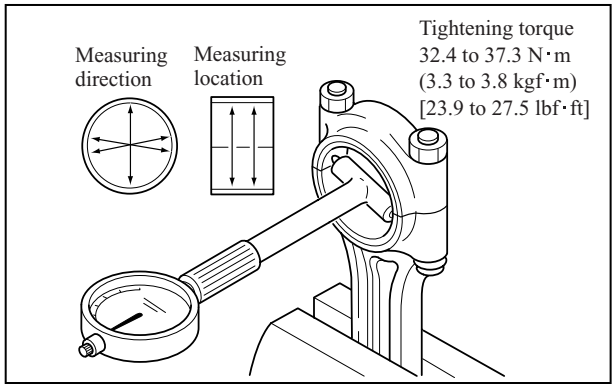
(4) If the measured oil clearance still exceeds the limit, use the undersize bearings [0.25 mm (0.0098 in.), 0.50 mm (0.0197 in.), 0.75 mm (0.0295 in.) U.S.]

Also, grind the crank pin accordingly to the finished dimension shown below.

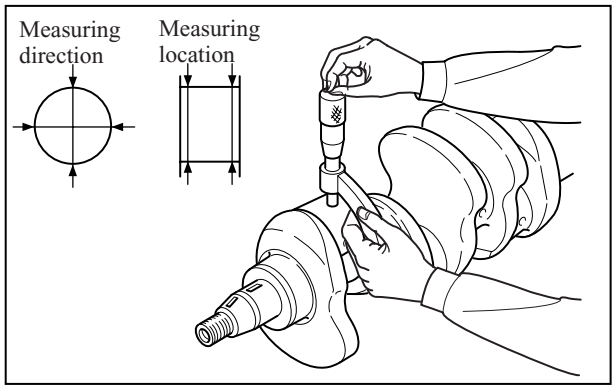
Crank pin ground dimensions

Unit: mm (in.)

| | | Finished dimension |
|---|---|---|
| Crank pin undersize | 0.25 (0.0098) | $\phi 47.75^{-0.035}_{-0.050}$ ($1.881^{-0.0014}_{-0.0020}$) |
| | 0.50 (0.0197) | $\phi 47.50^{-0.035}_{-0.050}$ ($1.871^{-0.0014}_{-0.0020}$) |
| | 0.75 (0.0295) | $\phi 47.25^{-0.035}_{-0.050}$ ($1.861^{-0.0014}_{-0.0020}$) |




Measuring the connecting rod bearings inner diameter

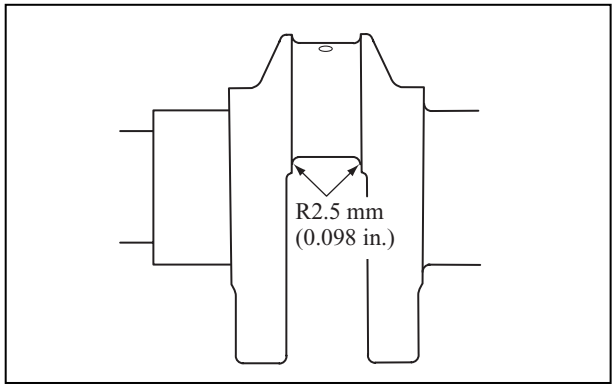



Measuring the crank pin diameter

**⚠ CAUTION**

(a) If any of the crank pins need grinding, grind all crank pins on the same crankshaft to the same dimension.

(b) Finish the fillets to a radius of 2 mm (0.08 in.).

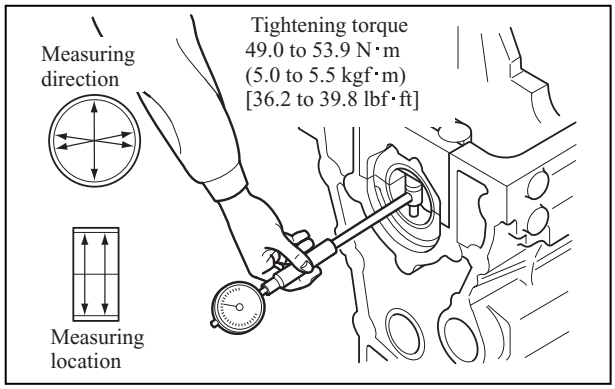



Finished radius dimension of fillet

## 3.8 Inspecting the main bearings oil clearance

(1) Place the main bearings (upper and lower) onto the cylinder block and the main bearing cap. Assemble them together and tighten the cap bolts to the specified torque. Measure the inner diameter of the main bearings.

(2) Measure the diameter of the mating crank journal. The difference between the main bearings inner diameter and the crank journal diameter is the oil clearance for the main bearings.




Measuring the main bearings inner diameter

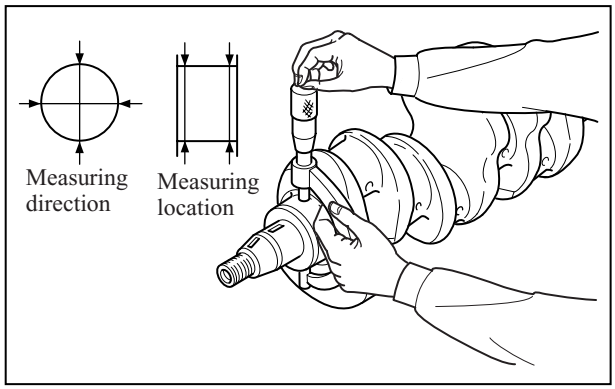
Unit: mm (in.)

| | Nominal value | Standard value | Limit |
|---|---|---|---|
| Crank journal diameter(STD) | ϕ52 (2.0488) | 51.985 to 52.000 (2.0482 to 2.0488) | — |
| Oil clearance for main bearings | — | 0.030 to 0.077 (0.0012 to 0.003) | 0.100 (0.0040) |

(3) If the measured oil clearance exceeds the limit, replace the main bearings. With the new bearings installed, measure the oil clearance again.

(4) If the measured oil clearance still exceeds the limit, use the undersize bearings [0.25 mm (0.0098 in.), 0.50 mm (0.0197 in.), 0.75 mm (0.0295 in.) U.S.]

Also, grind the crank journal accordingly to the finished dimension shown below.




Measuring the crank journal diameter

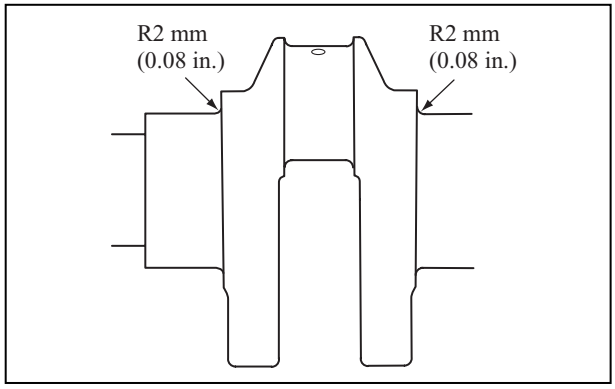
Crank journal ground dimensions

Unit: mm (in.)

| | | Finished dimension |
|---|---|---|
| Crank journal undersize | 0.25 (0.0098) | $\phi 51.75^{0}_{-0.015}$ ($2.0374^{0}_{-0.006}$) |
| | 0.50 (0.0197) | $\phi 51.50^{0}_{-0.015}$ ($2.0276^{0}_{-0.006}$) |
| | 0.75 (0.0295) | $\phi 51.25^{0}_{-0.015}$ ($2.0177^{0}_{-0.006}$) |

**⚠ CAUTION**

(a) If any of the crank journals need grinding, grind all crank journals on the same crankshaft to the same dimension.
(b) Finish the fillets to a radius of 2.5 mm (0.098 in.).

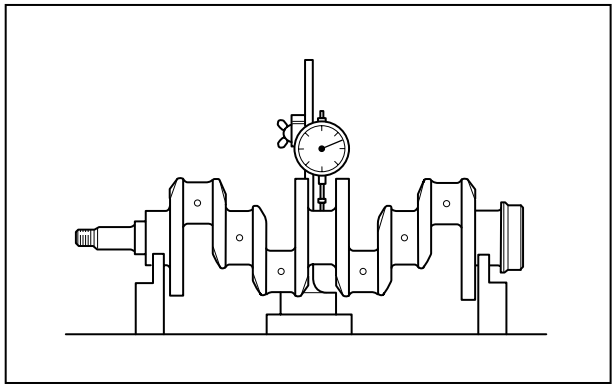



Finished radius dimension of fillet

### 3.9 Measuring the crankshaft for bend

Support the crankshaft at the front and rear crank journals with a V block. Using a dial gauge, measure the center journal for a swing of the gauge needle (to both directions). If the measured value moderately exceeds the standard value, correct the bend by grinding. If the measured value far exceeds the standard value, correct the bend using a press or other similar equipment.

If the measured value exceeds the limit, replace the crankshaft.



Measuring the crankshaft bend

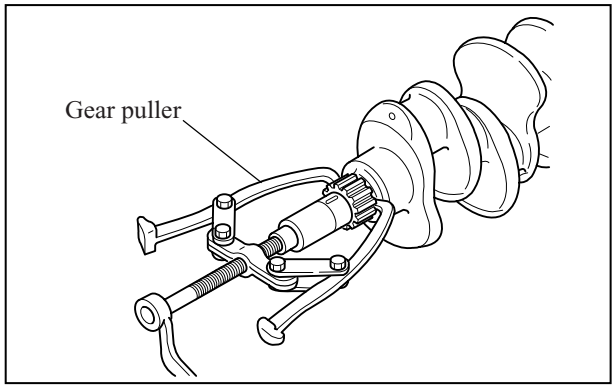
Unit: mm (in.)

| | Standard value | Limit |
|---|---|---|
| Crankshaft bend | 0.025 (0.0010) | 0.050 (0.0020) |

### 3.10 Removing the crankshaft gear

Use a gear puller to remove the crankshaft gear.

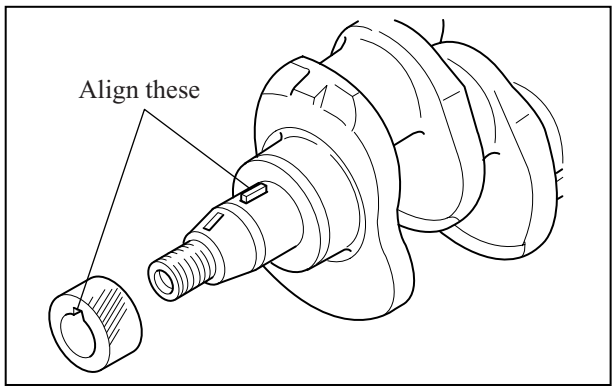
Note: Do not remove the crankshaft gear unless the crankshaft or the gear is faulty.




Removing the crankshaft gear

### 3.11 Installing the crankshaft gear

(1) Install the key to the crankshaft.
(2) Align the keyway in the crankshaft gear with the key on the crankshaft, and press-fit the gear fully until it stops.

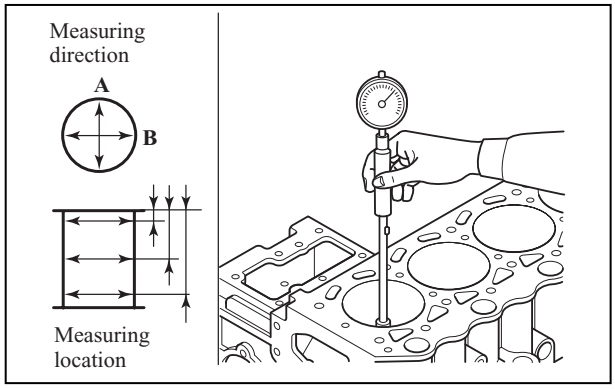



Installing the crankshaft gear

## 3.12 Measuring the cylinder bore

Using a cylinder gauge, measure the cylinder bore and cylindricality. If any of the cylinders exceeds the limit, bore all cylinders of the same engine and replace the pistons and the piston rings with oversize parts.

Measure at 3 locations as shown in the fig., each in directions A and B.




Measuring the cylinder bore

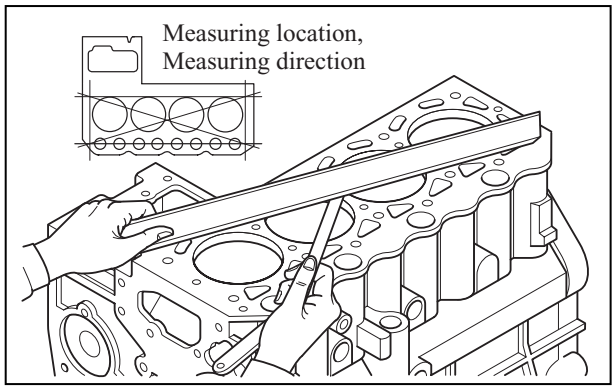
Unit: mm (in.)

| Pistons and piston rings available | | Cylinder bore | |
|---|---|---|---|
| Size | Code | Standard value | Limit |
| STD | STD | $\phi 78^{+0.03}_{0}$ ($3.07^{+0.012}_{0}$) | Standard value +0.2 (0.0080) |
| 0.25 OS | 25 | $\phi 78.25^{+0.03}_{0}$ ($3.08^{+0.012}_{0}$) | |
| 0.50 OS | 50 | $\phi 78.50^{+0.03}_{0}$ ($3.09^{+0.012}_{0}$) | |
| Cylinder bore out of cylindricality | | $\pm 0.01$ (0.0004) max | — |

## 3.13 Measuring the cylinder block top face for distortion

Using a straight edge across the top face of the cylinder block and a thickness gauge, measure for any distortion.

If the measured distortion exceeds the limit, correct by grinding the top face.




Measuring the cylinder block top face for distortion

Unit: mm (in.)

| | Standard value | Limit |
|---|---|---|
| Cylinder block top face distortion | 0.05 (0.002) max | 0.10 (0.004) |

**⚠ CAUTION**

The combined grinding limit for the cylinder block top face and the mating cylinder head bottom face is 0.2 mm (0.008 in.).

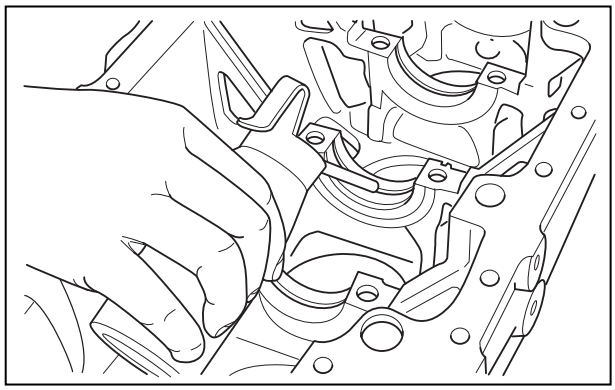
# ENGINE MAIN PARTS - REASSEMBLY

## 1. Cylinder Block, Crankshaft, Pistons, Oil Pan

To reassembly, follow the disassembly sequence in reverse.

### 1.1 Installing the main bearings

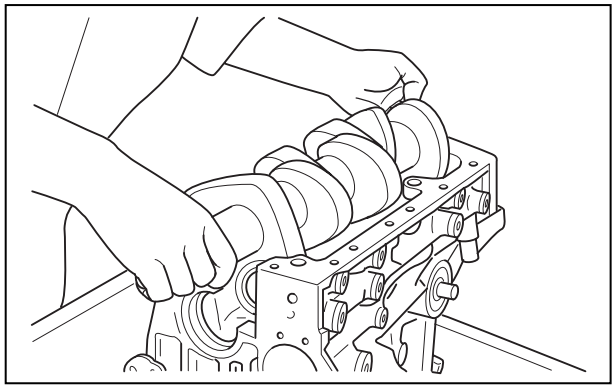
(1) Install the main bearings (upper and lower) onto the cylinder block and the main bearing cap, ensuring that the lugs engage with the lug grooves.
(2) The flanged main bearings should be installed onto the No. 3 crank journal.
(3) Lightly coat the inner surface of each bearing with engine oil.



Installing the main bearings

### 1.2 Installing the crankshaft

(1) Wash the crankshaft thoroughly in wash oil. Dry the crankshaft using compressed air.
(2) While holding the crankshaft horizontally, lower it slowly onto the cylinder block.
(3) Lightly coat the crank journals with engine oil.



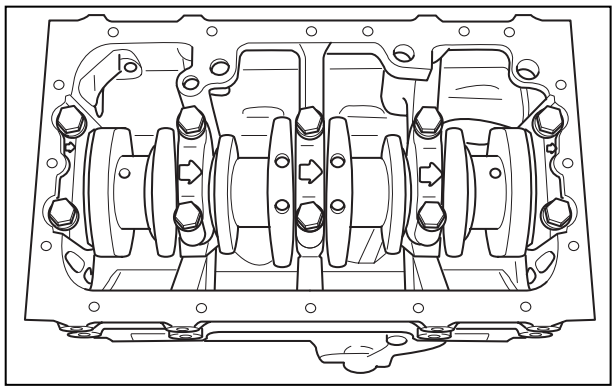
Installing the crankshaft

### 1.3 Installing the main bearing caps

(1) Apply sealant onto the mating faces of the front and rear main bearing caps and the cylinder block.

| | |
|---|---|
| Sealant | ThreeBond 1212 |

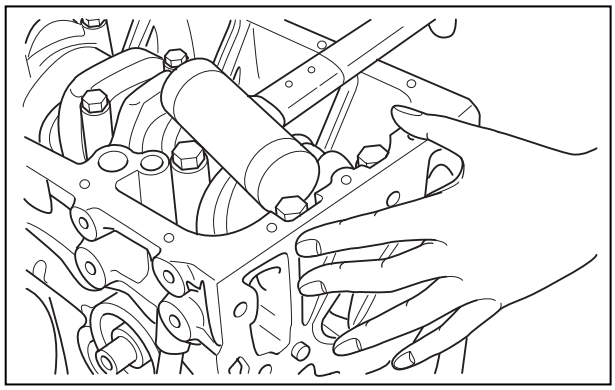
(2) Install the main bearing caps so that their arrow marks point the front of the engine and that the cap numbers are in the order from the front to the rear of the engine.
(3) Loosely tighten the cap retaining bolts.



Correct installation of main bearing caps

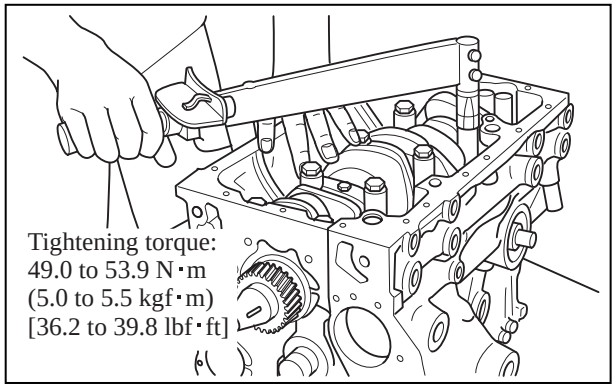
**⚠ CAUTION**

Install the front and rear main bearing caps so that they are flush with the cylinder block.



Installing the main bearing cap

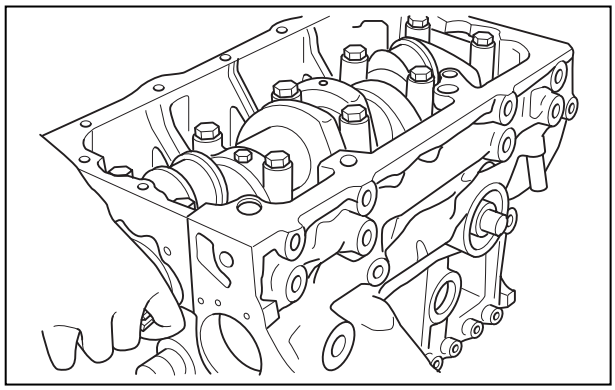
(4) Tighten the main bearing cap bolts progressively in diagonal sequence and tighten to the specified torque at the final step.




Tightening the main bearing cap bolts

(5) Ensure that the crankshaft rotates smoothly, without any binding.

(6) Measure the crankshaft end play (refer to Page 2-14).
If the measured value exceeds the limit, loosen and retighten the main bearing cap bolts.



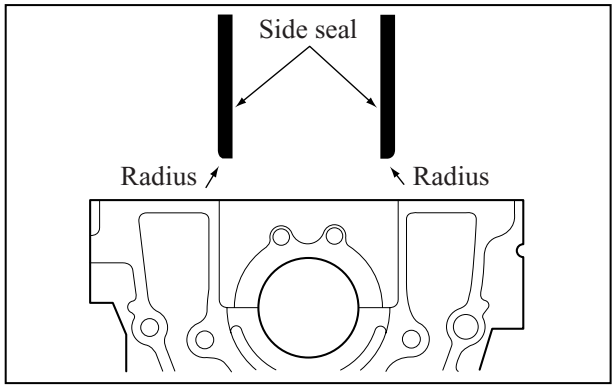
Ensure that the crankshaft rotates smoothly

## 1.4 Inserting the side seals

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

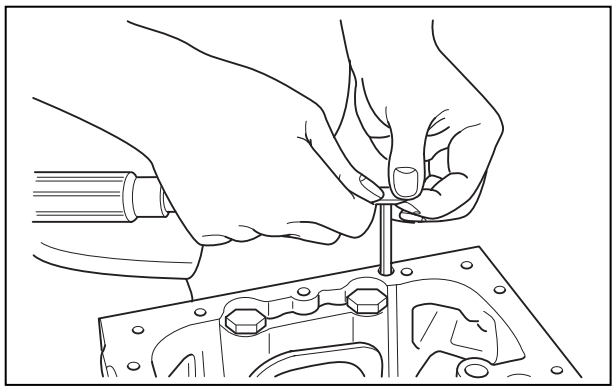
| | |
|---|---|
| Sealant | ThreeBond 1212 |

(2) With the seal radius faced outside, insert the side seals with your hand into the front and rear of the cylinder block.




Face the side seals correctly

(3) Using a flat piece, push the last portion of the side seals fully into the cylinder block, taking care not to bend the seals.



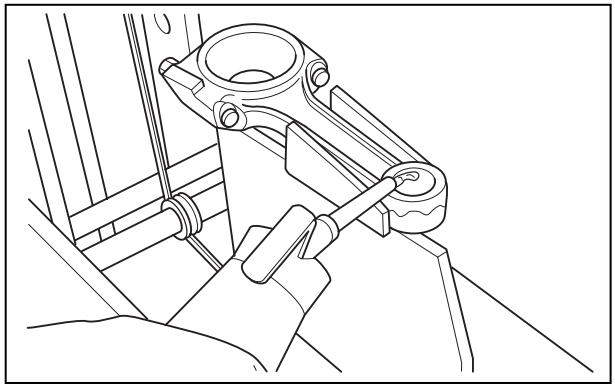
Inserting the side seal

## 1.5 Assembling the piston onto the connecting rod

(1) Install the special tool Piston Pin Setting Tool onto a hydraulic press.

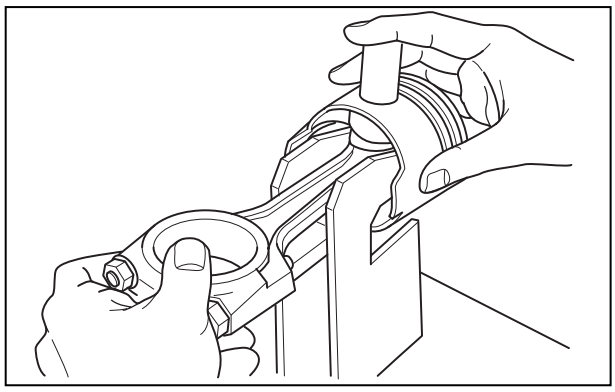
| Special tool | Part number |
|---|---|
| Piston Pin Setting Tool | 31A91-00100 |

(2) Place the connecting rod on the tool. Coat the connecting rod small end with engine oil.



Piston Pin Setting Tool

(3) Install the piston onto the connecting rod so that the arrow on the top face of the piston faces the side of the connecting rod that has the engine type embossed. Insert the piston pin slightly into the pin boss.

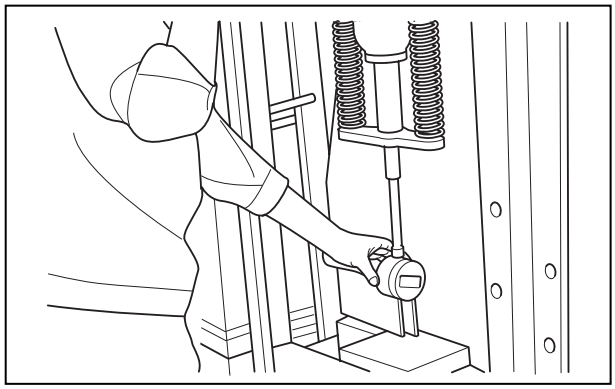


Inserting the piston pin

(4) Using the push rod of the tool, press the piston pin into the pin boss.

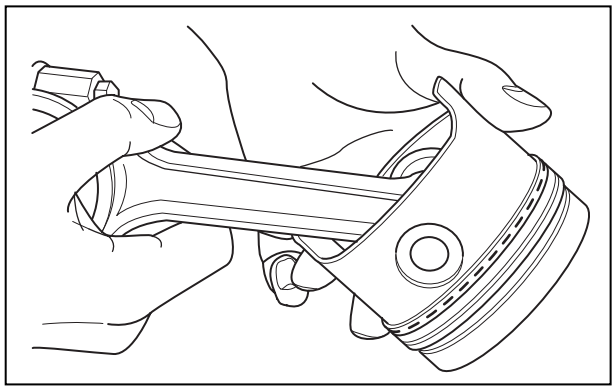
**⚠ CAUTION**

When the hydraulic press needle almost exceeds the 50 kgf (110.23 lbf) while the piston pin is being pressed, stop pressing the pin. Reset the push rod and start pressing again.



Inserting the piston pin with a hydraulic press

(5) With the piston and the connecting rod assembled together, check that they slide smoothly about the piston pin.



Check that the piston and the connecting rod slide smoothly about the piston pin

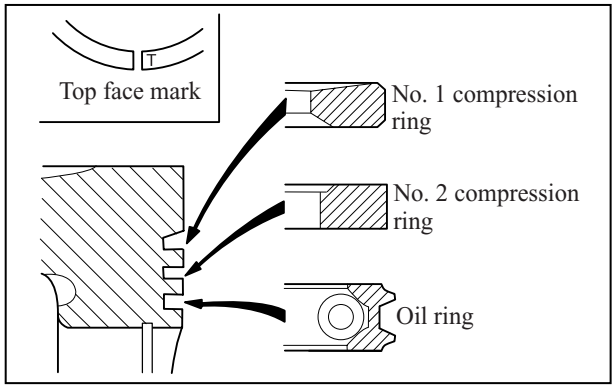
## 1.6 Installing the piston rings

Using the special tool Piston Ring Pliers, install the No. 1 ring, No. 2 ring, and oil ring onto the piston.

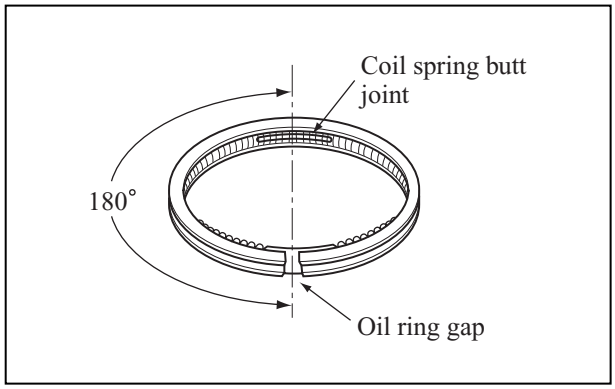
| Special tool | Part number |
|---|---|
| Piston Ring Pliers | 31391-12900 |

Note: (a) Install the rings so that "T" mark faces the top of the piston.

(b) The oil ring should be installed so that the butt joint of the coil spring is located at 180o relative to the ring gap as illustrated.




Piston ring arrangement




Assembling the oil ring

## 1.7 Installing the piston/connecting rod assemblies

(1) Apply engine oil onto the periphery of the piston and the piston rings.

(2) Position the piston ring gaps as illustrated. The gaps should not face the same direction as the piston pin or squarely with the piston pin

(3) Install the connecting rod bearing (upper) onto the connecting rod, ensuring that the lug engages with the lug groove.

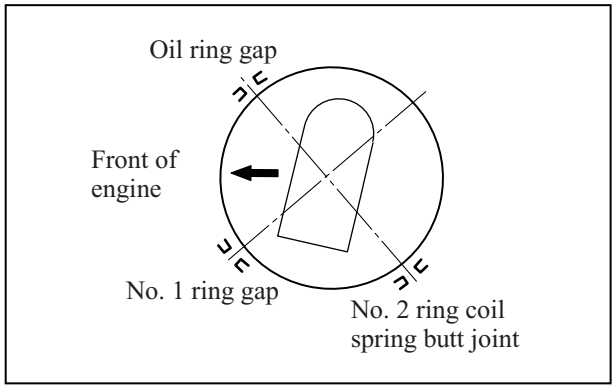
(4) Rotate the crankshaft until the crank pin onto which the piston/connecting rod assembly is being installed comes to the top dead center.

(5) Face the piston/connecting rod assembly so that the arrow mark on top of the piston points to the timing gear case side (front) of the engine.

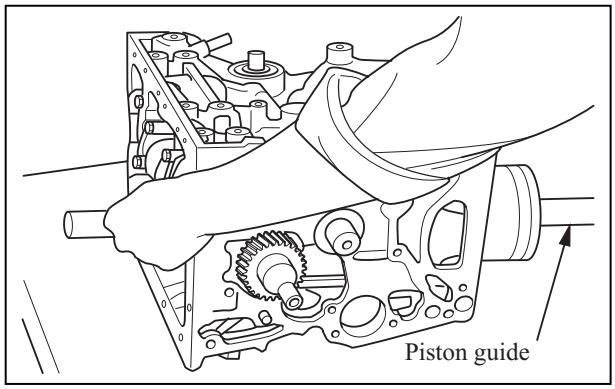
(6) Using a piston guide (available on the market), insert the piston/connecting rod assembly from the top of the cylinder block down.

**⚠ CAUTION**

Do not tap the piston too hard. Doing so may break the piston rings or damage the crank pin.




Locating the piston ring gaps




Installing the piston/connecting rod assembly

## 1.8 Installing the connecting rod caps

(1) While pressing the top of piston down to keep the connecting rod large end attached to the crank pin, rotate the crankshaft 180°.

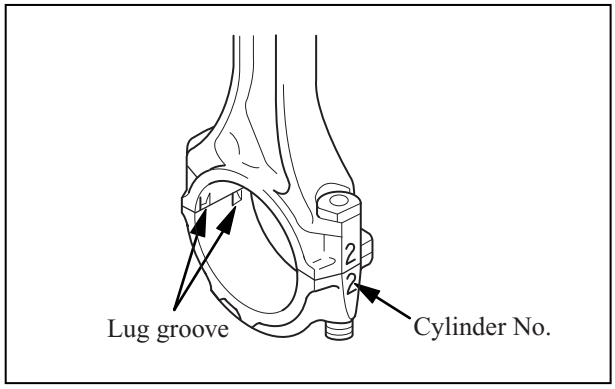
(2) Install the connecting rod bearing (lower) onto the connecting rod cap, ensuring that the lug engages with the lug groove.

(3) Install the bearing cap onto the connecting rod, observing the mating marks made during disassembly.

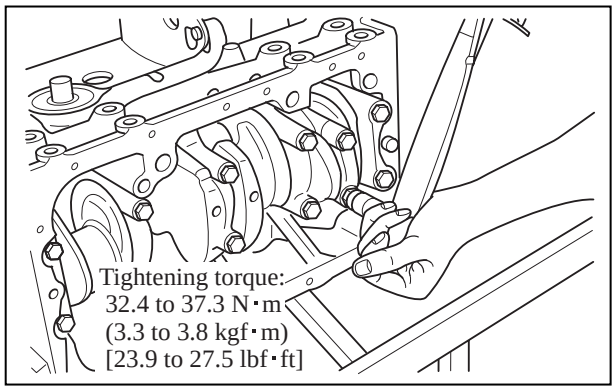
Note: If a new connecting rod without mating marks is being installed, ensure that the lug grooves, designed to prevent the bearings from turning, are assembled on the same side.

(4) Tighten the connecting rod cap nuts alternately in several steps, and finally to the specified torque.

(5) Check the connecting rod end play.




Installing the connecting rod cap

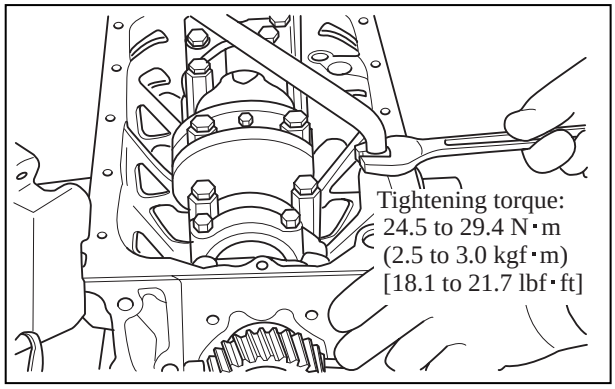



Tightening the connecting rod cap nuts

## 1.9 Installing the oil strainer

(1) Position the cylinder block with the oil pan mounting face up.

(2) Install the oil strainer so that the tip of the strainer will not contact the oil pan when installed. Tighten the nut to the specified torque.



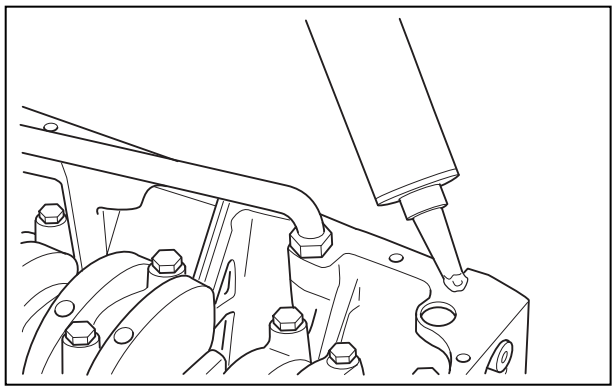

Installing the oil strainer

## 1.10 Installing the oil pan

(1) Clean the mating faces of the cylinder block and the oil pan.

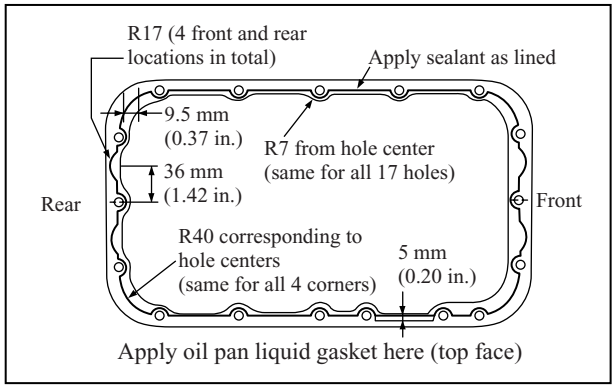
Apply sealant to the entire periphery of the oil pan mounting face of the cylinder block.

| | |
|---|---|
| Sealant | ThreeBond 1207C |

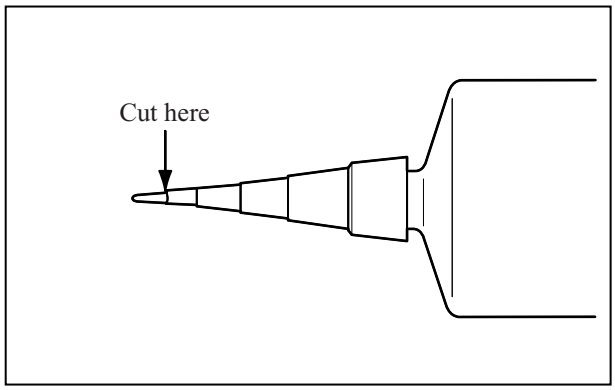


Applying sealant to the oil pan mounting face of the cylinder block

Note: (a) Apply sealant in a bead of 4 mm (0.1575 in.) and in the illustrated pattern.
(b) Cutting the end of the sealant tube at the illustrated location will provide a 4 mm (0.1575 in.) bead.

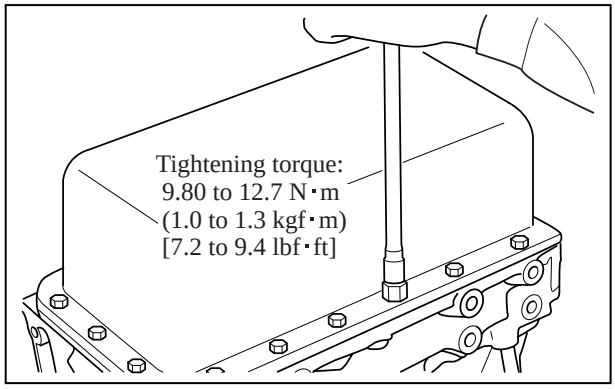



Sealant application pattern




Cutting the end of sealant tube

(2) Tighten the oil pan retaining bolts diagonally in several steps, and finally to the specified torque.



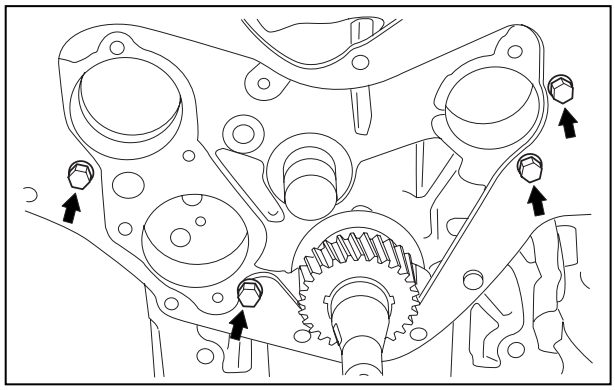

Installing the oil pan

## 2. Flywheel, Timing Gear, Camshaft

To reassembly, follows the disassembly sequence in reverse.

### 2.1 Installing the front plate

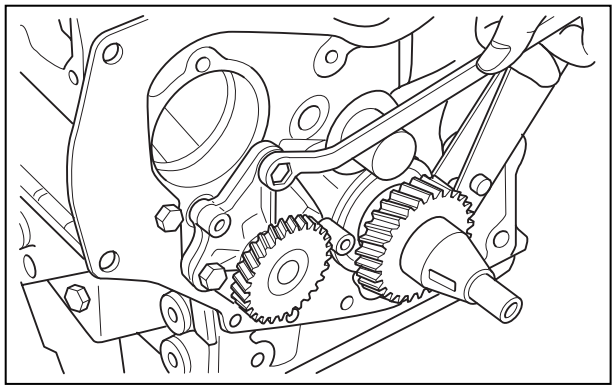
(1) Completely scrape off any remaining gasket from the cylinder block and the front plate.
(2) Install the front plate onto the cylinder block. Tighten the four retaining bolts.
(3) Apply sealant onto the side of the gasket that is to be mated to the front plate. Attach the gasket onto the front plate. The sealant will prevent the gasket from moving.



Front plate retaining bolts

### 2.2 Installing the oil pump

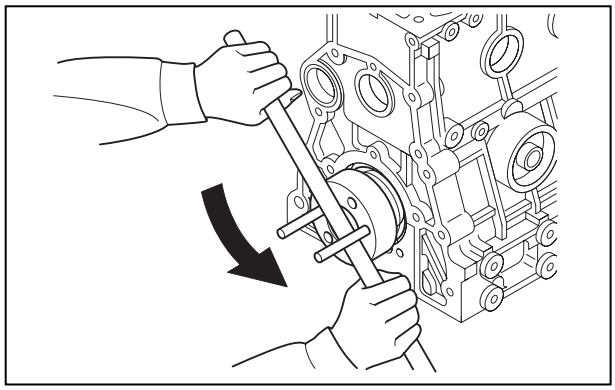
(1) Ensure that the oil pump is correctly fitted with packing.
(2) Install the oil pump onto the crankcase. Tighten the three retaining bolts evenly.
(3) Ensure that the oil pump gear rotates smoothly.



Installing the oil pump

### 2.3 Rotating the engine

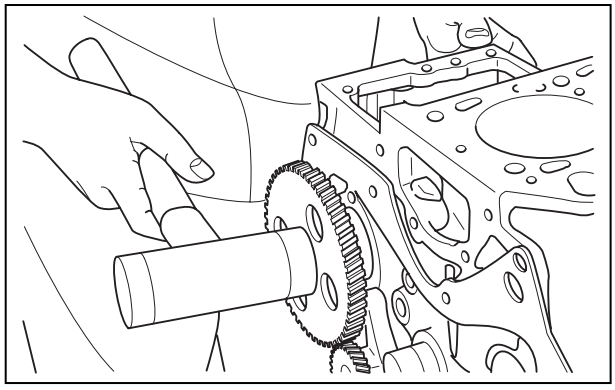
(1) Install two studs (M12×1.25) into the flywheel mounting holes in the crankshaft.
(2) Place a bar between the studs and rotate the crankshaft until the No. 1 cylinder comes to the top dead center.



Rotating the engine

### 2.4 Tapping the fuel injection pump camshaft into place

(1) Insert the fuel injection pump camshaft (complete with the bearing and the gear) into the cylinder block.
(2) Tap the gear with a plastic hammer until the bearing is completely inserted into the mounting hole in the cylinder block.
(3) Ensure that the fuel injection pump camshaft rotates smoothly.
(4) Tighten the stopper bolt.



Tapping the fuel injection pump camshaft into place

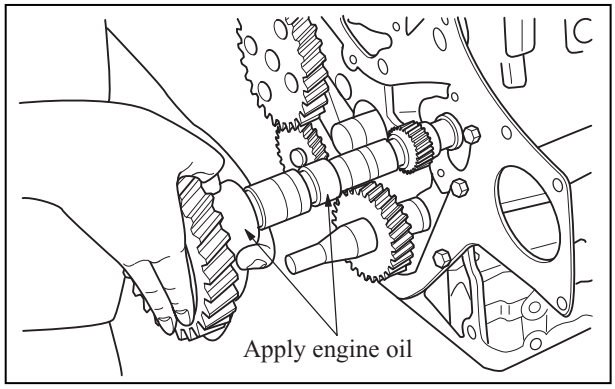
## 2.5 Installing the camshaft

(1) Apply engine oil to the journals and cams.

(2) Insert the camshaft (complete with the camshaft gear) into the cylinder block.

**⚠ CAUTION**

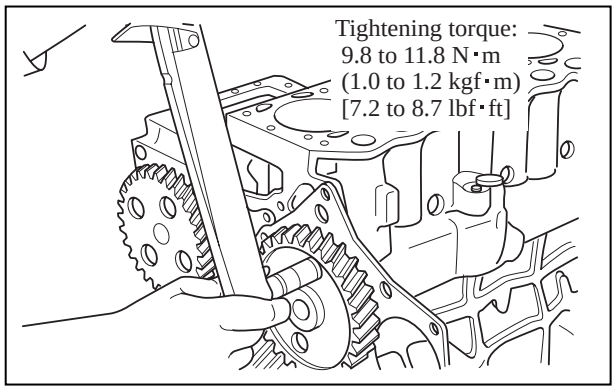
Take care not to damage the journals or cams when inserting the camshaft into the cylinder block.




Installing the camshaft

(3) Using an appropriate torque wrench and socket, tighten the thrust plate mounting bolts to the specified torque.

(4) Ensure that the camshaft rotates smoothly. Also ensure that there is some end play by sliding the camshaft to the front and rear.




Installing the thrust plate

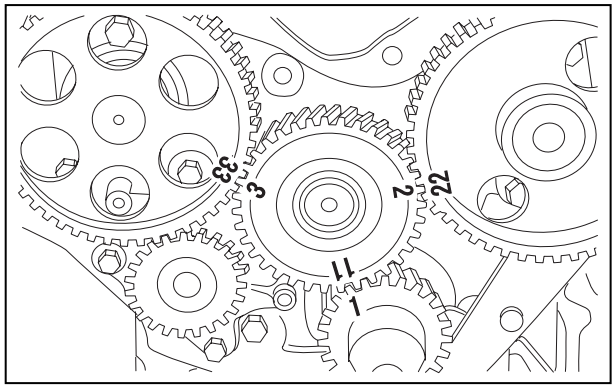
## 2.6 Installing the idler gear

(1) Apply engine oil to the idler shaft.

(2) Install the idler gear so that the timing marks are aligned with those of the meshing gears.

(3) Check the backlash between the gears.

Note: Refer to "Measuring the timing gear backlash" on Page 2-23.



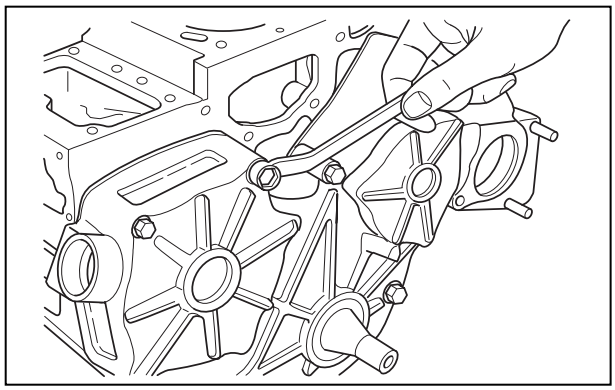

Aligning the timing marks

## 2.7 Installing the timing gear case

(1) Apply sealant onto the gasket and stick it in place. Then, install the timing gear case onto the front plate.

(2) Apply engine oil to the oil seal lips.

(3) Tighten the timing gear case retaining bolts.



Installing the timing gear case

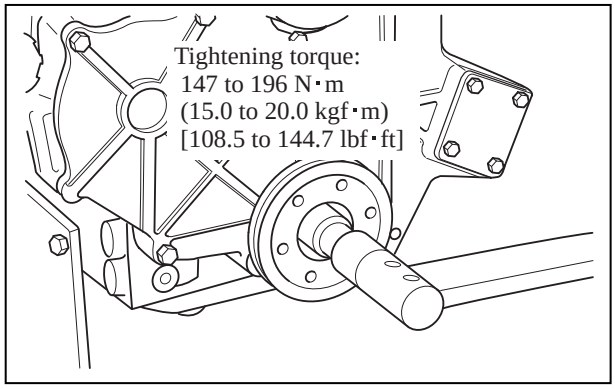
## 2.8 Tightening the crankshaft pulley nut

(1) Use the studs and the bar described in Section "2.3" to lock the crankshaft.

(2) While locking the crankshaft, tighten the crankshaft pulley nut to the specified torque.

**⚠ CAUTION**

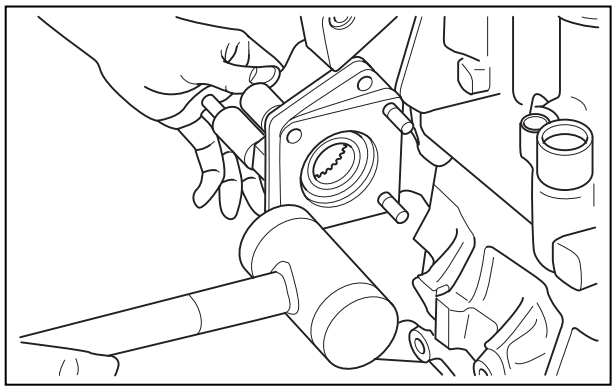
The locking studs and bar should be sufficiently strong to avoid any accident.




Tightening the crankshaft pulley nut

## 2.9 Installing the PTO gear

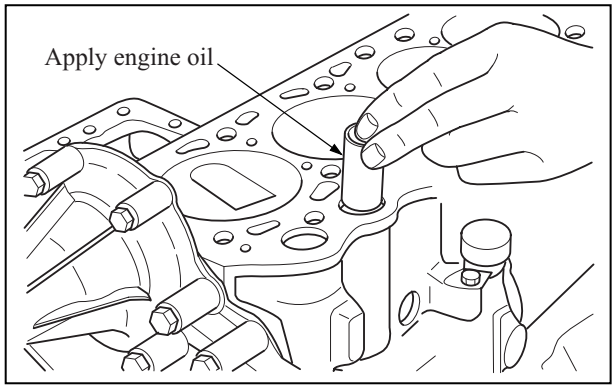
Drive the PTO gear into the timing gear case. Ensure that the side of the gear with no oil hole faces the rear of the engine.



Driving the PTO gear into place

## 2.10 Inserting the tappets

Apply engine oil to the periphery of the tappets, and insert them into the tappet holes in the cylinder block.

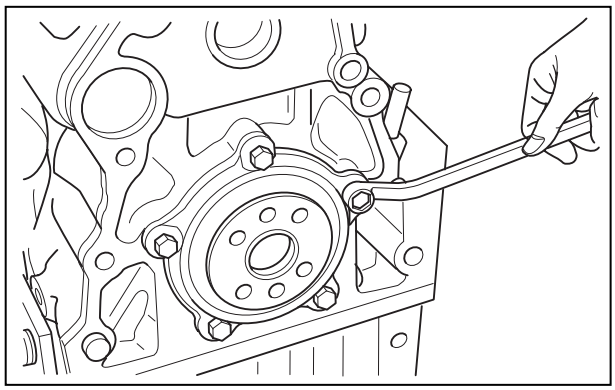



Inserting the tappet

## 2.11 Installing the oil seal case

(1) Install a new oil seal case gasket.

(2) Apply engine oil to the entire periphery of the oil seal lips, and install the oil seal and case onto the cylinder block.

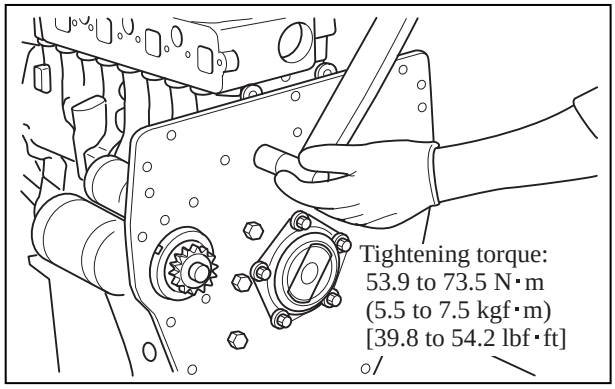


Installing the oil seal case

## 2.12 Installing the rear plate

(1) Install a new rear plate gasket.
(2) Install the rear plate, aligning it with the dowel pins. Tighten the retaining bolts to the specified torque.

Note: Install the rear plate complete with the starter. This will facilitate the subsequent reassembly.

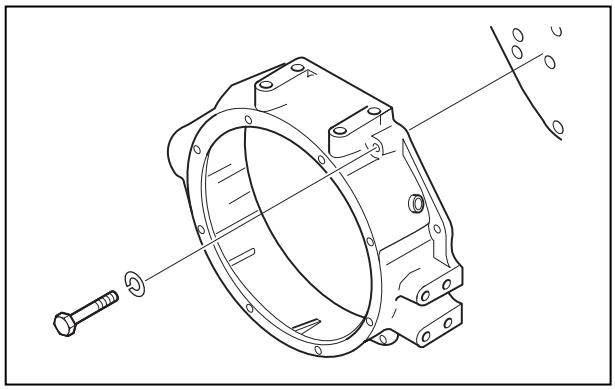



Installing the rear plate

## 2.13 Installing the flywheel housing

Install the flywheel housing, aligning it with the knock pins. Tighten the retaining bolts evenly.

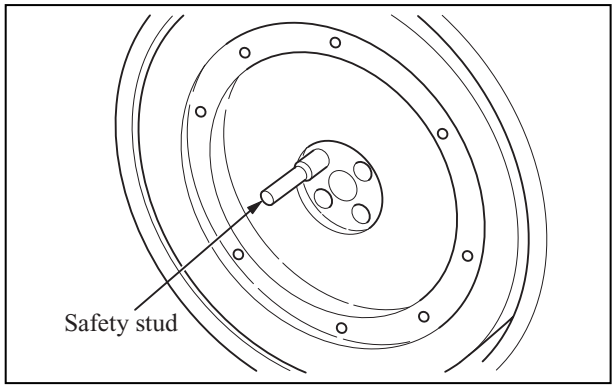
Note: Replace the knock pins with new parts if the knock pins are worn or if a new flywheel housing is being installed.



Installing the flywheel housing

## 2.14 Installing the flywheel

(1) Screw in a safety stud (M12×1.25) into one of the flywheel retaining bolt holes at the rear end of the crankshaft.
(2) Insert the flywheel through the safety stud and onto the crankshaft.
(3) Loosely tighten the three flywheel retaining bolts.
(4) Replace the safety stud with the 4th retaining bolt, and loosely tighten it.

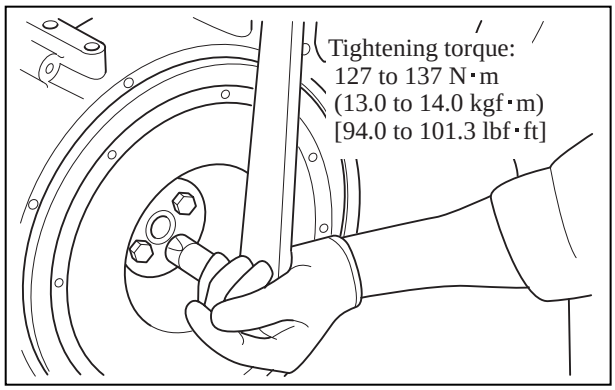



Installing the flywheel

(5) Using a torque wrench or other similar tool, lock the crankshaft pulley nut.
(6) Tighten the flywheel retaining bolts to the specified torque.

**⚠ CAUTION**

The person who locks the crankshaft pulley nut should do so with extreme care. Communicate with each other closely to prevent accidents.




Tightening the flywheel bolts

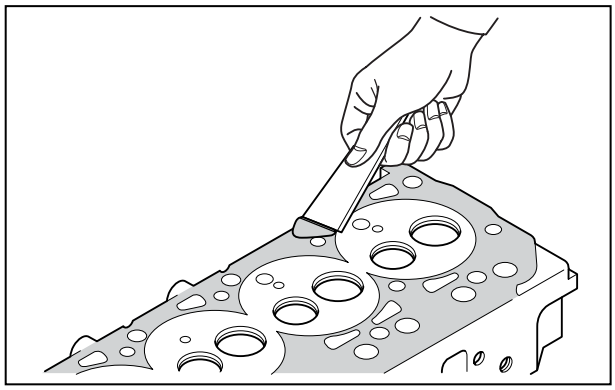
## 3. Cylinder Head, Valve Mechanism

To reassembly, follows the disassembly sequence in reverse.

### 3.1 Cleaning the bottom face of the cylinder head

Scrape off any gasket from the mating faces of the cylinder head and the cylinder block, taking care not to damage the faces.

Note: Use a scraper to roughly remove the remaining gasket. Then, using an oil stone and engine oil, polish away fine residue.



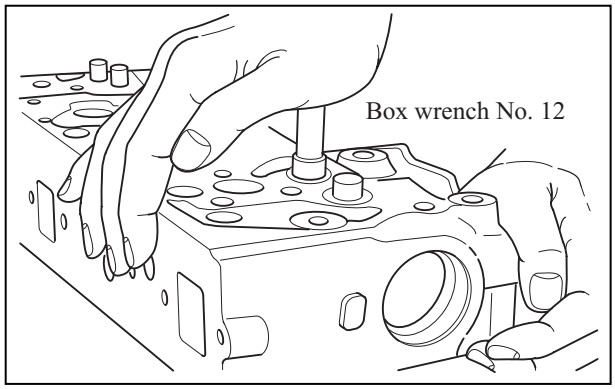
Removing the old gasket

### 3.2 Installing the valve stem seals

Using a box wrench No. 12, install the valve stem seal on the valve guide.

Ensure that the seal has been correctly installed the valve guide.

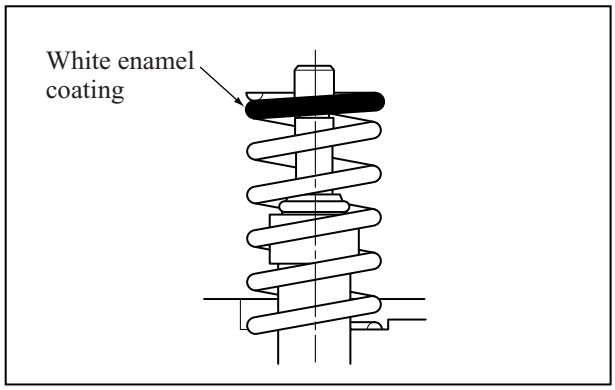
Note: Incorrectly installed stem seals will lead to oil leaking down through the seal-to-guide gap and into the combustion chamber.




Inserting the valve stem seal

### 3.3 Installing the valve springs

Install the valve spring with the white enamel-coated end facing up.



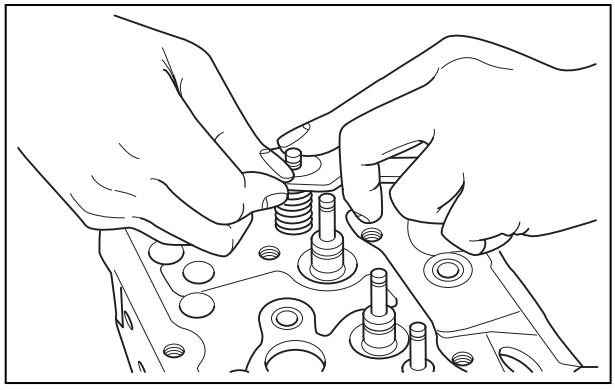

Installing the valve springs

### 3.4 Installing the valve locks

Install the valve lock by compressing the valve spring using a valve lifter.

**⚠ CAUTION**

Do not compress the valve spring too hard as the bottom of the retainer may contact and damage the stem seal.



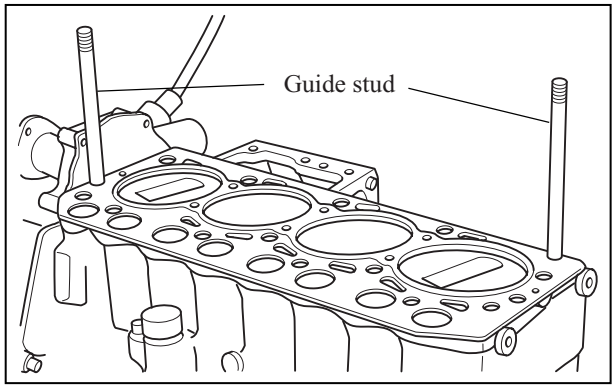
Installing the valve lock

### 3.5 Installing the cylinder head gasket

(1) Ensure that the cylinder block top face and the piston top faces are clean.
(2) Insert two guide studs (M10×1.25) into the bolt holes in the cylinder block.
(3) Install the cylinder head gasket through the studs and onto the cylinder block.

**⚠ CAUTION**

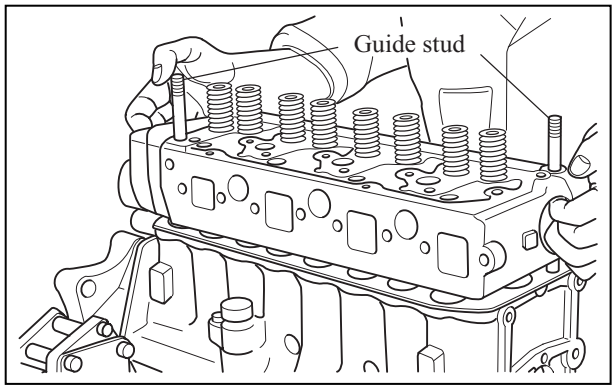
Do not use liquid packing or other similar sealant.




Installing the cylinder head gasket

### 3.6 Installing the cylinder head

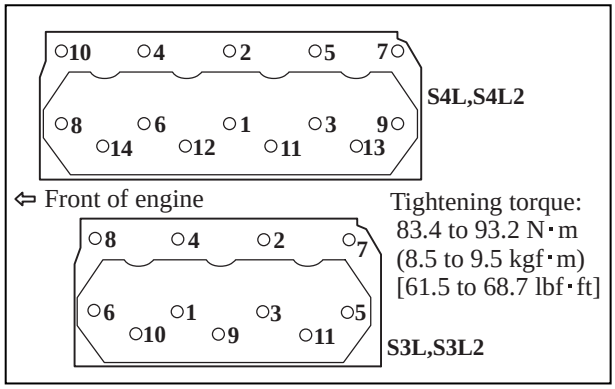
Install the cylinder head through the guide studs and onto the cylinder block.




Installing the cylinder head

### 3.7 Tightening the cylinder head bolts

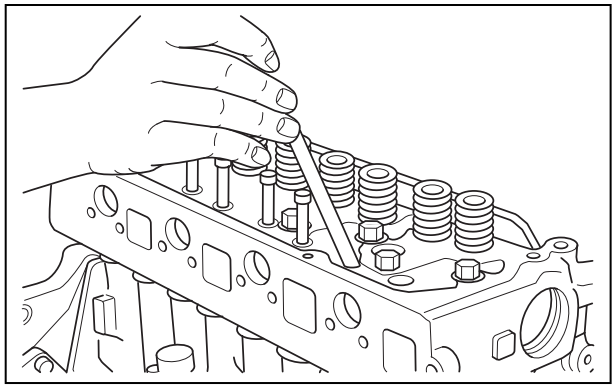
(1) Remove the guide studs. Install the cylinder head bolts.
(2) Tighten the cylinder head bolts in the order illustrated in a couple of steps, and finally tighten to the specified torque.




Tightening order for the cylinder head bolts

### 3.8 Inserting the push rods

(1) Insert the push rods into the holes in the cylinder head.
(2) Ensure that the ball end of the push rod rests on the recess of the tappet.

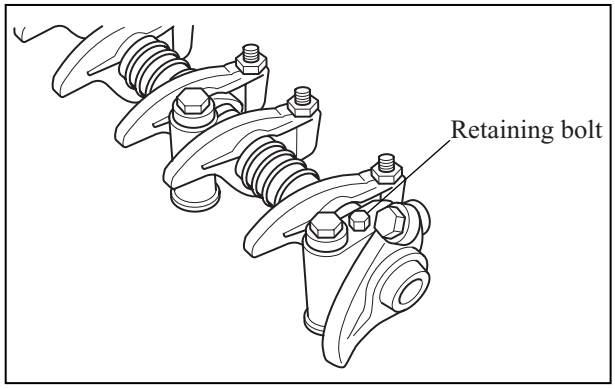


Inserting the push rod

### 3.9 Assembling the rocker shaft assembly

(1) Assemble the rocker shaft components to ensure the correct reassembly and tighten the retaining bolt.

(2) Ensue that the rocker arms move smoothly.

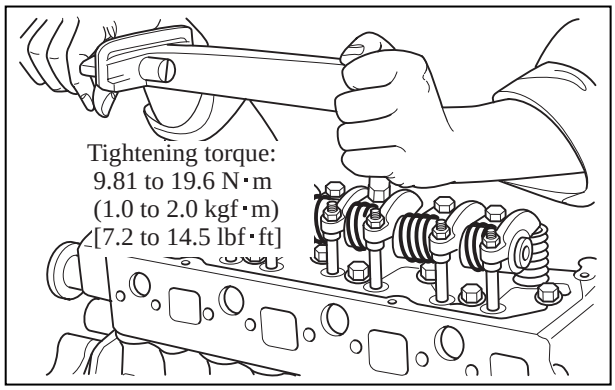



Assembling the rocker shaft assembly

### 3.10 Installing the rocker shaft assembly

(1) Install the valve caps.

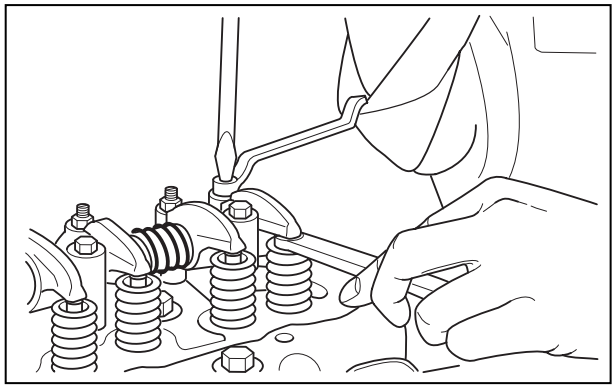
(2) Install the rocker shaft assembly onto the cylinder head. Tighten the mounting bolts to the specified torque.




Installing the rocker shaft assembly

### 3.11 Adjusting the valve clearance

Refer to “1.3 Adjusting the valve clearance” on Page 8-3.

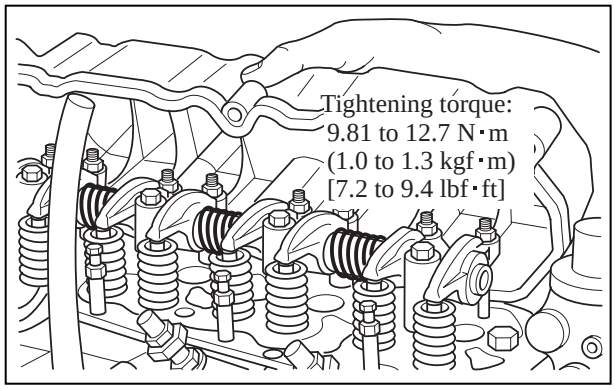


Adjusting the valve clearance

### 3.12 Installing the rocker cover

(1) Ensure that the rocker cover is correctly fitted with gasket.

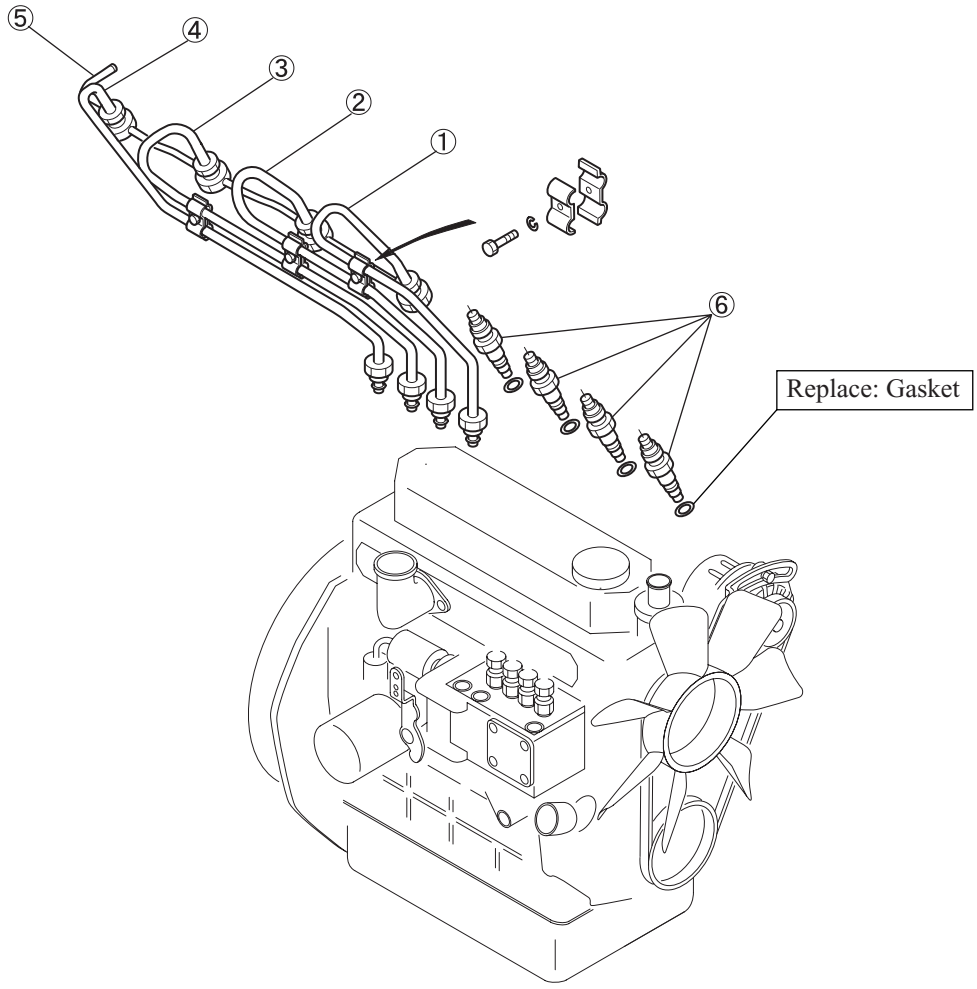
(2) Tighten the rocker cover retaining bolts to the specified torque.




Installing the rocker cover

# FUEL SYSTEM - REMOVAL

## 1. Fuel Injection Pipes, Fuel Leak-off Pipe, Fuel Injection Nozzles




Removal of fuel injection pipes, fuel leak-off pipe, and fuel injection nozzles

<Removal sequence>

① No. 1 fuel injection pipe
② No. 2 fuel injection pipe
③ No. 3 fuel injection pipe
④ No. 4 fuel injection pipe
⑤ Fuel leak-off pipe
⑥ Fuel injection nozzle

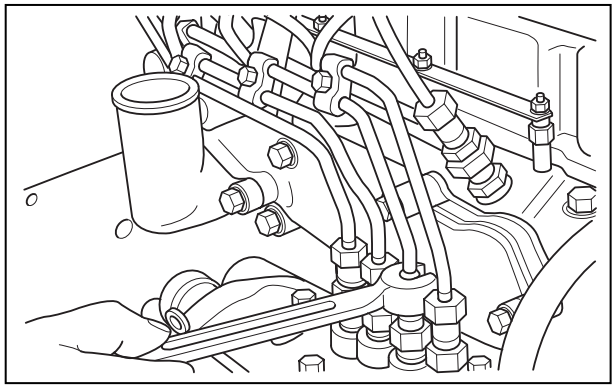
**⚠ CAUTION**

To prevent dirt from entering into the fuel system, plug the injection pump openings, the nozzle inlet connectors, and the injection pipes.

## 1.1 Removing the fuel injection pipes

Remove the fuel injection pipes and the fuel leak-off pipe.

Note: To prevent dirt from entering into the system, plug the fuel injection pump openings and the fuel injection nozzle connectors.

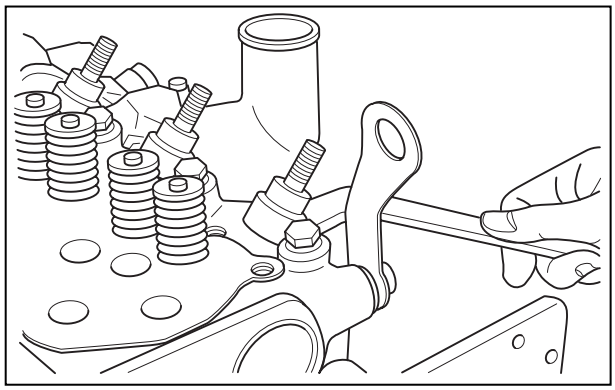


Removing the fuel injection pipe

## 1.2 Removing the fuel injection nozzles

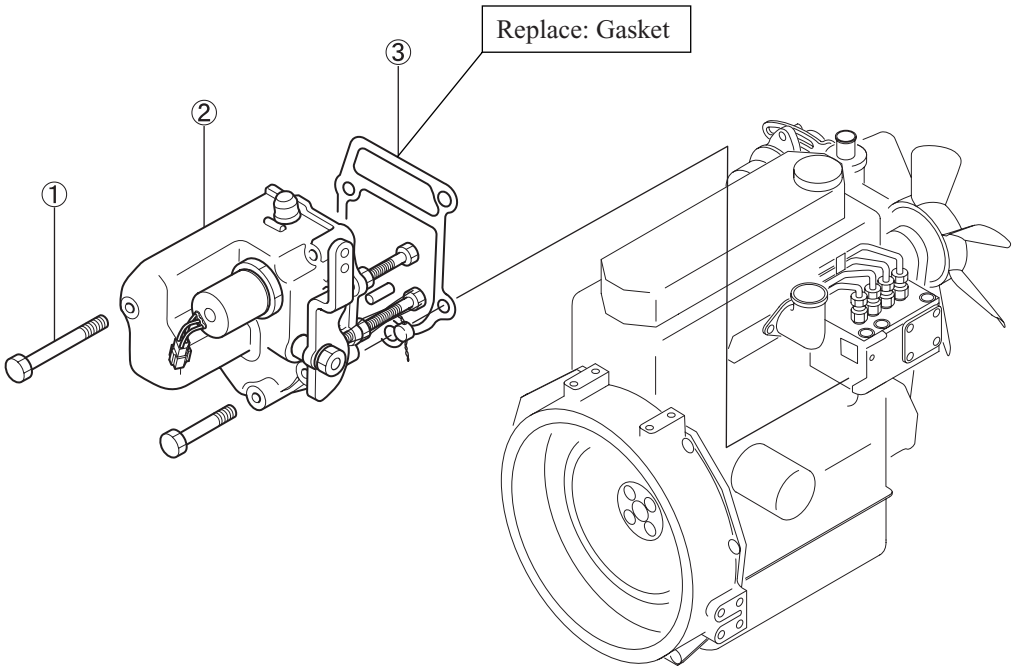
Using a wrench, loosen the fuel injection nozzles. Remove the nozzles and gaskets.

Note: Use a wire or a screwdriver to remove the fuel injection nozzle gaskets from the cylinder head. Faulty gaskets should be replaced.



Removing the fuel injection nozzle

## 2. Governor

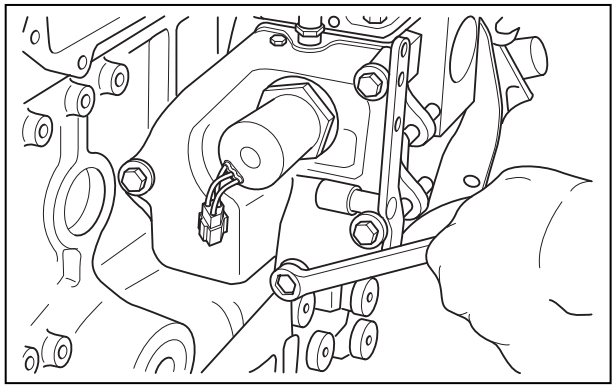



Removal of the governor

<Removal sequence>
① Bolt
② Governor assembly
③ Gasket

## 2.1 Removing the governor assembly

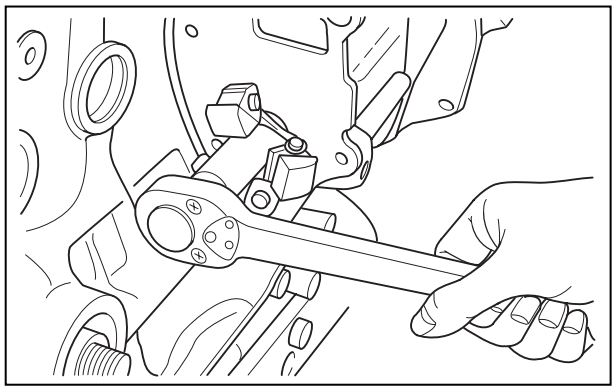
(1) Remove the tie-rod cover.
(2) Using a pair of cutting pliers, remove the tie-rod spring. Disconnect the tie-rod from the pumps.
(3) Remove the governor assembly.



Removing the governor assembly

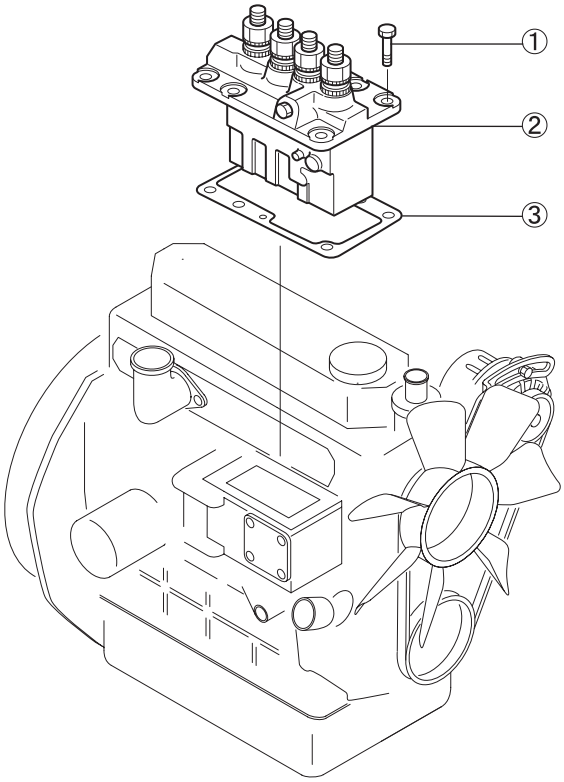
## 2.2 Removing the governor weights

(1) Remove the sliding sleeve.
(2) Remove the sliding sleeve shaft and then the governor weights.



Removing the governor weights

## 3. Fuel Injection Pumps



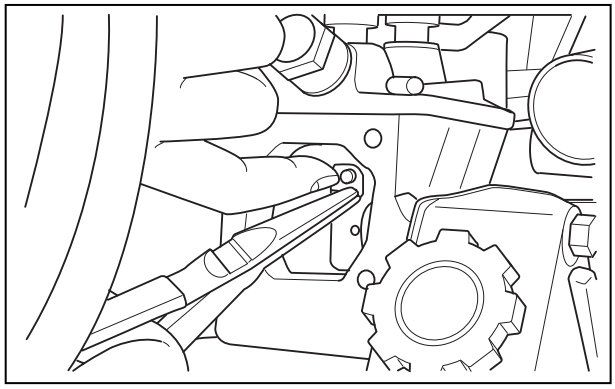

Removal of the fuel injection pumps

<Removal sequence>
① Bolt ② Fuel injection pump ③ Shim

## Removing the fuel injection pumps

(1) Remove the tie-rod cover.

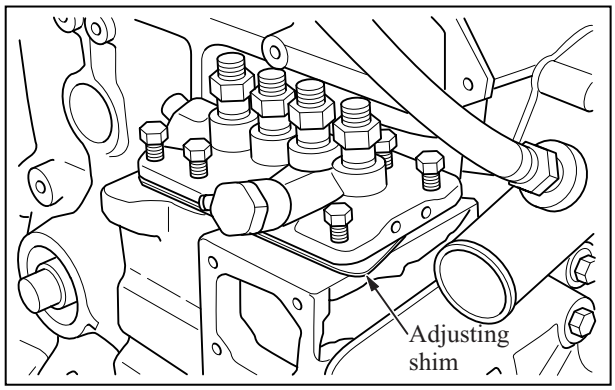
(2) Using a pair of cutting pliers, remove the tie-rod spring. Disconnect the tie-rod from the pumps.



Removing the tie-rod

(3) Removing the fuel injection pumps

Note: Note the thickness of shim pack for the adjustment of the fuel injection timing.

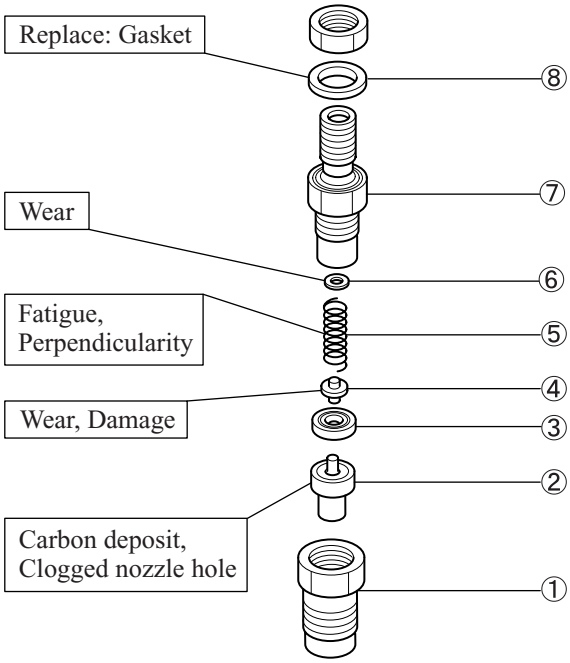



Removing the fuel injection pump

# FUEL SYSTEM - DISASSEMBLY, INSPECTION AND REASSEMBLY

# 1. Fuel Injection Nozzles

## 1.1 Disassembling the fuel injection nozzles




Disassembly of the fuel injection nozzle

<Reassembly sequence>

① Nozzle retaining nut
② Nozzle tip assembly
③ Piece
④ Pin
⑤ Spring
⑥ Washer
⑦ Nozzle holder
⑧ Gasket

## 1.2 Inspecting the fuel injection nozzle

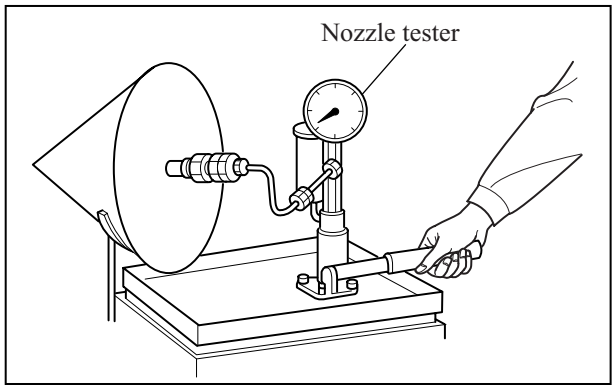
Conduct the following inspections and, if faulty, repair or replace as required.

(1) Injection valve opening pressure

(a) Install the fuel injection nozzle onto the nozzle tester. Pump the tester handle up and down to bleed air.

(b) Pump the tester handle at a rate of approx. one cycle per second while observing the needle of the tester.

Note: The needle should rise slowly and, during fuel injection, should vibrate. The pressure at which the needle starts to vibrate is the injection valve opening pressure.




Inspecting the injection valve opening pressure

(c) If the measured pressure does not conform to the standard value, disassemble and adjust by changing the thickness of the washer.

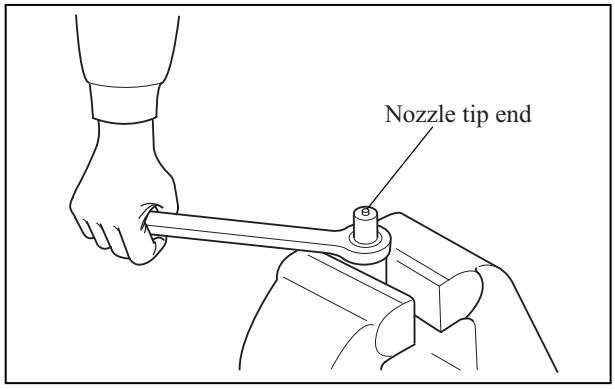
Unit: MPa (kgf/cm$^2$) [psi]

| | Standard value |
|---|---|
| Injection valve opening pressure | 14.22 to 15.00<br>(145 to 153)<br>[2062 to 2176] |

(d) Change in washer thickness by 0.1 mm (0.004 in.) results in a pressure change of 1.0 MPa (10 kgf/cm$^2$) [145 psi].
Washers are available in 10 different thicknesses at intervals of 0.05 mm (0.002 in.) in the range between 1.25 and 1.70 mm (0.049 and 0.067 in.).

**⚠ CAUTION**

Never touch the spray of fuel from the fuel injection nozzle.

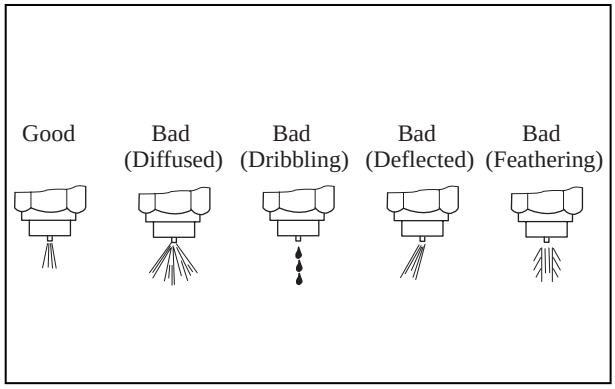



Replacing the fuel injection nozzle tip assembly

(2) Inspecting the fuel spray pattern from the fuel injection nozzle

(a) When inspecting the injection valve opening pressure using the nozzle tester, also check for such as clogged nozzle hole, fuel spray pattern and fuel leakage from the nozzle hole.

(b) When the tester handle is pumped at a rate of approx. one cycle per second, fuel should be sprayed in a fairly straight pattern.




Fuel spray patterns

(3) Clean or replace when spraying badly

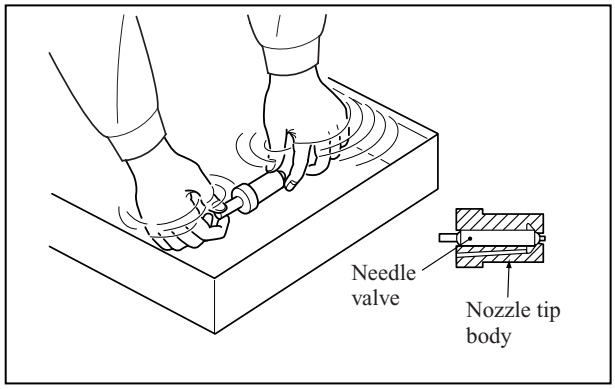
(a) Loosen the nozzle retaining nut to remove the nozzle tip assembly. Clean the needle valve and the nozzle tip body.

**⚠ CAUTION**

When removing the nozzle tip assembly, never tap on the end of the assembly.

(b) Wash the needle valve and the nozzle tip body in clean wash oil. Reassemble them in clean light oil.

Note: The needle valve and the nozzle tip body are precision machined parts. Handle with care and never change their combination.




Cleaning the fuel injection nozzle tip components

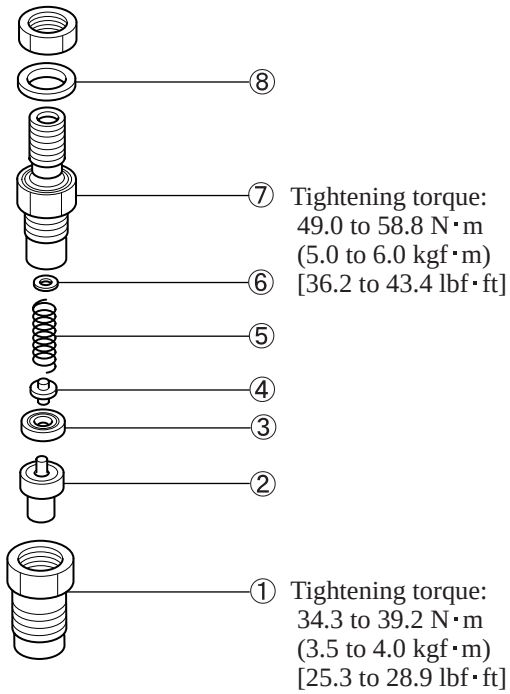
(c) Assemble the fuel injection nozzle, tightening the nozzle retaining nut to the specified torque.

(d) If the fuel spray pattern is still not good, replace the nozzle tip assembly.

Note: (a) Never touch the sliding surface of the needle valve with your hands.

(b) If the nozzle tip assembly is to be replaced, remove the seal peel (synthetic resin film) from the new nozzle tip assembly and slide the nozzle and needle valve in clean wash oil to remove the anti-corrosive agent completely.

## 1.3 Reassembling the fuel injection nozzle




Reassembly of the fuel injection nozzle

<Reassembly sequence>
⑧→⑨→⑥→⑤→④→③→②→①

# 2. Fuel Injection Pumps

## 2.1 Inspecting the fuel injection pump on vehicle

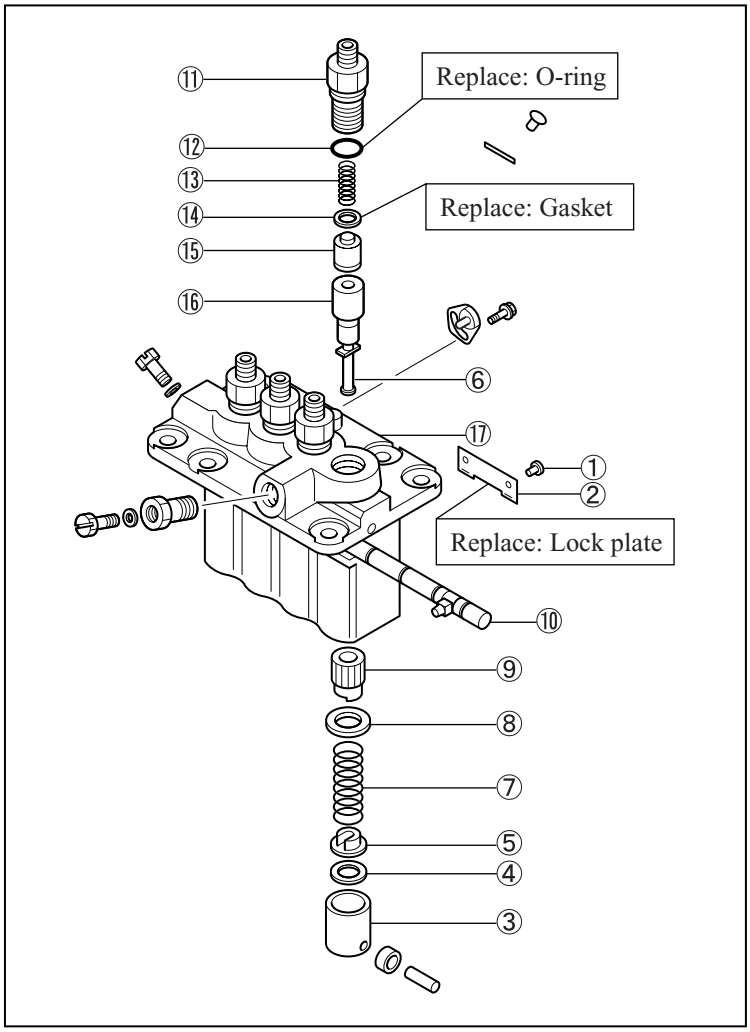
Do not disassemble the fuel injection pump unless it is necessary.

If the pump is suspected to be faulty, it is recommended that the entire pump assembly be replaced.

| Inspection item | Description | PASS criteria |
|---|---|---|
| Low idle speed | Inspect the low idle speed | 1000±25 $min^{-1}$ |
| Exhaust gas color | 1) Observe the exhaust gas color during no-load rapid acceleration<br>2) Observe the exhaust gas color under load | No excessive black smoke |
| Nozzle injection pattern | To inspect the spray pattern, remove the nozzle from the engine and then place the nozzle outside by correcting the injection pipe. Crank the starter and check the spray pattern. | Good spray pattern |

## 2.2 Disassembling the fuel injection pumps

① Tappet guide pin
② Lock plate
③ Tappet
④ Tappet adjusting shim
⑤ Spring lower seat
⑥ Plunger
⑦ Plunger spring
⑧ Spring upper seat
⑨ Control sleeve
⑩ Control rack
⑪ Delivery valve holder
⑫ O-ring
⑬ Delivery valve spring
⑭ Delivery valve gasket
⑮ Delivery valve
⑯ Plunger barrel
⑰ Pump housing

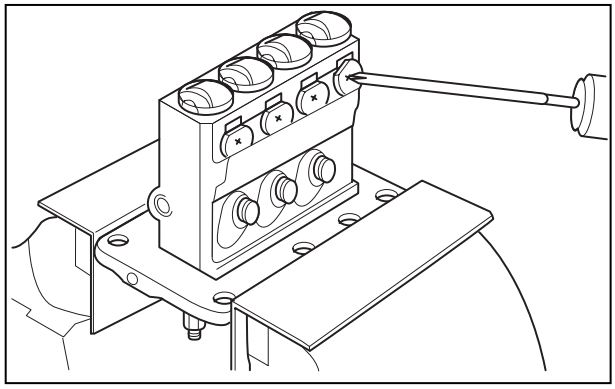



Disassembly of the fuel injection pumps

(1) Removing the tappets

(a) Open the claws of the lock plate using a screwdriver or other similar tool.

(b) Rotate the tappet and the guide pin by 180º to align the guide pin cutout with the mating portion of the pump housing.

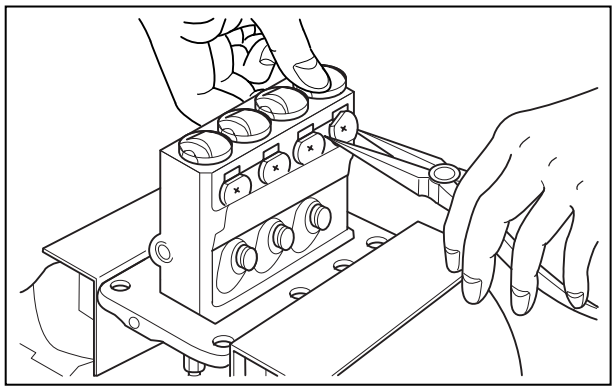


Removing the tappet guide pin

(c) While pressing the tapped down, remove the tappet guide pin using a pair of pliers.

**⚠ CAUTION**

Hold the tappet, otherwise it will jump out. Be careful not to drop the tappet.



Removing the tappet

(2) Removing the plungers

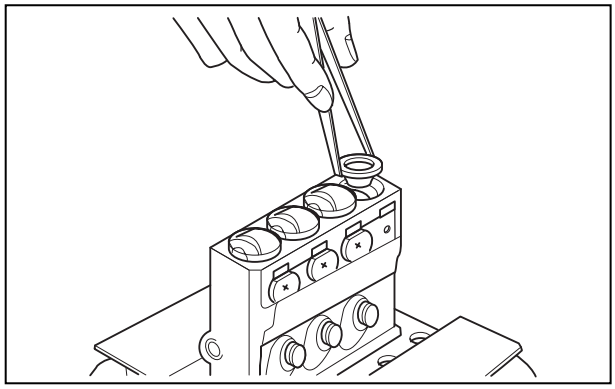
(a) Remove the tappet adjusting shim.

(b) Using a pair of tweezers, pull out the spring lower seat and the plunger together.

(c) Remove the plunger spring.

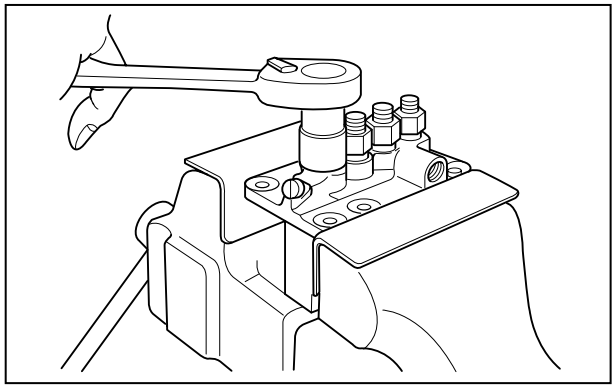
(d) Remove the spring upper seat and the control sleeve together.

(e) Pull out the control rack.



Removing the plunger

(3) Removing the delivery valve
  (a) Place the pump upwards in a vice.
  (b) Remove the delivery valve holder.
  (c) Remove the delivery valve gasket.

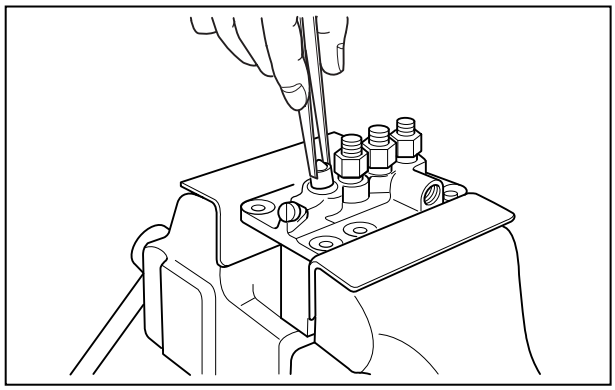


Removing the delivery valve holder

  (d) Using a pair of tweezers, remove the delivery valve.

**⚠ CAUTION**

The delivery valves are an ultra-precision part. They should be free of dirt or damage.

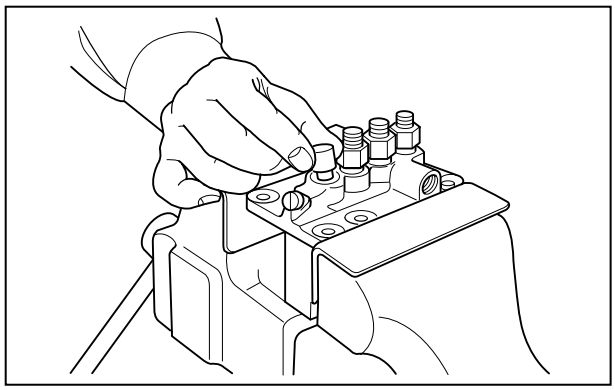


Removing the delivery valve

(4) Removing the plunger barrels
Pull out the plunger barrel.

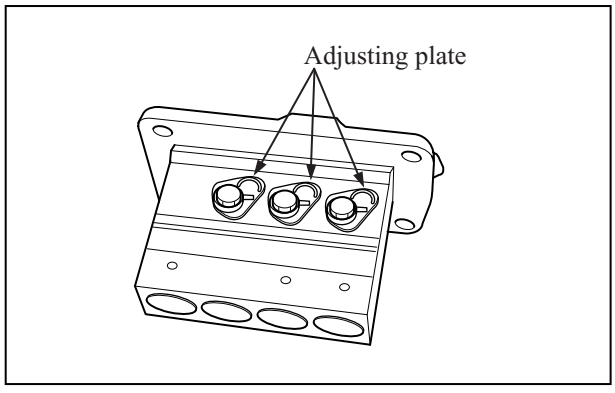
**⚠ CAUTION**

(a) The plunger barrels are an ultra-precision part. They should be free of dirt or damage.
(b) Keep the plunger barrels and the plungers in the original pairs for each of the cylinders. Do not use them in wrong pairs.



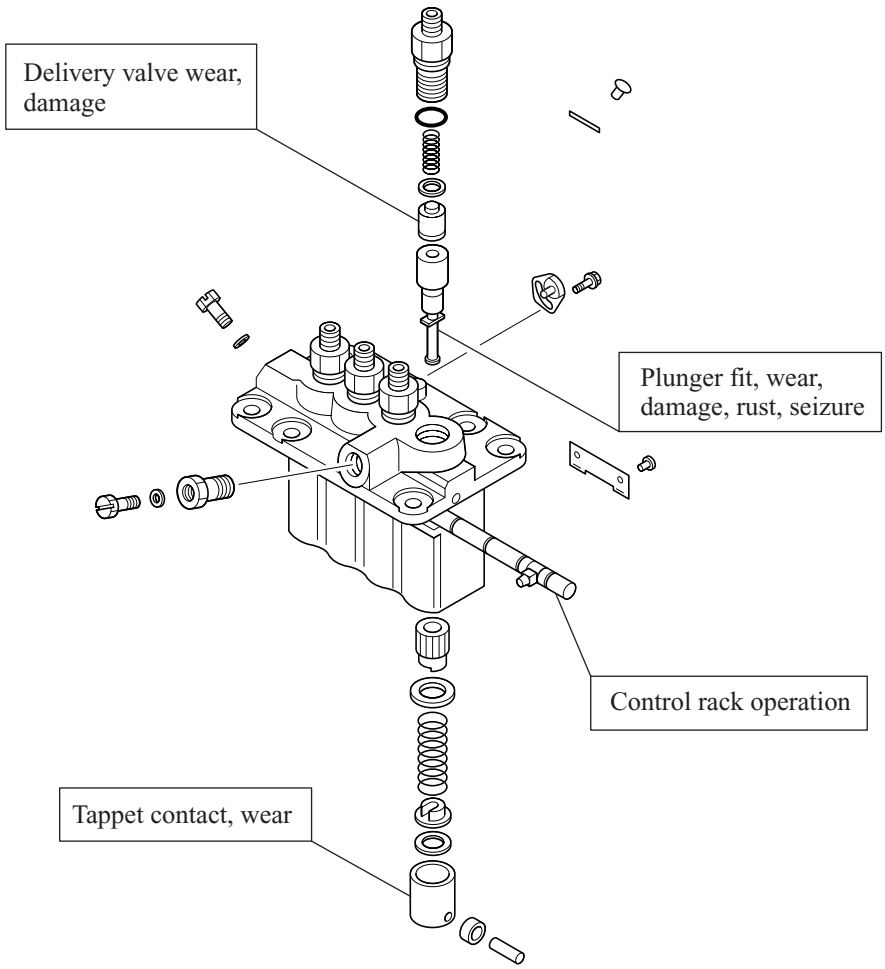
Removing the plunger barrel

Note: (a) When replacing the plunger barrels or the delivery valves, do not loosen the adjusting plates between the cylinders.
  (b) If the barrels or valves are to be replaced, fuel injection volume must be measured. The measurement requires pump tester cam box.
  (c) Keep the parts removed in clean light oil.



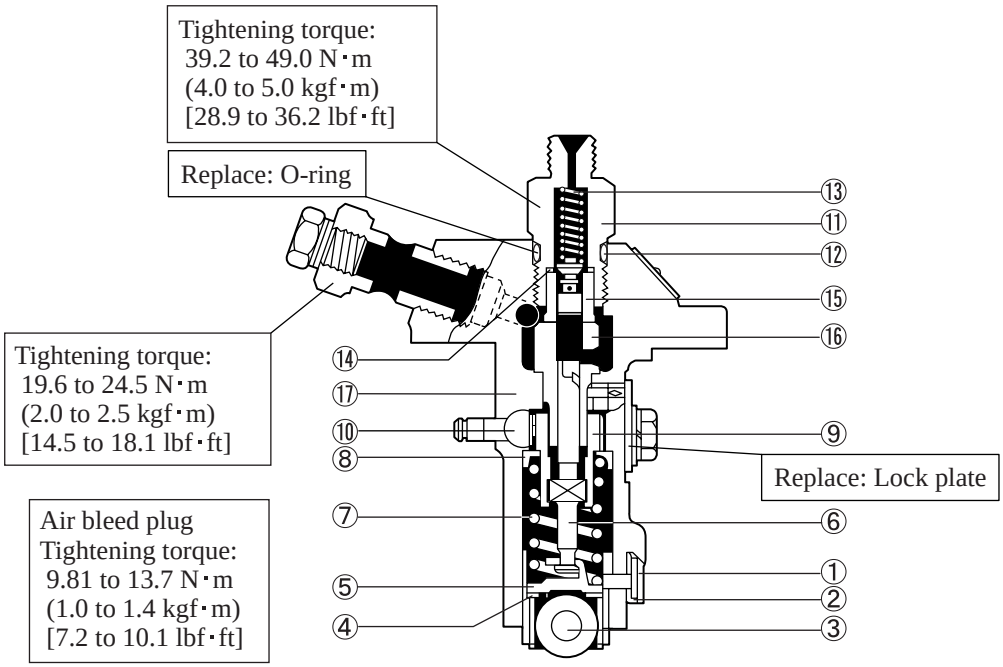

Do not loosen these plates

## 2.3 Inspecting the fuel injection pumps




Inspection of the fuel injection pumps

## 2.4 Reassembling the fuel injection pumps

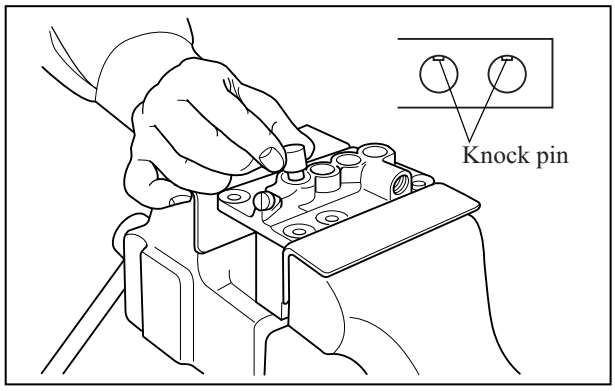



Reassembly of the fuel injection pumps

To reassembly, follows the disassembly sequence in reverse and do the following steps.

(1) Inserting the plunger barrels
Ensure that the plunger barrel groove is aligned with the knock pin of the pump housing.

Note: If the plunger barrel groove is not aligned with the knock pin, the O-ring will not seat properly in the pump housing when the delivery valve holder is being loosely tightened in the next operation.



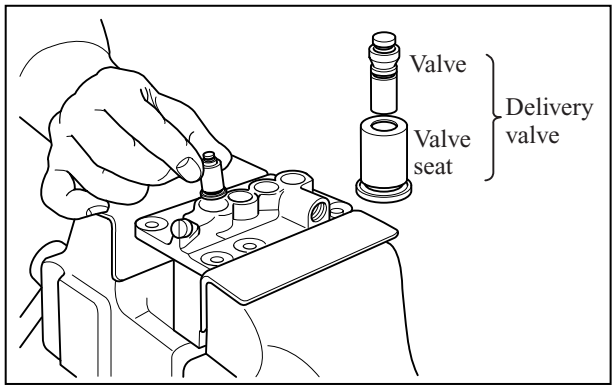

Inserting the plunger barrel

(2) Installing the delivery valves
Install the delivery valve, gasket, spring and O-ring. Loosely tighten the delivery valve holder.

**⚠ CAUTION**

(a) Discard the old O-ring. Replace with a new part.

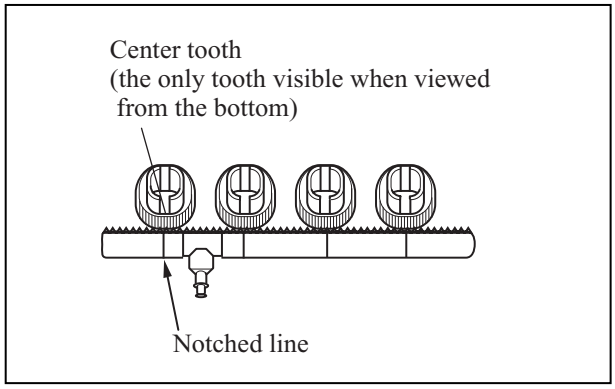
(b) While reassembling, take care not to cut the O-ring with the threaded portion of the valve holder.




Installing the delivery valve

(3) Installing the control sleeves

(a) Assemble the control sleeves onto the control rack so that each sleeve is aligned with the notched line.

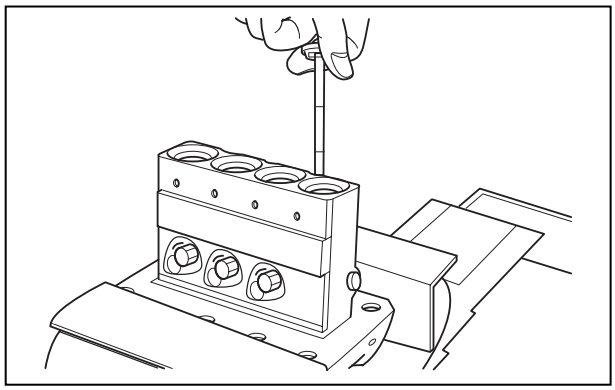



Installing the control sleeves

(b) Insert the plungers into the sleeves.

**⚠ CAUTION**

Insert the plungers so that their cuts face the adjusting plates.



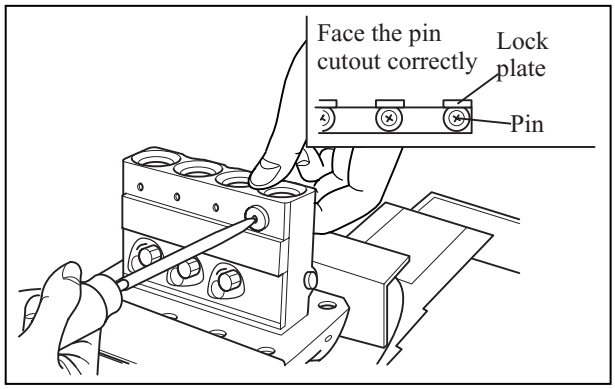
Inserting the plunger

(4) Installing the tappets

While pressing the tappet down, move the control rack. When the tappet groove is aligned with the tappet guide pin hole in the pump housing, install the lock plate and the tappet guide pin.

**⚠ CAUTION**

Do not use the old lock plate. Replace with a new part.




Installing the tappet

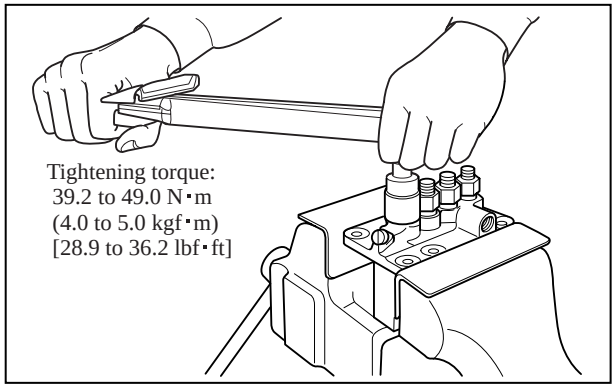
(5) Tightening the delivery valve holders

Tighten the delivery valve holders to the specified torque.

**⚠ CAUTION**

(a) Do not overtighten the plungers as they will seize.

(b) Do not undertighten neither as it will cause the fuel to mix in the engine oil.




Tightening the delivery valve holder

(6) Inspecting the control rack for smooth operation

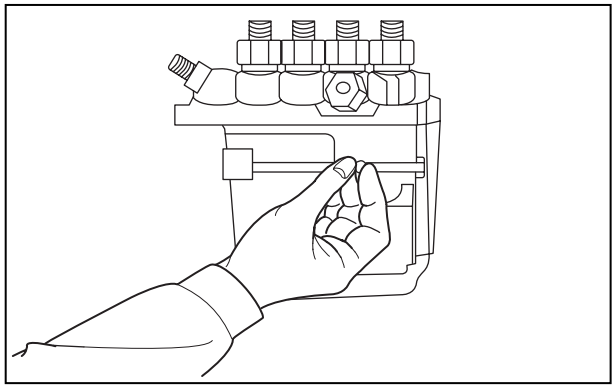
(a) With the fuel injection pumps assembled, ensure that the control rack slides smoothly.

(b) If not, possible causes include the following.

1) The elements do not slide smoothly.
2) Foreign matter is trapped between the teeth of rack and sleeve.
3) The delivery valve holders have been overtightened.

Disassemble and inspect.

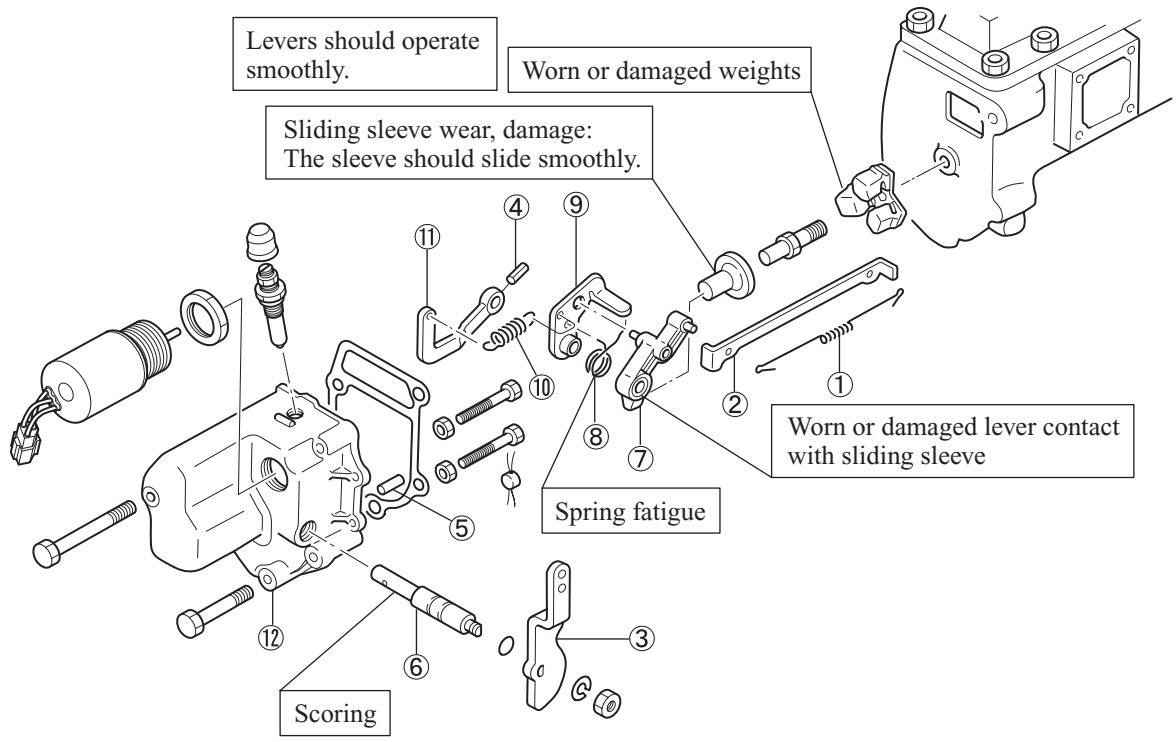
(c) After reassembly, check the fuel injection timing.



Inspecting the control rack for smooth operation

# 3. Governor

## 3.1 Disassembling and inspecting the governor




Disassembly and inspection of the governor

<Disassembly sequence>

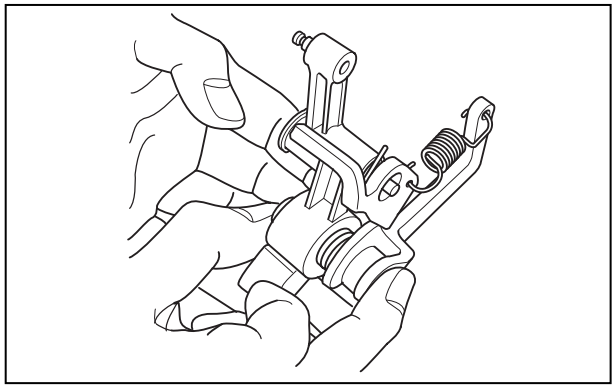
① Tie-rod spring
② Tie-rod
③ Speed control lever
④ Spring pin
⑤ Grooved pin
⑥ Governor shaft

(Remove ⑦ to ⑪ as an assembly.)

⑦ Governor lever
⑧ Start spring
⑨ Tension lever
⑩ Governor spring
⑪ Governor spring lever
⑫ Governor case

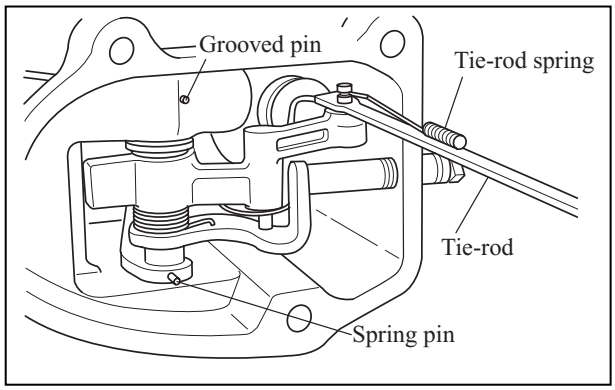
## 3.2 Reassembling the governor

(1) Install the levers first.



Installing the levers

(2) Install the O-ring onto the governor shaft.
(3) Insert the governor shaft into the governor case, and combine it with the levers.
(4) Hold the grooved pin and the spring pin in place, and knock them in with a soft hammer.
(5) Install the tie-rod and the tie-rod spring.




Assembling the governor

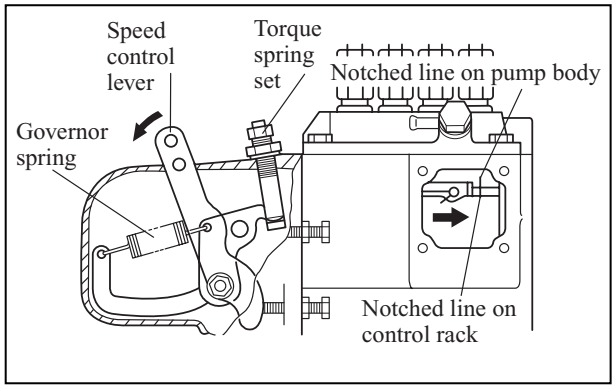
## 3.3 Installing the torque spring set

Prior to installation, adjust the low and high idle speeds of engine. Stop the engine for installation and adjustment of the torque spring set.

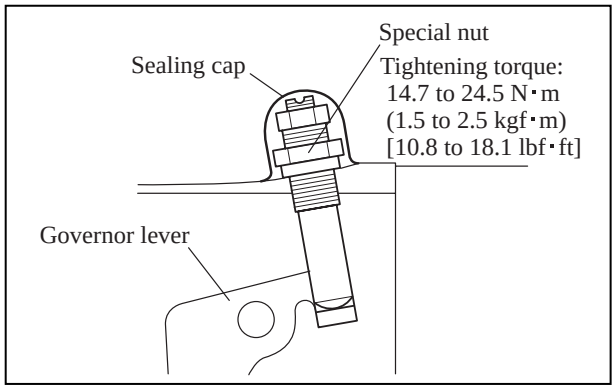
(1) Remove the tie-rod cover.
(2) Pull the speed control lever to the high idle speed position and hold it there.
(3) Pull the tie-rod in the direction of the arrow until a slight resistance is felt.

Note: This is the initial resistance by the governor spring. Do not pull the tie-rod further to try to overcome the resistance.

(4) While holding the tie-rod in this position, screw in the torque spring set until the notched line on the control rack is aligned with that on the pump body.
(5) With both notched lines aligned, lock the torque spring set by tightening the special nut to the specified torque.
(6) Place the torque set sealing cap over the torque spring set, and stake it in place.




Installing the torque spring set




Adjusting and sealing the torque spring set

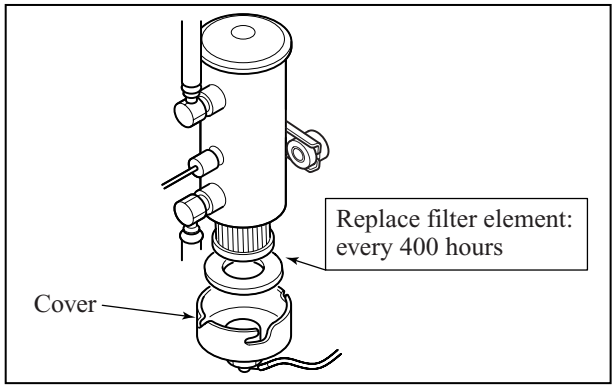
# 4. Fuel Pump

## Inspecting the fuel pump

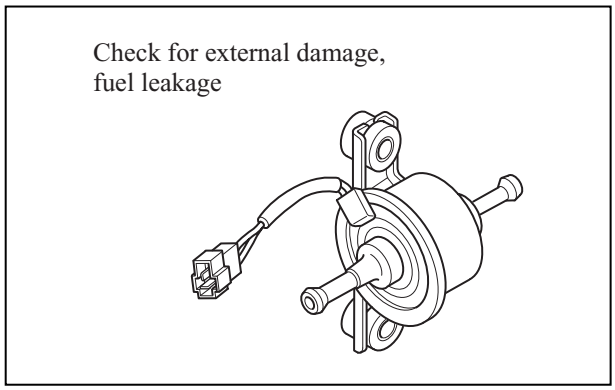
The engine is equipped with one of the following three types of fuel pump depending on the engine specifications.

(1) Plunger-type fuel pump

There are two types; one is the standard with a filter element and the other, compact-size, without a filter element. As for standard type, remove the cover and clean or replace the filter element. On either pump, ensure that the pump operates normally without fuel leakage.



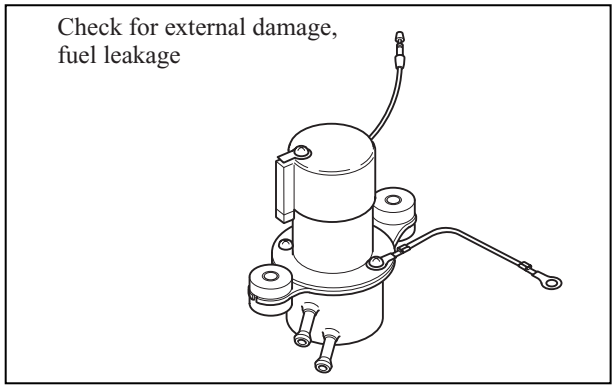

Plunger fuel pump (standard)




Plunger fuel pump (compact-size)

(2) Diaphragm-type fuel pump

Never attempt to disassemble this type of fuel pump. Like the compact-size plunger fuel pump, ensure that the pump operates normally without fuel leakage.



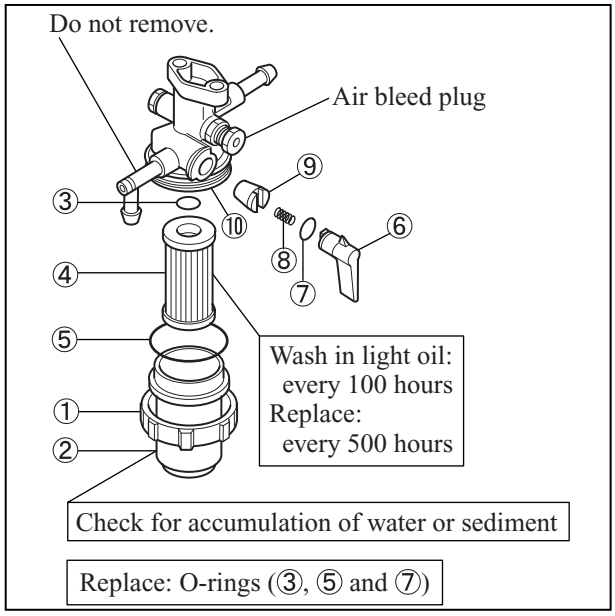

Diaphragm fuel pump

## 5. Fuel Filter

### 5.1 Disassembling, inspecting and reassembling the fuel filter (with a selector cock)

(1) Normally, only remove the filter element. Do not disassemble the cock lever unless so required.

(2) If the cock lever is disassembled, clean it and apply silicon oil to the O-ring before reassembly.

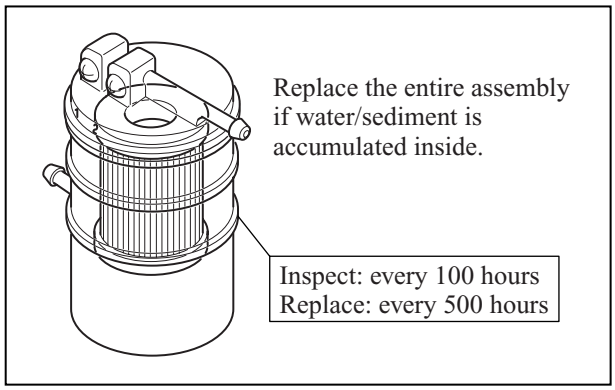



Disassembling, inspecting and reassembling the fuel filter

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

### 5.2 Inspecting the fuel filter (cartridge type)

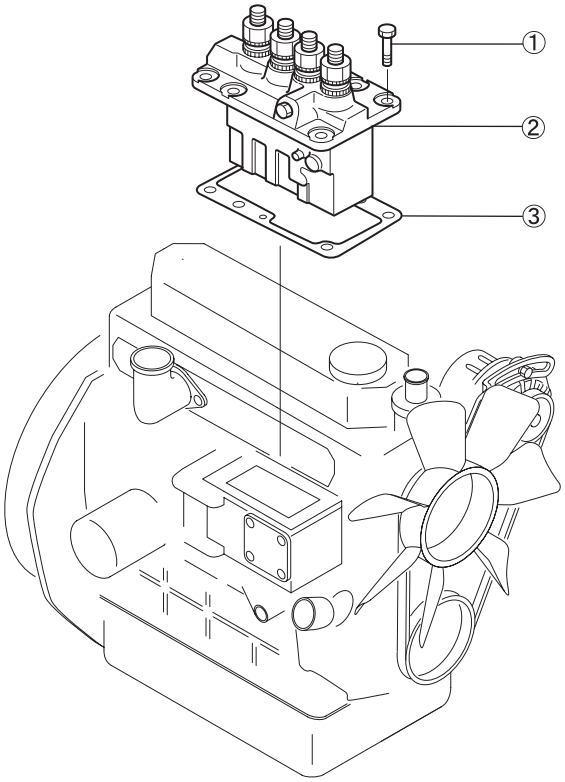
If water or sediment is accumulated on the bottom of the case or in the filter element, replace the entire assembly. Replace the fuel filter assembly approx. every 500 hours. However, it is recommended that the fuel filter be checked every 100 hours and, if faulty, replace at that time.




Inspecting the fuel filter

# FUEL SYSTEM - INSTALLATION

## 1. Fuel Injection Pumps

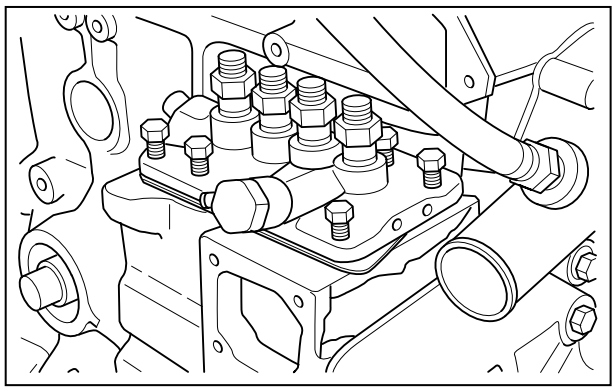



Installing the fuel injection pumps

<Installation sequence>
③→②→①

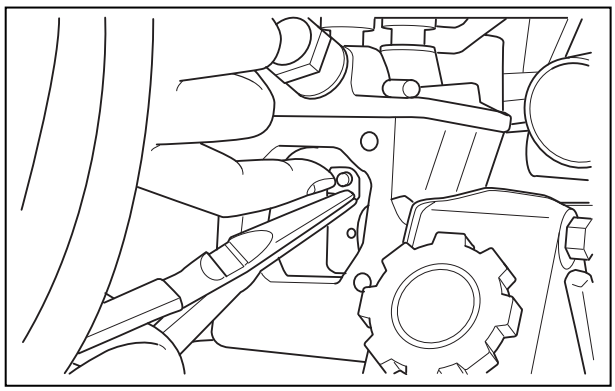
## Installing the fuel injection pumps

(1) Install the fuel injection pump housing complete with the pumps onto the cylinder block, and tighten the retaining bolts.



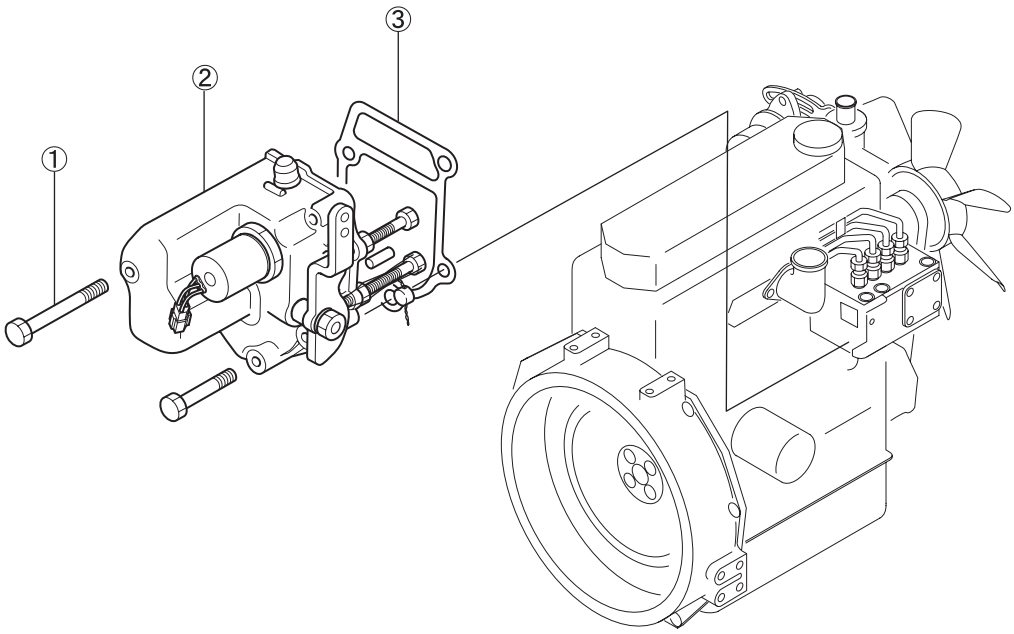
Installing the fuel injection pump housing complete with the pumps

(2) Install the governor assembly, inserting the tie-rod and the tie-rod spring into the fuel injection pump housing.



Installing the tie-rod

## 2. Governor

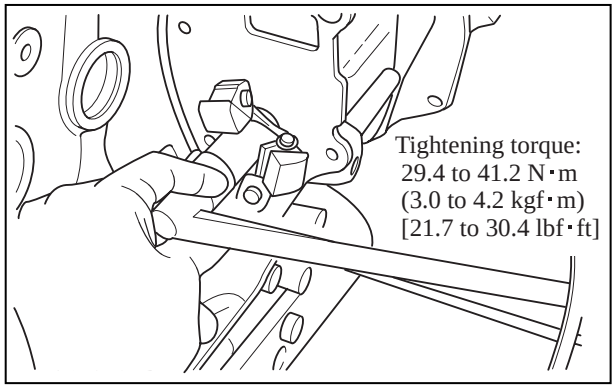



Installing the governor

<Installation sequence>
③→②→①

## 2.1 Installing the governor weights

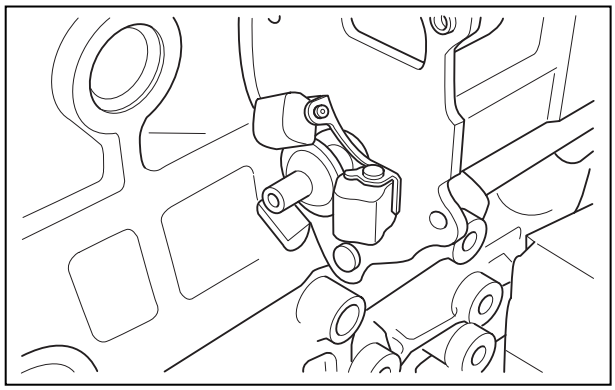
Install the governor weights onto the rear end of the pump camshaft and tighten the sliding sleeve shaft to the specified torque.




Installing the governor weights

## 2.2 Installing the sliding sleeve

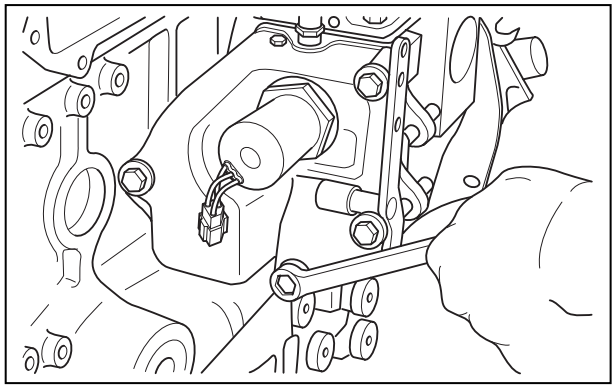
Install the sliding sleeve onto the sliding sleeve shaft. Ensure that the sleeve slides smoothly.



Installing the sliding sleeve

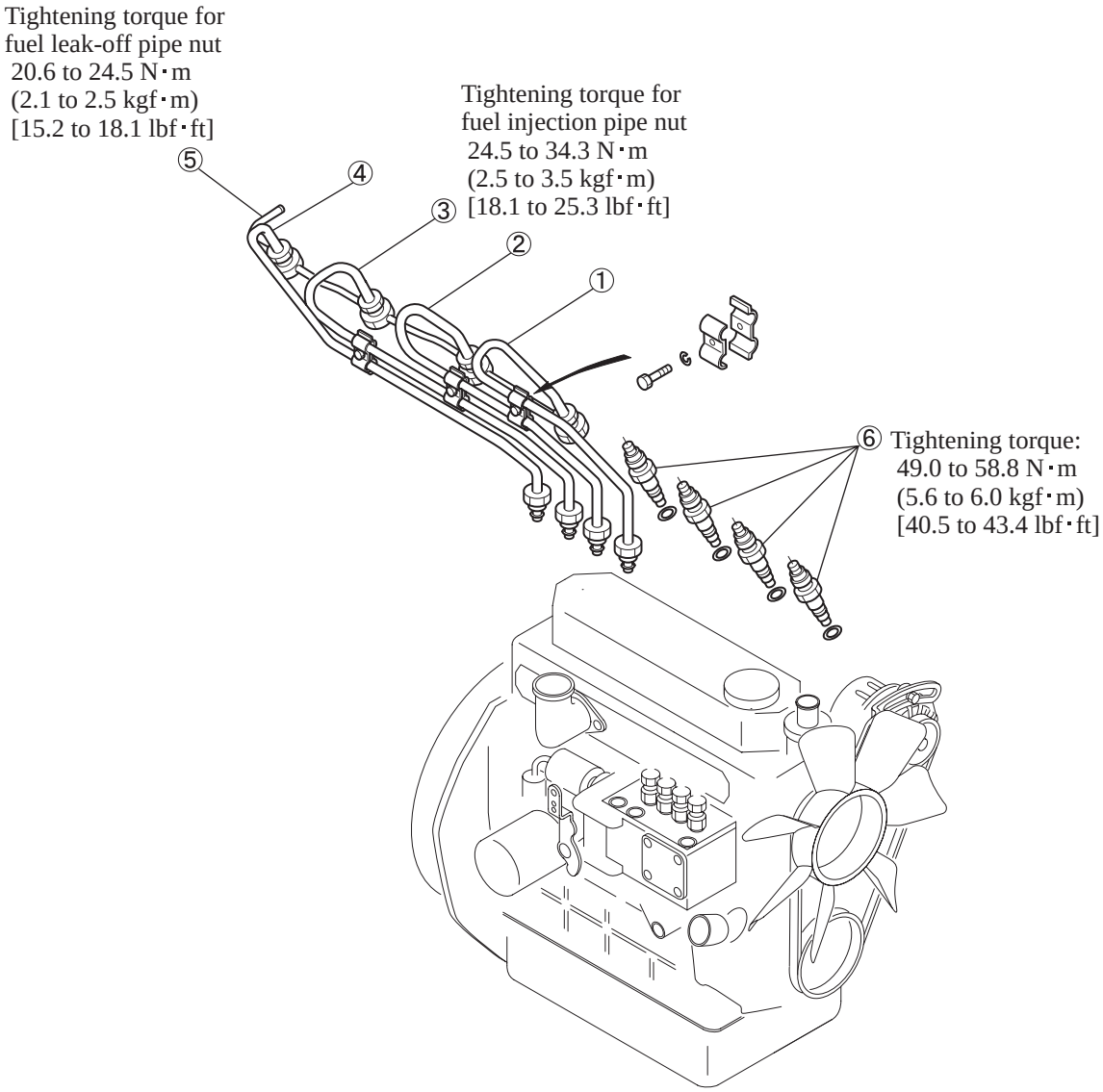
## 2.3 Installing the governor assembly

(1) Install the governor assembly onto the pump housing.
(2) Connect the tie-rod and the tie-rod spring to the pumps.
(3) Install the tie-rod cover.



Installing the governor assembly

## 3. Fuel Injection Pipes, Fuel Leak-off Pipe, Fuel Injection Nozzles

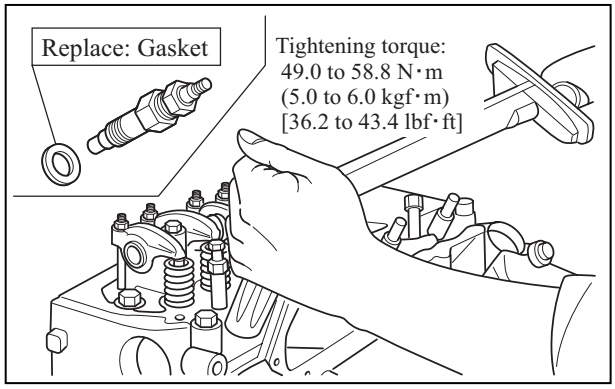



Installation of the fuel injection pipes, fuel leak-off pipe, and fuel injection nozzles

<Installation sequence>
⑥→⑤→④→③→②→①

### 3.1 Installing the fuel injection nozzles

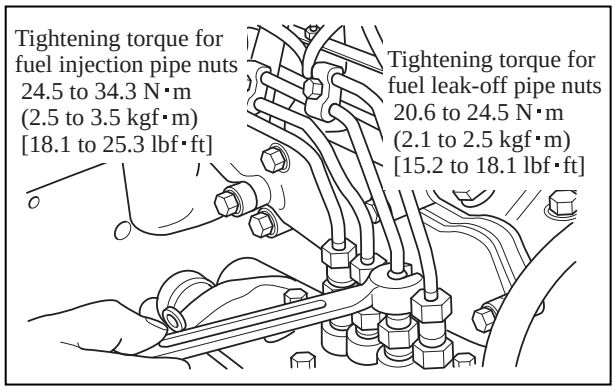
(1) Install the gaskets onto the fuel injection nozzles.
(2) Insert the fuel injection nozzles into the cylinder head, and tighten to the specified torque.




Installing the fuel injection nozzles

### 3.2 Installing the fuel pipes

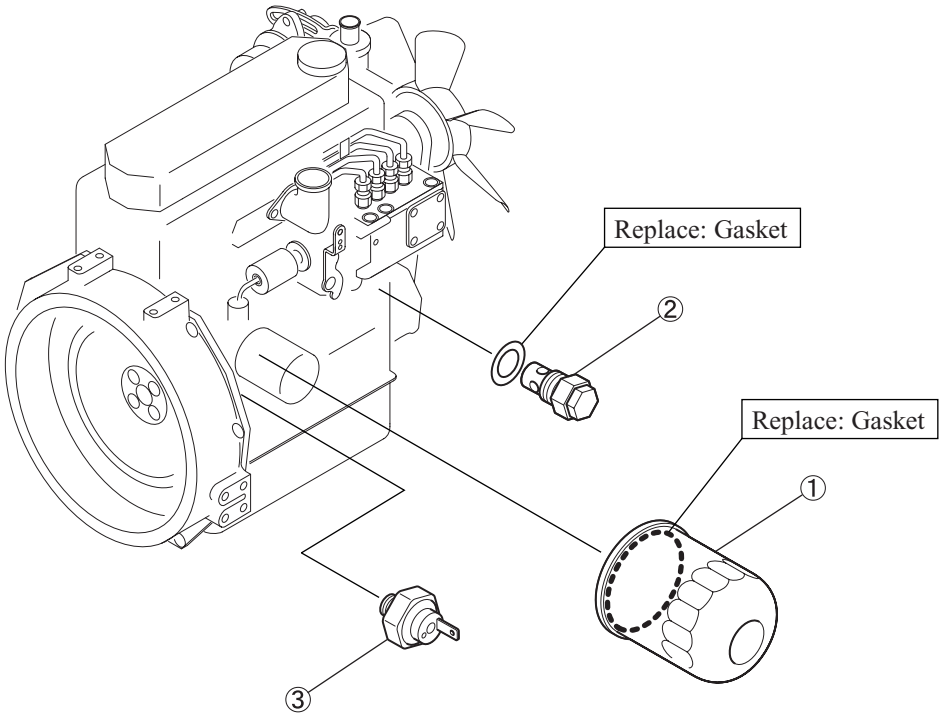
(1) Install the fuel leak-off pipe onto the fuel injection nozzles.
(2) Install the fuel injection pipes, and hold them in place with clamps.
(3) Tighten the fuel leak-off and fuel injection pipe nuts to the specified torques.




Installing the fuel pipes

# OIL SYSTEM - REMOVAL

## 1. Oil Filter, Relief Valve and Oil Pressure Switch

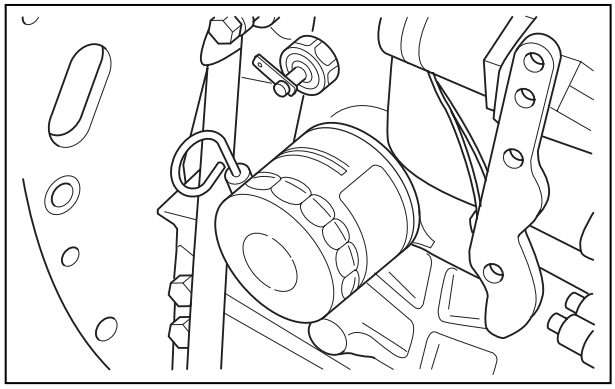



Removal of the oil filter, relief valve and oil pressure switch

<Removal sequence>
① Oil filter ② Relief valve ③ Oil pressure switch

## 1.1 Removing the oil filter

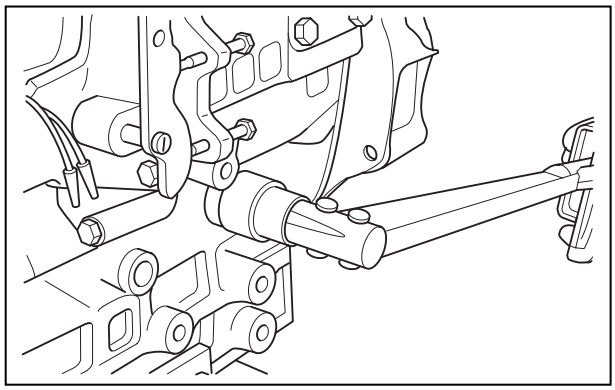
(1) Place an drip pan under the oil filter.
(2) Using a filter wrench, remove the oil filter.



Removing the oil filter

## 1.2 Removing the relief valve

Remove the relief valve.

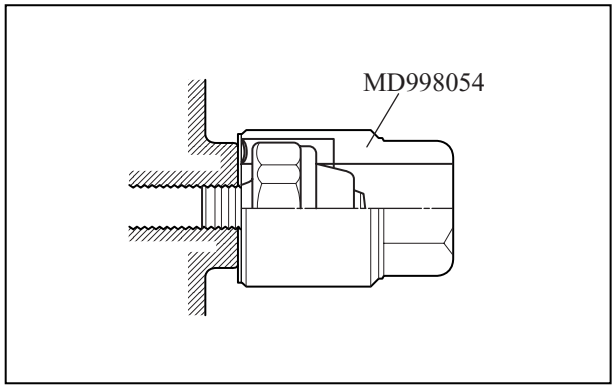


Removing the relief valve

## 1.3 Removing the oil pressure switch

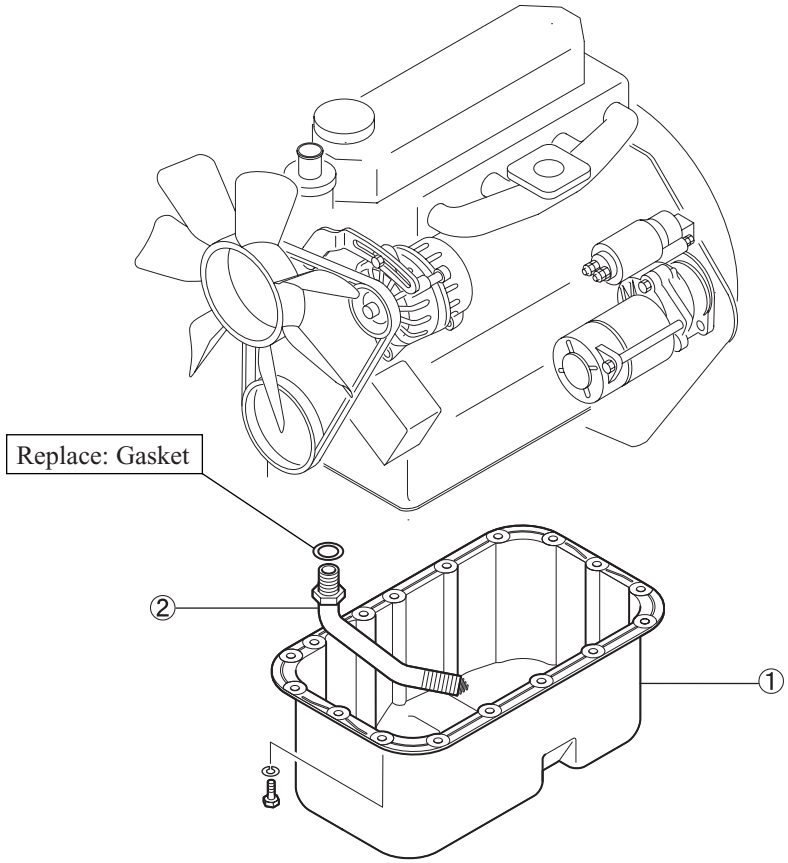
Using the special tool Oil Pressure Switch Socket Wrench, remove the switch.

| Special tool | Part number |
|---|---|
| Oil Pressure Switch Socket Wrench | MD998054 |




Removing the oil pressure switch

## 2. Oil Pan, Oil Strainer




Removal of the oil pan and oil strainer

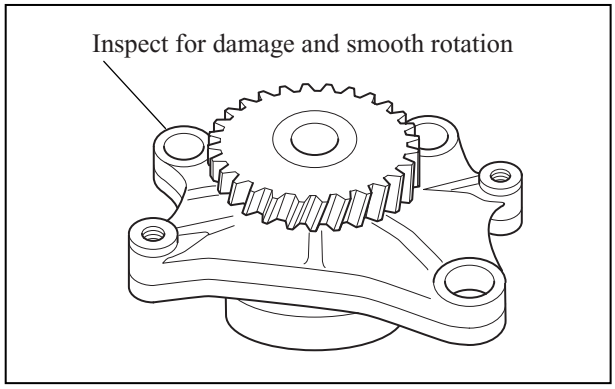
<Removal sequence>
① Oil pan
② Oil strainer

# OIL SYSTEM - DISASSEMBLY, INSPECTION AND REASSEMBLY

# 1. Oil Pump

## Inspecting the oil pump

Check the oil pump for any damage, and whether or not it rotates smoothly. If faulty, replace the entire pump assembly.




Inspecting the oil pump

# 2. Relief Valve

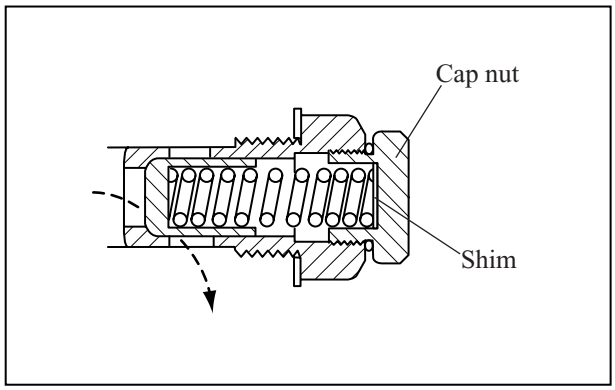
## Inspecting the relief valve

(1) Inspect for proper valve-to-seat contact, spring fatigue, breakage or any other damage. If faulty, replace.

(2) Measure the relief valve opening pressure (at rated engine speed). If the measured pressure exceeds the standard value, remove the cap nut and adjust by shimming.

(3) Engine oil pressure port: Right-hand side of engine

| | |
|---|---|
| Relief valve opening pressure | 0.35±0.05 MPa<br>(3.5±0.5 kgf/cm$^2$)<br>[50±7.2 psi] |

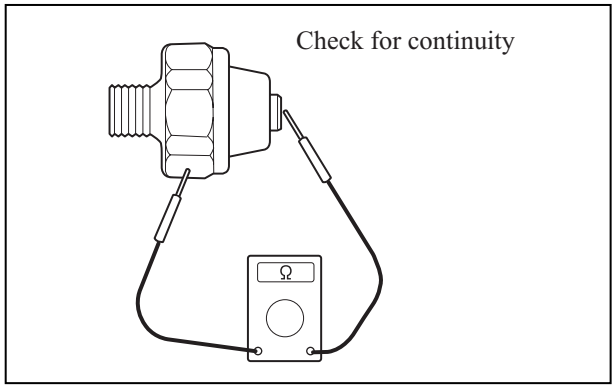



Inspecting the relief valve

## 3. Oil Pressure Switch

### Inspecting the oil pressure switch

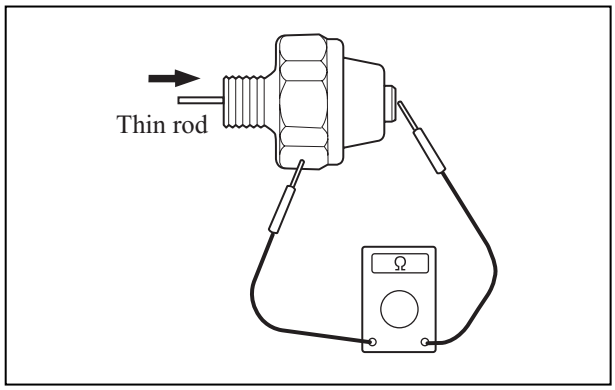
(1) Connect a tester (ohm meter) between the oil pressure switch terminal and the switch body. The tester should indicate continuity. If not, replace the switch.




Inspecting the oil pressure switch (1)

(2) With the tester still installed, insert a thin rod into the oil hole and gently press the rod. The tester should indicate no continuity. If continuity is indicated, replace the switch.

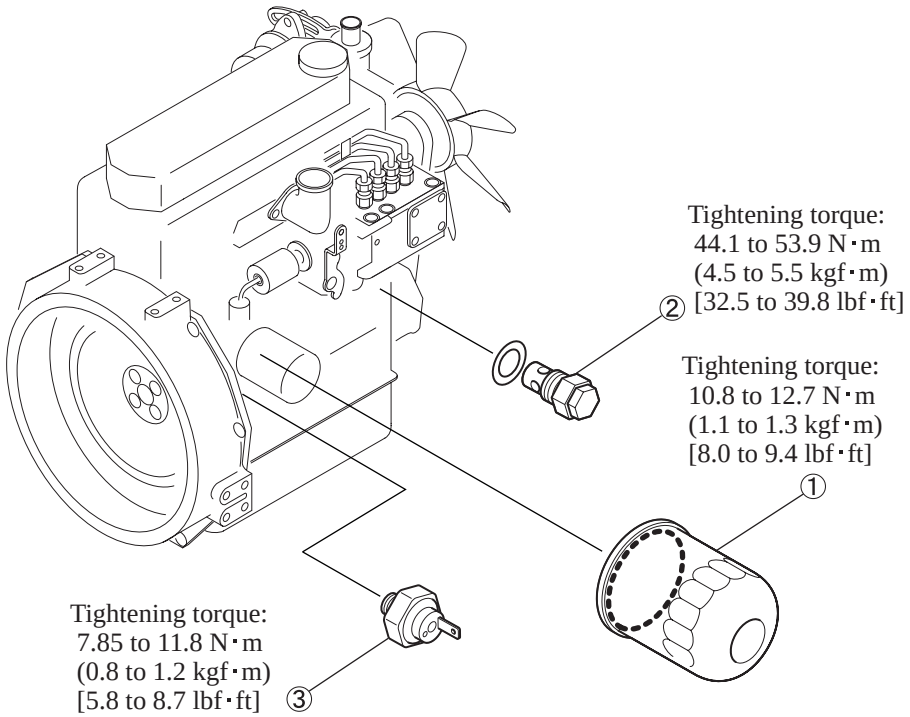
(3) With the tester still installed, apply an air pressure of 0.05 MPa (0.5 kgf/cm$^2$) [7 psi] into the oil hole. The tester should indicate no continuity.
Check also for any air leakage. If air is leaking, the diaphragm is broken. Replace the switch.




Inspecting the oil pressure switch (2)

# OIL SYSTEM - INSTALLATION

# 1. Oil Filter, Relief Valve and Oil Pressure Switch




Installation of the oil filter, relief valve and oil pressure switch

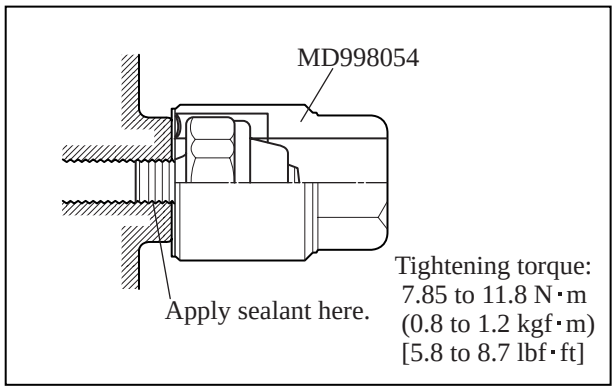
<Installation sequence>
③→②→①

## 1.1 Installing the oil pressure switch

(1) Using the special tool Oil Pressure Switch Socket Wrench, tighten the switch to the specified torque.

| Special tool | Part number |
|---|---|
| Oil Pressure Switch Socket Wrench | MD998054 |

(2) Apply sealant (ThreeBond 1102) onto the threaded portion of the switch.



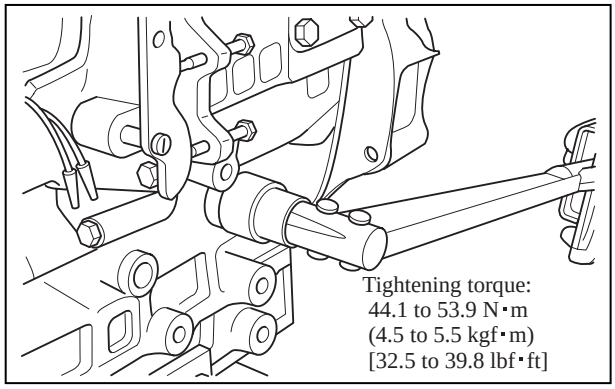

Installing the oil pressure switch

**⚠ CAUTION**

(a) Apply proper amount of sealant so that it will not be squeezed out to the tip of the threaded portion.
(b) Do not overtighten.

### 1.2 Installing the relief valve

Install the relief valve onto the side face of the cylinder block, tightening it to the specified torque.

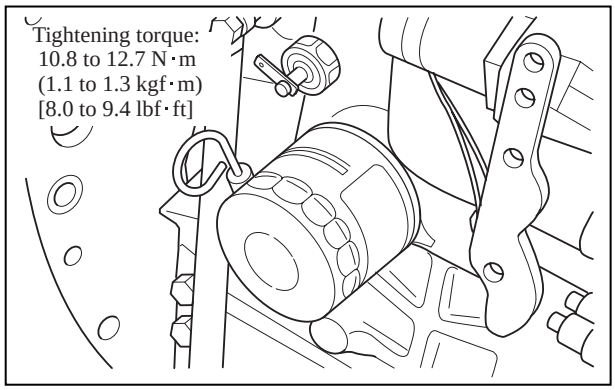



Installing the relief valve

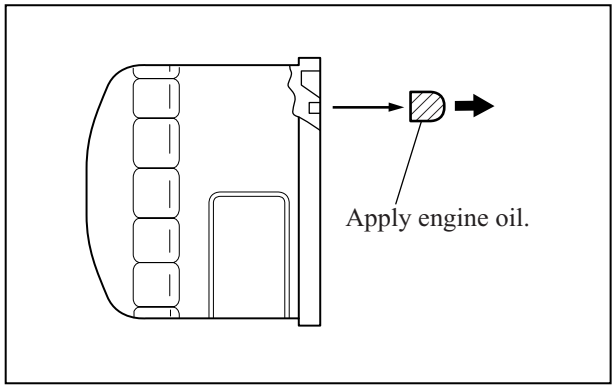
### 1.3 Installing the oil filter

(1) Apply a thin coating of engine oil to the oil filter gasket.

(2) Screw in the filter until the gasket contacts the mounting face. Then, tighten to the specified torque.

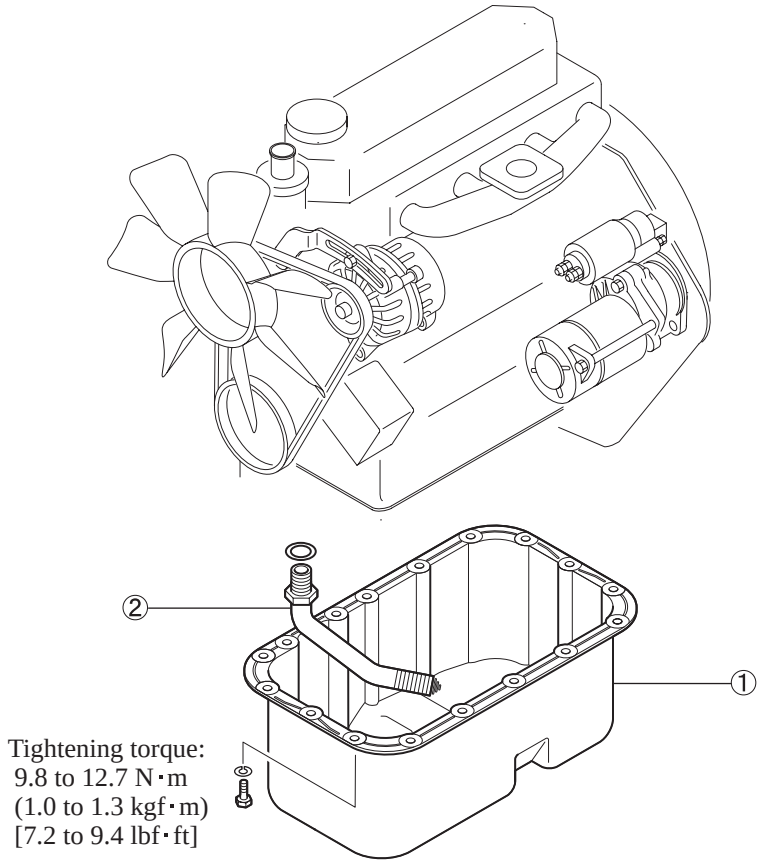



Installing the oil filter (1)




Installing the oil filter (2)

## 2. Oil Pan and Oil Strainer

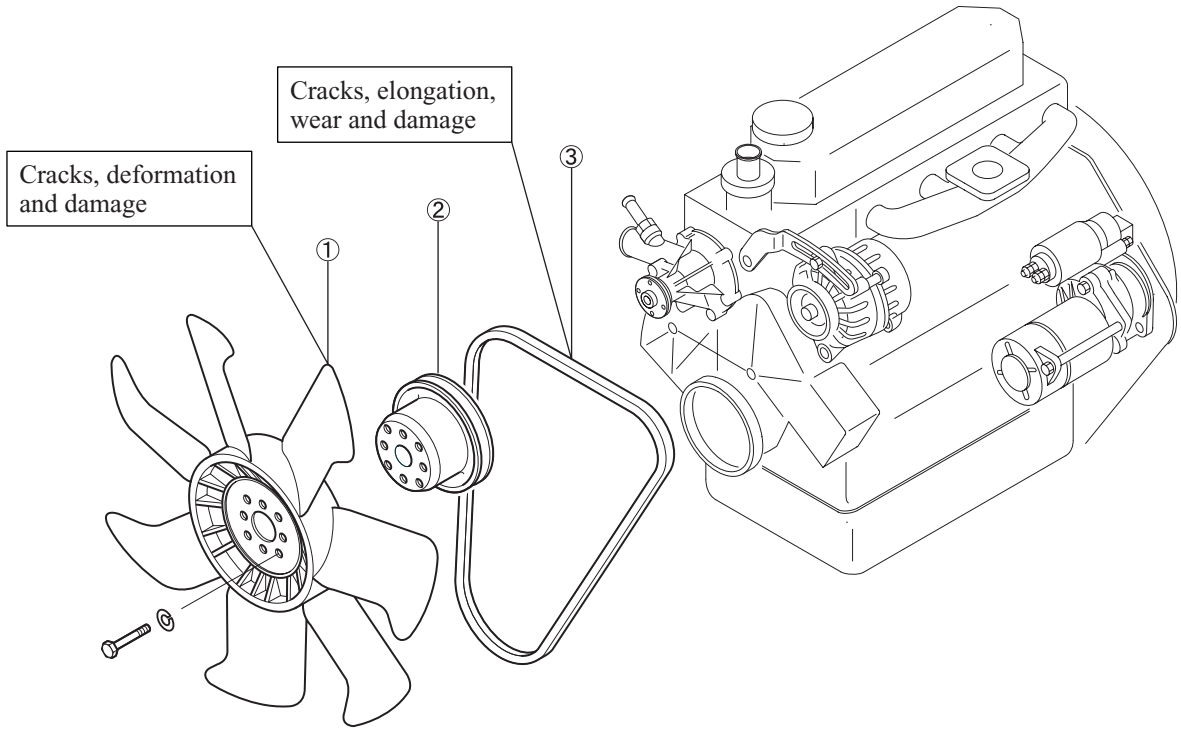



Installation of the oil pan and oil strainer

<Installation sequence>
②→①

# COOLING SYSTEM - REMOVAL

## 1. Cooling Fan, Fan Pulley and V-Belt

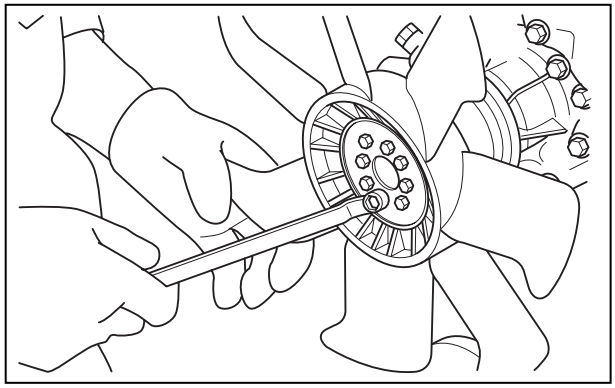



Removal of the cooling fan, fan pulley and V-belt

<Removal sequence>
① Cooling fan ② Water pump pulley ③ V-belt

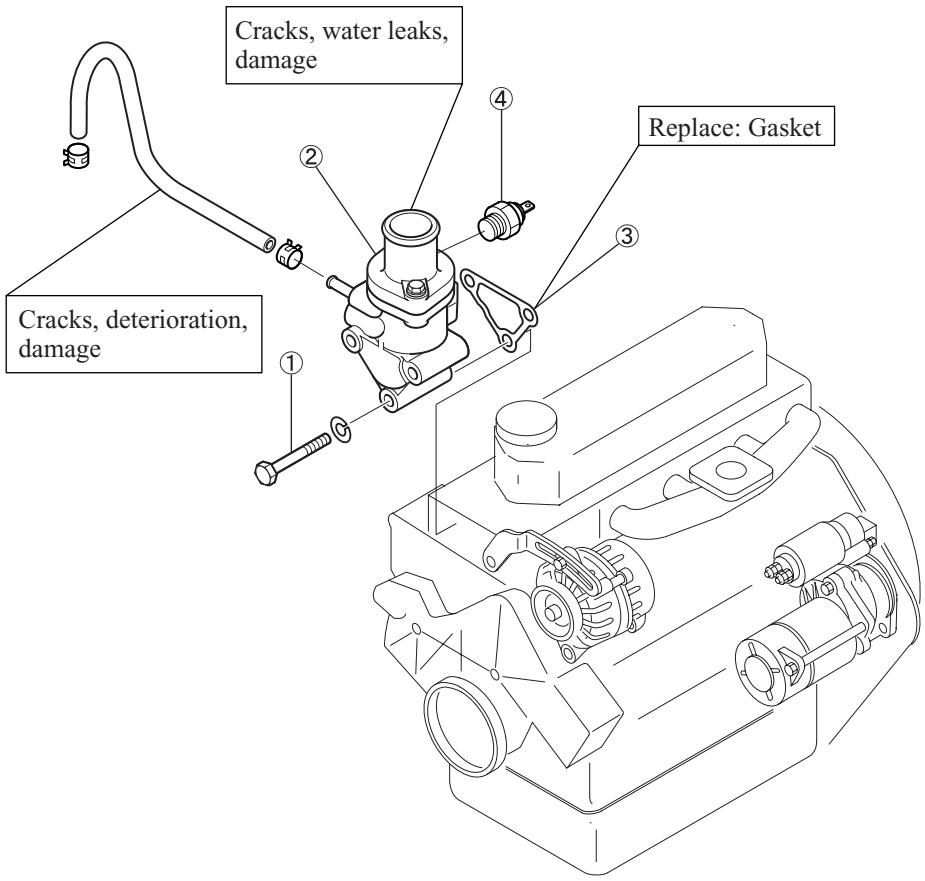
### Removing the cooling fan

(1) While holding the cooling fan with your hand, loosen its retaining bolts to remove the fan and fan spacers.
(2) Be sure to record the installation directions and positions of the fan spacers.



Removing the cooling fan

## 2. Thermostat and Thermoswitch



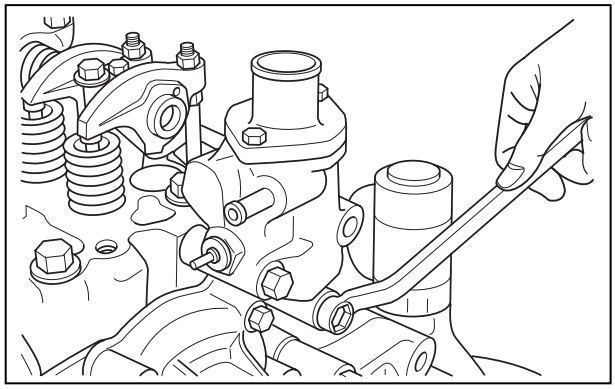

Removing the thermostat and thermoswitch

<Removal sequence>

① Bolt
② Thermostat
③ Gasket
④ Thermoswitch

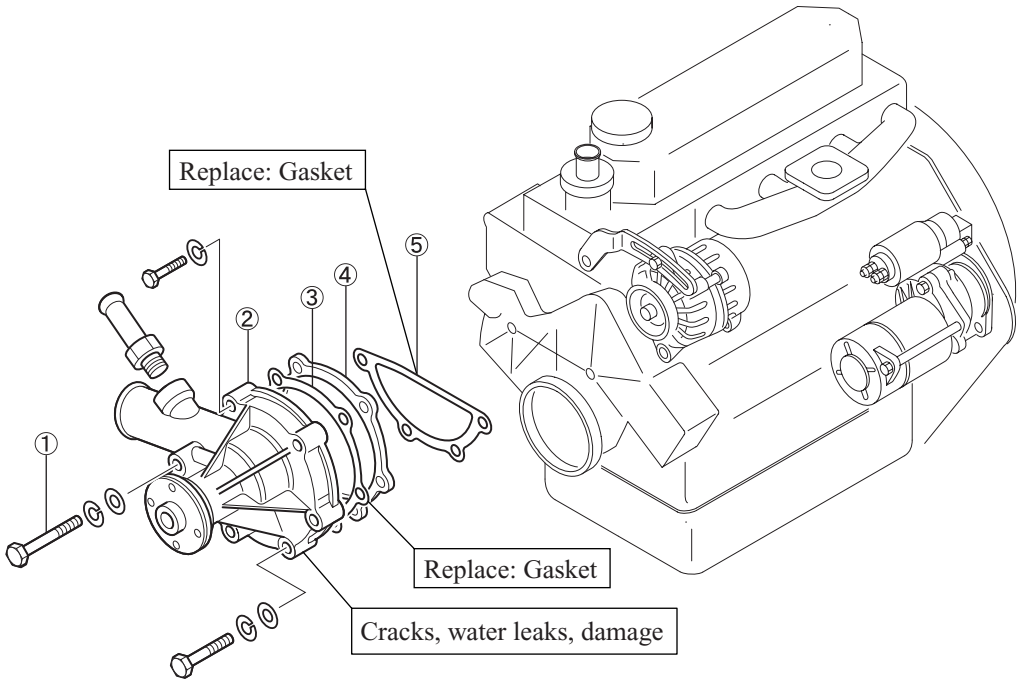
### Removing the thermostat case

Remove the thermostat case with thermostat.



Removing the thermostat case

## 3. Water Pump

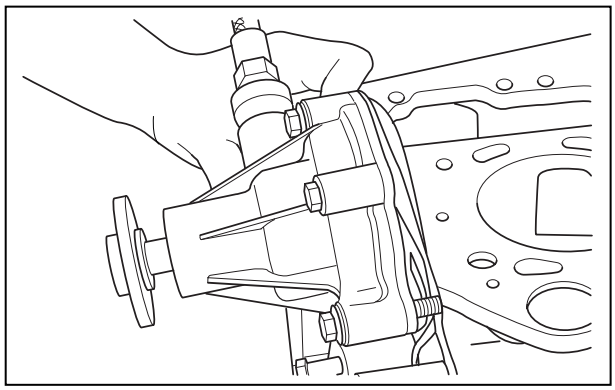



Removing the water pump

<Removal sequence>
① Bolt
② Water pump
③ Gasket
④ Water pump plate
⑤ Gasket

### Removing the water pump

Remove the water pump.

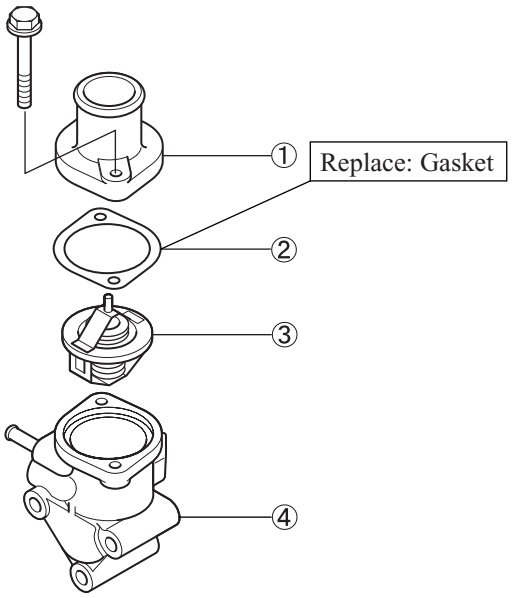


Removing the water pump

# COOLING SYSTEM - DISASSEMBLY, INSPECTION AND REASSEMBLY

# 1. Thermostat

## 1.1 Disassembling the thermostat




Disassembly of the thermostat

<Disassembly sequence>

① Thermostat cover
② Gasket
③ Thermostat
④ Thermostat case

## 1.2 Inspecting the thermostat

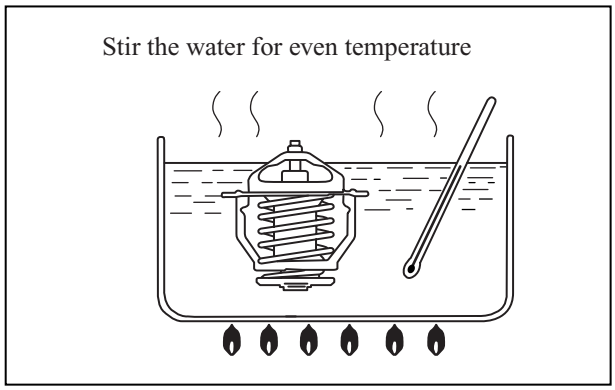
Place the thermostat in a container filled with water. While heating the water, measure the water temperature at which the thermostat starts to open, and also the water temperature at which the valve lift reaches 8 mm (0.315 in.). If the measured temperatures do not conform to the standard values, replace the thermostat.

Unit: ℃ ( ℉ )

| Valve opening temperature | 8 mm (0.315 in.) valve-lift temperature |
|---|---|
| 82±1.5 (179.6±2.7) | 95 (203) |

**⚠ CAUTION**

This is a “hot” operation. Pay every attention to prevent burns and fire.




Inspecting the thermostat

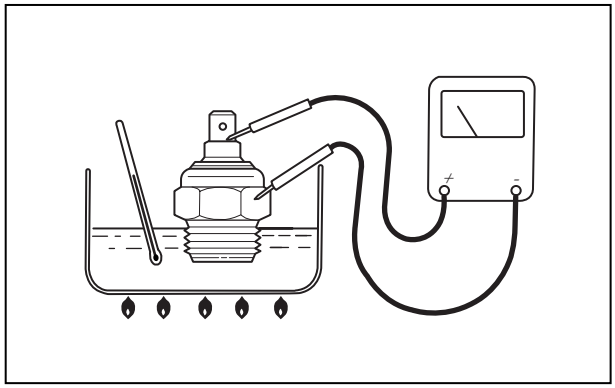
## 2. Thermoswitch

### Inspecting the thermoswitch

Dip the temperature sensing element of the thermoswitch in oil as illustrated. While warming the oil, measure the resistance at the oil temperature of 105°C (221 °F). If the measured value is substantially out of the standard value, replace the thermoswitch.

Unit: MΩ

| Temperature | Standard value |
|---|---|
| 105°C (221 °F) | 30 |



Inspecting the thermoswitch

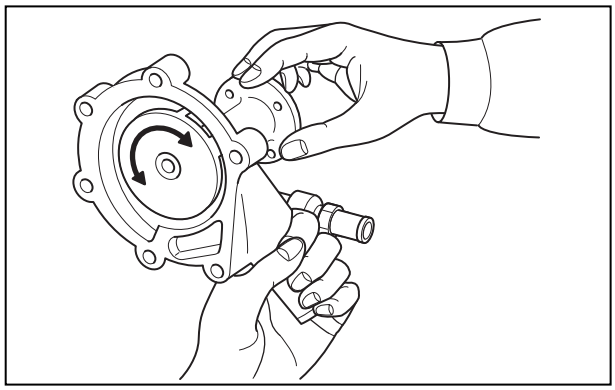
**⚠ CAUTION**

This is a "hot" operation. Pay every attention to prevent burns and fire.

## 3. Water Pump

### Inspecting the water pump

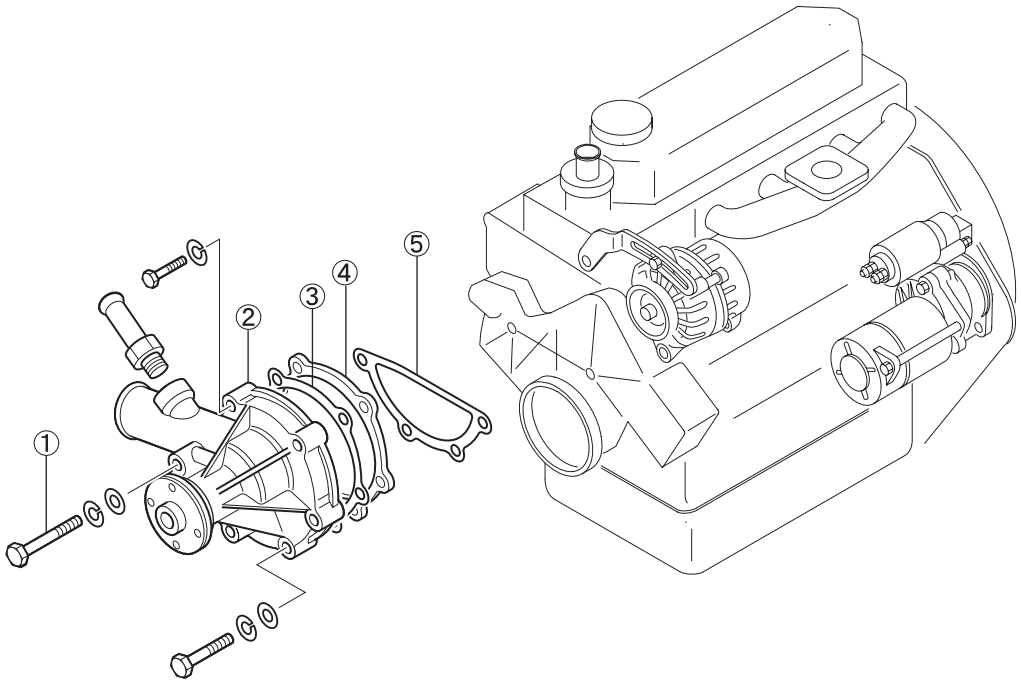
Rotate the impeller and the shaft for any noise or binding. If faulty, replace the entire pump assembly.



Inspecting the impeller and shaft for smooth rotation

# COOLING SYSTEM - INSTALLATION

# 1. Water Pump

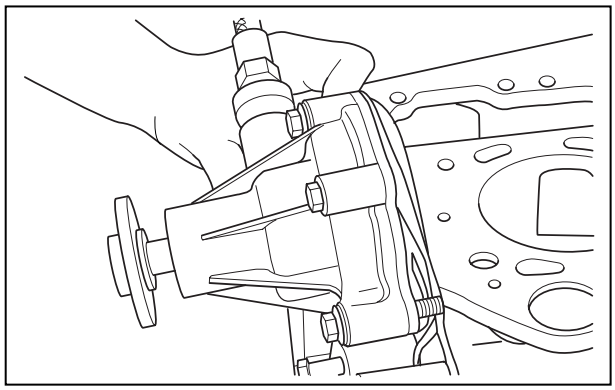



Installation of the water pump

<Installation sequence>
⑤→④→③→②→①

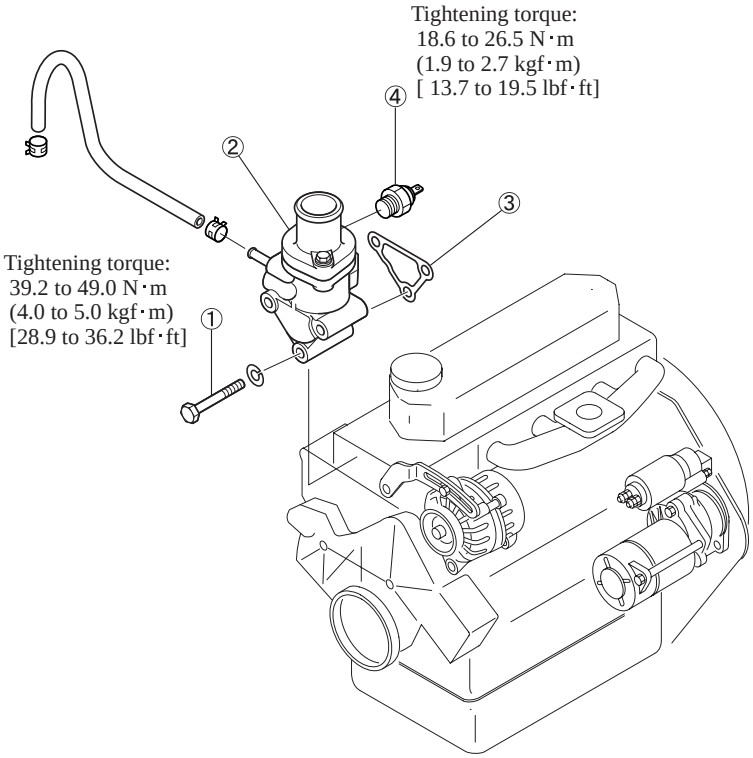
## Installing the water pump

Install the water pump with a new gasket onto the cylinder block.



Installing the water pump

## 2. Thermostat and Thermoswitch

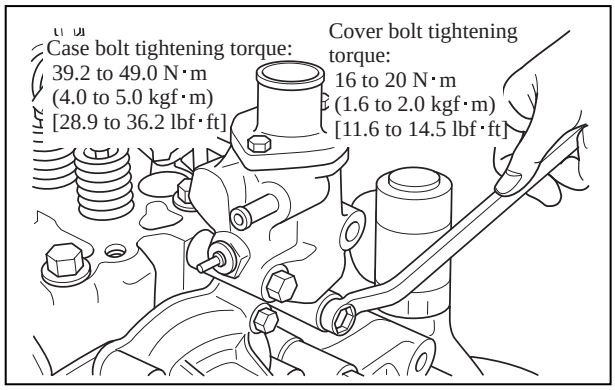



Installation of the thermostat and thermoswitch

<Installation sequence>
④→③→②→①

### 2.1 Installing the thermostat case

(1) Assemble the thermostat into the thermostat case.
(2) Using a new gasket, install the thermostat assembly onto the cylinder head.

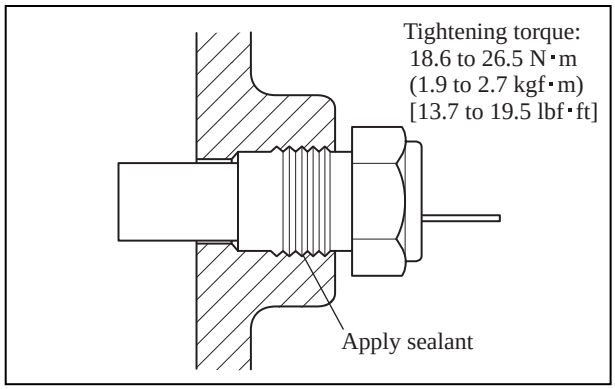



Installing the thermostat assembly

### 2.2 Installing the thermoswitch

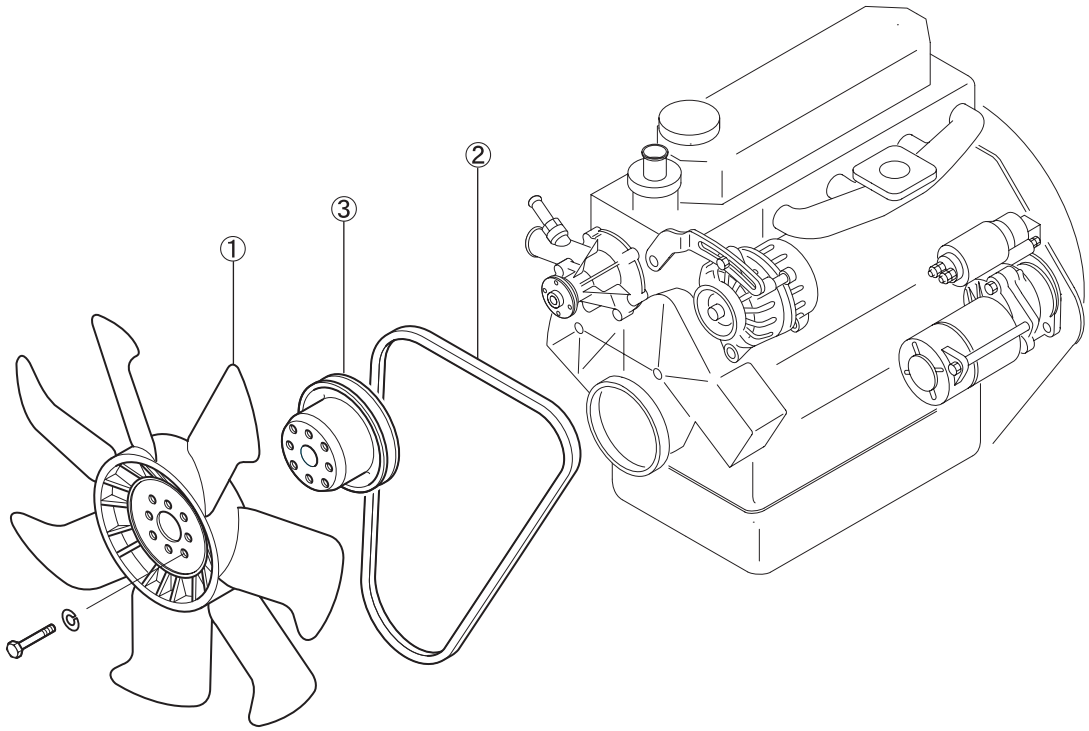
Apply sealant to the threaded portion of the switch, and tighten it to the specified torque.

| | |
|---|---|
| Sealant | ThreeBond 1104 |




Installing the thermoswitch

## 3. Cooling Fan, Fan Pulley and V-belt



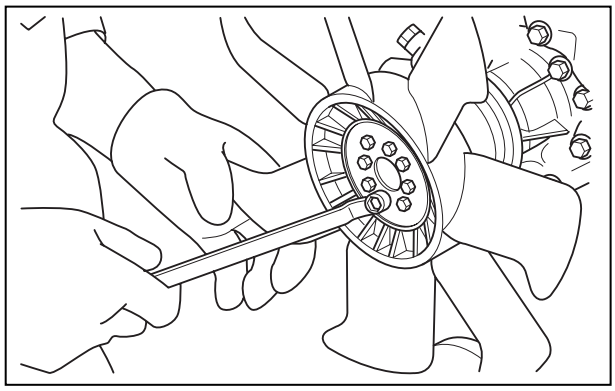

Installation of the cooling fan, fan pulley and V-belt

<Installation sequence>
③→②→①

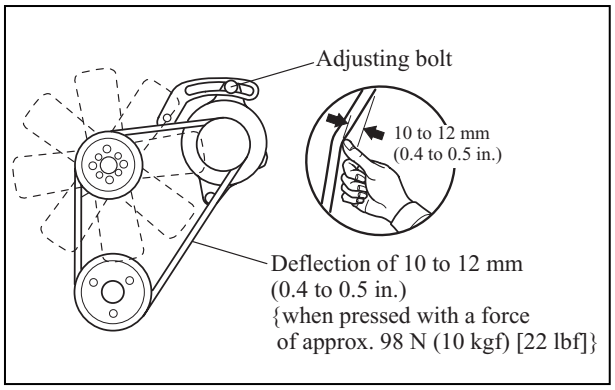
### Installing the cooling fan

(1) Install the pulley onto the water pump.
(2) Install the cooling fan onto the water pump pulley, and tighten the retaining bolts.
(3) Loosen the alternator adjusting bolt. Attach the V-belt over the water pump pulley, alternator pulley, and crankshaft pulley.
(4) Correctly tension the V-belt by moving the alternator and tightening the adjusting bolt.
(5) Check the V-belt tension.

| | |
|---|---|
| V-belt tension<br>{when pressed with a force of approx. 98 N (10 kgf) [22 lbf]} | 10 to 12 mm<br>(0.4 to 0.5 in.) |



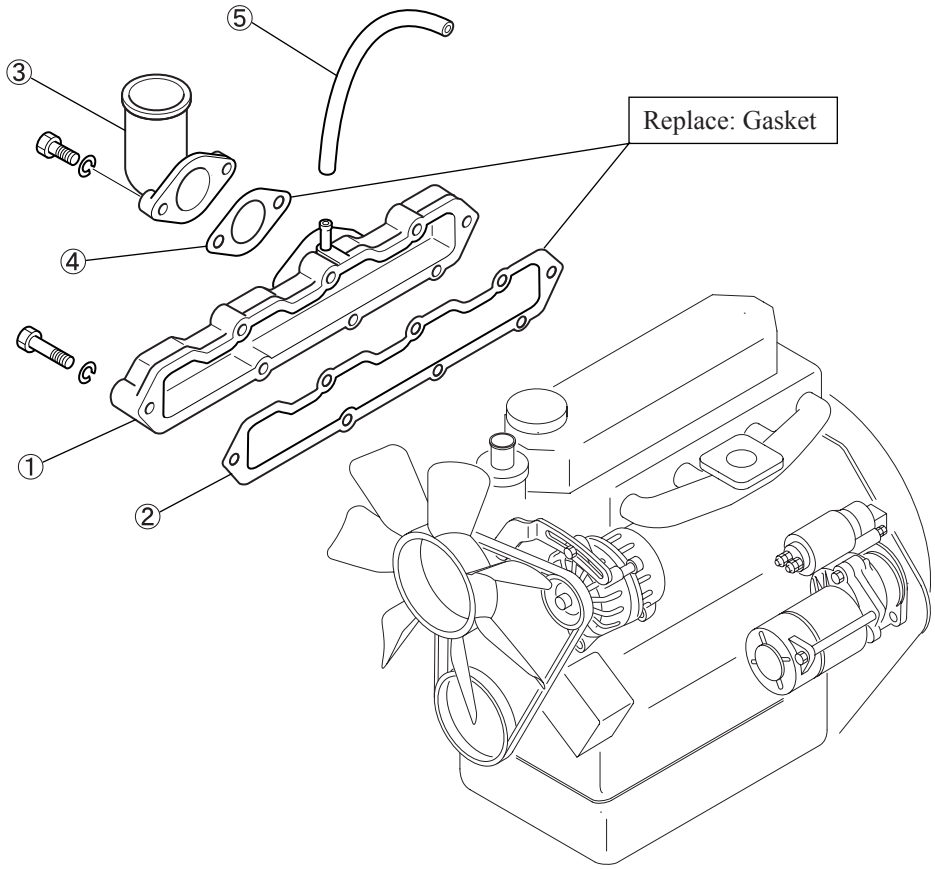
Installing the cooling fan




Adjusting the V-belt tension

# INLET AND EXHAUST SYSTEMS - REMOVAL

## 1. Inlet Cover



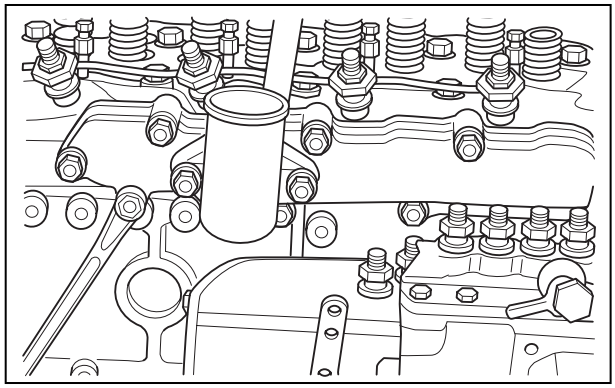

Removal of the inlet cover and air pipe

<Removal sequence>

① Inlet cover
② Gasket
③ Air pipe
④ Gasket
⑤ Breather pipe

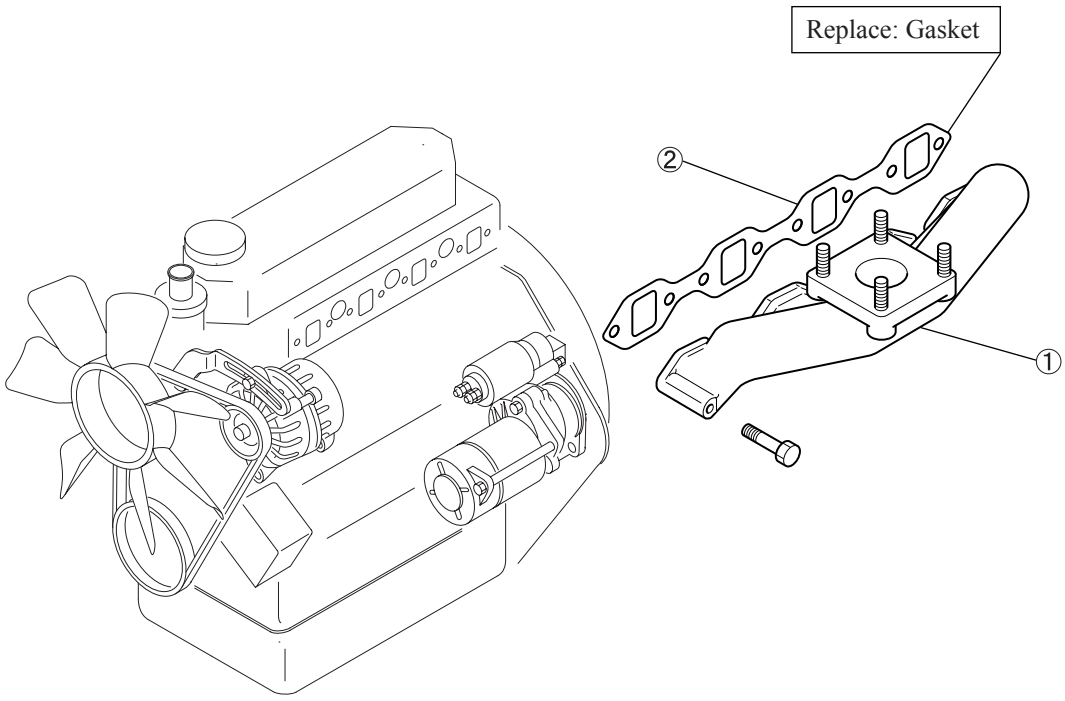
### Removing the inlet cover

Remove the inlet cover.



Removing the inlet cover

## 2. Exhaust Manifold

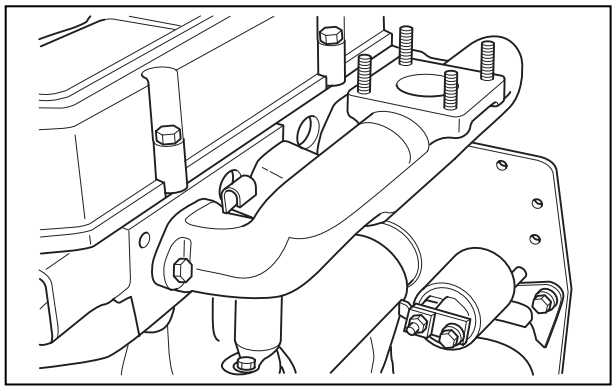



Removal of the exhaust manifold and gasket

<Removal sequence>
① Exhaust manifold ② Gasket

### Removing the exhaust manifold

Remove the exhaust manifold.

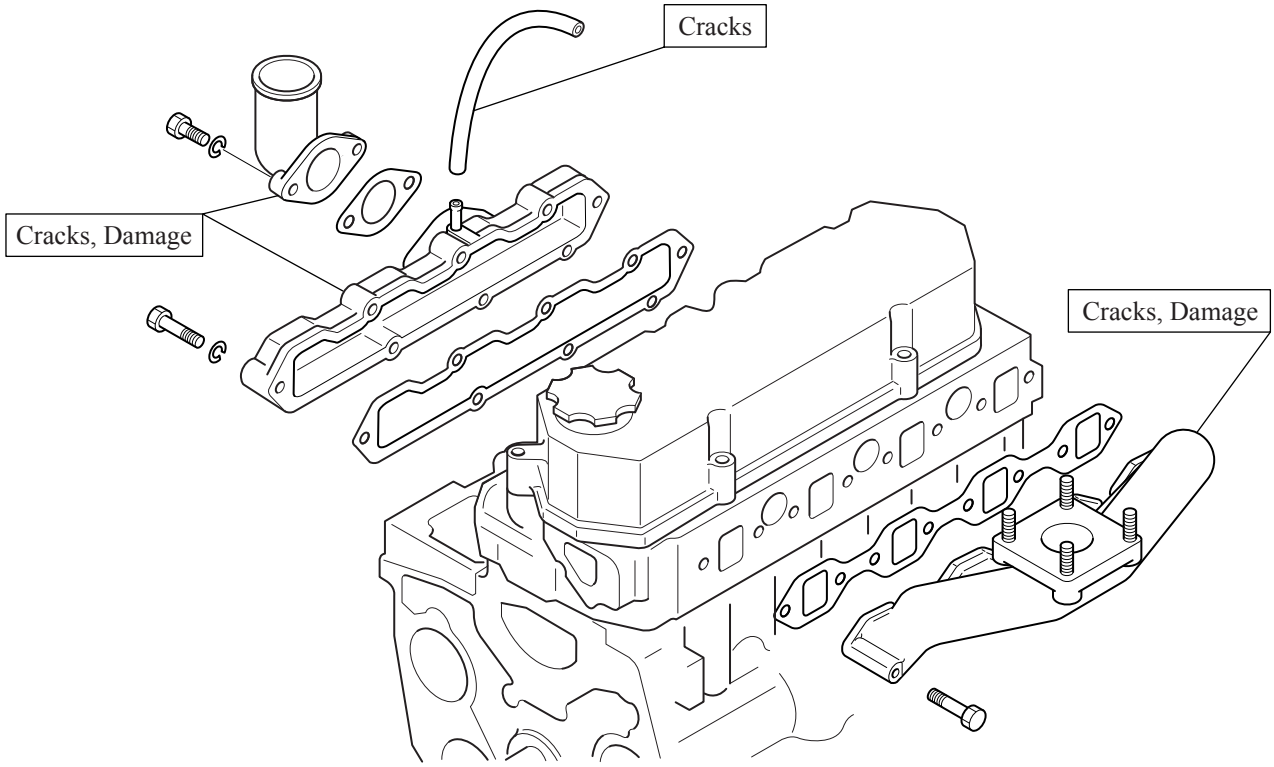


Removing the exhaust manifold

# INLET AND EXHAUST SYSTEMS - DISASSEMBLY, INSPECTION AND REASSEMBLY

# 1. Inlet Cover and Exhaust Manifold

## 1.1 Inspecting the inlet cover and exhaust manifold




Inspecting the inlet cover and exhaust manifold

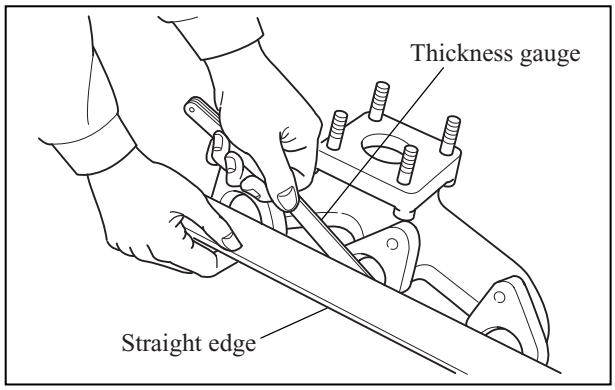
## 1.2 Measuring the exhaust manifold mounting face distortion

Using a straight edge across the exhaust manifold mounting face and a thickness gauge, measure any distortion.

If the measured distortion exceeds the limit, correct by grinding or replace the manifold.

Unit: mm (in.)

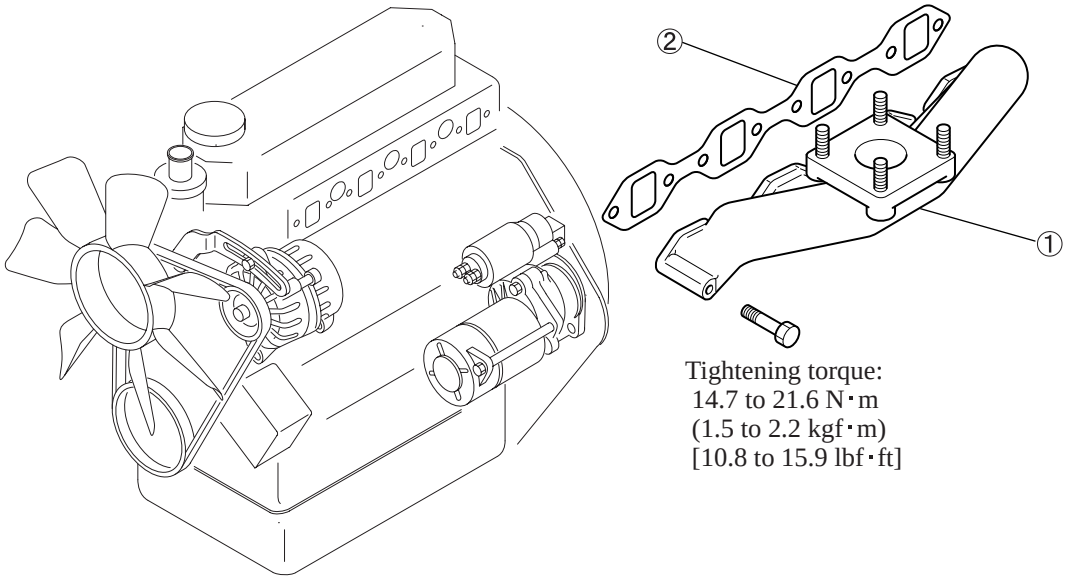
| | Limit |
|---|---|
| Exhaust manifold mounting face distortion | 0.15 (0.006) or less |




Measuring the exhaust manifold mounting face distortion

# INLET AND EXHAUST SYSTEMS - INSTALLATION

# 1. Exhaust Manifold

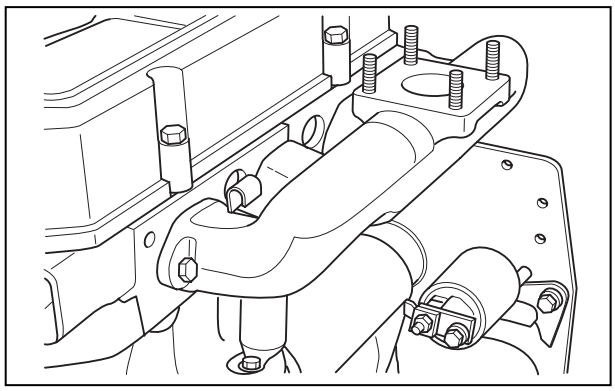



Installation of the exhaust manifold and gasket

<Installation sequence>
②→①

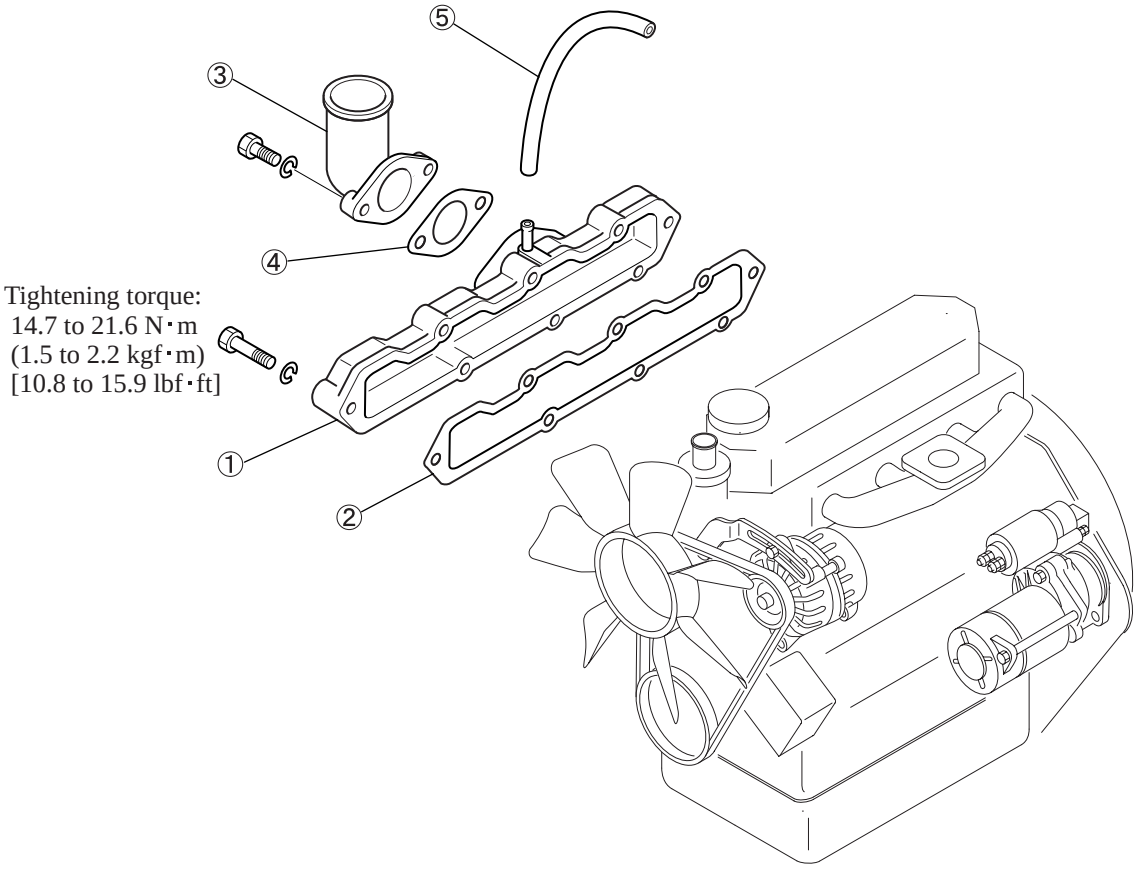
Installing the exhaust manifold

Install the exhaust manifold and tighten the retaining bolts to the specified torque.



Installing the exhaust manifold

## 2. Inlet Cover

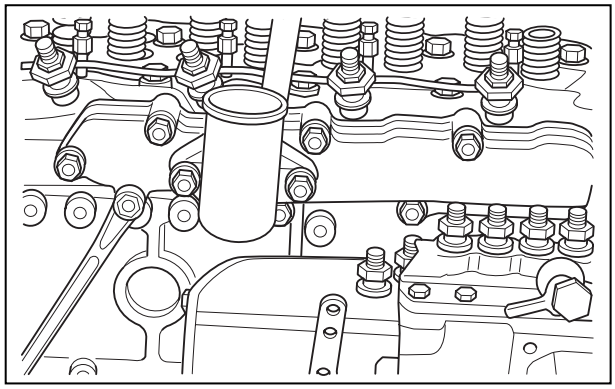



Installation of the inlet cover and air pipe

<Installation sequence>
⑤→④→③→②→①

Installing the inlet cover

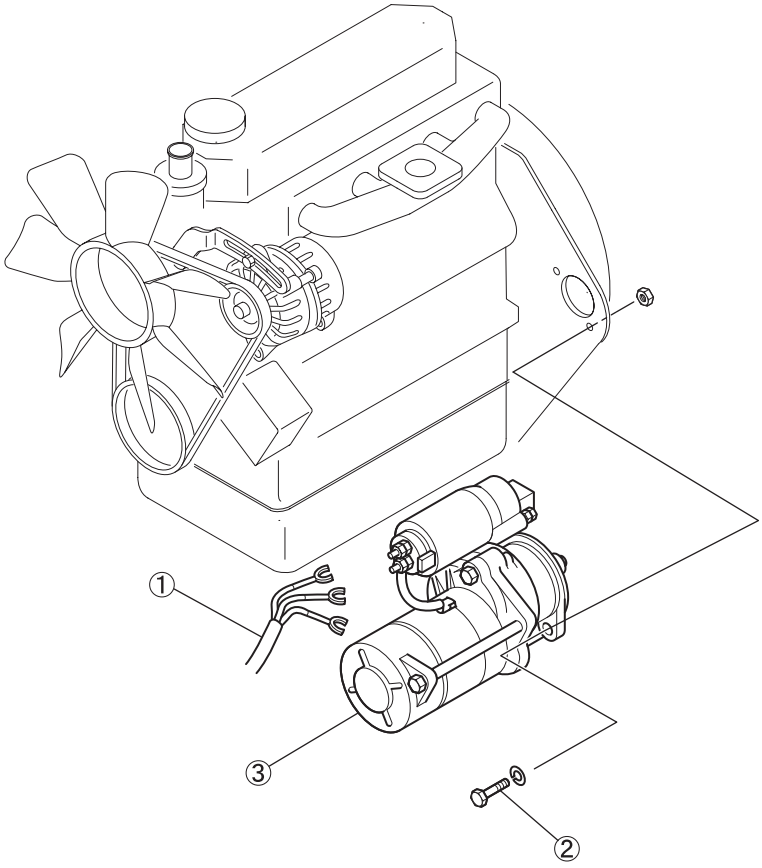
Install the inlet cover and tighten the retaining bolts to the specified torque.



Installing the inlet cover

# ELECTRICAL SYSTEM - REMOVAL

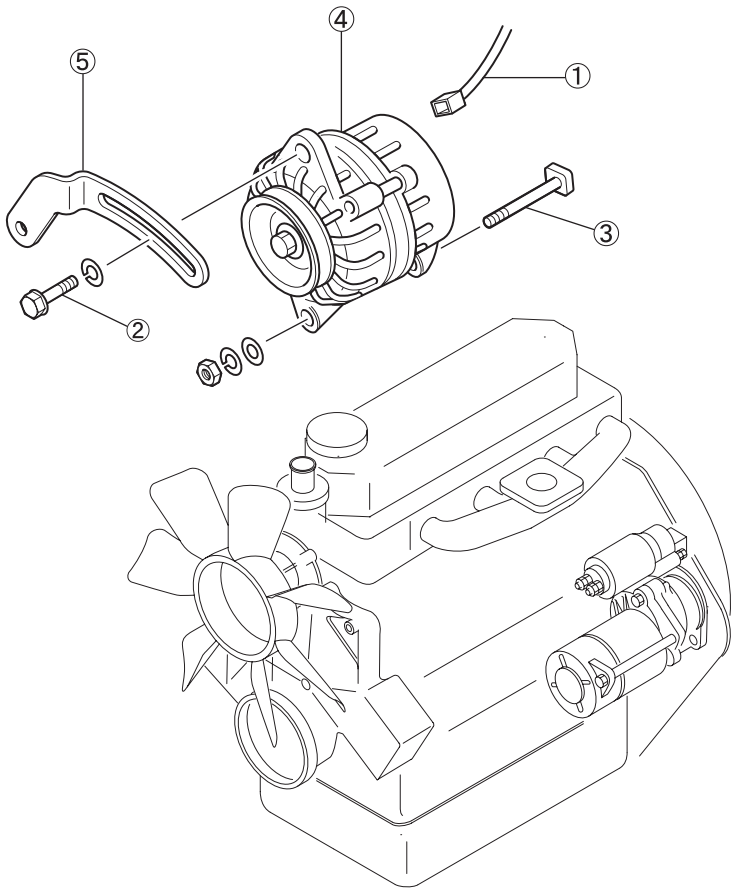
# 1. Starter




Removal of the starter

<Removal sequence>
① Harness ② Bolt ③ Starter

## 2. Alternator

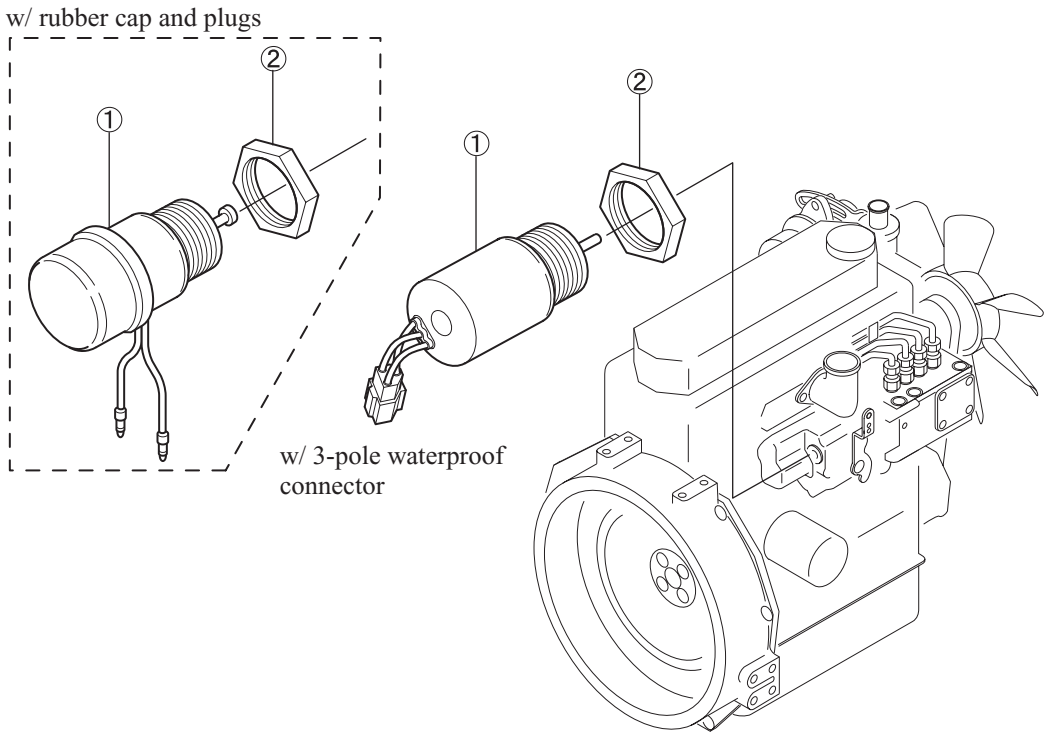



Removal of the alternator

<Removal sequence>

① Harness
② Adjusting bolt
③ Retaining bolt
④ Alternator
⑤ Adjusting plate

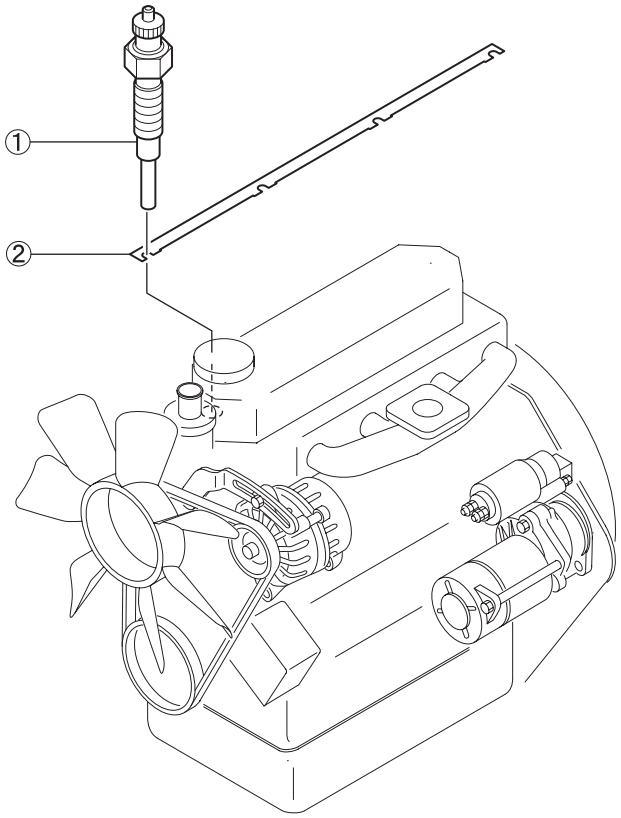
## 3. Stop Solenoid




Removal of the stop solenoid

<Removal sequence>
① Stop solenoid
② Nut

## 4. Glow Plug




Removal of the glow plug

<Removal sequence>
① Glow plug
② Connection plate

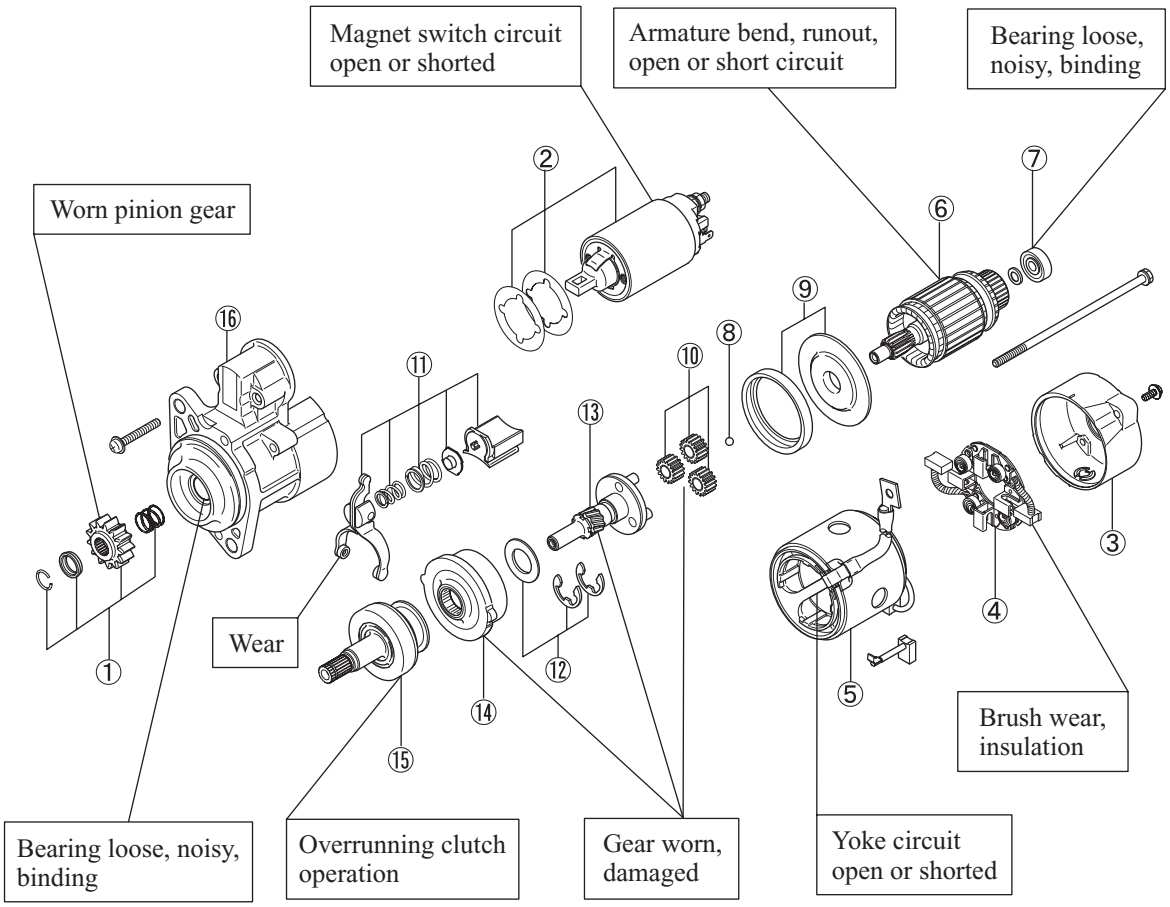
# ELECTRICAL SYSTEM - DISASSEMBLY, INSPECTION AND REASSEMBLY

# 1. Starter

## 1.1 Removing the starter

M008T70471A

M008T81071A

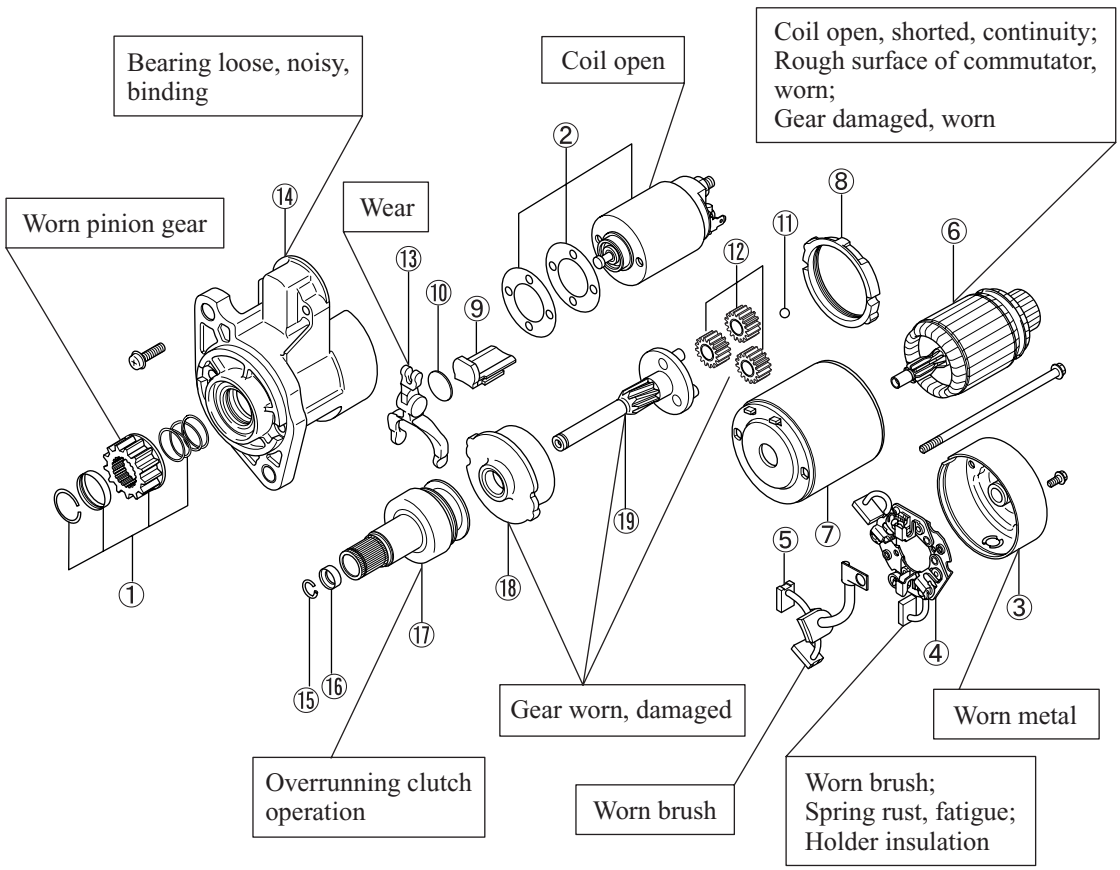



Disassembly of the starter

<Disassembly sequence>

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

M001T68281

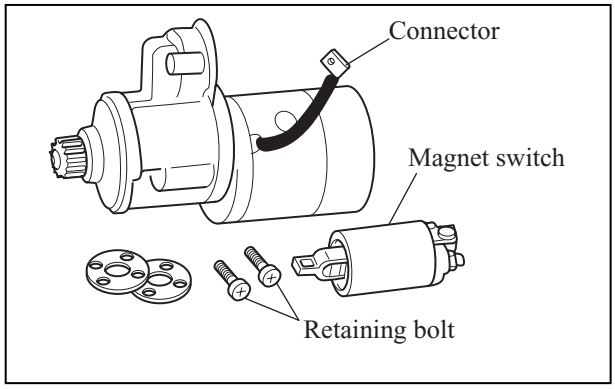



Disassembly of the starter

<Disassembly sequence>

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

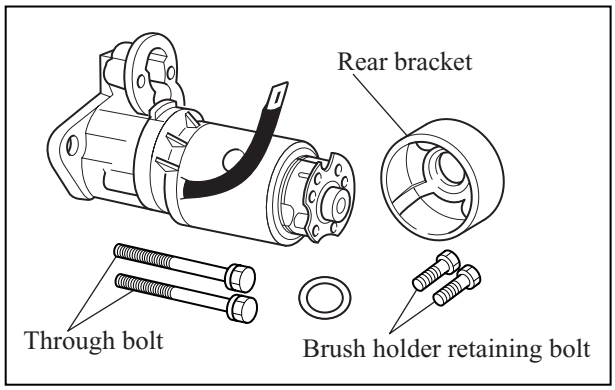
(1) Removing the magnet switch
  (a) Loosen the nut at M terminal, and disconnect the connector.
  (b) Loosen the two magnet switch retaining bolts, and remove the magnet switch.




Removing the magnet switch

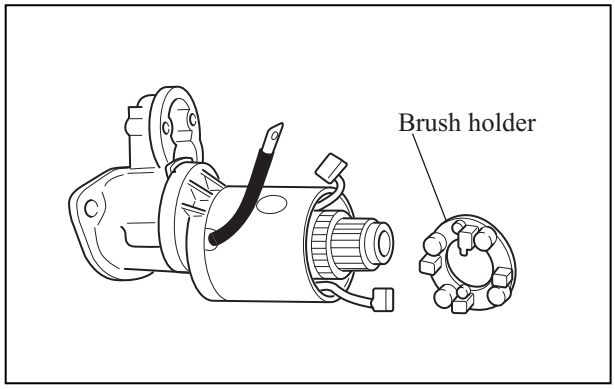
(2) Removing the rear bracket
Loosen the two through bolts and the two brush holder retaining bolts. Remove the rear bracket.

Note: There is an adjusting washer in the rear bracket. Do not lose it.



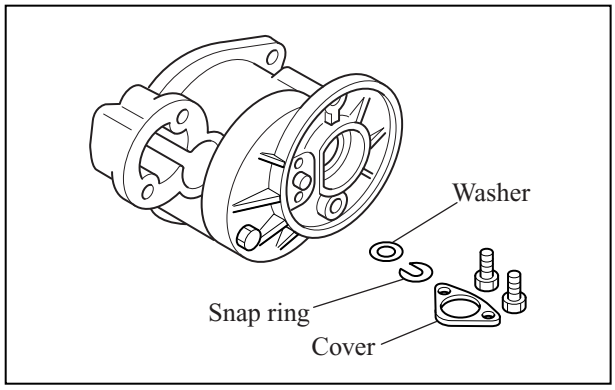

Removing the rear bracket

(3) Removing the brush holder
While lifting the two brushes, remove the yoke and brush holder assembly. Pull out the armature from the yoke.



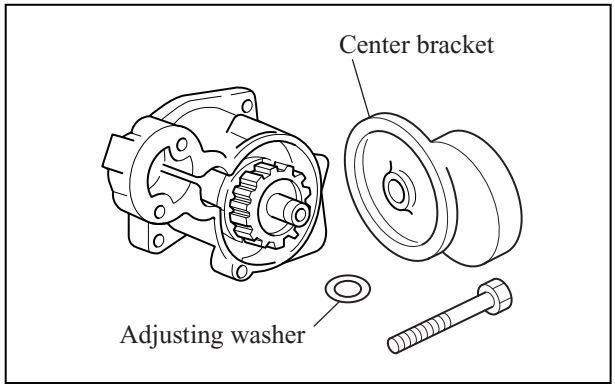

Removing the brush holder

(4) Removing the cover
Remove the cover, and take out the snap ring and the washer.




Removing the cover

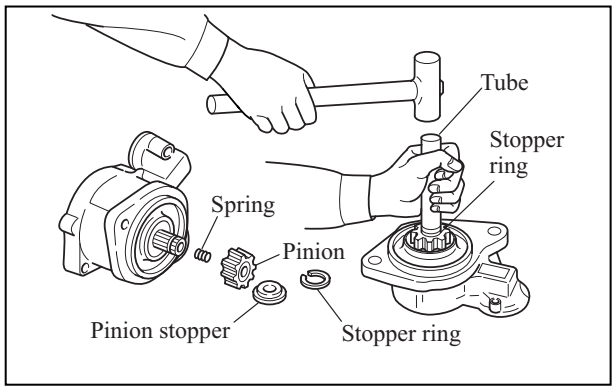
(5) Removing the center bracket
Loosen the bolt and remove the center bracket. Behind the center bracket, there is a washer for adjusting the pinion shaft end play.




Removing the center bracket

(6) Removing the pinion
(a) 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.
(b) Using a pair of pliers, remove the stopper ring. Remove the pinion.

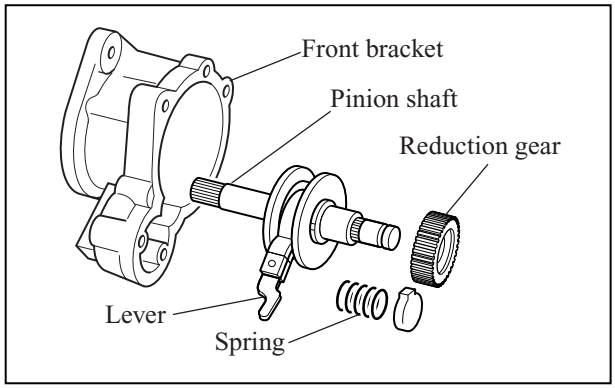
Note: The stopper ring should not be reused on reassembly.




Removing the pinion

(7) Removing the pinion shaft
Pull out the spring, lever, reduction gear and pinion shaft from the front bracket.

Note: To facilitate reassembly, note the correct installations of the lever and the spring as they are removed.




Removing the pinion shaft

(8) Removing the bearings
Using a bearing puller or other similar tool, remove the ball bearings at both ends of the armature.
The ball bearing that has been press-fit into the front bracket cannot be replaced. If the bearing is worn or faulty, replace the entire front bracket assembly.

## 1.2 Inspecting and correcting the starter

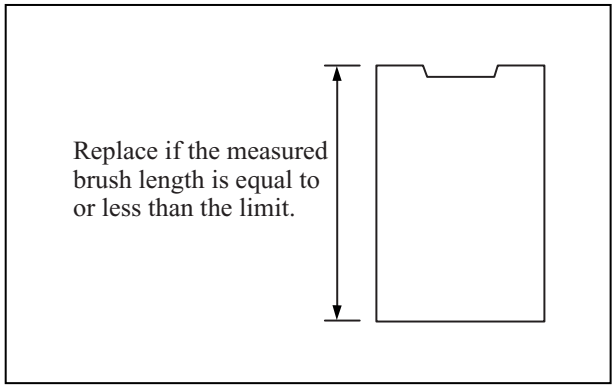
(1) Inspecting the brushes

(a) Brush wear

Measure the length of the brushes. If the measured value is equal to or less than the limit, replace both the brush assembly and the brush holder assembly.

Unit: mm (in.)

| | | Standard value | Limit |
|---|---|---|---|
| Brush length | M001T68281 | 16.5 (0.65) | 10.0 (0.39) |
| | M008T70471A M008T81071A | 18.0 (0.71) | 11.0 (0.43) |



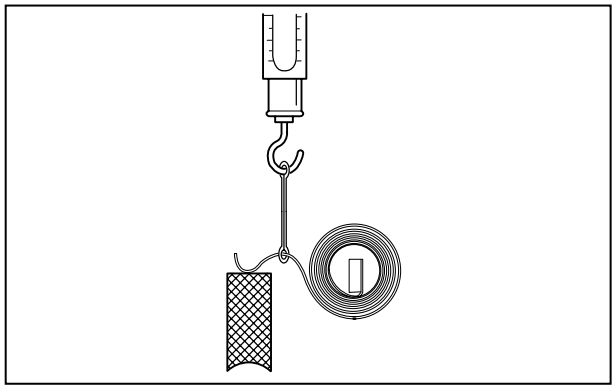

Inspecting the brushes

(b) Measuring the brush spring load

Using a new brush and a spring balance as illustrated, measure the spring load at which the spring lifts from the brush. If the measured value is equal to or less than the limit, replace the spring.

Unit: N (kgf) [lbf]

| | | Standard value | Limit |
|---|---|---|---|
| Brush spring load | M001T68281 | 17.5 to 23.7 (1.78 to 2.41) [3.9 to 5.3] | 6.90 (0.70) [1.6] |
| | M008T70471A M008T81071A | 29.4 to 39.2 (3.0 to 4.0) [6.6 to 8.8] | 13.7 (1.40) [3.1] |

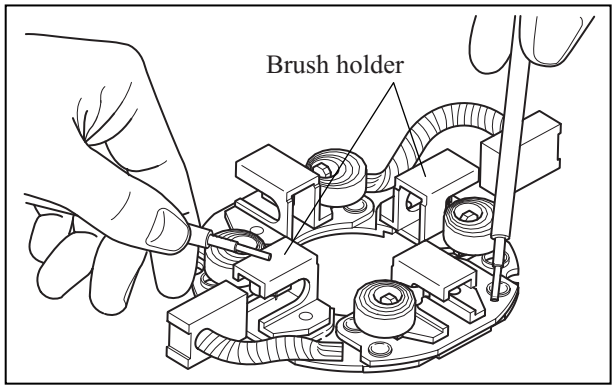


Measuring the brush spring load

(c) Brush holder insulation

Measure between each brush holder and the brush holder base for continuity. If continuity is indicated, replace the entire brush holder assembly.

Check the brush holder for looseness.



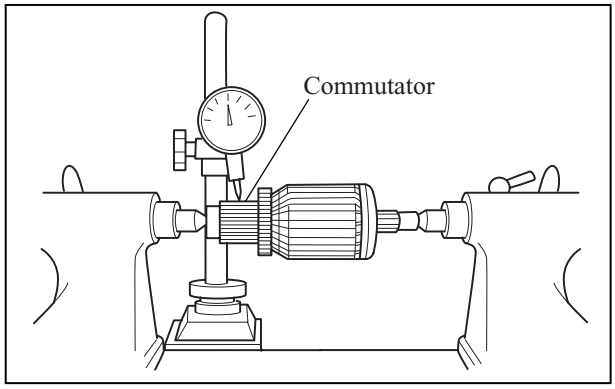

Checking the brush holder insulation

(2) Inspecting the armature

(a) Using a dial gauge, measure the commutator for radial runout. If the measure value is equal to or exceeds the limit, correct (within the diameter limit) or replace.

Unit: mm (in.)

| | | Standard value | Limit |
|---|---|---|---|
| Commutator radial runout | M001T68281 | 0.05 (0.002) | 0.10 (0.004) |
| | M008T70471A M008T81071A | 0.03 (0.001) | |

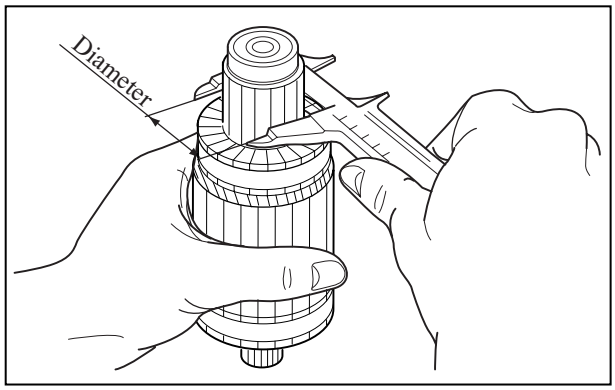



Measuring the commutator radial runout

(b) Measure the commutator diameter.
If the measured value is equal to or less than the limit, replace.

Unit: mm (in.)

| | | Standard value | Limit |
|---|---|---|---|
| Commutator diameter | M001T68281 | 29.4 (1.16) | 28.8 (1.13) |
| | M008T70471A M008T81071A | 32.0 (1.26) | 31.4 (1.24) |

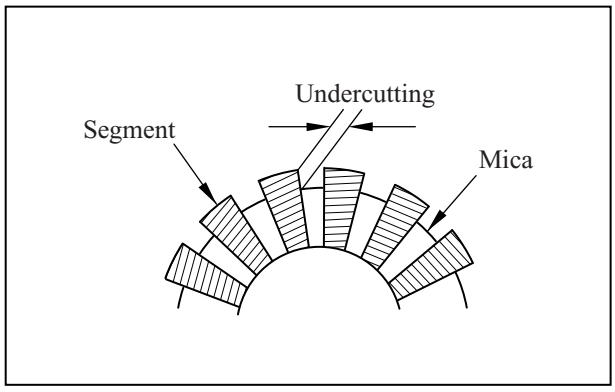



Measuring the commutator diameter

(c) Measure the depth of undercutting between the commutator segments.
If the measured value is equal to or less than the limit, correct or replace.

Unit: mm (in.)

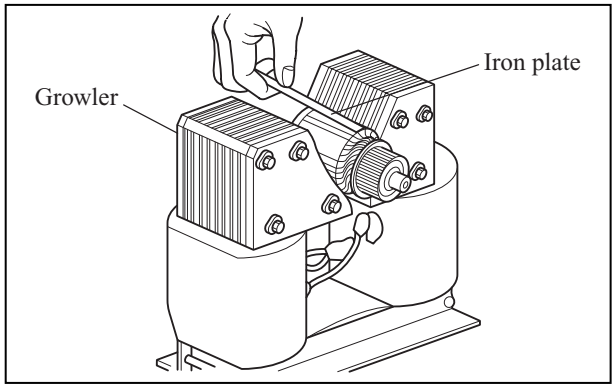
| | | Standard value | Limit |
|---|---|---|---|
| Mica undercutting depth | M001T68281 M008T70471A M008T81071A | 0.5 (0.02) | 0.2 (0.01) |




Measuring the mica undercutting depth

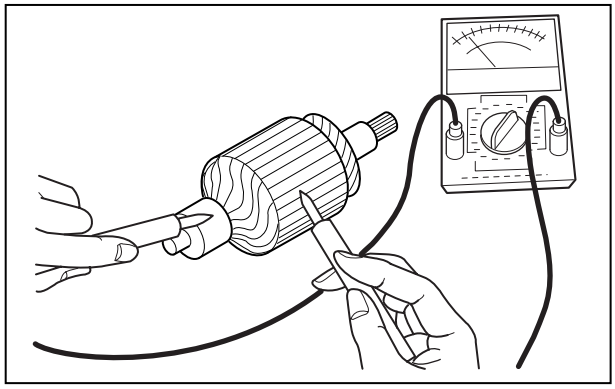
(d) Armature coil short circuit
Using a growler, test the armature coil for short circuit. Replace if short circuit is indicated.

How to inspect: (Before inspection, remove any debris from the armature coil.) With a thin iron plate positioned parallel with the armature coil, slowly rotate the armature coil. While the coil is running, the iron plate should not be pulled onto the coil or vibrate.



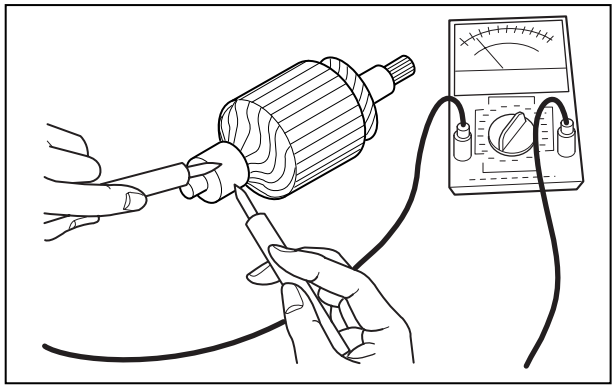

Testing the armature coil for short circuit

(e) Armature coil continuity
Measure between the commutator segment and the armature coil. There should be no continuity. If continuity is indicated, replace the armature.



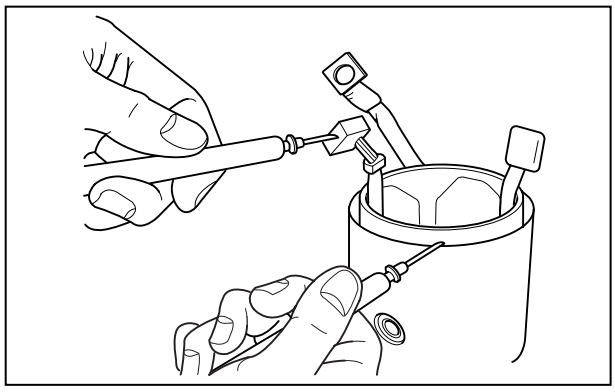
Testing the armature coil

(f) Armature coil open circuit
Measure between the segments in various combinations. There should be continuity. If no continuity, replace the armature.



Testing the armature coil for open circuit

(3) Inspecting the field coils
(M008T70471A, M008T81071A)
(a) There should be no continuity between the coil end (brush) and the yoke.
(b) There should be continuity between the coils (brushes).
(c) The pole-shoes and the coils should not be loose. If faulty, replace the yoke.



Inspecting the field coils

(4) Inspecting the bearings
Ensure that the bearings rotate smoothly without abnormal noise. If faulty, replace.

(5) Inspecting the rear bracket
If the metal is worn, replace the rear bracket.

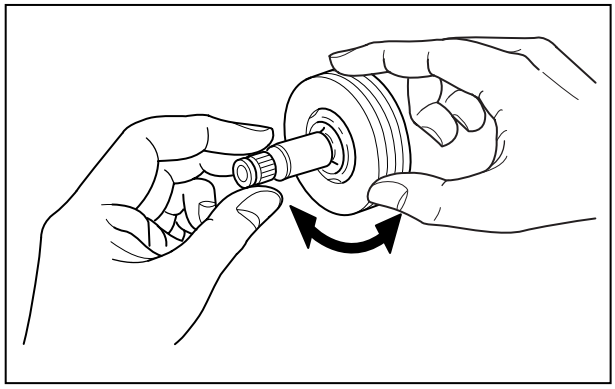
(6) Inspecting the overrunning clutch

(a) The shaft should rotate smoothly in one direction, but should not rotate in the opposite direction.

(b) Check the pinion for wear or damage. If faulty, replace.

**⚠ CAUTION**

Do not wash the overrunning clutch in wash oil.



Inspecting the overrunning clutch

(7) Front bracket

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

(8) Internal gear, planetary gears, and armature shaft gear

Replace if worn or damaged.

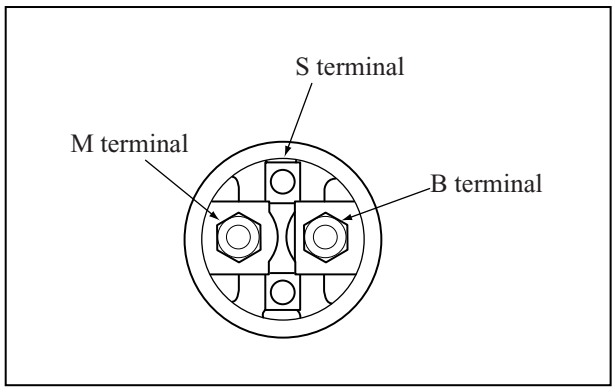
(9) Lever

As the lever's friction surface with the overrunning clutch wears, the pinion gap goes out of the standard value. If so, adjust or replace the lever.

(10) Magnet switch

Measure between M terminal and the body. If no continuity is indicated, replace the magnet switch.

Measure between B and M terminals. If continuity is indicated, replace the magnet switch.




Inspecting the magnet switch

## 1.3 Reassembling the starter

Reassembly follows the disassembly procedures in reverse while observing the following.

(1) Lubrication

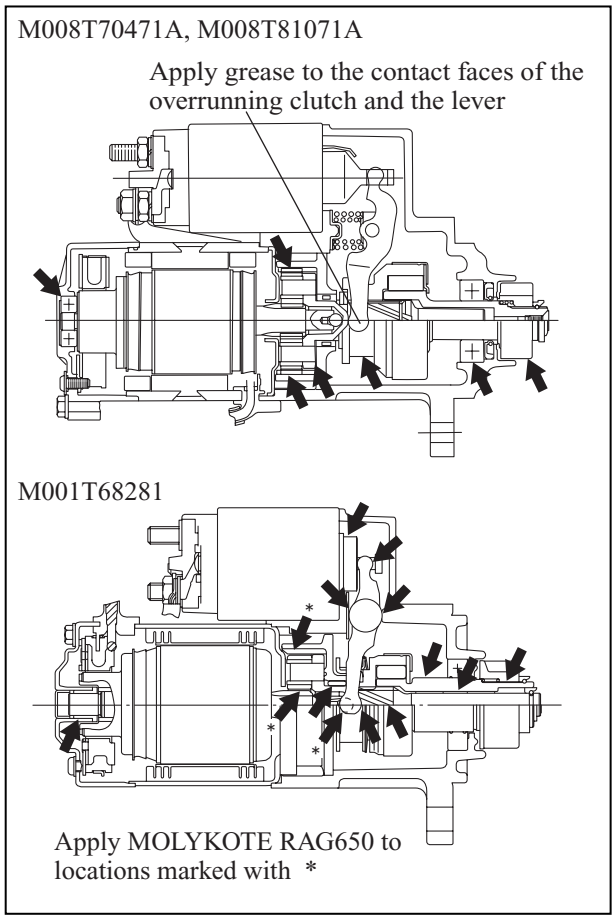
When the starter is overhauled, apply grease to the following sliding surfaces, gears and bearings.

| | |
|---|---|
| Grease | Multemp PS2 (KYODO YUSHI CO.,LTD) or equivalent |

(a) Armature shaft gear, reduction gears
(b) Bearings
(c) Pinion shaft washer and stopper ring
(d) Pinion
(e) Lever's sliding surfaces

**⚠ CAUTION**

Ensure that the starter mounting face, the brushes, the commutator and other current-carrying parts are not smeared with grease.

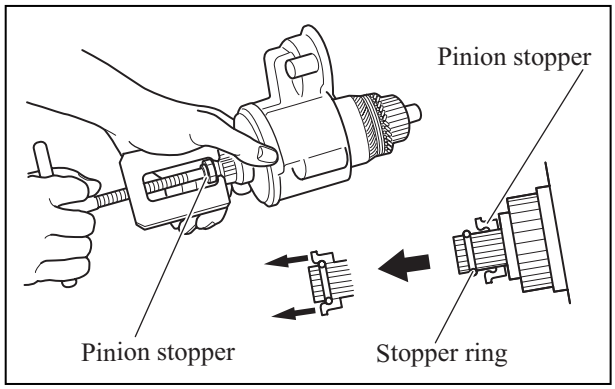



Grease points

(2) Installing the stopper ring

Install a new 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.

Note: On reassembly, use a new stopper ring.



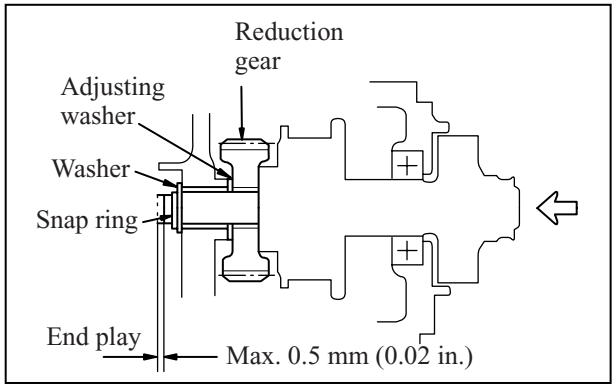

Installing the stopper ring

(3) Adjusting the pinion shaft end play

Adjust the end play (thrust gap) to 0.5 mm (0.02 in.) or less as illustrated by inserting an appropriate washer between the center bracket and the reduction gear.

(a) Install the pinion shaft complete with reduction gear washers and a snap ring onto the center bracket.

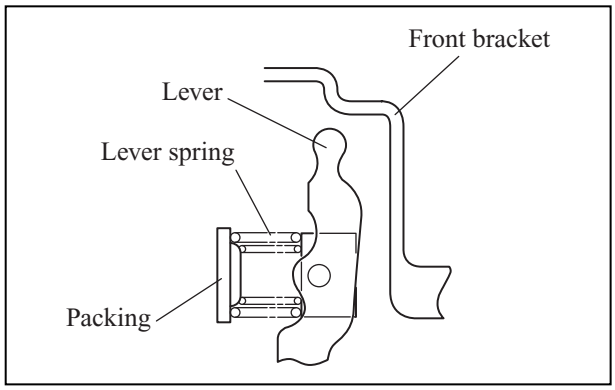
(b) Measure the pinion shaft end play by moving the shaft in the axial direction. If the measured value exceeds 0.5 mm (0.02 in.), correct by adding adjusting washers.




Adjusting the pinion shaft end play

(4) Installing the lever

Install the lever in the correct orientation.

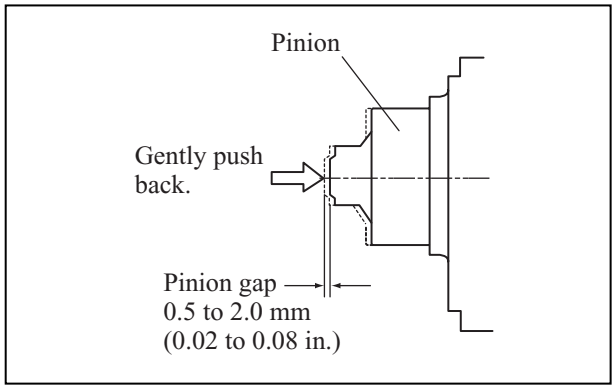



Installing the lever

(5) Inspecting the pinion gap

With the pinion fully pulled out to the rear, gently push back the end of the pinion with a finger and measure the distance that the pinion has moved back.

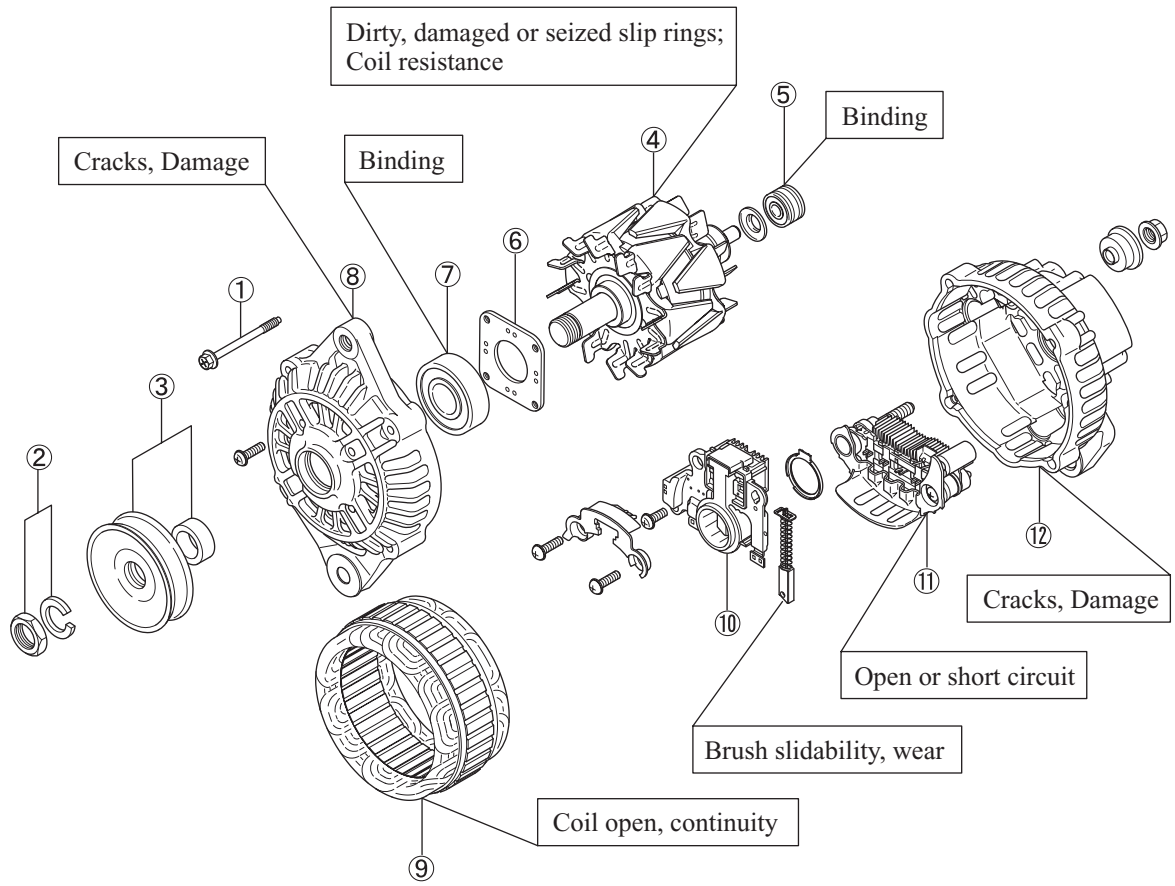
If the measured distance is out of the 0.5 to 2.0 mm (0.02 to 0.08 in.) range, add or reduce the packings mounted at the magnetic switch. If the pinion gap is too great, add the packings. If the pinion gap is too small, reduce the packings.




Adjusting the pinion gap

# 2. Alternator

## 2.1 Disassembling the alternator




Disassembling the alternator

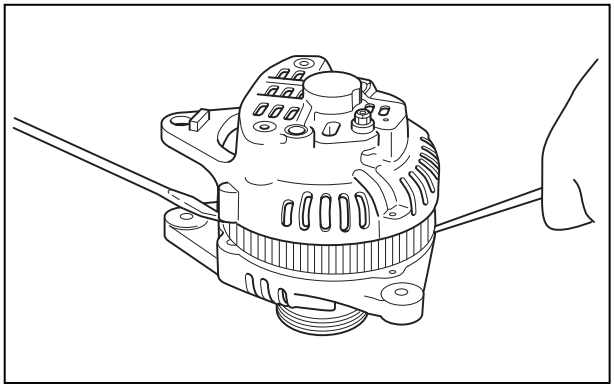
<Disassembly sequence>

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

(1) Separating the front bracket from the stator core
With flat-head screwdrivers positioned between the front bracket and the stator core, pry them away from each other.

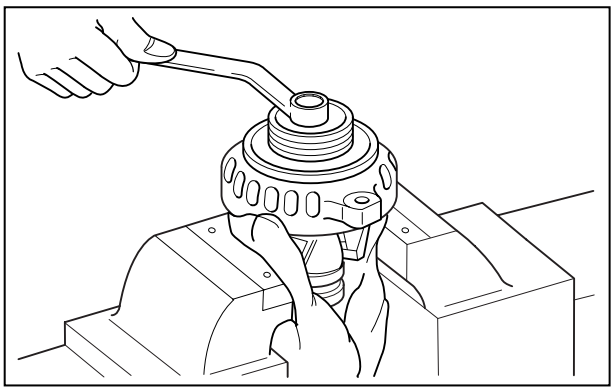
**⚠ CAUTION**

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



Separating the front bracket from the stator core

(2) Removing the pulley
(a) Protecting the rotor with cloth, place the front bracket and rotor assembly in a vice. Remove the pulley nut, then remove the pulley and the spacer.
(b) Pull out the rotor from the front bracket.



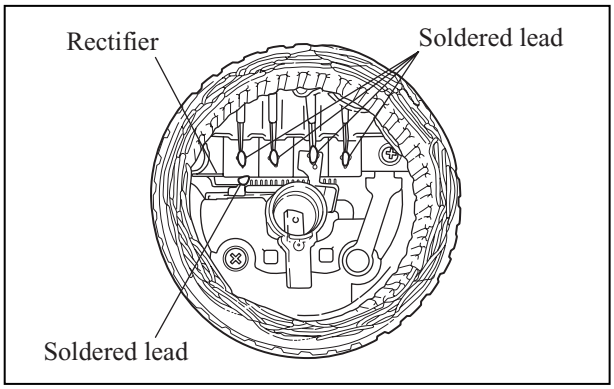
Removing the pulley

(3) Removing the stator core and the rectifier
(a) Unsolder the stator core leads at the rectifier. Remove the stator core.

**⚠ CAUTION**

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

(b) Loosen the retaining screws and remove the rectifier.




Removing the stator core

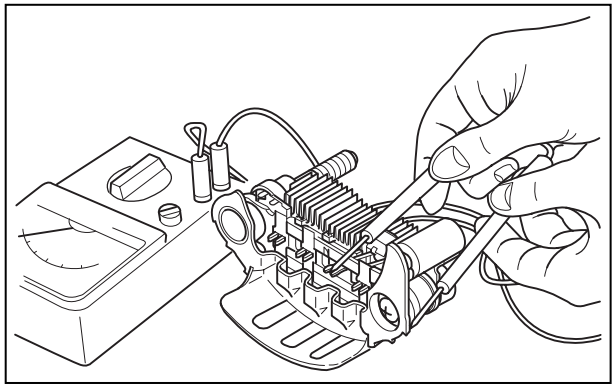
## 2.2 Inspecting and correcting the alternator

(1) Inspecting the diodes

Perform continuity test on each of the rectifier diodes in the following manner.

(a) Connect a tester between the diode lead terminal and the casing of that diode. A great resistance should be indicated in one direction and a small resistance in the opposite direction.

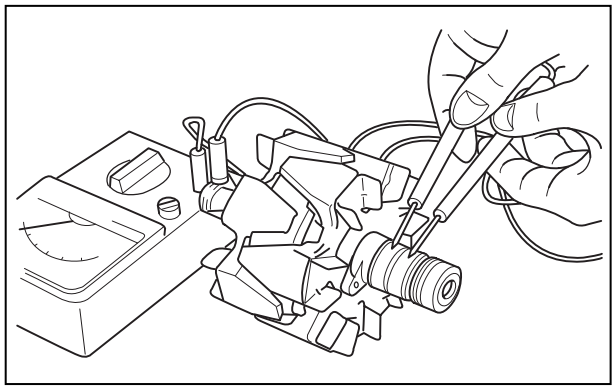
(b) If the same level of resistance is indicated in both directions, replace the rectifier. Perform this test on all diodes.



Inspecting the diodes

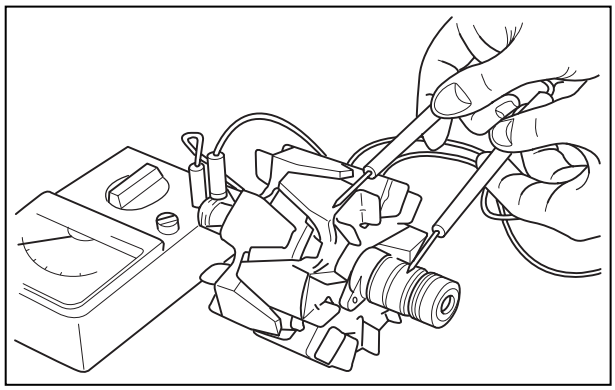
(2) Inspecting the field coils

(a) Measure between the slip rings. Replace if no continuity is indicated (open circuit).



Testing the field coils for open circuit

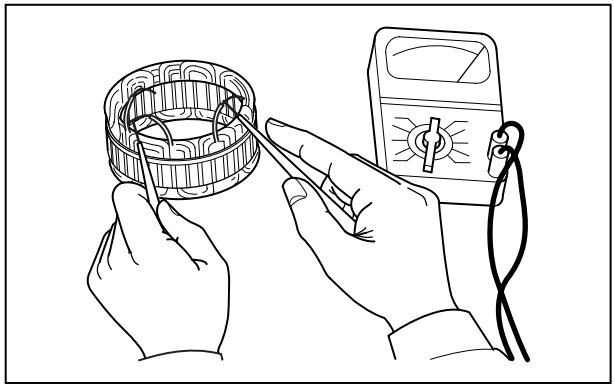
(b) Measure between the slip ring and the shaft (or the core). Replace if continuity is indicated.



Testing the field coils for continuity

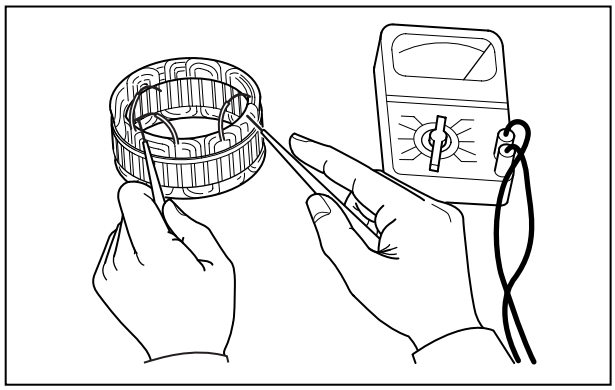
(3) Inspecting the stator core

(a) Measure between the stator leads in various combinations. Replace if no continuity is indicated (open circuit).



Testing the stator core for open circuit

(b) Measure between each lead and the stator core. Replace if continuity is indicated.



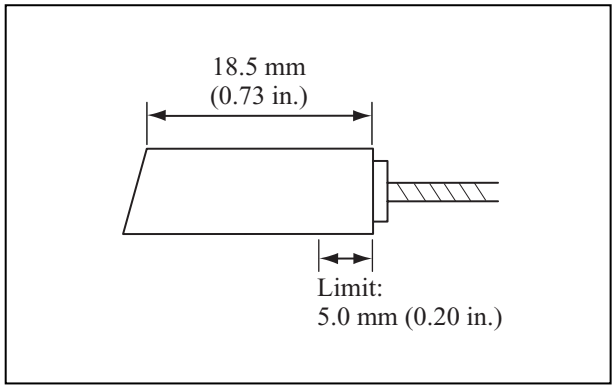
Testing the stator core for continuity

(4) Inspecting the brushes

(a) Measure the brush length. Replace if the measured value is equal to or less than the limit.

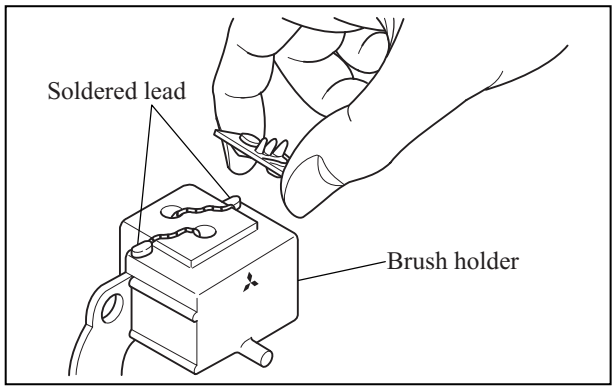
Unit: mm (in.)

| | Standard value | Limit |
|---|---|---|
| Brush length | 18.5 (0.73) | 5.0 (0.20) |



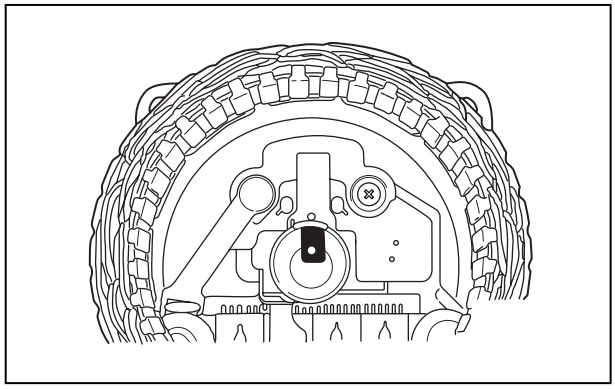

Inspecting the brush length

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




Removing the brush

(c) Push a new brush into the brush holder before soldering the brush lead.



Installing a new brush

## 2.3 Reassembling the alternator

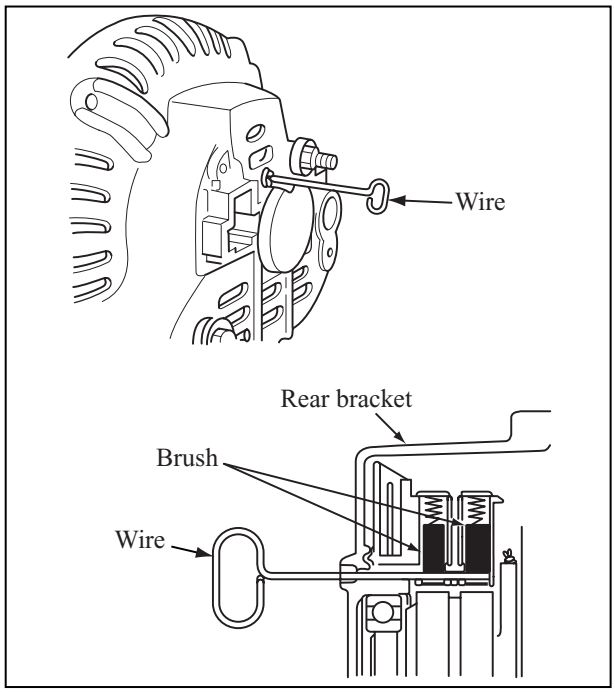
To reassembly, follows the disassembly sequence in reverse and do the following steps.

(a) The rear bearing has an eccentric groove around the periphery. The deepest portion of this groove should be aligned with the lug on the snap ring.

(b) When replacing the rear bearing, a new bearing should be press-fitted so that the groove on its periphery is placed to the slip ring side.

(c) Heat the rear bracket before press-fitting the rear bearing into the bracket.

(d) When installing the rotor into the rear bracket, insert a wire through a small hole in the bracket to lift the brushes. After installation, remove the wire.




Reassembling the alternator

# 3. Stop Solenoid

## 3.1 Reassembling the stop solenoid

### Stop solenoid with rubber cap and plugs

(1) Apply sealant onto the threaded portion of the stop solenoid.

Note: Apply sealant only to the area that will be concealed by the governor case when installed.

| Sealant | ThreeBond 1212 |
|---|---|

(2) Loosely install the stop solenoid and the nut onto the governor case.

(3) Move the fuel injection pump control rack fully to the stop position.

(4) While pushing the plunger, screw in the stop solenoid until the plunger contacts the control rack. At this position the clearance A should be 0 mm (0 in.) (the position where the plunger is screwed in along with the stop solenoid).

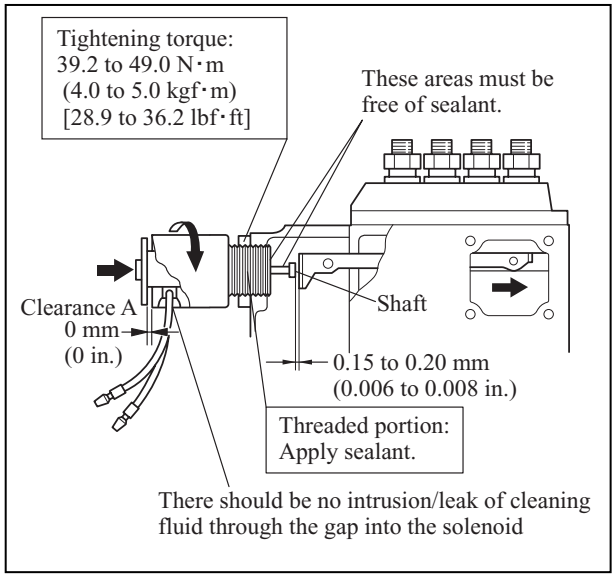
(5) Back off the stop solenoid by 30° to 45° from the position achieved in step (4) above until the clearance between the rack and the plunger becomes 0.15 to 0.20 mm (0.006 to 0.008 in.). Tighten the nut to the specified torque.

(6) Start the engine. When the plunger is fully pushed in, the engine should stop.

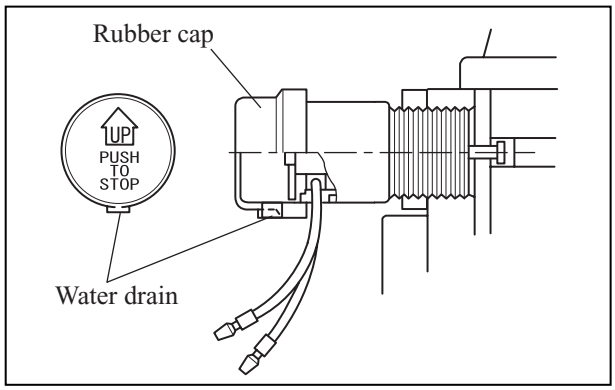
(7) Install the rubber cap so that the arrow points upwards (the water drain faces downwards) as illustrated.

**⚠ CAUTION**

Ensure that the solenoid terminals and inner parts (wiring and shaft) will not be exposed to cleaning fluid.




Installing the stop solenoid




Installing the rubber cap

Stop solenoid with 3-pole waterproof connector

(1) Apply sealant onto the threaded portion of the stop solenoid.

Note: Apply sealant only to the area that will be concealed by the governor case when installed.

| Sealant | ThreeBond 1212 |
|---|---|

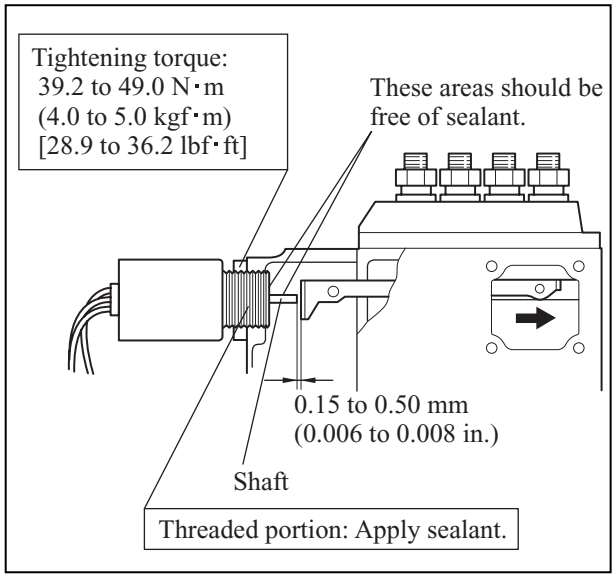
(2) Loosely install the stop solenoid and the nut onto the governor case.

(3) Move the fuel injection pump control rack fully to the stop position.

(4) While pushing the plunger, screw in the stop solenoid until the shaft contacts the tie-rod.

(5) Back off the stop solenoid by 30° to 45° from the position achieved in step (4) above until the clearance between the rack and the plunger becomes 0.15 to 0.20 mm (0.006 to 0.008 in.). Tighten the nut to the specified torque.

(6) Start the engine. When the plunger is fully pushed in, the engine should stop.




Installing the stop solenoid

### 3.2 Checks after reassembly

(1) Start the engine and turn the key OFF. The solenoid should trip, causing the engine to stop.

(2) With the engine running, ground the oil pressure switch terminal to the switch body. The engine should stop.

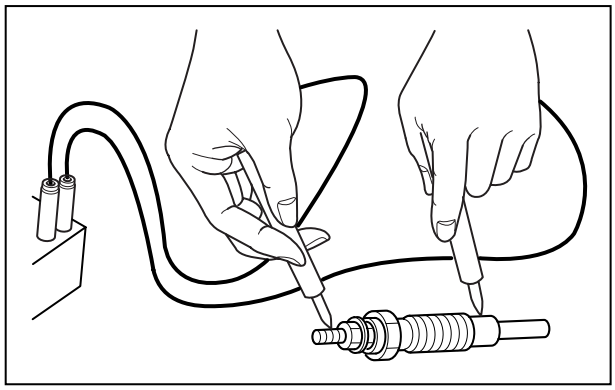
## 4. Glow Plug

### Inspecting the glow plug

Measure between the terminal and the body. Replace if no continuity is indicated or the resistance measured is too great.

Unit: Ω

| | Standard value |
|---|---|
| Resistance | 0.55 |

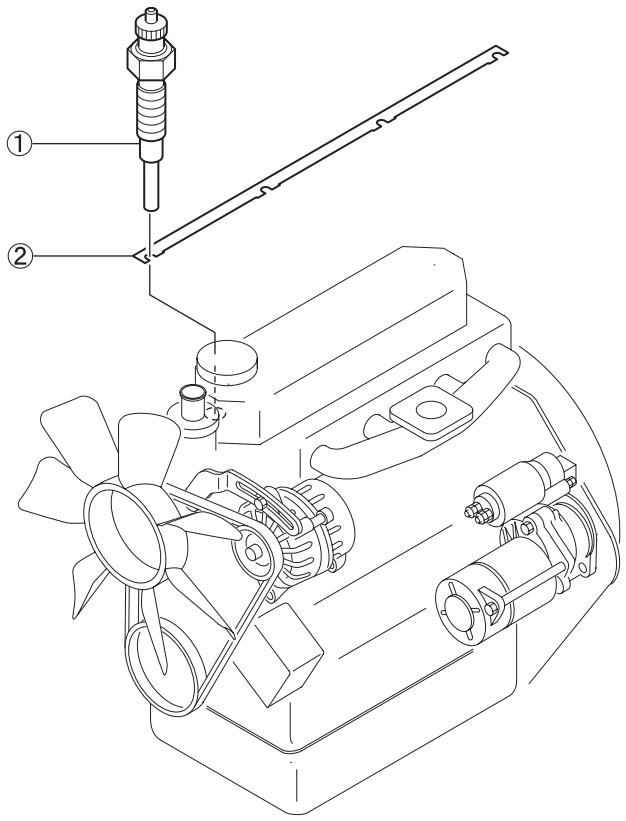


Inspecting the glow plug

# ELECTRICAL SYSTEM - INSTALLATION

## 1. Glow Plug

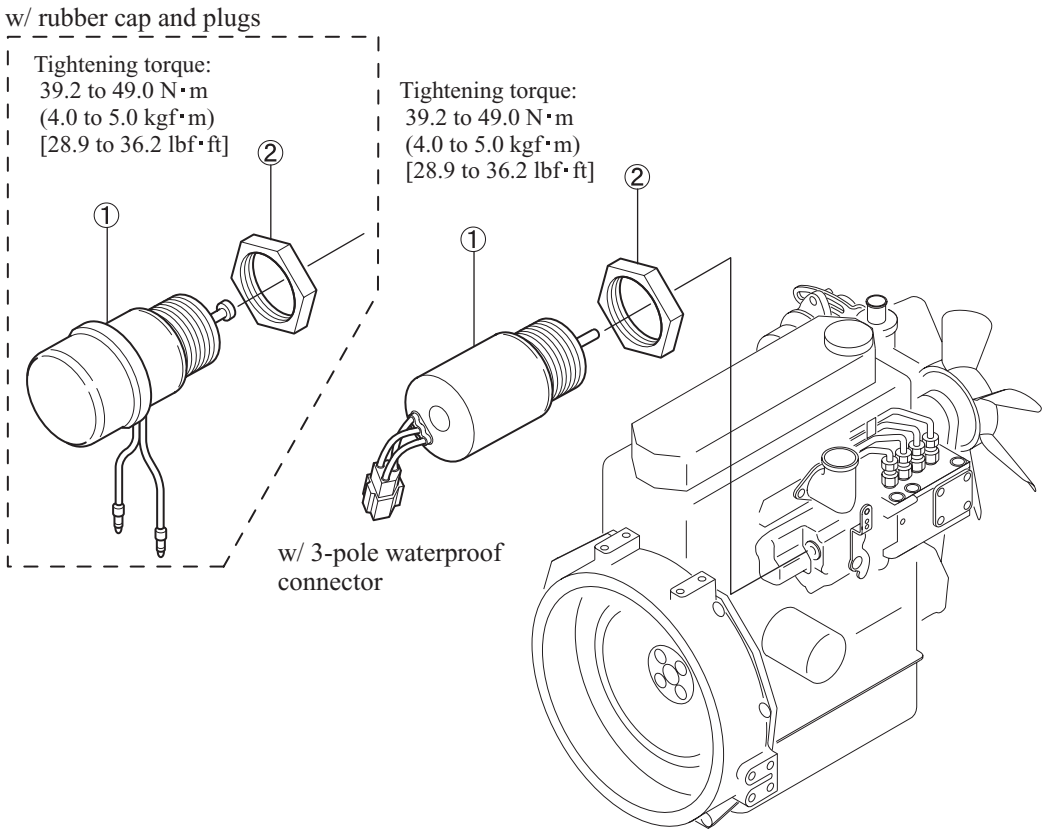
Tightening torque:
14.7 to 19.6 N·m
(1.5 to 2.0 kgf·m)
[10.8 to 14.5 lbf·ft]




Installation of the glow plug

<Installation sequence>
②→①

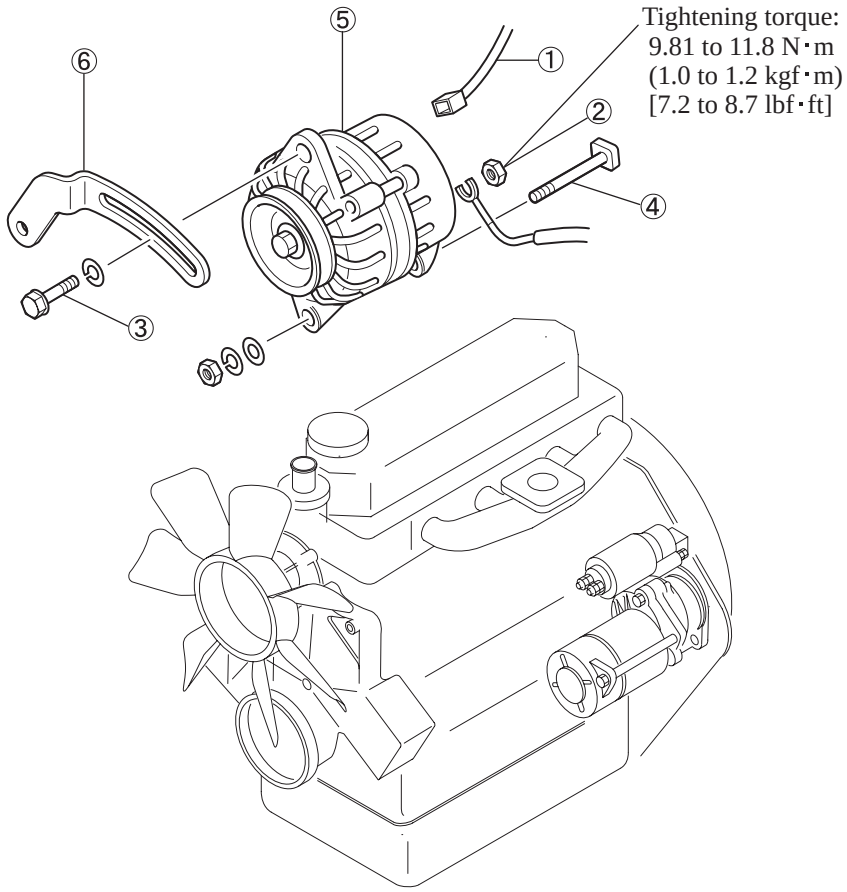
## 2. Stop Solenoid




Installation of the stop solenoid

<Installation sequence>
②→①

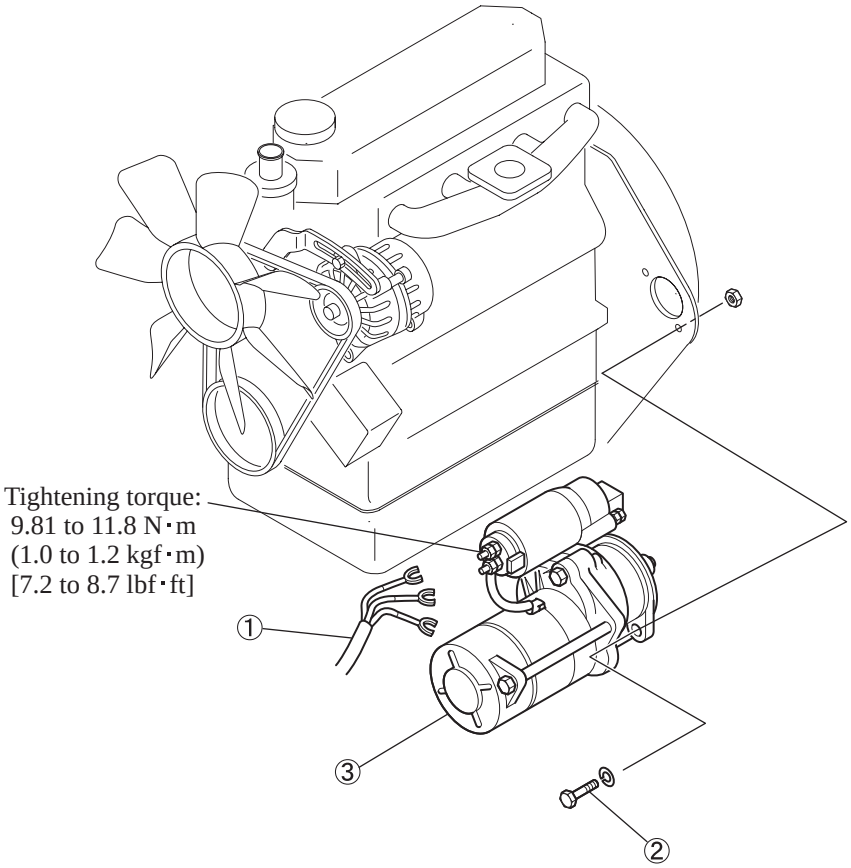
## 3. Alternator




Installation of the alternator

<Installation sequence>
⑤→④→③→②→①

## 4. Starter




Installation of the starter

<Installation sequence>
③→②→①

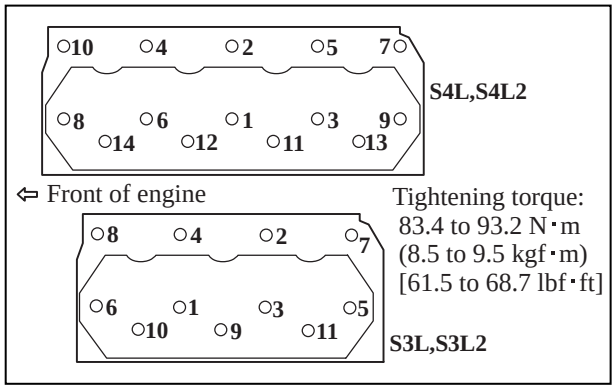
# ENGINE - INSPECTION / ADJUSTMENT, RUNNING-IN TRIAL AND PERFORMANCE TEST

# 1. Inspection and Adjustment of Engine

## 1.1 Preparations for valve clearance inspection and adjustment

(1) Inspection and adjustment of valve clearance should be performed when the engine is cold.

(2) Slightly loosen the cylinder head bolts. Then, tighten them to the specified torque in the order illustrated.




Tightening order for the cylinder head bolts

## 1.2 Inspecting the valve clearance

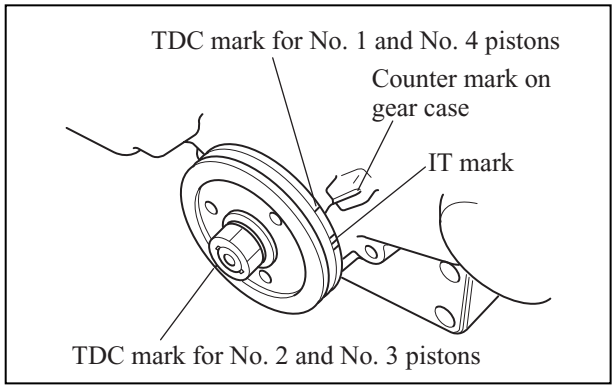
(1) Move the piston of the No. 1 cylinder to the top dead center of the compression stroke. This is achieved by aligning the TDC mark on the crankshaft pulley with the counter mark on the gear case.

(2) To verify that the No. 1 piston is at the top dead center of the compression stroke, rotate the crankshaft approx. 20º in both forward and reverse directions. If the relevant rocker arm does not move while rotating the crankshaft, the No. 1 piston is at the top dead center of the compression stroke.

(3) If the rocker arm moves, the piston of the No. 1 cylinder is at the exhaust top dead center. Try again to set the No. 1 piston at the top dead center of the compression stroke by rotating the crankshaft one more turn.

(4) Starting with the No. 1 cylinder and moving to other cylinders in the firing order, inspect and adjust the valve clearance. With the valve clearance for the No. 1 cylinder adjusted, set the piston of the next cylinder in the firing order to the top dead center of the compression stroke. To do this, rotate the crankshaft in the forward direction (clockwise when facing the timing gear case) by 180º.

| Firing order (Cylinder No.) | Crankshaft rotation angle |
|---|---|
| 1-3-2 | 240º |
| 1-3-4-2 | 180º |



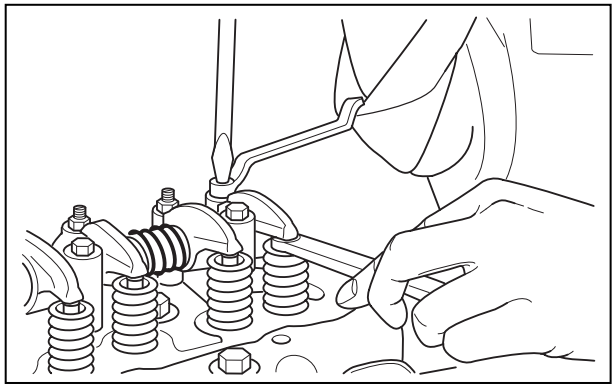

Timing marks

## 1.3 Adjusting the valve clearance

(1) Loosen the rocker arm nut. Using a thickness gauge, set the valve clearance to the standard value by screwing in or out the adjusting screw.

Unit: mm (in.)

| | | Standard value |
|---|---|---|
| Valve clearance | Inlet | 0.25 (0.01) |
| | Exhaust | 0.25 (0.01) |



Adjusting the valve clearance

(2) While holding the adjusting screw to prevent it from turning, tighten the nut.

**⚠ CAUTION**

If the valve clearance is adjusted during engine overhaul, check the valve clearance again after rotating the crankshaft a couple of turns.

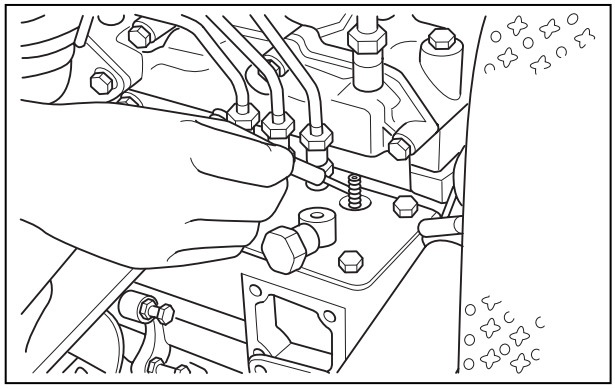
## 1.4 Inspecting and adjusting the fuel injection timing

(1) Preparations

(a) Close the fuel filter cock.

(b) Disconnect the No. 1 fuel injection pipe at both ends.

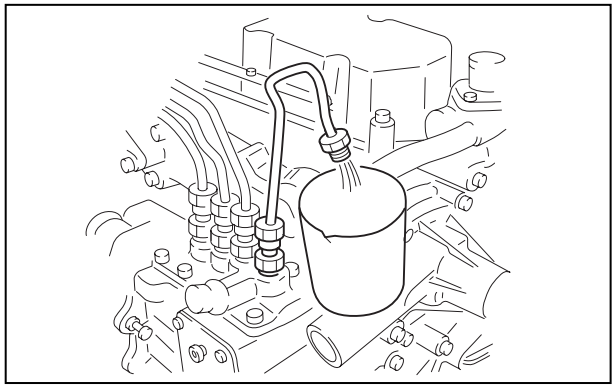
(c) Remove the No. 1 delivery valve holder. Take out the delivery valve and the spring. Install the delivery valve holder only.



Removing the delivery valve and the spring

(d) Reconnect the No. 1 fuel injection pipe at the pump end only to see the fuel flow.

(e) Set the speed control lever to LOW speed.



Fuel coming out

(2) Inspecting the fuel injection timing

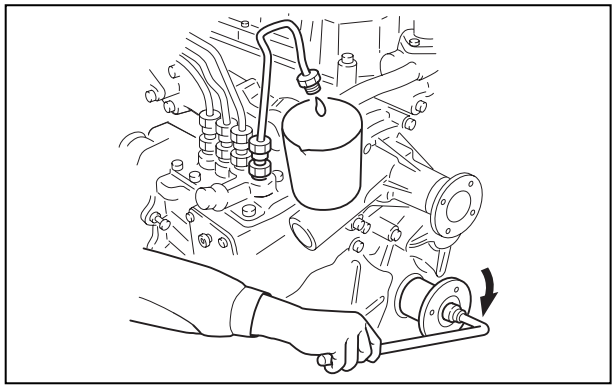
(a) Open the fuel filter cock. If the engine is equipped with a fuel pump, turn the key ON.

Note: Place a container under an open end of the fuel injection pipe to collect fuel coming out in the next step. On the engine equipped with a fuel pump, be prepared as fuel will come out fiercely.

(b) Slowly rotate the crankshaft clockwise. Fuel will come out of the fuel injection pipe. The injection timing (IT) is just when the fuel stops coming out.

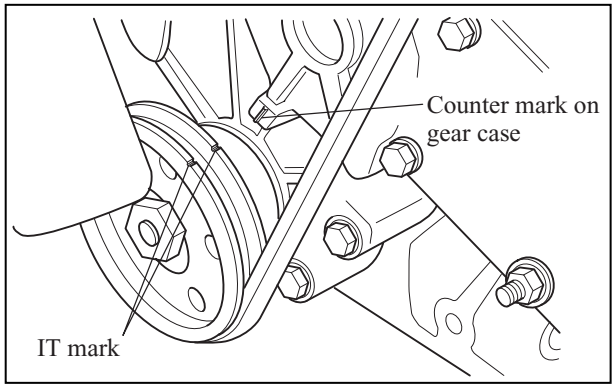
Note: When fuel has stopped coming out, slightly rotate the crankshaft in the reverse direction and then slowly rotate it clockwise to let fuel come out. This will show more exactly when fuel stops coming out.

(c) Just when fuel stops coming out, the IT mark on the crankshaft pulley should be aligned with the counter mark on the gear case.



Fuel stops coming out

| Injection timing (BTDC) |
|---|
| 17° |




Timing marks (2)

(3) Adjusting the fuel injection timing

(a) If the fuel injection timing does not conform to above specified BTDC, adjust the shim thickness under the fuel injection pump housing. Changing the shim thickness by 0.1 mm (0.004 in.) will change the fuel injection timing by approx. 1°

(b) Increasing the shim thickness will retard the fuel injection timing. Reducing the shim thickness will advance the fuel injection timing.

| Adjustment range | Standard value ±1.5º |
|---|---|

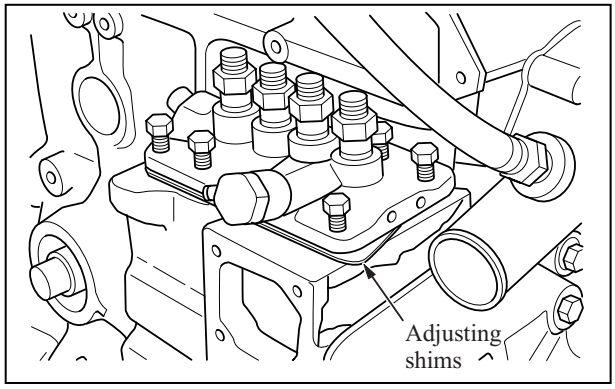
Shims are available in thicknesses of 0.2 mm (0.008 in.), 0.3 mm (0.012 in.), 0.4 mm (0.016 in.) and 0.8 mm (0.031 in.). Thicknesses are not indicated on shims. Measure the thickness of the shim being used with a pair of vernier calipers or other similar tool to confirm the thickness.

**⚠ CAUTION**

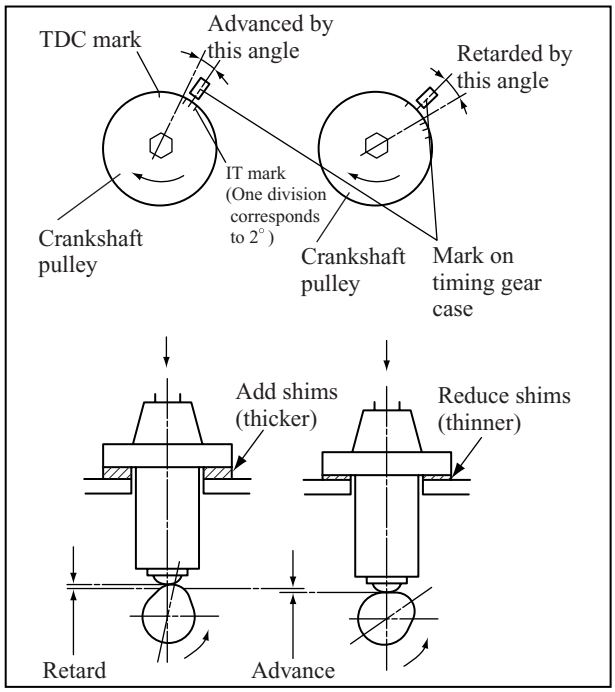
Apply sealant to both sides of the shim to prevent oil leakage.

(c) Verify the fuel injection timing after adjustment.

(d) Close the fuel filter cock. Install the delivery valve spring and the fuel injection pipe.




Shims for adjusting the fuel injection timing

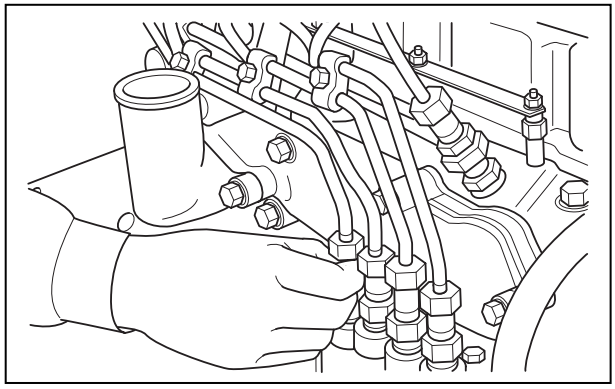



Adjusting the fuel injection timing

## 1.5 Alternative adjustment method

Removing the delivery valve to check and adjust the fuel injection timing is a sure way to observe fuel coming out and stop. However, this also runs the risk of allowing foreign matter to enter into the system. The following alternative method can be tried which allows you to check the fuel injection timing without removing the delivery valve.

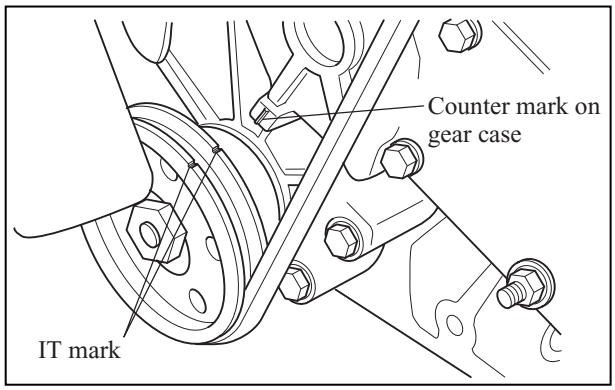
(1) Disconnect the No. 1 fuel injection pipe at the nozzle holder end.



Removing the No. 1 fuel injection pipe

(2) Slowly rotate the crankshaft clockwise while observing the open end of the pipe. When fuel starts to bulge out from the pipe end, check the location of the IT mark on the crankshaft pulley. In this case, allow for approx. 1º from the specified fuel injection timing.

Note: Bleed the system of air before rotating the crankshaft.




Timing marks (2)

## 1.6 Replacing the fuel filter

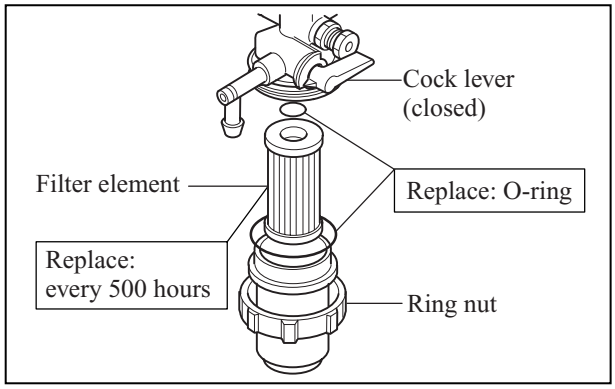
(1) Fuel filter with selector cock

(a) Close the cock lever. Loosen the ring nut, then remove the filter element.

(b) Install a new filter element.

(c) Using a new O-ring, tighten the ring nut.

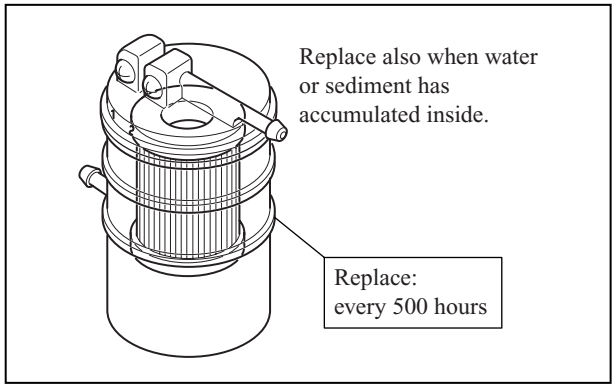
(d) Open the cock lever. Bleed the filter of air.




Replacing the fuel filter

(2) Fuel filter (cartridge type)

Replace the entire fuel filter assembly. After replacement, bleed the filter of air.




Replace also when water or sediment has accumulated inside.

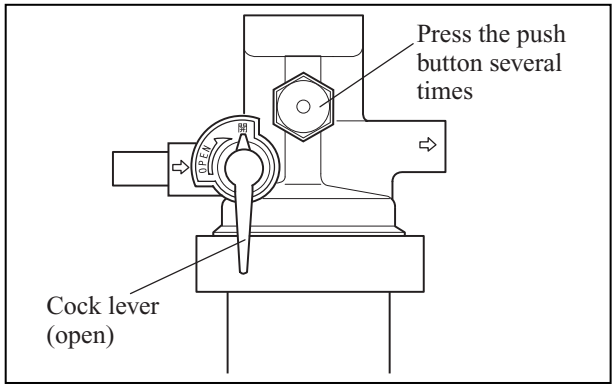
## 1.7 Bleeding the fuel filter of air

(1) Fuel filter with selector cock (push-button type)

(a) Open the cock lever and press the push button several times. Fuel will automatically come down into the filter. With the engine equipped with the fuel pump, turning the key ON will cause fuel to enter into the filter.

(b) Repeatedly press the button until fuel with air bubbles no longer comes out.

(c) Air trapped in the fuel injection pipe and the nozzle will be bled automatically by cranking the engine.



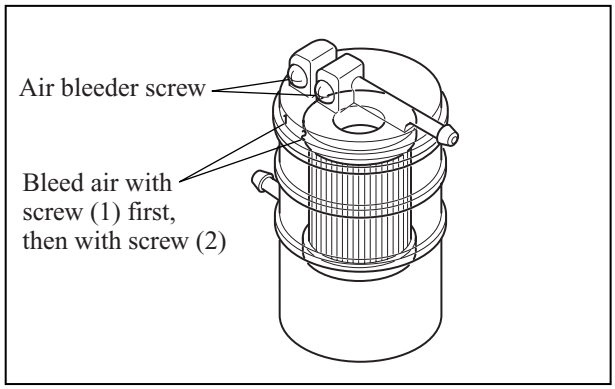

Bleeding the fuel filter of air (push button type)

(2) Fuel filter (cartridge type)

(a) With the engine equipped with the fuel pump, turn the key ON. Fuel will automatically come down into the filter.

(b) Loosen the air bleeder screw (1). When fuel with air bubbles no longer comes out, tighten the screw.

(c) Loosen the air bleeder screw (2). When fuel with air bubbles no longer comes out, tighten the screw.




Bleeding the fuel filter of air (cartridge type)

## 1.8 Adjusting the low and high idle speeds

(1) Preparations

(a) Warm up the engine until the coolant temperature reaches 60℃ (140 ℉) or above.

Note: Ensure that the valve clearance and the fuel injection timing are correctly adjusted and that the nozzles operate normally.

(2) Adjusting the low idle speed

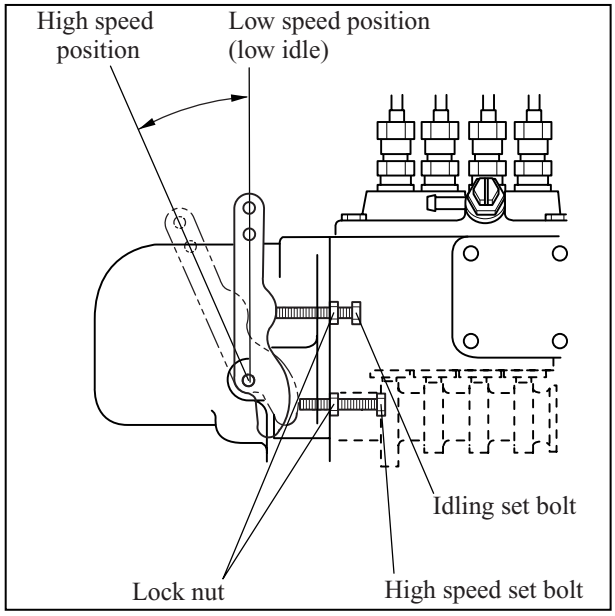
Loosen the lock nut for the idling set bolt. Screw in or out the bolt to set the low idle speed to specification. Tighten the lock nut.

| | |
|---|---|
| Low idle speed | $1000 \pm 25$ min$^{-1}$ |

(3) Adjusting the high idle speed

Loosen the lock nut for the high speed set bolt. Screw in or out the bolt to set the high idle speed to specification. Tighten the lock nut.

| | |
|---|---|
| High idle speed | $2700\ ^{+30}_{-10}$ min$^{-1}$ |




Adjusting the idle speeds

## 1.9 Inspecting the fuel injection nozzle

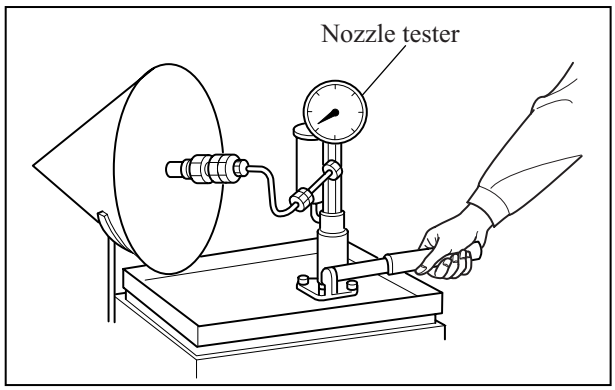
Perform the following inspections and, if faulty, repair or replace as required.

(1) Injection valve opening pressure

(a) Install the fuel injection nozzle onto the nozzle tester. Pump the tester handle to bleed air.

(b) Pump the tester handle at a rate of approx. one cycle per second while observing the needle of the tester.

Note: The needle should rise slowly and, during fuel injection, should vibrate. The pressure at which the needle starts to vibrate is the injection valve opening pressure.




Inspecting the injection valve opening pressure

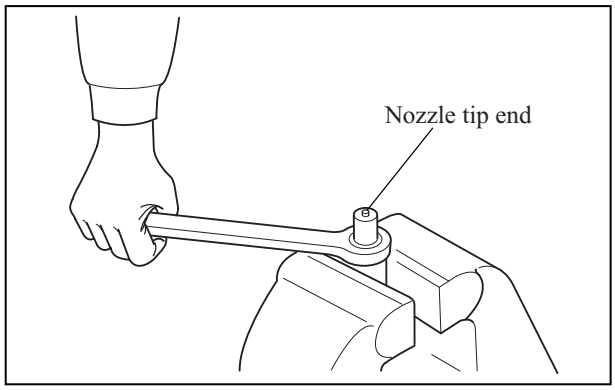
(c) If the measured pressure does not conform to the standard value, disassemble and adjust the thickness of the washer.

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

| | Standard value |
|---|---|
| Injection valve opening pressure | 14.22 to 15.00<br>(145 to 153)<br>[2062 to 2176] |

(d) Change in washer thickness by 0.1 mm (0.004 in.) results in a pressure change of 1.0 MPa (10 kgf/cm$^2$) [145 psi].

Washers are available in 10 different thicknesses at intervals of 0.05 mm (0.002 in.) in the range between 1.25 and 1.70 mm (0.049 and 0.067 in.).




Replacing the fuel injection nozzle tip assembly

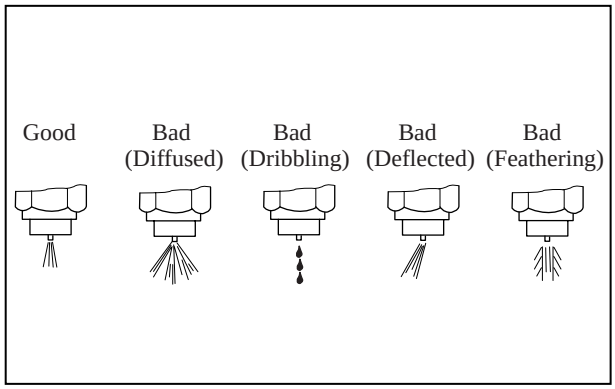
**⚠ CAUTION**

Never touch the spray of fuel from the fuel injection nozzle as it can cause severe burn.

(2) Inspecting the fuel spray pattern from the fuel injection nozzle

(a) When inspecting the injection valve opening pressure using the nozzle tester, also check for such as clogged nozzle hole, fuel spray pattern and fuel leakage from the nozzle hole.

(b) When the tester handle is pumped at a rate of approx. one cycle per second, fuel should be sprayed in a fairly straight pattern.



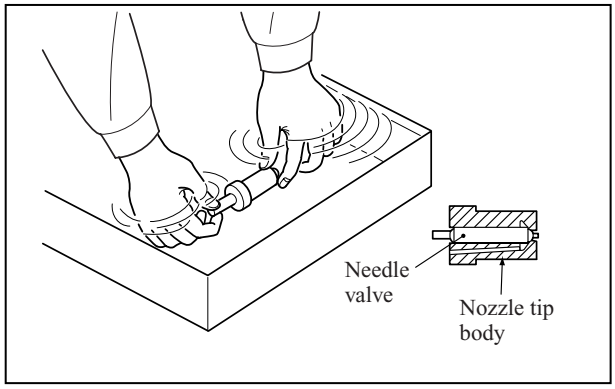

Fuel spray patterns

(3) Clean or replace when spraying badly

(a) Loosen the nozzle retaining nut and remove the nozzle tip assembly. Clean the needle valve and the nozzle tip body.

**⚠ CAUTION**

When removing the nozzle tip assembly, never tap on the end of the assembly.




Cleaning the fuel injection nozzle tip components

(b) Wash the needle valve and the nozzle tip body in clean wash oil. Reassemble them in clean light oil.

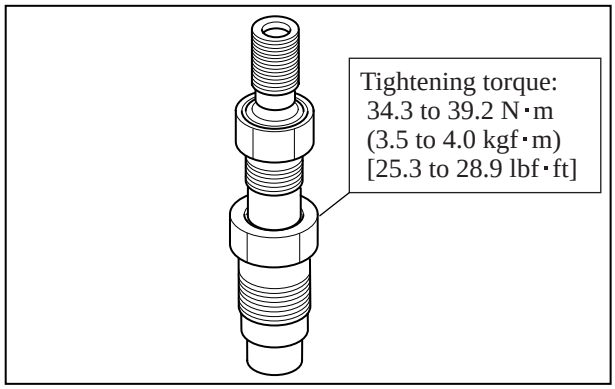
Note: The needle valve and the nozzle tip body are precision machined parts. Handle with care and never change their combination.

(c) Assemble the fuel injection nozzle, tightening the nozzle retaining nut to the specified torque.

(d) If the fuel spray pattern is still not good, replace the nozzle tip assembly.

Note: (a) Never touch the sliding surface of the needle valve with your hands.

(b) If the nozzle tip assembly is replaced, remove the seal peel (synthetic resin film) from the new nozzle tip assembly and slide the nozzle and needle valve in clean wash oil to completely remove the anti-corrosive agent.

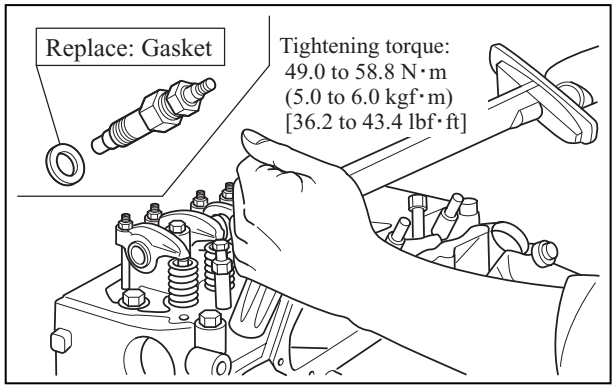



Tightening the retaining nut

(4) Installing the fuel injection nozzles

(a) Install a new gasket onto the fuel injection.

(b) Insert the fuel injection nozzle into the cylinder head, and tighten to the specified torque.




Installing the fuel injection nozzle

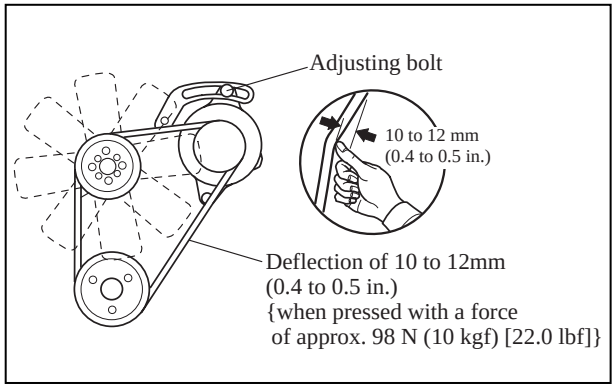
## 1.10 Inspecting the V-belt tension

(1) Press the V-belt at the midpoint of the alternator pulley and the crankshaft pulley, and measure the deflection of the belt.

Unit: mm (in.)

| | Standard value |
|---|---|
| V-belt tension {belt deflection when pressed with a force of approx. 98 N (10 kgf) [22.0 lbf]} | 10 to 12 (0.4 to 0.5) |

(2) If the measured deflection does not conform to the standard value, loosen the adjusting bolt and move the alternator for adjustment.




Adjusting the V-belt tension

## 2. Running-in Trial

Whenever the engine is reassembled after overhaul, run in the engine on a dynamometer. While the engine is being run-in, also perform the inspections listed below.

### 2.1 Starting the engine

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

(2) With fuel shut off, operate the starter for approx. 10 seconds to crank the engine in order to distribute oil throughout the engine.

(3) Move the control lever slightly in the direction of increased fuel delivery (moving the lever to the full delivery position is not recommended). Turn the starter key switch to the START position to start the engine.

(4) With the engine started, move the control lever to the no-load, low idle position.

### 2.2 Inspecting the engine during running-in

While the engine is being run-in, check the followings. If faulty, stop the engine. Locate the cause and take appropriate actions to eliminate it.

(1) Oil pressure at the rated and low idle speeds
The oil pressure should be 0.29 to 0.39 MPa (3.0 to 4.0 kgf/cm$^2$) [42.07 to 56.57 psi] at the rated speed, and 0.098 MPa (1.0 kgf/cm$^2$) [14.22 psi] or above at the low idle speed.

(2) The coolant temperature, which should be 75 to 85℃ (167 to 185 ℉).

(3) The temperature of engine oil in the oil pan, which should be 60 to 95℃ (140 to 194 ℉).

(4) There should be no leakages of oil, coolant or fuel. Pay particular attention to the turbocharger lubrication oil pipe connections.

(5) Diesel knock should disappear as the coolant temperature rises. Other than that, there should be no noise.

(6) The exhaust gas for any abnormal color or smell.

### 2.3 Running-in timetable

The following table shows the running-in phases together with the relevant load and time duration for each phase.

Running-in timetable

| | Engine speed | Load (PS) | Time (min) |
|---|---|---|---|
| 1 | Idle speed | No load | 5 |
| 2 | 1200 | No load | 10 |
| 3 | Rated speed | 25 % | 10 |
| 4 | (varies depending on | 50 % | 10 |
| 5 | engine specifications) | 75 % | 30 |
| 6 | | 100 % | 20 |

### 2.4 Inspection and adjustment after running-in

(a) Adjust the valve clearance

(b) Inspect the fuel injection timing

(c) Check the external bolts and nuts for tightness

## 3. Performance Test

While a number of methods exist for testing the performance of engines, the following are excerpts from "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 tests methods of diesel engines (JIS D0006-2)."

Test items will need to be expanded in a manner appropriate for specific applications. The performance of the engine should be determined based on the overall test results.

### 3.1 Standard ancillaries

The engine being tested should be equipped with those ancillaries that are essential for the engine to operate normally, including the radiator fan, air cleaner, and alternator.

### 3.2 Test items and purposes

(1) Working load test

This test is aimed at obtaining the output, torque, fuel consumption, and governor performance under various loading.

(2) Continuous load test

This test, in which the engine is run continuously for 10 hours under a 90% (continuous) load at the engine speed achieving the nominal net brake power, is aimed at obtaining the fuel consumption and other operating conditions, as well as determining as to whether or not the engine can withstand continuous operation.

(3) No-load minimum speed test

This test is aimed at confirming as to whether or not the engine can run stably at the specified speed under no load.

### 3.3 Other tests

Check for and correct any leakage of exhaust gas, coolant or oil, abnormal odor, hunting, etc.

### 3.4 Adjusting the engine power

Engine power can be affected by the atmospheric pressure, temperature and humidity. The power of the engine being tested should be adjusted for normal atmospheric conditions.

(1) Normal atmospheric conditions are:

Reference temperature: 298 K [25℃ (77 ℉)]

Atmospheric total pressure: 100 kPa (750 mmHg)

Reference dry atmospheric pressure : 99 kPa (743 mmHg)

(2) Correcting the engine output

Measured brake power and torque should be corrected by multiplying them by the diesel engine correction coefficient described below.

| Corrected output = correction coefficient ($\alpha_c$) × measured brake output |
|---|

・Atmospheric conditions for testing

Temperature(T):

283 K [10℃ (50 ℉)] ≦ T ≦ 313 K [40℃ (104 ℉)]

Dry atmospheric pressure:

80 kPa (600 mmHg) ≦ $P$ ≦ 110 kPa (825 mmHg)

(3) Calculating the correction coefficient

$\alpha_c=(fa)^{fm}$

$fa$: Atmospheric coefficient

$fm$: Engine coefficient

(a) Calculating the atmospheric coefficient

①Engine with no charger, or engine with mechanical supercharger

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

② Turbo-charged engine with no charge cooler, or turbo-charged engine with air-to-air charge cooler

$$fa=\left(\frac{99}{Pd}\right)\cdot\left(\frac{T}{298}\right)^{1.2}$$

③Turbo-charged engine with water-to-air charge cooler

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

(b) Calculating the engine coefficient($fm$)

$fm$=0.036 $qc$-1.14

$qc$: Corrected fuel delivery rate

① $qc=\dfrac{q}{r}$

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

$z$=120000(4-cycle engine)

$r$: Ratio of the outlet pressure of supercharger or charge cooler to the atmospheric pressure ($r$ = 1 on non-charged engine)

②Application range of engine coefficient

$37.2 \leqq qc \leqq 65$ mg/(ℓ cycle)

$\left\{\begin{array}{l} qc \leqq 37.2 \text{ mg/(ℓ cycle)}: fm=0.2(\text{constant}) \\ 65 \text{ mg/(ℓ cycle)} \leqq qc: fm=1.2(\text{constant}) \end{array}\right.$

(c) Application range of correction equation

Application range of correction($\alpha_c$) coefficient: $0.9 \leqq \alpha_c \leqq 1.1$

If the correction coefficient used is outside the range, record the corrected outputs together with the testing conditions on the performance test form.

# MISCELLANEOUS

# 1. Disassembly and Reassembly of General Parts

## 1.1 Oil seals

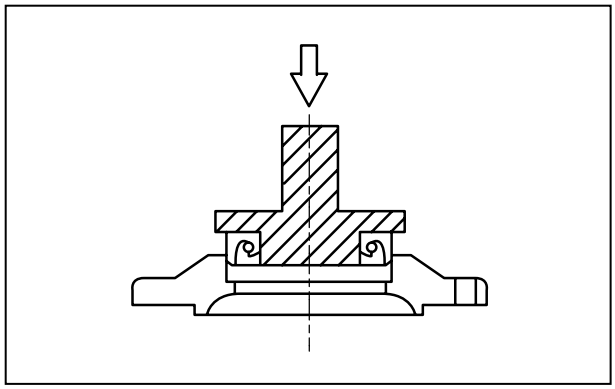
When installing oil seals, pay particular attention to the following points.

### Installing oil seals into the housing

(a) Check the seal, including for damage to the lip. When installing the seal, ensure that the lip faces the correct direction.

(b) Before installing the seal, lightly coat the seal's outer periphery (which contacts the housing) with grease.

(c) Use a seal installer like the one illustrated that is designed to guide the seal lip as well as hold the outer face of the seal. Using such a tool, install the seal straight into the housing. Do not try to tap the seal into place with a hammer or other similar tool as the seal can be damaged, resulting in oil leakage.

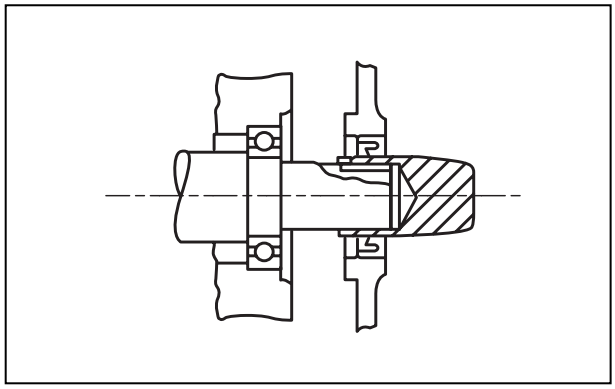


Oil seal installer

### Installing oil seals onto the shaft

(a) Apply grease onto the seal lip.

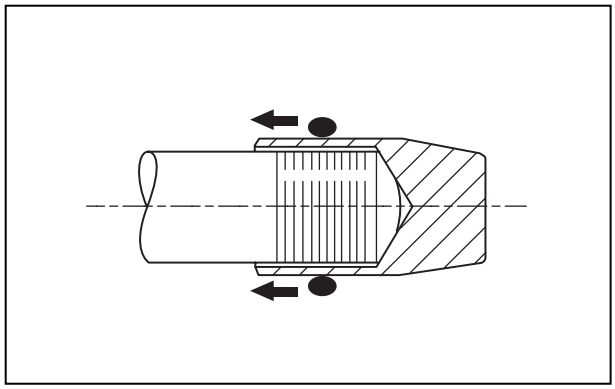
(b) When installing a seal onto a stepped, splined or threaded portion, or onto a surface with a key groove, use a guide like the one illustrated.



Oil seal guide

## 1.2 O-rings

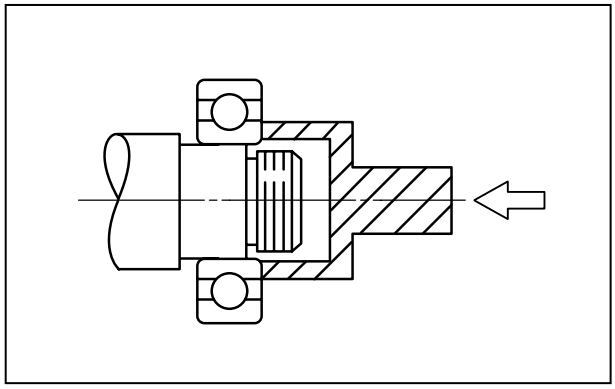
When installing an O-ring onto a stepped, splined or threaded portion, or onto a surface with a key groove, use a guide like the one illustrated. Before installation, lightly coat the O-ring with grease.



O-ring guide

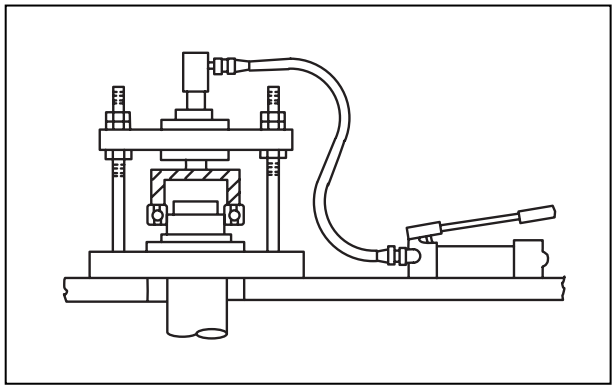
## 1.3 Bearings

(1) When installing a bearing, always tap on the inner or outer race whichever will seat against a stop. Use a tool like the one illustrated that aligns with the inner or outer race whichever is appropriate.



Bearing installer

(2) With a press, the installation will be smoother and more accurate.



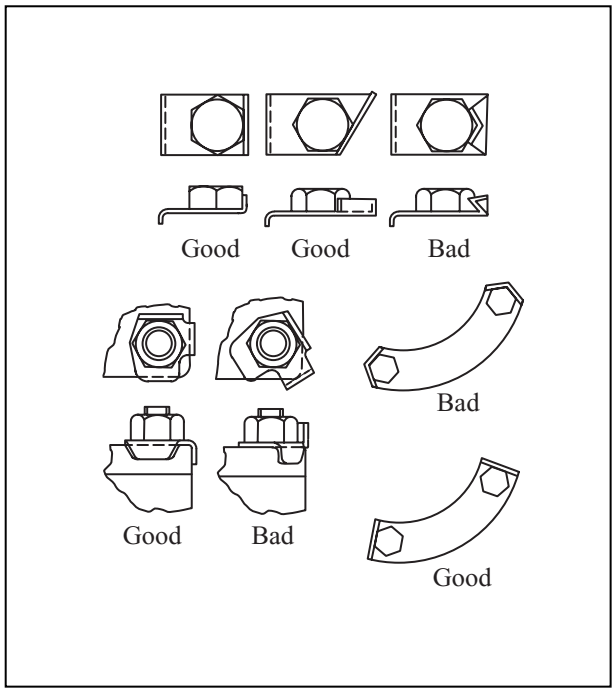
Using a press to install a bearing

## 1.4 Lock plates

Lock plates should be bent correctly as illustrated. Typical lock plates and their correct use are illustrated on the right.

## 1.5 Split pins, Spring pins

On every disassembly, split pins should be replaced with new parts.
Ensure that spring pins are clinched.
Ensure that spring pins are correctly installed.




Correct use of lock plates

No.0

# Engine Inspection Sheet

## Engine Inspection Sheets

1. Cylinder bore
2. Valve stem-to-guide clearance and valve stem diameter
3. Valve seat angle and width
4. Cylinder head bottom face distortion
5. Connecting rod bearings oil clearance
6. Rocker arm inner diameter and rocker shaft diameter
7. Piston pin boss inner diameter and piston pin diameter
8. Valve clearance
9. Fuel injection nozzle opening pressure
10. Camshaft journal diameter and camshaft bushing inner diameter
11. Crankshaft end play

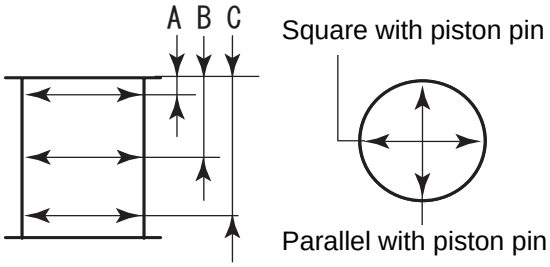
# Engine Inspection Sheet



S L

| | | | | | |
|---|---|---|---|---|---|
| Customer | | Engine model | | Date | |
| | | Engine number | | | |
| Item to be measured | Cylinder bore | | | Unit | mm (in.) |

Measuring location




Standard value

| | Nominal value | Standard value | Limit |
|---|---|---|---|
| Cylinder bore | ϕ78 (3.07) | 78.00 to 78.03 (3.0732 to 3.0743) | Standard value +0.2 (0.0080) |

Measurement

| Name | | Cylinder bore | | |
|---|---|---|---|---|
| No. | Location | A | B | C |
| 1 | X | | | |
| | Y | | | |
| 2 | X | | | |
| | Y | | | |
| 3 | X | | | |
| | Y | | | |
| 4 | X | | | |
| | Y | | | |

| Remarks | Approved by | Confirmed by | Measured by |
|---|---|---|---|
| | | | |

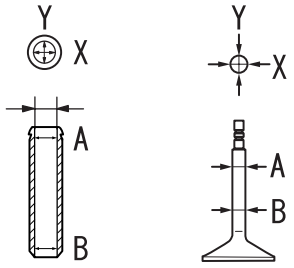
No.2

# Engine Inspection Sheet

S L

| | | | | | |
|---|---|---|---|---|---|
| Customer | | Engine model | | Date | |
| | | Engine number | | | |
| Item to be measured | Valve stem-to-guide clearance and valve stem diameter | | | Unit | mm (in.) |

Measuring location




Standard value

| | | Nominal value | Standard value | Limit |
|---|---|---|---|---|
| Valve guide inner diameter | Inlet | φ6.6 (0.260) | 6.600 to 6.615 (0.2600 to 0.2606) | - |
| | Exhaust | φ6.6 (0.260) | 6.600 to 6.615 (0.2600 to 0.2606) | - |
| Valve stem diameter | Inlet | φ6.6 (0.260) | 6.565 to 6.580 (0.2586 to 0.2592) | 6.500 (0.256) |
| | Exhaust | φ6.6 (0.260) | 6.530 to 6.550 (0.2572 to 0.2580) | 6.500 (0.256) |
| Valve stem-to-guide clearance | Inlet | - | 0.020 to 0.050 (0.0008 to 0.0020) | 0.100 (0.004) |
| | Exhaust | - | 0.050 to 0.085 (0.0020 to 0.0033) | 0.150 (0.006) |

Measurement

| Name | | Valve guide inner diameter | | | | Valve stem diameter | | | | Valve stem-to-guide clearance | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Location | 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 | | | | | | | | | | | | |
| 4 | Inlet | | | | | | | | | | | | |
| | Exhaust | | | | | | | | | | | | |

| Remarks | Approved by | Confirmed by | Measured by |
|---|---|---|---|
| | | | |

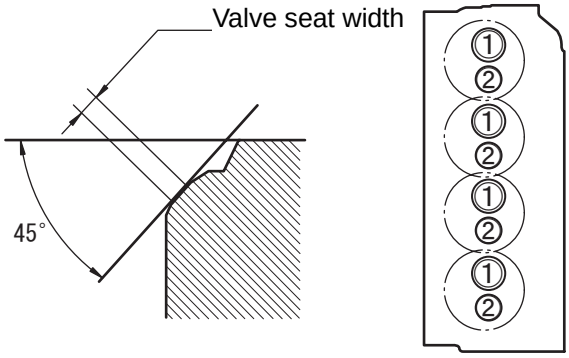
# Engine Inspection Sheet



S L

| | | | | | |
|---|---|---|---|---|---|
| Customer | | Engine model | | Date | |
| | | Engine number | | | |
| Item to be measured | Valve seat angle and width | | | Unit | mm (in.) |

Measuring location




Standard value

| | Standard value | Limit |
|---|---|---|
| Valve seat angle | 45 ° | - |
| Valve seat width | 1.3 to 1.8 (0.0512 to 0.0709) | 2.5 (0.0985) |

Measurement

| Name | | | Valve seat angle | Valve seat width |
|---|---|---|---|---|
| No. | Valve | | | |
| 1 | Inlet | ① | | |
| | Exhaust | ② | | |
| 2 | Inlet | ① | | |
| | Exhaust | ② | | |
| 3 | Inlet | ① | | |
| | Exhaust | ② | | |
| 4 | Inlet | ① | | |
| | Exhaust | ② | | |

| Remarks | Approved by | Confirmed by | Measured by |
|---|---|---|---|
| | | | |

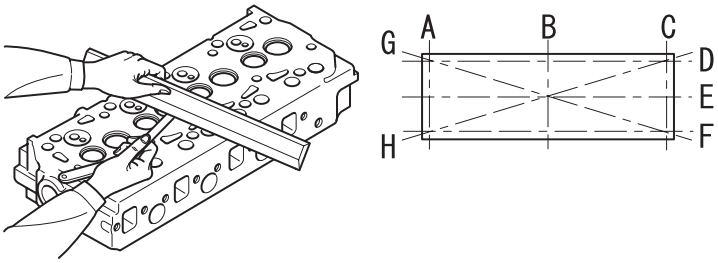
No.4

# Engine Inspection Sheet

S L

| | | | | | |
|---|---|---|---|---|---|
| Customer | | Engine model | | Date | |
| | | Engine number | | | |
| Item to be measured | Cylinder head bottom face distortion | | | Unit | mm (in.) |

Measuring location




Standard value

| | Standard value | Limit |
|---|---|---|
| Cylinder head bottom face distortion | 0.05 (0.002) or less | 0.10 (0.004) |

Measurement

| Name | Cylinder head bottom face distortion | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| No. | A | B | C | D | E | F | G | H |
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |

| Remarks | Approved by | Confirmed by | Measured by |
|---|---|---|---|
| | | | |

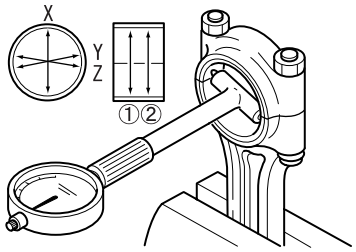
# Engine Inspection Sheet

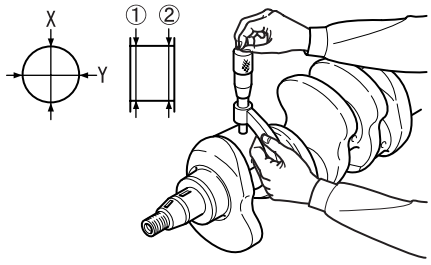


S L

| | | | | | |
|---|---|---|---|---|---|
| Customer | | Engine model | | Date | |
| | | Engine number | | | |
| Item to be measured | Connecting rod bearings oil clearance | | | Unit | mm (in.) |

Measuring location




Standard value

| | Nominal value | Standard value | Limit |
|---|---|---|---|
| Connecting rod bearings inner diameter | ϕ48 (1.89) | 47.950 to 47.965 (1.8892 to 1.8898) | - |
| Crank pin diameter | ϕ48 (1.89) | 47.950 to 47.964 (1.8892 to 1.8897) | - |
| Connecting rod bearings oil clearance | - | 0.025 to 0.072 (0.0010 to 0.0028) | 0.150 (0.0059) |

Measurement

| Name | | Connecting rod bearings inner diameter | | | Crank pin diameter | | Oil clearance |
|---|---|---|---|---|---|---|---|
| No. | Location | X | Y | Z | X | Y | |
| 1 | ① | | | | | | |
| | ② | | | | | | |
| 2 | ① | | | | | | |
| | ② | | | | | | |
| 3 | ① | | | | | | |
| | ② | | | | | | |
| 4 | ① | | | | | | |
| | ② | | | | | | |

| Remarks | Approved by | Confirmed by | Measured by |
|---|---|---|---|
| | | | |

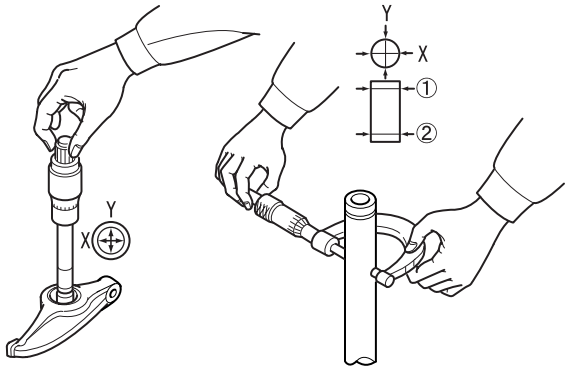
No.6

# Engine Inspection Sheet

S L

| | | | | | |
|---|---|---|---|---|---|
| Customer | | Engine model | | Date | |
| | | Engine number | | | |
| Item to be measured | Rocker arm inner diameter and rocker shaft diameter | | | Unit | mm (in.) |

Measuring location




Standard value

| | Nominal value | Standard value | Limit |
|---|---|---|---|
| Rocker arm inner diameter | ϕ19 (0.749) | 18.910 to 18.930 (0.7450 to 0.7458) | - |
| Rocker shaft diameter | ϕ19 (0.749) | 18.880 to 18.898 (0.7438 to 0.7445) | - |
| Rocker arm-to-shaft clearance | - | 0.012 to 0.050 (0.0004 to 0.0019 | 0.200 (0.0079) |

Measurement

| Name | | Rocker arm inner diameter | | Rocker shaft diameter | | Rocker arm-to-shaft clearance | |
|---|---|---|---|---|---|---|---|
| No. | Location | X | Y | X | Y | Max. | Min. |
| 1 | Inlet | | | | | | |
| | Exhaust | | | | | | |
| 2 | Inlet | | | | | | |
| | Exhaust | | | | | | |
| 3 | Inlet | | | | | | |
| | Exhaust | | | | | | |
| 4 | Inlet | | | | | | |
| | Exhaust | | | | | | |

| Remarks | Approved by | Confirmed by | Measured by |
|---|---|---|---|
| | | | |

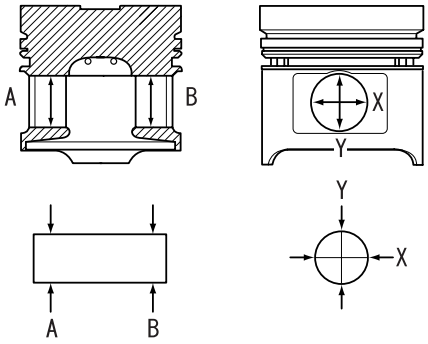
# Engine Inspection Sheet



S L

| | | | | | |
|---|---|---|---|---|---|
| Customer | | Engine model | | Date | |
| | | Engine number | | | |
| Item to be measured | Piston pin boss inner diameter and piston pin diameter | | | Unit | mm (in.) |

Measuring location




Standard value

| | Nominal value | Standard value | Limit |
|---|---|---|---|
| Piston pin inner diameter | ϕ23 (0.91) | 23.006 to 23.012 (0.9057 to 0.9060) | - |
| Piston pin diameter | ϕ23 (0.9062) | 22.994 to 23.000 (0.9039 to 0.9062) | - |
| Piston pin-to-boss clearance | - | 0.006 to 0.018 (0.0002 to 0.0007) | 0.050 (0.002) |

Measurement

| Name | | Piston pin inner diameter | | Piston pin diameter | | Piston pin-to-boss clearance | |
|---|---|---|---|---|---|---|---|
| No. | Location | X | Y | X | Y | Max. | Min. |
| 1 | A | | | | | | |
| | B | | | | | | |
| 2 | A | | | | | | |
| | B | | | | | | |
| 3 | A | | | | | | |
| | B | | | | | | |
| 4 | A | | | | | | |
| | B | | | | | | |

| Remarks | Approved by | Confirmed by | Measured by |
|---|---|---|---|
| | | | |

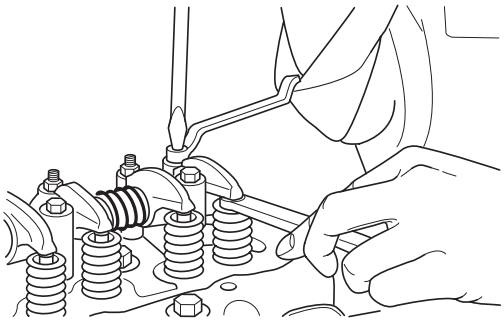
No.8

# Engine Inspection Sheet

S L

| Customer | | Engine model | | Date | |
|---|---|---|---|---|---|
| | | Engine number | | | |
| Item to be measured | Valve clearance | | | Unit | mm (in.) |

Measuring location



Standard value

| | | Standard value |
|---|---|---|
| Valve clearance | Inlet | 0.25 (0.01) |
| | Exhaust | 0.25 (0.01) |

Measurement

| No. | | Valve clearance | |
|---|---|---|---|
| | | Inlet | Exhaust |
| 1 | Before adjustment | | |
| | After adjustment | | |
| 2 | Before adjustment | | |
| | After adjustment | | |
| 3 | Before adjustment | | |
| | After adjustment | | |
| 4 | Before adjustment | | |
| | After adjustment | | |

| Remarks | Approved by | Confirmed by | Measured by |
|---|---|---|---|
| | | | |

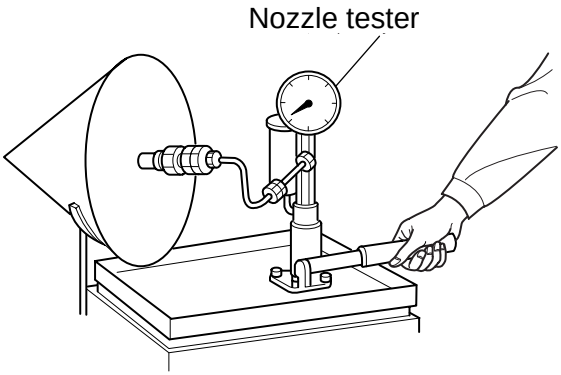
# Engine Inspection Sheet



S L

| | | | | | |
|---|---|---|---|---|---|
| Customer | | Engine model | | Date | |
| | | Engine number | | | |
| Item to be measured | Fuel injection nozzle opening pressure | | | Unit | MPa (kgf/cm$^2$) [psi] |

Measuring location




Standard value

| | Nominal value | Standard value |
|---|---|---|
| Valve opening pressure | 14.22 (145) [2062] | 14.22 to 15.00 (145 to 153) [2062 to 2176] |

Measurement

| No. | Valve opening pressure | Hours used (h) | Valve opening pressure |
|---|---|---|---|
| | Before adjustment | | After adjustment |
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |

| Remarks | Approved by | Confirmed by | Measured by |
|---|---|---|---|
| | | | |

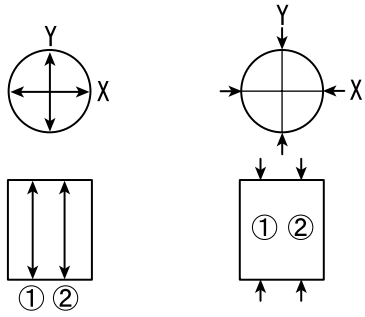
No.10

# Engine Inspection Sheet

S L

| | | | | | |
|---|---|---|---|---|---|
| Customer | | Engine model | | Date | |
| | | Engine number | | | |
| Item to be measured | Camshaft journal diameter and camshaft bushing inner diameter | | | Unit | mm (in.) |

Measuring location




Standard value

| | | Nominal value | Standard value | Limit |
|---|---|---|---|---|
| Camshaft bushing inner diameter | No.1 | ϕ45 (1.77) | 45.000 to 45.055 (107730 to 1.7751) | - |
| Camshaft journal diameter | No.1 | ϕ45 (1.77) | 44.930 to 44.950 (1.7702 to 1.7710) | - |
| Camshaft journal-to-bushing clearance | No.1 | - | 0.050 to 0.125 (0.0020 to 0.0050) | 0.15 (0.0060) |

Measurement

| Name | | Camshaft bushing inner diameter | | Camshaft journal diameter | | Camshaft journal-to-bushing clearance | |
|---|---|---|---|---|---|---|---|
| No. | Location | X | Y | X | Y | Max. | Min. |
| 1 | ① | | | | | | |
| | ② | | | | | | |

| Remarks | Approved by | Confirmed by | Measured by |
|---|---|---|---|
| | | | |

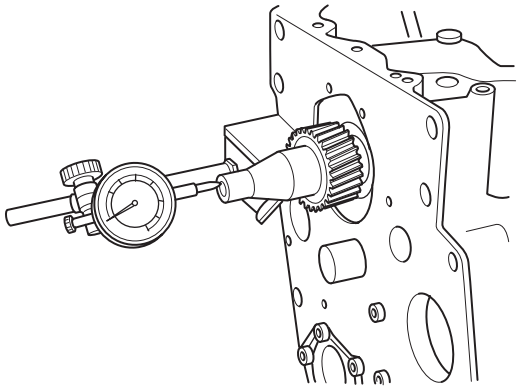
# Engine Inspection Sheet



S L

| | | | | | |
|---|---|---|---|---|---|
| Customer | | Engine model | | Date | |
| | | Engine number | | | |
| Item to be measured | Crankshaft end play | | | Unit | mm (in.) |

Measuring location



Standard value

| | Standardvalue | Limit |
|---|---|---|
| Crankshaft end play | 0.050 to 0.175<br>(0.0020 to 0.0069) | 0.500<br>(0.0197) |

Measurement

| On disassembly | On reassembly |
|---|---|
| | |

| Remarks | Approved by | Confirmed by | Measured by |
|---|---|---|---|
| | | | |